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- INFRASTRUCTURE -

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List of abbreviations

Abbreviation	Fill text
AI	Artificial Intelligence
AIS	Automatic Identification System
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
AR	Augmented Reality
ATA	Actual Time of Arrival
ATD	Actual Time of Departure
AtoN	Aids to Navigation
bIENC	bathymetric Inland Navigational Chart
CAD	Connected and automated driving
CCNR	Central Commission for the Navigation of the Rhine
CCTV	closed-circuit television
CEMT	Classification of European Inland Waterways (CEMT Class I–VII)
CESNI	European Committee for drawing up standards in the field of inland navigation
CSIRT	Computer Security Incident Response Team
DAPhNE	Project DAPhNE. Danube Ports Network
DDoS	(Distributed) denial of service
DINA	Digital Inland Navigation Area
DIONYSUS	Project DIONYSUS. Integrating Danube Region into Smart & Sustainable Multi-modal & Intermodal Transport Chains
DIP	Digital Index Ports
DIWA	Project Masterplan DIWA
DR	Danube Region
DTLF	Digital Transport and Logistics Forum
EC	European Commission
ECDIS	Electronic Chart Display and Information System
eFTI	Electronic Freight Transport Information
ETA	estimated time of arrival
ETD	estimated time of departure GNSS
EU	European Union
EUSDR	EU Strategy for the Danube Region
GNSS	Global navigation satellite system
GPS	Global Positioning System
IALA	The International Association of Marine Aids to Navigation and Lighthouse Authorities
ICT	Information and Communication Technologies
IENC	Inland Electronic Navigational Chart
IMO	International Maritime Organisation

Abbreviation	Fill text
IoT	Internet of Things
IPCSA	International Port Community Systems Association
IT	information technology
IWT	Inland Waterway Transport
JIT	Just-in-time
KIR	Project KIR. Integrated port information system in Hungary.
LiDAR	Light Detection and Ranging
MitM	Man in the Middle
ML	Machine Learning
NIS	Directive 2016/1148 concerning measures for a high common level of security of network and information systems across the Union
NoTN	Network of Trusted Networks
NtS	Notices to Skippers
OPS	On shore power supply
PIANC	World Association for Waterborne Transport Infrastructure
PCS	Port Community System
PDC	port development company
RCC	Remote control Centre
RIS	River Information Services
RPIS	Project RPIS 4.0 - smart community system for the Upper Rhine Ports
RTA	Requested Time of Arrival
SaaS	Software as a service
SAF	sustainable alternative fuels
SW	Single Window
UNECE	United Nations Economic Commission for Europe
VDES	VHF Data Exchange System
VHF	Very high frequency
VR	Virtual Reality
VTS	Vessel Traffic Service
WG	Working Group
WP	Work-package

Executive summary

Digitalisation, automation and smart shipping are very broad concepts. Digitalisation and automation can be understood as two separate concepts, which overlap in parts. Smart shipping is based on the concepts of automation and digitalisation. Many navigational and operational tasks and processes performed on-board of a vessel but as well on-shore are already supported and, in some cases, even replaced by automation systems.

Being part of the *PLATINA3 WP4* dealing with Infrastructure and the *Task 4.3 Smart waterway and port infrastructure and management*, this report focuses on the implications of digitalisation and automation developments in inland navigation on inland waterways and ports infrastructure. The report is mainly based on desk research to existing literature. The findings of relevant projects, studies and initiatives are consolidated in the report. In addition, interviews were conducted with experts in the field. Automation and digitalisation are broad concepts, however the scope of task 4.3 is limited and therefore not all aspects of digitalisation and automation are included in the scope of this deliverable. The following topics are left out of the scope:

- automation of vessels, digital freight solutions, etc.,
- detailed analysis of the legal situation, required amendments to the legal practices or similar,
- financing and funding options of automation and digitalisation in inland navigation and in ports.

Terminology and definitions

Work on cross-cutting issues in the field of digitalisation, automation and smart shipping requires clear, accessible and understandable terminology. The aim of *Task 4.3 Smart waterway and port infrastructure and management* is not to develop new definitions but rather built upon existing knowledge. This report summarises existing terminologies and definitions elaborated by other platforms like CCNR, PIANC W210, project DIWA or the ones used in a business environment and builds upon them in this report. Where necessary, in order to improve understanding or limit the scope of this report, further clarifications are provided. The following terms are explained: (digital) technologies, automation, digitalisation and digital transformation, smart shipping, smart ports. The terminology is still subject to international coordination and agreement. Nevertheless, the report contains suggestions for such terminology, which is as well used throughout the report.

One of the defining characteristics of a smart shipping concept is the ability of a vessel to function autonomously. There are six levels of automation in inland navigation as developed and adopted by the CCNR, starting with level 0, the full-time human-based navigation and steering mode with *no automation*, up to level 5, which stands for *full automation* (see Annex 1: CCNR - Definition of levels of automation in inland navigation). The report focuses on the (future) infrastructural requirements to enable higher levels of automation in inland navigation, meaning scenarios addressing levels 3-5 of automation in inland navigation are the ones discussed.

The recently published PIANC WG210 report on "Smart Shipping on Inland Waterways" offers definitions of smart shipping and defines smart shipping in a broader term than just autonomous vessels. It as well defines the components of smart shipping such as Smart Vessels, Smart Traffic Management and Infrastructure, Smart Travel and Transport, Smart Regulation and Facilitation.

Inland waterways infrastructure

There are two main elements in waterway systems, vessels and infrastructure. Vessels are the means of transport. Infrastructure, like waterways, locks, bridges and ports are to guarantee a sound navigation and execution of relevant transport operations. Vessels navigating on inland waterways are also impacted by the external environment such as water levels, discharge, wind, ice or waves. Furthermore, rules and regulations provide framework to the skippers and crew onboard, specifying for example types of manoeuvres that should be taken in situations where there is a risk of collision.

Smart vessels (in the report addressed also as automated and remotely controlled) are vessels that use automated onboard systems, onboard sensors and external data to optimise their key operations, whether those of navigational character, including the remote navigation, or operations linked to management of fuel consumption, power management or maintenance. To allow smart vessels sailing on European waterways, a reliable, safe, efficient and smart waterway network is needed.

Research, developments and experiments regarding further automation of navigational tasks, remote control of inland vessels, or autonomous navigation is ongoing. The novel products, advanced sensors and positioning technologies to be deployed onboard vessels are already on the market. They primarily focus on assisting the skipper in navigation operations, supporting in decision-making, mitigating the effects of poor visibility, and eliminating blind spots (e.g. due to hull). Combining data from multiple onboard sensors creates a complete digital picture of the environment around a vessel. Such enhanced <u>situational awareness</u> enables safer manoeuvring in ports, effective navigation on waterways, or identification of potentially hazardous targets. Situational awareness is a critical building block on the pathway to greater vessel autonomy. These products are thus aimed at making sailing safer, more sustainable, more comfortable or more efficient.

It has to be noted that when adding automated vessels into the system of the traffic, a mixed environment will be created. In inland navigation it is hardly possible that (fully) autonomous vessels will use different route trajectories, different locks, or bridge openings etc. than human-driven vessels (such as it may be possible in road transport with physically separated lanes). In this sense, rules and regulations for the mixed traffic environment will need to top up the currently existing ones, sustaining the already very high safety and efficiency levels of IWT.

The chapter for inland waterways infrastructure looks into requirements around shipping operation areas:

- <u>navigation</u> consisting of voyage planning, navigation on rivers and ports, passing locks and movable bridges, berthing, anchoring and docking manoeuvres, situational awareness and also collision avoidance,
- <u>communication network and system</u> to transfer data externally and internally.

Voyage and route planning

The voyage plan (and its updates) is done based on environmental conditions, (expected) traffic conditions on route and require often manual input based on the personal experience and information collected from various scattered (electronic) sources.

Future (fully) autonomous and remote-controlled vessels will use voyage planning systems that automatically determine optimal route trajectories, taking into account definable constraints such as voyage time optimisation, fuel emissions reduction, or other configurable settings. For this purpose, the latest updates of navigation charts and other nautical information necessary for the intended voyage are required together with accurate, complete and real-time information on navigational restrictions (both permanent and temporary), water levels, bridge clearances, and weather and traffic (both actual information and forecasts).

The EuRIS portal, developed in the RIS COMEX project, will provide information services for reliable voyage planning (and other shipping operations) to improve the operations of skippers, terminals and ports. EuRIS gathers relevant RIS information from national data sources to provide optimised fairway, infrastructure and traffic-related information services through a single point of access for users, thus enabling reliable voyage and route planning, and many other operations on a pan-European level.

Navigation on the rivers, canals or in ports

Navigation refers to tasks performed from a vessel's departure to its arrival at the destination, while interacting with the environment to avoid collision, grounding, or other hazards. Many conventional vessels (crew onboard) are already fitted with sensors and systems, such as radars, ECDIS, AIS and instruments showing own vessel's condition. Sensors already assist the skipper in navigational tasks, and some of these tasks are even being replaced by automatic systems. Sensors help the skipper to obtain information on situational awareness. Combining this with information the skipper receives through own senses, such as sight, hearing and vessel movements, the skipper gets a complete situational awareness. On conventional vessels, decision making and control are still performed by the skipper and crew.

In the future, an autonomous navigation system will be able to dynamically plan and adjust the optimal route in real time to avoid collisions, groundings, or other hazards. Decisions will be done (depending on autonomy level, with or without human intervention) based on accurate situational awareness achieved through fusion of data from onboard sensors combined with real-time information from infrastructure providers about environmental conditions and (expected) traffic conditions on the route. Future developments will also enable greater connectivity between vessels and their environment, allowing cooperation and coordination between vessels themselves and between vessels and infrastructure, for example by sharing short-term intentions of vessels, planned route trajectories (thus optimising traffic management) or real-time information about the state of the fairway.

Besides accurate, complete IENCs as well the regularly updated depths contour lines based on riverbed characteristics (bIENC overlay) contribute to accurate situational awareness. Supplementary up-to-date collaborative depth data measured and shared by vessels, along with bIENC overlay, allow selection of a safe path for navigating along the route. Information about critical sections (with least sounded depth information) and critical infrastructure objects e.g. vertical clearance of (at least) critical bridges support skippers in their navigational decisions, and will be essential for the future.

Passing locks and bridges (approach, waiting and passage)

The scheduling of the lock and bridge passages influences the safety and also economic efficiency of inland vessels. The coordination is required between a vessel and locks or movable bridges whenever a vessel requires passage. At present, communication when planning passage, but also when passing locks or movable bridges, is almost exclusively done via VHF. In addition to VHF communication, infrastructure managers know that vessels are approaching a specific lock or bridge, either via AIS or through other systems such as IVS Next in the Netherlands.

The lock passage is a complex manoeuvre requiring high concentration from the skipper for adjusting the rudder, speed, bow thrusters, etc. External challenges comprise little space (in case of some locks, poor visibility with vessel hull blocking the sight, secure attachment of a vessel to the lock, or loss of accurate positioning information due to tall walls of a lock, etc.). Increased onboard sensors, lock passage assistance systems, high accuracy positioning and solutions for securing a vessel in the lock chamber are currently investigated in various research projects and remain the preconditions for safe passage of locks and bridges, when considering (fully) autonomous and remotely controlled vessels.

Mooring, anchoring and docking manoeuvre

(Public) mooring places, waiting quays or berths in ports and at terminals represent another challenge for (fully) autonomous and remotely controlled vessels. At present, the information about berth opportunities are scattered and available through various national websites or systems (e.g. BLIS system in the Netherlands). The berth reservation systems are in their infancy. The complex overview of the berth options along the corridors, and in some countries as well the berth reservation, is expected to be offered through the EuRIS portal.

Besides provision of information about mooring/anchoring places, or planning and scheduling of the mooring/ anchoring, the docking manoeuvre in itself will remain a challenge, especially for (fully) autonomous and unmanned vessels. Similar to the situation in locks, vessels need to be secured when moored, in particular during (un-)loading. Especially for unmanned vessels this may require infrastructural adaptations in the future, e.g. magnetic or vacuum mooring technology, fender systems at the docking stations currently installed and used in (pilot) projects.

Situational awareness

Reliable external perception of vessel's surroundings is a pre-requisite for (fully) automated and remotely-controlled vessels to perform necessary functions safely. For autonomous vessels navigating in complex environments such as on rivers, efficient *detection of nearby and small vessels and other obstacles* is essential to ensure safe navigation. There is a variety of obstacles like river edges, other vessels, fishermen, swimmers, people by the riverside, or infrastructure such as locks and bridges. Currently, the position of vessels is transmitted via AIS. All vessels equipped with AIS transponders and also on-shore AIS base stations can see the transmitting vessels within their range. Thus, skippers, remote vessel operators, or autonomous vessels themselves have an overview of live traffic in the vessel's vicinity. However, AIS-based vessel detection has its shortcomings (lower standalone accuracy, not all "swimming" objects are equipped with AIS).

Various aspects of the obstacle (target/object) detection and avoidance is discussed in the report. The reliable external perception is becoming a reality thanks to the increasing development and evolution of embedded technologies, integrated sensors and machine visions.

Communication system and network & connectivity

Automation requires reliable communication facilities, digital data exchange, and a cyber-security framework in order to provide the trust needed to remove people from processes. The future communication must be digitally coded, sent automatically as well as being machine-readable. Vessels must communicate with each other and with the infrastructure. Connectivity is therefore the key to increase the efficiency of smart shipping. Nowadays, traditional vessel communication system relies on AIS to provide low data services such as position, course, heading, destination, tonnage, speed, etc. Besides AIS, radio communication (voice over VHF), takes place between vessels, and with competent authorities. The reporting is done electronically or where no obligation, the reports are submitted even on paper. The mobile communication (4G/LTE/5G) and WiFi (where available) are used to transmit data to the shore. However, regional differences in mobile or broadband coverage can make communication hard.

The report summarises the future requirements on the communication networks, taking into account the criticality of the information to be exchanged. It addresses the need for high positioning information, the new developments in the Automated Identification System communication infrastructure (VDES), reliable mobile communication network along inland waterways, or need for local communication networks at critical infrastructure locations.

Take-aways

Not all navigational tasks will and should be replaced at once, nor does that seem feasible at this stage. Shipping operations related to the voyage and route planning, navigation and sailing on rivers, canals and in ports with necessary communication networks and sufficient connectivity, or assistance in case of lock and movable bridge passages are already in the focus of current R&D projects, and in some cases even in commercial deployment projects.

Other operations, which would require the changes in the physical infrastructure, may take longer on the way towards (fully) autonomous inland shipping. Commercial inland vessels dock significantly often, at locks, movable bridges, for (un)loading, supplies and change of crew. Replacing these activities by on-shore ad hoc crews is an option, however, it would be an organisational and financial challenge, in particular in times when also operations of locks and movable bridges changes from the operator which is currently present at the location to remotely controlled infrastructure.

Independently on how fast or which direction the automation in the inland shipping will go, for the sector it is important to know which waterways (their sections) are (will be) ready to provide information and services essential for different levels of automation. The classification of waterway network on its readiness for automation shall support the autonomous and remotely operated vessels to operate under more predictable environment. To prepare such classification, activities in road transport such as ISAD (Infrastructure Support for Autonomous Driving) may be taken as an example to gain insights into classification of infrastructure readiness for automation. Having elaborated such classification, the open topic remains where to embed it: standalone agreed unofficially by all European inland waterway countries, river commissions, CEMT classification or even consider to include such classification under newly assessed RIS directive, or TEN-T directive and its linked (future possible implementing/delegated) acts.

Ports

The chapter on Ports focuses on the identification of user requirements arising from the water side (vessel operators) and from the shore side (transport operators, infrastructure operators, authorities, etc.), it lists existing gaps and emphasizes potential benefits of using digital and automation tools which shall allow port communities to manage their processes and activities in the most efficient, effective and sustainable way. The methodology proposed starts from assessing the digital maturity of ports in relation to the port's needs, giving concrete examples of several digital tools and applications from selected European ports from the Rhine and the Danube regions.

Based on the five identified digitalisation levels, it then continues with identifying digital tools targeting the different levels of digitalisation and it continues with listing requirements for integrating smart technologies into existing and planned port infrastructure. At the same time, the chapter highlights potential benefits related to the use of digital tools and applications from the infrastructure owner perspective, user perspective as well as from the authority perspective. It concludes with a recommendations table, summarizing at operational and policy levels - requirements, benefits and gaps in relation to dedicated target groups' needs which are in correlation with findings of other respective project reports.

Ports across Europe have different development trends behind them (related to regionalisation, multimodality, innovation, digitalisation, or optimisation of port operations), different operational and ownership models, specializing in different cargo and offering different services. For example, for most inland ports, digitalization is still a new topic, therefore they find themselves in a position where they need to follow the digitalization examples of major European sea and of ports from other regions.

For inland ports a hot topic of the present and for the next 5-10 years arises in relation to the adoption of a port community system solution. Based on the results of several projects dealing with the topic of port digitalisation (e.g. DAPhNE, Dionysus, RPIS, KIR, DIWA), it can be concluded that it is absolutely not necessary that all inland ports have a PCS as a standalone solution, since it can be foreseen that a national or a regional solution (on the SaaS basis) can fulfil all requirements within reasonable costs and at the highest service level. Teaming up enables inland ports to make use of economies of scale, as investment and running costs can be split between several users (ports), hence avoiding the situation that only one port needs to support the entire financial burden. Besides the financial aspects, another important factor reflects on aspects in relation to data sharing, data ownership and data protection & security from the point of user rights, liabilities and responsibilities. The complexity of these aspects requires strong cooperation, especially if several countries are involved (both EU and non-EU Member States).

Seaports are forerunners in the digitalisation transformation/adoption trend. In Europe, several seaports such as Rotterdam, Amsterdam, Hamburg, Antwerp, Barcelona, Valencia, etc. have already built-up impressive experience in dealing with new technologies. In the area of seaports, the long-term vision is *a network of trusted networks - global network of Smart Ports***.** It is expected to be an informal network of independent Smart Ports, sharing real-time information concerning the maritime supply chain and fostering the development and implementation of innovations. By joining this network of Smart Ports, seaports also benefit from optimized transport flows.

It can be concluded that an enhanced regional cooperation with an outlook to corridor integration is a viable and relevant solution for European inland ports, whereas only the integration of both inland and seaports will enable ports to become reliable partners in the European and global efficient and sustainable transport chains.

Cybersecurity

While information and communication technologies enable automation in the shipping industry, these technologies also imply new hazards that are to be identified and new associated risks that are to be mitigated. The increased communication among vessels and between vessels and the shore brings concerns about the cybersecurity of related systems. The more interconnected inland navigation becomes, the more vulnerable it is to cyber-threats. Therefore, the design of both the infrastructure and vessels should take cybersecurity into account by applying multiple layers of mechanism, functions and barriers aiming at preventing, detecting and limiting the damage of potential security breaches.

The report gives brief insights into the typology of cyberthreats, their actors and motivations as well as various techniques used. This is followed by insights into cybersecurity aspects in inland navigation as well as potential impacts on cybersecurity breaches. The latter can be divided into impacts onboard a vessel and those on infrastructure, either physical or digital infrastructure. The damages in case of inland waterways infrastructure – caused by cyber-attacks – could result in serious damage on private and public properties, traffic disruptions, economic and environmental damages or end with casualties. Risks are greatest in case of vessel traffic planning services and IT systems, as these use an array of technologies, including radar, GNSS, and custom geodata. Next to that, information is routinely exchanged between shipping companies and with the public authorities or between private companies along a logistics chain; many of these data exchanges fall under the RIS umbrella whereas technologies used vary, e.g. AIS, web portals, etc. Many onboard systems and networks enable communication between each other, being it wheelhouse, machinery control systems; onboard sensors and instruments like AIS, GPS, ECDIS interact with each other; web-based terminals are used for reporting to authorities, etc. Once an unauthorised access to a shipboard network is obtained, attackers could well be able to interact with everything to which it is connected.

Therefore, the network components, servers, or operator stations should be configured to reduce the likelihood and consequences of cyber security breaches, with critical systems protected or even isolated from the public internet. This applies both for systems onboard of a vessel as well as any onshore system, being it remote control centre, vessel traffic centre, the infrastructure network or other.

Concerning the further coordination activities on cybersecurity, the 1st international workshop on cybersecurity in inland navigation was held in Bonn in September 2019. During the workshop the inland navigation sector expressed the wish to, under the lead of CCNR, establish a coordination platform bringing the main inland navigation players together with cybersecurity experts. Besides establishment of a coordination platform, a strong need for awareness, training and information among the different waterway users were highlighted.

1 Introduction

The Horizon 2020 PLATINA 3 project provides a platform for the implementation of the European Commission's NAIADES III action programme[1], dedicated to inland navigation. PLATINA3 is structured around four fields: i. market (WP1), ii. fleet (WP2), iii. jobs and skills (WP3) and iv. infrastructure (WP4). The WP4 "Infrastructure" deals with various aspects of the infrastructure, such as a changing climate (Task 4.1), alternative energy infrastructure along the waterway and in ports (Task 4.2), smart waterway and port infrastructure and management (Task 4.3) or barriers to infrastructure implementation (Task 4.4).

This report is the deliverable of the Task 4.3 and is structured into following chapters:

Chapter 2 Scope of the report defines the scope of the report by explaining what is the focus and what is outside the scope of the report. Being part of the PLATINA3 WP4 dealing with Infrastructure and Task 4.3 Smart waterway and port infrastructure and management, this report focuses on the implications of digitalisation and automation developments in inland waterway sector on inland waterways and ports infrastructure. It is mainly based on the desk research of existing literature. The findings of relevant projects, studies and initiatives are consolidated in the report. In addition, the interviews were conducted with experts in the field. The following topics are out of the scope of this report:

- automation of vessels, digital freight solutions, etc.,
- detailed analysis of the legal situation, required amendments to the legal practices or similar,
- financing and funding options of automation and digitalisation in inland navigation and in ports.

Chapter 3 Going smart summarises existing terminologies and definitions elaborated by other platforms like CCNR, PIANC WG210, project DIWA or used in business and builds upon them in the report. Where necessary, in order to improve understanding or limit the scope of this report, further clarifications are provided. The terminology is still subject to international coordination. Nevertheless, proposals for a terminology as used in this report are made below. The following terminologies are explained: (digital) technologies, automation, digitalisation and digital transformation, automated – connected – cooperative, smart shipping, smart ports.

Chapter 4 Inland waterways infrastructure looks into the requirements of (future) autonomous and remotely controlled vessels towards infrastructure and infrastructure operators, in terms of data, information, services, processes, communication systems, or connectivity. The requirements are analysed for vessel related shipping operations, such as voyage planning, navigation, passing locks and bridges or docking operation, and also for improved situational awareness (perception of vessel's surrounding). Each of the shipping operations sub-chapters starts with the overview of the current state, looking into information exchange between vessels and infrastructure. The analysis continues with the possible (desired) future state which envisions the (fully) autonomous and remotely controlled vessels sailing on European waterways. Chapter 4 concludes with summary of benefits, requirements, existing gaps and recommendations for future smart infrastructure.

Chapter 5 Ports focuses on the identification of user requirements arising from the water side (vessel operators) and from the shore side (transport operators, infrastructure operators, authorities, etc.). It lists existing gaps and emphasizes potential benefits of using digital and automation tools which shall allow port communities to manage their processes and activities in the most efficient, effective and sustainable way. Based on the five identified ports' digitalisation levels, chapter identifies digital tools targeting the different levels of digitalisation and it continues with listing requirements for integrating smart technologies into existing and planned port infrastructure.

[1] NAIADES III: Boosting future-proof European inland waterway transport. COM(2021) 324 final. 24.6.2021. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0324

2 Scope of the report

Digitalisation, automation and smart shipping are very broad concepts. Digitalisation and automation can be understood as two separate concepts, which overlap in parts. Smart shipping is based on the concepts of automation and digitalisation. Many navigational and operational tasks and processes performed on-board of a vessel but as well on-shore are already supported and, in some cases, even replaced by automation systems.

Being part of the *PLATINA3 WP4* dealing with *Infrastructure and Task 4.3 Smart waterway and port infrastructure and management*, this report does not look at the automation of vessels, digital freight solutions etc. as such, but focuses on the implications of such digitalisation and automation developments on inland waterways infrastructure and ports infrastructure.

This report consolidates findings on implications of digitalisation and automation developments in inland waterway sector on inland waterways and ports infrastructure. It is done based on the desk research of existing literature, studies or project outcomes as well as interviews conducted with experts in the field. The report consolidates requirements, gaps and benefits for digital and automation tools for:

- *inland navigation* – the focus is on automation and digitalisation of navigation-related operations of vessels and implications on the infrastructure providers, both in terms of physical and digital infrastructure, as well as the requirements towards the communication infrastructure (in particular among vessels and vessel-shore),
- *inland ports and sea ports* – the focus is on the identification of potential benefits of using digital tools and applications as well as automation for the efficiency and effectiveness of port processes in response to the ports' needs, for meeting the ports' targets (economic, environmental and social) and for closing the existing gaps in terms of digital development.

The requirements, gaps and benefits are addressed from the point of view the user (vessels, terminal operators), infrastructure operator (waterway, lock, bridges, mooring and anchoring places, port authority/administration).

The report is built upon the assumption, also enshrined in the CCNR Vision, that expects no significant changes to be done on the physical infrastructure and a requirement that automated vessels (independently on the level of automation) should be able to navigate in the existing infrastructure in a first phase of implementation. It needs to be mentioned that certain shipping operations, like automated docking and undocking may require the changes in the physical infrastructure, but these requirements will not be investigated into details in this report.

Furthermore, the report aims to deliver also recommendations towards policy makers and/or legislators (CCNR, DC, EC, national/regional governments). However, the report will not provide a detailed analysis of the legal situation, necessary amendments to the legal practices or similar. There were some studies carried out with this respect that can be found for example of the website of the Dutch initiative called "*SMASH!*"[2].

The report will neither assess nor measure the effectiveness of the different digital and automation tools on selected port processes, but rather indicate options which can be made use of in order to support ports in their digitalisation pathway, which shall facilitate their integration into smart and sustainable intermodal supply chains as well as contribute to synchromodality and Physical Internet.

Last but not least, the report does not look into the financing and funding options of automation and digitalisation developments in inland navigation and in (inland and sea) ports. Depending on the maturity of the technology and business cases, there are various financing and funding (grant) options available, both for the commercial and also for public entities, on European, national and regional levels.

[2] URL: www.smashroadmap.com

3 Going smart

3.1 Context

Work on cross-cutting issues requires clear, accessible and understandable terminology. The aim of the *Task 4.3 Smart waterway and port infrastructure and management* is not to develop new definitions but rather built upon on existing knowledge. Therefore, this report uses existing terminologies and definitions elaborated by other platforms like CCNR, PIANC W210, project DIWA or used in a business environment. Where necessary, in order to improve understanding or limit the scope of this report, further clarifications are provided. The terminology is still subject to international coordination. Nevertheless, proposals for a terminology as used in this report are made below.

3.1.1 (Digital) Technologies

Technological progress offers huge potentials for all economic sectors. When discussing about the **digital transformation**, technologies are not far behind. They go hand-in-hand with digital transformation. ***Digital technologies*** *are profoundly changing our daily life, our way of working and doing business, and the way people travel, communicate and relate with each other. They are generating an ever-increasing amount of data, which, if pooled and used, can lead to a completely new means and levels of value creation*[3].

Modern technologies are already being applied in transport and logistics sector, including inland navigation, or are on the verge of becoming reality. The use of modern technologies (such as cloud computing, Internet of Things (IoT), blockchain and cryptocurrency, big data analytics, artificial intelligence & machine learning, robotics and automation, virtual and augmented reality and other modern technologies) offer the potential to revolutionise decades-old processes.

3.1.2 Automation

Automation impacts different transport modes, be it road, rail, air, maritime or inland navigation. Automation covers a broad range from basic assistance systems for skippers to fully autonomous vessels. Compared to conventional shipping, enhanced automation in shipping is a great opportunity for the stakeholders of the navigation sector to improve reliability, reduce costs or contribute to the safety in general.

Various national and international research projects, such as LAESSI, NOVIMAR, AUTOSHIP, etc.[4] aim to innovate and automate certain technical processes, primarily but not exclusively on vessels, by developing more automated navigation. The automated navigation covers a wide spectrum of tasks and technical processes on-board of a vessel, making the life of crew on-board easier and work more efficient. In a long term, currently tested innovations create a basis for future replacement of crew on inland vessels. However, there are still many steps to be taken before fully autonomous sailing can be achieved. This includes changes to the existing social and legal framework and also the change of mindset of all stakeholders.

One of the defining characteristics of a smart shipping concept is the ability of a vessel to function autonomously. There are six levels of automation in inland navigation as developed and adopted by the CCNR, starting with level 0, the full-time human-based navigation and steering mode with *no automation*, up to level 5, which stands for *full automation*. Definitions are available in the Annex 1: CCNR - Definition of levels of automation in inland navigation. The report will make use of the terminology established by CCNR, where applicable.

As this report focuses on the implications of digital and automation tools (expected to be) deployed on vessels and the (future) requirements on infrastructure to enable higher levels of automation in inland navigation, primarily

[3] European Commission: Shaping Europe's digital future. Feb 2020. URL: https://ec.europa.eu/info/sites/default/files/communication-shaping-europes-digital-future-feb2020_en_4.pdf. ISBN 978-92-76-16363-3.

[4] CCNR. Listing of pilot and research projects in the field of automation in inland navigation. URL: https://automation.ccr-zkr.org

the scenarios addressing levels 3-5 of automation in inland navigation will be discussed, in which the "system performs the entire dynamic navigation tasks" (CCNR. 2018). The following (future) scenarios building upon different levels of automation of vessels are considered in this report:

- Steering Assistance / Partial Automation (Level 1 and 2) covers vessels with assistance systems controlling either *steering (Level 1)* or both *steering and propulsion (Level 2)* related navigational tasks. These arrangements support a human boatmaster during navigation, whereas the boatmaster performs all remaining aspects of the dynamic navigation tasks. Examples of the steering assistance are rate-of-turn regulator, or trackpilot[5].
- Conditional Automation / High Automation (Level 3 and 4) are handled together, since the same (or very similar) requirements apply from the point of view of the infrastructure provider. Both Levels of Automation expect a *sustained context-specific*[6] performance by a navigation automation system of all dynamic navigation tasks. The requirement of the fallback performance (Level 4), without expectations that a human boatmaster intervenes, where the level differs, is a requirement that needs to be addressed on the side of a vessel itself, a requirement which is not addressed in this report.
- Autonomous = Full Automation (Level 5) is the ultimate goal in the automation efforts in inland navigation, which shall *unconditionally* perform all navigational tasks and fallback performance without interventions of a human boatmaster. To achieve this level, also changes in the existing physical infrastructure might be needed, e.g. to ensure the fully autonomous vessel manages the passage through locks, (un-)docking and similar manoeuvres without requiring the human intervention.

Furthermore, two different degrees of control, namely the direct control on-board of a vessel or control via a remote-control centre) are considered: (A) remotely-controlled vessels - steered from a remote-control centre & (B) autonomous vessels (towards CCNR level 5).

3.1.3 Digitalisation and digital transformation

Digitalisation serves as an enabler and goes hand-in-hand with automation. The WATERBORNE vision on "Connected and automated waterborne transport" states that *"Digitisation will connect smart ships and vessels as well as smart ports and smart infrastructure. It will enhance data flows. It will also lead to a higher degree of automation and autonomy, automated and autonomous systems, ship operations (both maritime and inland navigation) and remote control from the shore by 2030. Future ships and vessels will be designed so that they can be continuously updated with the digital technologies throughout their lifecycle. Connectivity and automation will not only improve nautical operations or the energy-efficiency of Waterborne transport, but will also improve logistics and mobility flows.[7]"*

Digital trends in transport and logistics enable, among others, a higher level of automation, better and broader connectivity as well as data driven decisions and operations.

Digital transformation is more than digitalisation. It means the integration of digital technologies in all areas of a business, fundamentally changing the way it operates and providing value to its customers. It improves workflows, optimises existing processes, increases customer satisfaction and internal efficiency.

Driven by the prospect of innovative transformations powered by new technologies, transport and logistics sectors are engaging in digital transformation initiatives focused on new business processes, services, and competitive strategies. Digitalisation is transforming these sectors along the whole transport supply chain. Inland navigation is

[5] Trackpilot is a track-keeping system for inland vessels along pre-defined guiding lines. (CCNR. 2018)

[6] Context-specific is understood as confined (limited, restricted) 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. (CCNR. 2018)

[7] WATERBORNE Vision on "Connected and automated waterborne transport". URL: www.waterborne.eu/vision/connected-and-automated-waterborne-transport. Accessed: 30.3.2022.

not an exemption. Digital transformation impacts vessel design, infrastructure (waterways, bridges, locks, ports, terminals), transport operations (cargo management, vessel and shipment tracking and tracing, capacity allocation…), supporting services (like warehousing, monitoring and inspection), maintenance and repair services, information and documents transmission among involved stakeholders (i.e. shippers, vessel operators, authorities, customs, port and terminal operators).

3.1.4 Smart shipping

The DIWA-project describes the concept of "**smart shipping**" as: *'"smart interaction of intelligent and sustainable vessels, intelligent infrastructure, communication technology and regulations"* [DIWA, p.61]. The waterway infrastructure, which is in the focus of this report, is therefore an integral part of smart shipping.

A range of novel technologies such as advanced analytics, autonomous shipping, robotics and artificial intelligence, as well as the availability of high-quality data and provision of intelligent information services are changing the way in which planning and operations in inland shipping are (to be) executed. They expand the possibilities for new business developments and are enablers of smart shipping solutions. Development varies from vessel trains (NOVIMAR), remotely controlled vessels (SEAFAR) or trials with fully automated vessels (e.g. Zeabuz[8], Roboat[9] and FERRY[10]). In the context of smart shipping, it is assumed that vessels will be highly automated, equipped with systems using smart onboard sensors and (external) data to optimise vessels' operations and management. This will require adaptations to digital, and in some cases also physical, infrastructure.

Smart Shipping is about being connected[11]. Recently the PIANC WG 210 issued a report on "Smart Shipping on Inland Waterways"[12]. The report is prepared from the perspective of infrastructure providers and traffic managers and with the focus *"on the interaction between a ship with autonomous capability and infrastructure (both physical and digital) as well as between ships with autonomous capabilities"*. The report describes the smart shipping in broader term than just autonomous vessels and defines following components of the Smart Shipping:

- Smart Vessel - *Smart vessels are vessels that are highly automated and are therefore equipped with automated systems using (external) data to optimise the key functions of the vessel. (navigation, real-time planning, fuel consumption management, etc.)* [PIANC, p.7]
- Smart Traffic Management and Infrastructure - *The management of the inland waterways takes into account real-time (external) data coming from ships, infrastructure and third parties. Also, the existing operational tasks of bridge/lock operators, traffic planners, vessel traffic service/traffic guidance are expected to change* [PIANC, p.7]. The Vlaamse Waterweg defines smart infrastructure as *"waterway infrastructure that is highly automated and operated remotely. Interaction between infrastructure and vessels takes place digitally in order to guide traffic as safely as possible.[13]"*
- Smart Travel and Transport - *The interaction between ships and third logistic parties are evolved into a smart, smooth and flexible process. This consists of two parts. First is the simplification and international integration of procedures that users of the waterways need to follow. Second, next to smart navigation, smart cargo handling should be developed too* [PIANC, p.7].
- Smart Regulation and Facilitation - *This is regulation that supports innovation and future-oriented initiatives, and this always with an eye for safety* [PIANC, p.7].

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[8] zeabuz urban mobility. URL: www.zeabuz.com. Accessed: July 2022.

[9] ROBOAT. Self-driving technology to transform urban waterways. URL: https://roboat.org. Accessed: June 2022

[10] FERRY. URL: thefuturemobility.network/vaar-met-ferry-ons-eerste-autonome-pontje-van-start-in-de-gemeente-teylingen-koudenhoorn

[11] SmartPort: Smart ships and the changing maritime ecosystem. How digitalization and advanced automation of barges, service vessels and sea ships create new opportunities and challenges for the maritime industry. URL: www.researchgate.net/publication/327704347_Smart_ships_and_the_changing_maritime_ecosystem. Status: 22.03.2022

[12] PIANC WG210: Smart Shipping on Inland Waterways. March 2022. ISBN 978-2-87223-015-0

[13] De Vlaamse Waterweg NV. Smart Shipping. URL: www.vlaamsewaterweg.be/smart-shipping-english-version. Accessed 22.3.2022.

3.1.5 Smart Ports

There is not an internationally accepted definition, but based on literature review and sector initiatives, a **smart port** is a digital port that continuously uses real–time information generated by smart technology solutions to increase its efficiency, effectiveness and security by making itself:

- more operationally efficient,
- energy efficient,
- environmentally sustainable,
- economically efficient
- as well as capable of handling increased volumes of cargo and passengers
- while at the same time limiting/reducing congestion and improving safety
- as well as bringing added value to the port community and the supply chain as a whole.

At the same time, a smart port equips the workforce with relevant skills and technology to solve the unique internal and external challenges of the organisation, and to facilitate the efficient movement of goods, delivery of services and smooth flow of information.

The European Union defined in 2014 the meaning of smart city and smart community. As ports are considered a special case of a smart community, they have to meet similar requirements, which have been adapted to the port situation. As such, European smart ports, should consider the following Regulation on Transport, Energy and Information and Communication Technologies - ICT (selected most relevant ones, list is not comprehensive):

TRANSPORT	ENERGY	ICT
• COM 2011(144) Roadmap to a Single European Transport Area • Directive 2013/1315 Trans European Network (Core Network, Core Network Corridors, Comprehensive Network)	• Directive 2013/33 Sulphur Emission Control Area • Directive 2014/94 Clean Power for Transport	• Directive 2005/44/EC & Regulation 414/2007 On harmonized River Information Services • Directive 2010/40 Intelligent Transport Systems • Directive 2010/65 Electronic Single Windows • Directive 2016/1148 On security of network and information systems • Regulation 2016/679 & Regulation 45/2001 GDPR

Table 1: Overview of (selected) regulations to be considered by smart ports

3.1.6 Cybersecurity and Data privacy

Cybersecurity

While information and communication technologies enable the automation in the shipping industry, these technologies also imply new hazards that are to be identified and new associated risks that are to be mitigated. The increased communication among vessels and between vessels and the shore brings concerns about the cybersecurity of related systems.

According to the ISO Standard (ISO/IEC 27032), which is currently under revision, the "***cybersecurity** stands for preservation of confidentiality, integrity and availability of information in the cyberspace".*

Further definitions and details related to cybersecurity are elaborated in the chapter 4 Cybersecurity.

Privacy

When sharing information between different users, **privacy** should be guaranteed at any time, e.g. through allowing the data owner to determine who can see which information at which moment. Data privacy is an important topic in the smart shipping concept. However, this report does <u>not</u> look into the data privacy related issues as it is linked to the type of data exchanges, which was and is investigated in other projects like RIS COMEX, or DIWA Masterplan.

3.2 Policy background & initiatives

Compared to conventional shipping, enhanced automation in shipping is a great opportunity for the stakeholders of the inland navigation sector to improve safety, reliability and reduce costs. Research, developments and experimentations in the area of automation and remotely controlled vessels are carried out, in particular on the side of vessels, data sharing and provision by the authorities or in ports. Developments are broad. However, enhanced automation, related new operational concepts and novel technologies that are introduced in the inland shipping may not meet the existing regulations or technical requirements.

To overcome this non-compliance, in the maritime shipping, the classification societies provide guidance on processes to follow for obtaining approval of alternative designs, which support the development and introduction of new concepts and novel technologies in the area of autonomous and remotely controlled shipping. The aim is to document that an equivalent or better level of safety will be ensured, when compared to a conventional vessel designed and operated in accordance with existing rules and regulations. Currently, the recommendations and guidance are available for the maritime sector, however a similar outline may be applied also to inland shipping. Legislation will not allow vessels to sail autonomously, if it cannot be proven that these vessels are as safe as (or even safer than) the conventional vessels used in inland navigation.

Classification societies like Bureau Veritas[14], Lloyd's Register[15] or DNV-GL[16] set out recommendations and guidance for the design and operation of systems which may be used to enhance the automation in shipping. Nevertheless, it is necessary to point out that the area of autonomy and remote operation of vessels is still an immature field where new ideas and technical solutions are being introduced. Therefore, currently it is not possible or desirable to provide detailed rules for all areas and combinations of concepts.

In May 2022, the Maritime Safety Committee (MSC) of the International Maritime Organization (IMO) has completed a regulatory scoping exercise analysing a substantial number of IMO treaty instruments[17]. The scoping exercise was the first step for a focused discussion to ensure that regulations will keep pace with technological developments. Varying degrees of autonomy were considered: crewed ship with automated processes and decision support (degree 1); remotely controlled ship with seafarers (degree 2) or without seafarers on board (degree Three); and fully autonomous ship (degree 4). The outcome highlights a number of high-priority issues, cutting across several instruments, that would need to be addressed at a policy level to determine future work. Similar extensive exercise would be needed for the inland navigation.

At the moment (2022), there is no regulation reflecting different levels of autonomy or related smart shipping concepts in inland navigation. There are temporary regulations or temporary permits issued for testing vessels with less or no crew aboard. Such arrangements are currently in Belgium, the Netherlands or in Germany, where test fields were initiated whereas testing is allowed as soon as the crew is on-board.

To foster the further development of automation in inland navigation, CCNR is working on a framework for the authorisation of pilot projects which require temporary derogations from CCNR regulations. The aim is to gather experience and to take this into account in future work on adapting the CCNR regulations.

In parallel, CESNI working groups started to collect experience gained with pilot projects for automation of inland navigation and the possible regulatory needs.

[14] Bureau Veritas: Guidelines for Autonomous Shipping. Guidance Note. Oct 2019. URL: https://erules.veristar.com/dy/data/bv/pdf/641-NI_2019-10.pdf.

[15] ShipRight: Design and Construction. Additional Design Procedures. LR Code for Unmanned Marine Systems. Feb 2017. URL: www.lr.org/en/unmanned-code.

[16] DNV-GL: Class Guideline. Autonomous and remotely operated ships. DNVGL-CG-0264. Sep 2018. URL: https://rules.dnv.com/docs/pdf/DNV/cg/2018-09/dnvgl-cg-0264.pdf.

[17] IMO: Autonomous ships: regulatory scoping exercise completed. URL: www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx. Accessed: July 2022

CCNR Vision for the development of automated inland navigation

On 17 October 2018, the inland navigation Ministers of the 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"[18]. As a result, the CCNR adopted in late 2018 the first international definition of automation levels in inland navigation (levels 0-5), which were subsequently reconfirmed in 2020[19]. In November 2021, the CCNR published a summary of the vision[20] to support the harmonised development of automated navigation. In early 2022, the summary was further developed into a "detailed vision to support the development of automated navigation in the CCNR"[21], hereafter referred to as "the CCNR Vision".

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 development, 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, such as:

- the composition and qualification of crews,
- technical requirements of vessels,
- navigation in a closed and restricted environment, taking into account 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),
- cybersecurity.

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

- continue to guarantee an equivalent level of safety of navigation on the Rhine,
- contribute to the prosperity of Rhine navigation by adapting it to new challenges,
- 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 reacting appropriately to requests for assistance or in case of system failure, either on board or remotely), 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, the 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 referred to by several national authorities (e.g.

[18] CCNR: Mannheim Declaration. 17 October 2018. URL: www.ccr-zkr.org/files/documents/dmannheim/Mannheimer_Erklaerung_en.pdf.

[19] CCNR: Automated navigation. Definition of levels of automation in inland navigation. Nov 2020. www.ccr-zkr.org/files/documents/AutomatisationNav/NoteAutomatisation_en.pdf.

[20] CCNR: Summary of the CCNR's vision to support the harmonised development of automated navigation. November 2021. URL: www.ccr-zkr.org/files/documents/cpresse/cp20211117en.pdf.

[21] CCNR: Vision détaillée pour soutenir le développement de la navigation automatisée au sein de la CCNR. March 2022. URL: www.ccr-zkr.org/files/documents/AutomatisationNav/Vision_detaillee_fr.pdf.

Maritime Autonomous Surface Ships - UK Code of Practice[22]) and international institutions such as the UNECE or PIANC, in particular within Working Group 210 ("WG 210 – Smart Shipping on Inland Waterways").

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,
- designing and implementing a derogation procedure for authorising and monitoring pilot tests on Rhine,
- develop requirements and/or recommendations for intelligent assistance systems used in levels 1 and 2,
- develop framework conditions for allowing autonomous as well as remotely controlled inland navigation vessels.

Since 2018, the Police Regulation Committee of the CCNR has developed an inventory of relevant pilot and research projects. As of April 2022, 35 national and international projects in CCNR Member States have been referenced[23]. At present, there is no administrative procedure for authorising pilot projects to derogate from CCNR regulations to carry out tests on the Rhine. A CCNR procedure would be useful for project promoters who wish to carry out trials on the Rhine that require a derogation from CCNR regulations. The procedure that will be implemented on the Rhine could also inspire CCNR Member States to develop their own national procedures, especially if they do not yet have one. Thus, a uniform procedure would be useful both for the national authorities and for the promoters of a pilot project, thereby significantly reducing the administrative burden, especially when examining cross-border projects.

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 on the results of the pilot projects benefiting from a derogation. Thus, a dedicated CCNR Committee (Comité restreint de navigation - RN) will steer the work related to automated navigation within the other CCNR Committees. It is also responsible for monitoring the implementation of derogations approved by the CCNR and reports to other Committees on its implementation in the Member States.

CCNR Member States delegations stressed that they did not wish to modify the existing physical infrastructure (in particular locks) to allow the navigation of automated vessels. However, that does not exclude sensors installed at infrastructure. Beyond the physical infrastructure, however, the need to consider the digital infrastructure was stressed, especially since automated vessels might require the transmission of additional information in a different form than that currently provided.

[22] Maritime UK: Maritime Autonomous Surface Ships Industry Conduct Principles. December 2020. URL: UK Code of practice | V4.

[23] CCNR: Listing of pilot and research projects in the field of automation in inland navigation. URL: https://automation.ccr-zkr.org/1000-en.html. Accessed: April 2022

4 Cybersecurity

Cybersecurity in European inland navigation

With the Mannheim declaration of 17 October 2018, the inland navigation Ministers of the CCNR Member States (Belgium, France, Germany, the Netherlands, Switzerland) called upon the CCNR to "press ahead with the development of digitalisation, automation and other modern technologies, thereby contributing to competitiveness, safety and sustainability in inland navigation".[24] Since the end of the last century, the number and complexity of navigational and ICT equipment[25] on inland navigation vessels and infrastructure have steadily increased. ICT technologies are transforming shipping, bringing support in navigational tasks as well as enhanced monitoring, communication, and connection capabilities, and thereby facilitating the development of new generations of intelligent transport systems, including automated inland navigation vessels.[26] However, this profusion of connectivity may also bring about cybersecurity challenges. To fully benefit from the advantages of digitalisation and ensure a safe and seamless integration of ICT technologies into inland navigation vessels and infrastructure, the sector needs to take cybersecurity issues seriously.

To this end, the first international workshop on cybersecurity in inland navigation was held in Bonn in September 2019 under the auspices of the CCNR and in partnership with the German Federal Ministry of Transport and Digital Infrastructure (BMVI) and PIANC.[27] Over 100 participants, from both the public and private sector, addressed the complexity of the cybersecurity related challenges which remain to be overcome to achieve the digital transition, while also fostering exchanges and reinforcing the level of information on cybersecurity among the different stakeholders. Over and above a strong need for awareness, training and information among the different waterway users, the question of cooperation was specifically highlighted. Many of the participants expressed the wish that the CCNR, together with its partners, take a leading role in the cybersecurity domain in inland navigation, e.g. as a coordination platform bringing the main inland navigation players together with cybersecurity experts.

Cyber-definitions in inland navigation

A **cyber-threat** is an actor, circumstance or event that may have a negative impact on an organisation (its operations, assets, image or people) or, through it, on other organisations linked to it. To achieve this, the threat must exploit one or more vulnerabilities according to a certain scenario. The more likely the scenario, the more important the vulnerabilities and the more numerous the threats, the higher the probability of a cybersecurity incident.

The term **impact** refers to the consequences of a cybersecurity incident - i.e. a cyberthreat that has materialised. The impact is always assessed without taking into account the threat.

Finally, the term **cyber-risk** is used to assess a set of threats to a system that are more or less likely to occur, with more or less serious consequences. Cyber-risks are thus the assessment of the likelihood of the threat to materialize per its potential impact. Or in short RISK = (equals) THREAT *(times) IMPACT.

Typology of cyberthreats, its actors and their motivations

Cyberattacks cover a plethora of techniques used with often malicious intent. The shipping industry association BIMCO[28] identifies two types of attacks: targeted and untargeted attacks. **Targeted attacks** may be more sophisticated and use tools and techniques specifically created for targeting a certain company or vessel.

[24] CCNR, "Mannheim declaration", October 2018, CCNR | Mannheim Declaration [EN].
[25] ICT, or Information and Communication Technology, is the infrastructure and components that enable modern computing.
[26] PIANC, "Awareness Paper on Cybersecurity in Inland Navigation", InCom Task Group n°204, January 2019.
[27] CCNR, "Workshop on cybersecurity in inland navigation", September 2019, CCNR | Cybersecurity workshop [EN].
[28] BIMCO: Guidelines on cybersecurity onboard ships. December 2020 URL: BIMCO | Cybersecurity guidelines [EN].

Untargeted attacks are likely to use tools and techniques available on the internet, which can be used to locate, discover, and exploit widespread vulnerabilities that may also exist in a company and onboard a vessel.

Both types of attacks can make use of one or multiple of the following **techniques**:

- **Social engineering**: A non-technological technique used by potential cyber-attackers to manipulate insider individuals into breaking security procedures or reveal information that can be used by the cyber-attacker at a later stage. This technique uses normally, although not exclusively, interaction via social media.
- **Brute force**: An attack trying all possible passwords with the hope of eventually finding it within a reasonable time. The attacker may check all possible passwords systematically or he may use algorithms to find quicker passwords that are based on words from the dictionary.
- **Credential stuffing**: Using previously compromised credentials or specific commonly used passwords to attempt unauthorized access to a system or application.
- **(Distributed) denial of service (DDoS)**: A denial of service prevents legitimate and authorised users from accessing information, usually by flooding a network with data. A “Distributed” Denial of Service is when the attacker is flooding the network using a big number of computers simultaneously, making it even more difficult to stop.
- **Phishing**: Sending emails to many potential targets asking for specific pieces of sensitive or confidential information. The email may also contain a malicious attachment or request that a person visits a fake website using a hyperlink included in the email.
- **Spear-phishing**: Like phishing but the individuals are targeted with personal emails, often containing links that automatically download malicious software.
- **Subverting the supply chain**: Attacking a company or vessel by compromising equipment, software or supporting services being delivered to the company or vessel.
- **Injection**: Injection attacks exploit a variety of vulnerabilities to directly insert malicious input into the code of a web application that will then be interpreted and executed by the server. Successful attacks may expose sensitive information, execute a DDoS attack, or compromise the entire system.
- **Malware**: Malicious software designed to access or damage a computer without the knowledge of the owner. There are various types of malwares, including trojans, ransomware, spyware, viruses, and worms. Usually, they are hidden in another (legitimate) software, so that the user installs it without knowing he also installs the malware. Very often, the legitimate software is a free software downloaded on the Internet.
- **Man in the Middle (MitM)**: An MitM attack involves intercepting communications between two endpoints. The attacker can eavesdrop on the communication, steal sensitive data, and impersonate each party participating in the communication.[29]
- **Water holing**: Establishing a fake website or compromising a genuine website to exploit unsuspecting visitors.
- **Typosquatting**: Also called URL hijacking or fake URL. Relies on mistakes such as typos made by internet users when inputting a website address into a web browser. Should a user accidentally enter an incorrect website address, they may be led to an alternative and often malicious website.

Cyberthreats can originate from a variety of **actors** with varying motivations and objectives. These include, but are not limited to:

- **Nation states**: Hostile countries’ cyber agencies or state-sponsored organizations can launch cyberattacks against other nations’ networks, companies, or institutions, aiming to interfere with communications, cause disorder, and inflict damage.

[29] Imperva: Cybersecurity threats. 2022. URL: www.imperva.com/learn/application-security/cyber-security-threats.

- **Terrorist groups**: Terrorists conduct cyberattacks aimed at destroying or abusing critical infrastructure, threaten national security, disrupt economies, and cause bodily harm to citizens.
- **Private individuals**: Individual hackers are usually motivated by financial gain, revenge, or political activity. Hackers often develop new tools and sometimes attack scenarios to advance their criminal ability and to improve their personal standing in the hacker community. They may also be opportunists seeking to cause mischief or detect vulnerabilities in complex systems for the thrill of the challenge.
- **Private hacker groups**: organized groups of hackers aim to break into computing systems for economic benefit. These groups use phishing, malware and all the techniques defined above for extortion, theft of private information, and online scams.
- **Script kiddie**: A relatively unskilled, usually juvenile individual who uses scripts or tools developed by others. The typical script kiddie uses existing and frequently well-known and easy-to-find techniques found on the Internet - often randomly and with little regard or perhaps even understanding of the potentially harmful consequences.
- **Companies**: Certain companies may attempt to gain information about their competitors through industrial espionage.
- **Malicious insiders/disgruntled employees**: An employee who has legitimate access to company assets and abuses their privileges to steal information or damage computing systems for economic gain or revenge. These could also be outsiders who have compromised a privileged account and are impersonating its owner.

To tackle such cyberthreats and combat incursion by cybercriminals of any kind, an Incident Response (IR) is generally implemented, and refers to the steps used to prepare for, detect, contain, and recover from a data breach and/or cyberattack.

Potential impacts

In inland navigation, the potential impact can be divided into two: impact **onboard a vessel**, on the one hand, and impacts on both physical and digital **infrastructure**, on the other.

Into the first of the above categories fall incidents arising from loss of control of a vessel navigation, propulsion or steering systems (with potential for collisions), loss of other control systems, such as cargo management systems (with potential for destabilisation or sinking of vessels), and incidents involving dangerous cargo (e.g. explosions, fires, leaks, flooding, and damage to cargo or vessels).

Into the second category fall incidents arising from loss of control of locks and sluices (e.g. potential flooding of areas surrounding waterways or rendering impassable sections of a waterway), moving bridges or similar infrastructure (with potential for collisions or other accidents), corruption or sabotage of data on which safe operations depend (e.g. navigational warnings with potential to cause collisions or accidents, information about dangerous cargos with potential to cause explosions, fires, leaks or damage to cargo or vessels).[30]

Measures to cope with cyber-risks in inland navigation

At EU level, Directive 2016/1148 concerning measures for a high common level of security of network and information systems across the Union (hereafter, “the NIS Directive”) provides a legal framework to boost the

[30] PIANC, *op.cit.*

overall level of cybersecurity in the EU. IWT is mentioned in relation to possible ‘operators of essential services’. The NIS Directive raises awareness in the EU by ensuring:

- **Member States' preparedness**: the NIS Directive requires Member States to be appropriately equipped, e.g. via a Computer Security Incident Response Team (CSIRT) and a competent national NIS authority.
- **Cooperation among Member States**: the NIS Directive requires Member States to set up a cooperation group to support and facilitate strategic cooperation and information exchange. They will also establish a CSIRT Network, to promote swift and effective operational cooperation on specific cybersecurity incidents and sharing information about risks.
- **A culture of security across sectors** which are vital for the economy and society at large, and moreover rely heavily on ICTs, such as energy, transport, and digital infrastructure. Businesses in these sectors identified by the Member States as ”operators of essential services” will have to take appropriate security measures and notify serious incidents to the relevant national authority. Also, key digital service providers (e.g. search engines, cloud computing services and online marketplaces) will have to comply with the security and notification requirements under the Directive.
    - For example, the IT systems of the French national waterway authority, Voies Navigables de France (VNF), are considered of vital national interest and so must comply with procedural and technical IT security rules established nationally to protect critical systems and strategic infrastructure.

Accordingly, EU and other data protection regulations make the implementation of mitigation measures against cyber-risks even more necessary and urgent.

Cybersecurity in inland waterway infrastructure

The cyber-risk to infrastructure in inland navigation is similar to that in other sectors dealing with strategic and critical infrastructure. Damages to these works would result in severe traffic disruptions, economic and environmental damages, and costly repairs. In inland navigation, the main threat concerns waterway infrastructure associated with the movement of large objects, such as docks or movable bridges, which could incur damages if operated improperly. This is also the case with equipment used for water level management, such as sluices and locks, which could lead to flooding if misused as a result of a cyberattack.

The risks associated with disruption are greatest in the case of IT systems involved with traffic planning where river authorities operate a vessel traffic service (VTS). For example, a VTS traffic control centre uses an array of technologies, including radar, GNSS, and custom geodata. Although such centres are professionally managed with cybersecurity in mind, the potential impact of an attack on such a facility points to a need for constant vigilance.

Furthermore, information is routinely exchanged between shipping companies and with the public authorities or between private companies along a logistics chain. Many of these exchanges fall within the River Information Services (RIS)[31] umbrella which can include safety critical information such as the location or schedule of dangerous cargo. The technology underpinning this information exchange is typically AIS (which has its own vulnerabilities) or via the internet (e.g. web portals). These vulnerabilities require specific and targeted solutions to improve safety without hindering efficiency.

Many vessels have on-board networks (e.g. wheelhouse systems) which allow:

- to communicate with machinery control systems (e.g. steering);
- instruments like AIS, GPS and ECDIS to interact;

[31] River Information Services (RIS) is the concept whereby information services support traffic and transport management in inland navigation, including interfaces with other modes of transport.

- ECDIS to update itself via the internet;
- or the crew to transfer information from proprietary cargo systems to internet-enabled terminals to make statutory reports to public authorities.

Once such unauthorised access to a shipboard network is obtained, attackers could well be able to interact with everything to which it is connected. Critical systems are therefore often protected or even isolated from the public internet by a firewall or an air gap. But there may well be an operational need to transmit information or data across these defences. A USB stick or another removable storage device may be used for these purposes. This, again, offers an opportunity to spread computer viruses or Trojan horses within the abovementioned systems.

Third parties – including vendors, service providers, independent consultants, contractors, and partners – often need access to on-board and shore-based IT networks in order to conduct essential updates and maintenance. Controlling this access is cited by fleet operators as a security challenge. Mitigation against unauthorized intrusion during third-party connection to on-board networks includes tightly controlling access by use of a virtual private network which the vessel master can terminate if an intrusion or an anomaly is detected.

Finally, RIS frequently rely on web services. Databases can be disrupted, corrupted, or deleted. One example is introducing statements through applications which do not prevent such statement injection. This could include safety-critical information such as statutory reporting of hazardous cargo or Notices to Skippers. All systems may incorporate so-called ‘distributed devices’ such as barcode scanners, wireless control boxes, or smartphones running specialised apps. These should not be forgotten in considering overall system security.

Cybersecurity in inland ports

As the world continues to grow more interconnected and more reliant on digital services, cybersecurity attacks are only increasing. Multiple ports (mostly seaports) have been victims of cyberattacks in the past few years, demonstrating this sector is not an exception to the rule.

In June 2017, the APM terminal in Rotterdam’s Maasvlakte harbor basin (Maersk’s flagship terminal) was struck by a ransomware virus. The Rotterdam port, widely known as a “smart port” with automated navigation systems aboard ships and connected containers, was heavily crippled by a virus, losing days of operational time. Cranes were out of action and container processing fell idle. The impacts of this cyber-attack were felt throughout the port and shipping environments, confirming the already widely known fact that cyber threats are no longer confined to purely IT dependent sectors. Indeed, as ports like Rotterdam’s grow increasingly connected, digitalized, and dependent on advanced IT systems, they also become more exposed to cyber-attacks of the like. The Rotterdam cyber-attack is a notable example of the threats facing ports today, but examples are becoming more and more numerous and spanning all kinds of critical industrial sectors.

Addressing such threats raises the clear need for comprehension and mitigation of cybersecurity risks in the inland port environment. The CESNI/TI Working Group is currently developing the “Best Practice Guide: Cybersecurity for Inland Ports”[32]. In this context, cybersecurity must be understood as improving security in cyberspace. This includes protection against intentional damage, for example from hacking, but also against unintentional failure, for example arising from a software glitch or a human error in operating an IT system.

The “Best Practice Guide: Cybersecurity for Inland Ports” will comprise

- a presentation of the inland port context with a full survey of the inland port digital assets, or elements that could be vulnerable to cyberattacks,

[32] CESNI: Best Practice Guide - Cybersecurity for Inland Ports. (Publication expected in 2023)

- a threat taxonomy: threat actors to the ports, types of cybersecurity threats, and the potential impacts these threats can have on the inland port if exploited by actors,
- three case studies on different attack scenarios determined through interviews with relevant inland port stakeholders and
- specific mitigation measures against the risks mentioned above are proposed. These measures are organized into three sub-sections:
    - organization policies and procedures,
    - information technology/operational technology policies and
    - technical security measures.
- A method to self-assess its maturity level in Cybersecurity and choose the most relevant mitigation measures to put in place locally.

From a broader point of view, the European Union Agency for Cybersecurity (ENISA) released the 2020 Threat Landscape report[33] reiterating cyber-attacks are becoming more sophisticated, widespread and undetected than ever before. This report highlighted several aspects of note on proliferating cyber-attacks, reaffirming the need for a comprehensive understanding of cybersecurity issues at stake in environments such as maritime ports identified as critical infrastructures by EU Directive 2005/65/EC.

[33] European Union Agency for Cybersecurity (ENISA). ENISA Threat Landscape 2020. URL: https://www.enisa.europa.eu/news/enisa-news/enisa-threat-landscape-2020

5 Inland waterways infrastructure

There are two main elements in waterway systems, these are the vessels and the infrastructure. Vessels are the means of transport. Infrastructure, like waterways, locks, bridges, ports are to guarantee a sound navigation and execution of relevant transport operations. Vessels navigating on inland waterways are also impacted by the external environment such as water levels, discharge, wind, ice or waves. Furthermore, rules and regulations provide framework to the skippers and crew onboard, specifying for example the types of manoeuvres that should be taken in situations where there is a risk of collision.

Smart vessels (in the report addressed also as autonomous and remotely controlled) are vessels that use automated on-board systems, onboard sensors and external data to optimise their key operations, whether of navigational character, including the remote navigation, or operations linked to management of fuel consumption, power management or maintenance.

Research, developments and experiments regarding automation of navigational tasks, remote control of inland vessels or autonomous navigation is ongoing. The novel products, advanced sensors and positioning technologies to be deployed on board vessels are already on the market. They primarily focus is on assisting the skipper in navigation operations, supporting in decision-making, mitigating the effects of poor visibility, and eliminating blind spots (e.g. due to hull). These products aim at making sailing safer, more sustainable, more comfortable or more efficient. Combining data from multiple onboard sensors creates a complete digital picture of the environment around a vessel. Such enhanced situational awareness enables safer manoeuvring in ports, effective navigation on waterways, or identification of potentially hazardous targets. Situational awareness is a critical building block on the pathway to a greater vessel autonomy.

On the other hand, with increased amount of data from onboard sensors or external systems, vessel operations (will) face the major challenge of increased complexity and also introduce new danger to the operations: *information overload problem*. The crew members receive a large volume of messages so that (s)he can easily overlook important ones. The data on a vessel comes from many sources, and in different formats. *Data integration*, therefore, is becoming vital for safe operation of autonomous and remotely controlled vessels. It combines this data (fusion, cleansing, and validation) and provides a unified view. Another major challenge is then the *presentation and user interaction* with the offered data. An easy and intuitive data visualisation and interaction for onboard crew and also for onshore control centres, support teams or other experts is essential.

However, the degree of digitalisation onboard of many inland vessels in Europe is still relatively low. Often the onboard systems are still standalone, data comes from different scattered sources and via various communication channels (AIS, VHF, internet) and is not integrated in the wheelhouse (echo sounders, cargo tonnage measurements or water levels from external system integration into navigation assistance solutions).

In addition to the urgently needed increase of digitalisation onboard inland vessels (integration of sensors, data and systems), another precondition for the uptake of smart vessels on European waterways is a reliable, safe, efficient and smart waterway network and also adjustments to the regulatory framework.

Few recent developments (like Seafar[34]) focus on remotely controlled vessels. The remote-controlled (semi-autonomous) navigation is expected to have less requirements toward infrastructure and, from a traffic controller point of view, is currently not seen as very different compared to conventional vessels. The interviewees, addressed in the course of elaboration of this report, expect (full) automation on busy routes, including ports, only in the long term, while remote-controlled navigation can be expected in the short to medium term, at least in busy areas.

In the following chapters, the report examines in detail what is currently happening and what is still needed in the future (data, information, framework conditions or even infrastructural or organisational adjustments) for the uptake of smart shipping on European waterways.

[34] Seafar Remote Navigation. URL: https://seafar.eu.

5.1 Activities to be impacted by smart shipping

When discussing smart shipping, the existing guidelines of classification societies related to automation in the (maritime) sector and other smart shipping literature distinguish certain vessel related (shipping) operations. The requirements addressed in this chapter are consolidated around the following shipping operation areas:

1. Navigation

   The goal of the Navigating Automation System (NAS) is to be able to navigate a ship safely and efficiently along a predefined voyage plan considering of traffic and weather conditions [Bureau Veritas[35]]. It deals with matters related to:

   a. Voyage planning, including route planning – chapter 5.2
   b. Navigation on the rivers, canals or in ports – chapter 5.3
   c. Passing locks and bridges (approach, waiting and passage) – chapter 5.4
   d. Mooring, anchoring and docking manoeuvre – chapter 5.5
   e. Situational awareness (environmental perception) – chapter 5.6

2. Communication network and system

   The goal of the communication network and system is to be available to transfer data externally (ship to Remote control Centre - RCC, ship to shore, ship to ship) and internally, without compromising their integrity [Bureau Veritas]. It is expected that the number of vessels being automated to automation level 4 (Annex 1: CCNR - Definition of levels of automation in inland navigation) will increase on all waterways. This will lead to a more mixed use of the waterway by automated and less automated vessels. It is however also expected that the human will remain as a backup in the years coming. Therefore, both *voice and digital communication* will need to be still considered in the design of the systems. The details are described in the chapter 5.7 Communication system and network & connectivity.

3. Other shipping operations - <u>out of scope</u>

   There are other <u>shipping operations</u> that are necessary to be addressed when discussing automation and digitalisation in the inland navigation and (inland and sea) ports. However, as explained in the chapter 2 Scope of the report, this report does not look at the automation of vessels, digital freight solutions etc. as such, but focuses on the implications of such digitalisation and automation developments on inland waterways infrastructure and ports infrastructure. Therefore, detailed investigations into requirements, gaps and benefits related to the following (shipping) operations and the impact of automation and digitalisation of these operations on the waterway infrastructure and ports will <u>not</u> be covered in this report:

   - Machinery system (vessels only): *the goal of the machinery automation system is to ensure that safety in all sailing conditions, including manoeuvring is equivalent to that of a ship having machinery spaces manned.* [Bureau Veritas]
   - Cargo & passenger related operations: *The goal of the cargo and passenger management automation system is to ensure that cargo does not compromise the safety of the ship or not degrade environment as well as to ensure the safety of passengers during a voyage.* [Bureau Veritas]
   - *Electronic reporting of vessels towards authorities*. Vessel needs to comply with the basic reporting requirements set in the existing legislation. Reporting requirements remain independently on the level of vessel autonomy. The vessel operators will need to make sure to comply with these obligations.
     As for reporting the cargo and vessel related data, a <u>uniform communication standard</u> was developed to make electronic reporting possible (ERI). Once voyage, cargo and vessel related data are received by the (port) authorities this data shall be exchanged between the different authorities seamlessly without interaction of the skipper.

[35] Bureau Veritas. Guidelines for Autonomous Shipping. Guidance Note. Oct 2019.

The overview of requirements and gaps in the following chapters provides a summary of the results of various studies, projects and stakeholder discussions addressing requirements of smart shipping in relation to the inland waterway infrastructure.

Outcome of workshops conducted with stakeholders and system developers as part of the PIANC Working Group activities, the DIWA Masterplan project [DIWA, p.28] or PLATINA3 did not result in clear and specific parameters such as “the accuracy of AIS data should be X cm”.

Few shortcomings on the way to autonomous navigation were identified dealing with object detection, collision avoidance, dynamic positioning[36] (i.e. a virtual anchor, where the ship maintains its position), data quality and some more. The required data accuracy or correctness depends on the purpose for which the data is needed. Accuracy needs to be much higher for mooring or entering the lock than for other applications, for example. Data about the water levels and weather conditions needs to be more accurate around locks and bridges than on a broad, straight waterway section. These issues, and also missing regulatory and legal adaptation such as permissions to navigate with less crew, hinder the pioneers in the sector to go fully autonomous.

[36] Dynamic Positioning (DP) is a vessel capability provided via an integration of a variety of individual systems and functions*. A computer control system automatically maintains a vessel's position and heading by using her own propellers and thrusters. URL: www.nautinst.org/resource-library/technical-library.html.

5.2 Voyage planning, including route planning

The voyage plan describes full voyage from departure to arrival destination, including all stop-overs, the amount and type of the cargo (to be) loaded and the time schedule. The voyage plan can be defined and updated at any time (prior and during sailing) by the onboard crew or by a remote operator. The voyage plan (and its updates) is done based on environmental conditions, (expected) traffic conditions on route and require often manual input based on the personal experience and information collected from various scattered (electronic) sources.

Commercial *electronic voyage planning solutions* are available and are used by vessel operators. Particular attention is paid to the planning of vessel's maximum cargo load, which depends primarily on the available water levels or bridge clearances. These solutions can also incorporate other features, such as route management, stowage calculations or fuel saving algorithms, depending on the individual supplier. However, still some vessel operators do not use the electronic voyage planning (acc. to DINA[37] Study carried out in 2017 less than 25% of vessels).

The *route planning* requires information about waterway conditions, water levels, bridge clearances and weather forecasts, infrastructure operation schedules as well as information about fairway restrictions in the planned sailing area[38]. On route, the coordination is required between a vessel and infrastructure like locks, bridges, terminals, whenever vessel requires passage or services. Currently, the ETA and RTA exchange is done through involvement of operators (e.g. voice communication via VHF), thus human interaction and communication between skipper and infrastructure (lock, bridge, terminal…) operator.

Further to the route planning, *supplies* like fuel, water, lubricants, waste disposal or other needs are to be planned. Activities to prepare a vessel for its voyage such as bunkering, waste disposal, and maintenance and repair are currently carried out by the onboard crew. Bunkering (refuelling) in particular requires highly specialised skill and safety precautions. On the other hand, engine rooms can already be monitored remotely, which reduces crew involvement.

Last but not least, compliance with *reporting* formalities is part of the voyage and route planning activities. Reporting formalities such as provision of voyage and cargo information to the responsible authorities are often done through VHF. With further automation, more reporting will be done electronically. For this reason, the responsible authorities set up own reporting systems (single points of entry). Such examples are eRIBa in Belgium[40], IVS Next in the Netherlands or recently developed single point of reporting for the Danube countries, CEERIS system[39]. On the market there are also various reporting software solutions installed onboard vessels and compatible with the reporting platforms of authorities[40]. The *standardised ERI messages*, integral part of River Information Services, are used. Electronic reporting facilitates data exchange between vessels and traffic centres compared with reporting by radio telephony or in writing. In recent years, European countries have been gradually introducing *mandatory electronic reporting*. Thus, for example on the Rhine, the electronic reporting obligation, previously applicable only to convoys and vessels carrying containers on board, was recently extended to other types of inland vessel such as those carrying dangerous cargo, longer than 110m, cabin vessels, etc.[41] In Flanders (Belgium), from March 2021, electronic reporting is mandatory for ships transporting dangerous goods.

This report does not deal with activities related to stockpiling, bunkering, waste disposal, maintenance and repairs, i.e. activities related to the vessel's internal processes.

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[37] L.M. Punter, W.J. Hofman (TNO). Digital Inland Waterway Area. Towards a Digital Inland Waterway Area and Digital Multimodal Nodes. ISBN 978-92-79-76485-1. European Union, 2017

[38] Fairway and traffic related messages shall be available in a standardised and machine-readable Notices to Skippers.

[39] CEERIS. Central & Eastern European Reporting Information System. URL: https://ceeris.eu.

[40] For example, eRIBa (a smart communication platform for the exchange of digital reporting information between the inland shipping operator and the waterway authorities in Flanders and on the Western Scheldt) lists an overview of the software suppliers compatible with eRIBa. URL: https://eriba-platform.be/en/#software-suppliers. Accessed: June 2022.

[41] CCNR: Electronic reporting (ERI). URL: www.ccr-zkr.org/12040800-en.html. Accessed: June 2022

Future State

Future (fully) autonomous and remote-controlled vessels will use voyage planning systems that automatically determine optimal route trajectories, taking into account definable constraints such as voyage time optimisation, fuel emissions reduction, or other configurable settings. For this purpose, the latest updates of navigation charts and other nautical information necessary for the intended voyage will be available together with accurate, complete and real-time information on navigational restrictions (both permanent and temporary), water levels, bridge clearances, and weather and traffic (both actual information and forecasts).

Single point of access for data and information

The EuRIS portal[42] will provide information services for reliable voyage planning to improve the operations of skippers, terminals and ports. EuRIS gathers relevant RIS information from the national data sources to provide optimised fairway, infrastructure and traffic-related information services in a single point of access for the users, thus enabling reliable voyage and route planning (among others) on a pan-European level. Port and waterway authorities will be able to communicate with vessels, be informed about their voyage plans and regulate the traffic.

With increased automation and digitalisation, the need for the data and information services grows. *The availability of the high-quality (accurate and complete) data* is essential prerequisite for operation of (fully) autonomous and remotely controlled vessel. Possibility to access and retrieve data via machine-readable interfaces and from single point of access provides an added value necessary for voyage and route plans and enables their updates at any time.

- *Availability of static and dynamic information about infrastructure,* such as data on *waterway network, dimensions, (virtual) buoys, sailing speed (maximum speed), bridges, locks and their operating times, IENC* [DIWA, p.23] with 3D bathymetric charts (at least) for critical bottlenecks, and other navigational limitations and hazards.
- *Availability of real time traffic information and forecasts*. According to the indication of vessel operators [DINA, p.45], the current lack of real-time information on traffic conditions limits the possibilities for adaptations of voyage plans. The availability and sharing the real time traffic information by the competent authorities, such as delays at locks or bridges, allocation of berths, updates of terminal calls or other traffic conditions, will enable a real-time updates of voyage plans. The readiness to share voyage plans in digital way and also their updates along the voyage considering the real-time traffic, ETAs/RTAs is, on the other hand, a precondition for provision of the real-time traffic information by the competent authority.
- *Information about critical sections and critical infrastructure objects*. Prior to voyage planning and loading of autonomous vessels, information on actual bridge clearances (and forecasts) is needed for a safe passage of critical bridges. The lowest value determines the possible air draught. The least fairway depth (also considering water level forecasts) determines vessel's maximum cargo load.

Voyage route planning and update

A remote-controlled or (fully) autonomous vessel will be capable managing a predefined voyage plan and updating it in real-time if relevant, navigating according to the predefined voyage plan and avoid collisions with obstacles coming from the traffic or unexpected objects.

- *Route planning (track, speed)* will be updated automatically at regular intervals (medium term) reflecting time losses/gains or to reflect planning and scheduling of locks/bridges passage or terminal operations.

[42] Developed in RIS COMEX project. URL: www.riscomex.eu

Short term updates can be made for immediate assessment of emerging traffic conditions, port approaches and/or external communications which require an unforeseen manoeuvre.

- *Ability to notify deviation from the planned course*. Depending on degree of automation, the crew (if onboard) or remote operators will be notified each time when the vessel deviates from the planned course (pre-programmed), sending alerts if the deviation is outside set margins.

Collaborative (cooperative) coordination

Currently, the waterway manager does not have access to the full voyage plan of a vessel, which is limiting its possibility to accurately predict congestion. Future *collaborative (cooperative) coordination* with intentions shared between vessels and with the traffic manager allows for further optimisation of voyage and route planning[43]. It allows vessels to coordinate and adjust their voyage details to avoid congestion and use resources efficiently. It also allows vessels to choose alternate routes if it becomes too busy or obstructed due to accidents, traffic congestions or other limitations.

[43] The interviews have shown that Rijkswaterstaat has performed an experiment with commercial parties that offer track pilot software (currently about 600-800 vessels of the Rhine fleet have some kind of track pilot system in use) concerning "intention sharing". Intentions from one vessel were made known electronically and displayed on the mapping software of another vessel. This way, the skipper could take this information into account when making manoeuvres. The motivation for this is enhanced safety.

5.3 Navigation on the rivers, canals or in ports

Navigation refers to tasks performed from a vessel's departure to its arrival at the destination, while interacting with the environment to avoid collision, grounding, or other hazards. *Unlike road vehicles whose operations are generally governed by well-structured and universal roads, the vessels are expected to follow region-specific unstructured spaces where lanes are not well defined. Furthermore, inland areas are characterised by many diversified constructions such as locks and bridges, and the limits of the river canal. Inland vessels are supposed to navigate in restricted and congested waterways, shallow waters, and sharp river bends, enter and leave locks, and pass under bridges. All these features make the fluvial environment more complex than other environments*[44].

Many conventional vessels (crew onboard) are already fitted with sensors and systems, such as radars, ECDIS, AIS and instruments showing own vessel's condition. Sensors already assist the skipper in navigational tasks, and some of these tasks are even being replaced by automatic systems. Sensors help the skipper to obtain information on situational awareness. Combining this with information the skipper receives through own senses, such as sight, hearing and vessel movements, the skipper gets a complete situational awareness. On conventional vessels, decision making and control are still performed by the skipper and crew.

During the voyage, reporting the vessel's position is key information to be exchanged between the vessel and the competent authority. Along waterways where AIS infrastructure is available, the position of vessels is automatically transmitted via AIS messages, whereas GNSS with the correction data is the source. A vessel equipped with an AIS transponder sends static (e.g. ship number, call sign, name), dynamic (e.g. position, speed, course) and voyage-related (e.g. draught loaded, destination, estimated time of arrival) data. All vessels equipped with transponders, as well as Inland AIS base stations on the shore, can see the transmitting vessel which is within reach on the display of the transponder or on a computer with Inland ECDIS software. Hereby, skippers are provided with an accurate overview of live traffic within the surrounding area of their vessel.

Further information about the destination(s) and cargo onboard is reported via VHF, in writing or electronically. Electronic reporting is becoming common practice as more and more regions and countries make electronic reporting mandatory. (See chapter 5.2 Voyage planning, including route planning for more details).

Where present, inland Vessel Traffic Services – VTS[45] (local traffic management) are part of River Information Services. VTS belongs to the group of traffic management services with the emphasis on information service and traffic organisation[46]. VTS (operator) guides skippers through the area, offers traffic related information, provides traffic management and incident management. The example of the common interaction between the skipper and VTS can be generalised as follows: *"Skippers know they are entering a VTS area (it is 'known knowledge'), and check in with the VTS operators via VHF link. The skippers make their destination and desired route clear. This is used by the VTS operators to generate a forecast for that route and to check if the forecast is being interfered with by other forecasts from other vessels. If yes, this will be announced to the skippers. If necessary, the VTS operators also give prescribed instructions to avoid accidents. The responsibility for the sailing behaviour remains with the skipper."*[47]

In the port areas themselves, the information flows are similar to sailing in a VTS area. Where available, the port authority offers skippers traffic information and traffic management. Besides traffic monitoring and management, ports also focus on their logistics function: cargo handling, (un-)loading activities, etc. This chapter does not look into details of ports' processes (more on port can be found in the chapter 6 Ports).

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[44] Wided Hammedi. Smart River: Towards Efficient Cooperative Autonomous Inland Navigation. Artificial Intelligence [cs.AI]. Université Bourgogne Franche-Comté, 2022. English. NNT: 2022UBFCK001

[45] Inland Vessel Traffic Services (VTS) is a service implemented by a Competent Authority, designed to improve the safety efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area. (Source: RIS-Guidelines 2007/414/EC) URL: https://risdefinitions.org/files/RISrelatedDefinitionsPartII.pdf

[46] PIANC InCom Permanent WG 125. Guidelines and recommendations for River Information Services. Aug 2019. URL: www.pianc.org/publications/inland-navigation-commission/wg125-1 alternatively https://izw.baw.de/publikationen/pianc/0/InCom-WG-125-1.pdf (content overview). Accessed: June 2022

[47] Summary is consolidated based on interviews carried out within PLATINA3.

Future State

In the future, an autonomous navigation system will be able to dynamically plan and adjust the optimal route in real time to avoid collisions, groundings, or other hazards. Decisions will be done (depending on autonomy level, with or without human intervention) based on accurate situational awareness achieved through fusion of data from onboard sensors combined with real-time information from infrastructure providers about environmental conditions and (expected) traffic conditions on the route. Future developments will also enable greater connectivity between vessels and their environment, allowing cooperation and coordination between vessels themselves and between vessels and infrastructure, for example by sharing short-term intentions of vessels, planned trajectories (thus optimising traffic management) or real-time information about the state of the fairway.

Digital map support (semi-static digital information on network)

Inland Electronic Navigational Charts (IENC) in line with the Inland ECDIS standards are available for most European waterways and are regularly updated. IENCs contain digital static information like layout of waterway, junctions, waterway/fairway width. Future requirements to meet the needs of smart shipping:

- Increasing the accuracy, completeness (e.g. bridge contour lines in ECDIS map [PIANC & DIWA, p.28]) and reliability requirements for the services (e.g. production of IENCs)
- Regular update of the bIENC overlay (bathymetric riverbed information), visualised as depth contour lines, based on riverbed characteristics
- Supplementary up-to-date collaborative depth data measured and shared by vessels[48], along with bIENC overlay, allowing for selection of a safe path for navigating along the route

Dynamic digital information on network

Further to the semi-static digital map information, the accurate, complete and up-to-date dynamic digital information about the network will be required with the increased automation, connectivity and cooperation in inland shipping. This includes that dynamic waterway signs and marking and dynamic information about incidents, weather warnings, or water level and discharge information.

- *Provision of meteorological information*. Contains information on actual weather and predictions, weather warnings, actual and predicted ice situation, expected restrictions and ice breaking measures (such information is made available via standardised NtS messages and interfaces).
- *Provision of water level related information*. Contains information on (actual/forecast) water levels, discharge, etc. (NtS Standardised message)
- *Provision of information on obstructions and limitations*. Contains information on temporary obstructions, long-term and permanent obstructions. (NtS Standardised message)
- *Provision of information on navigation rules and regulations.* Contains information on aids to navigation (malfunction, short term changes), traffic signs, traffic rules and regulations, waterway signs and markings,

[48] One such solutions is CoVadem (www.covadem.com) available on a commercial basis in the Rhine region. CoVadem provides real time data on depths and bridge clearances. Based on the cooperative depth information, CoVadem produces and provides bIENCs (high detailed ENCs with depth contours) that can be used with the Inland ECDIS. The project PROMINENT (www.prominent-iwt.eu) looked in the similar solution building on a cooperative sharing of depth and other vessel operation related data in the Danube region.

Information about critical sections and critical infrastructure objects

In order to enable safe navigation, especially on free-flowing rivers, and to avoid groundings or collisions with bridges, the provision of accurate, complete and up-to-date information, in particular shallow sections (including least fairway depth) or bridge clearance, is essential.

- *Actual bridge clearance and forecasts.* Data and information about the bridge clearance are of importance to avoid the collision.
  - *Additional sensors for (the most) critical objects*, like bridges, could be beneficial (not only) for autonomous sailing. Therefore, at least critical bridges could be equipped with additional sensors[49] (e.g. for actual bridge clearance) or calculations based on the corresponding water levels relevant for bridges. If bridge clearance is not provided by a waterway authority (or is done in different ways or compared to different reference water levels), there is a strong need to verify the bridge clearance by other means. This can be done by for example sharing the information or helping the interpretation by e.g. installing reflectors on bridges [DIWA. p.24]
  - *Data collected from onboard sensors* to be verified with data received from on-shore bridge height measurements systems (data redundancy). In case of vessel trains investigated in the NOVIMAR project, such data fusion enables the leader vessel to take the necessary measures, e.g. thanks to warning to avoid possible collision with the bridge.
- *Provision of information on shallow sections (critical sections),* including (actual/predictions) water levels for critical sections, (actual/predictions) least sounded depth information, depth profile of the fairway in the critical section.

Traffic information from infrastructure operators

As shipboard automation increases, so does the need for external information to enable safe navigation and also to provide redundancy. Redundancy is an important fall-back scenario for any operation (critical) system; not to be dependent on single system, sensor, or input parameter. RIS corridor management and information is and will be a useful information platform to collect and distribute such infrastructure and traffic related information, and to create redundancy to verify data gathered by onboard sensors[50]. *Central access point* for provision of real-time information about infrastructure and traffic shall offer harmonised quality level across borders and also standardised interfaces.

The particular challenge is the quality of data, thus provision of accurate, complete and up-to-date data.

- *Continuous traffic situation overview and density*. Vessels navigating with a high level of autonomy require additional information for their decision-making process (and for speed, fuel consumption optimisation)
  - comprehensive and forward-looking overview of the traffic situation, like encountering traffic, times required for lock/bridge → e.g. a reliable traffic image via dense of AIS base stations network,
  - buoy positions transmitted by AIS to support dynamic determination of fairway boundaries for manoeuvring operations → e.g. via network of (AIS) Aids to Navigation (AtoNs),
  - traffic restrictions such as one-way traffic → e.g. signals communicated by AIS, or via NtS.

[49] Germany: There are more than 1.300 bridges over the German inland waterways. It is impossible for the waterway authority to capture the actual bridge clearance and send this information on-board of a vessel. Therefore, vessel would need an on-board bridge height measurement system. Source (slightly updated to improve readability): DIWA SuAc 2.1 Smart Shipping. May 2022.

[50] DIWA Masterplan summarised the services out of RIS environment necessary for smart shipping[50] (details to each to be found in the Annex)

- *Passage durations and waiting times at locks and bridges*. Based on position in relation to a network model, current travel times for waterway sections can be queried to optimise voyage planning or vessel speed.
- *Provision of recommended tracks*. Assistance systems require guiding lines which they can follow along their route. For an automatic guidance mode, recommended guiding lines could be provided by authorities based on AIS traffic analysis for selected river sections as supplementary service. These guiding lines classified in upstream and downstream and could consider vessel classifications and actual water depths.
- *Boundary lines of manoeuvring corridor*. The execution of autonomous manoeuvring could in case of assistance systems require the determination of fairway boundaries to delimit the fairway width and depth available for manoeuvring. In the view of changing water levels and varying vessel draughts these boundary lines must be considered as dynamic information. Once corridors are required for autonomous manoeuvring, waterway authorities might offer to implement related corridor marking services.
- *Obstacles detection*. Incidents and other (temporary) limitations in the fairway will change the fairway layout, which require the vessel (depending on autonomy level) or skipper to interpret real-time changes, such as e.g. narrowing of fairway with the help of e.g. temporary virtual (digital) buoys.

Precise navigational manoeuvres

- *High accuracy positioning*. When the situation demands precise manoeuvres, relying on GNSS (Global Navigation Satellite System) alone is not enough. Alternative (or redundant) reliable positioning technologies become a necessity. Smart sensors technologies could assist operations in improving safety, provide precise position, situational awareness, and hazard detection in crowded inland navigation environment.
- *Increased onboard sensors (as redundancy)*. Smart sensors installed on the vessel, like advanced laser, LiDAR, short-range high-resolution radar, and (night vision) camera technologies provide both local position information (where the vessel is relative to its surroundings) as well as situational awareness (what is around the close vicinity of the vessel). They provide digital vision in conditions where humans are literally blind (night, fog, etc.), for vessels passing locks or movable bridges, entering (busy) ports, performing autodocking, or sailing the urban areas where the GNSS signal can get lost.

5.4 Passing locks and bridges (approach, waiting and passage)

The Detailed Future Vision to Support the Development of Automated Shipping in the CCNR states that *"The systems developed within the framework of automated navigation must take into account available and existing infrastructure (Goal 17)".* With this regard *"The Delegations have stressed that they do not intend to significantly modify the existing inland waterway infrastructure (locks in particular) to allow automated vessels to navigate."*[51]

During the voyage, a vessel interacts with locks, movable bridges and passes them. At present, communication when planning passage, but also when passing locks or movable bridges, is almost exclusively via VHF. In addition to VHF communication, infrastructure managers know that vessels are approaching a specific lock or bridge, either through position information received from a vessel via AIS or through other systems such as IVS Next in the Netherlands, which is based on vessel reports[52]. Since ship information is in the system and information is linked and exchanged between locks, bridges and traffic posts, navigation is smooth, transport and cargo are on schedule.

Considering the above statement from the *"Detailed Vision of the Future..."* improvements in digital infrastructure, communication technologies and data availability are primarily considered to support, with possible minor changes to the existing physical infrastructure. It is expected that improvements in communication networks, novel onboard sensors, artificial intelligence or new intelligent scenarios and systems for the passage of a lock or bridge will be looked into in the future along with the type and form of information needed.

In addition, the existing operational tasks of lock and bridge operators are expected to change in the future and remote operations are expected. This chapter, however, does not deal with the automation and remote operation of locks or bridges themselves.

Future State

Planning and scheduling of lock or bridge passage

The scheduling of the lock and bridge passages influences the safety and also economic efficiency of inland vessels. The coordination is required between a vessel and locks or movable bridges whenever vessel requires passage. Currently, this is done through involvement of operators, thus human interaction and communication between skipper and infrastructure operator. The increased automation, and improved connectivity between vessels and their surrounding (vessel and infrastructure) provide new challenges and opportunities to this scenario.

- Through increased sensorics and automation, vessel will communicate its status to the lock or bridge (like ETA, schedule, speed, etc.) and request a passage slot. In future, there will be an ETA negotiation process, where the vessel provides an ETA considering also the actual traffic situation in a corridor, and the lock responds with an RTA (requested time of arrival)[53].
- Further automation of processes, assisting the vessel and infrastructure operators in decision making, enables *automatic (slot) planning* of lock/bridge passage. The RTA will be communicated to a vessel and the sailing speed will be adjusted automatically. If needed, reservation of waiting quays, based on the ETA and quay availability is expected to be also automated.
- At the level of full autonomy, lock/bridge decisions are expected to be made automatically, while considering *plans of other vessels* (connectivity & cooperation) in the vicinity and requesting the passage of the same lock/bridge.

[51] CCNR: Detaillierte Zukunftsvision zur Unterstützung der Entwicklung der automatisierten Schifffahrt in der ZKR. [p.20] March 2022. URL: www.ccr-zkr.org/12050000-de.html

[52] IVS Next is the Shipping Information and Tracking System intended for all vessels using the Dutch main waterways, primarily used for inland navigation. By means of the system, a skipper registers his ship and cargo data once. After registration at an IVS post, the relevant data remains available along the entire shipping route. IVS Next obtains its information from registration systems such as BICS. URL: www.rijkswaterstaat.nl/zakelijk/verkeersmanagement/scheepvaart/scheepvaartverkeersbegeleiding/ivs-next. Accessed: July 2022

[53] In the Netherlands, automated RTA messages can be made available when vessel approaches the lock. Other examples are: while waiting to enter or when preparing to leave the lock, the automated "gates open, green line" signals can be transmitted [DIWA, p.23].

Lock or bridge passage

The lock passage is a complex manoeuvre requiring high concertation from skipper, adjusting rudder, speed, bow thrusters. Some locks provide little space for manoeuvring because vessels are built to fit locks on their voyage. Further, the skipper has poor visibility with vessel hull blocking the sight of the front of the vessel. Currently, to support a skipper, a crew member informs a skipper via radio about the space available. Furthermore, when being in the lock, the vessel needs to be securely attached to the lock whereas the process is supported by crew onboard. New challenges and opportunities to this scenario are expected for autonomous and remotely controlled vessels.

- *Lock Passage Assistance Systems*, which rely on data from onboard sensors and on-shore systems from infrastructure providers, are already available and are expected to be installed vessels in the future. Depending on the level of automation, the assistance system will support a skipper (either on board or in the Remote-Control Centre) or navigate fully autonomous vessel safely through the manoeuvre. A trigger for activation of Lock Passage Assistance System, such as entry or exit permission from the lock operator, may be received via e.g. VDES[54], Wi-Fi, or other communication system (chapter 5.7 Communication system and network), together with the lock status.
- *High accuracy positioning*. When approaching and in particular when passing a lock or a bridge, the position information is critical to avoid accidents, damage on infrastructure and vessels. Currently, the position of vessels is transmitted via AIS messages, whereas GNSS with the correction data is the source. The lower standalone accuracy[55] is not sufficient for precise navigational manoeuvres and challenges of, in particular, of lock passage. Errors shall be eliminated from the location data to achieve high accuracy positioning making use of novel technologies, like for example PPP (Precise Point Positioning), RTK (Real Time Kinematic) and more recently their hybridisation, PPP-RTK, which was further developed to achieve this.
- *Increased onboard sensors*. In certain critical situations (high lock chambers or under bridges) the position available via satellites (GNSS) gets lost. After signal lost, it can take a longer time to restore sufficient positional accuracy. Therefore, redundancy via increased onboard sensors and on-shore digital infrastructure is needed to compensate this loss. This may be done with short-range onboard sensing technologies, like short-range radar, LiDAR, or cameras, helping to determine the vessel position in relation to detected objects (locks, vessels in the lock, etc.). These solutions support entering or exiting lock chambers with centimetre accuracy, even without a known global position.
- *Securing vessel in the lock chamber*. Further research is required on “if and how to safely secure (fully) autonomous vessels during locking process”, which are sailing with limited or without crew onboard. Some approaches can be *securing a vessel by using fenders, digital beacons in the lock that support 3D positioning of a vessel* [PIANC, p.30], or dynamic vessel positioning[56] (known from maritime transport). See as well 5.5 Mooring, anchoring and docking manoeuvre.

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[54] VDES (VHF Data Exchange System) includes existing functionalities of AIS. It offers higher capacity and true global two-way data connectivity for the ship bridge. This way the VDES is expected to allow for a broad range of new e-Navigation services and can foster the emergence of (unmanned) autonomous vessels in the inland navigation. Examples of use indicated for maritime sector range from transmission of ice maps (current or predictions provided in close-to-real-time, sensor data from critical machinery reported regularly, smart buoys to report environmental measurements incl. remote control of such buoys). Many more solutions and offerings, most of which do not exist today, will be enabled by VDES [Moltsen, L., Pielmeier, S. (Sternula. Connecting the Oceans): Introduction to VDES. VHF Data Exchange System. Sep 2019]. VDES can offer more robust, secure, reliable and efficient service with relatively simple transition for vessels, a VDES technology (currently) requires only a change of transponder, with no need to replace the antenna or ECDIS URL: https://info.alen.space/advantages-of-vdes-vs-ais-in-maritime-satellite-communications. Accessed: May 2022.

[55] DGNSS has an accuracy of 0.5-1m. In the project SciPPPer, the accuracy of 5-10cm was tested with the use of PPP-RTK. Source: SciPPPer Project.

[56] Dynamic Positioning (DP) is a vessel capability provided via an integration of a variety of individual systems and functions. A computer control system automatically maintains a vessel's position and heading by using her own propellers and thrusters. URL: www.nautinst.org/resource-library/technical-library.html

5.5 Mooring, anchoring and docking manoeuvre

Public mooring places provide important infrastructural services for commercial shipping by serving general purposes such as compliance to resting times, crew changes, going ashore (supplies, medical visits, leisure activities), conducting repairs, or in case of emergencies. Waiting quay are used for vessels destined for lock, bridge or lift passage or waiting to enter ports for (un)loading activities. Berths in ports and at terminals are used for cargo (un)loading.

The *information about berths* (including dimensions, vessel types allowed, extra facilities such as car drop-off) and also their real-time availability is essential for route planning and especially during the voyage. In some cases, such information is already provided by infrastructure managers. Example can be the BLIS system in the Netherlands[57]. This system, however, does not offer berth reservation. The *assignment of a berth, waiting quay or mooring place* is currently coordinated through involvement of operators, i.e. human interaction and communication between skipper and operator. Online *berth reservation* is considered a service in some countries, and it will be implemented as one of the features of the new EuRIS portal in the near future.

The *docking manoeuvre* is performed by the skipper, who is assisted by the crew. Docking is considered a complex, high-risk process in which a vessel must follow (port) rules, avoid static and dynamic obstacles, reach the desired berth, and maintain its position while waiting to be moored.

This chapter does not address the services that may be offered at the mooring infrastructure (shore-side electricity, waste disposal, access bridges for cars, etc.), nor the requirements for such services when used by (fully) autonomous or remote-controlled vessels.

In the report the term “mooring place” is interchangeable with the term “berth”.

Future state

Semi-static and dynamic digital information on network

Digitalisation and automation require sufficient information about network. For mooring and anchoring, PIANC report summarises information from infrastructure that needs to be fed into the smart shipping solutions as follows: *Dimensions of berth place; Availability of several (automated) berthing systems and facilities; Position of bollards, Allowable force on bollards; Bollards equipment; Anchoring places; Anchoring allowed/prohibited; Planning of other vessels already moored or to be expected; Docking / mooring / anchoring place allocation*. (see as well Annex 3: Information from the Infrastructure (PIANC WG 210).

Planning and scheduling of mooring and anchoring

The berth is usually allocated based on expected arrival time (ETA), size of the vessel, cargo etc. In the future, it is and will be possible to book the mooring place digitally based on the voyage plan (see 5.2 Voyage planning, including route planning) or on demand during the voyage.

With higher autonomy and digitalisation, time-slot reservation of waiting quays (at locks, bridges, lifts), mooring places and other berths locations is expected to be automated based on the ETA (in negotiation process). Through increased connectivity and cooperation, decisions about mooring, anchoring locations are expected to be made automatically, considering as well plans of other vessels in the vicinity.

- *Increased onboard sensors*. With increased number of sensors, the vessel can constantly communicate its exact status to relevant infrastructure operator, including information on expected arrival time (ETA), voyage plan and specifics about the vessel and cargo onboard. Based on this input, optimal timeslots, which are conveyed back to the vessel, can be reserved.

[57] URL: www.ccr-zkr.org/files/documents/workshops/wrshp081118/13_Weekhout_03.pdf

- *Digital solutions offered by infrastructure operators*. With increasing digitalisation and automation, RIS systems and other ICT solutions such as port community systems (will) offer the reservation of berths and mooring places, based on the shared voyage plans of (fully) autonomous vessels, exact status of vessels and quay availability, whereas the exchange is expected to be also automated. Some corresponding (standardised) interfaces already exist and will be increasingly needed to ensure the real-time data/information exchange.

Docking manoeuvre

Autonomous docking is a vital part of achieving vessel autonomy, being it for (fully) autonomous or remote-controlled vessel.

- *Increased onboard sensors*. Through deployment of sensor technologies, the vessel's behaviour can be accurately measured so that semi-automated manoeuvres can be performed safely and efficiently. The improved accuracy and visibility help the skipper to moor a vessel, minimising or even fully eliminating damages of quays or vessels. In the future, devices that support the safe docking of a smart vessel (e.g. pressure sensors, radar, …) shall be part of the vessel's design. The docking process will be thus monitored by sensors to ensure that there are no obstacles to safe operations. See 5.6 Situational awareness.
- *Docking assistance systems*. Autonomous vessels could benefit from developments in docking and dock locking systems. Automated docking and dock locking systems could be both vessel- and shore-side[58]. Such systems can enable mooring of vessels without crew. See as well *Infrastructural adaptations (Automated Docking Systems)* below.

Infrastructural adaptations (Automated Docking Systems)

The berths, quays, lock walls and other mooring locations are not usually equipped to allow automated mooring with onboard devices. To replace the mooring task, two options may be considered: first, assistance by a shore-based personnel/steward for a mooring/locking manoeuvre, or second, to use an automatic mooring system.[59]

For a fully automated and unmanned vessel (Level 5), also infrastructure may require adjustments. There are several products already on the market, mainly deployed for the maritime sector[60]. They can be on-shore and/or on-board, using e.g. magnetic or vacuum mooring technology, fender systems at the docking stations. Some designs of automated docking stations keep the vessel at a safe distance from the wall. Bollards are supported by automated docking stations that are built inside the lock walls, at terminals, at waiting points which can be dynamically adjusted for various water depth or height according to the loading status of the vessel and could be used in all-weather circumstances.

However, not all navigational tasks will and should be replaced at once, nor does that seem feasible at this stage. This includes the docking procedures as well. Commercial inland vessels dock significantly often, at locks, movable bridges, loading, for (un)loading, suppling rations and change of crew. Replacing these activities by on-shore ad hoc crews is an option, however, it would be an organisational challenge, in particular in times when also operations of locks and movable bridges changes from the operator present at the location to remotely controlled infrastructure.

[58] NOVIMAR. URL: https://novimar.eu/areas-of-interest/waterway-infrastructure-operations

[59] *"Depending on the level of automation, there may be a need for stewards on locks to assist less crewed vessels. With highest level of automation and no crew on board, there will be need for more infrastructural solutions that facilitate automated mooring at bridges, locks, (un)-loading quays, and 24/7 operation of locks and bridges."* Economische effecten smart shipping, Painteia&Ecorys, 31-05-2021

[60] E.g. Auto-mooring system with vacuum pads to pull the side of the vessel towards the quay's fenders (e.g. in Port of Helsinki). Automated docking station able to power-charge a vessel (Wärtsilä). Grip-based auto-mooring with a vertical guiding system (MacGregor).

Concerning automation in docking assistance systems, few open questions are listed below[61]:

- *Tailor-fitting*. Maritime design has to be tailor-fitted for inland navigation.
- *Standardisation*. Focusing on one type of mooring technology and making it a standard to adjust the entire infrastructure, increases the opportunity costs. When the implementation is finally there, other and better systems could be available, thus chosen technology becomes already obsolete. In case of rapidly changing development in the world of robotics and automation, it will be also difficult to keep pace with realistic standards and requirements.
- *Liability*. Even if rather expensive automated devices are available on-shore, the issue of liability could be the reason not to use it. If something goes wrong, the berth operator could become responsible and not the crew on-board.

[61] Verberght, Edwin: Innovative Inland Navigation research (INN-IN) in assignment of CCNR. 2019.

5.6 Situational awareness

For autonomous vessels navigating in complex environments such as inland rivers, efficient detection of nearby and small vessels and other obstacles is essential to ensure safe navigation. There is a variety of obstacles like river edges, other vessels, fishermen, swimmers, people by the riverside, or infrastructure such as locks and bridges.

Currently, the position of vessels is transmitted via AIS[62], whereas GNSS with the correction data is the source of position information. All vessels equipped with AIS transponders and also on-shore AIS base stations can see the transmitting vessels within their range. Thus, skippers, remote vessel operators, or autonomous vessels themselves have an overview of live traffic in the vessel's vicinity. However, AIS-based vessel detection has its shortcomings (lower standalone accuracy, not all "swimming" objects are equipped with AIS). GNSS has problems in dense and urban areas, where position signal is often lost [Source: SEAFAR]. Similarly, in certain critical situations (high lock chambers, under bridges), the position available through satellites (GNSS) gets also lost [Source: Project SmartWaterways]. In addition, vessels that are exempt from AIS transponder requirement, such as non-commercial craft, recreation boats, yachts, and other small craft, cannot be unambiguously identified by traffic monitoring systems that rely on AIS.

Future state

Obstacle (target/object) detection and avoidance

Reliable external perception of vessel's surroundings is a pre-requisite for (fully) automated and remotely-controlled vessels to perform necessary functions safely. This is becoming a reality thanks to the increasing development and evolution of embedded technologies, integrated sensors and machine visions. For the purpose of autonomous navigation, the vessels shall be able to detect not only other vessels but as well other objects on rivers and canals. Increased amount of (onboard) devices (e.g. sensors) contribute to accurate situational awareness by sensing the vessel's environment and its own operational status.

- Due to shortcomings of AIS, additional solutions for *better and automatic target detection* shall be offered (as add-on to AIS), in particular in critical sections, like intricate junctions, narrow (one-way) fairway sections, or waterways and canals without AIS coverage.
- Various projects look into obstacle (target/object) detection and avoidance. *SHREC* project analysed of multiple camera streams using image processing methods with text recognition to identify passing vessels, especially non-conventional vessels, correctly[63]. *Roboat* project in Amsterdam maps the surrounding environment by automatic object recognition[64]. SmartWaterways project combines data from onboard sensors like laser, LiDAR, (short-range) radar technology, cameras and other smart environmental sensors (GNSS, wind sensors, echosounder etc.).
- *Presentation of situational awareness (environment perception).* When navigation is performed from a remote location, the sensor data should be presented to the remote vessel operators in such a way that (s)he can obtain an equivalent situational awareness. This can be done through (i) image transmission which for sailing on rivers does not need to be continuous or of high definition, but shall be sufficient to perceive all relevant surrounding conditions. In case depth and distances are required for navigational purposes the two-dimensional images shall be compensated with e.g. distance sensors and merging a graphical presentation of this into the image presentation. Another option can be (ii) virtual models which use different sensor technologies, fuse the sensor data and represent this data in the form of a virtual model.

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[62] A vessel equipped with an AIS transponder sends static (e.g. ship number, call sign, name), dynamic (e.g. position, speed, course) and voyage-related (e.g. draught loaded, destination, estimated time of arrival) data.

[63] Marta Wlodarczyk-Sielicka and Dawid Polap. "Automatic Classification Using Machine Learning for Non-Conventional Vessels on Inland Waters". In: Sensors 19.14 (2019). issn: 1424-8220. doi: 10.3390/s19143051. URL: www.mdpi.com/1424-8220/19/14/3051.

[64] The primary source of information comes from a lidar sensor but robots are also equipped with cameras, GPS and a digital compass. Roboat's onboard computer combines and processes all data and runs the Roboat software, so it can successfully complete its mission plan.

5.7 Communication system and network & connectivity

Automation requires reliable communication facilities, digital data exchange, and a cyber-security framework in order to provide the trust needed to remove people from processes. The future communication must be digitally coded, sent automatically as well as being machine-readable. Vessels must communicate with each other and with the infrastructure. Connectivity is therefore the key to increase the efficiency of smart shipping with automated, connected and cooperative vessels. However, adding connectivity introduces some key requirements such as latency, vessels privacy protection, (shared) data security protection.

Nowadays, traditional vessel communication system relies on AIS to provide low data services such as position, course, heading, destination, tonnage, speed, etc. Besides AIS, radio communication (voice over VHF), takes place between vessels, and with competent authorities. The reporting is done electronically or where no obligation, the reports are submitted even on paper. The mobile communication (4G/LTE/5G), WiFi (where available) are used to transmit data to the shore. However, regional differences in mobile or broadband coverage can make communication hard. This is especially the case when a constant connection between the vessel and an operator is required (in case of remote control for example). Usage of new communication technologies, like Starlink (high-speed, low-latency broadband internet) may be considered in the future.

Future state

Communication system and network

The digital infrastructure should enable secure communication with (fully) automated and remotely-controlled vessels. A distinction in the use of the communication system or network shall be made based on criticality (time, safety relevance, …) with mostly short messages with low latency requirements and the content which may require high bandwidth to function properly.

- *Positioning information and systems*. Currently, the position of vessels is transmitted via AIS messages, whereas GNSS with the correction data is the source. The lower standalone accuracy GNSS is not sufficient for precise navigational manoeuvres of (fully) autonomous and remotely controlled vessels. Project SciPPPer[65] tested elimination of errors from the location data to achieve high accuracy positioning making use of novel technologies such as PPP (Precise Point Positioning), RTK (Real Time Kinematic) and more recently their hybridisation, PPP-RTK, which was further developed to achieve this.
- *Automated Identification System communication infrastructure*. Additional burdens on AIS should be avoided. The “next generation of AIS”, VHF Data Exchange System (VDES)[66] can give more capacity, new frequencies and optimised reception security. VDES is closely connected to e-navigation developments in IMO and IALA.
- *Mobile communication network*. Vessels may also communicate over larger distances to send and receive more information. Some communication is likely to rely on mobile network infrastructure. Generally, it is assumed that the latest technology network (5G) will be required. Stakeholders require provision of a good communication infrastructure (4G/5G). In the short to mid-term, 5G in mobile networks does not appear to be essential to kick-start autonomous sailing. What is more important is *reliable mobile communication with extensive geographic coverage* and *sufficient capacity along waterways*. 5G will improve communication networks in the future and pave the way for further development of autonomous sailing.
- *Local communication networks at critical infrastructure locations*. Communication infrastructure and technology needs to be improved (e.g. broadband is not everywhere in place). *In areas with a poor mobile*

[65] Project SciPPPer (SChleusenassistenzsystem basierend auf PPP und VDES für die BinnenschifffahRt). URL: http://scippper.de
[66] VDES is expected to take into account the requirement for more data exchange capabilities. VDES will include the functionality of AIS as well as the VHF data exchange system in the maritime mobile VHF-band and provide extra channels for Application Specific Messages (ASM)

network coverage (due to mountains or inside locks) there could be a loss of 4G and 5G communication (with remote-control centre). A local network may need to be set-up by the authority. [PIANC, p.31]

Standardisation and harmonisation

- *Communication standards for vessel-to-vessel and vessel-to-shore communication*. Currently, there are no agreed communication standards applicable in inland navigation (in comparison with C-ITS on the road). The *input* received for DIWA report indicated that inland navigation stakeholders expects authorities to take the lead in formulating these communications standards for vessel-to-vessel and vessel-to-shore communication [DIWA, p.23 & 24].

5.8 Inland Waterways Infrastructure - Conclusions

5.8.1 Inland waterways infrastructure: Benefits

Infrastructure is an investment in the economic, social and the environmental prosperity of the region and people living there. Infrastructure, thus also waterways and ports addressed in this report, is backbone of an economy, facilitating trade, triggering economic opportunities, and is a necessity for substantiated and sustainable long-term growth.

Increased digitalisations and automation in inland navigation creates new opportunities for more efficient, more sustainable, and safe operations with reduced human involvement. When discussing the smart shipping, and related digitalisation and automation in the inland navigation sector, the benefits are measured mainly in terms of their contribution to the sector and to the society.

The table below summarises some of the benefits which could be gained by the further developments towards autonomous navigation and smart shipping. In line with previous considerations it should be noted that the benefits presented in the table are mainly obtained by the vessel owners and operators and not so much on the infrastructure side. The infrastructure plays more of a facilitating role in the process towards smart shipping.

Domain	Benefits of digitalisation and automation in inland navigation
Economic sustainability[67]	• Keeping operational expenses low, in particular crew-related costs • Offering a (partial) solution to the shortage of crew • Reduced energy (fuel) consumption also through on-board energy efficiency management • Increased efficiency resulting from the omission of accommodation section • More efficient propulsion systems • Thanks to automation of shipping processes, a vessel could be used for a longer period of the day. In case of fully autonomous vessels, even 24/7 operation may be possible depending on the type of a vessel and operations.
Organisation of transportation and processes *(Examples)*	• Cost reduction (simplified collaboration among involved organisations, exchange of information, etc.) • Streamlining the operations (more efficient, reliable processes, improved resource planning, information flow through the transport route/chain) • Shorter time delays (shorter waiting times for vessels, faster processing at ports/terminals) • Advanced shore-based assistance services through improved connectivity
Optimised traffic management	• In case of fully autonomous navigation, the planned route trajectory and intentions of the vessel will be known and can be adapted to the trajectory of other vessels [PIANC, p. 29], resulting in a better and more predictable real-time traffic overview and forecasts, or improved navigational traffic safety due to more and easier surveillance, monitoring and control.
Social acceptance / sustainability (Safety, etc.)	• Focus shift from navigational assistance systems for enhancing situational awareness of skippers (human operators as humans are at the core of collision avoidance) towards the automated vessels. • If automated technology reduces or eliminates human errors, as is generally expected, then benefits for inland waterway transport safety may be substantial. (Incidents in Inland Waterway Transport (IWT) change and are experienced to increase in severity & cost of claims. Human factors account for about 70 -80% of all incidents, according to databases and literature[68].)

[67] The other side of the economic aspects linked to increased digitalisation and automation are added (capital) costs due to required redundancy in machinery and also energy production, or the need for more reliable and operator independent technical systems.

[68] Intergo. Human factors root causes of accidents in inland navigation: HMI and wheelhouse design. Oct 2021. URL: https://www.inlandwaterwaytransport.eu/wp-content/uploads/Intergo_Report-phase-2a_final.pdf

	• Increased safety due to moving trivial operational tasks from crew to onboard automation (decreasing fatigue) • Partially unmanned wheelhouses and engine rooms, thus more flexible working hours for the onboard crew (as a result of intermediate steps of enhanced vessel system automation) • Enabling shore-based and family friendly monitoring jobs for nautical personnel ashore
Technologies *(Examples)*	• New emerging technologies (new business opportunities, business transformation, etc.) • Processing of large amount of data (leading to increase of competitiveness …) • Increased high-tech business activity and boost for the high-tech industry supplying necessary shore and onboard equipment facilitating smart shipping (e.g. sensors, ICT solutions, …)
Ecological sustainability / drivers	• Enabling new and innovative ways to reduce overall fuel consumption • Reduction of exhaust gas emissions and air pollution caused by inland navigation o by reducing the fuel consumption: it is expected that an (fully) autonomous vessels can be operated more efficiently with more advanced automatic energy management systems and improved routing and navigation[69] o through exploiting synergies between the electric (propulsion) solutions for vessels (expanding the range of viable energy sources beyond tradition) and automation: electrical backbone (foundation for propulsion system of vessels), integrated with automation and control systems, will contribute to transformation towards smart shipping (and from merely connected operations to collaborative and automated operations) • Less congestion on roads (through modal shift towards IWT)

5.8.2 Inland waterways infrastructure: requirements, gaps and recommendations

The degree of digitalisation of vessels is (still) relatively low. There are different reasons. The investment costs into automation are high, "of-the-shelf systems" are missing on the market because of differences between systems installed and used onboard of inland vessels. The skippers, crew, vessel operators lack knowledge, skills and capacity (time to explore digitalisation and automation opportunities). There are unclarities in certain legal aspects, like sailing with less or no crew, liabilities, etc.

Despite of this, the digitalisation and automation developments in the inland navigation sector will proceed. Developments already exist in a limited scope addressing automation of (un-)loading, automated mooring, maintenance, cargo planning, loading schemes, or various other assistance systems are under development (lock assistance, track assistance), etc.

The table below provides an overview of requirements, gaps and recommendations focusing merely on the infrastructure and actors active in this field. These requirements, gaps and recommendations go hand in hand with the increased automation and digitalisation in inland navigation.

[69] Project MUNIN. URL: www.unmanned-ship.org/munin. Accessed: June 2022

Topic	DIWA	Future requirements and needs	Gap / Justification	Recommendation
Reliability of data provided by authorities and waterway users	2.1 (11)	*Machine-readable data exchange (system to system communication)* Need for increased system-to-system communication, thus exchange of data and information services in the *machine-readable* way (instead of voice communication).	Machine-readable information is essential for autonomous and remotely controlled vessels. This will also be the requirement for the voice communication commonly used today. In the years coming, human still stays in the loop. However, the role will slowly move from decision and action to monitoring of systems. As there will be still a mixed traffic in the coming years, the rules for such a mixed co-existence of autonomous and conventional vessels and exchange of information need to be elaborated.	Further develop of communication standards, data sets to be exchanged and interfaces for sharing data in a machine-readable way. Elaborate rules on exchange of information between vessels and with the on-shore authorities for a mixed navigation situation (co-existence of autonomous and conventional vessels). Investigate and test novel technologies and solutions replacing the voice communication in the mixed navigation situation (co-existence of autonomous and conventional vessels).
	2.1 (1)	*Increased importance of data quality – authorities* The higher the level of automating is, the more important becomes the *data quality and correctness*. Need for a clarity on quality (metadata) of existing data.	The level of automation highly depends on the availability of quality and correct data. [Gap] There are various national/regional data and information sources ("silos") → currently being consolidated into one European platform for inland navigation = EuRIS	Increase the quality of the data by investing in quality of existing data rather than on sharing new types of data. Ensure the easy & user-friendly feedback loop from sector concerning the quality of data provided by authorities.
		Increased importance of data and its quality – vessels, waterway users & external sources Need for high quality (accurate, correct and complete) data from the vessels.	Data quality provided by the authorities depends also on the availability of accurate, correct and complete data received from external sources and as well from vessels sailing of inland waterways. The accuracy and reliability of the services depends for a substantial part on the willingness of vessel operators and logistic service providers to share their data and information in addition to the different fairway authorities. [Gap] Slow progress of digitalisation in the sector (vessels) [Gap] Willingness of sector to share data and information. [Gap] Lack of integration of data from onboard sensors and systems, and also data from external sources (e.g. water levels) into one in the system wheelhouse: Lot of systems are still stand alone (e.g. those for navigation tasks). Lot of sensors on vessels, such as echo sounder, cargo tonnage measurement, are not integrated, and skipper only has visual instruments near the steering wheel.	Increase awareness for digitalisation and automation in the inland navigation sector, in particular vessel operators Support digitalisation efforts of inland vessels (through financial support and other incentives, creation of favourable regulatory framework, …)

<table>
<tr><th>Topic</th><th>DIWA</th><th>Future requirements and needs</th><th>Gap / Justification</th><th>Recommendation</th></tr>
<tr><td></td><td></td><td>Data redundancy
Increased importance to <u>verify correctness of data</u> gathered by onboard sensors increases.</td><td>Data from waterway and traffic management authorities can play an important role here - first for verification of correctness of onboard data, in future enabler of further development of smart systems.</td><td></td></tr>
<tr><td></td><td>2.1 (12)</td><td>Data, formats and protocols standardisation and harmonisation
• Need for standardised data models (or at least a minimal agreed representation of actual situations, navigational data)
• Need for standardisation and harmonisation of data formats and communication protocols</td><td>The standardisation and harmonisation are required in order to:
• Enable higher levels of automation in dynamic environments between various operators and actors
• Enable exchange of data between systems, not losing the data due to incompatibilities
• Make sure the data exchange is possible throughout corridors and with other sectors</td><td>Continue the standardisation and harmonisation processes, which started with RIS, with requirements autonomous and remotely controlled navigation in mind</td></tr>
<tr><td></td><td></td><td>Single point of access for collection and provision of data
• Need for streamlining the data exchanges between authorities and waterway users.
• Need for real-time and forecasted fairway-, infrastructure-, traffic and transport information available from one place.
• Need for efficient and transparent electronic reporting procedures aiming to reduce administrative barriers and reporting burdens</td><td>[Gap] Currently, the static and dynamic infrastructure and traffic related data is available from various scattered (electronic) sources; national or regional river information or vessel traffic management systems. RIS COMEX developed EuRIS which shall become such single point of access for inland navigation stakeholders.</td><td>Continue development of EuRIS as the default digital information platform for IWT with respect to real-time and forecasted fairway-, infrastructure-, traffic and transport information, covering the entire European fairway network relevant for IWT (inland Waterway Transport).</td></tr>
<tr><td>Readiness of waterway network for automation</td><td>2.1 (3)</td><td>Readiness of waterway network for automation (classification)
Need for guidance for autonomous and remotely controlled vessels on <u>waterway network readiness</u> for autonomous navigation.

Clarity on the presence, availability and quality of services offered by fairway authorities
Since current levels of service differ per stretch of fairway, it is important that the services offered per location, including the (data) quality of these services are known to vessel operators.</td><td>[Gap] It is not clear for the sector which waterways (their sections) are (will be) ready to provide information and services essential for different levels of automation.
The classification of waterway network shall support the automated vessels to operate under more predictable environment.
Activities in road transport and ISAD (Infrastructure Support for Autonomous Driving) can provide insights into classification of infrastructure readiness for automation.</td><td>Research should be conducted regarding how the classification of waterways can be done providing the insight into the readiness (maturity) of European waterway network for automation</td></tr>
</table>

Topic	DIWA	Future requirements and needs	Gap / Justification	Recommendation
Communication, networks and systems & Connectivity		*High accuracy positioning* Need for high accuracy positioning information for precise navigational manoeuvres, including entering and exiting locks	Currently, the position information (AIS) based on GNSS with the correction data is used. [Gaps] Lower standalone accuracy of GNSS; lower GNSS position continuity in urban environments (cities, etc.) due to obstruction of the direct line-of-sight; lower GNSS position continuity at waterway infrastructure (locks, bridges, etc.).	Investigate, research and pilot deployment of novel technologies providing improved correction data. Project SciPPPer with testing PPP (Precise Point Positioning), RTK (Real Time Kinematic) and more recently their hybridisation, PPP-RTK) Investigate newer precise positioning solutions Investigate alternative solutions for critical infrastructure objects and urban areas
		Reliable and high-capacity radio communication systems for vessel-to-vessel (next generation AIS) Need to overcome the limitations of AIS (system for exchange of vessel identification and limited set of safety relevant navigational information).	[Gap] AIS was developed with safety in mind. However, current developments show its limitations: limited capacity, is not encrypted, can become saturated in areas with a high concentration of vessels, etc.	Look into the further standardisation and adaptation of VDES to the needs of inland navigation.
	2.1 (8)	*Reliable connection with sufficient bandwidth* Need for good and reliable communication infrastructure and connectivity along waterways with sufficient bandwidth to exchange information, in particular in critical section.	[Gap] Reliable mobile communication with sufficient capacity (4G/5G) is not available in all regions along the waterways. [Gap] Lack of local communication networks at critical infrastructure locations. Reliable (mobile) communication with extensive geographic coverage and sufficient capacity along waterways is essential for data and information provision and exchange. Mobile networks, especially 5G (5G smart modules) can act as redundant and back-up links for AIS / (future) VDES communications.	Primary focus on (critical) bottlenecks and infrastructure like bridges, locks, waterway section difficult to navigate due to high traffic of geographical conditions.
Cybersecurity		*Raising effective cybersecurity awareness* Need for improved awareness on cyber-threats, impacts of cybersecurity breaches, preparedness and mitigation measures	While digitalisation in inland navigation sector is progressing, the general awareness of the need for protection against cyberattacks is still lacking behind. Smaller operators are still hesitant to invest in protecting themselves and their fleet, many feel relatively secure from cyberattacks. They often lack the awareness and financial means to develop strategies, hire IT and cybersecurity specialists, set up own cyber units.	Create an awareness in inland navigation sector through e.g. information campaign or dedicated trainings for administrations, authorities and waterway users. Establish a coordination platform bringing the main inland navigation players together with cybersecurity experts *(this is an outcome of the 1st Cybersecurity workshop in Bonn, Sep 2019: CCNR who organised the workshop was asked to play central role in the cybersecurity domain in inland navigation)*

Topic	DIWA	Future requirements and needs	Gap / Justification	Recommendation
		Uniform cybersecurity standards for vessels and onshore (control) centres and practical guidance for inland navigation Need for minimum cybersecurity standards applicable in inland navigation and practical guidance suggesting suitable methods for deployment of appropriate measures to achieve level of cybersecurity requested by standards	Autonomous and remotely controlled vessels need to meet the highest requirements in terms of cyber threats and data privacy. *Example from maritime sector: IMO's Interim Guidelines on Maritime Cyber Risk Management and the Guidelines for Cyber Security Onboard Ships*	Elaboration of standards – what is required. For onboard as well as onshore systems. Elaboration of guidance – examples on how to proceed in application of cybersecurity measures. *(While standards may state what must achieved without too much regard to the methods used, guidance should address not only the outcome and applicable metrics but suggest suitable methods.)*
		Securing systems against cyber-attacks Need for securing the systems, both onboard and onshore systems, when it comes to cybersecurity. Network components, servers, or operator stations should be configured to reduce the likelihood and consequences of cyber security breaches.	The increased communication between the vessel and remote systems is bringing with it a concern about the cyber security for all related systems	Consider cybersecurity requirements in the design of digital and automation solutions for infrastructure and vessels (by applying e.g. multiple layers of mechanism, functions and barrier aiming at hindering, detecting and limiting the damage of security breach).
		Redundancy of systems, equipment, functions, data communication links All critical systems must also have their fallback systems. Data communication links must also have sufficient redundancy.	A partial or full redundancy are some solutions to improve the availability for critical systems such as communication infrastructure or machinery.	Application of "building-in redundancy" principle, both in design and deployment of critical systems. Integration of redundancy of critical systems principle into relevant standards.
		Cybersecurity consideration in new application areas Given the ever-increasing level of connectivity in areas like automated driving and applications relating to 5G, cybersecurity will continue to gain importance and should therefore always be taken into consideration in new application areas.	[Gap] Waterway users Lack of awareness and lack of resources to address threats (in particular in case of smaller vessel operators) [Other Gaps] Unpreparedness, Unknown threats, Lack of monitoring, Mobile / home / travel security (cyber security must be extended beyond the office (laptops, mobile phones…), Third Party / Vendor Risks (assessment of the security levels of these external parties), Internet of things (increased connectivity across devices and systems means that once isolated attack is a much more serious, People risk (create awareness/educate about risks and responses)	Application of cybersecurity requirements in the design of digital and automation solutions in all new emerging application areas. Raise awareness in the inland navigation sector Raise awareness at the competent authorities (NIP directive) Various preparatory steps, mitigation actions and responses to threats (see as well Gap/Justification or chapter 4. Cybersecurity)

Topic	DIWA	Future requirements and needs	Gap / Justification	Recommendation
Data privacy		*Compliance with the data privacy regulations* Need for clear regulation and interpretation of relevant data protection law, and guidance on deployment of the data privacy in inland shipping	The need for data will grows with increased digitalisation and automation, whereas some of these data may be privacy sensitive. The data owner should at least be able to determine who can see which information when, but standards for this are not yet in place. Autonomous vessels (will) require a vast amount of data to operate safely, e.g. position, direction of vessels, what other vehicles, landmarks, objects are nearby. Sensors, cameras, radars (sensor and image data) improve situational awareness. This technology may also capture images of people or events that occurred outside the vehicle. Location (e.g. AIS position data) or sailing route are crucial for the safe operation. These data sets, and various others in the future, if not treated properly, could pose privacy concerns.	Application of "privacy-by-design" principle, meaning "data protection through technology design (at the outset of data processing practices). Application of agreements on sharing certain kind of data. Sharing privacy related information should only be done with consent of the information owner. For all users it should be clear if data is provided for the use by others as well.
Regulatory and legal aspects *For completeness the overview of main regulatory and legal requirements and gaps is provided. The input is based on the PIANC WG 210 report and the CCNR Vision. This report <u>does not</u> elaborate the requirements and challenges in detail.*		*Non-ambiguous regulations which allow and facilitate (fully) autonomous and remotely controlled vessels* *Minimal crew requirements legislation* Need for a legal framework allowing navigation with less crew. *Technical requirements for inland vessels* Need for evaluation of technical requirements for inland vessels related to construction, fitting, equipment, etc on inland vessels must be evaluated (ES-TRIN). *Digitalised traffic rules* Need for non-ambiguous digitalised traffic rules to allow safe navigation (especially in mix traffic situations).	Experimenting with smart shipping products is possible based on (nationally issued) exemption from the valid legislation, whereas the rules for such exemption permit vary from country to country. [Gap] Current legislation, both on a National and European level does not take into account (fully/highly) automated vessels (e.g. it requires skipper onboard, does not allow crew reduction). [Gap] No clear liability in case of incidents/accidents with autonomous vessels or infrastructure that support shipping operations by autonomous vessels (e.g. docking, etc.) [Gap] Missing non-ambiguous digitalised traffic rules to allow safe navigation (especially in mix traffic situations) [Gap] No overall overview of legislations that will be impacted by deployment of autonomous vessels	Carry out regulatory scoping exercise to identify, analyse various legislative acts and assess how smart shipping (autonomous vessels) could be regulated (similar to the IMO scoping exercise[70]). Coordinate work with CESNI, in particular in case of crew, technical requirements for vessels, etc. Integrate the agreed rules into European and national legislations. Short-term: *CCNR works currently on development of a procedure for the approval of pilot projects derogating from the provisions of the CCNR.*

[70] URL: www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx

Topic	DIWA	Future requirements and needs	Gap / Justification	Recommendation
		Responsibilities and liabilities Need for more clarity concerning the responsibilities and liability issues in case of an accident when using smart shipping systems (interpreted as "accidents with vessels of higher levels of automations") *Communication* Communication between vessels and vessels and the authorities is an integrative part of some regulations and legally binding documents, which need to also be revised.		
Type of data, information, services		*Need for specific data, information and services* Details to be found in relation to the shipping operation in the chapters 5.2 – 5.7	Refer to chapters 5.2 – 5.7	Refer to chapters 5.2-5.7

Table 2: Inland waterways: Overview of requirements, gaps and recommendations

6 Ports

The focus of this chapter is attributed to potential tools and measures which support the further digitalisation & automation of port infrastructure, processes and operations in line with the objectives of the smart ports of the future, reflecting upon requirements, benefits and gaps from the user, infrastructure operator and policy makers perspective.

Digitalisation and automation hold great potential for making transport chains more efficient, flexible, agile and resilient. They open up the possibility for ports to meet the challenges of sustainability, globalisation, and urbanisation. Therefore, currently one of the essential directions of port development (valid for both inland and seaports) is digitalisation and IT systems implementation.

Port digitalisation is one of four key categories of port innovation. These innovations consist of:

- robotics - encompasses the integration of automated systems,
- process automation - is processes that minimize human involvement. For example, driverless trucks, drones, and crewless vessels,
- decision-making automation - is planning optimization, for example, automation of vehicle and equipment scheduling,
- **and digitalisation - is the use of technologies for all operations. Technologies include: IoT, Big Data, blockchain, 5G connections, Artificial Intelligence, wearable devices, unmanned aircraft systems, and other smart technology-based methods to improve performance and economic competitiveness.**

6.1 Assessing the digital maturity of ports

One of the first steps in the digitalization journey of ports is to determine the digitization and digitalisation level of the port's current activities/processes. Based on existing good practices, the digitalisation of ports is handled in a 5 step-approach. Level zero considers no digitization, all information is available and is being handled in analogue format. The starting point is digitalisation **level 1** (which considers that information is available in digital format), and is represented by the port authority as a closed system, followed by **level 2 port community** (digital interaction is enabled between all stakeholders in the port) and then moving one step higher by bringing the **hinterland into the process of digital interaction (level 3)**. The last step **(level 4) is to connect smart ports all over the world** to each other (forming one single world-wide port community).[2]

Figure 1: Digital & automation maturity levels © Port of Rotterdam

The above concept has proved to be very helpful in assessing at which level of digital development, for example, the Danube inland ports currently are. Following the DAPhNE[71] project, seventeen Danube Region (DR) ports took part in port sector survey, which was elaborated in the frame of the Danube Transnational Programme funded project **DIONYSUS**[72], and which assessed the ports digital maturity as well as their real digital needs. The majority of replies received were from inland ports, as well as from two combined (sea/river) ports:

- Many of the tasks related to port operations are not digitalized and provided in an outdated way (emails, spreadsheets, phone calls).
- Communication platforms among port stakeholders and private / public entities involved in port operation are missing in most of DR ports.
- Instant digitalized monitoring of ports is mostly reduced only to CCTV, with no other information (water pollution, ongoing loading/unloading etc.).
- Reported cyber-attack rate is quite low. Less than half of DR ports interviewed consider the currently used solutions as reliable.
- DR ports are interested to implement automated digital solutions for port operations, communication and monitoring of port assets.
- Invoicing and port statistics are identified as the most suitable and the most desirable for automation in the nearest future.
- Significant demand for a single (common) PCS solution for the DR ports was identified.

Therefore, it can be concluded that Danube Region ports are at digital maturity level 0 or 1 according to the concept presented above. Whereas it shall be noted that some terminal operators have their internal systems and e.g. in Hungary a Port Community System for all Hungarian Danube ports is in operation since Q2/2022 (KIR)[73].

On the Rhine, since 2012, 9 ports (Basel, Weil am Rhein, Mulhouse, Colmar/Neuf-Brisach, Strasbourg, Kehl, Karlsruhe, Ludwigshafen and Mannheim) have been engaging in creating, operating and managing the first digital inter-port platform of the Upper Rhine ports[74]. The platform allows the ports to optimise container transport on the Upper Rhine, as well as the transport of general cargo, bulk and river cruise traffic management. In the frame of the **RPIS 4.0 - smart community system for the Upper Rhine Ports** project, a follow-up of the projects “Upper Rhine, a connected corridor” and “Pilot implementation of an ICT Upper Rhine Traffic Information Platform”, new digital port services have been investigated and developed, whereas a feasibility study for the integration with rail transport services has been elaborated. Therefore, it can be concluded that the Upper Rhine ports are at digital maturity level 2-3.

In the lower Rhine region, the Dutch Inland Ports Association is also aware of the importance of digitisation in the inland ports and has incorporated it as the number one theme in its strategic agenda.[75] An extensive two-phased programme was launched and conducted in the period 2020-2021 on the digitisation of inland ports, which resulted in, among other things, a manual and guidelines for digitisation and also a Global Roadmap for Digitisation and Inland Ports.[76]

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[71] Project DAPhNE. Danube Ports Network. URL: www.interreg-danube.eu/daphne. Accessed: July 2022.

[72] Project DIONYSUS. Integrating Danube Region into Smart & Sustainable Multi-modal & Intermodal Transport Chains. URL: www.interreg-danube.eu/dionysus. Accessed: July 2022.

[73] Project KIR. Integrated port information system in Hungary. https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/2016-hu-tmc-0164-s. Accessed: July 2022.

[74] Upper Rhine Ports. A connected Corridor. URL: www.upper-rhine-ports.eu/en. Accessed: July 2022.

[75] Nederlandse Vereniging van Binnenhavens: The Strategic Agenda of the NVB from 2020 – 2025. URL https://havens.binnenvaart.nl/nvb-kennisbank/strategische-agenda. Accessed: July 2022.

[76] Nederlandse Vereniging van Binnenhavens: 'Digitalisation' category of the NVB Knowledge Base. URL: https://havens.binnenvaart.nl/nvb-kennisbank/digitalisering. Accessed: July 2022.

Seaports are forerunners in the digitalisation transformation/adoption trend. In Europe, several seaports such as Rotterdam, Amsterdam, Hamburg, Antwerp, Barcelona, Valencia, etc. have already built-up impressive experience in dealing with new technologies, in most cases for their container terminals, falling under maturity level 3.

The **PortForward of Rotterdam** includes software tools that enables port authorities to manage their port operations more efficiently and safely and reduce costs on the assets. The solution encourages collaboration and coordination between all port users, allowing for faster handling of ships, trains and inland vessels, which leads to a strengthening of the port's competitive position. PortForward additionally offers digital solutions for shippers, freight forwarders and traders who want to increase their insight and control of their logistic chains. Consider for example a smart route planner that displays all the transport options from the coast through to the hinterland.

The **Port of Antwerp Bruges** has centered its operational improvement plan on NxtPort, an "information sharing system." The goal for its use of NxtPort, which allows the port to share information with companies like BASF, MSC, Katoen Natie, DP World and PSA, is to become a self-sustaining data commercialization company that will gather, centralize, store, analyse and exchange data from a wide variety of logistic actors. Eventually, customs, governmental agencies, food quality control, and IT app developers will be able to access the information on the platform as well. The port also plans to monetize the data it is receiving from the system, which will help individual users reduce costs through better planning. Moreover, not only will this generate more income for the port, but it will also improve logistics, lower truck exhaust emissions, and reduce the number of containers in depots. The Port of Antwerp Bruges is also exploring the use of blockchain for container collection, which will allow "digital rights" to be transferred from one party to another, which means only one party can pick up the container, rather than anyone with a PIN number. This will reduce fraud by validating the container transfers.

The Spanish **Port of Valencia** has been named the smartest port in the Spanish port system, leading the ranking in categories such as environment. The port of Valencia has been trialling since 2018 Internet of Things (IoT) technology aimed at improving its operational efficiency. For example, truck fleets have been equipped with dedicated IoT devices, allowing for near real-time tracking of movement of vehicles in order to help the port authority predict and manage potential congestions, as well as to anticipate truck arrivals at the gates. The Port of Valencia installed black boxes on 200 cranes, straddle carriers, trucks and forklifts that collect a variety of data "such as their location or energy consumption, which could help terminal staff find ways to reduce idle time. The information from the black boxes is analysed in real time and shared with terminal staff to "identify operating bottlenecks and initiate appropriate action." The anticipated results of the black boxes include lowering operating costs by 10% by reducing equipment idle time and minimizing energy use. Additionally, this port installed a smart illumination system that only light up when vehicles come in the vicinity of the port, which has cut energy consumption by 80%.

The **Port of Barcelona** uses the PortIC telematic platform, which connects the entire Port Community. This smart platform ensures coordinated management of all the services provided in the Port's waters (pilots, tugs, mooring, provisioning, etc.); and the storm forecasting system developed jointly with the national authority Puertos del Estado. The port is also in the process of implementing a project to collect Radar and AIS (Automatic Identification System) signals from vessels passing through the Port in order to anticipate possible incidents. This is expected to increase the port's safety. The Ecocalculator[77], a tool in use at the Port of Barcelona, allows customers to quantify their cargo's environmental footprint and meet their environmental goals. Barcelona's Container Tracking Application allows the port and container owners to track the physical process of a container, from the moment the vessel arrives, when the container touches the ground, is processed by customs, leaves the terminal and other points.

The **Port of Hamburg** has conducted tests with 5G, the next-generation communication network in diverse applications. Sensors on port service vessels were installed to transmit movement and environmental data in real time across large areas of the port. In another test, the port linked traffic lights to the mobile network in order to control traffic remotely through the port, as well as improving safety and efficiency processes. A third trial allowed

[77] The Port de Barcelona Ecocalculator. URL: www.portdebarcelona.cat/en/web/port-dels-negocis/ecocalculadora. Accessed: July 2022

the port to access all the data it collects outside of existing networks, transmitting 3D data to an augmented reality application. The success of the trials led to more secure links between ports and logistics companies and provided the foundation for a more intelligent Internet of Things (IoT) supply chain.

The **Port of Amsterdam** first introduced its Digital Port Programme in 2017. By making data available using digital services, the port became more transparent for users and was able to handle vessels more quickly and intelligently. The port was also the first to create a test zone for aquatic drones and more recently trialled a new monitoring system to explore drone usage in its airspace.

Another practice in the field is represented by ports applying a **digital index (DIP)** to evaluate their digitalisation level. The index is usually based on selected factors groups' analysis, making reference to selected activities and parameters. In the article entitled "Ports Digitalisation Level Evaluation"[78], the following groups of factors have been distinguished:

- Scoring group 1 (SG1): navigation (v1); port surface (ports maps) (v2); ships location in port (v3); cargo type in ports, especially dangerous goods (v4).
- Scoring group 2 (SG2): people entering the port, according to ISPS code or terminals' technology requirements (v5); emergency procedures in port (v6); ETA and ATA of ships (v7); real (actual) depths in port (v8); legal documents valid in the port (e.g., port rules, navigational regulations, etc.) (v9); public procurement issues (v10); port annual reports (v11).
- Scoring group 3 (SG3): port statistical data (v12); port development programs (v13); port development projects (v14); port newsletters (v15); companies operating in port and their activities (v15); technology (v16); port promotion materials (e.g., video, audio) (v17).
- Scoring group 4 (SG4): port organization (v18); port administration working time (v19); additional services in port (v20); port dues and tariffs (v21), human factor (v22)

The above list is not exhaustive, and can be of course adjusted based on the specificities of each port.

6.2 Digital tools for each level of digitalisation

Level 0 – No digitization; documents are handled in paper based /analogue format; no computer is being used and no internet connection is available. Communication is supported by phone and fax.

According to the 2020 study[79] of Singaporean port management software firm, Innovez-One[80], the majority of the 4,900 sea & river ports in the world are not yet using digital technology for even the most basic processes; 80% of ports continue to rely on manual, legacy solutions such as whiteboards or spreadsheets to manage critical marine services such as towage, pilotage and mooring. The lack of digitalisation at most ports makes the last mile of a journey at sea a weak link in the global logistics chain, opening up risks of delays, late payments, increased fuel consumption and emissions, reduced revenues, and even safety concerns stemming from a lack of traceability, as mentioned by Innovez-One.

Level 1 – Port Authority/Administration/Port Development Company

Representing the starting point in the digital & automation maturity assessment, this level considers that there is no digital interaction or automation between the port authority/administration/port development company and the other port stakeholders. However, inside the port authority/administration/port development company, there

[78] Paulauskas, V.; Filina-Dawidowicz, L.; Paulauskas, D. Ports Digitalization Level Evaluation. Sensors 2021, 21, 6134. URL: https://doi.org/10.3390/s21186134

[79] https://www.innovez-one.com/80-of-ports-missing-out-on-the-benefits-of-digitalisation-creating-last-mile-risks/

[80] Innovez One (innovez-one.com)

are several digital & automation tools that are being used in order to manage own resources (such as HR, infrastructure, assets, etc.) and related internal processes (such as finance management, inventory & equipment management, purchase management, supplier management, IT, project management, etc.)

Shortly defined as **Port Management System,** this solution fully integrates people, capital, work, knowledge, information, commerce flows and supports core port operations, enhances operation control, lowers operating costs and improves port service quality and in the end customer satisfaction.

Another important system is the **Harbour Master System**. The safety of navigation for any vessel utilising the port and its approaches is the Harbour Master's primary concern. Harbour Masters regulate the manner in which vessels conduct their navigation in port (including also recreational boating - visiting yachts, tour boats operators, power boats, etc.). From port calls to determining the berthing of vessels, provision of pilotage and tugs, confirmation of mooring resources, liaison with stevedores on the ETA/ETD of the vessel to enable them to plan their resources for loading/discharge effectively, key loading/discharge plant and equipment availability and reliability, security requirements and liaison with other authorities (such as port state control, customs, veterinary agencies, health agencies, environmental agencies, local government and utilities) where necessary, all these are functionalities of a harbour master system.

Level 2 – Port Community

A port community brings together all port actors with a dedicated interest and involvement in a certain port activity. Starting from port authority/administration/PDC to terminal operators, shipping lines, shipping agents, forwarders, inland transport operators (road, rail, barge), stevedores, navigation authorities, customs, other authorities, financial and insurance companies and representatives of the civil society, the port community requires a solid platform built upon existing stakeholders' relationships which shall enable intelligent and secure information exchange.

Port Community System (PCS): According to the International Port Community Systems Association (IPCSA)[81], a PCS is an electronic platform which connects the multiple systems operated by a variety of organisations that make up a port community. It is a modular system with functionality designed to provide all the various players within a port community environment with the tools specific to them, thus delivering a tightly integrated system. Developed for port users by port users, a PCS in general provides a huge range of services and key features which can be summarised as follows:

- Easy, fast and efficient information exchange, re-use and centralisation, available 24/7/365
- Customs declarations
- Electronic handling of all information regarding import and export of containerised, general and bulk cargo
- Status information and control, tracking and tracing through the whole logistics chain
- Processing of dangerous goods
- Processing of maritime and other statistics

To this end, a PCS optimises, manages and automates smooth port and logistics processes through a single submission of data and by connecting transport and logistics chains, being acknowledged as the most advanced method for the exchange of information, interconnecting multiple information management systems within a single or national port community infrastructure.

Annex 2: Reference list PCS run in Europe presents an overview of leading European Port Community Systems, providing an important learning start to those port organisations looking forward to develop their own PCS.

[81] Port Community Systems – General – IPCSA International. URL: www.ipcsa.international/pcs

Level 3 – Integration of the Port Community with hinterland stakeholders

This level considers the integration of the port community system with several other digital platforms/systems being operated by third parties such as, for example, logistics service providers, transport operators, logistics centers/warehouses and other key stakeholders in the respective supply chains as well as infrastructure managers from other modes of transport, which shall enable fully transparent door-to-door logistics, making overall transport more efficient, predictable, sustainable and resilient.

Along with suitable infrastructure, the proper deployment of smart concepts and technologies can improve port-hinterland connections, allowing vehicle flow operational visibility and synchronisation. The coordination across individual transport and logistics operations in the port-hinterland interface can lead to efficient and reliable port logistic systems, mitigating risks and favouring the competitiveness of involved supply chains.

For example, the Port of Rotterdam has entered into a **digital logistics partnership** with the Lower Rhine Ports, making transportation and logistics operations more sustainable, as well as increase access to the North Rhine Westphalian hinterland.

Level 4 – Global connectivity and complete integration of all supply chains

The last level in the proposed methodology is represented by an overall integration of all supply chains, a global connectivity enabled by the concept of **network of trusted networks - global network of Smart Ports.** It is expected to be an informal network of independent Smart Ports, sharing real-time information concerning the maritime supply chain and fostering the development and implementation of innovations.

To this end, global supply chains competitiveness depends on the existence of effective and efficient port logistic systems. Local, national, regional or even global PCSs may be designed in such a way in order to enhance the overall PCS performance in both local and foreign trade activities. In any of the cases, a further standardization of interfaces and processes is an important prerequisite.

6.3 Digital transformation in relation to a port's function and management model

While digitalisation refers to enabling or improving processes by leveraging digital technologies and digitized data without changing or transforming them, as well as taking a process from a human-driven event or series of events to a software-driven one, digital transformation is business transformation enabled by digitalisation. The process of digital transformation implies new qualities. The acceleration of innovation speed enabled by the technological connection of people and objects, the enormous potential of data collection and analytics, sensors and the mobile accessibility are examples of aspects which need to be considered when talking about digital transformation. Digital transformation must remain linked to the objectives and strategies of the Port Authority/Administration, combining practices and techniques to generate new value proposals.

There are three main axes in which the developments carried out by Port Authorities are being framed for the digitalisation of the sector and for the application of new technologies in the logistics-port area:

- Digitalisation of systems, implementing new technologies in all port areas, allowing sustainable management of port operations and services, using for this purpose all the capacity and power offered by ICT.
- Deployment of integral technological platforms to standardize and integrate the different systems that are part of a port, to turn the port into a more efficient, innovative and oriented to user service using a Smart Port concept.
- Changes in logistic and transport parameters, including the elimination of intermediation and the improvement of modal exchange, in order to improve the competitiveness of transport chains based on automation and on robotization.

All related digitalisation concepts are shaped in relation to the real digitalisation needs of the ports, which are to a great extent influenced by the port's roles & functions, which are:

- Gateway (Port serves as logistics node for volumes generated in the hinterland including transit volumes to/from third countries transiting the country by land)
- Industrial (Port serves as an industrial (raw material processing) zone with required infrastructure where feedstock comes in and (semi) finished products go out)
- Transhipment (A port where cargo is transferred from one carrier to another or from one vessel of a carrier to another vessel of the same carrier without the cargo leaving the port.)

Another factor worth considering when talking about port digitalisation and digital transformation is making clear what the port's governance/ management model is and which are the derived roles & responsibilities, especially of the port authority/administration. From landlord, tool port to public port and full-private service ports, all have a wide variety of workflows that need to be planned, managed and invoiced. However, when it comes to investments in digital infrastructure, tools and applications as well as management during and post implementation, the governance model plays a decisive role.

6.4 Making smart port technologies a reality

Implementation of digital solutions is essential and allows ports and related industries to increase their efficiency and sustainability, decrease costs and performance time of selected operations, improve information flow and decision-making, reduce paper documents in operational processes, increase safety, decrease the negative impact of transport on the environment in ports and in port areas as well as enhance innovation.

6.4.1 Emerging technologies for overcoming operational challenges of ports

Within the wider transport and logistics sector, more and more companies are experimenting with a range of connectivity and data-enabled technologies. In a post-pandemic scenario, ports worldwide are facing several challenges like the peaks in freight traffic, rising pressure to comply with stricter environmental targets and complex supply chain operations. Emerging technologies are necessary instruments for ports to overcome these challenges and gain a competitive advantage over their peers.

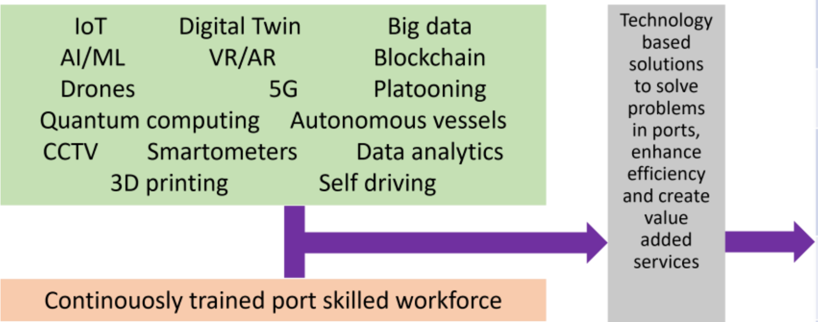
In aggregate, an example of such technologies forms the **Internet of Things (IoT)**, which represent a convergence between the physical and digital worlds, ultimately using data as a source of value. It is expected that in the near future, all objects in the port – such as vessels, cranes, trains, trucks, containers, weather stations, pilot vessels, etc. – will become increasingly smarter and will be able to communicate with each other in real time through the Internet of Things platforms. With its ability to digitize the delivery process with the aid of smart sensors, IoT can monitor the condition of port equipment, keep track of temperature, gas and humidity levels and enable radiofrequency identification of containers, monitor the use of physical assets.

Blockchain is the next big technology for the ports of the future. Being the preferred technology for data security, it can establish the provenance or origin of cargo, enabling port authorities to maintain traceability, transparency and accountability of their transactions.

Unlocking **big data** from port operations makes it easier to optimise usage of resources and infrastructure. For example, a typical crane operator works only one quarter of the time, remaining idle for the other three, waiting to get a container ready to load or unload. Increasing the number of trucks may not be a viable solution given the congestion it would cause. As such, big data analysis could synchronise movements, so that the crane operator works more time. For instance, signals related to crane position, status, and GPS position signals could sync movement of trucks and containers to reduce idling time. Also, cranes show different performance levels according to various factors such as skill of driver, workload, weather, container type and yard density. Understanding such patterns makes it possible to either find solutions to overcome the roadblocks, or sync operations to factor such limitations, ultimately enhancing productivity.[82]

6.4.2 Port digital solutions to fixing problems, enhancing efficiency and creating added value services

A digital port, where operations are made predictable and safe by the use of real-time data generated by different digital technologies complemented by skilled workforce, makes use of custom-made solutions targeting the needs and problems of its users (such as congestion, emissions, etc.), contributing to enhancing own operational efficiency and creating value added services, which translates into higher customer satisfaction and in the end higher returns. The following chart depicts the use of digital technologies integrated into dedicated digital solutions leading to viable solutions for a wide portfolio of port activities in the field of energy, safety & security, environment, etc.



Operations for ports and port users	
Operations	Operations management (PMIS, TOS, VTS, Cooperative Intelligent Transport Systems, etc.)
Trade	Trade management (PCS, Single Windows, etc.)
Environment	Environmental management system, Emissions and pollution control, waste management, water management, etc.
Energy	Energy consumption, Production and use of renewables, energy management, etc.
Safety & Security	Safety & security management systems, integrated monitoring and optimization systems, cybersecurity systems, etc.
Other	Business management (EAI, ERP, HRMS, etc.) Office management (CMS, email, etc.)

Figure 1: Diagram adapted from STC International, Smart Ports, Virtual Expert Group Meeting (Nov 2020)

6.5 Smart Port Challenges - Current Trends & Applications

Different areas of ports' functions are covered by digital transformation, such as asset management, port business management and planning of activities, management of commercial activities and supporting services, contact with clients, navigation, (predictive) maintenance, worker safety, data sharing and management, etc.

The overall goal of Industry 4.0, Logistics 4.0 and Port 4.0 and thus the goal of Port Authorities/Administrations around the world is the further improvement of efficiency and effectiveness. An increase in effectiveness can be achieved by improving the flexibility and adaptability of services, processes and products. Agility is becoming the decisive competitive advantage in the supply chain in the Smart Port Authorities' environment. Agility primarily means being able to anticipate rapidly changing market and demand conditions and react immediately across the whole value-added chain. In contrast to classical supply chains, agile supply chains are therefore able to achieve the greatest possible flexibility along the value chain without adversely affecting the efficiency of the partners. Agility is based on the availability of real-time information throughout the supply chain, ensuring better collaboration and cooperation between the parties involved, giving companies and terminal operators the opportunity to increase the flexibility of all business processes. It includes the variety of offered products, the production as well as the delivery, which leads to an increase in efficiency and thus to a growing competitiveness.

[82] Niraj Mahapatra: The use of big data in ports and in terminals. 2016. URL: www.academia.edu.

6.5.1 Roles and functions

This section lists non-exhaustively activities deriving from a port's role and function which can be supported by digital tools and automation applications, contributing to its efficiency and sustainability targets. The list is structured into three main categories, namely:

- Infrastructure owner/operator
- Government bodies
- User

A. INFRASTRUCTURE OWNER/OPERATOR	
Port authority/ administration/ PDC	Internal administrative aspects (closed system), role assignment
	Asset management
	Real-time update of cargo volumes transhipped in the port
	Traffic and transport information retrieved from RIS
	Infrastructure management (e.g. on-shore power supply (OPS), automated mooring systems)
	Emissions monitoring
	Water depth monitoring
	Sediment monitoring/dredging
	Noise monitoring (aerial and underwater)
	Smart buoys
	Waste management
	Monitoring of dangerous goods cargo
	Management of accidents
	Management of hazards
	Statistics
	Data management, predictions & projections
	Customer management (contract management, billing of terminal operators, etc.)
	Safety
	Security & cybersecurity
Harbour master	Port calls (AIS receipt, recording ETA/ATA – ETD/ATD, predicting the arrival of vessels)
	Berth allocation
	Port dues
	Charging the use of port services (water, electricity, etc.)

B. GOVERNMENT BODIES	
Other authorities: navigation, customs, water police, sanitary, environmental)	Status of customs clearance
	Real-time tracking of controls of the vessels, crew & cargo (e.g. databases developed under the auspices of EUSDR PA11 and in the NL)

C. USERS	
Port/terminal operators	Internal tools for administrative processes
	Transport order – rail & road planning
	Gate in/Gate out procedure
	Cargo management (& cargo flow optimisation);
	Passenger management
	Equipment management, automation
	Tracking and tracing of cargo in the terminal
Vessel operator/ shipper (at the mooring position)	Pre-arrival cargo declaration
	Electronic bill of lading/river waybill
	NOR (Notice of Readiness)
	Loading & unloading status of the vessel
	Cargo information / declaration
	Waste disposal
	Dangerous goods notification
	SOF (Statement of Facts)
Other transport operators – carriers (truck, rail)	Real-time information on the availability of transport operators and their capacities
Hinterland stakeholders (directly involved in the transport chain – warehouses, distribution center, transhipment location, etc.)	ETA/ATA & ETD/ATD, predictions
	Tracking & tracing
	Electronic BL
	Allocation of Loading/Unloading spot
Business community (agents, forwarders, shipbrokers, etc.)	Real-time information on logistics services availability & pricing (marketplace)
Indirect stakeholders (insurance companies, banks, equipment & technology providers, etc.)	Filtered information for general overview
Civil society	Tools to manage civil society insights & feedback

Figure 2: Roles & functions in ports (non-exhaustive list)

6.5.2 Integration in the European digital environment

On 9 March 2021, the European Commission presented a vision, targets and avenues for a successful digital transformation of Europe by 2030. The Commission proposes a Digital Compass for the EU's digital decade that evolves around four cardinal points: government, skills, business and infrastructures. The four fields of action are very much relevant for port operations and their objective of being an integrated part of a competitive, climate-resilient and sustainable transport system.

In the field of transport and in particular inland navigation, DTLF[83] and DINA[84] are two initiatives that provide platforms for structural dialogue, technical expertise, cooperation and coordination between the Commission, Member States and the transport and logistic sector. DINA focuses on driving the digitalisation of inland waterway transport, including linking it with the other transport modes. DTLF brings together public and private stakeholders from various transport and logistics communities to support the European Commission in promoting the digital transformation of the transport and logistics sector. DTLF provides technical assistance for the implementation of eFTI and development of corridor freight information systems for interoperable data sharing between all type of actors in multimodal freight transport and logistics chains.

To this end, digital services and systems such as Port Community Systems (PCS), River Information Services (RIS), National/European Maritime Single Window, Electronic Freight Transport Information (eFTI), Customs Single Window, European Mobility Dataspace contribute to the Union's activities and programmes targeted at digital interoperability and data exchange in a shared, secured and trusted transport and logistics dataspace.

The chart below is a high-level overview of the applicable services and systems mentioned above and the connection to each other.

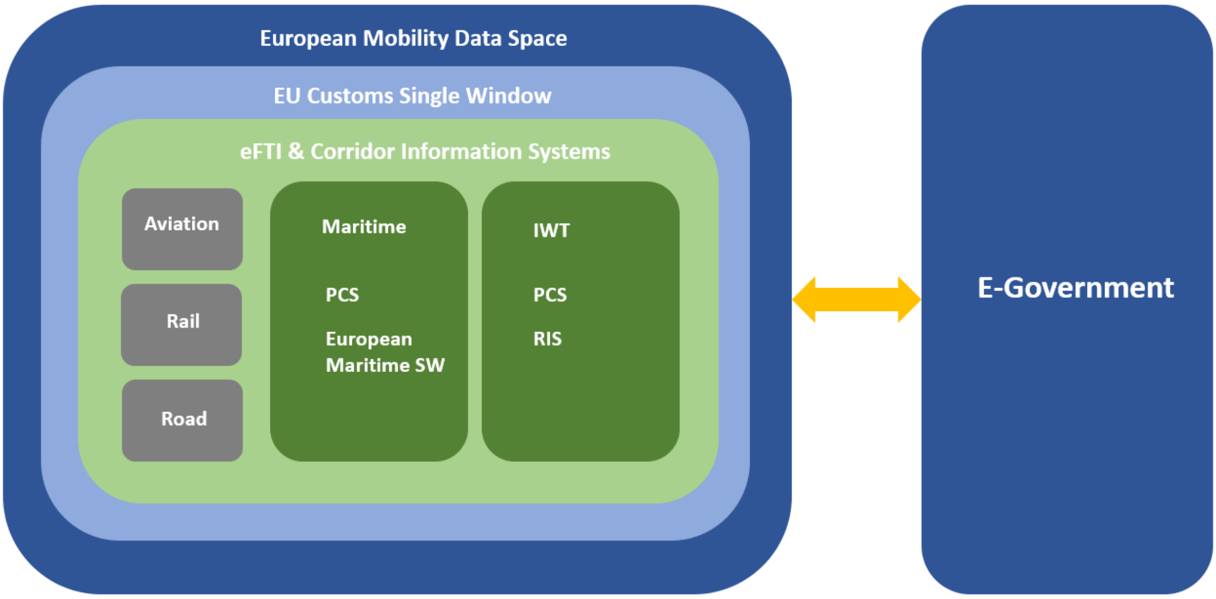


Figure 3: High level overview of applicable systems & services

[83] Digital Transport and Logistics Forum (DTLF). URL: transport.ec.europa.eu/transport-themes/digital-transport-and-logistics-forum-dtlf_en

[84] Digital Inland Navigation Area Commission Expert Group. URL: https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?lang=en&groupID=3505

6.6 Identification of requirements, benefits and gaps and outline of policy recommendations

The following bi-directional table lists requirements, benefits and gaps identified by port stakeholders at operational level as well as at policy level. From the user (business) & infrastructure owner & operator perspective, the following table reflects the short and long term needs of ports (from the infrastructure provider and business operator perspectives), among which digitalisation, implementation and management of information technologies and information & communication systems play a very important role in the port's overall business success.

At policy level (entries depicted in orange), the following perspectives have been formulated in order to ensure favourable framework conditions for ports:

- Provide proper legal framework together with mandatory requirements and incentives
- Provide harmonised standards as well as measuring criteria
- Adequately position European waterborne transport including ports in the complete logistics chains

	OPERATIONAL & POLICY PERSPECTIVE	TARGET GROUP
Requirements	Optimise processes in terminals	User (fleet operator, logistics service provider, terminal operator)
	Proper operation and management model of the PCS	Infrastructure owner/operator (port authority)
	Environmental/ decarbonisation targets, emissions reduction	Government bodies - Competent authorities
	Data protection	Infrastructure owner/operator (port authority) User (fleet operator, logistics service provider, terminal operator)
	Integration with booking and transport management platforms	User (fleet operator, logistics service provider, terminal operator)
	Reduce/limit congestion	Infrastructure owner/operator (port authority) User (fleet operator, logistics service provider, terminal operator)
	Supply chain transparency & integration	User (fleet operator, logistics service provider, terminal operator)
	JIT (just-in-time) operations	User (fleet operator, logistics service provider, terminal operator)
	Financing from external sources (e.g. EU)	Government bodies - Competent authorities
	Reporting only once	Government bodies - Competent authorities
Benefits	Less empty runs	User (fleet operator, logistics service provider, terminal operator)
	State of the art booking applications for utility services such as OPS, water, waste & sewage water disposal, etc	Infrastructure owner/operator (port authority)
	Lower transhipment costs	User (fleet operator, logistics service provider, terminal operator)
	Better planning of capacities (e.g. berth allocation)	Infrastructure owner/operator (port authority) User (fleet operator, logistics service provider, terminal operator)
	Reduction of waiting times	User (fleet operator, logistics service provider, terminal operator)
	Optimal use of port infrastructure (e.g. cranes)	Infrastructure owner/operator (port authority)
	Utilisation of data can be used to understand and highlight patterns in accidents and risk areas to improve safety	Infrastructure owner/operator (port authority)

	OPERATIONAL & POLICY PERSPECTIVE	TARGET GROUP
	Reduced fuel consumption	User (fleet operator, logistics service provider, terminal operator)
	Operational efficiency of port-hinterland transport flows	User (fleet operator, logistics service provider, terminal operator)
	Higher service level	User (fleet operator, logistics service provider, terminal operator)
	Optimal lead-time of ships and cargo in port or terminal	Infrastructure owner/operator (port authority)
	Improved and increased human resources in ports	Infrastructure owner/operator (port authority)
Gaps	Timing – collaborative approach is needed to support a balanced use/implementation of digital technologies – currently ports in the northern hemisphere are more digitalised than the ones in the southern hemisphere (reduce disparities between regions in Europe)	Government bodies - Competent authorities
	Better digital collaboration between private and public entities across the entire supply chain	Infrastructure owner/operator (port authority)
	Political conflicts and market instability	Government bodies - Competent authorities
	Lack of hinterland infrastructure – no physical or digital integration	Government bodies - Competent authorities
	Weather independent transhipment facilities	Infrastructure owner/operator (port authority)
	Lack of sufficient support of ports' development and management within the EU & national transport policy	Government bodies - Competent authorities

Table 3: Ports: Overview of requirements, benefits and gaps per stakeholder (operational and policy level)

6.7 Inland Ports – next steps

Inland ports across Europe have various development trends behind, various operational and ownership models, specialize on different cargo and provide various services. For example, for most Danube Region ports, digitalization is still a new topic, therefore they find themselves in a position where they need to follow the digitalization examples of major European sea and inland ports from other European regions.

For inland ports a hot topic of the present and for the next 5-10 years arises in relation to the adoption of a port community system solution. Based on the results of several projects dealing with the topic of port digitalisation (e.g. DAPhNE, Dionysus, RPIS, KIR, DIWA[85]), it can be concluded that it is absolutely not necessary that all inland ports have a PCS as a standalone solution, since it can be foreseen that a national or a regional solution (on the SaaS basis) can fulfil all requirements within reasonable costs and at the highest service level. Teaming up enables inland ports to make use of economies of scale, as investment and running costs can be split between several users (ports), hence avoiding the situation that only one ports needs to support the entire financial burden. Besides the financial aspects, another important factor reflects on aspects in relation to data sharing, data ownership and data protection and security from the point of user rights, liabilities and responsibilities. The complexity of these aspects requires strong cooperation, especially if several countries are involved (both EU and non-EU Member States).

It can be concluded that an enhanced regional cooperation with an outlook to corridor integration is a viable and relevant solution for European inland ports, whereas only the integration of both inland and seaports will enable ports to become reliable partners in the European and global efficient and sustainable transport chains.

Besides the interconnection between IWT and maritime ports, the interconnection between them and the other (land) transport modes is another aspect to be considered. The (larger) IWT ports, in particular those found on the Rhine, have started to harmonize their systems. However, many of the other are still lagging behind, a fact that will to a significant extent obstruct their development. This will also have an impact on other transport-related aspects, in particular the achievement of modal shift at the EU level.

It must be also mentioned that this integration also needs to consider the energy aspects – which will also have a digital component. On the one side, the growing electrification of the land transport sector is complementary to the increased electrification needs of ports, in particular the sea ones. This also makes it easier in a way for the ports and the adjacent stakeholders to manage the needs, and will contribute to making some of the ports true energy hubs. Smart grid systems will be key here. On the other side, the sustainable alternative fuels (SAF) will likely have a less cohesive effect, at least in the coming decades. Different types of ships are using one SAF or the other; and this differentiation is widened by the different needs of the maritime and IWT segments. This will mean the integration of several types of SAFs within the same port, in particular for the IWT ports closer to the larger, dual ports. For the smaller IWT ports, this challenge can be better addressed with the help of 'smart' tools and harmonization between them.

A digitalisation roadmap applicable to inland ports will identify practical actions required across several intervention areas implementing a good port governance, ensuring maximal stakeholder involvement, improving cybersecurity and facilitating trade while using smart technologies in the port customers' interests, therefore the elaboration and adoption of such a roadmap shall be given highest priority in the upcoming period.

6.8 Seaports – next steps

Despite that some environmentally friendly alternatives are becoming available at some ports with electrical and alternative fuels powered ships, the maritime industry is still considered not green enough. Integrated digital solutions allowing port call optimisation and Just-In-Time operations are therefore becoming more important than ever. Ensuring that service providers start working exactly when it is needed avoids idling equipment and staff, as well as needless movements in and around the port.

[85] DIWA – Masterplan Digitalization of Inland Waterways (masterplandiwa.eu)

In the area of seaports, the long-term vision is **a network of trusted networks - global network of Smart Ports.** It is expected to be an informal network of independent Smart Ports, sharing real-time information concerning the maritime supply chain and fostering the development and implementation of innovations. By joining this network of Smart Ports, seaports also benefit from optimized transport flows. The International Port Community Systems Association (IPCSA) has launched the Network of Trusted Networks (NoTN)[86], a secure port-to-port and cross-border data exchange solution. The NoTN has been launched as a two-year proof-of-concept project, with 14 IPCSA members taking part in the pilot. Together the 14 members cover 70 ports, ten airports and multiple inland terminals. NoTN users are trusted, neutral platforms such as Port Community Systems, Cargo Community Systems and Single Window operators, maintaining the principle of commercial confidentiality, which is the cornerstone of Port Community System and Single Window operators. The technical provider for the NoTN proof of concept is API first, data sharing platform NxtPort. As the facilitator, IPCSA has tailored the NxtPort offering to suit the neutrality of the NoTN initiative.

The information below has been taken from the Strategic Research and Innovation Agenda (SRIA) of the Zero-Emission Waterborne Transport Partnership (ZEWT cPP; June 2021)[87] and the WaterborneTP Ports & Logistics SRIA (June 2021)[88].

6.8.1 Digitalisation in sea ports

A deep and massive digitalisation process based on new technologies (Internet of Things - IoT, smart sensors, Big Data analytics, Artificial Intelligence, 5G, etc.) will be the trend for sea ports and all its stakeholders in the next 5-10 years. Consequently, forecasts, analysis and predictions will be dramatically improved and assisted port operations will achieve a more efficient use of resources (dynamic optimisation systems, predictive maintenance systems, advanced dredging materials management, just-in-time ship arrivals, etc.).

However, to achieve a truly integrated approach and use the data that will become available, shared frameworks and standards need to be implemented at a European level (Digital Transport and Logistics Forum - DTLF and European Sustainable and Smart Mobility Strategy). The standards developed for the maritime sector (in waterborne) need to be connected to those already set for logistical and distributional transport networks (in the framework of the Alliance for Logistics Innovation through Collaboration in Europe - ALICE).

The digitalisation and port automation processes will require innovative strategies to guarantee safety and security in automated and semi-automated environments and ecosystems. The integration of cybersecurity and physical systems related to port infrastructure is critical, particularly given the increased and frequent threats. In this regard, active cooperation between ports and countries and effective and resilient threat identification systems are urgently required. The improvement and development of new technologies, equipment and devices allowing intelligent, passive and active interactions with passengers and goods have to be considered with the aim of fostering a completely safe and secure environment.

The development of new collaborative solutions and the corresponding tools and business models will facilitate capacity sharing along the supply chain and should take into account all the different transport flows (e.g. people and cargo movements; intercontinental flows; short-sea flows; hinterland transport network, port clusters, etc.). The maritime sector is characterised by the high degree of interactions of intermediaries along the supply chain, where the ports are vital players representing the primary interface between the sea/river and the hinterland, through the transportation and movement of goods.

[86] Network of Trusted Networks – IPCSA International

[87] 210601_SRIA_Zero_Emission_Waterborne_Transport_1.2_final_web_low.pdf

[88] 210609_SRIA_non-cPP_-_4_-_Ports_Logistics.pdf (waterborne.eu)

6.8.2 Automation in sea ports

Automation and robotisation are an important field for port operations and transport: autonomous and remote-controlled vessels, vehicles, cranes, etc. There is a need to enhance and develop new situational awareness systems for multiple functions, combining physical and digital assets. In this regard, a wide range of solutions (e.g. cutting-edge Vessel Traffic Service - VTS; modern control towers; innovative vehicle traffic management services; equipment control systems, autonomous and remote-controlled port services ships; automated mooring; etc.) needs to be defined and assessed for the implementation of an effective pathway towards a fully connected and automated port.

The development of new advanced solutions and systems to support the progressive automation of nautical services for vessels (piloting, tugging, mooring, underwater maintenance, etc.), cargo handling and other port operations is also envisaged to overcome the current limitations. Improved solutions for human-machine interactions, including the application of new technologies such as artificial intelligence, predictive analytics, big data and augmented reality are also part of the future of ports.

Therefore, traditional job qualifications will evolve and training needs will change, along with existing jobs and staff that will have to be adapted to match the new technological developments. Human factor aspects, including ethical issues, will have to be thoroughly assessed and addressed, especially with regards to automation technologies (e.g. the dockworker of the future; remote working; cobotics[89] and mobile robotics; etc.).

6.8.3 Cooperation with other transport modes

The expected growth of freight operations within and around the challenging urban environment calls for a seamless waterborne transport chain and integration of maritime and port-hinterland transport. The development of an improved linking of waterborne transport with other modes of transportation will enable seamless switching between modes - synchromodal transport, a topic which is detailed in the PLATINA 3 Task 1.3.

Technologies related to keeping track of cargos are fundamental to effectively promote an integrated approach for freight flows within the port and hinterland framework (reliable, highly efficient sustainable port operations). In this regard, seamless tracking and tracing devices need to be improved to enhance goods connections with transport networks along the supply chain. Moreover, innovative design and optimisation of cargo units should be able to deal with several issues that characterise the sector. Among the most relevant topics, modularity, system interoperability and overall capacity, as well as handling, should be promptly addressed.

Other improvements should be considered for storage. In particular, energy-efficient refrigeration technologies are, indeed, an appealing solution to enable sustainable maritime and inland waterway transport for different types of cargos, including perishables, pharma and electronics.

Seamless and improved track and trace technology will connect the individual goods with the means of transportation along the supply chain. The development of new freight and passenger services, as well as disruptive innovations in waterborne transport, require the development of new port infrastructure and services.

The increase in the number of autonomous vessels requires new port services (vessel traffic management services, including forms of pilotage, new advanced solutions Ro-ro/ Lo-lo and others, autonomous and remote-controlled port services ships, automated mooring solutions, vessel maintenance, etc.). These services should include also vessels not calling at a port (e.g. cargo handling between vessels, fuelling vessels at sea, urgent delivery of small cargo, waste, ship supplies, etc.).

[89] Collaborative robotics

7 Conclusion

This deliverable analysed the requirements towards digital and automated inland navigation from the perspectives of both the infrastructure operator and user. Profound attention is given to the concepts of digitalisation and automation and how they fit into the infrastructure context.

It has been analysed what the requirements will be for infrastructure when automated vessels will be added into the traffic system. These concern the requirements around shipping operation areas. Implications of automation/digitalisation and the requirements have been identified in the field of voyage and route planning, navigation on waterways and in ports, passing locks and bridges, mooring, anchoring and docking manoeuvre, situational awareness and communication system and network & connectivity.

In view of automation/digitalisation, not all navigational tasks will and should be replaced at once, nor does that seem feasible at this stage. Shipping operations related to the voyage and route planning, navigation and sailing on rivers, canals and in ports with necessary communication networks and sufficient connectivity, or assistance in case of lock and movable bridge passages are already in the focus of R&D projects and in some cases even in commercial deployment projects.

Other operations, which would require changes in the physical infrastructure, may take longer on the way towards (fully) autonomous inland shipping. Commercial inland vessels dock significantly often, at locks, movable bridges, for (un)loading, supplies and change of crew. Replacing these activities by on-shore ad hoc crews is an option, however, it would be an organisational and financial challenge, in particular in times when also operations of locks and movable bridges changes from the operator which is currently present at the location to remotely controlled infrastructure.

Independently on how fast or which direction the automation in the inland shipping will go, for the sector it is important to know which waterways (their sections) are (will be) ready to provide information and services essential for different levels of automation. The classification of waterway network on its readiness for automation shall support the autonomous and remotely operated vessels to operate under more predictable environment. To prepare such classification, activities in road transport such as ISAD (Infrastructure Support for Autonomous Driving) may be taken as an example to gain insights into classification of infrastructure readiness for automation. Having elaborated such classification, the open topic remains where to embed it: standalone agreed unofficially by all European inland waterway countries, river commissions, CEMT classification or even consider to include such classification under newly assessed RIS directive, or TEN-T directive and its linked (future possible implementing/delegated) acts.

Specific attention has been given to automation and digitalisation in ports. User requirements arising from the water side (vessel operators) and from the shore side (transport operators, infrastructure operators, authorities, etc.) have been identified. In view of these requirements, gaps have been listed and potential benefits of digital and automation tools are identified. It can be concluded that an enhanced regional cooperation with an outlook to corridor integration is a viable and relevant solution for European inland ports, whereas only the integration of both inland and seaports will enable ports to become reliable partners in the European and global efficient and sustainable transport chains.

Cybersecurity is a subject that is very much related to digitalisation and automation and is gaining in importance. This topic has been treated as an overarching one. New technologies in the field of automation and digitalisation imply new hazards that are to be identified and new associated risks that are to be mitigated. The more interconnected inland navigation becomes, the more vulnerable it is to cyber-threats. Therefore, the design of both, the infrastructure and vessels should take cybersecurity into account by applying of multiple layers of mechanism, functions and barriers aiming at preventing, detecting and limiting the damage of security breaches.

The 1st international workshop on cybersecurity in inland navigation showed a wish from the sector to, under the lead of CCNR, establish a coordination platform bringing the main inland navigation players together with cybersecurity experts. Besides the establishment of a coordination platform, a strong need for awareness, training and information among the different waterway users were highlighted.

8 Annexes

8.1 Annex 1: CCNR - Definition of levels of automation in inland navigation

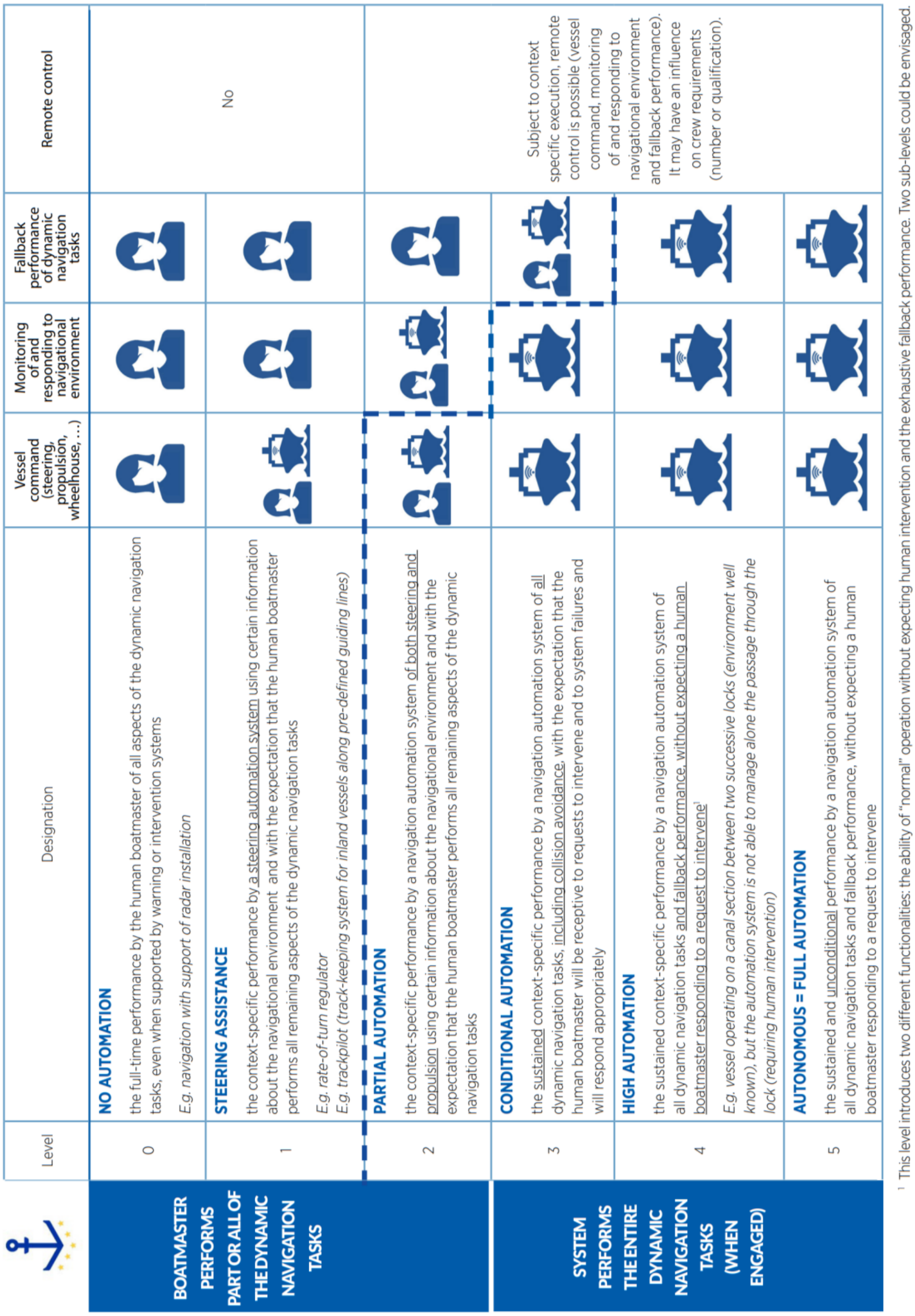


Figure 4: CCNR: Definition of levels of automation in inland navigation.
URL: www.ccr-zkr.org/files/documents/AutomatisationNav/NoteAutomatisation_en.pdf

8.2 Annex 2: Reference list PCS run in Europe

SOGET, Le Havre, France
www.soget.fr

PORTIC, Barcelona, Spain
www.portic.net

MCP Plc, Felixstowe, UK
www.mcpplc.com

DAKOSY, Hamburg, Germany
www.dakosy.de

dbh, Bremen, Germany
www.dbh.de

Portbase, Rotterdam The Netherlands
www.portbase.com

APCS, Antwerp, Belgium
www.portofantwerp.com/apcs

Hamburg Port Authority, Hamburg, Germany
www.hpa.hamburg.de

Port of Venice Authority, Venice, Italy
www.port.venice.it

8.3 Annex 3: Information from the Infrastructure (PIANC WG 210)

Source: PIANC WG210: Smart Shipping on Inland Waterways. March 2022. ISBN 978-2-87223-015-0. Page 28-29

Ships interact with their infrastructure: information about the lay-out of the waterway, traffic lights and signs, weather conditions, etc. are very important. This information needs to be fed to the smart shipping solutions in order to know how to navigate the ship and to avoid collisions. In addition, the inventory analysis (see Section 2.3.1) shows that the focus of ongoing projects is often on the interaction with infrastructure. Therefore, the information needed from the infrastructure is investigated into more detail here.

The following information is needed:

- Lay-out of the waterway: waterway contours, junctions, bridges/locks, etc.
  - Also dynamic information: anticipated blockages of waterways due to maintenance, etc.
- Water state information: water level/depth, tide, current, riverbed, sandbanks (real-time and
- forecast), river discharge, wave height/direction
- Data about AIS ATONs: outline, shape, danger zone
- Predicted traffic and capacity of the waterway
- The information that is currently shown by the traffic lights
- Piers and free spots
- Environmental information
- Fixed static obstacles: bridges, locks, etc.
- Dynamic obstacles:
  - All obstacles on the water surface need to be known: pleasure crafts, water sporters, temporary buoys
  - Pattern recognition of obstacles on the water surface
  - Position information of encountering traffic
- Weather and environmental conditions: wind speed and direction, storm surge, ice
- Bridges and locks:
  - Bridge clearance: now and future
  - Bridge profile: passage width, passage height, passage depth, number of passage lanes and their dimensions
  - Approach conditions, such as wind speed and direction
  - Opening times
  - Status object: open or closed
  - Waiting time/lock planning
  - Location of waiting places
  - Lock lay-out: number of lock chambers and their dimensions, position of devices to fix your vessel lines during levelling process, actual water level, passage width, passage height, passage depth
  - Position of vessel in lock chamber
- Berthing and anchoring:
  - Dimensions berth place
  - Availability of several (automated) berthing systems and facilities
  - Position of bollards
  - Allowable force on bollards
  - Bollards equipment
  - Anchoring places
  - Anchoring allowed/prohibited
  - Planning of other vessels already moored or to be expected

9 Source list

DIWA Masterplan SuAc 2.1 Smart Shipping. May 2022. [DIWA]

L.M. Punter, W.J. Hofman (TNO). Digital Inland Waterway Area. Towards a Digital Inland Waterway Area and Digital Multimodal Nodes. ISBN 978-92-79-76485-1. European Union, 2017 [DINA]

PIANC WG210: Smart Shipping on Inland Waterways. March 2022. ISBN 978-2-87223-015-0 [PIANC]

Further literature is indicated in the footnotes of relevant texts and paragraphs.

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