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Regulatory scoping exercise for the future adoption of autonomous inland ships in Europe

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Abstract

Shipping is a heavily regulated sector, and autonomous ships will by no means be able to escape the public regulator's agenda. Furthermore, regulatory adaptation is necessary because current laws oppose the introduction of this new technology. In contrast to maritime shipping, in which considerable regulatory work on autonomous ships has already been achieved, the process of adapting inland shipping regulations for autonomous vessels is rather slow, thereby considerably hindering the further development of the sector. An important reason for this is the multi-levelled regulatory institutional structure in European inland shipping, which consequently has less unified rules than its maritime counterpart. In addition, previous research on regulatory obstacles is highly fragmented and restricted in scope. This study presents a systematic regulatory analysis of relevant inland shipping regulations by following the approach adopted by the International Maritime Organisation with respect to maritime shipping regulations, with the objective of identifying potential obstacles in relevant regulatory instruments and common themes across them. It also discusses the existing possibilities under current European Union law for the exceptional operation of autonomous inland ships and describes the latest policy directions taken by the European legislator to foster innovation development within the sector.

Keywords: Autonomous inland shipping, Unmanned ships, Regulation, Policy, Europe, International Martitime Organisation (IMO), Maritime Autonomous Surface Ships (MASS)

Introduction

As is often the case when it comes to new technologies, legislation lags behind innovation. Either the law remains silent on the new technology and, therefore, does not directly oppose it, or the law directly poses a hindrance to the implementation of the innovation by implicitly or explicitly prohibiting it. The first scenario could cause an unregulated market introduction of the new technology, thereby offering an opportunity for unbalanced risk distribution and opening a door to self-regulation by the industry. The implication of the second scenario is that the law would create a direct end to the further development and implementation of the innovation.

In light of the disruptive autonomous ship technology, the latter scenario and its subsequent implications hold true: Shipping is a heavily regulated sector, and

autonomous ships will by no means be able to escape the public regulator's agenda if their future implementation is sought. More specifically, autonomous ships cannot be operated under current laws and regulations because many legal provisions are based on the assumption of a human operator on board the ship. The absence of crew hereby presents a hard regulatory obstacle to the operation of autonomous ships. Consequently, existing legislation needs to be adapted for autonomous ships mainly because these are uncrewed, thereby opposing provisions requiring crew on board for navigation, safety and security purposes as well as environmental protection duties. Another important reason is that autonomous shipping, when implemented, presents a disruptive technology that will have consequences that are not yet entirely assessed and are expected to continue changing over time following further technological developments. Nevertheless, there seems to be a high potential that the benefits gained from implementing autonomous shipping on a wide scale in Europe make the sector safer, more efficient and sustainable (UNECE 2018); arguably, the overall economic benefit of this new technology is still being discussed in the literature (Verberght and van Hassel 2019; Streng and Kuipers 2020; Ziajka-Poznańska and Montewka 2021). Thus, to support innovation-implementation but also to outweigh potential risks and uncertainties, the legislator has been urged to take action.

In contrast to maritime shipping, in which considerable work on regulatory adaptation has already been achieved, the inland shipping sector has not had a similar development. Apart from experimental legislation to allow real-environment testing, regulatory work for the purpose of either modifying existing provisions in order to make them conform with autonomous inland ships or adopting new provisions with the objective of mitigating (newly) emerging risks remains very limited. The reason for this relatively slow process is—compared to maritime shipping—the very different public regulatory institutional structure in inland shipping; the latter consists of a multi-levelled regulatory landscape with different supranational, regional and national authorities. The rules and regulations adopted by these authorities diverge as to their binding or nonbinding nature, their geographical scope of application and their hierarchical importance throughout Europe. This also means that unification of rules and regulations is less present in inland shipping (Cinčurak Erceg 2018), consequently making a harmonised approach to the regulation of autonomous inland ships generally more onerous.

The objective of the present study is twofold: First, by following a systematic methodological approach, the study investigates to what extent the current regulatory framework would be affected by autonomous inland shipping technology; second, the study sheds light on the specific regulatory obstacles that exist across the fragmented transnational pan-European inland shipping framework by identifying common gaps and themes that will require addressing for the regulation of autonomous ships. To address this objective, the main research-guiding question is:

> *To what extent would the existing European inland shipping regulatory framework be affected by autonomous inland ships?*

To answer this question, three sub-research questions have been formulated as follows:

(1) Which regulations fall within the scope of the regulatory scoping exercise on currently applicable European inland shipping regulations?
(2) What common potential gaps and/or themes can be identified in the different regulatory instruments?
(3) What potential links can be established across the different regulatory instruments?

The study design was inspired by a regulatory development in maritime shipping regarding autonomous shipping technology, as explained in more detail below. Based on the same methodological approach, inland shipping regulations with a focus on technical, safety- and security-related subject matters were analysed with regard to regulatory obstacles against the introduction of autonomous shipping technology. The study's focus hereby laid on disclosing common potential gaps and/or themes in existing regulations that require addressing for the introduction of autonomous ships rather than a detailed presentation of individual provisions concerning safety functions that would need to be tackled for uncrewed shipping operations; due to many similar provisions in existing regulations, this would have been too extensive and, above all, redundant in nature. Besides, the literature review presented below included only literature dealing with autonomous or unmanned inland shipping from a purely regulatory perspective; therefore, studies dealing with safety related to autonomous inland shipping technology from a mostly technical perspective have been excluded.

As to the remainder of the paper, the following section presents a comprehensive literature review with regard to regulatory analyses conducted in relation to autonomous or unmanned inland shipping technology. The subsequent section first describes the regulatory methodology adopted in maritime shipping, then explains the method applied to inland shipping regulations, and presents the outcome of the analyses conducted. The next section continues with a discussion on current and future regulatory developments and the role of the European legislator in facilitating and implementing autonomous inland shipping. Finally, the last section concludes, puts forward possible ways for public regulators and policymakers, and provides future research pathways.

Literature review

Most of the literature written on the regulation of autonomous ships focuses on maritime shipping operations: Numerous studies, amongst these are Van Hooydonk (2014), Deketelaere (2017), Veal and Ringbom (2017), and entire books, for instance, Soyer and Tettenborn (2020, 2021), Ringbom et al. (2021), have extensively explored whether autonomous ships can be applied to existing maritime regulations, what kind of amendments would need to be enacted and what new provisions would need to be adopted for a regulation of autonomous maritime ships.

In contrast, a literature review of previous research about regulatory aspects related to autonomous inland ships confirms the complex task of regulating this innovative technology in European inland shipping. Existing studies on regulatory adaptation for the future deployment of autonomous inland ships in Europe are limited and highly restricted in terms of the scope of the analysed regulations, the methodologies used and the subsequent findings. This has resulted in a fragmented research landscape on regulatory obstacles hindering the introduction of autonomous inland ships in Europe.

Verberght (2019) studied the factors that determine success or failure for different innovations in inland navigation; one of these is the readiness of the sector for the deployment of autonomous vessels, taking into consideration the institutional peculiarity of the sector with its multi-levelled policymaker landscape. Understanding the complex institutional setting and consequential lawmaking in European inland shipping is indispensable for any analysis of the existing regulatory framework for autonomous ships. According to Verberght (2019), regulation would be needed to create a level playing field for the different stakeholders involved, and it could give more legal certainty to the innovation; however, a situation in which regional or national authorities adopt their own definitions and regulations for autonomous inland ships could be problematic for an international sector, such as inland navigation, and could be detrimental to its competitiveness vis-à-vis other modes of transport by driving the costs of the innovation as a result of additional compliance costs for each regime. Verberght (2019) also noted that legal derogations from the existing regulatory regime would constitute important elements for any future development of the sector. Regarding legal derogations with the objective of fostering innovation through real-environment testing, the Erasmus School of Law (2019) investigated the extent to which automated, remotely controlled and autonomous shipping operations are allowed in Dutch inland waterways under the current legislation and the legal limitations and possible adjustments that would need to be made to allow their exceptional and structural deployment. The legislation analysed included Dutch national legislation and international legislation applicable to inland navigation in the Netherlands. The report concluded that, in principle, existing legislation precluded uncrewed operations in Dutch inland waterways; however, it also emphasised possibilities under Dutch law to grant exemptions for the exceptional deployment of uncrewed operations subject to specific conditions.

Despite analysing the status quo of existing regulations to support innovation development for the purpose of identifying legal derogations to allow real-environment experiments with highly automated and autonomous ships, only a few authors have gone further in the problem analysis. Particularly, few studies have examined the regulatory framework in respect of current bottlenecks which need to be addressed for a general introduction of autonomous inland ships in the near future.

Nzengu et al. (2021) analysed a specific case study vessel as to the vessel's compliance with applicable safety and security-related regulations. The case study's subject involved an uncrewed barge, and the operational environment was refined to Belgian inland waterways. The applicable regulatory instruments identified were analysed in respect of provisions containing human elements, thereby precluding uncrewed operations by either implicitly or explicitly requiring the presence of a human on board the vessel. The authors found that new definitions are required with regard to the responsibilities of the boatmaster, the crew and the remote control station. Notably, the objective of the research conducted was not to establish a set of recommendations to eventually allow vessels to sail autonomously but to investigate the extent to which the on-board (offshore) responsibilities of the boatmaster and the crew could be shifted to onshore personnel (i.e. the remote control station); this could be achieved by following the principle of equivalence with regard to existing safety and security standards, as identified in the provisions involving the interactions of humans on board the vessel. A subsequent study

complements these findings by proposing regulatory solutions to the identified issues and applicable to the specific case study (Ahmed et al. 2023).

Bačkalov (2020) examined technical regulations in light of the concept of ship safety. Detached from the premise of 'a ship is safe when its humans on board are safe', the rules were analysed in terms of the extent to which their safety functions could still be ensured via remote control or autonomous application in the cases of automated (crewed), remotely controlled and fully autonomous operations. This analytical approach offered two important findings: first, safety functions in provisions not precluding uncrewed operations as such may still be ensured by the human operator from onshore; second, provisions ensuring the safety of humans on board do not preclude uncrewed operations but become simply obsolete in the case of autonomous ships.

The above-cited research demonstrates that, depending on the region investigated, different regulations may fall within the scope of regulatory analysis. Furthermore, based on the parameters used in the analysis, the regulatory obstacles identified and for which subsequent recommendations were issued may significantly differ. To conclude, the current state-of-the-art in research is a highly fragmented research landscape where individual study outcomes stand for themselves without contributing to the identification of the actual status quo of inland shipping regulations with regard to autonomous shipping in general. However, as noted earlier, regulatory adaptations for autonomous inland shipping that are not harmonised could be detrimental to the benefits that would otherwise be gained from introducing this new technology to the market. A harmonised regulation of autonomous inland shipping is therefore indispensable. Without neglecting the peculiar institutional structure present in European inland shipping, this study aims to contribute to the highly fragmented research landscape through a systematic and holistic analysis of relevant regulatory instruments; particularly, it adopts the methodology applied by the International Maritime Organisation (IMO) in its regulatory scoping exercise on maritime shipping regulations.

Regulatory scoping exercise

The following section describes the methodological approach from which inspiration has been drawn for the present study. The methodology, which has been applied to answer the research questions, is subsequently explained, and the results of the analyses are presented.

Regulatory scoping exercise of the IMO

In contrast to inland shipping regulations, those of maritime shipping are generally more unified. The reason for this is that safety, security and environmental issues are subject to international conventions, and a high adherence rate by states to these conventions fosters a universally adopted and implemented regulatory framework. In addition, fragmented or outdated international conventions are regularly updated by the IMO, which adopts more specific laws, including laws to adapt existing conventions in light of technological developments (van Logchem 2022). This is not the case in inland shipping: Different institutions adopt regulations that are not universally applicable but only applicable to specific member states, and the revision of existing rules and regulations remains the individual responsibility of each institution. The reason for this is the

division of regulatory competencies amongst the different regulators in inland shipping, as will be explained in more detail below.

Initiated in 2017, the Maritime Safety Committee (MSC) and the Legal Committee of the IMO completed their so-called 'Regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS)' in 2021. The objective of the exercise was to assess the degree to which the existing maritime shipping regulatory framework might be affected by addressing the varying degrees of MASS operations, including highly automated (crewed) ships, remotely controlled (with and without crew on board) and fully autonomous (uncrewed) ships. The methodology applied consisted of a three-step approach. First, the relevant instruments were identified on the basis of their subject matters relating to maritime safety and security. Second, the provisions contained in the identified instruments were analysed by considering, inter alia, human elements, technology and operational factors. Lastly, common themes were established across the different instruments.

Several important conclusions could be gained from the outcome of the IMO's regulatory scoping exercise (IMO/MSC 2021; IMO/LEG 2021): The issues that were identified as high-priority included the definitions and responsibilities of the 'master', 'crew' and 'responsible person'; the meaning of a remote control station; and the meaning of a remote operator as seafarer. Furthermore, common potential gaps and/or themes categorised as high-priority might require policy decisions prior to any future regulatory work. By contrast, issues not categorised as high-priority concerned, for example, insurance and insurance certificates, which could be dealt with outside the regulatory framework adaptation. In general, instruments were categorised as high-priority (to be addressed before all others and containing the many common potential gaps and/or themes), medium-priority (to be addressed after high-priority) or low-priority (requiring no significant action).

The MSC subsequently issued the recommendation that the many common potential gaps and/or themes found across the instruments analysed would be best addressed in a holistic manner by developing a new instrument (e.g. a goal-based MASS instrument) instead of revising individual instruments; this can be made mandatory by amending an existing IMO convention, which would help to avoid inconsistencies, confusion and potential barriers. Following the completion of the regulatory scoping exercise, the IMO aims to adopt a nonmandatory goal-based MASS code that will take effect in 2025, which will later be followed by a mandatory goal-based MASS to be effective from 2028.

Even though the regulatory instruments identified in the regulatory scoping exercise of the IMO are not applicable to inland shipping, the objective of such an exercise on inland shipping regulations is the same—to identify potential gaps and/or themes in the relevant regulations and to subsequently establish common links across the different instruments. The identified common gaps and/or themes could then serve as orientation tool for future regulatory work on inland shipping regulations in a harmonised manner.

Methodology applied

To answer the research questions stated above, the applied methodology for the regulatory scoping exercise on inland shipping regulations also consisted of a three-step approach. First, relevant regulatory instruments were identified on the basis of existing

research findings and a search of supranational public regulators in inland shipping and their regulatory instruments on technical, safety- and security-related subject matters. In light of the identified common potential gaps and/or themes in the IMO regulatory scoping exercise, the identified regulations were subsequently analysed regarding the existence of similar issues by considering human elements, technology and operational factors. Ultimately, common links across the analysed regulatory instruments were established.

The outcome of a regulatory scoping exercise, such as the one performed on maritime regulations, may present important findings on the adaptability of the existing regulatory framework applicable to inland shipping. Furthermore, addressing common potential gaps and/or themes in existing inland shipping regulations to adapt these later on through future holistic amendments will pave the way forward to a harmonised approach of regulating autonomous inland shipping across Europe.

Regulatory scoping exercise for inland shipping regulations

The pan-European inland shipping landscape consists of different supranational, regional and national public regulators whose regulatory instruments in the field of safety, security and technical requirements differ in scope of application and enforceability across Europe.

From a geographical scope of application, the United Nations Economic Commission for Europe (UNECE), a specialised United Nations agency, has the most far-reaching policymaking powers for inland shipping regulation in Europe. The UNECE acts as an important supranational policymaker but cannot adopt mandatory regulatory instruments itself. Instead, the organisation issues recommendations and assists in the preparation of important pan-European legal instruments by other inland waterway regulatory bodies that are embedded with powers to adopt mandatory rules. Less far-reaching in respect of the geographical scope of application than the UNECE but still considered the predominant public regulator in European inland shipping is the European Union (EU) because of its powers to adopt binding legal instruments that are directly applicable in its Member States (in the case of regulations), or that are subject to mandatory transposition into national law (in the case of directives).

Continental Europe consists of several important transnational inland waterways which meet the conditions for an international river by running through two or more states and are navigable from the sea (United Kingdom et al. v. Poland 1929, p25). Transnational waterways naturally constitute favourable conditions for a single shared market amongst their riparian states (Tournaye 2015); consequently, river commissions were established 'to lay down a legal framework providing a level playing field within the market created and to monitor and coordinate public infrastructure work' (Tournaye 2015, p383). For historical and/or political reasons, some states are members of river commissions despite not being a riparian state (Verberght 2019). The most important river commissions related to the pan-European inland waterway network include the Central Commission for the Navigation of the Rhine (CCNR), the Moselle Commission, the International Sava River Basin Commission (Sava Commission) and the Danube Commission. Whereas the first three can adopt binding decisions, the latter can only issue

recommendations; nevertheless, it plays an important role in coordinating the national authorities governing the use of the Danube River.

The European Committee for drawing up standards in the field of inland navigation (CESNI) holds a special function in-between these regulators; it has been set up in a cooperative effort between the EU and the CCNR, with the objective of harmonising current standards for crew and technical requirements. The standards of CESNI are not automatically binding but need to be incorporated into the respective regulatory frameworks.

Besides the aforementioned public regulators, national authorities adopt legally binding decisions in their individual states and are placed at the bottom of the regulatory pyramid in inland shipping. Nevertheless, they play an important role in managing the sector by being responsible for the regulation of every safety- and security-related aspect that has not been regulated at the supranational and transnational levels above them.

Common themes to be adapted

In its regulatory scoping exercise, the IMO included a variety of relevant instruments dealing with the safety and security aspects of maritime shipping. In the following exercise on inland shipping regulations, the same approach was adopted. Based on findings from the literature and complemented by an own web search (referred to as 'N/A'), regulatory instruments falling within the scope of the exercise included mandatory and non-mandatory regulations adopted by the aforementioned supranational and transnational (but regional) public regulators and relating to the safety and security aspects of inland shipping. These ranged from technical requirements, including communication, to special requirements for the transport of dangerous goods, navigational policies, additional requirements in case of passenger transport, professional qualifications and working requirements, and waste management obligations. The scope of the analysis excluded regulatory instruments adopted at the national level and conventions with a focus on private law issues, such as liability and insurance. The objective was to conduct an analysis solely of regulations enacted for the safe operation of vessels in European inland waterways.

Following a top-down approach, these regulations included, at the supranational level, the European Code for Inland Waterways (CEVNI) (UNECE 2021) (as identified by Nzengu et al. 2021; Erasmus School of Law 2019) and the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) (UNECE 2023) (referred to in Bačkalov 2020; Verberght 2019) adopted by UNECE; European Directive 2016/1629/EC on the technical requirements for inland waterway vessels (European Parliament and Council of the European Union 2016) (as identified by Erasmus School of Law 2019; Verberght 2019; Nzengu et al. 2021), European Directive 2008/68/EC on the inland transport of dangerous goods (European Parliament and Council of the European Union 2008) (referred to in Nzengu et al. 2021), European Directive 2017/2397 on the recognition of professional qualifications in inland navigation (European Parliament and Council of the European Union 2022) (repealing Directive 1996/50/EC and as identified by Nzengu et al. 2021) and European Directive 2014/112/EC on the organisation of working time in inland waterway transport (Council of the European Union 2014) (referred to in Nzengu et al. 2021) as well as European

Regulation 1177/2010 on the rights of passengers in sea and inland waterway transport (European Parliament and Council of the European Union 2010) (as identified by Verberght 2019); the European Standards laying down Technical Requirements for Inland Navigation Vessels (ES-TRIN) (CESNI 2023b) (referred to in Erasmus School of Law 2019; Verberght 2019; Bačkalov 2020; Nzengu et al. 2021), for Qualifications in Inland Navigation (ES-QIN) (CESNI 2019) (as identified by Verberght 2019) and for River Information Services (ES-RIS) (CESNI 2023a); and the Convention on the Collection, Deposit and Reception of Waste Produced during Navigation on the Rhine and Inland Waterways (CDNI) (CDNI Secretariat 2023) (referred to in Nzengu et al. 2021).

At the transnational (regional) level, these included the Police Regulations for the Navigation of the Rhine (RPR) (CCNR 2023b) (as identified by Nzengu et al. 2021), Regulations for Rhine Navigation Personnel (RPN) (CCNR 2023c) (referred to in Nzengu et al. 2021; Erasmus School of Law 2019) and the Rhine Vessel Inspection Regulations (RVIR) (CCNR 2022b); the Danube Convention (DC) (Danube Convention 1948); the Police Regulation for the Navigation of the Moselle (PRNM) (Moselle Commission 2022); the Navigation Rules on the Sava River Basin (NRSRB) (Sava Commission 2013); the Sava Manual for the Radiotelephone Service in the Sava River Basin (MRSSRB) (Sava Commission 2019); and the Handbook on Radiocommunication for Inland Navigation (HRIN) (Danube Commission, Moselle Commission and CCNR 2017), which was adopted in a joint effort by the CCNR, Danube and Moselle Commissions.

The identified instruments were subsequently analysed for common potential gaps and/or themes similar to those referred to in the maritime regulatory scoping exercise related to fully autonomous, and hence uncrewed, ships but with the possibility of a remote control station for supervision purposes, corresponding to level 5 of the CCNR's 'International definition of levels of automation in inland navigation' (CCNR 2022a) and equivalent to level 4 in the regulatory scoping exercise of the IMO (Table 1). For this, the identified regulations were analysed with regard to the existence of a human element, which was met by a provision either stipulating that an action is to be performed by conventional shipping personnel, such as boatmaster or crew, or requiring human handling of a specific task. The aim was not to establish a detailed list of provisions opposing the introduction of autonomous inland ships but to determine whether common potential gaps and/or themes could be identified in the respective regulatory instruments.

Similar to the findings in the IMO regulatory analysis, the potential gaps and/or themes identified in inland shipping regulations included provisions requiring crew on board ('crewing requirements') and/or specific persons (e.g. master or crew personnel) to perform duties ('definition, responsibilities and qualifications') or provisions stipulating that (a) human(s) on board shall manually perform a task ('manual operations by the personnel on board'). Provisions requiring actions by humans on board automatically demonstrate the absence of provisions which would otherwise allow the specific task to be performed from outside the autonomous vessel ('remote control from the onshore station'). Furthermore, definitions, responsibilities and qualifications for remote control station personnel will need to be adopted. Provisions concerning communication either between on-board personnel in the vessel or between the vessel and the shore or with other vessels require adaptations to enable entirely digitalised communication ('communication'). Similarly, in the case of communication of data or situational awareness

Table 1 Common gaps/themes to be adapted

Regulatory instrument	Potential gaps/themes that require addressing	References (if applicable)
UNECE		
CEVNI (UNECE 2021)	Definition, responsibilities and qualifications of 'master'	Bačkalov (2020)
	Definitions, responsibilities and qualifications of 'crew', 'qualified person', 'helmsman' and 'person responsible'; crewing requirements; certificates; communication; manual operations by the personnel on board; remote control from the onshore station; acquisition and transfer of data	N/A
ADN (UNECE 2023)	Definition, responsibilities and qualifications of 'master'; crewing requirements; remote control from the onshore station	Bačkalov (2020)
	Definition, responsibilities and qualifications of 'crew'; manual operations by the personnel on board; certificate; remote control from the onshore station	N/A
EU		
Directive 2016/1629/EC (European Parliament and Council of the European Union 2016)	Certificate; remote control from the onshore station; definitions, responsibilities and qualifications of 'inspection bodies', 'chairman' and 'experts'	N/A
Directive 2008/68/EC (European Parliament and Council of the European Union 2008)	Certificate	N/A
Directive 2017/2397 (European Parliament and Council of the European Union 2022)	Definitions, responsibilities and qualifications of 'persons involved in the operation of a craft navigating', 'deck crew members', 'passenger navigation experts' and 'boatmaster'; certificate; communication; crewing requirements; remote control from the onshore station; manual operations by the personnel on board	N/A
Directive 2014/112/EC (Council of the European Union 2014)	Definition, responsibilities and qualifications of 'boatmaster'; remote control from the onshore station	Nzengu et al. (2021)
	Definitions, responsibilities and qualifications of 'navigation personnel (crew members)' and 'shipyard personnel'	N/A
Regulation 1177/2010 (European Parliament and Council of the European Union 2010)	Manual operations by the personnel on board	N/A
CESNI		
ES-TRIN (CESNI 2023b)	Manual operations by the personnel on board; remote control from the onshore station; crewing requirements	Nzengu et al. (2021)
	Acquisition and transfer of data; manual operations by the personnel on board; remote control from the onshore station; crewing requirements	Bačkalov (2020)
	Crewing requirements; manual operations by the personnel on board	Erasmus School of Law (2019)
	Communication; definitions, responsibilities and qualifications of 'shipboard personnel', 'boatmaster' and 'crew'; certificate	N/A

Table 1 (continued)

Regulatory instrument	Potential gaps/themes that require addressing	References (if applicable)
ES-QIN (CESNI 2019)	Manual operations by the personnel on board; remote control from the onshore station; certificate; communication; acquisition and transfer of data	Verberght (2019)
	Definitions, responsibilities and qualifications of 'boatman', 'crew', 'shipboard personnel' and 'passenger navigation experts'	N/A
ES-RIS (CESNI 2023a)	Definitions, responsibilities and qualifications of 'crew', 'conning (navigating) skipper' and 'boatmaster/shipmaster'; acquisition and transfer of data; communication; remote control from the onshore station; manual operations by the personnel on board; certificate	N/A
CDNI		
CDNI (CDNI Secretariat 2023)	Definition, responsibilities and qualifications of 'boatmaster'; manual operations by the personnel on board	Nzengu et al. (2021)
	Certificate; remote control from the onshore station; communication	N/A
River Commissions		
CCNR		
RPR (CCNR 2023b)	Definition, responsibilities and qualifications of 'master'; manual operations by the personnel on board; crewing requirements; remote control from the onshore station	Nzengu et al. (2021)
	Definitions, responsibilities and qualifications of 'crew' and 'other persons on board'; certificate; communication; acquisition and transfer of data	N/A
RPN (CCNR 2023c)	Crewing requirements; definition, responsibilities and qualifications of 'ADN expert'	Nzengu et al. (2021)
	Crewing requirements	Erasmus School of Law (2019)
	Certificate; definitions, responsibilities and qualifications of 'boatmaster', '(deck) crew (members)', 'shipboard personnel', 'safety personnel' and 'passenger navigation expert'; communication; remote control from the onshore station; manual operations by the personnel on board	N/A
RVIR (CCNR 2022b)	Certificate	N/A
Danube Commission		
DC (Danube Convention 1948)	Definition, responsibilities and qualifications of 'pilots'	N/A
Moselle Commission		
PRNM (Moselle Commission 2022)	Definitions, responsibilities and qualifications of 'boatmaster', 'crew' and 'other persons on board'; communication; acquisition and transfer of data; certificate; manual operations by the personnel on board	N/A

Table 1 (continued)

Regulatory instrument	Potential gaps/themes that require addressing	References (if applicable)
Sava Commission		
NRSRB (Sava Commission 2013)	Definitions, responsibilities and qualifications of 'boatmaster', 'crew' and 'other persons on board'; certificate; crewing requirements; remote control from the onshore station; acquisition and transfer of data; communication	N/A
MRSSRB (Sava Commission 2019)	Manual operations by the personnel on board; communication; acquisition and transfer of data	N/A
CCNR/Danube Commission/Moselle Commission		
HRIN (CCNR, Danube Commission Moselle Commission 2017)	Manual operations by the personnel on board; communication; acquisition and transfer of data	N/A

ensured by the personnel on board, new provisions are needed ('acquisition and transfer of data'). Lastly, provisions dealing with either specific certification requirements or the obligation to carry non-digitalised documents on board and to hand them over, for example, in case of inspection, raise new issues for their applicability to autonomous vessels ('certificate').

Potential links between instruments

Upon the identification of the potential gaps and/or themes in each instrument, the potential links across the regulatory instruments were established (Table 2). Similar to the outcome of the IMO regulatory scoping exercise, the identified gaps and/or themes are not all of the same nature. The most critical and fundamental issues are provisions in which a human element explicitly precludes autonomous operations. Consequently, before existing regulations can be adapted, new definitions, responsibilities and qualifications for the master and crew need to be elaborated and changed, as the case may be, to remote control station personnel. These may be subject to policy decisions, as they likely have far-reaching implications on how regulations will address autonomous inland shipping in the future. Other issues seem to be less critical; however, they will nevertheless play an important part in the future regulation of autonomous inland ships. Amongst these are how to handle communication and data transfer as well as the adoption of new certification procedures for compliance and inspection purposes.

Besides the need for policy decisions on the most critical issues identified, the potential links regarding common gaps and/or themes across the different regulatory instruments may serve as important bases for how future regulatory work can be achieved in a holistic, harmonised manner.

In contrast to the IMO, the adoption of a universally applicable code on autonomous inland shipping seems more than unlikely because of the very different rulemaking procedures amongst the various, multi-levelled policymakers in inland shipping. However, the rationale to address the most critical common gaps and/or themes in a single regulatory instrument presents the undeniable advantage of establishing the foundation for a universal implementation of autonomous inland ships on pan-European inland

Table 2 Potential links between instruments

Regulatory instrument	Crewing requirements	Definitions, responsibilities and qualifications	Manual operations	Remote control	Communication	Data	Certificates
General recommendations							
CEVNI (UNECE 2021)	x	x	x	x	x	x	x
Transport of dangerous goods							
ADN (UNECE 2023)	x	x	x	x			x
Directive 2008/68/EC (European Parliament and Council of the European Union 2008)							x
Technical requirements							
ES-TRIN (CESNI 2023b)	x	x	x	x	x	x	x
Directive 2016/1629 (European Parliament and Council of the European Union 2016)		x		x			x
RVIR (CCNR 2022b)							x
Navigational policies							
RPR (CCNR 2023b)	x	x	x	x	x	x	x
DC (Danube Convention 1948)		x					
PRNM (Moselle Commission 2022)		x	x		x	x	x
NRSRB (Sava Commission 2013)	x	x		x	x	x	x
Labour							
ES-QIN (CESNI 2019)		x	x	x	x	x	x
Directive 2017/2397 (European Parliament and Council of the European Union 2022)	x	x	x	x	x		x
Directive 2014/112/EC (Council of the European Union 2014)		x		x			
RPN (CCNR 2023c)	x	x	x	x	x		x

Table 2 (continued)

Regulatory instrument	Crewing requirements	Definitions, responsibilities and qualifications	Manual operations	Remote control	Communication	Data	Certificates
Passengers							
Regulation 1177/2010 (European Parliament and Council of the European Union 2010)			x				
Communication							
ES-RIS (CESNI 2023a)		x	x	x	x	x	x
HRIN (CCNR, Danube Commission and Moselle Commission 2017)			x		x	x	
MRSSRB (Sava Commission 2019)			x		x	x	
Waste management							
CDNI (CDNI Secretariat 2023)		x	x	x	x		x

waterways. Therefore, the chance to pave the way towards a harmonised regulation in Europe could rest with one of the supranational regulators, for instance, the UNECE and/or CESNI, that could create a nonmandatory regulatory framework or set of recommendations from which other public regulators could gain inspiration for the adoption of new rules or future adaptations of their existing regulations. As for the content of the rules, the nonmandatory regulatory framework should not be too prescriptive in nature as technology is expected to continuously change over time, but rather follow the goal-based approach adopted by the IMO to set standards that are of a more fundamental nature and focus on the outcome to be achieved.

Autonomous inland ships: from experimental to structural deployment

Technology is constantly evolving, and its regulation becomes difficult without sufficient scientific knowledge of what is possible from a technological point of view. For this reason, technology needs to be tested practically to gather sufficient data for risk and socio-economic assessments. The European legislator has created a legitimate way of doing so, without opening the door to an unregulated market introduction of autonomous ships.

Existing possibilities under current EU law for autonomous inland ships

Despite the existing regulations implicitly prohibiting the deployment of autonomous inland ships in Europe by explicitly stipulating crewing requirements or actions to be performed by the human operator on board the vessel, the EU has created a gateway for innovation development in inland shipping. In light of Preamble (11) and by way of Articles (24) and (25) of Directive 2016/1629 (European Parliament and Council of

the European Union 2016), EU Member States are allowed to derogate from the existing provisions, which can be used to authorise the exceptional operation of autonomous inland ships within national inland waterways while maintaining an adequate level of safety. Exempting autonomous ships from current rules and standards does not mean that these ships can be operated in an entirely unregulated manner; rather, it means that by adopting specific legislation to allow for the experimental operation of autonomous vessels, those vessels will be regulated in a way that neither restricts their operational capabilities nor poses any risk to society (Smeele 2021).

Based on these exemption provisions provided under EU law, national legislative adaptations and operational guidelines have been enacted in Belgium (Flemish Government 2019), the Netherlands (Dutch Ministry of Infrastructure and Water Management 2018) and France (French Ministry of Maritime Affairs 2021); following on from these enactments, subsequent experiments with autonomous inland ships have already taken place in Belgium and the Netherlands or will soon be conducted in France and Germany (BMDV 2021). The CCNR is also currently in the process of allowing derogations from its regulations to pave the way for transnational experiments with autonomous vessels on the Rhine (CCNR 2023a). These experiments are subject to prior national authorisation by the competent (national) authorities and are limited in their geographical scope of operation and duration. Consequently, the authorised derogation from the existing regulatory framework can only have as an objective to advance the development of the existing state of technology; it cannot be regarded as constituting a legal foundation as such for the introduction of autonomous inland ships within the EU on a large scale.

A new regulatory approach to innovation

From the European legislator's perspective, the way forward to a sound regulation of autonomous inland shipping technology will greatly differ from the current regulatory derogation and will require more than one regulatory phase. Nevertheless, the knowledge gained from these experiments can be considered to constitute an important element for any future regulation.

Innovation principle

The EU legislator has introduced the so-called 'innovation principle' to support innovation-friendly EU policy and lawmaking. To ensure that both existing and future legislation is innovation-friendly, the principle covers all three stages of regulation, including agenda-setting, adoption of laws and implementation. Although there has been no universally acknowledged and agreed-upon definition of the principle (Renda and Simonelli 2019), it is applicable to all domains when developing or updating EU policy or regulations (Council of the European Union 2016a). Regulatory frameworks compliant with the innovation principle are 'future-proof, more goal-oriented and technology neutral, foster research and innovation and avoid imposing unnecessary burdens' (Council of the European Union 2016b, p2).

There has been a dynamic discussion of whether the innovation principle could potentially undermine the EU's precautionary principle. The latter is based on the premise that if a given policy or action might possibly cause harm to the public or the environment and if there is still no scientific agreement on the issue, the policy or action in question

should not be carried out. According to views opposing the innovation principle, risk-taking behaviour could be encouraged, which can result in an imbalanced distribution in revenue and risks stemming from innovation between the business sector and civil society (Renda and Simonelli 2019). However, the prevailing opinion seems to be that the two principles do not contradict but rather complement each other in a way that allows future policy and regulation in an innovation-friendly approach (Council of the European Union 2016b).

With respect to regulating autonomous inland shipping, the innovation principle can be used to support a technology-friendly regulatory process that considers the flexibility needed to adapt regulations in light of continuous innovation development. In contrast to the opinion that the innovation principle could potentially harm a more precautionary, restrictive approach to regulating autonomous inland shipping, it is important to keep in mind that regulating disruptive technologies is a means by the public regulator to ensure risk mitigation before the implementation phase of the new technology and any subsequent risk distribution take place. Moreover, by taking a more critical look at the precautionary principle, the European legislator can have recourse to a more innovation-friendly and science-based interpretation of it: According to this interpretation, the principle can be applied in cases where scientific knowledge about potential risks and negative impacts is present, yet incomplete. Without preventing the introduction of the innovation, the legislator hereby applies the principle with regard to the missing scientific knowledge and, by this, ensures that the lacunae in risk and negative impact analysis are filled in subsequent regulatory phases through the means of 'ex post evidence' (Todt and Luján 2014; Smismans and Stokes 2017). Thus, the application of the precautionary principle is justified based on scientific 'ex ante evidence', following a risk assessment with the outcome of potential adverse effects (Smismans and Stokes 2017). It is therefore perfectly possible that the European legislator will regulate autonomous inland shipping through a balanced approach by applying, on the one hand, the innovation principle thereby allowing a more innovation-supportive regulation, and, on the other hand, the precautionary principle to acknowledge the fact that this new technology needs a fundamentally new approach to regulation, including risk and socio-economic impact assessments on a continuous basis. By allowing derogations from existing regulations, the EU has already started to investigate the status quo of scientific knowledge available with regard to autonomous shipping technology.

Latest policy directions of the EU legislator in inland waterway transport

The EU not only plays the predominant role in adopting binding inland waterway regulatory instruments but also in shaping the future of the inland waterway transport sector through its policymaking and agenda-setting powers. Based on the promise to fundamentally transform the sector towards zero emissions, the EU has taken up the ambitious task of facilitating 'the elaboration of a holistic vision for the sector's digitalisation and automation' (European Commission 2021, p11). The latest policy directions taken by the EU that could potentially be relevant to a future regulation of autonomous inland shipping consist of a proposal for smart and flexible EU crewing rules. In this initiative, the EU acknowledges outdated crewing requirements for inland waterway transport despite that 'considerable developments have taken place in recent years that affect the

sector' (European Commission 2023, para1). The objective of the initiative is not as far-reaching as introducing rules governing uncrewed vessels; but an adapted, much more digitalised and especially harmonised approach to current crewing requirements could speed up the process of future regulatory adaptation for autonomous vessels.

Conclusion

The task of regulating autonomous inland shipping in Europe is challenging. The regulatory scoping exercise on inland shipping regulations followed the example of the IMO's regulatory scoping exercise on maritime shipping regulations. The regulatory scoping exercise was conducted with the objective to present the status quo of the current regulatory framework in European inland shipping with regard to the disruptive autonomous shipping technology and to investigate what kind of modifications would need to be made across the fragmented regulatory landscape. To address this objective, the main research-guiding question inquired to what extent the existing European inland shipping regulatory framework would be affected by autonomous shipping technology. To answer this question, three sub-research questions were phrased with regard to (1) which regulations fall within the scope of the regulatory scoping exercise on currently applicable European inland shipping regulations; (2) what common potential gaps and/or themes can be identified in the different regulatory instruments; and (3) what potential links can be established across the analysed regulations.

(1) The study identified several relevant regulatory instruments adopted at the supranational and transnational (but regional) levels and relating to the safety and security aspects of inland shipping, which need to be modified for autonomous shipping operations.
(2) Despite the differences in terms of their geographical scope of application and their hierarchical importance throughout Europe, a subsequent analysis of the identified regulations revealed various common potential gaps and/or themes. The most critical amongst these are new definitions, responsibilities and qualifications for the boatmaster, crew and remote control station (personnel).
(3) By comparing the identified gaps and/or themes with the respective regulatory instruments, many potential links could be established. This means that, despite the many different public regulators in inland shipping and the consequential fragmentation of regulatory instruments, the potential gaps and/or themes identified across the different instruments are (almost) identical and will require a similar approach in their regulation.

Consequently, based on the outcome of the regulatory scoping exercise, the answer to the main research-guiding question is that the regulatory obstacles standing in the way of introducing autonomous inland ships are of a similar nature and occur throughout Europe in a wide variety of regulations. In other words, the same regulatory barriers and potential gaps are present across Europe; however, they are only adopted by different public regulators. In light of this finding, a possible way forward for regulatory intervention is the issuance of a holistic set of regulatory recommendations by one of the supranational institutions, for instance, the UNECE and/or CESNI. These regulatory

solutions can then be incorporated into the other regulatory frameworks. Based on this, a multi-levelled adoption of similar regulatory provisions could follow, which would eventually lead to a harmonised regulation of autonomous inland shipping in Europe. Further research is needed to understand how the identified gaps and/or themes are best addressed through the different means of regulation, and how this can be achieved in a multi-levelled governance structure as it is present in European inland shipping. This includes finding regulatory solutions for safety concerns associated with autonomous shipping technology, as there are many technical and also ethical issues involved in ensuring the safe operation and interaction of these ships, which will need to be regulated.

Abbreviations

ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
CCNR	Central Commission for the Navigation of the Rhine
CDNI	Convention on the Collection, Deposit and Reception of Waste Produced during Navigation on the Rhine and Inland Waterways
CESNI	European Committee for drawing up standards in the field of inland navigation
CEVNI	European Code of Inland Waterways
DC	Danube Convention
Directive 2017/2397	Directive 2017/2397 on the recognition of professional qualifications in inland navigation
Directive 2016/1629/EC	Directive 2016/1629/EC on the technical requirements for inland waterway vessels
Directive 2014/112/EC	Directive 2014/112/EC on the organisation of working time in inland waterway transport
Directive 2008/68/EC	Directive 2008/68/EC on the inland transport of dangerous goods
ES-QIN	European Standard for Qualifications in Inland Navigation
ES-RIS	European Standard for River Information Services
ES-TRIN	European Standard laying down Technical Requirements for Inland Navigation Vessels
EU	European Union
HRIN	Handbook on Radiocommunication for Inland Navigation
IMO	International Maritime Organisation
LEG	Legal Committee
MASS	Maritime Autonomous Surface Ships
MRSSRB	Sava Manual for the Radiotelephone Service in the Sava River Basin
MSC	Maritime Safety Committee
NRSRB	Navigation Rules on the Sava River Basin
PRNM	Police Regulation for the Navigation of the Moselle
Regulation 1177/2010	Regulation 1177/2010 on the rights of passengers in sea and inland waterway transport
RPN	Regulations for Rhine Navigation Personnel
RPR	Police Regulations for the Navigation of the Rhine
RVIR	Rhine Vessel Inspection Regulations
Sava Commission	International Sava River Basin Commission
UNECE	United Nations Economic Commission for Europe

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