PLATINA3

IWT policy platform

D2.3 Report on vision and roadmap on pathway for automation and on board systems

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Executive Summary

The PLATINA3 project

The Horizon 2020 PLATINA3 project provides a platform for the implementation of the NAIADES III Action Plan. PLATINA3 is structured around four fields (Market, Fleet, Jobs & Skills, Infrastructure) of which Work Package (WP) 2 deals with various aspects of the inland navigation fleet, such as 1) zero-emission strategy; 2) climate-resilient vessels; 3) automated vessels; 4) fleet data; and 5) funding the energy transition for the fleet; 6) energy label index for vessels; 7) regulations for zero-emission vessels.

This report presents the conclusions from PLATINA3's Task 2.3 which aims to facilitate the development of regulatory frameworks at European level for onboard systems allowing automation of inland navigation vessels. This deliverable is based on desk research building upon existing studies and analyses and is further substantiated by expert interviews. The outcomes of the 5th PLATINA3 Stage Event (19-20 October 2022), where experts made presentations on this topic, a draft deliverable was showcased, and an interactive workshop was held, are also integrated into this report.

Scope of the report, core definitions, and methodology

The scope of this report is limited to systems allowing automation as well as remote-control of navigational tasks and the corresponding European regulatory frameworks for vessels. Issues related to professional training and qualifications, police requirements, economic and market-related implications, infrastructure, liability and insurance, dangerous goods, and fuel, emissions, and sustainability aspects, are outside the scope of this report.

The core definitions used in this report are based upon the CCNR's levels of automation, the first international definitions of automation tailor-made for the IWT sector. The levels of automation range from steering assistance and partial automation (levels 1-2) to progressive delegation of tasks without intervention of the boatmaster (levels 3-4). Fully autonomous vessels correspond to level 5 (independent command with no human involvement), the most advanced stage of automation.

The report distinguishes whether the vessel is remotely controlled or not, and the degree to which it is automated, i.e. which tasks are completely delegated to the computer, which remain in the human domain, and which are handled by both. Although automation and remote-control are not completely independent from each other, they are functionally different concepts.

This report employed a step-by-step approach based upon an incremental and primarily inductive research design. An analysis of European pilot projects was carried out to determine the TRL and evaluate the RD&I needs of the various systems allowing automation of inland navigation vessels. The report then identified the main functions allowing automation of navigation-related tasks as well as their associated safety concerns. Considering these functions, a gap analysis of relevant European legislation was carried out to identify the possible regulatory barriers/gaps and thereby propose new requirements via a technologically neutral approach. Ultimately, the outcome of this analysis was translated into recommendations accompanied by a Roadmap.

Current state of play and policy context

On 17 October 2018, the inland navigation Ministers of the five CCNR Member States (Belgium, France, Germany, the Netherlands, Switzerland) adopted the Mannheim Declaration and called, *inter alia*, for the "development of digitalisation, automation and other modern technologies in order to contribute to the competitiveness, safety and sustainable development of inland navigation". In 2022, the CCNR published a vision to support the harmonised development of automated navigation via a holistic and technologically neutral approach.

In response to the Paris Agreement, the European Commission adopted the European Green Deal (EGD) in December 2019, which aims to shift a substantial portion of the freight transported by road (currently accounting for circa 76% of EU inland freight) to inland navigation (circa 6%) and rail (circa 18%). As transport accounts for a quarter of the EU's greenhouse gas emissions and is growing, achieving climate neutrality implies that a 90% reduction in transport emissions is required by 2050. All transport modes must contribute to make climate-neutral, resilient, and intelligent synchro-modal automated transport by 2050 a reality. Through this, the EU will unleash the full potential of data, integrate electronic ticketing facilities for seamless multimodal transport, and deploy automated mobility.

As the transport arm of the EGD, the Sustainable and Smart Mobility Strategy (SSMS) lays the foundation for how the EU transport system can achieve its green and digital transformation ambitions and become more resilient to future crises. It underlines the need to increase the use of more sustainable transport modes and indicates that IWT and short-sea shipping should each increase by 25% by 2030 and by 50% by 2050. The SSMS envisions that automated mobility will be deployed at large scale by 2030 to increase the efficiency and reliability of transport, logistics and supply chains. Automation is also identified as a driver of smart mobility in achieving seamless, safe, and efficient connectivity.

In June 2021, the EC launched the NAIADES-III initiative, which sets a 35-point "Inland Navigation Action Plan 2021-2027" aligned with the Multi-Annual Financial Framework to meet the objectives of the EGD and SSMS. Its two core objectives are to shift more cargo to Europe's rivers and canals and facilitate the transition to zero-emission barges by 2050 to boost the role of IWT in environmentally sustainable mobility and logistics systems. One of the eight NAIADES-III policy flagships aims to support the development, demonstration, and deployment of holistic, smart, and automated shipping concepts with a focus on the most promising applications in terms of feasibility and commercialisation, as well as in terms of environmental benefits.

Analysis of European pilot and research projects

The analysis of pilot projects revealed that conducting pilot tests allows regulators and innovators alike to gather critical knowledge, data, and real-life experience to adapt the relevant regulations to achieve automation. Most of the systems needed for automated vessels are already available but some technologies must be further developed and tested before becoming fully operational. Furthermore, questions related to the interoperability between software and onboard systems remain unanswered, both onboard the automated vessel (human-machine interface) and in relation with other vessels (communications, signalling, intent sharing) in a mixed navigation environment.

There is a need for both overall pilot projects on long stretches or the entirety of a given waterway to test the operational feasibility of automated navigation, as well as very localised projects to test specific operations, such as entering locks, passing infrastructure and chokepoints, or making challenging turns. To avoid fragmentation, there is a need to develop industry-wide standards or guidelines. The IWT transport sector would benefit from standardization activities at European level for the scaling-up of automation. Where possible, there would be a clear added value to have similar standards across the waterborne sector.

Systems and functions allowing automation of inland navigation vessels

Six main functions allowing the automation of inland navigation vessels were identified. These are situational awareness, collision avoidance, communications, navigation control, safety, and fall-back capability. Each of these main functions is further broken down into sub-functions, including several 'reliability guarantees'. Each sub-function is underpinned by several system families in varying combinations, such as sensors (RADAR, LIDAR, cameras), positioning systems (GNSS, inland ECDIS), communication systems (4/5G internet, AIS, VHF), computer components (IMU/GPU, centralized PLC system, AI/machine learning), and more. For each subfunction, minimal requirements are identified, both in terms of technical regulations, safety prescriptions, systems' interactions, and human involvement. Some proposed solutions to address common safety concerns are provided to guide the work of regulators.

In terms of Technological Readiness Levels (TRL) and outstanding RD&I needs, it appears that most of the systems needed for low level automated navigation (levels 1-2) are already in a relatively high state of market readiness. This includes the core systems allowing automation (RADAR, LIDAR, cameras, GNSS, communications, global internet, track pilots etc.), which are considered to have reached a high TRL level. On the other hand, techniques and systems for high automation and autonomy (levels 3-5) have comparatively low TRL levels. Indeed, the most advanced systems (collision avoidance, AI, neural networks, sensor fusion and integration, etc.) still need additional technical improvements to move from TRL 5-6 to TRL 9. Furthermore, on some small sections of the Rhine and on most of the Danube, high speed internet connectivity (4G/5G) remains unavailable, which is a virtual precondition for operating a significant share of automated vessels, especially remote-controlled vessels. Finally, encryption, data integrity, and cybersecurity systems and protocols still need additional testing and improvements to become fully mature. This remains critical for the safe deployment of remote-controlled vessels and other higher automation applications.

Some systems allowing high levels of automation are currently in use, although there is always a human as a supervisor and backup - either onboard or in an RCC. More testing locations for automation levels 3 and above are needed to gather as much data as possible. This data is necessary for developers to improve the performance of their systems and for regulators to make informed decisions.

Results of the regulatory gap analysis and recommendations

The identified regulatory obstacles to the uptake of automated inland navigation vessels in ES-TRIN fall into two main categories. The first category regards provisions that constitute regulatory barriers and therefore do not allow or contradict the aims of automation. These typically refer, explicitly or implicitly, to the presence of a boatmaster and/or crew members onboard, either to perform an action or to interact with equipment designed for manned operations (e.g. doors to be passed, signs to be read, etc.). These provisions should, broadly speaking, be amended to account for the specificities of automated inland navigation vessels. The second category regards the absence of regulations pertaining to specific functions identified as necessary for the safe automation of inland navigation vessels – i.e. regulatory gaps. This absence could generate a legal vacuum leading to a proliferation of patchwork solutions and possible low safety standards. At the very least, these functions should be incorporated into the regulatory framework.

Regulators (EU, CCNR, CESNI), standardisation bodies (CEN, ETSI) and classification societies should work together to fund, support, and learn from pilot projects to gather the necessary data and experience to better regulate the IWT policy area to allow the automation of inland navigation vessels. Regulatory work should be complemented by targeted interventions to bridge the financial gap and the respond to the outstanding RD&I needs for automation-enabling systems to reach technological maturity in the short to medium term.

List of abbreviations

AI	Artificial Intelligence
AIS	Automatic Identification System
ARPA	Automatic RADAR Plotting Aid
CCAM	Connected, Cooperative and Automated Mobility
CCNR	Central Commission for the Navigation of the Rhine
CESNI	European Committee for drawing up Standards in the field of Inland Navigation
CO_2	Carbon Dioxide
DC	Danube Commission
DG MOVE	Directorate-General for Mobility and Transport
DVW	De Vlamse Waterweg (Belgium)
EC	European Commission
ECDIS	(Inland) Electronic Chart Display Information System
EGD	European Green Deal
ES-TRIN	European Standard laying down Technical Requirements for Inland Navigation vessels
ETSI	European Telecommunications Standards Institute
EU	European Union
FV	Follower Vessel
GA	Grant Agreement
GHG	Greenhouse gas(es)
GNSS	Global Navigation Satellite Systems
HMI	Human-Machine Interface
ICE	Internal combustion engine
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
INGA	Inland Navigation Guidance Assistant
ISRBC	International Sava River Basin Commission
ITS	Intelligent Transport Systems
IWT	Inland Waterway Transport
IWW	Inland Waterways
LIDAR	Light Detection And Ranging

LNG	Liquefied Natural Gas
LV	Leader Vessel
MASS	Maritime Autonomous Surface Ships
PIANC	World Association for Waterborne Transport Infrastructure
PLATINA II	Platform for the Implementation of NAIADES Action Plan 2
PLATINA3	Platform for the Implementation of NAIADES Action Plan 3
R&D	Research and Development
RADAR	Radio Detection And Ranging
RCC	Remote Control Centre
RD&I	Research, Development and Innovation
RN	Small Navigation committee (CCNR)
RP	Police Regulation committee (CCNR)
RVIR	Rhine Vessel Inspection Regulations
SME	Small and Medium-sized Enterprise
SSMS	Sustainable and Smart Mobility Strategy
SSS	Short Sea Shipping
TGAIN	Track Guidance Assistant for Inland Navigation
Tkm	Tonne-kilometre (transport performance)
TRL	Technological Readiness Level
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
US	United States (of America)
VDES	VHF Data Exchange System
VHF	Very High Frequency (radio)
VNF	Voies Navigables de France
VT	Vessel Train
VTS	Vessel Traffic Services
WP	Work Package

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1. Introduction

1.1 Objectives and perimeter of the report

The Horizon 2020 PLATINA3 project[1] provides a platform for the implementation of the European Commission's (EC) NAIADES-III action programme dedicated to inland navigation. PLATINA3 is structured around four core fields of study: Market, Fleet, Jobs and Skills, and Infrastructure. The fleet study field is part of Work Package 2 (WP2) and deals with various aspects of the fleet, such as:

1. a zero-emission fleet;
2. a climate resilient fleet;
3. digital and automated vessels;
4. technical regulations and standards for the fleet and fuels;
5. accurate fleet data.

This report addresses the topic 'digital and automated vessels', which is part of task 2.3 of PLATINA3 according to the Grant Agreement. The title of task 2.3 is "Roadmap for onboard systems allowing automation of inland navigation vessels" and the CCNR Secretariat leads the execution of this task. The objective of this task is to: "*prepare and facilitate the development of regulatory frameworks at EU level for onboard systems allowing automation of inland navigation*".

Based on existing regulations and current knowledge trends related to automated navigation, the report aims to propose a roadmap to start regulatory work with the objective to allow the development of safe, seamless, reliable, and user-friendly automated vessels, following a technologically neutral approach. At the same time, the research, development, and innovation (RD&I) needs are evaluated.

As pilot projects are critical to test these new technologies in real conditions and to gather the data needed to properly regulate them in the future, this report also addresses the facilitation of derogations to existing rules and the collection of experience. In this context, the authors pay special attention to the needs and concerns of the IWT sector, in particular the shipowners, the shipyards, the equipment/solution providers, and classification societies.

Therefore, the scope of this report is limited to:

- ➔ Systems allowing automation as well as remote-control of navigational tasks (both dimensions addressed for regulatory gaps);
- ➔ European regulatory frameworks (EU and beyond) for vessels.

The following elements are outside of the scope of this report:

- ➔ Professional training and qualifications;
- ➔ Police requirements;
- ➔ Economic and market-related implications;
- ➔ New and smart infrastructure at ports, docks, and locks;
- ➔ Insurance-related questions;
- ➔ Specific requirements related to waste and transport of dangerous goods via automated vessels;
- ➔ Fuels, emissions, and sustainability aspects.

This report will not duplicate but draw upon and take into account the results of PLATINA3 task 1.1 on modal shift, task 2.7 on regulatory pathways towards zero emissions for the fleet, task 3.3 on competence standards, and task 4.3 related to smart waterway and port infrastructure and management.

In the following sections, the main terms used in this report will be defined and the methodology – based on a step-by-step approach – will be specified. In Chapter 2, the general context surrounding the

[1] PLATINA3, "Platform for the implementation of a future inland navigation action programme", https://platina3.eu/.

development of automated inland vessels will be analysed, including the current policies and regulatory frameworks, the expected benefits of automation, and which lessons can be learned at this stage from automation in other transport sectors. Chapter 3 analyses pilot projects and outputs of European research projects to determine the technological readiness level (TRL, 1-9) of the various systems needed for automating inland navigation tasks. As these systems cannot be disassociated from their use, Chapter 4 focuses on previously identified systems' functions in the context of inland navigation, which also allows for a technologically neutral approach. Chapter 5 presents a regulatory gap analysis of European vessel requirements in light of pre-identified systems and functions. Finally, Chapter 6 provides recommendations to national and international policymakers (such as the EU and the CCNR) and to standardisation bodies (such as CESNI), as well as a roadmap with a suggested chronology for the development, adoption, and implementation of regulations to fill the regulatory gaps.

1.2 Definitions of automation and other keys terms

In recent years, numerous categorizations have been developed to describe the automation of a system. Some of them were specifically designed for vessels and in particular for the maritime sector. For instance, in the Smart Port White Paper[2], three stages of autonomy (beyond manual operation) are considered, ranging from 1 (increased sensors & decision support) to 3 (fully autonomous). The Institute of Marine Engineering, Science and Technology (IMAREST)[3] expresses the relation between operator and machine in five ''human and machine interface status'' levels, additionally specifying for each level if operators are located on the vessel or not. However, it was not until 2018 that a specific categorization was developed for the IWT sector.

In 2018, the Central Commission for the Navigation of the Rhine (CCNR) adopted the first internationally recognized definition of the various levels of automation in inland navigation (levels ranging from 0-5)[4]. The CCNR believes that this definition should not be set in stone but rather be continuously amended and improved to take into account new technical, regulatory and economic developments. As such, the definitions were reviewed and updated in January 2023. Automated navigation now covers a wide spectrum of technical processes spanning numerous use cases, from simple navigational assistance to fully automated (autonomous) navigation.

The CCNR levels of automation constitute therefore the variable that offers the best understanding of the concept of automation in inland navigation, as it is tailor-made for the sector. It ranges from steering assistance and partial automation (levels 1-2) to progressive delegation of tasks without intervention of the boatmaster (levels 3-4). Fully autonomous vessels correspond to level 5 (independent command with no human involvement), the most advanced stage of automation. A schematic overview of the various levels of automation can be found in **Figure 1** below. Hereafter, the CCNR definitions will be used throughout this deliverable as the primary reference for automation in inland navigation.

The report focuses on automated vessels in light of existing pilot projects (mainly levels 1-4). It should be noted that the CCNR does not envision full automation (autonomous, level 5) in the short- to medium-term.[5] The path towards automated vessels should be based on a gradual, progressive, and step-by-step approach allowing regulations to be adapted to technical improvements and developments, while always prioritizing safety.

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[2] Smart Port, "Smart ships and the changing maritime ecosystem", April 2019, Smart Port | Report [EN].

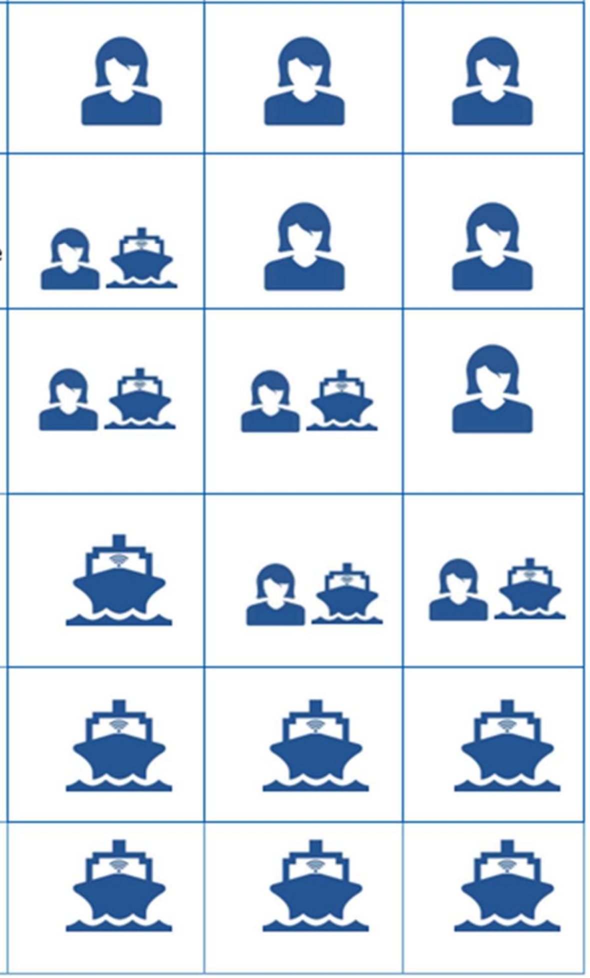
[3] IMAREST, "Autonomous shipping: Putting the human back in the headlines", September 2019, IMAREST | Report [EN].

[4] CCNR, "Definition of levels of automation in inland navigation", November 2021, CCNR | Automation levels [EN].

[5] CCNR, "Vision détaillée pour soutenir le développement de la navigation automatisée", March 2022, CCNR | Detailed Vision [FR].

Figure 1: Definition of levels of automation in inland navigation. ***Source****: CCNR.*

	Level of automation[1]	Designation	Craft command (steering, propulsion, wheelhouse, etc.)	Monitoring of and responding to navigational environment	Fallback performance of dynamic navigation tasks
BOATMASTER PERFORMS PART OR ALL OF THE DYNAMIC NAVIGATION TASKS	**0**	**NO AUTOMATION** the full-time performance by the boatmaster of all aspects of the dynamic navigationtasks, even when supported by warning or intervention systems			
	1	**STEERING ASSISTANCE** the context-specific performance by a steering automation system using certain informationabout the navigational environment and with the expectation that the boatmaster performs all remaining aspects of the dynamic navigation tasks			
	2	**PARTIAL AUTOMATION** the context-specific performance by a navigation automation system of both steering and propulsion using certain information about the navigational environment and with the expectation that the boatmaster performs all remaining aspects of the dynamic navigation tasks			
SYSTEM PERFORMS THE ENTIRE DYNAMIC NAVIGATION TASKS (WHEN ENGAGED)	**3**	**CONDITIONAL AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks, including collision avoidance, with the expectation that the human boatmaster will be receptive to requests to intervene and to system failures andwill respond appropriately			
	4	**HIGH AUTOMATION** the sustained context-specific performance and fallback performance, by a navigation automation system of all dynamic navigation tasks without expecting a boatmaster responding to a request to intervene[2]			
	5	**AUTONOMOUS = FULL AUTOMATION** the sustained and unconditional performance and fallback performance, by a navigation automation system of all dynamic navigation tasks, without expecting a boatmaster responding to a request to intervene			



[1] Different levels of automation may make use of remote control but different conditions to be defined by competent authorities might apply in order to ensure an equivalent level of safety.

[2] This level introduces two different functionalities: the ability of "normal" operation without expecting human intervention and the exhaustive fallback performance. Two sub-levels could be envisaged.

The report distinguishes whether the vessel is remotely controlled or not, and the degree to which it is automated, i.e. which tasks are completely delegated to the computer, which remain in the human domain, and which are handled by both. Although automation and remote-control are not completely independent from each other, they are functionally different concepts that cannot be used interchangeably. Indeed, remote control is not a "level" of automation but is linked to automated tasks (see **Figure 1**), as remote control always requires some level of onboard automation and digitalisation, in particular as a back-up in case of failure of the remote-control system (communication interruption, emergencies). Yet, remote control also implies some form of either direct or indirect human supervision of the vessel that is not akin to automation, as the onboard systems do not perform (semi-)independent navigational tasks but simply transform the human input into mechanical actions in order to implement decisions taken by humans located elsewhere. An extreme example would be a vessel with no crew or operators onboard permanently tele-guided by a remote-control centre (RCC) that would still be considered as automation level 1 at best.

Other preliminary definitions relevant in the context of this report include the concepts of "dynamic navigation tasks", "navigational environment", "context-specific navigational conditions", and "collision avoidance".[6]

- **Dynamic navigation tasks**: are understood as the set of tactical vessel operations, such as operation of rudder apparatus, propulsion, anchor winches or elevating wheelhouse. The complexity of these tasks is dependent upon the context considered (for example, manipulation of anchor winches can be excluded where the use of anchors is forbidden).
- **Navigational environment**: is understood as the fixed and dynamic conditions affecting navigational operations, such as the waterway's shape, water level, weather, visibility, vessel crossing, etc. The automated navigation system can use only part of the information available (for example, for level 1, rate-of-turn indicators do not use information on vessel crossing). The response to the navigational environment includes radiocommunication with boatmasters from other vessels.
- **Context-specific**: is understood as confined navigational conditions such as navigation on specific river waterway sections or lock crossing, as well as vessel arrangements with convoys or platooning. The context includes infrastructure relevant for automation, for example type and capacity of radio transmission networks.
- **Collision avoidance**: is the most critical task in responding to the navigational environment, and includes all possible manoeuvres to avoid the vessel hitting another vessel, object, person or animal.

Finally, the concepts of "automated navigation", "automation of vessel operation", and "automated vessel command" have been discussed within the CCNR. A revision - evolution rather than revolution - of their definitions was undertaken by the CCNR and published in early 2023.

- "Automated navigation" would cover a global approach in the field of automation, including operation, equipment, training related aspects. In automated navigation, the skipper may need special skills to use the new equipment. The term will be largely based on the different levels of automation identified above.
- "Automation of vessel operation" aims at having a general term for all tasks related to the operation (docking, unloading, bunkering, steering, etc.) of an automated vessel.
- "Automation of vessel command" would be limited to the tasks necessary to determine, execute and maintain the course or speed of the vessel. For example, the Track Guidance Assistant for Inland Navigation (TGAIN, or track pilot) would be considered as an equipment used for automated navigation.

[6] CCNR definitions, *op.cit.*

1.3 Methodology: a step-by-step approach

Given the novel and prospective nature of the topic at hand, this report employed a step-by-step approach based upon an incremental and primarily inductive research method. Firstly, starting from the key notions defined above, an analysis of European pilot and research projects was carried out through a desk study substantiated by expert interviews. This research method also allowed to determine the TRL and evaluate the RD&I needs of the various systems.

The second milestone was the identification of the main functions of systems allowing automation of navigation-related tasks (excluding maintenance) and remote-control of inland vessels, as well as their associated safety concerns. Thirdly, considering these functions, an analysis of relevant European legislation was carried out. It allowed to identify the possible regulatory obstacles/gaps and to propose new requirements as well as ways to implement/control these requirements via a technologically neutral approach.

The hypothesis used as well as the preliminary outcomes of the analysis were shared and discussed with IWT sector representatives and other stakeholders during a dedicated workshop (PLATINA3 stage event 5, Budapest, 19-20 October 2022). Ultimately, the outcome of this analysis – taking into account input collected from experts and sector representatives during the stage event – was translated into recommendations to guide the work of policymakers and regulatory bodies. The recommendations are accompanied by a suggested chronology for the development, adoption, and implementation of regulations (roadmap).

2. General context

2.1 Policy and regulatory context

The current policy and regulatory context surrounding the development of automation of inland navigation is characterized by interlocking international, EU/European, and national (sometimes even sub-national) legislations, regulations, and commitments. These include the Mannheim Declaration and relevant CCNR initiatives (2018-2022), the European Green Deal (EGD, 2019), the EU Sustainable and Smart Mobility Strategy (SSMS, 2020), the EC's NAIADES-III Action Plan for Inland Navigation (NAIADES-III, 2021), and other relevant international (IMO) and national regulations and initiatives.

2.1.1 CCNR: from the Mannheim Declaration (2018) to the CCNR Vision (2022)

On 17 October 2018, the inland navigation Ministers of the five CCNR Member States (Belgium, France, Germany, the Netherlands, Switzerland) adopted the Mannheim Declaration and called, *inter alia*, for the "development of digitalisation, automation and other modern technologies in order to contribute to the competitiveness, safety and sustainable development of inland navigation".[7] As a result, the CCNR adopted in late 2018 the first international definition of automation levels in inland navigation (see section 1.1), which were subsequently updated in December 2022.[8] In November 2021, the CCNR published a summary of the vision to support the harmonised development of automated navigation.[9] In early 2022, the summary was further developed into a "detailed vision to support the development of automated navigation in the CCNR", hereafter referred to as "the CCNR Vision".[10]

The CCNR Vision is conceived as a dynamic document subject to improvement, revision, and change. It is also a policy instrument for steering and coordinating the work to be carried out in the period 2022-2028, and beyond. As automation implies a fundamental transformation that will affect almost all aspects of inland navigation, encompassing technical, legal, ethical, and social considerations, it justifies the holistic approach enshrined at the heart of the CCNR Vision. The specificities of inland navigation with regard to automation must be taken into account, including:

- composition and qualification of crews;
- technical requirements of vessels;
- navigation in a closed and restricted environment, taking into account the limited dimensions of the waterway;
- infrastructure requirements (passage of locks, changing water levels and height of bridges);
- the manoeuvrability of the vessels;
- legal issues (liability, data protection, police rules);
- communication issues (land/vessel, vessel/vessel, with possible human-machine interfaces (HMI]);
- cybersecurity.

The development of automated navigation is not an end in itself, but aims to meet several objectives:

- ensure an at least equivalent level of safety of navigation on the Rhine;
- contribute to the prosperity of Rhine navigation by adapting it to new challenges;
- support the sector's future growth into a more competitive and innovative digital paradigm;

[7] CCNR, "Mannheim Declaration", 17 October 208, CCNR | Mannheim Declaration [EN].

[8] CCNR, "Automated navigation: Definition of levels of automation in inland navigation", November 2020, CCNR | Automation levels [EN].

[9] CCNR, "Summary of the CCNR's vision to support the harmonised development of automated navigation", November 2021, CCNR | Summary of the Vision [EN].

[10] CCNR, "Vision détaillée pour soutenir le développement de la navigation automatisée", March 2022, CCNR | Detailed Vision [FR].

- promote the sustainable development of inland navigation in environmental, social, and economic terms.

As a first step, the CCNR will strive to develop requirements and/or recommendations for intelligent assistance systems for automation levels 1, 2 and 3 (i.e. a human boatmaster, either on board or remotely, reacting appropriately to requests for assistance or in case of system failure), and develop the framework conditions allowing remotely-controlled automated vessels to operate. The CCNR will work on this topic, as on others, in close co-operation with the European Union (EU), the United Nations Economic Commission for Europe (UNECE), the other river commissions, and the World Association for Waterborne Transport Infrastructure (PIANC), in order to arrive at a common understanding of automated navigation. Widespread participation in workshops to present the work of the CCNR will help to make it known beyond the Rhine. For example, the international definition of automation levels is already referred to by several national authorities (e.g. Maritime Autonomous Surface Ships - UK Code of Practice[11]) and international institutions, such as the UNECE or PIANC, in particular within PIANC Working Group 210.[12]

To turn automation aspirations into a tangible reality, inland navigation needs pilot projects to test the technical feasibility of innovative solutions and to identify, if necessary, appropriate regulatory measures. This approach has been adopted in other areas such as alternative fuels. The CCNR will therefore, in the short term, focus its work on the following tasks:

- monitoring and analysing the results of pilot projects;
- implementing a derogation procedure for authorising and monitoring pilot tests on the Rhine;
- develop recommendations for intelligent assistance systems used in levels 1 and 2;
- develop framework conditions for allowing automated as well as remotely controlled inland navigation vessels.

Since 2018, the CCNR has developed an inventory of relevant pilot and research projects. As of June 2022, 36 national and international projects in CCNR Member States have been inventoried.[13] The CCNR recently developed a uniform procedure allowing the authorisation of a pilot project for automated navigation on the Rhine requiring a derogation from the three CCNR Regulations (RPR, RVIR, RPN).[14] It also published a list of authorities competent to receive such a request in the five CCNR Member States.[15]

A harmonized and uniformed procedure at the level of the CCNR will be useful for project promoters who wish to carry out trials on the Rhine that require a derogation from CCNR regulations, thereby significantly reducing the administrative burden, especially when examining cross-border projects. The procedure could also inspire other European nations to develop their own national procedures, especially if they do not yet have one.

[11] Maritime UK, “Maritime Autonomous Surface Ships Industry Conduct Principles”, December 2020, UK Code of practice | V4.

[12] PIANC, “WG 210 – Smart Shipping on Inland Waterways", March 2022, PIANC | WG 210.

[13] CCNR, “Listing of pilot and research projects in the field of automation in inland navigation”, June 2022, CCNR | Inventory.

[14] CCNR, “Procedure for authorising a pilot project for automated navigation”, April 2022, CCNR | Procedure pilot projects [FR]. The regulations concerned are: the Police Regulations for the Navigation of the Rhine (RPR), the Rhine Vessel Inspection Regulations (RVIR) and the Regulations for Rhine Navigation Personnel (RPN).

[15] CCNR, “List of authorities competent to receive a request for authorisation of a pilot project in automated navigation requiring a derogation from the CCNR regulations”, April 2022, CCNR | List of competent authorities [FR].

The experience gained from different pilot projects should help assess the need to adapt and update the regulatory framework on the basis of a common understanding. In this respect, it is necessary to be able to draw upon the results of pilot projects.

2.1.2 European Union: from the European Green Deal (2019) to the Sustainable and Smart Mobility Strategy (2020)

In response to the Paris Agreement, the EC adopted the European Green Deal (EGD) in December 2019.[16] The EGD aims to, *inter alia*, shift a substantial portion of the freight transported by road (currently accounting for circa 76% of EU inland freight) to inland navigation (circa 6%) and rail (circa 18%), namely through measures to increase modal shift and reduce emissions, which will require more fleet capacity coupled with a better utilization of assets. As transport accounts for a quarter of the EU's GHG emissions and is growing, achieving climate neutrality and the ambitions of the EGD implies that a 90% reduction in transport emissions is required by 2050. All transport modes will need to collaborate to make climate-neutral, resilient, and intelligent synchro-modal automated transport by 2050 a reality.[17] Through this, the EU will unleash the full potential of data, integrate electronic ticketing facilities for seamless multimodal transport, and deploy automated mobility. On 14 July 2021, the EC published the "Fit for 55" legislative package to deliver the EGD, a set of proposals to make the EU's climate, energy, taxation and especially transport policies fit for reducing net GHG emissions by at least 55% by 2030, compared to 1990 levels.[18] Significantly, in early June 2022 the EU voted to ban the sale of new internal combustion engine (ICE) cars by 2035, an additional milestone towards carbon neutrality.

As the transport arm of the EGD, the Sustainable and Smart Mobility Strategy (SSMS), adopted on 9 December 2020, lays the foundation for how the EU transport system can achieve its green and digital transformation ambitions and become more resilient to future crises.[19] It underlines the need to increase the use of more sustainable transport modes and indicates that IWT and short-sea shipping (SSS) should each increase by 25% by 2030 and by 50% by 2050. The SSMS envisions that automated mobility will be deployed at large scale by 2030 to increase the efficiency and reliability of transport, logistics and supply chains. Automation is also identified as a driver of smart mobility in achieving seamless, safe, and efficient connectivity. Flagship 6 of 10[20], under the umbrella of smart mobility, wishes to make connected and automated multimodal mobility a reality, with the inclusion of IWT. Within this umbrella, the EU plans to take full advantage of smart digital solutions, intelligent transport systems (ITS) and connected, cooperative and automated mobility (CCAM) concepts.

2.1.3 NAIADES-III (2021)

In June 2021, the EC launched the NAIADES-III initiative, which sets a 35-point "Inland Navigation Action Plan 2021-2027" aligned with the Multi-Annual Financial Framework to meet the objectives of the EGD and SSMS. [21] Its two core objectives are to shift more cargo to Europe's rivers and canals and facilitate the transition to zero-emission barges by 2050 to boost the role of IWT in environmentally sustainable mobility and logistics systems. One of the eight NAIADES-III policy flagships aims to support the development, demonstration, and deployment of holistic, smart, and automated shipping concepts with a focus on the most promising applications in terms of feasibility and commercialisation, as well as in terms of environmental benefits. [22] This will facilitate the elaboration of a holistic vision for the sector's digitalisation and automation efforts, also identifying necessary adjustments to existing regulations.

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[16] European Commission, "A European Green Deal", December 2019, A European Green Deal | European Commission (europa.eu).

[17] *Ibid*.

[18] European Commission, "Fit for 55 package", July 2021, Delivering the European Green Deal | European Commission (europa.eu).

[19] European Commission, "Sustainable and Smart Mobility Strategy", December 2020, Mobility Strategy (europa.eu).

[20] Flagships are key areas for action to make the vision a reality https://transport.ec.europa.eu/transport-themes/mobility-strategy_en

[21] European Commission, "NAIADES III action plan", June 2021, NAIADES III action plan (europa.eu).

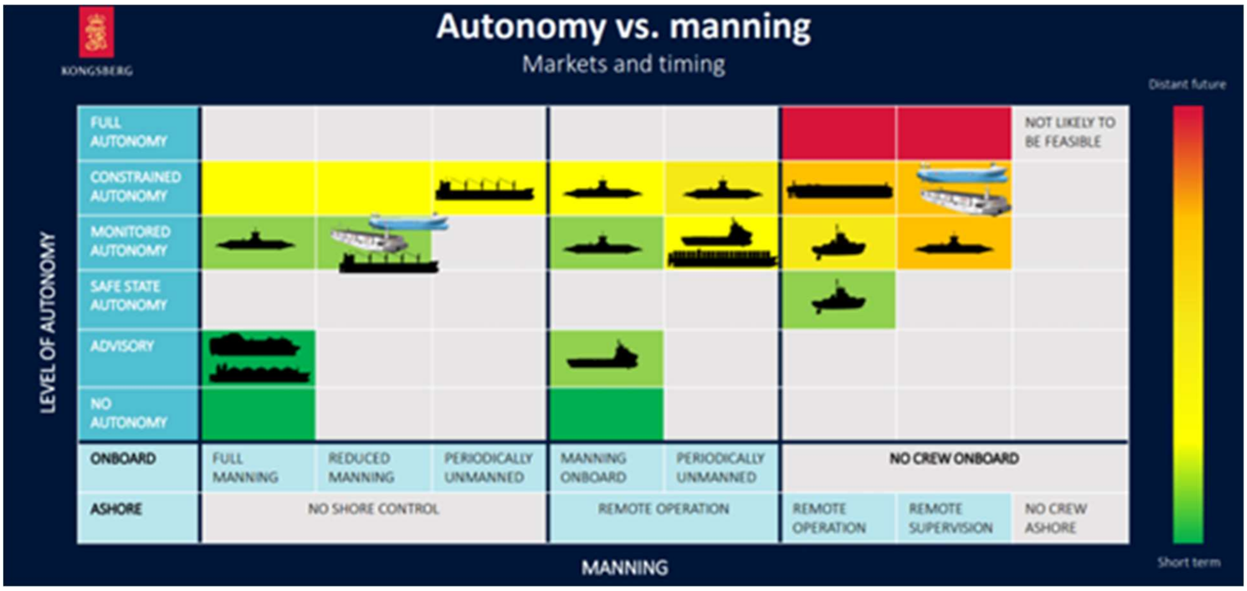
[22] Flagship 6: A roadmap for digitalisation and automation of IWT.

2.1.4 The International Maritime Organization and related developments

The International Maritime Organization (IMO) developed its own definitions for progressive automation in the maritime sector, based upon four degrees of automation[23]:

1. crewed ship with automated processes and decision support;
2. remotely controlled ship with seafarers on board;
3. remotely controlled ship without seafarers on board;
4. fully autonomous ship.

One of the main companies involved in automation in the waterborne transport sector, Kongsberg, even went further in the classification of autonomy as compared to manning by also taking into account the markets (vessel types) and the expected timeframe, as illustrated in **Figure 2** below.



***<u>Figure 2</u>**: Automation vs. manning. **Source**: Kongsberg, IMO MASS session, 27 January 2022.*

In the context of these ongoing discussions within IMO, the One Sea Ecosystem is currently developing a vision and strategy to create the framework conditions to make an autonomous maritime ecosystem possible by 2050, including all technical, operational, ethical, and regulatory related implications.[24]

Utilizing national rules based on this IMO framework, several inland/estuary vessels were already controlled remotely with seafarers onboard in Belgium, the Netherlands and Norway (degree 2). Artificial Intelligence (AI) is also already being applied for the detection and identification of objects, which is needed to further evolve to degree 3.

2.1.5 Other relevant national regulations and initiatives

Automation of inland navigation vessels faces numerous gaps in legislations at European level. In this context, pioneer countries aiming to modernise and drive innovation forward in a sector that carries symbolic importance at national level such as the Netherlands[25] and Belgium (and especially in

[23] IMO, "Autonomous shipping", 2022, IMO | Autonomous shipping [EN]. See also: IMO, "Outcome of the Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS)", 3 June 2021, IMO | MASS Scoping Exercise [EN].

[24] One Sea, "Autonomous maritime ecosystem", 2022, https://www.oneseaecosystem.net/.

[25] In the Netherlands, the Rijkswaterstaat developed a "Smart Shipping Loket", a platform where one can apply for permission to carry out pilot projects on Dutch waterways. More information available at: Smart Shipping | Rijkswaterstaat [NL].

Flanders[26]) already initiated regulatory work to authorise pilot projects. In Flanders, the procedure usually requires applicants to submit all documents necessary to assess the technical feasibility and the safety risk of the pilot test. This includes a thorough risk analysis provided by the applicant, a multi-stage interview process with the regulatory authorities, and the establishment of an agreement between the applicant and the regulator which strictly delimitates the objective, duration, and scope of the test.[27]

In the Netherlands, the SMASH! programme was launched in 2020 and is supported by regional and national governments and the industry. SMASH! is a network programme that brings together the waterborne transport sector to implement automated navigation to strengthen the industry's competitive position. Knowledge gathering, consolidation and dissemination, also in relation to relevant laws and regulations regarding automated navigation, is one of the activities in this respect.

In France, the Ministry of Ecological Transition is currently funding a doctoral thesis on autonomous vessels in inland navigation and their implications in terms of regulation, safety, crew composition, and professional qualifications, which should be published by late 2024.

2.2 Expected benefits of automation for inland navigation

Automated navigation is expected to bring economic benefits to various parts of the general economy.[28] In general, automated navigation could generate benefits in the form of, namely increased efficiency, safety, and sustainability. Automation could potentially contribute to the two core objectives identified in NAIADES-III, i.e. 1) shifting more freight transport to inland waterways, and 2) an irreversible path to zero-emissions. Automation could also generate new and potentially more attractive jobs with high qualifications (e.g. shore-based supervision of multiple automated vessels).

In terms of efficiency, automated inland navigation will facilitate day-to-day operations for skippers by lightening the workload on the boatmaster and greatly modernize and digitalize navigational tasks. By facilitating the real-time exchange of data, automation could also increase interoperability and multi/synchro-modal logistics and transport. Moreover, as the crew onboard will likely be greatly reduced or located entirely on shore (unmanned), smaller vessels with lower capacity could be used. These vessels would be able to make use of a waterway network with smaller dimensions (draught, width), thus limiting the cost of transfers to other modes of transport and thereby increase the modal share of inland waterways (IWW) in the overall transport network.

Automated vessels have the potential to improve existing transport concepts while at the same time enabling completely new concepts to be realised by lowering crew-related costs, also due to the vessel's ability to operate nearly 24/7, thereby generating economies of scale. If combined with new vessel concepts, such as small craft devoid of wheelhouses for urban logistics, additional gains could be achieved.[29] This would lead to increased energy efficiency by removing all energy uses associated with the personnel onboard (lighting, heating, cooking, waste storage and disposal, etc.) as well as by providing more space for cargo in a given vessel class size, while at the same time increasing the vessel's overall cargo carrying capacity. As less energy is being consumed onboard, this will lead to less overall emissions, thereby contributing to reaching the abovementioned climate objectives. Especially in the

[26] The Flemish regulatory authority responsible for inland waterway infrastructure management, De Vlamse Waterweg (DVW), created a procedure to grant permission to run pilot tests and experiments without skippers onboard the vessels. More information available at: DVW | Derogation procedure [EN].

[27] Insights gathered during the interview with Ann-Sophie Pauwelyn (De Vlamse Waterweg) on 11 May 2022 and Louis-Robert Cool (SEAFAR) on 27 May 2022.

[28] https://zoek.officielebekendmakingen.nl/blg-1038578.pdf

[29] Examples include Zulu vessels, the Green Wave and smaller KOTUG e-pushers. In this context, see also PLATINA3 deliverable 1.1 (Increased decarbonisation and modal shift), Chapter 3.1 on urban transport and logistics.

case of small crafts used in busy city centres, the local road network in historic centres can also be relieved of damage to paving and quay walls caused by heavy lorries.
Personnel productivity is expected to increase even more if the necessary systems and processes can be automated to such high standards that the navigational crew is no longer required to be present on board. In this case, remote control could allow a smaller number of staff to operate multiple vessels from an RCC. This could be especially beneficial to ferries with long operating hours and relatively low passenger numbers (no skippers required onboard or automated systems allowing the skipper to rest while the vessel keeps travelling). However, realising these potential benefits poses its own set of ethical challenges since many vessels already operate with a low number of crew members, meaning productivity gains would only really make a difference if all crew could be absent from the vessel.

Automated navigation can positively impact not just the transport segment itself, but also its interaction and positioning with the other transport modes and their shared infrastructures. Automation could ease and speed up the transport of cargo in the logistic chain, including loading and unloading from IWT vessels. Thus, a faster and more efficient IWT fleet will also incentivize different customers to use it, and it would also strengthen the current multi-modal operations, while perhaps making new ones available. This also links to the European Green Deal's objective to achieve intelligent and automated synchromodal transport in the near future.

Furthermore, automation is expected to improve safety in all transport modes. Human error is a major source of accidents and heightens other related risk factors. According to a recent study, accidents in inland navigation seem to increase in severity and cost of claims in recent years, and human error is a contributing factor in 70-80% of all accidents.[30] The main sources of human errors include:

- Inadequate or poor-quality communication (limited use of standard communication protocols and phraseology, limited command of shared common language);
- Crews' lack of qualifications, experience and craftsmanship;
- Limited familiarity with navigational areas and infrastructure;
- No easy access to reliable information such as actual water levels;
- Heavy workloads and operational pressure leading to fatigue and stress.

In this context, it is expected that automated navigation will allow to reduce human-related errors and improve safety along European inland waterways.[31] Indeed, removing the human factor from vessel operation could have large benefits, by lowering accident rate and severity, and the potential for improvement should be high, particularly when automation is combined with systems' continuous deep learning. Safer operations are not based on the fact that automation itself is always safer. But this is largely due to the high demands that we as a society place on automated systems. The tolerance for errors made by automated systems is lower than the tolerance for errors made by human actors. Hence, automated vessels will only be deployed if they are safer than the status quo.

That being said, delegation of control to an automated system poses ethical questions, especially in case of malfunctions and accidents causing damages to property and endangering human lives. The liability implications of such scenarios remain currently unresolved[32]. The technology might also prove more reliable, especially if combined with human operators monitoring activities for safety purposes from

[30] INTERGO, "Human factors root causes of accidents in inland navigation", October 2021, INTERGO | Report.

[31] Netherlands Maritime Technology, "Nederlandse Autonome Veerponten: Innovatie Stappenplan", December 2021, NMT | NAVIS [EN].

[32] However, it is safe to assume that at least for the foreseeable future many companies will not easily accept (full) liability for a software and/or hardware that is not their own development. Especially since automation systems are and will be far from cheap, and they will also come with guarantee periods, like any other equipment or technology that is integrated on vessels.

RCCs. However, a fast and widespread adoption of automation may also lead to blind trust and errors, which should be addressed in the regulations.[33]

Following interviews held for this deliverable, there is also a complementary line of thought which states that automation will make navigation safer. Not because it is safer per se, but because we, as a society, will only accept automation systems with very low failure rates.[34] This leads to a safer future, but also makes it very hard to get systems to the required level of capability, especially because our bias for autonomous systems also plays a role in allowing tests and demonstrations in real life environments.

In terms of sustainability, Ehlers et al. (2022) expect that highly automated, remote-controlled, or fully autonomous vessels are intended to improve safety and lead shipping into a more sustainable future.[35] This is echoed by the SSMS, which posits that increasing the modal shares of automated mobility will significantly lower pollution and congestion from transport. Indeed, automated navigation could potentially increase long-term usage of vessels and inland waterways, thereby contributing to modal shift from road to IWT. This shift will be more likely if automated navigation can further improve the environmental performance of IWT in terms of CO_2 emissions per Tonne-kilometre (Tkm), as well as the connection between seaports and the hinterland. Furthermore, an electric platform lends itself better to automated applications. It is therefore possible that fully automated vessels will be electrically powered sooner than conventional vessel, which will further stimulate the transition to a greener fleet.

On the other hand, Taiebat et al. (2018) anticipate net positive environmental impacts at the vehicle, transportation, and urban system levels in all transport modes, but expect greater vehicle utilization and shifts in travel patterns at the society level to offset some of these benefits, arguing that focusing too narrowly on vehicle-level improvements associated with automated technology is likely to yield excessively optimistic estimates of its environmental benefits.[36]

Automated inland navigation could also improve the reliability of transport systems due to increased and easier surveillance, monitoring, and control. This applies to both cargo and passenger vessels, as automated ferries could contribute to increase the density and utilisation of the public transport network compared to the *status quo ante*, due to their being able to operate in the evenings and at night.

Finally, as in other transport sectors, automation could lead to the reduction in and/or replacement of certain jobs, mostly linked to manual, navigational and operational tasks, and the creation of new, highly skilled jobs related to the specificities of automated vessels.[37] This includes better qualified boatmasters trained in the supervision of automated vessels, land-based public officers mainly concerned with traffic safety and control, and engineers maintaining the software, infrastructure, and communication systems needed for automated navigation. However, it is likely that certain maintenance, repair, and operational tasks might not be automated, even in the distant future. Personnel qualifications and training methods

[33] INTERGO, *op.cit.*

[34] Expert opinion retrieved from a consultation with SMASH!.

[35] Ehlers, Tobias, Martin Portier and Doreen Thoma, “Automation of maritime shipping for more safety and environmental protection”, *Automatisierungstechnik*, vol. 70, no.5, 2022, pp. 406-410, https://www.degruyter.com/document/doi/10.1515/auto-2022-0003/html.

[36] Taiebat, Morteza, Austin Brown, Hannah Safford, Shen Qu, and Ming Xu, “A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles”, *Environmental Science and Technology*, vol. 52, no. 20, 2018, pp. 11449-11465, https://pubs.acs.org/doi/full/10.1021/acs.est.8b00127.

[37] Acemoglu, Daron and Pacual Restrepo, “Low-Skill and High-Skill Automation”, *Journal of Human Capital*, vol. 12, no. 2, 2018, https://economics.mit.edu/files/15118.

will most likely have to be adapted accordingly and in a timely manner.[38] Naturally, this will also have an impact on the training and necessary competences of teachers in nautical schools and relevant courses.

Overall, automated vessels carry the promise of improved efficiency, sustainability, and safety, as well as increased economic growth and innovation, yet will need to be managed in an ethically and socially responsible way by promoting the upskilling and transition of IWT crews to these new innovative machines.[39]

2.3 Lessons learned from other transport sectors

The road and rail sectors face similar difficulties as the IWT sector with regards to automation. Various degrees of automation have already been achieved, up to level 5 equivalent (depending on the transport segment), the main regulatory barriers were removed for some levels of automation, and operational best practices have been developed. However, technological, legal, and operational barriers remain for the higher levels of automation in the case of most land transport segments. That being said, work has already begun to improve the regulatory framework.

2.3.1 Automation in the maritime sector

The developments in the maritime sector are particularly relevant for two main reasons.

Firstly, the maritime and IWT segments of the waterborne transport sector share a number of similarities. Consequently, the developments recorded in one sector can serve as ‘lessons learned’ or ‘best practices’ for the other, even if each sector faces its own specific constraints. Moreover, these similarities also mean that the different technologies and practices can be easily transferred from one sector to another thus reducing overall costs and increasing the pace of innovation, deployment and change in the IWT segment.

The second reason is that the maritime sector, also being a larger segment than IWT, can to a certain extent drive the direction and characteristics of these developments. And as the hardware and/or software providers will look to optimize the invested resources, it is likely that they will prefer to adapt existing proven maritime solutions instead of developing new ones just for the needs of IWT needs, as long as these common solutions take into account the difference in legal frameworks between the two sectors. In the recent period, and complementary to the initial situation, a couple of the waterborne transport stakeholders have considered that IWT can be better suited for the implementation of some automation technologies, even though fairway conditions are not easier and fundamentally different. In fact, these are more difficult on inland waterways as compared to the open sea (excluding seaports and some choking points such as the Channel). However, this can be seen as an opportunity to test the systems more rigorously.

Overall, the state-of-play in the maritime sector shows that, when looking at technologies such as those enabling autonomous operations, not only the technologies installed on the vessel itself, but the entire system of interest should be taken into consideration: the vessel, the connectivity solution and the remote operation centre.[40] Each system of interest knows different technology providers and challenges that now need to work together on one integrated solution. Although different definitions exist between IWT and the maritime sector, these are nevertheless broadly aligned.

[38] See also: European Transport Workers Federation, “Making the future together - Automation in European IWT”, October 2018, ETF | Position on IWT automation [EN].

[39] For more information on the crew-related implications of automated navigation, see PLATINA3 deliverable 3.3 on “Standards for competence for on-board systems for automation”.

[40] Kongsberg, “System of Interest”, IMO MASS session, 27 January 2022.

2.3.2. Automation in the rail sector

The rail sector is divided into two main categories: mainline rail and urban rail. The first category is about the ‘regular’ rail passenger and freight services that are operated between cities, communities, or logistics centres. Mainline rail also comprises high-speed rail. Urban rail is even more diverse, but it is divided into three main categories: metros, tramways/light rail, and suburban or regional rail. The boundaries between the three categories are not always clearly delimited, as there is variation according to the different legal, operational, and technological solutions implemented by the different national and especially local public and private entities involved. Furthermore, there is a significant overlap between the suburban and regional category and the ‘regular’ mainline rail. However, unlike mainline rail, the almost exclusive focus of the urban rail systems is on passenger transport.

Both mainline and urban rail share some similarities and have specific characteristics. In terms of operations, neither segment has any driving or steering wheel (or similar), unlike the waterborne and road transport sectors. For their operations, they are heavily reliant on the infrastructure and on the dedicated signalling system that they use. The signalling system is composed of two main types, each of them with different components and roles:

- the wayside signalling system, part of the rail infrastructure;
- the on-board signalling system, part of the rolling stock (the vehicles, and in particular the locomotive).

From this point of view the rail system is in a way closer to the waterborne transport sector than to the road transport sector due to the infrastructure-related systems and their interactions with the onboard equipment. However, the nature of the rail systems implies that an incipient form of automation was present early on, making the rail sector more prone to the uptake of automation technologies.

For the purpose of this report, we will only discuss the first two categories: the metro and the tram/light rail segments.

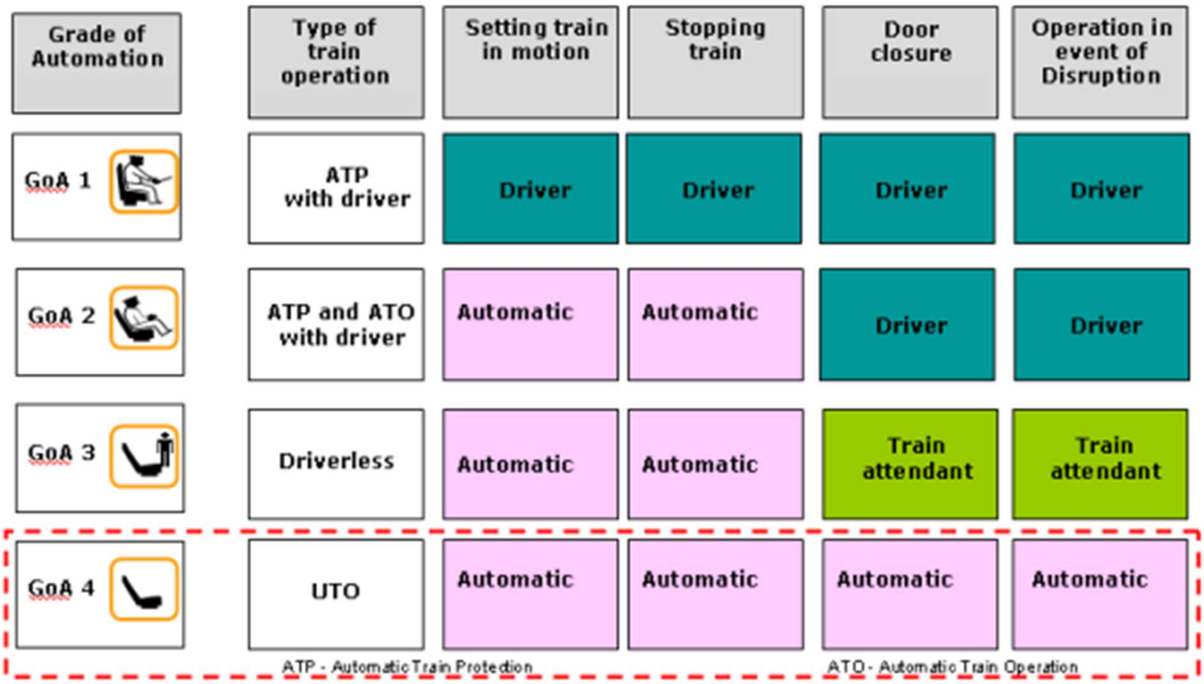
Automation in metro systems

In metro systems, automation refers to the process by which responsibility for operation management of the trains is transferred from the driver to the train control system. There are various degrees of automation (or Grades of Automation, GoA). These are defined according to which basic functions of train operation are the responsibility of staff, and which are the responsibility of the system itself. GoA0 corresponds to on-site operation, like a tram running on street traffic. GoA4 refers to a system in which vehicles are run fully automatically without any operating staff onboard.[41]

A metro system usually enjoys a set of special characteristics, as it has a dedicated infrastructure, often separated from any other transport-related infrastructure but also from much of the outside environment, in particular the metro tunnels or the elevated guideways – here in the sense of the actual train tracks, not of the metro system as a whole.

This separation of the infrastructure and the largely controlled/controllable environment has enabled the introduction of different automation systems that have evolved up to full automation in terms of operations. The first line to be operated with Automatic Train Operation (ATO) was London Underground's Victoria line, which opened in 1967, although a driver was present in the cabin. And the systems have evolved so that in the 1980s the technology of driverless trains (no person in the cabin/no cabin) was in operation. As the driver and the cabin are gone, the emphasis is put on the signalling infrastructure – both its on-board and wayside components.

[41] International Association for Public Transport, “Metro automation facts, figures and trends” 2012, IAPT | Metro automation [EN].



Grade of Automation	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of Disruption
GoA 1	ATP with driver	Driver	Driver	Driver	Driver
GoA 2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver
GoA 3	Driverless	Automatic	Automatic	Train attendant	Train attendant
GoA 4	UTO	Automatic	Automatic	Automatic	Automatic

ATP - Automatic Train Protection
ATO - Automatic Train Operation

__Figure 3__: Typology of metro automation. ***Source****: International Association for Public Transport, see footnote 40.*

There are three key elements for automation in this case:

- **Automatic Train Protection (ATP)** is the system and all equipment responsible for basic safety. It avoids collisions, red signal overrunning and exceeding speed limits by applying brakes automatically. A line equipped with ATP corresponds (at least) to a GoA1.
- **Automatic Train Operation (ATO)** ensures partial or complete automatic train piloting and driverless functionalities. The ATO system performs all the functions of the driver, except for door closing. The driver only needs to close the doors, and if the way is clear, the train will automatically proceed to the next station. This corresponds to a GoA2. Many newer systems are completely computer controlled. Most systems still elect to maintain a driver, or a train attendant of some kind, to mitigate risks associated with failures or emergencies. This corresponds to a GoA3.
- **Automatic Train Control (ATC)** performs normal signaller operations such as route setting and train regulation automatically. The ATO and the ATC systems work together to maintain a train within a defined tolerance of its timetable. The combined system will marginally adjust operating parameters. There is no driver, and no staff assigned to accompany the train, corresponding to a GoA4.[42]

Although there are different market-ready proprietary systems developed by EU and non-EU companies alike, the development and deployment of automation has also required a certain level of cooperation and standardization at the international level. The best examples are:

- the standard(s) IEC Railway applications – Urban guided transport management and command/control systems 62290-1:2014 and 2:2014, with the former outlining, among others, the accepted definition of the GoAs for the train operations;
- the standard(s) IEEE 1474.1-2004 and 2-2003 that defined the Communications-Based Train Control (CBTC) systems.

[42] *Ibid.*

The main gains observed following the introduction of automation in the metro systems, including full automation, are the following:
- greater flexibility in operation;
- impressive safety records;
- increase in quality of service and passengers' experience;
- financial feasibility in the longer run, but each investment and technology used needs to be assess on a case-by-case basis.

Many metro systems have only implemented GoA2 for different reasons, including social aspects related to the workforce.

Automation in the tramways and light rail systems
Tramways, also known as streetcars, are one of the first means of rail-based passenger transport services in and around cities (though sometimes used for freight transport as well). They have witnessed a steady operational and technological development throughout their lifetime, in particular in the last two decades or so, also influenced by the local context in which the tramways infrastructures have been developed, thus creating a significantly more fragmented sector. Broadly speaking, tramways can be divided into two main types:
- the 'classic' tramways, which run on the normal tramway tracks on the public urban streets.
- the light rail systems, tramways that benefit from dedicated rights-of-way, thus having a (mostly) separate infrastructure from the road (or pedestrian) traffic.

The technological progress and in particular the digitalization of systems has also created the opportunity to introduce various automation features in the case of trams. For classic tram systems, few automation features have been implemented due to the lack of a dedicated infrastructure and the traffic mix. Because of this and due to the nature of the driving method of any rail-based systems, this has meant that these automation features are often related to the infrastructure (signalling) side. However, there are different driver assistance systems (DAS) employed by trams in order to help the driver better 'interact' with the infrastructure and the traffic in general.

The light rail systems, due to their mostly segregated right-of-way, can better accommodate automation features on both the infrastructure and the vehicles. For the latter, more complex DAS have been put in place, though the diver remains in control of the operations in the majority of cases. Nevertheless, there have been some cases of implementing a higher degree of automation for light rail.

Automation in mainline rail
Although mainline rail systems have mostly dedicated infrastructures, both their length and the geographical conditions make it impossible to be segregated from their environment. The main exceptions to this are high-speed rail lines, which require a better separation and isolation between the lines and any interference from their surroundings to ensure both the high-speed services and their necessary safety levels. However, even the high-speed lines do not have the same level of separation as in the case of the metro lines, or even some of the light rail lines. Consequently, the developments in mainline rail automation have been much slower.

High-speed rail lines, due to their specific conditions, were the first segment to bring in more automation features. The trend has been picked-up and continued by the regular mainline rail services. A significant boost in the mainline rail automation efforts has taken place through EU investments in the rail system, in particular those related to TEN-T developments via the introduction of the European Rail Traffic Management System (ERTMS), which is the system of standards for management and interoperation of signalling for railways by the EU. It comprises three main parts:
1. GSM–R (communication);

2. European Train Control System (ETCS, signalling);
3. European Train Management Layer (ETML, payload management).[43]

However, in the context of RD&I activities at the EU level, work has been on-going to further automate mainline rail systems. The purpose of this activity is to contribute to the development of European ATO over ETCS specifications. The intention is to have ETCS as the ATP system, which supervises the train movement from a safety point of view. The ATO onboard will be able to drive the train automatically, based on timetable information from the trackside. It will attempt to meet the timetable and, where possible, do this in an energy efficient way. The ATO on-board has an interface with the ETCS on-board. These specifications will progressively cover GoA 2 – GoA 4.[44]

The main attempts now at the EU level and not only are to enable as many operations to move towards the GoA2 level of automation, and achieve GoA3 where possible.

2.3.3 Automated road transport

Automated systems in the road transport sector can be divided into two main categories. The automation systems designed for personal cars and those designed for public transport (e.g. buses). There are also some specific systems, as those used around logistics centres or airports, but these also use common elements. However, given the predictability of the itineraries and timetables as well as the availability of segregated infrastructure and proven demand, public transport is usually best adapted for the uptake of automation. Automated/driverless trucks already exist from a technological standpoint, yet are not yet fully fine-tuned nor allowed to operate on roads at any significant scale.

Similar to the rail sector, a huge challenge is related to the infrastructure, or better said the lack of segregated infrastructure for the use of the automated systems. More than in the case of rail or waterborne transport, road transport infrastructure is subject to various types of interferences, both from within (other cars) and from the outside (the surrounding environment, pedestrians etc.). Another challenge is the fact that road transport operations are more dependent on the vehicle or the driver than on the infrastructure. This, compounded by the lack of segregated infrastructure, means that most automation aspects must be solved by the on-board systems, with less support from the infrastructure or other external 'sources'. The public transport sector has an advantage here, as some of the bus or trolleybus lanes benefit from various degrees of separation from the rest of transport infrastructure and the surrounding environment.

Last but not least, non-technical aspects such as legislation, economic factors, insurance, etc. [have played a role in the more cautious development of automation features for the road sector]. Many of them are also closely related to safety (and sometimes security) issues, a similarity with the deployment of automation in the rail sector.

Consequently, the automation of the road transport sector has also been an uneven one. In the case of personal cars, the massive investments in the EU and elsewhere have achieved mixed results. The most advanced systems can cope with different situations and enable a fairly smooth driving, but are still unable to match the drivers' skills in more sensitive situations. In the last years several cities in and outside the EU have begun testing larger buses / shuttles in real-life operations.

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[43] ERTMS, "RTMS provides the European Union with a unique opportunity to create a seamless railway system", 2022, https://www.ertms.net/.

[44] ERTMS, "Automatic train operation", 2022, ERTMS | Automation [EN].

***Keolis*[45]**

The public transport sector is a good example of successful autonomous vehicles implementation. Fully automated Keolis mini-buses able to transport people are already fully operational in different locations.[46] Keolis bases itself on SAE established automation definitions for the road sector.[47] Keolis is also a river operator in some cities in France (Bordeaux) and Australia (Newcastle) and an SSS (short sea shipping) operator in Brest, and has internal working groups on trams and metros, focussing on how to make higher levels of automation possible in a knowledge sharing approach ('*contribution au bien commun*'). The overarching objective is to demonstrate the reliability of the technology in many different transport modes.

In all 14 countries where Keolis is active, authorisation procedures respond to derogatory regimes. As there are no regulations, the vehicles are not authorised via certification but through homologation.

In France, Keolis carries out pilot tests on a private testing facility to experiment with the new vehicles that constructors produce. The pilot tests allow Keolis to verify that what is advertised by the manufacturer is verified in the field, under strict testing procedures. The tests ensure that the vehicles' hardware is sound: only 3/10 vehicles tested are actually accepted by Keolis. Keolis also tests all software developments. The French Ministry of Transport then gives Keolis a special derogation to carry out these tests on open road, but in a strictly controlled framework (exact path, duration, time of day, expected kilometres etc.). To run those open road tests, documentation must be provided according to Annex 5 of ministerial order of 17 April 2018: an extremely precise risk assessment (before testing), bi-annual reports on overall performance and statistical data (after testing), as well as documents on technical components and performance.[48] To test and assess performance, Keolis does not run virtual simulations, although it recognises its proven potential (e.g. air industry). If the tests are convincing, derogations granted by the Ministry are valid for 1-2 years. To be renewed, they must be re-audited to take into account new data, regulations and/or any disruptive developments (accidents, new technologies…).

In other countries, Keolis works directly with local authorities and Parliaments (e.g. Quebec). Although derogatory regimes are the norm, some countries have different approaches. For example, the US Federal Road and Highway Authority usually grants permissions easily if companies can produce a document bearing their name and certifying the vehicles as safe, thereby incurring the entire liability. In case of accidents, the issue is resolved in multi-million-dollar class action lawsuits.

2.3.4 Conclusion: lessons drawn from other transport sectors

Although automation in the other transport sectors had to take into account the different specificities, there are a number of conclusions that can be drawn with relevance for the IWT sector. It must be underlined that the list below does not represent a ranking of the importance of these conclusions.

A first aspect is that the approach to defining the different automation levels is very similar throughout the transport sectors. Indeed, the CCNR took inspiration from the road sector to develop its own automation levels in inland navigation, as the IMO definitions for the maritime sector were paradoxically less relevant to IWT.

[45] Insights based upon an interview with Clément Aubourg, Head of Autonomous Vehicles at Keolis (7/07/2022).

[46] Such as the KEOLIS minibuses in Paris and Las Vegas, [Global leader in autonomous vehicles | Keolis]

[47] SAE International, "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles", April 2021, [SAE | Definitions automated road vehicles [EN]].

[48] Ministère des Transports, Annexe 5, "Arrêté du 17 avril 2018 relatif à l'expérimentation de véhicules à délégation de conduite sur les voies publiques", [Legifrance | Annexe 5 [FR]].

Secondly, regardless of how complex and/or performant the on-board systems that enable automation are, there is always a need to place them in connection with the enabling infrastructure, the immediate surroundings and, where applicable, the remote-control centre. This mirrors the point outlined by the maritime sector approach towards automation (vessel, connectivity solution, remote control centre).

Thirdly, safety aspects play a key role in the development, implementation and upgrading of the automation systems. Informally, the GoA4 automation systems in the rail/metro systems are first considered as safety systems before being understood as driving systems. The prominence of safety issues is due not only to the different operational and technical requirements, but also to legal, economic and/or public opinion factors. All of these aspects must be carefully taken into account in the case of the IWT sector.

Moreover, the need for an integrated approach is reflected through the adoption of standards. As outlined above, there are different standards covering automation in the wider rail sector, and work is still on-going. The IWT transport sector would do well to further invest resources in standardization activities at European level for the scaling-up of automation. It can also adopt or be inspired by some of the technical aspects already developed in other transport modes, if applicable. Where possible, there would be a clear added value to have similar standards in both the IWT and maritime sectors to facilitate and improve the maritime-inland connection needed for increased modal shift and modal integration of IWT into global logistic chains.

Finally, RD&I and implementation of automation in multiple transport segments is a long-term endeavour. Several companies and organisations have been working on the topic since the 1960s in the case of the rail sector, and have benefitted from EU-funded RD&I projects since the EC's Framework Programme 6 (FP6, 2003-2008). Financing RD&I is also an aspect to be considered for the development of automation in the IWT sector.

3. Analysis of pilot projects, outputs of European research projects and other initiatives

The following section proposes an analysis of the most relevant pilot and research projects, commercial applications, and other activities dedicated to automation of IWT on a European scale based on the 38 projects listed by the CCNR.[49] A selection of relevant national-level public and private initiatives is also considered. Conclusions based on the lessons learnt from pilot testing are drawn at the end of this Chapter.

3.1 European research projects and pilot initiatives

NOVIMAR [50]

NOVIMAR (2017-2021) investigated how IWT and short-sea shipping (SSS) transport systems can make optimal use of the inland navigation network (waterways, vessels, and ports/terminals) by introducing the waterborne version of 'platooning', the Vessel Train (VT). The VT is composed of a number of lowly manned/unmanned Follower Vessels (FV) with own sailing/manoeuvring capabilities temporarily led by a manned Leader Vessel (LV). Vessels will be able to join and leave such trains at places adjacent to their points of origin and destination at seaside or inland.

The envisaged main benefits and impacts are the following:

- reduction of crew costs of up to 81% for IWT and up to 14% for SSS;
- enhanced logistical flexibility;
- 5-10% fuel savings and their corresponding emissions reduction;
- new solutions for overcoming barriers between transport modes and high potential for reducing road congestion and associated costs;
- lower costs increase the attractiveness of small vessels at sea and inland, thereby increasing access to urban areas located at small waterways (CEMT I/II), with no need for sizeable investments in infrastructures;
- SMEs' benefits include enhanced competitiveness and improved working conditions for vessel owners/operators, and market opportunities for equipment suppliers.

NOVIMOVE [51]

The ability of ports to ensure efficient cargo transfers is central to their overall function and an important factor that influences port terminal attractiveness. The EU-funded NOVIMOVE project (2020-2024) conducts research on how to improve the logistics of this transport system. The project will reduce waiting times at seaports by improving river voyage planning and execution and facilitating smooth passages through bridges and locks. Focussing on the Rhine–Alpine water corridor from Rotterdam/Antwerp all the way to Basel, it will validate its new technology with virtual simulations, scaled model tests and full-scale demonstrations.

IWT advantages as low-energy and low CO_2 emitting transport modes are not fully exploited today due to gaps in the logistics system. Inland container vessels pay 6-8 calls at seaport terminals with long waiting times. More time is lost by sub-optimal navigation on rivers and waiting at bridges and locks. In addition, low load factors of containers and vessels impact the logistics systems with unnecessary high

[49] CCNR, "Listing of pilot and research projects in the field of automation in inland navigation", 24 November 2022, CCNR | List of pilot projects [EN].

[50] CORDIS, "NOVel Iwt and MARitime transport concepts (NOVIMAR)", November 2021, EU | NOVIMAR [EN].

[51] CORDIS, "NOVel Inland waterway transport concepts for MOVing freight Effectively (NOVIMOVE)", 2021-2024, EU |NOVIMOVE [EN].

numbers of containers being transported and trips being made. NOVIMOVE's strategy is to "condense" the logistics system by improving container load factors, reducing waiting times at seaports, optimizing river voyage planning and execution, and facilitating smoother passages through bridges and locks.

NOVIMOVE's innovations are: (1) cargo reconstruction to raise container load factors, (2) mobile terminals feeding inland barges, (3) smart river navigation by merging satellite (Galileo) and real time river water depths data, (4) smooth passage through bridges/locks by dynamic scheduling system for better corridor management along the TEN-T Rhine-Alpine route, (5) concepts for innovative vessels that can adapt to low water condition while maintaining a full payload, and (6) close cooperation with logistic stakeholders, ports and water authorities along the Rhine-Alpine corridor: Antwerp, Rotterdam, Duisburg, Basel.

AUTOSHIP [52]

AUTOSHIP is short for Autonomous Shipping Initiative for European waters. It is a project with several European partners and is funded by the EU under the Horizon 2020 program. The objective is to hold two demonstrations with vessels equipped with Smart Shipping technology, with a focus on transport. One demonstration takes place in Norway and focuses on SSS with the aim of crew reduction. The other demonstration takes place in Flanders and focuses on IWT, with a Zulu vessel from BLL. The route goes from the lock in Wintam to Willebroek and then back via the Rupel. During this demonstration there will be no crew on board and full control will therefore be at the RCC. The tasks mainly consist of ensuring that the route in Flanders runs safely. Completion of the trajectory is planned for mid-2023. The intention is to use the results from both tests as optimally as possible given that they provide critical information about legislation, security, socio-economic factors and cybersecurity. AUTOSHIP will then develop a roadmap, standards and methods that can be used by future developers and thus further facilitate the commercialization of automated sailing.

DEME [53]

DEME is headquartered in Zwijndrecht, Belgium, but has built a strong presence all over the world. They work around the highly specialized areas of dredging and land reclamation, solutions for the offshore energy market, environmental and infra-maritime works. Since October 2020, they have been testing the autonomous vessel Marine Litter Hunter (MLH) at the Scheldt bridges Temse-Bornem. In the first phase, testing was carried out with crew and since March a switch has been made to unmanned navigation. The MLH now sails autonomously and takes certain mitigating actions itself in the event of problems. In case of unforeseen problems, a supervisor can help the MLH if necessary. Therefore, a responsible person will always be designated as an "Autonomous Ship Supervisor", provided with a valid navigation license, to supervise the operations of the MLH from a distance.

The set-up consists of a combination of a fixed installation that continuously removes "passive" floating waste from the water and a mobile system that "actively" collects larger floating debris, which can be harmful to shipping in the Scheldt. This mobile part is responsible for the part where shipping is allowed and focuses on larger floating debris (> 200mm) that can cause damage to shipping, such as ropes / mooring lines, fishing nets, wooden beams, pallets, and plastic items, etc. The system consists of:

- a camera detection system by means of Artificial Intelligence (AI);
- a Marine Litter Hunter (the workboat is fully electrically powered and equipped with an open push blade for actively catching floating debris and bringing it to the trap);
- a docking station, which is located at the Belgomine quay.

[52] AUTOSHIP, "The project", 2022, https://www.autoship-project.eu/.

[53] DEME, "DEME deploys autonomous plastic collector on the river Scheldt", 2022, DEME | Plastic collector [EN].

Large floating waste and objects (such as tree trunks) are detected by smart cameras (AI) installed on the old Temse bridge at the height of the navigation channel. The waste gathers in the collecting pontoon and is regularly transferred into a container by means of a crane equipped with a grab. The fixed crane is remotely controlled by an operator, using VR-3D vision technology. The container is on the workboat. When the container is full, the vessel autonomously takes it to the docking station, where the container is unloaded by means of a transhipment crane on the Belgomine quay. The waste is transferred to a DVW waste container. The testing ended in October 2021.

AEGIS [54]

The Horizon 2020 AEGIS (Advanced, Efficient and Green Intermodal Systems) is a three-year project that started in June 2020, with a total funding of 7.5 M€ from the EU's Horizon 2020 research and innovation program. The consortium aims to design Europe's next generation sustainable and highly competitive waterborne logistics system comprising more autonomous vessels and automated cargo handling. Standardized cargo units and digital connectivity are key elements in the AEGIS system. To achieve this, AEGIS runs three use cases in Northern Europe that are applicable to other areas of the continent. All cases represent typical Short Sea Shipping (SSS) connections that must be linked to last mile distribution systems. The first case focusses on SSS terminals serviced by feeder calls from larger ports such as Rotterdam. The regular process will be changed by using fewer terminals where the feeder calls at, so that the service speed to those terminals is increased. The last legs will be taken over by a flexible systems of small unmanned vessels (preferably autonomous and electric). The second case aims to create an interface between RORO transport from several North European ports and inland navigation. Examples of ports are Rotterdam in Netherland and Ghent and Zeebrugge in Belgium. These ports can then be connected to smaller inland destinations in Flanders and create waterway connections. This brings the cargo as close to the end destination as possible (final delivery). In addition to the automated transportation system, zero emission vessels will make the system even more sustainable. The third case hopes to set an example for revitalising regional ports and terminals in city centres. This is mainly to be achieved by multimodal logistics solutions.

SCIPPPER [55]

The project SciPPPer (SChleusenassistenzsystem basierend auf PPP und VDES für die BinnenschifffahRt) aims to develop a driver assistance system to enable automated lock passage for inland vessels. The project was carried out in partnership with the companies Alberding GmbH, Argonav GmbH, Argonics GmbH and Weatherdock AG as well as the Federal Institute for Water Engineering (Bundesanstalt für Wasserbau - BAW), the German Aerospace Centre (DLR) and the Federal Waterways and Shipping Administration (WSV).

The provision of reliable, high-precision information on the position, location and speed of an inland waterway vessel is the technological basis for the new driver assistance function. On the one hand, this information must be provided by high-precision satellite radio navigation. The necessary correction data should be made available via the new very high frequency data exchange system VDES2. A considerable reduction in the data transfer rate can be achieved by using the precise point positioning process PPP3. On the other hand, position and location determination should be improved and made more robust against disturbances by using suitable proximity sensors such as laser scanners (LIDAR). For high-

[54] AEGIS, "What if marine automation can take waterborne transport to the next level?", 2022, https://aegis.autonomous-ship.org/.

[55] SCHIPPPER, "Home", 2022, http://www.scippper.de/.

precision manoeuvring in front of and in the lock, a control system using generally available variables, such as the active dozer, rudder and motor speed, for multivariable control should be developed.

A-SWARM [56]
The aim of the A-SWARM project is to develop a transport system consisting of small floating units that can be operated independently or coupled together and are powered by electric propulsion with zero local emissions. The focus is on the development and testing of such an autonomously operating water vehicle. In particular, the feasibility of such a system is to be demonstrated in a real laboratory in the area of Berlin's Westhafen harbour.

The new route must be safe and navigable without further obstacles. In addition to the nautical chart data, the routes of other watercraft and mobile obstacles should also be taken into account according to the time horizon of the planning. The new route should be as energy efficient as possible, i.e. the energy demand for the planned route should be included in the trajectory planning as an optimisation criterion. The newly planned route should be able to be travelled through in as short a time as possible. The criteria mentioned above influence each other. The task of trajectory planning is therefore also to find a suitable weighting of the criteria. Whether this weighting is fixed or can be calculated on the basis of the current data situation is to be the subject of the research work in this sub-project.

This project, which will run until 31 August 2022, is funded by the Federal Ministry for Economic Affairs and Energy within the framework programme Maritime Research Strategy 2025 and is supervised by the Project Management Organisation Jülich (PTJ). Project partners in this joint project are SVA Schiffbau-Versuchsanstalt Potsdam GmbH (joint coordinator), the Department of Design and Operation of Maritime Systems at the Technical University of Berlin, Infineon Technologies AG Munich, Veinland GmbH Neuseddin and BEHALA - Berliner Hafen- und Lagerhausgesellschaft mbH.

3.2 Commercial applications

SEAFAR [57]
Seafar is a company that provides services to help operate unmanned and low-crew vessels. They support and control automated vessels via their RCC in Antwerp. Seafar has already received several approvals for testing. Since October 2019, tests have been carried out in the Westhoek on the Yzer and the Plassendale-Nieuwpoort canal with Watertruck X (CEMT class II – bulk) on behalf of Decloedt. In the first phase, navigation took place with a full crew onboard assisted by Seafar technologies such as cameras. This phase allowed for extensive testing of the installed equipment to be performed. In a second phase, still with a full crew onboard including the boatmaster, navigation tasks were temporarily transferred to an operator located in an RCC, the boatmaster onboard remaining fully and solely responsible. In a third phase, the crew was gradually reduced. These were fully piloted from the RCC – for some stretches at least - on fixed routes.

Seafar and De Vlaamse Waterweg (DVW) are in regular contact and each testing agreement was prepared via a an updated risk analysis, gap analysis, and various evaluation meetings. Since April 2020, Seafar also received permission to sail with a (different) Watertruck on the Leuven-Dijle Canal (on behalf of Celis). The actual tests only started at the end of October/November 2021. The Watertruck vessels are self-propelled barges, certified under Flemish regulations, in accordance with Article 24 of EU

[56] Universität Rostock, “A-SWARM”, 2022, Uni Rostock | A-WARM project [DE].
[57] SEAFAR, “Seafar remote navigation”, 2022, https://seafar.eu/.

Directive (EU) 2016/1629 with regard to exemptions for vessels that travel limited routes of local importance or in port areas.

ARGONICS – argoTrackPilot [58]

argoTrackPilot is a Track Guidance Assistant for Inland Navigation (TGAIN) system developed by Argonics GmbH used to sail vessels along pre-defined navigation routes (so-called 'guiding lines') in all weather and visibility conditions. The guiding lines can be further optimized depending on water levels and vessel loading conditions. Therefore, TGAINs can optimize path following which can translate into fuel savings of up to 5% through a 28% reduction of rate of turn changes. With this tool, the boatmaster is alleviated from tiring routine work during navigation and only takes action when necessary, by choosing an appropriate offset to the guiding line, for example to avoid an obstacle or pass another vessel.

The commercial development of TGAINs is a major step towards the realization of automated navigation. Today, more than 600 vessels are equipped with TGAIN systems in Western Europe. Other technology providers, such as Shipping Technology[59] or TRESCO[60], also produce TGAIN systems available for commercial use.

3.3 Other relevant national-level initiatives

SMASH! [61]

In the Netherlands, the SMASH! (Netherlands Forum Smart Shipping) programme is aiming to bring the waterborne transport sector in the Netherlands together to implement smart shipping and so increase its competitiveness. The idea behind SMASH! is to aggregate under one umbrella all (currently fragmented) initiatives regarding autonomous vessels. International linkage is also a key point of attention. To accomplish this, SMASH! brings commercial parties, governmental bodies and knowledge institutions together. SMASH! acts as a central point for automation in the sector, provides a roadmap for smart shipping, stimulates cooperation of SMASH! members in relevant projects and provides space to discuss regulations with government and the sector.[62] The SMASH! roadmap differentiates five use cases, a.o. the inland cargo vessel and inland ferry cases, and ten development areas.[63] The online roadmap summarises in an easy to understand and visual way the challenges that lie ahead to realise the 2030 vision of SMASH!, per use case and development area.

FERRY [64]

In 2021, over 3000 passengers were transported with an autonomous, electrical ferry between Kagerzoom and the recreational island of Koudenhoorn near Warmond in the Dutch province of South-Holland. The ferry, called FERRY, is electrical, sustainable and is ready for autonomous sailing. In the summer of 2021, a testing period was held. FERRY is able to accurately determine its own position and hold it even under heavy weather conditions. Navigation is done through a digital map, on which FERRY follows waypoints until its destination. In the last week of the testing period, FERRY successfully tested autonomous mooring and unmooring. FERRY is an initiative by several commercial parties and is supported by local governments.

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[58] Argonics, "argoTrackPilot", 2023, https://www.argonics.de/en/argoTrackPilot. The system was presented during the automation session at the 5th PLATINA3 Stage Event , held in Budapest on 20 October 2022.

[59] Shipping Technology, "ST BRAIN", 2023, https://shippingtechnology.com/products/black-box-pro/.

[60] TRESCO, "TrackPilot", 2023, https://www.tresco.eu/en/trackpilot/.

[61] SMASH!, "News", 2022, https://smashnederland.nl/en/category/news/.https://smashnederland.nl/category/nieuws/page/2/

[62] SMASH!, "Roadmap", 2022, https://www.smashroadmap.com/#cases.

[63] As of 2022, the SMASH roadmap is still under development for, in particular, the use cases "Deep Sea Ship" and "Unmanned Surface Vessel".

[64] Bollenstreek Omroep, "Zelf-varende veerpont in bedrijf", 2021, BO | Ferry [NL].

ZEABUZ [65]

ZEABUZ is a spin-off from the progressive research Center for autonomous marine operations and systems, at the Norwegian University of Science and Technology. ZEABUZ has worked on the milliAmpere project, where NTNU build two small ferries of which one was the first autonomous passenger ferry prototype. Milliampere is a battery powered 5 by 2.8-meter monohull with two azimuth thrusters that can carry up to 5 researchers. This has made the vessel a prime research platform. In December 2020 milliAmpere completed a three-hour fully autonomous operational test in Trondheim. The milliAmpere 2 is a full-scale prototype designed to become a living lab in Trondheim city, with capabilities and supporting infrastructure enabling trial passenger operation. It is a battery powered 8.5 by 3.5-meter monohull equipped with induction charging, 4 azimuthing thrusters, a similar sensor package as milliAmpere, a Dynamic Positioning (DP) system delivered by Marine Technologies and designed to transport 12 passengers. The milliAmpere 2 was first launched in Q1 2021 and will be put into trial operation during summer 2022. Based on this experience, ZEABUZ is planning to design and launch its first ferry system in 2023. ZEABUZ works on its system that can be set apart in four core parts: See, Understand, Plan and Act, which are actions the vessel must be able to undertake trough sensors, analysing data, route planning software, sailing software. This process is simulated in the Digital Twin simulator to test it.

UNMANNED SURFACE VESSELS [66]

Unmanned Surface Vessels (USV) are currently being developed by multiple parties, for instance by Fugro and Demcon and already used in operations. USVs are used for efficient collection of high-quality hydrographic data. The Fugro vessel's advanced situational awareness capability is enabled by integrated RADAR and automatic identification system (AIS) to detect near and far targets for obstacle and collision avoidance during operations. Situational awareness is also achieved by vessel status monitoring sensors and 360-degree cameras ensuring continuous site visibility.

ROBOAT [67]

Roboat is the world's first major research program on autonomous floating vessels in metropolitan areas. It allows for creating dynamic infrastructures, transportation of goods and people, and environmental sensing on Amsterdam's canals. Having worked earlier on prototypes on scales 1:4 and 1:2, full-scale prototypes have now been developed by a consortium of the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), the Massachusetts Institute of Technology (MIT), the City of Amsterdam and Waternet. In Q4 2020, four years of research culminated in the launch of the first full-scale Roboat prototype. Roboats are designed to transform waste collection in the city and transport people trough Amsterdam autonomously. A smart modular design including sensing techniques as LIDAR, GPS and Camera's allows the Roboats to sail autonomously on the canals, guided through its internal control system. The electrical vessels are equipped with four thrusters and a 12 kW battery, which guarantees 8 hours of autonomous sailing and can be charged wireless. The modular design allows for the same basic structure to be converted into Roboats for passenger transport of for waste collection. Roboats are further equipped with a latching system, allowing Roboats to latch to each other or to docking stations. Also, each boat is a mobile analysis laboratory capable of analyzing the quality of the water in real-time.

[65] Zeabuz, "PROJECTS", 2022, https://www.zeabuz.com/projects.

[66] Unmanned Systems Technology, "Unmanned Surface Vehicles (USV)", 2022, UST | USV Directory [EN].

[67] Roboat, "Self-driving technology to transform urban waterways", 2022, https://roboat.org/.

3.4 Lessons learnt from pilot testing

Conducting pilot tests allows regulators and innovators alike to gather knowledge, data, and real-life experience to inform future work in order to adapt the relevant regulations to the necessities of automation. The CCNR has developed a derogation procedure to allow pilot projects wishing to deviate from CCNR regulations to run pilot tests on the Rhine.[68] As part of this derogation procedure, information will be requested from the applicant in order to inform the development of future regulations. It hopes that the procedure developed for authorising such tests will inspire its Member States to examine transnational projects or projects on their national waterways and thus contribute to regulatory harmonisation on an international scale.

As a part of the procedure to grant derogations on the waters governed by the CCNR, each national authority is allowed to impose stricter requirements than the minimum set out in the CCNR procedure to maintain an equivalent level of safety.[69] If the derogation is for instance to sail without a skipper onboard, then the applicant must implement requirements to offset and mitigate risks. Furthermore, competent authorities can require additional prerequisites pertaining to the characteristics of the waterway, such as poor cellular connection.

Given the cross-sectoral nature of automation, the CCNR considers it necessary to develop simultaneously the requirements for vessel operation, personnel training, and crew composition, as well as the technical requirements for the fleet and those related to information technology and liability.

Currently, 38 pilot projects are listed by the CCNR, and real-life experimentation has begun only recently through pilot testing.[70] For example, the companies SEAFAR (Belgium), Shipping Technology (the Netherlands) and Argonics (Germany) were recently granted derogations by national waterway administrations to conduct pilot tests on their respective countries' national waterways. From these and other tests, it appears that most of the systems needed for automated vessels are already available but that some technologies must be further developed and tested before becoming fully operational. Furthermore, questions related to the interoperability between software and onboard systems remain unanswered, both onboard the automated vessel (human-machine interface) and in relation with other vessels (communications, signalling), be they automated or not (mixed navigation environment).

The analysis of pilot projects shows that there is a need for both overall pilot projects on long stretches of a given waterway to test the operational feasibility of automated navigation (e.g. the Vessel Train concept explored by NOVIMAR), as well as very localised projects to test specific operations, such as entering locks, passing infrastructure and chokepoints, or making challenging turns. The SCIPPPER project, for example, showed the technical limits of high-precision manoeuvring and positioning in real-time in and around locks.

This also poses the question of responsibility, insofar as these technical processes have an impact on humans, particularly in the event of an accident caused by a vessel whose navigation is largely automated. Indeed, there will be less tolerance for mistakes made by automated systems compared to

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[68] CCNR, "Procedure for authorising a pilot project for automated navigation", April 2022, CCNR | Procedure pilot projects [FR].

[69] For more information, see the new article 1.26 RPR (page 108): CCNR | 2022-II [FR].

[70] CCNR, "Listing of pilot and research projects in the field of automation in inland navigation", 15 December 2022, CCNR | List of pilot projects [EN].

those made by human operators in the already very safe IWT sector.[71] Until now, all provisions have been based on the boatmaster's responsibility. However, automated navigation is likely to introduce a significant change in the responsibilities on board. It is therefore legitimate to ask what legal basis is applicable when an automated vessel causes damage to a third party during its operations (especially for level 3 or higher), an aspect which will be investigated in ESR 15 of the AUTOBarge project.[72] Ultimately, automated navigation suggests a redistribution of responsibilities between the vessel owner, the boatmaster, and the manufacturer of automated navigation systems. This could even lead to fragmentation, which will imply a necessary adaptation of the existing regulatory framework.

To avoid fragmentation, there is a need to develop industry-wide standards or guidelines, as demonstrated in part by the AEGIS and AUTOSHIP projects. The IWT transport sector would benefit from standardization activities at European level for the scaling-up of automation. Where possible, there would be a clear added value to have similar standards across the waterborne sector.

[71] Van Cappelle, Laurien, Linying Chen and Rudy Negenborn, "Survey on Short-Term Technology Developments and Readiness Levels for Autonomous Shipping", *International Conference on Computational Logistics*, vol. 11184, 2018, https://link.springer.com/chapter/10.1007/978-3-030-00898-7_7.

[72] AUTOBarge project, 19 December 2022, https://etn-autobarge.eu/project/.

4. Systems and functions allowing automation of inland navigation vessels

The objective of this Chapter is to define minimal functions for automated navigation with an at least equivalent level of safety compared to conventional vessels on inland waterways. In this Chapter, the report focuses on automation of tasks related to navigation and excludes other tasks like those related to maintenance. The data underpinning the below analysis was gathered through a series of expert interviews conducted between May and October 2022 as well as comments received during the interactive Workshop organized during the PLATINA3 5th Stage Event (Budapest, 19-20 October 2022).

The analysis of the data reveals six macro-functions: situational awareness, collision avoidance, communications, navigation, safety, and fall-back capability. Each of these macro-functions is composed of several functions. This list is non-exhaustive and without prejudice to the possible evolution of current standards or the observance of stricter requirements.

4.1 Situational awareness

This section applies to automation levels 3 and above, according to the CCNR definition.

Description: Situational awareness refers to the perception of environmental data and events, the comprehension of their meaning, and the projection of their future status.[73] According to Van Baelen et al. (2022), two categories of semantic world models are needed for situational awareness to be achieved in automated inland navigation: the vessel's own properties and relationships (body model) and the external environment's properties and relationships (map model).[74] To compose these world models, sensors and systems allow to create a virtual representation of the vessel's body in relation to its external environment. To achieve sufficient situational awareness therefore requires the ability to monitor static and dynamic elements on the waterway but also monitor the situation onboard the vessel in lieu of the reduced or absent crew. The data produced by the sensors and systems translates into three functions: situational awareness of the short-range and long-range external environment, on the one hand, and situational awareness onboard the vessel, on the other. As these systems can fail, go offline or be damaged, redundancy is necessary, so that systems contributing to the same function can act as "safety back-ups" in case of damage and/or failure.[75] The human-in-the-loop, meanwhile, ensures that the data is correctly interpreted and acted upon.

Systems: Primary systems (RADAR, LIDAR, cameras, infra-red night vision, GNSS, inland ECDIS, AIS, VHF) and secondary systems (microphone, engine sensors etc.).

4.1.1 Short-range situational awareness (external environment model)

Description: This function allows to monitor the external environment in close proximity to the vessel (<350m, 1.07(2) RPNR).[76] This includes identifying static (shoreline, bridges, locks, buoys etc.) and dynamic (vessels, humans, mobile parts of infrastructure etc.) objects, judge distances and predict

[73] Endsley, Mica, "Towards a theory of situational awareness in dynamic systems", *Human Factors*, vol. 37, no. 1, 1995, pp. 32-64, https://journals.sagepub.com/doi/10.1518/001872095779049543.

[74] Van Baelen, Senne, Gerben Peeters, Hermann Bruyninckx, Paolo Pilozzi, and Peter Slaets, "Dynamic Semantic World Models and Increased Situational Awareness for Highly Automated Inland Waterway Transport", *Frontiers in Robotics and AI*, vol. 8, no. 739062, 2022, https://www.frontiersin.org/articles/10.3389/frobt.2021.739062/full.

[75] In this context, redundancy is understood as an independent secondary system which can fulfil the same functions as the primary system to the same degree.

[76] CCNR, "Police regulations for the navigation of the Rhine (RPR)", 2021, CCNR | RPNR [EN].

trajectories. This sub-function is critical for safe navigation, as it allows for the observation of traffic/police rules, collision avoidance, and passing waterway infrastructure safely.

Systems: optical sensors (LIDAR, cameras, infra-red night vision capability), acoustic sensors (microphone), positioning systems (RADAR, GNSS), inland ECDIS.

4.1.2 Long-range situational awareness (external environment model)

Description: This function allows to monitor the wider external environment surrounding the vessel (>350m). It refers to the vessel's ability to locate itself (position, speed, direction) with respect to the wider external environment, monitor vessels and infrastructure many kilometres ahead to pass them safely, anticipate challenging turns, chart course to estimate trajectory and estimated time of arrival (ETA), and signal its position, direction, and intentions to other waterway users. The Dutch waterway authority suggested that it could be an improvement to signal intentions earlier by multiple channels (VHF, visuals such as blinkers in cars etc.).

Systems: positioning systems (RADAR, GNSS), inland ECDIS, systems for signalling position and intentions to other users (AIS, VHF).

4.1.3 Onboard situational awareness (vessel body model)

Description: With reduced or no crew onboard, the boatmaster in the RCC or the computer must be able to monitor the situation onboard the vessel via the instruments. Specifically, information is needed regarding what is happening in the wheelhouse, on the upper deck, in the engine room, and any other area of the vessel which could compromise its safety (fire, fuel leak, flooding etc.). To do so, sets of sensors will be placed at strategic locations throughout the vessel to maintain high onboard situational awareness. In general, the land-based navigational equipment in the RCC should be able to fulfil the same functionalities performed by the onboard navigational equipment without any degradation of the situational awareness.

Systems: optical sensors (surveillance cameras and thermal cameras), sound sensors (microphone), inertial measurement unit (IMU) sensors (gyroscope, magnetometer, accelerometer), mechanical sensors (data on engine, propeller, rudder, bow thruster etc.), motion detector.

Furthermore, two underlying themes are common to the three functions identified above to ensure their reliability. These are systems' redundancy and human-in-the-loop/Human-Machine Interface (HMI).

4.1.4 Reliability guarantee 1: Redundancy

Presence of multiple systems for the same function to prevent critical loss of situational awareness in case one or more systems go offline and/or become damaged. E.g.: light cameras, infra-red cameras and LIDAR could be used interchangeably if one or more systems go offline. It is important that all the systems are interdependent but not too interdependent so that, in case of failure, the vessel can still navigate based on the remaining systems. Moreover, as a general rule, manual control must still exist on the vessel in case automated systems fail.[77]

In addition, certain failure scenarios will not allow only technical solutions to be viable. For example, when a navigational RADAR fails while sailing under conditions with reduced visibility (e.g. fog), there is no technical system aboard a vessel that could safely take over and still perform the same functionality. In this case, the Rhine Police Regulation would require that the vessel leaves the fairway and enter the

[77] Risk assessments that consider faster emergency accessibility must be taken into consideration when designing the system and need to be agreed upon with regulators.

next port. Therefore, the possibility for non-technical solutions for specific failure scenarios which do not allow for redundancy to maintain safety should be considered and investigated.

4.1.5 Reliability guarantee 2: Human-in-the-loop and Human-Machine Interface (HMI)

For safety reasons, automation will, at first, always rely on human monitoring of the vessel's activity, either directly from the wheelhouse (direct monitoring of automated navigation tasks with the option to intervene) or remotely from an RCC (either direct remote-control or supervision with the option of intervening). For large amounts of data to be properly understood, analysed, and responded upon in a timely and effective manner, the instruments must convey relevant and accurate data in real-time without the human operator being overloaded. Accounting for the increased complexity, the human-in-the-loop must be able to monitor all systems at a glance to make the best-informed decision possible in case of difficulties. Therefore, proper attention must be given to the design of the wheelhouse and/or the RCC piloting station, with specific emphasis on smooth and ergonomic HMI properties. They should include Human-Centred Design (HCD) features for improved situational awareness and reduced human errors.[78] The instruments must all be directly visible by the skipper and a clear view for cameras must be maintained (visible angle of at least 30 degrees for cameras, see 7.02 ES-TRIN 2021/1, ESI-II-6, 4.2.1(5)).[79] In addition, a uniform wheelhouse design and a standardisation of automated navigational functions could further improve security in this regard.[80]

***Figure 4**: Artistic view of the RCC and onboard wheelhouse of the future for improved situational awareness and HMI.* ***Source**: Courtesy of Trading Line.*

4.2 Collision avoidance

Description: Safe collision avoidance is rooted in situational awareness (and especially its short-range variant), combined with an effective control algorithm. As vessels become more automated, existing

[78] Kristoffersen, Cecilie, "Unmanned autonomous vessels and the necessity of human-centred design", *Proceedings of NordDesign,* 2020, https://www.designsociety.org/publication/42520/Unmanned+autonomous+vessels+and+the+necessity+of+human-centred+design.

[79] CESNI, "ES-TRIN 2021/1", 13 October 2020, CESNI | ES-TRIN 2021/1 [EN].

[80] Cf. IVR, "HMI & Wheelhouse Design", November 2021, Intergo phase 2a - v2.indd (ivr-eu.com).

collision detection and warning systems will need to be complemented by robust collision avoidance systems, either in an advisory role or as an automated feature. Therefore, to allow for automation, collision avoidance will most likely need to be integrated together with vessel control and decision-making capabilities.

Systems: collision avoidance technology, mechanical sensors (data on engine, propeller, rudder, bow thruster etc.), motion detector, bathymetry, computer (IMU/GPU components), centralized PLC system, TGAIN, engines, rudder, positioning systems (RADAR, GNSS), inland ECDIS, systems for signalling position to other users (AIS, VHF).

4.3 Communications

Description: Communications are especially critical for the safe operation of automated vessels. As they allow to interact with other involved stakeholders based on water and on shore, communications are split into two categories: vessel-vessel communication and vessel-shore communication. Crucially, communications to shore-based waterway authorities/administrations, and, when appropriate, with the RCC, must be guaranteed. Furthermore, a distinction must be made between vessels whose boatmaster is present in the wheelhouse and vessels whose boatmaster is located in an RCC.

In case of vessel-vessel communication with a boatmaster onboard, automated navigation will not differ significantly from regular navigation. Communications will be maintained with other waterway users, shore-based operators, and waterway administrations. If deemed necessary, the vessel could also integrate a specific signalisation to identify themselves as an automated vessel.[81]
f
In the case where the boatmaster is located in an RCC, they could use the shore-based systems to contact the desired waterway users in a transparent manner. In addition, robust communications will have to be maintained between the RCC and the vessel, namely through an internet connection complemented with a low-orbit satellite connection as back-up. Manual control or a locally installed automated procedure will still be present onboard the vessel in case of communications failure or malfunction (see section 4.5 on fall back capability). Communications will be maintained with other waterway users, shore-based operators, and waterway administrations. If deemed necessary, the vessel could also integrate a specific signalisation to identify itself as an automated vessel. Further, adding intent-sharing technology in the future could prove valuable for automated vessels to optimize route planning and pass each other safely, for example in conjunction with TGAIN technology.

In all cases, communications should be based on standardised radiocommunication phraseology to prevent misunderstandings and associated unsafe situations.[82] CESNI standards for competences provide for details of the essential competence requirements on the management and operational levels.[83] The ability to use standardised communication phrases is part of the knowledge and skills required in the standards. A free mobile app (LE SINCP) was developed to enable students to listen and learn the most common standardised phrases in four languages (German, English, French and Dutch).[84]

[81] In Flanders, for example, automated vessels are required to hoist a pink sphere atop one of their masts for signalling purposes.

[82] Based on, *inter alia*, the CCNR radiocommunication guide, RIVERSPEAK, and relevant police regulations. See: CCNR, Part 4 in "Guide de radiocommunication pour la navigation intérieure", 2022 edition, CCNR | Radiocommunication guide [FR]; CCNR, "Article 4.05: Radiocommunication", Police Regulations p.34, 1 June 2022, CCNR | Police regulations [FR]; De Alk & Heijnen, "RIVERSPEAK", https://www.imlpbooks.com/books/RS.

[83] A non-binding standard exists and is used by training institutions : CESNI, "Standards for standardised communication phrases in four languages, "Resolution CESNI 2021-I-2, CESNI | Standardised communication phrases [4 languages].

[84] App Store, "Le SINCP", 2022, https://apps.apple.com/ch/app/le-sincp/id1617915720?l=fr.

Furthermore, a challenge will arise as we move towards higher levels of automation. The automated vessel's software will not face significant issues in transmitting pre-recorded and standardised communication signals to other water- or shore-based users. However, receiving and interpreting vocal signals from multiple users - with varying phrasing, languages, accents, and voice patterns - will be the main challenge. Therefore, a distinction between technologies automating the production of signals to those automating the reception and interpretation of signals must be made.

Finally, it must be noted that most experts are of the opinion that communications are not a navigational function *per se*, but rather a transversal feature enabling all other automated navigational functions to be performed.[85] However, communications are a critical means to ensure safe navigation.

Systems: The key technologies to communicate with other waterway users (for conventional or automated vessels) are AIS[86] and VHF, with the inclusion of the VHF Data Exchange System (VDES). In case of remote control, the VHF radio is relayed to IP and is then transmitted to the RCC. In certain specific circumstances, it might be useful to know that the vessel is automated. As a transitional measure, to quickly identify an automated vessel without radio contact verbal communication, these key technologies could include a sound signal upon leaving/entering port (e.g. specific horn sequence) as well as a visual component hoisted on the highest mast (e.g. coloured flag/banner/sign), in accordance with police regulations (see definitions in section 1.2).

Other technologies are needed to ensure the link between the RCC and the vessel: 4G/5G internet connection, low-orbit satellite connection.

Other technologies are needed for voice communication: speech synthesis and recognition, combined with standardised communication protocols.

4.3.1 Reliability guarantee: Redundancy

Several redundancy communication lines would be desirable, especially if the vessel is remotely controlled from an RCC.

4.4 Navigation

Description: Automated vessels will have to perform several navigational functions that were previously executed by humans. The main functions include route planning and execution (charting and maintaining course via a TGAIN track pilot) and anchoring/mooring/station-keeping. Other core tasks that are specific to inland navigation (e.g. wheelhouse height adaptation for bridge passage, lock passage, hydrodynamic interactions between vessels in overtaking manoeuvres, etc.) will also need to be automated but are beyond the scope of this report. Control of the vessel is significantly influenced by the water depth available and thus accurate pathing models, which are key to providing accurate thrust allocation to the propulsion systems and thereby enabling automated inland navigation, which is often characterised by very confined and shallow spaces. In this context, most tasks will be controlled by a computer, via a centralized PLC system, yet always under human supervision (either direct supervision onboard or remote supervision from the RCC).

[85] See van Cappelle et al. 2018. Observation consistent with the insights shared by Marco Scholtens during an interview (11 July 2022).

[86] AIS transceivers automatically broadcast information, such as their position, speed, and navigational status, at regular intervals via a VHF transmitter built into the transceiver. The information originates from the vessel's navigational sensors, typically its GNSS receiver and gyrocompass. Other information, such as the vessel's name and VHF call sign, is also transmitted regularly. The received information can be displayed on an inland ECDIS, showing the other vessels' positions similar to a RADAR display.

4.4.1 Route planning and execution

Description: The computer will control steering and propulsion based upon the TGAIN and data on the external environment produced by its sensors, always under the supervision of the human boatmaster located either onboard or in the RCC. Under certain circumstances, the computer will propose collision avoidance manoeuvres subject to approval by the human boatmaster. Furthermore, predicting certain environmental conditions (esp. water depth) can help automate and optimize the loading of the vessels, including by identifying the potential use of additional buoyancy systems in given voyage stretches.[87]

Systems: situational awareness systems, bathymetry, computer (IMU/GPU components), centralized PLC system, TGAIN, engines, rudder.

4.4.2 Immobilizing the vessel

Description: Immobilizing the vessel is a special case as it encompasses several sub-functions. In addition to regular anchoring/mooring, automated emergency anchoring/mooring and station-keeping will be necessary sub-functions that the vessel should be able to perform almost autonomously. In case of a non-navigation emergency on the vessel (e.g. the monitoring system of liquid bulk temperature go offline), the vessel whose boatmaster is not onboard would be expected to go to a place where it can be reached by a technician and there anchor/moore quite regularly. If the vessel is in direct risk of collision and the boatmaster cannot manoeuvre in time (due to lack of communications for instance), the vessel might be expected to react by evading the collision, but in a last resort it might also have to drop its anchor or run itself aground. Finally, if there is no immediate danger and the vessel cannot drop its anchor (due to a protected riverbed, presence of cables etc.), the vessel should be able to perform station-keeping on its own. Station-keeping, also known as active or virtual anchoring/mooring, allows a vessel to use its engines and rudder to fight the current/flow of the river to remain in a stationary position with regards to the shoreline while it awaits the arrival of support (technician, boatmaster etc.). In places where it is allowed, spudpoles (telescopic pipes that can be vertically extended under the vessel until they hit the bottom, which secures the vessels' location) might be used. The advantage over a regular anchor would be that the vessel is tighter kept in place than while using anchors.

Systems: anchor, spudpoles, bathymetry, engines, rudder, computer (IMU/GPU components), centralized PLC system, TGAIN, communication systems (internet connection, satellite connection), positioning systems (RADAR, GNSS), inland ECDIS, systems for signalling position to other users (AIS, VHF).

4.5 Safety

Description: With possible reduced crew onboard and increased reliance on electronic equipment and digital connectivity services, automated vessels would benefit from additional safety functions. These include notably the systems and protocols to control and contain fires, to mitigate cybersecurity risks, and to manage collisions leading to water ingress. Other safety sub-functions might also be considered.

4.5.1 Fire safety

Description: The human-in-the-loop will act as the primary source of safety for the vessel. In case of vessels with reduced crew, certain additional safety systems would be required onboard. Automated vessels should be able to 1) contain the spread of the fire onboard, and 2) fight against the fire to buy time for emergency rescue services to arrive. To achieve these functions, vessels must be able to quickly detect the ignition of a fire - especially in the most sensitive areas (tanks, engine room, wheelhouse) - and notify the human-in-the-loop, isolate and contain the fire through flame-retardant and fire-resistant

[87] NOVIMOVE is currently working on such a concept.

materials (e.g. A60 fireproof doors), and combat its spread by activating automatic sprinklers and fire extinguishers. Fire regulations onboard automated inland navigation vessels could be based on ES-TRIN requirements (especially Article 19.11)[88] as well as the Fire Test Procedures (FTP) Code developed by the IMO for maritime vessels.[89]

Systems: Fire/smoke detectors, communication systems, fireproof material (doors, walls, equipment…), automatic water sprinklers, fire extinguishers.

4.5.2 Cybersecurity

Description: Automated navigation will include ICT technological components which are vulnerable to cyberattacks, which could potentially lead to navigational mistakes and accidents. In most instances cyberattacks may result in economic damages only. However, human lives and the wellbeing of the river basin environment could be at risk as well. To mitigate such a risk, emergency manual override to prevent disastrous outcomes should remain possible and will heavily rely on the ability of the crew or shore operator to detect the computer system's unexpected behaviour. Synergies with emergency anchoring/mooring functions (see above) should be pursued. Experience gained in the road sector shows the need to establish comprehensive cybersecurity principles for automated driving.[90] Similarly, collision avoidance in inland navigation should never "depend on access to shared external communication channels alone" and automated vessels should be designed in such a way that "safety-critical systems are functionally independent and cannot fail in case of connectivity issues". Measures must include contingency plans with procedures on how to manage situations where the integrity of ICT systems has been compromised due to cyberattacks. For a vessel, this may require discontinuing a journey; for waterway authorities, discontinuation of certain services.

Systems: communication systems, anchoring/mooring systems, route planning and execution systems.

4.5.3 Collisions and water ingress

Description: Collisions on inland waterways might occur and lead to flooding. The vessel design aims to limit the consequences of collisions. The vessel's bow (ahead of the collision bulkhead) is made to withstand substantial collisions and deform. Frontal collisions do not often result in significant flooding, as the collision bulkhead protects the rest of the vessel from water ingress. The situation is similar for the stern, which is equipped with an aft-peak bulkhead. Side collisions present a higher risk. In case of significant damage being incurred due to a collision, an attempt is made to move the vessel to a safer location and the crew is evacuated, but sinking is often difficult to prevent. Moreover, collisions do not lead only to water ingress, but also to internal damage, including spills (vessel fuel or liquid cargo), which could cause hazards onboard and environmental damages. Pre-existing sensors and alarm systems monitoring the internal structure should be able to notify the human operator (either onboard or remotely) in case of damages.

Therefore, the automated system must be able to replace the boatmaster or deckman by performing four core actions:

1. Detect water ingress and assess its severity (especially ahead of the collision bulkhead and aft of the aft-peak bulkhead via dedicated sensors);
2. Warn the crew – either onboard or shore-based – via alarm systems to allow timely and safe evacuation;

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[88] CESNI, Article 19.11 in "ES-TRIN 2021/1", 13 October 2020, CESNI | ES-TRIN 2021/1 [EN].

[89] IMO, "Fire Test Procedures (FTP) Code", 3 December 2010, IMO | FTP Code [EN].

[90] International Transport Forum, "Safer roads with self-driving cars?", May 2018, ITF | Safety and automated cars [EN].

3. Once the damage is confirmed by the crew – either onboard or shore-based –, notify and signal the location of the accident and its intentions to competent authorities in a timely manner;
4. Attempt to move the vessel to a safer location, at the very least away from the navigable channel, and preferably near the closest berth.

Disclaimer: collision and water ingress safety requirements should not be made more stringent for automated vessels than for conventional vessels. The objective is not to prevent an automated vessel from sinking, but rather to ensure crew safety, protect the environment from pollution, and minimise traffic disruptions.

Systems: flooding sensors and detectors in the compartments ahead/aft of the collision and aft-peak bulkheads, pumps, positioning systems (RADAR, GNSS), inland ECDIS, communication systems (internet connection, satellite connection), computer (IMU/GPU), systems for signalling location to competent authorities (VHF, AIS).

4.6 Fall back capability

In case of major failure or unexpected circumstances, clear limits must be set on the intervention of the automated system in the form of a “fall back capability”, which has already been sketched out in the fourth column of the CCNR levels of automation (see also **Figure 1**, p.2).[91]

Without prejudice to other unforeseen circumstances which might arise, three main scenarios will likely call for such a capability to be activated:

- The system fails;
- The system operates outside of its predefined range of use;
- A disruptive external event not linked to the system's parameters occurs (communication interruption, accident, damage on sensors etc.).

In such scenarios, mechanisms and procedures should be in place to ensure the vessel’s continued safety.

A distinction must be made between (lowly) manned and completely unmanned vessels. In the case of lowly manned vessels, a trained member of the onboard crew with appropriate skills could be responsible for taking over the command of the vessel and either continue the journey until its final destination or guide the vessel to a safe location where assistance will arrive. Alternatively, a similar approach to the urban rail sector (metro automation GoA 3) can be employed: the vessel will have a one-person crew which will be in charge of safety-related or other specific tasks (also depending on the vessel type), while navigation tasks would remain with the onboard system or passed on to a remote control centre.

In the case of a completely unmanned vessel, a fall-back procedure must be developed so that the vessel is able to reach a safe state alone. Depending on the context, this safe state could be that the vessel autonomously navigates to the closest available safe location and there await the arrival of assistance. This safe state could also mean either dropping its anchor, perform station keeping, and/or deploy its spudpoles (see section 4.3.2 on immobilizing the vessel).

For this to be achieved, automated systems shall be provided with self-diagnostic and/or self-monitoring features. This will allow the computer to notify the boatmaster in case of failures leading to the activation of the fall-back procedure. For example, when the self-diagnostic detects a failure, a situation

[91] CCNR, “Definition of levels of automation in inland navigation”, November 2021, CCNR | Automation levels [EN].

too complex to handle, or a malfunction, an acoustic and optical alarm signal will be triggered in the wheelhouse and any other location permanently manned by crew (the RCC for instance). The automated system should display information about the malfunction to allow the crew to react swiftly and purposefully.

In other words, all automation-enabling equipment should meet “failsafe” requirements. Any failure or malfunction should cause its output to automatically adjust to a predetermined ‘safe state’, which is not limited to the electronic equipment but applies to the entire vessel and all its automated systems.

Finally, as noted in sections 4.1.4 and 4.4.2, manual intervention and override should always be possible to the greatest extent, and always for the critical functions identified in this report. As a minimum, it should be possible to hard switch off the automated systems. All automated systems should, as a principle, be linked to components which can always be operated by a human in the conventional way. However, while this is technically possible, it is not always feasible, operationally and financially. Indeed, such an approach requires a certain system duplication, both for software and hardware systems. In this case, it remains to be seen to which extent are the sector stakeholders and in particular the shipowners willing to sacrifice money, space and weight that would otherwise be used for the freight/passengers transported (their business case).

Disclaimer: Fall back conditions will heavily depend upon the navigational conditions of a given waterway. Reaching a safe state might be more challenging on busy and free-flowing rivers such as the Rhine, than on a small canal between two locks. The human-in-the-loop (either onboard supervisor or boatmaster located in the RCC) should be responsible for deciding the steps to take to accomplish a successful fall-back manoeuvre.

Systems: fall back mechanisms (self-diagnostic, self-monitoring, failsafe features) and procedures (acoustic and optical alarms), positioning systems (RADAR, GNSS), inland ECDIS, communication systems (internet connection, satellite connection), computer (IMU/GPU), systems for signalling location to competent authorities (VHF, AIS), anchor, spudpoles, engines, rudder etc.

4.6.1 Reliability guarantee: Data Integrity

Technical issues do not only stem from system failures but also from the deterioration in the quality of data produced and the accumulation of small errors which can compound into bigger errors with potentially severe consequences in terms of safety. For example, if a GNSS system fails, the absence of data or the presence of old or desynchronized data transmitted from the system can be easily detected. However, when the accuracy of the GNSS system begins to deteriorate (e.g. positioning worse than 10 metres), the computer might not be able to realise that the system does not fully comply with its obligations to guarantee safety of inland navigation. Consequently, technical solutions should be developed so that sensors and positioning systems are able to ensure and verify data integrity, provide metadata, and determine whether the information produced and/or received is accurate enough for automated navigation.

4.7 Technological readiness level (TRL) of identified onboard systems

In this section, the remaining and/or outstanding RD&I needs of the identified systems in the previous sections are evaluated, including the necessary continuous software development and updates. Currently, most research is being conducted at automation level 3 and below. Advanced AI and neural networks applied to automated IWT are for the time being sparse and far between, with some notable exceptions such as, *inter alia*, the Shipping Technology BRAIN[92] and the AutoBin project which heavily rely on machine learning.[93]

To evaluate their remaining RD&I needs, systems will be evaluated using the Technology Readiness Levels (TRL) scale. TRL are a type of measurement system used to assess the maturity level of a particular technology. The three technology solutions analysed in this report (Argonics' TGAIN, SEAFAR's RCC and Shipping Technology's BRAIN) are evaluated against the parameters for each technology level and are then assigned a TRL rating. There are nine technology readiness levels: TRL 1 is the lowest and TRL 9 is the highest.[94] A TRL number is obtained once the description in the diagram has been achieved. For example, successfully achieving TRL 4 (lab environment) does not move the technology to TRL 5. TRL 5 is achieved once there is component validation in a relevant environment. The technology remains TRL 4 until the relevant environmental validation is complete. A detailed description of the TRL scale is available in **Annex 1**.

In 2018, van Cappelle, Chen and Negenborn published a survey on the TRL levels for different systems needed for autonomous shipping in both maritime and inland navigation.[95] From several other research papers, they derived the following categorisation of subsystems needed for automated navigation: Navigation (including situational awareness and sensor fusion), Guidance (including collision avoidance, Global Path Planner, communication), Control (motion controller), and Hardware (engine, hull and sensors). Using these categories, techniques and subsystems for autonomous shipping were evaluated based on their technological maturity as of 2018. According to interviews held, many conclusions derived in 2018 are still largely applicable today.[96]

The first subsystem is **Navigation**, consisting of situational awareness and sensor fusion. Sensor fusion - i.e. the usage of available information from different sources to create a virtual representation of the real world - was already present in some tested and implemented technologies available in 2018 (e.g. Tesla fusion of ultrasonic, RADAR and visual cameras). TRL levels ranged from 3 to 7. However, these TRL levels were assigned to road-based vehicles instead of vessels. Situational awareness - perception and understanding of the surrounding environment - already saw usage of LIDAR and RADAR technologies (TRL 4, 5). Although not yet used in professional inland navigation, automatic RADAR Plotting Aid (ARPA) was then already at TRL 7, but only for supporting systems. Lower levels were found for systems designed for automation under human supervision, while no systems were found at all for situational awareness suitable for level 5 operations.

The second subsystem, **Guidance**, consists of three techniques: Global Path Planning, Collision Avoidance, and Communication. Global Path Planning, the optimization of the global path to be taken – especially relevant for a dense waterway network such as the Rhine, which must take into account locks closure times – is an optimization problem to find the most efficient way of movement. It benefits greatly from developments in computational logistics and falls in three categories: Line-of-Sight (LoS), potential

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92 Shipping Technology, "ST BRAIN", 2022, https://shippingtechnology.com/products/black-box-pro/.

93 Autonomes Binnenschiff, "Autonomous Inland Vessel", 2022, https://www.autobin.de/en/.

94 NASA, "Technology Readiness Level", 28 October 2012, NASA | TRL Levels [EN].

95 Van Cappelle, Laurien, Linying Chen and Rudy Negenborn, "Survey on Short-Term Technology Developments and Readiness Levels for Autonomous Shipping", *International Conference on Computational Logistics*, vol. 11184, 2018, https://link.springer.com/chapter/10.1007/978-3-030-00898-7_7.

96 Insights gathered during the interview with Rudy Negenborn on 7 July 2022.

field methods, and evolutionary algorithms. These systems are mature (TRL 8-9). Collision Avoidance techniques are either indicator-based, rule-based or a combination of the two. These techniques' TRLs range from 3 to 7. For rule-based systems, COLREGS (IMO regulation) was already used, but IWT police regulations were not in use yet. Regarding automation level 5 however, no prototype had been developed at the time of publication of the survey (TRL 5-6). The only prototype available was applicable only to automation under human supervision. Communication, either between vessels or between vessel and infrastructure, is deemed by the authors to be serviceable by the internet. From worldwide internet with better coverage to be offered by commercial parties (low orbit satellites for example), to a system for vessel-shore communication in development by the European Space Agency (ESA), TRL is evaluated to range between levels 2 to 9. The authors expect that these potential solutions for better communications can be adopted by the IWT sector on short notice.

The third subsystem, **Control**, consists of the motion controller. This is a challenging development to make on a vessel because of environmental disturbances. However, in 2018, there was already a system able to provide full remote supervisory control and monitoring of all systems on board. Furthermore, there was also an inland vessel (MSC Saluté) in the Netherlands operating at automation level 2 (following a pre-recorded track on its own, needing interventions under disturbance), which is one example among many. Although these systems have high TRL levels (9 resp. 7), control systems for level 5 were still far from operational.

Finally, for the **Hardware** subsystem, the engine and hull are described but the authors focus more on the greening of the fleet. Sensors, however, are described as critical for automation. A comparison of RADAR, LIDAR and ultrasound sensors proved that, although very expensive, LIDAR was the best option. Cameras are also irreplaceable for most use cases. In the **Overall** section of the survey, attention is drawn to developments of automated berthing. The available systems ranged from TRL 5 to 8, the highest level relating to a system that makes berthing easier, but does not take the step forward to full autonomy. A comprehensive overview of the results of the survey is available in **Figure 5** below.

	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Navigation	**D1.6 [40]** *('12)* Situation awareness		**D1.1 [18]** *('15)* State estimation	**D1.2 [5]** *('16)* Obstacle detection	**D1.9 [18]** *('15)* Radar for SA		**D1.3 [60]** *('16)* Obstacle detection		
			D1.7 [27] *('16)* Multiple sensors for SA	**D1.8 [59]** *('13)* Lidar for SA			**D1.4 [56]** *('14)* Wind measuring		
							D1.5 [49] *('17)* Sensor fusion		
							D1.10 [29] *('15)* APRA for obstacle detection		
Guidance		**D2.13 [48]** *('15)* Use of terrestrial internet	**D2.5 [52]** *('16)* Plot PAD to create CA		**D2.7 [61]** *('15)* Distributed CA over vessels	**D2.9 [57]** *('14)* Evolutionary algorithm	**D2.17 [50]** *('17)* Worldwide internet Facebook	**D2.1 [15]** *('10)* Collision Avoidance	**D2.4 [34]** *('03)* Line-of-Sight
			D2.6 [25] *('16)* TBA for CA		**D2.8 [55]** *('17)* Real-time DCPA and TCPA	**D2.10 [22]** *('16)* Collision avoidance by MPC		**D2.2 [43, 54, 9]** *('05)* Heuristic search algorithms	**D2.19 [65]** *('14)* Worldwide internet Google
			D2.14 [14] *('13)* Multi-hop network			**D2.12 [19]** *('17)* Path re-planning		**D2.3 [23, 58]** *('89)* Potential field methods	**D2.20 [6]** *('16)* Worldwide internet SpaceX
						D2.15 [33] *('12)* Switching between Internet sources		**D2.11 [20]** *('14)* Collision Avoidance	
						D2.16 [32, 63] *('15)* Mesh network among neighbouring vessels		**D2.18 [30]** *('14)* ESA two way communication	
Control		**D3.1 [64]** *('17)* Simplified control model			**D3.2 [2]** *('15)* H_∞ controller	**D3.3 [46]** *('15)* $\mathcal{L}_\infty$ adaptive backstepping with command governor	**D3.4 [38]** *('17)* Semi-Autonomous inland vessel		**D3.5 [16]** *('16)* Vessel automation system
Hardware			**D4.1 [17]** *('17)* Hybrid propulsion	**D4.5 [59]** *('13)* Disadvantages lidar		**D4.6 [42]** *('17)* Low-cost Hydrographic Survey		**D4.2 [26]** *('17)* Full-electric propulsion '17	**D4.4 [41]** *('13)* LNG and Hybrid propulsion
								D4.3 [4] *('17)* LNG-Electric propulsion '17	**D4.8 [59]** *('13)* Lidar best sensor
								D4.7 [8] *('17)* Network for depth-measurements	
Overall	**D5.1 [36]** *('17)* Platooning			**D5.7 [39]** *('16)* Maintenance Framework	**D5.2 [21]** *('17)* ANN for berthing	**D5.3 [51]** *('12)* ANN for berthing	**D5.4 [31]** *('15)* Quasi real-time control for berthing	**D5.5 [37]** *('17)* Laser ranging and docking for berthing	
	D5.6 [40] *('12)* Maintenance strategy						**D5.8 [24]** *('16)* INCASS innovative maintenance system		

a) In each cell, from left to right: label, sources, year of publication. Next line gives the short description.
b) The grey marked area highlights the developments that will become commercial on a short term.

***Figure 5**: Survey by van Cappelle, Chen and Negenborn, 2018.*

Although the above table and paragraphs from the 2018 survey already give interesting insights, it stands to reason that much has happened in the development of level 3+ systems since it was published. To fill this gap in the literature, a 2021 paper by Kooij and Hekkenberg is used.[97] Although this paper regards systems used onboard maritime vessels, it remains relevant in the field of inland navigation.The authors conducted a similar survey as a basis for their proposed implementation path for autonomous vessels, where they classify into 10 categories, among which are: Mooring (several automatic systems available), Navigation (systems available that need humans as backup, either on board or in a shore control centre), Engine room maintenance (monitoring of equipment needed, shore-based crew to come on board in ports to do maintenance), Maintenance on Deck (similar solution). The clusters and potential solutions for steps towards higher levels of automation (level 3+) as well as their expected timeframe are reproduced in **Figure 6** below. As can be seen, the authors are relatively hesitant regarding the timeframe of the availability of a fully operational RCC and computer aided navigation during the normal sailing phase (ranging from 5 to 10+ years into the future). The authors suggest the lack of a clear regulatory framework allowing the transfer of responsibility to the RCC as the main cause. This question is currently being examined within the CCNR for Rhine navigation.

Table 3. SUMMARY OF THE PRESENTED SOLUTIONS AND THE EXPECTED IMPLEMENTATION TIME OF THE SOLUTIONS.

Cluster	Potential solutions	Timeframe
Mooring	(a) Automated mooring system that interfaces with the current quayside infrastructure. (b) Shore crew that comes aboard the ship to perform mooring tasks	Available now
Navigation	(a) Computer aided navigation per ship during normal sailing phase. (b) Shore control station that monitors several ships at the same time	(a) 5–10 years (b) 10+ years
Maintenance in engine room	Maintenance is exclusively performed by maintenance team while the ship is in port.	Long term goal
Maintenance on deck	Maintenance is exclusively performed by maintenance team that performs their tasks while the ship is in port.	Available now
Bunkering	Supervision of bunkering is performed by an agent of the ship owner	Up to 1 year, organizational change
Administration	Administration is performed at the office of the ship owner	Up to 1 year, organizational change
Port supervision	Tasks are performed by an agent of the ship owner	Up to 1 year, organizational change
Responsibility	Cannot be automated under the current regulations, ideally the responsibility would be transferred to the shore control station	10+ years. This cluster can only be replaced if regulations allow it and a shore control station is available.
Cargo Available now	conditioning	Cell guides
Life support	Tasks cannot be performed off the ship and will need to be performed in some way while the ship is manned	Only when no people remain on board

***Figure 6**: Survey by Kooij and Hekkenberg, 2021.*

Combining the outcomes of these two surveys, it appears that most of the systems needed for low level automated navigation (levels 1-2) are already in a relatively high state of market readiness. This includes the core systems allowing automation (RADAR, LIDAR, cameras, GNSS, communications, global internet, track pilots etc.), which are considered to have reached a high TRL level. The first examples of highly automated vessels (levels 3-5) were described in Chapter 3, and it can be expected that more of these developments will become available in the coming years.[98] On the other hand, techniques and systems for high automation and autonomy (levels 4-5) have comparatively low TRL levels. Indeed, the most advanced systems (collision avoidance, AI, neural networks, sensor fusion and integration, etc.) still need additional technical improvements to move from TRL 5-6 to TRL 9. These conclusions are consistent with assessments made in the road sector, where the core systems allowing automation are considered to have reached a high TRL level, while the most advanced ones still need additional technical

[97] Kooij, Carmen and Robert Hekkenberg, "Identification of a task-based implementation path for unmanned autonomous ships", *Maritime Policy and Management*, vol. 48, no. 5, 2021, pp. 1-17, https://www.tandfonline.com/doi/full/10.1080/03088839.2021.1914878.

[98] Seafar, Novimar, Zulu.

improvements and testing.[99] Furthermore, on some small sections of the Rhine and on most of the Danube, high speed internet connectivity (4G/5G) remains unavailable, which is a virtual precondition for operating automated vessels.[100] Finally, encryption, data integrity, and cybersecurity systems and protocols still need additional testing and improvements to become fully mature. This remains critical for the safe deployment of remote-controlled vessels and other higher automation applications.

In conclusion, it appears that many of the functions needed for automated navigation are already in a relatively high state of market readiness. Technology and sensors used for situational awareness and navigation control especially have proven to be near market readiness or at market readiness. Systems, techniques, and communication systems used for the guidance of the vessel are also at high TRL levels but systems for collision avoidance are not yet market ready for level 4+ operations to be considered. This trend is observed even more strongly in the systems used to control an automated vessel by combining input from sensors and setting into work systems that steer/guide the vessel. Here, systems remain far from market ready. Although systems that offer very high levels of automation are currently in use, there is usually still a human as a backup - either onboard or in an RCC. Consequently, outstanding RD&I needs are mostly found in the control systems of automated vessels. Therefore, more testing locations for automation levels 3 and above are needed to gather as much data as possible that developers can then use to improve the performance of their systems.

The RD&I needs and developments for the IWT sector must also, to a certain extent, be checked and correlated with similar work being undertaken in the maritime sector. Such an approach will eliminate duplications, reduce the investments and time needed for market readiness and will also ensure greater similarity between the two waterborne transport segments, thus allowing for faster operations – in particular in and around dual ports.

[99] Interview with Clément Aubourg, Head of Autonomous Vehicles at Keolis, 7 July 2022.

[100] Insights gathered from multiple expert interviews.

5. Analysis of European vessel requirements in light of pre-identified functions

This report focuses on onboard systems allowing automation of inland navigation vessels. Therefore, this Chapter analyses the pre-identified functions against the applicable regulatory framework, especially the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN). Considerations pertaining to risk assessments and pilot projects are also included. Other relevant regulations, including police requirement, are not considered in this Chapter.

5.1 The European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN)

ES-TRIN contains provisions on inland navigation vessel construction and equipment as well as special provisions for certain categories of vessels such as passenger or container vessels. The objective of these technical requirements is to guarantee a high level of safety in inland navigation, thereby also protecting the surrounding environment and the crew onboard. ES-TRIN is updated every two years by the European Committee for drawing up Standards in the field of Inland Navigation (CESNI).

References to ES-TRIN are nowadays included in the legal frameworks of both the EU and the CCNR, respectively in directive (EU) 2016/1629 and the Rhine Vessel Inspection Regulations (RVIR).[101] As a consequence, a vessel operating on EU waterways or on the Rhine must carry either a Union inland navigation certificate or a Rhine vessel inspection certificate. Both certificates are issued by the competent national authorities (inspection bodies) and confirm the full compliance of the vessel with ES-TRIN.

Even though ES-TRIN is an EU-CCNR standard by way of CESNI, its applicability has been, since 2016, extended to other major European river basins which flow also outside the boundaries of the EU.

For inland navigation vessels on the Danube, the Danube Commission (DC) issued its “Recommendations concerning technical requirements for inland navigation vessels”, which are largely based on UNECE’s Resolution No. 61, and include elements from Resolutions 65, 72 and 76.[102] As of 2017, the DC incited its Member States to implement ES-TRIN directly, with due regard to the specificities of the Danube fleet and navigational conditions. Currently 8 Member states of the DC had already implemented ES-TRIN, while Ukraine and Moldova (as non-EU Member states) are planning to fully implement ES-TRIN into national legislation by early 2023.

As reflected in its Workplan 2021, the International Sava River Basin Commission (ISRBC) intends to create a reference to ES-TRIN in its legal framework in the coming years.[103]

The “Recommendations on Harmonized Europe-Wide Technical Requirements for Inland Navigation Vessels” (Resolution No. 61), adopted by the United Nations Economic Commission for Europe (UNECE), is regularly updated to follow ES-TRIN’s developments, but the major difference remains the absence of

[101] European Union, “Directive 2016/1629”, EU | 2016/1629 [EN] ; CCNR, “Technical requirements for vessels”, 2022, CCNR | RVIR [EN].

[102] Danube Commission, “Recommendations concerning technical requirements for inland navigation vessels”, 2014 edition, last amended in 2017, DC | Recommendations on technical requirements and amendments [DE, FR].

[103] ISRBC, “Work plan 2021”, item 1.1.6.

transitional provisions for existing vessels.[104] In practice, this means that EU Member States cannot fully apply the recommendations included in Resolution No. 61 because some are less stringent than EU law.

According to existing regulations, inland (passenger/cargo) vessels carrying less than 12 passengers and shorter than 20 metres do not have to comply with ES-TRIN. Although these types of vessels represent only a small fraction of the IWT sector's economic activities, they could provide concrete opportunities for the development of automation technologies, and especially in urban environments.[105] These include, for example, the FERRY initiative in the Netherlands and ZEABUZ in Norway (for more information, see Chapter 3.1 on pilot projects).

5.2 Current regulatory barriers and gaps in ES-TRIN for the uptake of automated inland navigation vessels

The identified regulatory obstacles to the uptake of automated inland navigation vessels in ES-TRIN fall into two main categories.

The first category regards provisions that constitute regulatory barriers and therefore do not allow or contradict the aims of automation. These typically refer, explicitly or implicitly, to the presence of a boatmaster and/or crew members onboard, either to perform an action or to interact with equipment designed for manned operations (e.g. doors to be passed, signs to be read, etc.). These provisions should, broadly speaking, be amended to account for the specificities of automated inland navigation vessels. Furthermore, within this category exist provisions that would not make practical sense anymore in the event of an automated vessel, yet do not strictly impede it from a regulatory standpoint (e.g. provisions related to living quarters, galley, cabins for crew members). Although they would not represent a regulatory barrier *per se*, such provisions would constitute economic disincentives to the development of automated navigation, which should be dealt with accordingly.

The second category regards the absence of regulations pertaining to specific functions identified as necessary for the safe automation of inland navigation vessels – i.e. regulatory gaps. This absence could generate a legal vacuum leading to a proliferation of patchwork solutions and possible low safety standards. At the very least, these functions should be incorporated into the regulatory framework.

Types of regulatory obstacles	Identified problem	General solution
Regulatory barrier	Explicit or implicit reference to the presence of a boatmaster and/or crew members onboard.	Amend provisions to account for the specificities of automated vessels.
Regulatory gap	Absence of regulations pertaining to specific functions identified as necessary for the safe automation of inland navigation vessels.	Incorporate the identified functions into the regulatory framework.

Figure 7: Summary of identified regulatory obstacles.

[104] UNECE, "Recommendations on Harmonized Europe-wide Technical Requirements for Inland Navigation Vessels", Resolution No. 61, Revision 2, 2020, UNECE | Res. 61 [EN].

[105] For more information, see PLATINA3 report D1.1 Increasing modal shift and decarbonisation, Chapter 3.1 Urban logistics.

In terms of situational awareness, Nzengu et. al (2021) identified a sample of ES-TRIN regulations which need to be adapted to allow automated vessels.[106] These include, for example, art. 7.02(1) which provides that "There shall be an adequately unobstructed view in all directions from the steering position". This regulation implies an attended steering position onboard. In the long term, this could interfere with the aim of removing all crew members from the vessel. As another example, Chapter 15 ES-TRIN refers to accommodation onboard a vessel. This Chapter implies the continuous presence of crew onboard. In the long term, this could interfere with the aim of removing some or all crew members from the vessel.

Similarly, Bačkalov (2020) identified several regulatory barriers, most of which do not allow remote-controlled operations to take place.[107] For example, article 10.17 of ES-TRIN states that "Switchboards for navigation lights shall be installed in the wheelhouse", which implies the presence of an operator to interact with them. Bačkalov adds that human-centred design features such as these should also be reviewed to allow for new designs that optimize automated operations to take place onboard a lowly manned and, eventually, a fully unmanned vessel. Another example regards art. 8.02(1) on engine design and safety equipment. This provision implies the presence of crew onboard to operate and maintain such equipment and does not allow remote monitoring. Once again, this could become problematic in the event of a completely unmanned vessel in the future.

In a similar vein, the SmartPort White Paper on Smart Shipping identifies that "there are stringent rules about the number of people that need to be onboard all the time" in the field of inland navigation. SmartPort advocates for "less specific regulations and more general guidelines", which would render the integration of innovative designs and operational concepts such as automation easier and faster in the future.[108] That being said, it is unlikely that regulators will accept waiving requirements based solely upon economic considerations without solid assurances about their safety-related implications, as was expressed in the conclusions of the automation session during the PLATINA3 5th Stage Event (see section 6.2 below).

In Chapter 4, several systems to fulfil the functions of situational awareness, communications, navigation, and fall-back capability were identified. These could be considered as technical solutions to the regulatory gaps. Based upon the structure and formulation of arts. 9.09 and 10.15 ES-TRIN, the general objectives of the function should be defined, while several solutions fulfilling the general objectives should be described. As such, high levels of safety can be combined with the necessary flexibility that innovators need to develop their systems. In other words, regulators should use an approach combining goal-oriented and prescriptive requirements to support innovation by allowing new technical solutions while also recognising technical solutions which are already available. As an additional benefit, their integration into ES-TRIN would generate legal certainty, a *sine qua non* condition for shipowners to invest in new technologies, as it considerably reduces risks and insurance costs.

In this regulatory work, automated vessels with reduced crew should be clearly distinguished from remote-controlled vessels, at least in terms of technical solutions to achieve the functional goal (details available in Chapter 4).

Given that the safety function (fire safety, cybersecurity, collisions, water ingress etc.) is covered to some extent in ES-TRIN, the solutions to overcome the regulatory barriers and fill the regulatory gaps for the

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[106] Nzengu, Wa, Jérôme Faivre, Ann-Sofie Pauwelyn, Victor Bolbot, Lars Wennensberg and Gerasimos Theotokatos, "Regulatory framework analysis for the unmanned inland waterway vessel", *WMU Journal of Maritime Affairs*, vol. 20, 2021, pp. 357–376, https://link.springer.com/article/10.1007/s13437-021-00237-z.

[107] Bačkalov, Igor, "Safety of autonomous inland vessels: An analysis of regulatory barriers in the present technical standards in Europe", *Safety Science*, vol. 128, no. 104763, 2020, https://www.sciencedirect.com/science/article/abs/pii/S0925753520301600?via%3Dihub.

[108] SmartPort, "Smart ships and the changing maritime ecosystem", September 2018, SmartPort | White Paper [EN].

uptake of automated vessels are more straightforward. The main adaptations needed pertain to the addition of safety features which can be operated automatically and/or remotely.
For example, in the case of fire safety, following the model of art. 19.12(9) for fixed fire-fighting systems on passenger vessels, such systems could be required on all types of automated vessels and not only in the engine room, but also elsewhere on the vessel. This would release the crew members from some firefighting duties, which could then be performed automatically and activated by an automated system or from a remote location. As another example, art. 3.03 ES-TRIN could be modified to require the presence of water ingress detection sensors in the collision and aft-peak bulkheads of automated vessels, as identified in section 4.4.3.

The reinforced use of goal-based requirements will generate further need for risk assessments of the vessel design to ensure that the automated vessel has an at least equivalent level of safety compared to conventional vessels.

5.3 Pilot projects

As stated in Chapter 3, pilot projects are critical for shared knowledge-building and for testing the safety and technical soundness of new technologies and concepts. Regulators would certainly continue to require special derogations before the technologies are certified, as one of the accepted solutions in the regulatory framework. Therefore, it is of major importance that pilot projects continue to be funded at the European level to ensure the continuity of knowledge collection and update.

Beyond the pilot projects in the field of inland navigation, the requirements applicable to maritime navigation could be examined in light of the lessons learned in this field. Similarly, some classification societies have developed rules that could be useful in this endeavour, especially to implement goal-based requirements.

6. Recommendations and roadmap

At the outset, it must be mentioned that the regulatory framework is only one tool among many to achieve an overarching goal, namely to promote the safety and harmonious development of automated inland navigation. The analysis clearly shows that automation-enabling systems cannot be allowed on European waterways without an independent evaluation supplemented by rigorous testing of the safety of such systems. Therefore, the following recommendations and roadmap should be understood as only one path towards achieving this common goal. Other activities of an economic, ethical, social, knowledge-sharing, and communications nature must also be pursued in parallel to the regulatory work.

6.1 Outcomes of the sector consultation during the 5th PLATINA3 Stage Event

During the 5th PLATINA3 Stage Event in Budapest (19-20 October 2022), the draft report for this task was presented during a two-hour long session followed by an interactive Workshop. Multiple speakers from different areas of the IWT sector were invited to speak alongside the PLATINA3 partners. The agenda of the session in available in **Annex 2**.

From the ensuing discussion, it was agreed that IWT needs integrated solutions towards high levels of safety that are economically viable, i.e. package solutions that allow compensation of costs by benefits. Furthermore, rolling out full-scale pilot projects was deemed vital for knowledge acquisition and for providing informed support to regulatory bodies, a key finding which is consistent with the outcomes of the expert interviews and desk research. Pilot projects are and will remain the main platform for the safe development and testing of onboard systems allowing the automation of inland navigation vessels.

Furthermore, speakers underlined the importance of intent sharing in collision avoidance software, a feature which could be investigated further and integrated into future automated systems. They emphasized the need for both real-time control and communication features to achieve viable and safe automation on inland waterways. Collision avoidance must integrate dynamic traffic management, including intent sharing between vessels and vessel traffic centres, to ensure safe and efficient interactions in a mixed navigational environment.[109] Finally, they noted that current police regulations are too human-centred and therefore not optimized for automated vessels in their current form.

The interactive Workshop produced several key insights. First, an overwhelming majority of participants consider that automation-enabling systems are no regret investments meaning that, overall and in the long run, investing in systems to move vessels up the automation ladder is worth the money and the potential risk. The only dissenting voices were due to remaining uncertainties about economic benefits (low fuel savings of ‘only’ around 5%, ‘more than 20 years to be profitable’), the lack of legal certainty and the overall safety of these new systems, with the notable exception of TGAIN (Track Guidance Assistant for Inland Navigation) systems for which the current business case seems sufficient.

Secondly, participants’ statements were broadly in line with the report authors’ own analysis regarding the most important systems allowing the automation of inland navigation vessels. Sensors contributing to situational awareness (RADAR, LIDAR, GNSS) came out on top, with the addition of cameras, ‘sensors’ in general or ‘sensor fusion’, and ECDIS (Electronic Chart Display and Information Systems). Other systems allowing connectivity and real-time communications such as 5G, ‘Internet connection’,

[109] Intent sharing refers to inland vessels communicating among themselves about their sailing route and destination, without human intervention. Rijkswaterstaat, SMASH!, Marin and three track pilot distributors are conducting research on sharing such intentions. In a simulator study, the track pilots exchanged information on sailing intentions so that fellow skippers in the area could see what the intentions of the other vessels in the trial were. For more information, see https://www.schuttevaer.nl/nieuws/actueel/2022/11/18/schepen-kunnen-straks-zelf-communiceren-wat-ze-gaan-doen/.

‘communication technology’ were highlighted multiple times. Finally, AIS, ‘thruster control’ and ‘common data interfaces’ were also mentioned.

Thirdly, it appears that the maritime sector’s technical guidelines could be a source of inspiration for future guidance or regulations in inland navigation, also in view of harmonizing the two sectors to increase synergies and intermodality.

Fourthly, participants mentioned that adapting regulations and providing legal certainty would help facilitate further uptake of remote-controlled vessels.

Finally, updating the manning requirements to account for the specificities of automated navigation appears as the most important regulatory action preferred by the participants (probably due to expectations in terms of cost savings). Significantly, multiple participants raised concerns about the need for further research through pilot projects to ascertain that automated vessels are safe before any regulatory action can be undertaken.

Concluding this session, Mr. Ivo ten Broeke (Dutch Ministry of Infrastructure and Water Management and Dutch Commissioner to the CCNR) advocated for caution, stating that there is no need to take any regulatory actions before incontrovertible proof that automated vessels are safe has become widely available. To gain such proof, several pilot projects and tests must be conducted. Guidelines (as recommendations from regulators), however, would be desirable to give manufacturers and innovators a clear view of the way ahead. The work of PLATINA3 contributes significantly to provide such guidance.

Systems allowing low levels of automation such as the TGAIN have proven that they can be economically viable and constitute a positive business case, especially with fuel savings, but for higher levels of automation, the only tangible economic advantage could only come from reduced crew onboard. Mr ten Broeke highlighted that collision avoidance technology will most likely become a key precondition for automated inland navigation. On the other hand, current technology often flags too many false positive collision warnings, so further RD&I is needed.

In the future, there will always be a mixed navigation environment (both automated and non-automated vessels), which will imply adapted training, communication and modes of operation, as well as new types of accidents which are difficult to predict. Pilot projects and safety studies about pilots are absolutely necessary for the smooth development of automation in inland navigation with the appropriate regulatory framework. He also advocates for a progressive approach, as future chances of success for lower levels of automation (especially levels 1-3) might be much higher than for fully autonomous navigation (level 5). Liability concerns should be resolved quickly or risk becoming a hindering issue.

6.2 Recommendations to policymakers, standardisation bodies and classification societies

This section contains 12 recommendations to international and national policymakers (such as CCNR, EU, UNECE), standardisation bodies (such as CESNI), and classification societies. These recommendations take into account the results of the analysis, the opinion of experts, as well as the outcome of the sector consultation.

6.2.1 Pilot projects and outstanding RD&I needs

Recommendation 1: Administrations in charge of IWT, in collaboration, if/where applicable, with River Commissions, should facilitate cross-border pilot projects to test automated navigation, including on major European waterways such as the Rhine or the Danube, by giving the proper derogations to the existing regulatory framework. Appropriate and enhanced safety mechanisms should be included to ensure equivalent levels of safety compared to conventional navigation during the tests.

Recommendation 2: In line with the objective of the European Green Deal (EGD) to make connected and automated multimodal mobility a reality, the European Commission should make more funding mechanisms available to bridge the financial gap regarding the outstanding RD&I needs of onboard systems and amend the work programmes to better target automation. Specifically, the European Commission should focus its RD&I funding and financing activities to accelerate the achievement of technological maturity in particular for collision avoidance technology, but also for AI and neural networks, machine learning, human-machine and machine-to-machine communication, sensor fusion, and better integration of RADAR and LIDAR technologies within automated systems.

Recommendation 3: Publicly funded pilot projects should supply accurate, timely, and up-to-date information and data on the most critical variables recorded during the tests. This information should be exchanged internationally, e.g. at the EU/CCNR/DC levels, to support policy making activities.

Recommendation 4: To make smart and connected inland navigation vessels a reality, the European Commission should provide dedicated financial support to reach full high-speed (4G/5G) internet connectivity coverage along the entirety of the main European waterways, and especially addressing the areas for which no network coverage is currently available.

6.2.2 Regulations and standards

Recommendation 5: Regulatory bodies should possess a sufficiently high technical understanding to properly assess how the technologies being regulated operate in practice.

Recommendation 6: Companies involved in the development and operation of automated IWT vessels should be organised within an existing or new European association to develop industrial standards or participate in the development of standards or regulations.

Recommendation 7: Standardisation and regulatory bodies (EU, CCNR, CESNI, CEN, ETSI…) should amend the rules which reflect a human-centred vessel design to facilitate the development of alternative designs for automated inland vessels, with reduced or no crew onboard, by enabling the execution of the safety functions even in the absence of the human operator, provided that an equivalent level of safety compared to conventional navigation is ensured.

Recommendation 8: Standardisation and regulatory bodies should introduce and define the notions of “remote operator” and “remote control centre (RCC)”, which could be located onshore or onboard another vessel. The difference between “automated vessels” and “remote controlled vessels” should be clarified in the standards and regulations.

Recommendation 9: In light of best practices from the sector, CESNI should develop the technical, phraseology, and redundancy requirements allowing automated vessels to ensure proper vessel-to-vessel and vessel-to-shore communications functions, including to and from an RCC.

Recommendation 10: In light of best practices from the sector, CESNI should develop recommendations or minimal requirements for the achievement of route planning, route execution and emergency immobilization functions to be performed by automated vessels, including a fall-back capability to ensure the automated vessel and surrounding navigation’s continued safety in case of major disruptions of the automated system.

Recommendation 11: In light of best practices from the sector, CESNI should develop safety requirements tailored to the specificities of automated vessels in terms of fire safety, cybersecurity, collisions, and water ingress management functions, as well as their corresponding safety procedures.

Recommendation 12: In light of best practices from the sector, CESNI should develop requirements for sensors and positioning systems to be able to ensure and verify data integrity, provide metadata, and determine whether information produced and/or received is accurate enough for automated inland navigation.

6.3 Roadmap for onboard systems allowing the automation of inland navigation vessels

Figure 8 below presents the suggested chronology for the development, adoption, and implementation of policy, regulatory and standardisation activities needed for the onboard systems allowing the automation of inland navigation vessels.

Nr	Who	What	By when	Priority level (I, II, III)
1	IWT administrations and River Commissions	Facilitate cross-border pilot projects, including on the Rhine and Danube, by giving proper derogations	2023	I
2	European Commission	Make more funding available and amend work programmes to better target IWT automation, focussing on reaching high TRLs for most advanced technologies	2027	I
3	European pilot project managers, EU, CCNR, DC	Supply accurate, timely and up-to-date information on pilot tests and share it broadly	Continuous	II
4	European Commission	Provide dedicated financial support to bolster 4/5G connectivity along main European waterways	2027	II
5	IWT sector and industry	Organise within an existing or new European association to develop industrial standards or guidelines	2025	III
6	EU, CCNR, CESNI, CEN, ETSI	Amend rules reflecting human-centred vessel design and facilitate the development of designs better suited to automated vessels	2027	II
7	EU, CCNR, CESNI, CEN, ETSI	Define notions related to remote-controlled navigation and their legal status	2025	I
8	CESNI	Develop technical, phraseology and redundancy requirements for communications on automated vessels	2027	I
9	CESNI	Develop technical requirements for route planning, execution, immobilization, and fall-back capability of automated vessels	2027	I
10	CESNI	Develop safety requirements tailored to automated vessels for fire safety, cybersecurity, collisions, and water ingress	2027	I
11	CESNI	Develop requirements for verifying data integrity	2027	I

Figure 8: Roadmap for onboard systems allowing the automation of inland navigation vessels.

Annex

Annex 1: Technological Readiness Level (TRL) scale

Technology readiness levels (TRL)

Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

1. TRL 1 – Basic principles observed
2. TRL 2 – Technology concept formulated
3. TRL 3 – Experimental proof of concept
4. TRL 4 – Technology validated in lab
5. TRL 5 – Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
6. TRL 6 – Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
7. TRL 7 – System prototype demonstration in operational environment
8. TRL 8 – System complete and qualified
9. TRL 9 – Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Source: Extract from European Commission Decision C(2014)4995, *HORIZON2020 Work Programme 2014-2015 General Annexes*.[110]

[110] Link: European Commission | TRL Levels.

Annex 2: Programme of the automation session during PLATINA3 Stage Event 5.

08:00 – 08:30	**Connectivity testing**
08:30 – 10:30	**Session 5 - Roadmap for on-board systems allowing automation of inland navigation vessels** – Moderator Michelangelo de Lisi, CCNR Secretariat
08:30 – 08:45	**Opening** ○ Keynote speech by Alina Colling, ABB
08:45 – 09:15	**Guest speakers** ○ Alexander Lutz, Argonics GmbH ○ Rudy Negenborn, TU Delft
09:15 – 09:30	**Presentation of the draft deliverable on Roadmap for onboard systems allowing automation of inland navigation vessels** o PLATINA3 partners (Mihai Barcanescu, WaterborneTP)
09:30 – 09:40	**Questions and answers – interactive discussion**
09:40 – 10:15	**Workshop on preliminary ideas for recommendations on the regulatory framework analysis and roadmap** ○ PLATINA3 partners (Salih Karaarslan, EICB)
10:15 - 10:30	**Concluding remarks** ○ Ivo ten Broeke, CCNR Commissioner, Rijkswaterstaat
10:30 – 10:45	**Coffee Break**

Annex 3: List of experts interviewed for the elaboration of this report.

Nr.	Interview date	Interviewee	Institution
1	11 May 2022	Ann-Sophie Pauwelyn	De Vlaamse Waterweg (BE)
2	27 May 2022	Louis-Robert Cool	SEAFAR (BE)
3	30 May 2022	Remco Pikaart	Shipping Factory (NL)
4	31 May 2022	Alexander Lutz	Argonics GmbH (DE)
5	1 July 2022	Igor Bačkalov	Development Centre for Ship Technology and Transport Systems (DE)
6	7 July 2022	Rudy Negenborn	Technical University Delft (NL)
7	7 July 2022	Clément Aubourg	Keolis (FR)
8	11 July 2022	Marco Scholtens	Netherlands Maritime Technology (NL)
9	21 July 2022	Mario Walterfang	GDWS/FWT (DE)
10	20 September 2022	Paul Ivanov	Trading Line (RO)
11	6 October 2022	Alina Colling	ABB (CH/SE), member of the Waterborne Technology Platform

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