DIWA Report

Sub-Activity 2.1.: Smart Shipping

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Main author: Project team Masterplan DIWA

Contributing: Generaldirektion Wasserstraßen und Schifffahrt, Vlaamse Waterweg, Viadonau, Voies navigables de France, Rijkswaterstaat

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Main author: Michael Schreuder | Rijkswaterstaat

Contributing:
Flores de Witte | Vlaamse Waterweg N.V.
Ann-Sofie Pauwelyn | Vlaamse Waterweg N.V.
Martin Broeschel | WSV
Katrin Steindl-Haselbauer | Viadonau
Marie-Claire Schug | Viadonau
Robert Schwarz | Viadonau
Alaric Blakeway | VNF
Therry van der Burgt | Rijkswaterstaat
Martijn van Hengstum | Rijkswaterstaat
Martijn Hage | Rijkswaterstaat
Philippe Govers | BDO
Laurien van den Heuvel | BDO
Natascha Peeters | Vlaamse Waterweg N.V.
Stephanie Plancq | VNF
Thomas Zwicklhuber | Viadonau

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Reading guide

Chapter 1 introduces the objective and scope of this study and the methodology being used. Chapter 2 further elaborates on the concept of smart shipping and also gives a short inside in the relevant aspects of Inland Waterway Transport (IWT) that has impact on the need and capabilities for investing in smart shipping. Chapter 3 describes the current developments regarding smart shipping on the inland waterways, both from the perspective of the logistic sector and the fairway authorities. Aspects are technical, operational and organizational status and challenges, financial aspects and differences between regions within the scope of this report. The chapter concludes with a general insight in the level of digitalisation related to smart shipping.

The same aspects are used in chapter 4 to create an inventory of future developments. The differences between the two chapters is used to perform a gap analysis in chapter 5. It makes it possible to determine the current and future needs for implementation of smart shipping. Using three different scenario's related to the role fairway authorities can take, this gives to an overview of the functional requirements for the upcoming ten years. In chapter 6, these functional requirements are used to draw a possible roadmap for the next levels of digitalisation, as far as that they are relevant for smart shipping.

A glossary is included in Annex 3 at page 62.

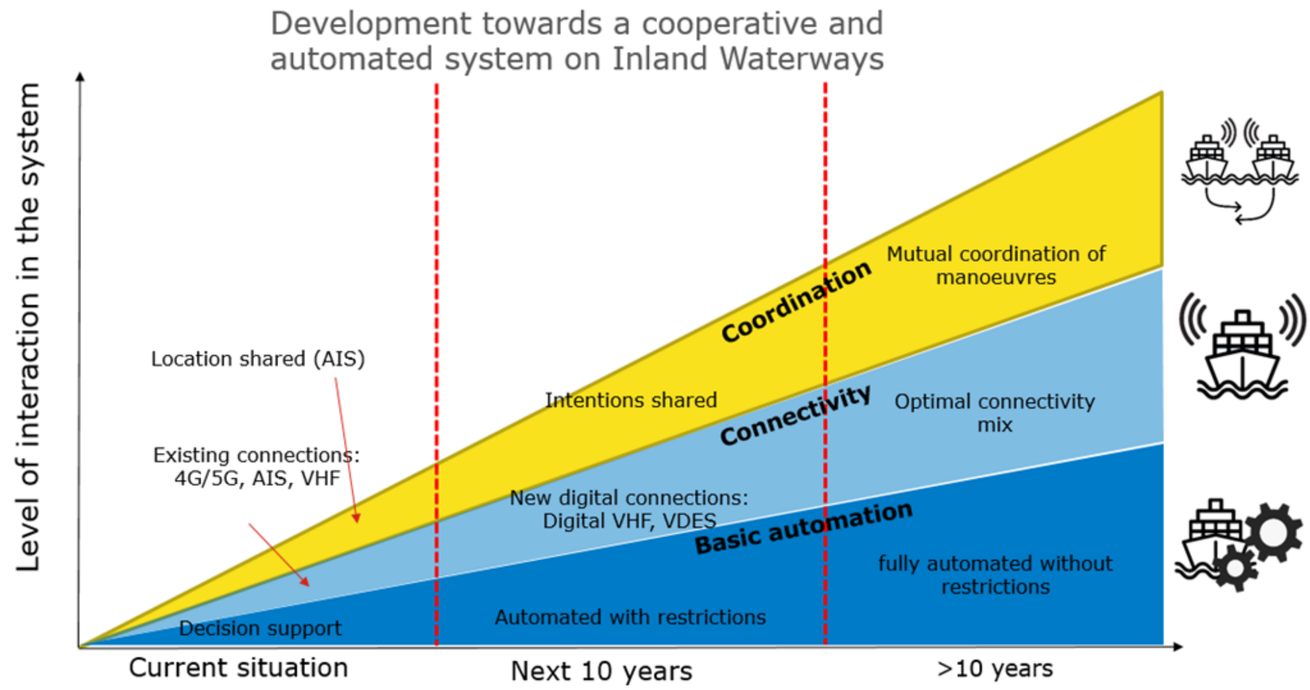
Executive summary

Smart shipping – the automation of sailing task on board of a ship - is a relatively new development in the digitalisation of inland waterway transport (IWT). The need for innovations to tackle the challenges regarding emission reduction, personnel shortages in combination with the current state of technological challenges seems to drive developments forwards.

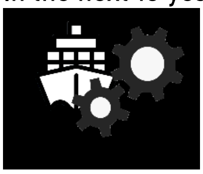
The business values of smart shipping developments are clear. If allowed by authorities, automated systems can fulfil tasks currently executed by personnel on board of ships. With this, reducing the staff needed to sail the ship and at the same time make work on a ship more interesting for new generations. Experiment with 'smart shipping' systems that support the skipper in sailing the ship, showed a reduction on the fuel consumption. Together with more integration in the total transport chain, this can help create more sustainable transport. While at the same time enabling new business models and with that support the competitiveness of IWT and the total transport chain.

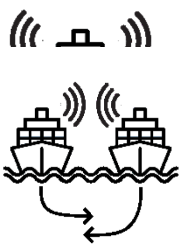
This report introduces a model to describe the development of smart shipping systems. The needed requirement to facilitate the development and the role that fairway authorities can play are extracted from the model. Three tracks are distinguished: basic automation, connectivity and cooperation.

Figure: Roadmap smart shipping on Inland Waterways



In the next 10 years:





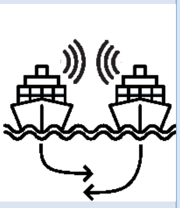
Basic automation: the maturity of automation enables ships to sail highly automated on specific part of the waterway without human back up. Systems on board are integrated to be able to share information that is needed for decision-making and actuation of those decisions within the defined space.

Connectivity: the majority of the fleet is connected, so able to at least receive information of other ships, although the level of connectivity does not enable sufficient coverages for all mission critical processes. A uniform data exchange standard is in place to ensure that systems development by different companies are able to communicate with each other. All parties in the supply chain agreed on a common data architecture and governance structure to data exchange between relevant parties. To be able to share information in a way that all other ships are able to receive and produce this information, standardized data models are in place.

Coordination: information about the short-term intentions of smart ships is send out and received by other users in the near surrounding of the ship. Other smart ships can use this information for their state estimation and decision-making process. Other, less automated ships, can receive this information as well as input for the skippers decision-making process.

Between the above situation and the current state, gaps exist on technological development but also related to operational and organisational aspects. The gap defines the potential aspects where further development could be beneficial for smart shipping development. The table below states the most important conclusions based on the gap analysis and describes functional requirements for the further development of smart shipping.

Topic	Conclusion	Functional requirement
Basic automation 	With the increase in automation on board of the ship, the need for external data and information to created redundancy and allow for safe navigation will grow.	1. Increase the quality of the data by investing in quality of existing data instead of a focus on sharing new types of data. A solution might be to build a digital twin of the waterway with the possibility for users to add or suggested changes.
	In the near future, the need for new data or information might be less than getting insight in the quality and availability of the data that is present for the whole European inland waterway network.	2. Need for more clarity on the quality (meta data) of existing data. This allows users to verify on critical functional parameters.
		3. Need for insight in the levels of support for automated navigation (ISAD). Give automated systems and their operator's guidance on the "readiness" of the waterway network for (further) automation.
	Without the necessary legal framework, developments are hard to implement safely in an operational environment.	4. Need for a legal framework that allows for navigation with less crew.
		5. Need for non-ambiguous digitalised traffic rules to allow for safe navigation (especially in mix traffic situations).
		6. Need for a clear demarcation where navigation with smart shipping systems is allowed and under which circumstances. Create parameters and apply them on the waterway. The operational envelops concept may be used.
		7. Need for more clarity of responsibilities and liability issues in case of an accident when using smart shipping systems.
Connectivity 	Connections between users and the infrastructure will increase. Connections ill grow to make sure that the safety on the waterway can stay as it is today with a mix of automated and less automated ships.	8. Need for reliable connection on the waterway – especially on critical sections.

	There should be a common language to communicate between ships and ships and shore with attention for cyber security and privacy.	9. Need for agreement of a common language to share information between users (like C-ITS) on the road following the work of CESNI.
		10. Need for a governance structure that allows for safe (cyber secure) communication and making sure that all privacy aspects taken care of (like Ishare).
Coordination 	A cooperative network where ships (and VTS) is connected and share intentions is seen as possibility to reduce complexity and allows for a safe (and easier) implementation of smart shipping	11. Need for increase in system to system communication – sharing data not by voice but with digital messages.
		12. Need for harmonized data.
		13. Need for coordination on the way in which a cooperative network should work.

1 Introduction

Development brings new possibilities. One of the developments that might bring opportunities for the shipping industry is 'smart shipping'. That is why this is the main topic of several business developments that are used for a vision on the future of Digital Inland Waterways (DIWA).

In this report we will discover what the potential business value can give the shipping sector. Subsequently, technical, operational and financial aspects will be investigated to see what gaps could hinder the development. This all leads to building blocks for the roadmap and a vision on how fairway authorities can prepare their digital infrastructure to make it fit for the future.

This introduction will outline the objective, scope, definition of smart shipping used in this study and give a short description of the methodology used.

1.1 Objective of the study

The main objective of this study is to give insight in the smart shipping development on inland waterways, by giving a broad overview of the actual developments. Subsequently the consequences for the digital transition in the period 2022-2032 will be assessed.

The input generated will be analysed to see how developments in the digital infrastructure of fairway authorities can contribute. This results in an overview on the needed functional integral and harmonized service, information and data requirements (guidelines) related to the digital transition of Inland Waterways.

1.2 Scope

This study focusses on the interdependency between the smart shipping developments on board and their environment. In the masterplan of the DIWA-project, the concept of "smart shipping" is defined as: '"smart" interaction of intelligent and sustainable vessels, intelligent infrastructure, communication technology and regulations'[1]. So, the waterway infrastructure is an integral part of smart shipping. Intelligent information services, information exchange technologies and high-quality data are required for an ideal "smart shipping" concept. It is often assumed that vessels will, in this context, be highly automated. They are equipped with automated systems using smart sensors and external data to optimize the operations and management of vessels sailing on Inland Waterways. This requires a (digital) waterway infrastructure that facilitates safe and efficient navigation. This assumption is the basis of this study.

Demarcation the smart shipping concept

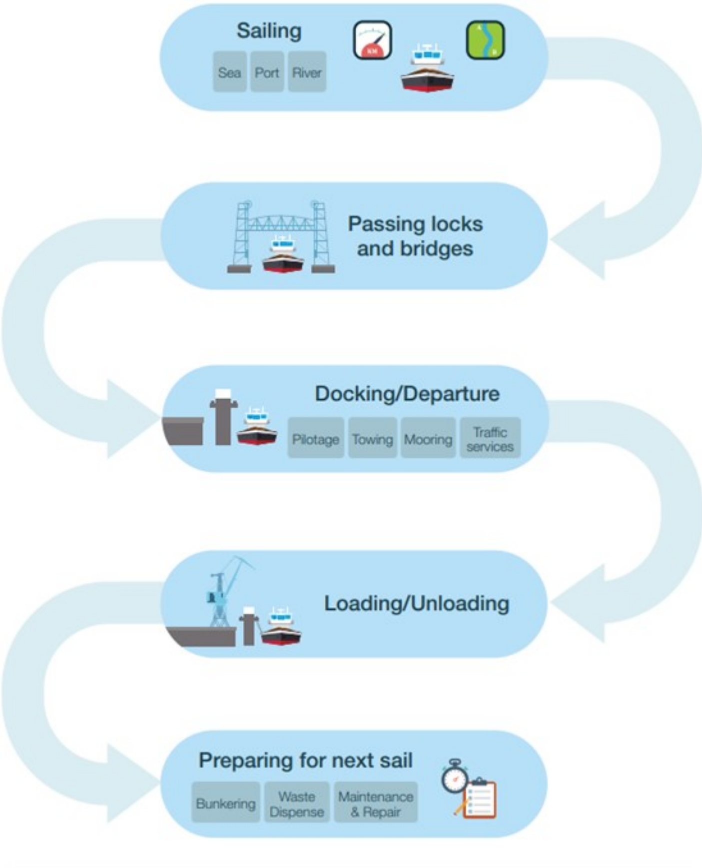
Smart Shipping is a broad concept. Sometimes described with the terms unmanned, autonomous of automated shipping. These terms all mean, sometime slightly, different thinks. For the scope of this report, it is important to briefly describe the differences.

1. Unmanned: no one on board of the ship.
2. Autonomous: all systems on board of the ship can function without a human in the loop. Humans are available for monitoring, on ship or ashore.
3. Automated shipping: certain processes on board of the ship are automated in such way that they can perform task without or with less human assistance.

The scope of this study limits to sailing: all activities that are needed to sail to sail from origin to destination (see figure 1.1.). Including one step that isn't including in figure 1.1.: the step before sailing. Before starting to sail a skipper prepares the voyage by: reporting dangerous goods, reserve berths and route planning. That means that other development, for example related to transport and traffic management, are not subject of the study. These will be considered within other sub activities within DIWA.

Figure 1.1. Overview of the main activities on board of a ship

[1] DIWA (2021). High-Level Vision DIWA. Version 2.1.



Source: Smartport (2018). Smart ships and the changing maritime ecosystem

Automation of the sailing process is a development seen in the whole shipping industry[2]. Deep sea shipping was the first to take advantage. However, inland shipping is catching up quickly, quite some research has been done already and in the past years commercial products have been introduced. This study will focus on inland waterways; although developments or used methods in other modes of transport are incorporated to determined how they might be useful for the digitalisation on inland waterways.

This study takes into account different types of developments on the inland waterways. Two developments are distinguish:

1. Drone developments: when referring to 'drones' small remotely operated ships are meant. These ships are newly designed based on new technical developments. Normally they are not equipped to facilitate a human on board of the ship. The technical challenges for smaller type ships, is different from bigger ships. Mainly because of their smaller size and the associated consequence that it isn't possible to take crew on board. That is why they are mentioned separately.
2. Development of more automation on board of conventional ships: existing's ships getting equipped with new technics for smart sailing. Although also new ships may be designed and build based on new development, they are heavily based on traditional ships.

Besides developments in Inland Waterway Transport (IWT), also the transport of people on waterways by automated systems is in development. This contains the digitalisation of ferries. This niche development is not taken into account in this study.

The geographical scope

The geographical scope is limited to the corridors to which the overall vision of DIWA (activity 5) applies. These are the corridors as stated below:

- North Sea-Mediterranean Corridor (Netherlands, France and Belgium)
- Rhine-Alpine Corridor (the Netherlands, German, Belgium and France)
- Rhine- Danube Corridor (Germany, France, Austria)
- North Sea-Baltic Corridor (Germany and the Netherlands) and
- Orient/East-Med Corridor (Germany).

It is, of course, recognized that there are lots of interesting development outside these corridors. The Scandinavian countries are at the front of the development of automated ships, mainly focusing on short sea shipping and automated ferries. The developments in China are interesting and promising as well. But these developments are not within the geographical scope of this activity.

[2] Potgraven and Lange de (2021)., Syllabus Smart Shipping (in Dutch), SMASH, 2021, https://smashnederland.nl/wp-content/uploads/2021/10/Syllabus-Smart-Shipping-SMASH-Editie-september-2021.pdf

1.3 Methodology

This report is mainly based on input from stakeholders[3]. This input was received via an inventory to several stakeholders engaged in research and development of smart shipping systems. Besides that, input gathered in workshops with external stakeholders was used as well. Input already been gathered by other initiatives such as the Dutch Forum for Smart Shipping[4] or PIANC Working Group 210 on smart shipping was gratefully used. All this was analysed by the DIWA WG with participants from the national fairway authorities.

To verify the results of the analyses, the output was presented, shared and discussed with representatives of the sector in a stakeholder consultation meeting that was held on the November 23th 2021.

Overview of the technical developments

The table below gives an overview of the projects or companies that received an inventory list or took part in a workshop. Besides this input, output of other projects was incorporated though desktop research (for example the work done by PIANC working group 210 – smart shipping). Despite the thoroughness, not every development in Europe will included.[5] Nevertheless the working group believes that this overview gives a representative picture of the developments on the (West)-European waterways.

Table 1.1. Overview of the technical logistical developments[6]

Name project/product	Focusing on	Functions	Navigation tasks
Seafar	Remote controlled navigation – reduced crew	Sensing, state estimation, decision-making and actuation	Navigating, passing locks and bridges
Shipping technology	Navigation assistance , collision detection,	Sensing, state estimation, decision-making and actuation	Navigating waterways
Roboat	New concepts for autonomous navigation	Sensing, state estimation, decision-making and actuation	Navigating (smaller waterways)
NOVIMAR	Development of vessel train concept	Sensing, state estimation, decision-making and actuation	Navigating waterways
Avatar	Development of prototypes of automated to autonomous units	Sensing, state estimation, decision-making and actuation	Navigating, passing locks and bridges
DEME	Waste collection with a small(er) unmanned drone	Sensing, state estimation, decision-making and actuation	Navigation, collision avoidance
AUTOSHIP	Build and operate 2 different autonomous vessels	Sensing, state estimation, decision-making and actuation	Navigating, passing locks and bridges
SCIPPPER	Navigation though lock	Sensing, state estimation, decision-making and actuation	Passing locks

[3] For the technical and operational developments on the logistic side, much of the input came for developers of technical systems or research project including knowlegde institutes. Trade associations and skipper were invited for a stakeholder consultation meeting but didn't join the workshop on smart shipping.

[4] In the Dutch Forum for Smart Shipping authoriies, knowlegde institities and commercial parties work together on the development of smart shipping

[5] For an overview of more development: https://automation.ccr-zkr.org/1000-en.html or the PIANC WG 210 report on smart shipping.

[6] Only developments purely related to smart shipping are taken into account in this table on the logistic side. Although some may argue that developments for example on data sharing for example are relevant as well, it is assumed that these developments will be part of other relevant business development sub-activities.

AutonomSOW II	Integration of IWT in multimodal transport processes	-	-
Fernbin E	Sensing, positioning	Sensing, state estimation	Navigating, passing locks and bridges
Fernbin	Remote operation of Inland Waterway Vessels	Sensing, state estimation, decision-making and actuation	Navigating waterways,

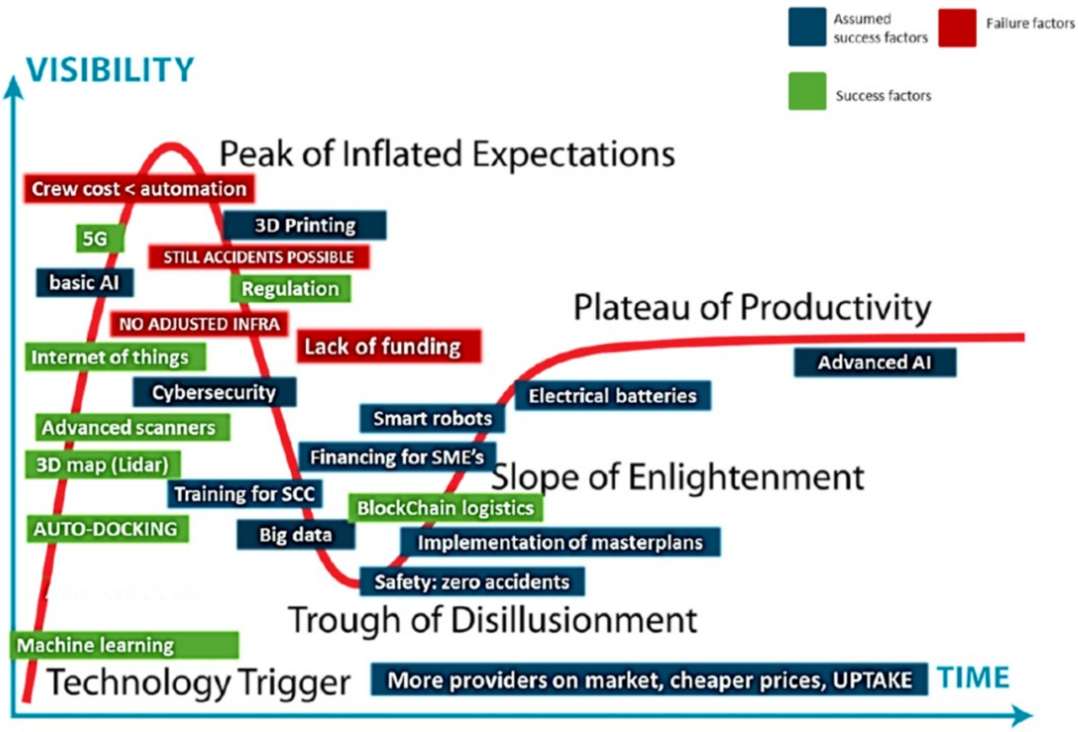
2 Introduction to Smart Shipping

Smart shipping is a broad concept often used to describe developments regarding the automation of ships. The goal of this section is to give a clear understanding of the definition of smart shipping used in this study.

2.1 The development of smart shipping

Smart shipping is a relatively new development in the digitalisation of inland waterway transport (IWT). What makes that smart shipping developments seem to really catch on now? Probably it's a combination of things, among them the need for further innovations in the IWT sector to cope with the challenges ahead (emission reduction, personnel shortages) and the current state of technological developments. More and more technology that are regarded to be essential for further development of navigation systems become available, become more mature and come available at lower cost. This makes the business cases more feasible.

Figure 2.1. The innovation Hype Cycle Gartner of Automated vessels



Source: Verberght (2019), INN-IN, innovative Inland Navigation

Figure 2.1 was made in 2019. Some developments have become even more matured since that date. The success factors essential for the implementation of smart shipping developments did not change.

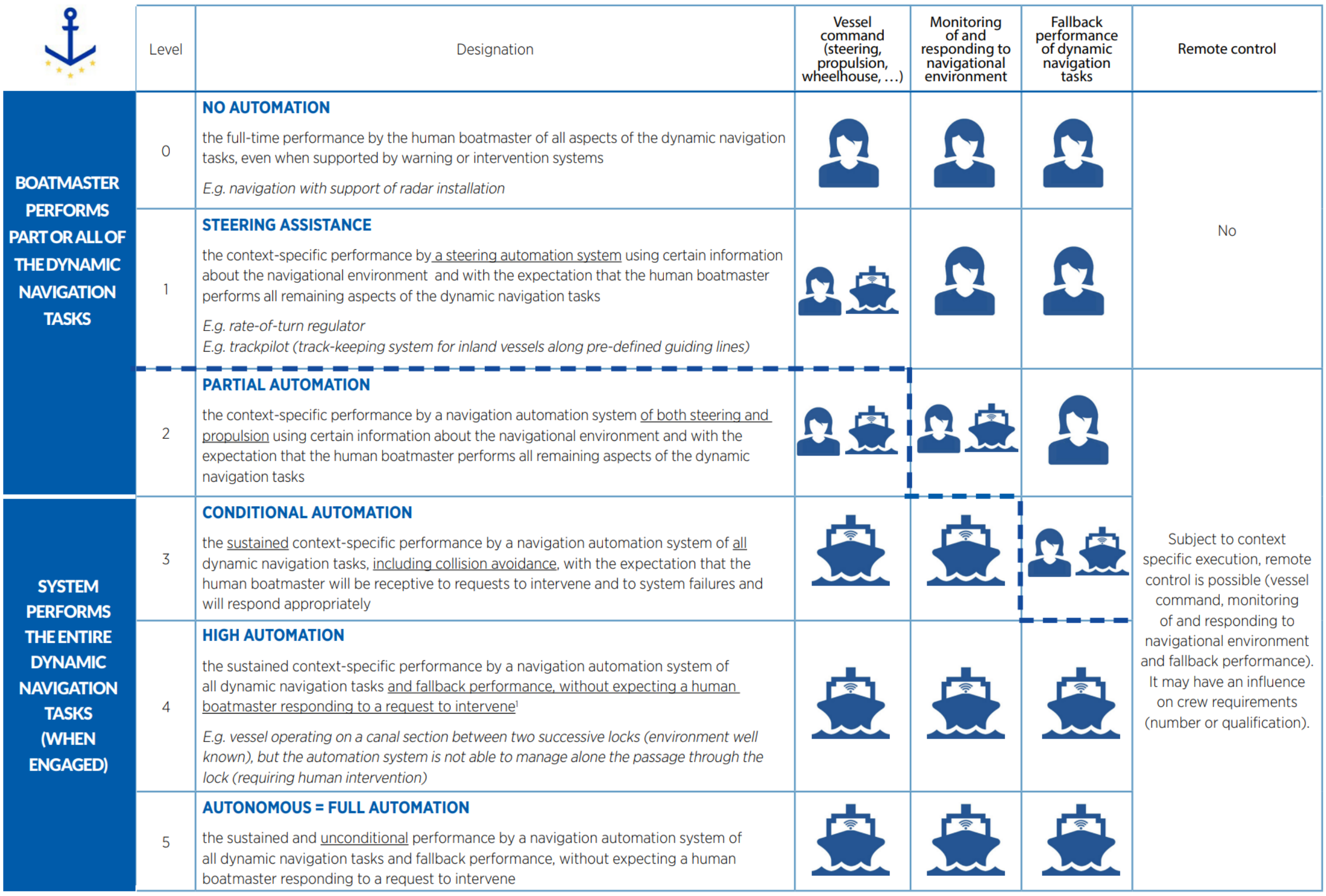
We see that the meaning of the concept smart shipping has already changed in the last few years. Smart shipping started as an IWT synonym for Smart Mobility, mainly focusing on systems, concepts or ideas that had a fully autonomous ship in mind. So a ship performing all its tasks without a human in the loop. This term was often mixed with the term 'unmanned vessel'. Which is, in many cases, not the same. As a vessel can be manned but controlled by a system. And in many cases, with autonomous, it was meant that the navigational tasks where automated. Other tasks that are performed during sailing, such as maintenance, planning the next trip, fire safety and loading and unloading were not included in this definition.

Influenced by discussions about the need, usefulness and business case of such concepts, the term smart shipping gradually evolved towards an overarching concept for all developments working towards some sort of highly automated way of navigating a ship. The word navigating is important in the latter sentence, because most developments considered smart shipping developments focus on automating the navigation task, supporting a skipper in his work. They are not aiming to take all personal off board, but are intended to reduce the crew or support the crew by taking over certain tasks for a period of time. That makes it possible to extend the working hours, reduce risks and work arduousness, and make operations more efficient.

Definitions and terminology

The Central Commission for the Navigation of the Rhine (CCNR) came up with the first international definition of the automation levels in inland navigation in 2018. This classification allows a structured approach to a global approach to automated sailing. The International Maritime Organization (IMO) did the same for developments in the maritime sector.

Figure 2.2. Definition of the automation level in Inland Navigation



	Level	Designation	Vessel command (steering, propulsion, wheelhouse, …)	Monitoring of and responding to navigational environment	Fallback performance of dynamic navigation tasks	Remote control
BOATMASTER PERFORMS PART OR ALL OF THE DYNAMIC NAVIGATION TASKS	0	**NO AUTOMATION** the full-time performance by the human boatmaster of all aspects of the dynamic navigation tasks, even when supported by warning or intervention systems *E.g. navigation with support of radar installation*				No
	1	**STEERING ASSISTANCE** the context-specific performance by a steering automation system using certain information about the navigational environment and with the expectation that the human boatmaster performs all remaining aspects of the dynamic navigation tasks *E.g. rate-of-turn regulator* *E.g. trackpilot (track-keeping system for inland vessels along pre-defined guiding lines)*				
	2	**PARTIAL AUTOMATION** the context-specific performance by a navigation automation system of both steering and propulsion using certain information about the navigational environment and with the expectation that the human boatmaster performs all remaining aspects of the dynamic navigation tasks				Subject to context specific execution, remote control is possible (vessel command, monitoring of and responding to navigational environment and fallback performance). It may have an influence on crew requirements (number or qualification).
SYSTEM PERFORMS THE ENTIRE DYNAMIC NAVIGATION TASKS (WHEN ENGAGED)	3	**CONDITIONAL AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks, including collision avoidance, with the expectation that the human boatmaster will be receptive to requests to intervene and to system failures and will respond appropriately				
	4	**HIGH AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks and fallback performance, without expecting a human boatmaster responding to a request to intervene[1] *E.g. vessel operating on a canal section between two successive locks (environment well known), but the automation system is not able to manage alone the passage through the lock (requiring human intervention)*				
	5	**AUTONOMOUS = FULL AUTOMATION** the sustained and unconditional performance by a navigation automation system of all dynamic navigation tasks and fallback performance, without expecting a human boatmaster responding to a request to intervene				

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

Source: The Central Commission for the Navigation of the Rhine (CCNR) (2018)[7]

So when speaking of a fully autonomous ship, every aspect (including for example maintenance, power management unto the communication and fire extinguishers) is developed in such way that they can perform in any circumstance without the need of a human in the loop. These fully autonomous concepts are not yet operational. When this study speaks of smart shipping, it refers to the automation of (aspects of) the navigation process. When one speaks of automated, it means that the navigation tasks are highly automated. This does not mean that the ship is unmanned.

The main focus in the current developments is on the automation of the navigational task. That includes functions such as sensing of surroundings (information acquiring), state estimation (using information to analyse the current situation) and decision-making (choose an action to perform based on the analyses) and then applying that action. It is important to make a distinction between the different functions because the degree in which the different aspects are automated can vary.

[7] cp20181219en.pdf (ccr-zkr.org)

The above mentioned functions can be applied to navigational tasks during the sailing process[8]:

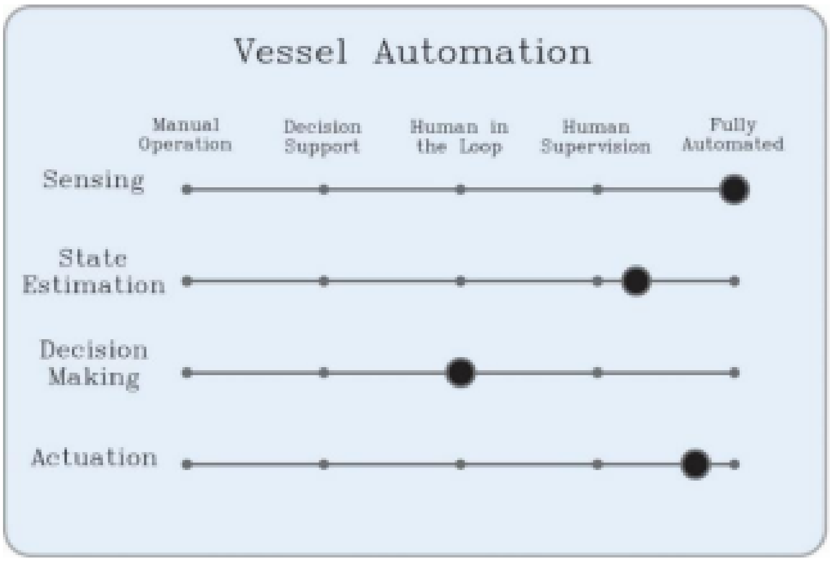
1. Route planning
2. Navigation on straight stretches of fairways and taking corners, including passing and overtaking ships
3. Passing bridges, including waiting
4. Passing locks, including waiting
5. Navigating waterway crossings
6. Mooring and unmooring

Smart shipping can be applied in the context of all these six tasks. The tasks differ in complexity, so it's assumed that there will be a difference in the pace in which products will be available to automate these tasks. A ranking in complexity can be given:

- Tools for route planning currently already exist. This is relatively easy because the tools don't have to take into account complex decision-making based on a dynamic situation on the fairway.
- Afterwards, relatively simple navigational tasks, such as sailing on straight stretches are automated (first sailing, then also passing and overtaking others). This task becomes a bit more complex because of the surrounding environment that has to be taken into account.
- With the following tasks, such as passing bridges and locks and crossing waterways, functions such as sensing, state estimation and decision-making become increasingly difficult due to more variables, input and decisions that have to be made.

If we combine the levels with the above described functions we can get more into depth on the level of automation for different functions. So, for example: a development can be categorized as level 2 but this could mean that the level for certain function can be higher or lower than that as shown in figure 2.3.

Figure 2.3. Degree of automation on different navigational functions



Source: Netherlands Maritime Technology (2021).

The degree of automation can even depend on the task. To take an example of automation on the road. A Tesla can control itself on a highway but in a crowded inner city, the driver has to drive the car. This is called: the Operational Design Domain (ODD). This could be of importance because this could mean that different navigational tasks could have different functional needs.

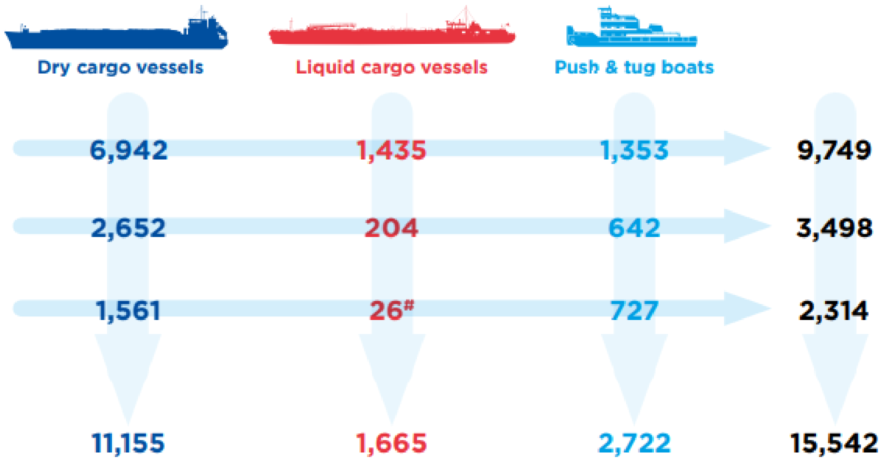
2.2 Description inland waterway sector

Broadly speaking, inland shipping can be divided into three submarkets (dry cargo, liquid cargo and push/tug boats), three types of entrepreneurship (family business, cooperation's and shipping companies) and three types of contracts (spot market, time charter and permanent contracts). Looking

[8] Based on: Panteia and Ecorys (2021). Economische effecten smart shipping.

at the market conditions in the inland shipping sector, it is important to take these aspects into account. The differences in submarket, entrepreneurship and contracts influence the need and the possibilities to invest and therefor they are briefly introduced in this paragraph. As does other aspects, such as the age of (systems) on board of the ship. Push and tugboats are left out of the description due to limited information on the investment capabilities.

Figure 2.4. Size of the fleet (in number of inland vessels) per macro-region in Europe



Source: The Central Commission for the Navigation of the Rhine (CCNR) (2021)

Dry cargo fleet

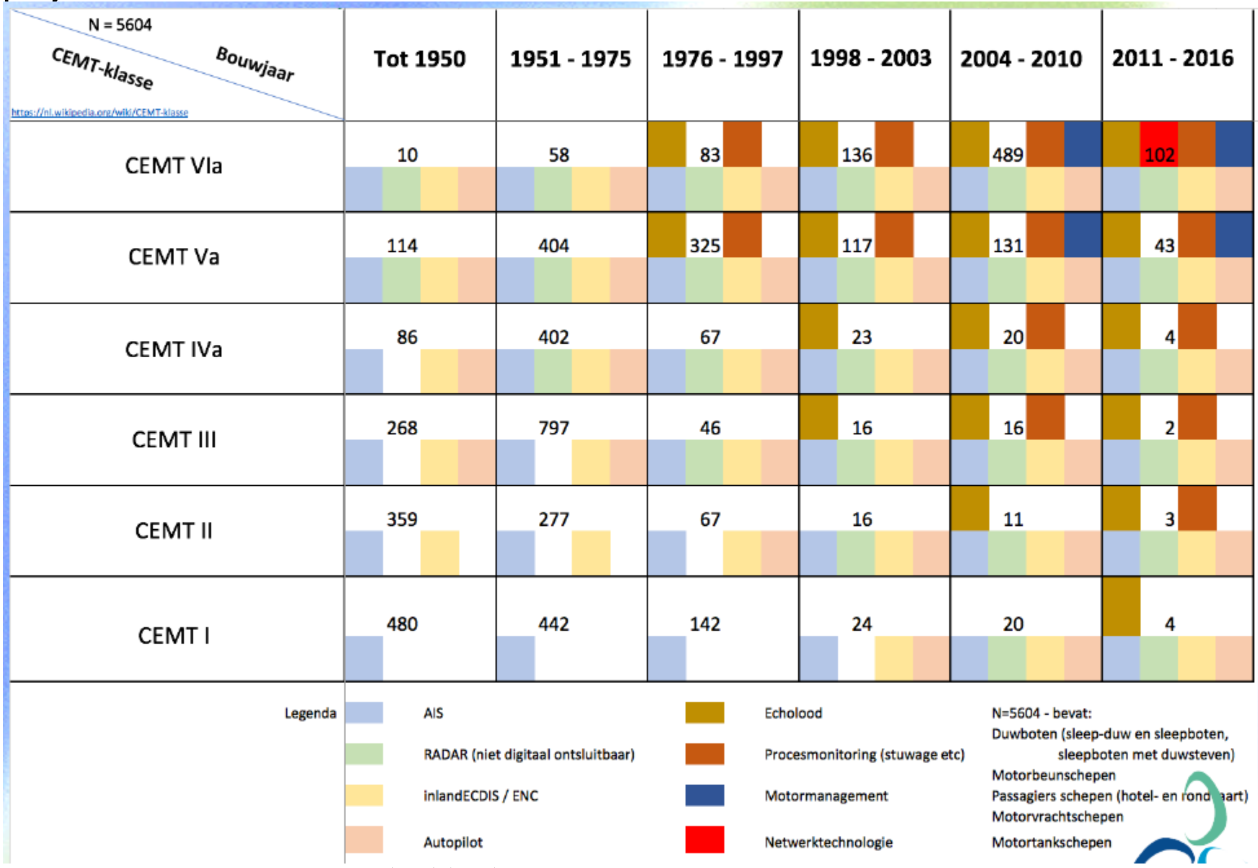
The dry cargo fleet is the biggest submarket in IWT. Generally speaking it is not that specialized in specific types of cargo and there is a large diversity in ship types. Quite a large part of this submarket exists of small ships (vessel up to 1,500 tons), see figure 2.6. These ships are often older and the initial investment is written off. The financial obligations by the owners of these ships are therefor often low.[9] At the same time, investments to update old systems and engines will generally be high compared to new ships. Bigg(er) ships are generally younger, have more digital systems on board and have a higher value. Figure 2.5 gives an example of the relation between the age of the ship, the size and the amount of digital systems on board of the ship in the Netherlands. This example underlines the statement that younger and bigger ships are often more digitalised. Often, this comes with high(er) capital cost and multi-year obligations with regard to repayments (to bank or investors).

For the Danube region, more than 70% of the total transported volumes is transported by pushed convoys.[10] This makes the character of the market somewhat different than in the Rhine region.

[9] Panteia and Ecorys (2021). Economische effecten smart shipping.

[10] Central Commission for the Navigation of the Rhine (CCNR) (2021). Annual report 2021.

Figure 2.5. Example of the (digital) systems on board of Dutch inland waterway vessels categorized per year of construction and CEMT-class



N = 5604 CEMT-klasse / Bouwjaar	Tot 1950	1951 - 1975	1976 - 1997	1998 - 2003	2004 - 2010	2011 - 2016
CEMT VIa	10	58	83	136	489	102
CEMT Va	114	404	325	117	131	43
CEMT IVa	86	402	67	23	20	4
CEMT III	268	797	46	16	16	2
CEMT II	359	277	67	16	11	3
CEMT I	480	442	142	24	20	4

Source: Bureau Telematica Binnenvaart (BTB) (2017)

Of the three types of entrepreneurship, the family business are most common in this submarket. Most of the time, married couples own the ship they sail on. For the Dutch fleet 90% of this submarket are companies owning only one ship that is mostly manned with the entrepreneurs and their family members. A small part of the companies is part of a cooperation. The other 10% are ships that are owned by a shipping company owning more the one vessel.

In the entire Danube vessel fleet the share of non-propelled barge is high, up to 64% in 2016. The oldest vessels have an age of over 80 years. The high average age of the fleet as well as the low level of technology on board will require significant investments in fleet modernisation. Due to a high share of pushed convoys containing a large number of non-propelled barges the implementation of smart shipping concept and navigation assistance systems is hard to achieve.

Figure 2.6. Composition of the dry cargo fleet per Rhine Country

Fleet	Small vessels (≤ 1,500 t)	All dry cargo vessels	Share of small vessels
Dutch fleet	1,796	3,434	52%
German fleet *	1,097	1,525	72%
French fleet	761	977	78%
Belgian fleet	537	978	55%

Source: The Central Commission for the Navigation of the Rhine (CCNR) (2021)

Liquid cargo vessels
This submarket has a more specific characteristic. The fleet is relatively modern, and the ships are generally big(ger) (>1.500 tonnages). In the Rhine region, the tanker fleet is the youngest fleet segment with 52% on the tankers being built in the 21th century. In comparison: for dry cargo vessels this is 16%.[11] The fleet is relatively new because of the mandatory phasing out of single hull ships, which led to investments in new ships and phasing out of older ships.

In contrast to the dry cargo fleet, much more shipping companies are active in this subsector. Another difference is the relative small spot market. Most contracts exist of time charters of permanent contracts for a year.

2.3 Investment capabilities

To make use of the technological developments and profit from the (financial) benefits of this developments, investments are needed. Both on board of ships and on the infrastructure. In chapter 3.4 more information in given on the nature of the investments and the general cost involved for both sides.

But to be able to invest, business will need the financial possibilities to do so. These possibilities differ between different segments of the inland waterway sector. A general overview will be given here to illustrate the challenges for investments. This information can be used in the consideration what the role of authorities might be in investments that are necessary for the implementation of smart shipping development throughout the sector.

Dry cargo
The general assumption is that the financial stability of this shipping companies is bigger than the (small) family businesses and with that the investment capabilities as well.

Another important factor that influences the investment capabilities is the type of contracts that is used. In the Netherlands, 60% of the dry cargo fleet is making use of the spot market. Which means that inland shipping companies, charterers and shippers negotiate prices and conditions for each individual shipment. Prices are volatile and depend of aspects such as the balance between supply and demand and water levels. Another type of contract is the permanent contract. Generally, with a commitment of one year. Permanent contracts will generally offer the inland shipping company a more stable income than the spot market. The last type of contract is the time charter, common for container transport. This type of contract uses fixed (day) prices. This type of contract often accounts for a stable income as well.

[11] Central Commission for the Navigation of the Rhine (CCNR) (2021). Annual report 2021.

This, together with drop in demand due to the Covid crisis and still recovering from other crisis (2009-2013) [12][13] makes that the financial position of much of the subsector is weakened. As a result of that, the investment capabilities are very limited, especially for entrepreneurs that are depending on the spot market. Ship size plays a role in the investment capacities as well: entrepreneurs with smaller ships have limited fixed costs but insufficient earning capacity, while the opposite applies to large ships. There are some parties that do have room for investment, often this concerns shipping companies with more stable income positions. But in general, the invest capabilities will be limited.

Liquid cargo

The financial position of shipping companies in this subsector was (up to 2020) generally good.[14] Although it is expected that the market for fuels will decrease in the next couple of years, the outlook for other segments of this subsector such as edible oils are good. Currently, the investment possibilities for this submarket look relatively good. The fleet is modern as well so there is little urgent need for big investments e.g. on engines. This makes the investment possibilities for other aspects bigger than in the dry cargo sector. Especially when these investments can be combined with measures to meet policy goals regarding limiting the emissions.

[12] Panteia and Ecorys (2021). Economische effecten smart shipping.
[13] Central Commission for the Navigation of the Rhine (CCNR) (2021). Annual report 2021.
[14] Panteia and Ecorys (2021). Economische effecten smart shipping.

3 Description of the current situation

3.1 Introduction

Although smart shipping is a relative new phenomenon for the IWT-sector, there are already systems in development. Some started outside the sector, others where especially developed for inland waterways, not always aiming at smart shipping.

To give an overview of the current business developments, several aspects will be described. Consecutively the business value, technical state of affair, operational and organizational issues, financial aspects and regional differences will be described. Attention will paid to both the logistic sector and the authorities. This allows for a conclusion on the level of digitalization for this business development.

The different aspects above will be viewed from a perspective of the logistics sector and the authorities. If the views on a certain topic differ, this will be mentioned.

3.2 The business value of smart shipping

The 'business' value of smart shipping developments for the logistic sector and for fairway authorities is an important aspect to start with. Without any business value, the need for smart shipping solutions will be zero. Business value can mean different things. For this study business value is defined as: 'the (added) value of a product for a business or in case of the fairway authorities for society.

Solution for staff shortage

Staff shortage is a real threat for the IWT-sector. Due to aging of the current labour force and the limited interest of young scholars to choose a profession on board of a ship, staff shortage will grow in the next ten years. Estimations in the Netherlands assume a decrease in staff of up to 25% by 2030.[15] Since a growth of total transport volumes is expected and a modal shift from road to IWT is desired, a growth of the transport volume for the IWT can be expected.16 This makes the staff shortage even more urgent.

The recruitment of future captains and crew members is a known issue on the Danube as well. Several training programs were already started to on board and attract young professionals. By introducing new concepts work in IWT can be made more attractive: replacing unpleasant tasks by machines or controlling a vessel from a shore control centre – making it possible to live with your family on land. An increase in the level of automation might also help to easy the access for new less experienced employees.

Sailing drones can be extra attractive performing 'dull, dangerous or dirty' jobs. Work that people rather would not do or where the risks are high. Development of these systems make certain work possible again with less cost involved. These sailing drones are often not used to transport cargo (these days) but to do surveys for example. In these types of jobs, sailing drones make it possible to make work cheaper or reach places that are not reachable with manned ships. Besides that, staff shortages plays a role here too. Manned ships often need a crew of minimum two personnel, where drone are often controlled by one person (or if it becomes possible by regulations without a person).

Increasing sustainability

The social desire for more sustainable transport is a driver for innovation, for example in inner city distribution by barges. Sustainability goes hand in hand with digital innovation. The European Green Deal aims climate-neutral transport in 2050.[17] For all modes of transport this means a significant reduction of emissions. For IWT, apart from (new) clean forms of propulsion, further digitalization is part of the solution. Experiment with 'smart shipping' systems that support the skipper in sailing the ship, showed a reduction on the fuel consumption. Corridor information services provided by fairway

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[15] Based on review of the Dutch Smart Shipping Forum, see Dutch Smart Shipping Forum Roadmap (2021).

[16] Based on the Dutch Smart Shipping Forum Roadmap, a shared vision of commercial parties, knowledge institutes and authorities on the vision on smart shipping in the Netherlands. This vision is made with 17 organizations and tested in a wide reference group.

[17] EC (2022). https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_nl

authorities for example on traffic situations that are incorporated into decision making support systems can help to optimise travel planning. Research showed that this can reduce emissions by at least 7%[18]

These innovations could also help in making inland shipping more resilient in fast changing circumstances due to climate change (low water periods for example). Dealing with long periods of draught and other periods with high water levels. Smart shipping solutions could help to adapt to these circumstances, for example optimizing route planning and navigation aids.

Staying competitive
Innovation in the transport sector made transport more transparent, cheaper and faster. Enabling users to track their goods around the globe. Innovation also helps in making transport more sustainable, for example by introducing alternative fuels or new transport concepts such as truck platoons. These development in other transport modes make these modes attractive, introducing the concept of reverse modal shift.

Combined with the impact and uncertainty that climate change can have on the inland waterways, this is a development that has to be acknowledges to make sure that IWT stays competitive and attractive. The mix of transport modes is essential for a smooth functioning transport system. Smart shipping solutions have the potential to ensure that IWT stays competitive: lower the cost by reducing operational cost, contribute to increasing sustainable transport and incorporating information services to become more resilient.

Maintaining safety
As a result of the increasing use of the waterways for other purposes besides navigation, more attention needs to pay to safe navigation. Smart shipping development might help increasing safety by adding warning systems or automated systems that allow ship-ship communication to coordinate navigational decisions between different ships, or even limit casualties in incidents simply because the ship is unmanned. How these developments will work out must be shown in practice, however.

The table below gives an overview of the most important elements of the business value of smart shipping for the inland waterway transport sector.

18 Witteveen & Bos (2021) Corridormanagement en duurzaamheid. On behave of Rijkswaterstaat.

Table 3.1. Business value for individual stakeholder groups

Stakeholder/reason	Staff shortage	Increase sustainability	Staying competitive	Maintaining safety
Authority	Important for a well-functioning sector	Policy goal	Economic value of the shipping industry, balance in modal split, relief overcrowded highways	Policy goal
Skipper	Necessary to stay in business	Customer needs, comply with regulations	Necessary to stay in business – lower cost	Economic aspect
Logistic party (terminal etc.)	Important to have options	Same as skipper	Reliability for optimal service – lower cost	Requirement
Ship builder/developer	-	Costumer requirement	European shipbuilders might be able to compete with other regions by specializing in this niche.	Costumer requirement

3.3 Technical development

The technical development of smart shipping systems is ongoing. Some sailing tasks are already supported or replaced by automated systems. Other developments focus on developing solutions for survey purposes. The CCNR started with an overview of the development in 2018[19]. Research, developments and experiments regarding further automation of navigational tasks and remote control or autonomous navigation are taking place. Despite these experiments, there are many uncertainties on how new technology that is used for smart shipping will impact the inland waterway sector. This paragraph will give a generic overview of the technical services and processes that are implemented and what the technical issues are that should be overcome to make these services and processes ready for widespread commercial use. This overview will give insight in the need for services from the side of the fairway authorities and the way these services will be able to contribute to the adoption of new technologies.

To know what systems and processes will be implemented, it is useful to know how mature developments are and on what level of autonomy they work. Nowadays we see that, generally speaking, the developments that are more mature do function on a low level of autonomy. These systems have been put into place mainly to support the captain in navigational tasks. However on the long run, new products can be built on those existing products.

3.3.1 Overview of the developments in the logistics sector

The current developments are divided into three categories: development on board of inland ships, remote control and new concepts (incl. drones).

Developments on board of inland ships

The products that are developed for use on board of ships are mainly focused on assisting the skipper in sailing tasks. These product are aimed at making sailing safer, more sustainable, more comfortable or more efficient.

Quite a lot of products focus on providing more or better information towards the skipper to support the decision making process. These are the products that belong to the sensing and state estimation category introduced in chapter 2. This category of products use existing information on board of the ship, for example provided by means of GNSS, AIS, radar, LIDAR, ECDIS, and systems on board that measure the rudder angle, power etc. to acquire information. External information, for example

[19] Central Commission for the Navigation of the Rhine (CCNR) (2018). https://automation.ccr-zkr.org/1000-en.html

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provided by RIS-services can be acquired as well. The information that is used, depends on the tasks that are supported. Navigation through a lock with assistance of systems requires other or more detailed information than navigating a straight stretch of fairway. To gain data that isn't already available, new products are developed that support in the information needed. Examples of such systems are bridge height detection systems, more detailed maps using new mapping technics (e.g. LIDAR) or cameras.

Track Pilot Assistants products go a step further and use information to sail the ship. The system creates a route including a track on the fairway, using information about the current state of waterway. Some systems already take into account other users of the fairway as well. The 'smart shipping' part here is that these systems are dynamic, taking into account real time information to keep the ship on track. Track Pilot Assistants can be considered the start of some form of automated sailing. New functions can be introduced using these functions, like collision warning, automatic overhauling of ships and adapting tracks based on actual water depth information.

Remote control
In case of remote control services, the control of the ship is done in a control center on shore. Certified skipper can take over the control of the ship, navigating it in the same way that a skipper on board of the ship does. To do so, the data and information that is available on board of the ship is needed.

Remote control is already applied on several ships for crew supported navigation making it possible to expand vessel capabilities, extend navigation times or optimize efficiency.

New shipping concepts
The introduction of new techniques makes it possible to completely redesign the ship. For example, when only small instruments have to be carried and manning is no longer required, the ship can be designed much smaller. It will give these sailing drones new possibilities, like continuing operation for a long period or sailing waters with limited depth.

Most of these drones are not able to carry any human on board of the ship due to their size. This can be problematic if legislation forbids sailing without a human captain on board. It can be expected however that legislation will be changed to make safe use of these sailing drones possible.

Apart from the drones described above, new techniques making it possible to sail without manning aboard will make it possible to new ship designs for shipping of cargo as well. Not only because the wheelhouse and the lodging of the manning can be taken from the ship. With the labour costs limited using smaller ships can become more feasible the nowadays, making it possible the use small ships on small waterways economically.

Another example of a new concept is the vessel train (developed in the NOVIMAR project): systems on board of the leader and following ships making it possible for the following ships to stay in the same track as the leader ship.

3.3.2 Analysis of the development in the logistic sector

The previous paragraph gave an general overview of the current developments. Looking at the developments in the sector, especially on the side of developers of products, there is a pattern that can be recognized.

Development of navigation supporting systems started long before the term smart shipping was introduced. As an example, the gyro pilot can be mentioned. This device might be seen as an automatic pilot keeping a predetermined course. Since long ago in sea shipping 'way points' were used to navigate. Current developments are built on these systems to let them evolve gradually towards more automated systems that offer more dynamic assistance and eventually may act as the basis for far reaching automation.[20] These developments are modular as well. Making it possible to implement new developments or updates along the way. A few examples were already mentioned: collision detection, warning and avoidance systems, systems that track static or dynamic objects and use this information for navigation advice to the skipper.

[20] Potgraven and Lange de (2021). Syllabus Smart Shipping.

This is a sharp contrast to the first years of smart shipping: the concepts and ideas in that period where far more disruptive. There were more concepts that focused on full autonomy. These ideas still exist, mainly in research and developments projects. But the developments that are more market ready, are those that evolving gradually out of existing systems. Smart ships are best seen as a further evolution of already existing subsystems of a ship, which together constitute an (autonomous) vessel.[21]

This finding can be explained with the example of the NOVIMAR project. A research and development program looking into the possibilities of introducing a vessel train concept. A concept looking much like the same examples on the road, where the first ship/truck is navigated by a skipper and several other ships follow that lead vessel (with a reduced number of crew members which have more time for other tasks and take over only when required) on board. Making a train of vessels on the waterway. This idea is quite disruptive, but the systems on board to make this technically possible are further developments of existing systems such as a track pilot which is made 'smarter'.

As we have seen, much developments in inland shipping take a gradual approach. Sailing drone developments often take a more disruptive approach. As described earlier, drones are often small vessels which are not designed to facilitate a skipper on board of the vessel. Therefore, the design is much different from many existing ships. Technology on board has to facilitate that the navigation tasks are not performed on board of the ship. Of course, also for these developments, gradual development of the initial design is possible.

Technically, a lot is already possible. But applying this in a dynamic environment in a continuous safe way, is still hard. As one of the stakeholders mentioned: 'We are able to sail fully autonomous in static and known environments, but whenever interaction between dynamic, unknown actors/objects is required, the level of autonomy decreases to 0, 1 or 2. Even if a vessel is able to detect, and account for, dynamic obstacles, it is generally not safe yet to allow for fully autonomous operations. There is often too much unpredictable, non-standard, and/or non-validated behaviour and decision-making.'

Another aspect is the market uptake. Developers and researchers see potential in further digitalisation of the navigation tasks. Digitalisation is always part of any vision or outlook towards the future in IWT. But this doesn't mean that every inland waterway vessel will be automated in any way. This doesn't have to do with unwillingness or ignorance, but the fact that digitalisation is not always favoured or possible. As we will see later on, digitalisation of the navigational process needs investment. Whether that investments pays off, depends on many factors. So technically, every ship could be automated, but we will have to deal with a mixed fleet for a long time. This has consequences for the way in which the (digital) infrastructure should be designed. When looking at the needs for proper functioning of systems, data is at the front of the developments. Sensing is key for any development.

In addition to that: on waterways there also is recreational traffic. Since much of the joy of sailing is the sailing itself, fully automated recreation vessels is not something that can be expected. Nevertheless we expect to see that for safety and comfort reasons the level of digitalization in recreation vessels will rise as well.

3.3.3 Technical challenges on the side the logistic sector

Many of the technical challenges are related to facilitation topics: data quality, standardisation & harmonisation of data, communication and cyber security. More general challenges are mentioned in this paragraph.

Implementation of smart shipping solutions in the inland waterway sector could be challenging because:

- The technical depreciation period of ships (especially inland waterway ships) can be up to 50 years or more. This makes innovation challenging implementation of state of the art techniques takes a long time. This is where retrofitting comes into place: placing new systems on existing ships. This is complicated however due to the large amount of different systems and different ships not being interoperable.

[21] Smartport (2019). Smart ships and the changing maritime ecosystem.

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- Lack of sufficient industry standards: connecting new systems on hardware that's already into place is difficult and most situations will need custom made solutions. This doesn't help the business case because cheap(er) 'of the shelf' solutions in higher quantities cannot be used.
- Digital communication, between ships and shore has its difficulties: 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). Currently no agreed standards are applicable (in comparison with C-ITS on the road).
- Ships that were built before the year 2000 are often equipped with analogue sensors. These sensors do not transmit signals digitally needed for the new digital 'smart shipping' systems to be used. Conversion of those signals will be needed, but even then this is not ideal.
- There is a lack of performance standards. The components present are often not intended to function in an integrated system with components from other suppliers. This can have technical causes, next to that there is also the fact that suppliers are protecting their market. We see that product suppliers sometimes are very reluctant to share information that makes it possible to connect to their product.
- By linking new third-party systems to existing systems, the supplier of the old systems can decide they will no longer fulfil the warranty and other contractual obligations.
- There is a lack of availability of data across a corridor and a lack of meta-data to verify the quality of the data for use in smart systems.

3.3.4 Overview and analysis development in the authorities

In the current situation there are several aspects in which a fairway authority can facilitate the development of smart shipping. Authorities have, and are willing, to share quite some information (EuRIS portal, RIS COMEX). Several endpoints to retrieve data are available and documented. This is not always known by external parties, who therefore assume that information is not available. At a first glance, quite some information is available to share, making it possible to sharpen the picture of the environment (perception), facilitate the execution of goals and help in the planning of this execution.[22]

Here are some examples of data and information that already are available. Remote operations and systems providers for autonomous vessel can use the data provided via websites and machine-readable interfaces (API's), for example in route and voyage planning:

- Fairway network
- Dimensions
- (virtual) Buoys
- Sailing speed (and maximum speed?)
- Bridges
- Locks
- Operating times
- iENC

During the trip, automated Requested Time of Arrival messages can be made available when a vessel approaches a lock.[23] This leads to reduce the speed, reduce the emissions, safe fuel and may even increases the profit. When the ship waits to enter a lock, automated "gates open, lights green" signals can be transmitted[24], as well as automated Object Access messages that inform a vessel operator about the assigned position in the lock basin[25]. The "gates open, lights green" signal can also be transmitted when preparing to leave a lock after levelling is complete.[26] The lights green signal can also be transmitted for movable bridges.[27]

Should an incident occur during a trip (e.g. blockage of a lock) or temporary measures encountered (e.g. speed reduction due to diving operations), the automated and corresponding Notices to Skippers

[22] There are some technical challenges in sharing this information (across national borders). These challenges will be addressed in the next paragraph regarding operational and organizational challenges.
[23] Currently limited to fairways in the Netherlands
[24] Currently limited to fairways in the Netherlands and Austria
[25] Currently limited to fairways in the Netherlands
[26] Currently limited to fairways in the Netherlands and Austria
[27] Currently limited to fairways in the Netherlands

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(NtS) message can be processed to compute a new optimal route and recalculate the ETA's along the route. An additional advantage of these automated data provision services is that they are EU standardized and will be available via the central EURIS portal, expected to be operational in 2022.

For low or high water periods there will be depth information of the fairway available facilitating the optimization of the route and the draft. The added value of this information depends on the availability, Smart shipping needs information/data of the inland waterway and the fairway. For this there will be AtoN's delivering information about digital/virtual buoys, safety areas, maximum speed zones, danger zones (low bridge clearance, etc.). This information can be by send via AIS-technology.

3.3.5 Technical challenges for fairway authorities

Many of the technical challenges are related to facilitation topics: data quality, standardisation and harmonisation of data, communication and cyber security. These topics are elaborated in the next paragraph. Other relevant challenges related to the technical development for fairway authorities are mentioned below:

- Communication standards: the input received in this report suggested that stakeholders in IWT expects the authorities to take the lead in formulation of communications standards for ship-ship communication and ship-shore.
- Often quite old infrastructure and systems: this might limit the possibilities to share information on for example the status of an object because the necessary sensors or systems to do so are not in place.
- In general authorities are reluctant to adopt new technologies that haven't proven themselves.
- Large network that spans a big geographical area. Because of this, the availability of data differs. And solutions to tackle challenges may not always be applicable to all part of the international network. Efforts to make more data available can be expensive, if possible at all due to the size of the total European waterway network.
- Data quality: sometimes authorities don't know the quality of our own data which makes it quite hard to know if it can be used by others for their specific purposes. Because there is a lack of (reliable) data, information must be interpreted. This interpretation process requires expensive systems and is complicated to do. With that hindering the fast and smooth implementation of systems. Example: if the navigational bridge height isn't shared by the fairway authority (or this is done in different ways or compared to different reference water levels), there is a strong need to verify the bridge height by other means. These means can be expensive, and therefore not implemented by companies because the business case does not support the investments needed. The implementation in this case can be helped by for example sharing the information or helping the interpretation by for example installing reflectors on bridges.
- Several parties indicated that there will always be a need to gather their own input, regardless of the information that will be provided by external parties. This has to do with redundancy.
- Translate legislation and guidelines into clearly formulated, non-ambiguous (traffic rules). When the sailing process becomes further automated the traffic rules have to be programmed into the smart shipping systems. These traffic rules can only be taken into account safely by the systems when they are not multi-interpretable.
- Sharing all available information in a machine-readable way.

3.4 Operational and organizational challenges

3.4.1 Introduction

As mentioned before, technically a lot is already possible. This doesn't mean that all developments are market ready or can be used throughout the whole network of waterways across Europe. The main topics that hinder the wide spread use of smart shipping technologies are described here. Although it must be clear that tackling these challenges, will not mean that all developments will be adopted. One of the most important factors in this process of adaptation is the business case: there has to be a return on investments. All developments, regardless of how safe, sustainable or innovative they are, will only be adopted if they are beneficial to the business operation of actors in the supply chain. The topic of economic feasibility will be described in the next chapter.

3.4.2 Challenges related to the facilitation topics

Standardisation and harmonisation

Standardisation is seen as a basic need to make sure that navigation can be done in a safe way. Proper standardised data models are required, or at least a minimal agreed representation of actual situations, navigational data, in order to be able to enable higher levels of automation in dynamic environments between various operators and actors. This is seen by one of the users as the 'common ground' for safe and explainable decision-making.

Standardisation and harmonisation is also related to data formats. Especially when system-system communication increases. If data input isn't standardized and the way in which data is delivered not harmonized, exchange of data between systems becomes hard and less reliable because some data will be lost. To exchange data, standardisation of communication protocols is needed as well. Making sure that data exchange is possible throughout corridors.

Cybersecurity and privacy[28]

As the development and use of smart shipping systems increases, the need for data will grow. Some of this data might be privacy sensitive. Because information services that are developed with other use than smart shipping in mind, can be input for smart shipping product, it is important that agreements made on sharing certain kind of data apply as well for use in other products. So for all users it should be clear if data is provided for the use by others as well. Sharing privacy related information should only be done with consent of the information owner.

With increasing dependency of connectivity between systems and infrastructure, the vulnerability to cyber security threats grows as well. Malicious persons or organizations could abuse this to wilfully share and communicate wrong information, threatening the security on the waterways. For example false AIS tracks: if they are used this could compromise the level of safety on the waterways.

The responsibility for cyber secure systems lies with the skipper of the vessel, the builder, supplier and installer of equipment on the vessel. The waterway authority is responsible for the cybersecurity within its own domain, for example no do distribute infected ENC's.

Cybersecurity is recognized by users and developers as an important aspect to take into account when developing new products. Clear technical requirements, especially related to smart shipping products are still in development at the moment. Therefor the current level of safety is based on the efforts of developers to make their products as save as possible.

Legal and regulatory

For an overview of the main legal and regulatory challenges related to smart shipping, the input is mainly received for IANC WG 210 report[29]. For a more in-depth description of the policy areas that might require adaptation the PIANC WG 210 report, chapter 3, gives a broad overview. The analysis of the legal and regulatory framework was completed at the beginning of 2021. This report researched several policy areas that might need to adjustments to make highly automated sailing legally possible on inland waterways.

Current legislation, both on a National and European level do not take into account highly automated ships. This prohibits a crew reduction on board of a ship when using smart shipping products. This doesn't mean that these product can't be used. On a national level experimenting with smart shipping is possible in several countries, some of them within the existing regulation, in other countries experiments can be excepted from normal legal rules. Restrictions and measures to ensure safety and to limit hindrance of other fairway users do apply.

The main challenge for highly automated sailing on inland waterways is the fact that legislation states that the skipper must on board of a ship. In national regulations and regulations of various river commissions a lot of the provisions are related to the presence of someone on board of the ship. This makes it legally not possible to sail with less crew on board of the ship. It also means that after

[28] Bolbot, V. et al. (2019). Safety related cyber-attacks identification and assessment for autonomous inland ships.
[29] PIANC (2022). InCom WG Report 210. Smart Shipping on Inland Waterways. Version 1.0

changing the law, for each task that the manning now has with respect to the law, an alternative has to be created.

The employment of captains and crew members on inland vessels has a limit. The working hours are limited to a certain number in a day. The composition of the crew on motorized cargo vessels, push boats or convoys depends on the size and equipment as well as on the operation structure. The points just mentioned are regulated by national legislation along the Danube. The crew prescribed for the respective mode of operation shall be on board the vessel at all times during the voyage, considering the rules for working and rest times.

Besides legislations, the current technical requirements don't take into account the smart shipping concept and their possible new technical needs. As the PIANC WG 210 stated: 'The ES-TRIN standard contains provisions on the construction, fitting and equipment of inland navigation vessels, special provisions for particular types of vessels, provisions on the model inland navigation vessel certificate and instructions on the application of the technical standard. All the provisions must be evaluated from the perspective of smart shipping'[30]. Smart Mobility on the road looks into a 'driving license' for autonomous vehicles, describing what a vehicle should be capable of. This concept is not yet know for the inland waterways. Related to this aspect: if something goes wrong and causes an accident while using a smart shipping product, responsibility and liability are not yet clear.

Earlier in this document, the communication between vessels and the communication between vessels and authority was reviewed from a technical perceptive. This communication is also part of some regulations. Currently these regulations also require a skipper on the ship. Besides this communication, other communications, such as RIS, might need to be adapted as well. The EU Directive 2005/44/EC and the RIS-standards are examples of standards that do not take into account highly automated sailing. Besides other documents that state traffic rules for example.

Work on evaluation all this standards and document has already started at several places, in the maritime world (IALA and IMO) but also on the inland waterways as well. As an example, below the vision on the CCNR is shortly introduced to underline the current work on this topic.

An example: the CCNR's vision to support the harmonized development of automated navigation.
To show the work that is already done on adapting the current rules and regulations to a future with more automated navigation a brief review of the vision of the CCNR is used as an example. This is done with the knowledge that other regulatory bodies are working on similar adaptations.

The Central Commission for the Navigation of the Rhine (CCNR) believes that automation implies a fundamental change for inland navigation and will affect most aspects of navigation. In their approach, they take into account the legal, ethical and social aspects. [31] *The CCNR started with the creation of a framework for authorization of pilot projects that require temporary derogations from existing regulation.*

'Given the cross-sectoral nature of automation, the CCNR considers it necessary to develop simultaneously the requirements for the operation of vessels, the training of personnel and the composition of crews, as well as the technical requirements for vessels and those relating to information technology and liability. To this end, the CCNR will update its own regulations (RPNR, RVBR, RPN) and also propose to the European Committee for drawing up Standards in the field of Inland Navigation (CESNI) the development of any standards it deems necessary to ensure the safety of navigation and to allow the harmonisation of regulations on a European scale. The CCNR has already made a start on the work required, in the knowledge that regulations to ensure the safety of navigation will also contribute to greater legal certainty for investments' stated the CCNR in their press release.[32]

[30] PIANC (2022). InCom WG Report 210. Smart Shipping on Inland Waterways. Version 1.0
[31] Central Commission for the Navigation of the Rhine (CCNR) (2021). Summary of the CCNR's vision to support the harmonised development of automated navigation.
[32] Central Commission for the Navigation of the Rhine (CCNR) (2021). Summary of the CCNR's vision to support the harmonised development of automated navigation.

At first the focus of the Small navigation Committee (RN), which is revived to tackle the challenges posed by automated navigation, will be on the minimum requirements and recommendations for inland navigation guidance aids for level 2 automation. This work than will be followed by further work for level 3 automation. Part of this work is to establish minimum requirements for track control assistants (TCA). These are systems that are used already in inland navigation although there a no rules yet on the use of these systems. In tie these systems could be used for further automation of inland vessels.

Data quality
As already described earlier, automation of the sailing process on board of a ship, requires information from different sources and systems. This is regardless of the level of automation. Although not all information is already availed, some is. With respect to the quality of that data the accuracy, completeness and availability play an important role. As the level of automation rises and the role of the human in the loop decreases, the importance of making sure that the data is correct increases. Besides high data quality, this also means more redundancy as reliability become even more important.

The three above mentioned parameters can be split. Some examples, based on the report of PIANC WG 210 are presented below.

Table 3.2. Overview of data quality indicators

Availability	Completeness	Accuracy
Update rate of ECDIS map is too low (e.g., more frequent update of buoy positions is needed);	Bridge contour lines in ECDIS map	The required data accuracy or correctness depends on the purpose for which the data is needed. Accuracy needs to be much higher for mooring than for other applications, for example. Data about the water and weather conditions needs to be more accurate around locks and bridges than on a broad, straight waterway section. It's important to know or measure the data accuracy or correctness. On the one hand, control mechanisms for the correctness of e.g. On the other hand, it's also important to add accuracy level information to the data (e.g., in the ECDIS map, AIS track evaluation, etc.).
Accurate forecasts of water levels on all waterways	Water depth;	
	Absolute heights for all objects;	
	Information on critical cross flows (distribution of flow velocities in cross-sectional profiles, or average flow velocities related to all relevant statistical water levels).	

Source: based on PIANC WG 210 – Final report – 15 December 2021 and addition based on the inventory analysis

The table above is just an example for the three mentioned data quality indicators. More aspects might be needed. Different systems and situations can require different data quality as well. Conversations and workshops with developers didn't lead to clear and specific parameters such as: 'the accuracy of AIS data should be X cm'. Related to these aspects is the quality of the meta-data. To use any data, the quality of that data must be known. Users must be able to check the quality and account for that. As one of the developers stated: "As long as they are known, systems are able to cope with potential losses of data, or bad connections, or limited quality (e.g. due to bad calibrations)."

Another aspect that should be mentioned is that there is a strong tendency to look at the currently availed data. So in the example of positioning data often AIS is mentioned as a source. AIS wasn't developed to be used for smart shipping. Therefore it should be investigated whether new ways of sharing and gathering data could fit the need that arises from the development of smart shipping solutions. An example of this is a research that is done in the Netherlands on 'intention sharing'. This research looks at the possibility to share not only the current position of a ship but also the course of the ship in the upcoming few minutes (more specific the location of the ship in the near future in time). It is a nice example of new types of information that can help a lot, since it will not be necessary any longer to calculate the behaviour of the other ship,

One last aspect that should be taking into account when looking at the (needed) data quality is the investments that are needed to update the quality of the data versus the use of the data. When investments that are needed to reach the required quality exceed the expected business value towards the users, other solutions should be investigated. The distinction between navigational tasks is an important factor when looking at the needed data quality. A task such as passing a lock or mooring is depending on much more accurate data than navigating a straight stretch on a canal.

3.5 Financial impact and challenges

This chapter will discuss the economic impact and success factors of smart shipping, based on several verified assumptions that were made in research done in the Netherlands, Flanders as well as case studies carried out within the project NOVIMAR.

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Recent studies[33] indicate that the Rhine and Danube corridors differ in several aspects such as business structures and vessel types. A further aspect are wages, which are significantly lower in the Danube corridor, as crew cost reductions are one of the main economic benefits of smart navigation. On the Rhine family-owned vessels are navigating with family members as employees. On the Danube, external crew members are to operation at an enhanced operating regime. It was found that mobile workforce increasingly leaves for employment in the Rhine region to obtain higher wages. Furthermore, the fleet composition differs with only 18% self-propelled barges on the Danube in comparison with 78% on the Rhine. The share on the Danube increases as barges are replaced by second hand self-propelled Rhine vessels. The Rhine including its tributaries crosses a densely populated region with much shorter average transport distances amounting to 200 km compared to 600 km on the Danube resulting in a higher density of cargo and traffic. Shallower water conditions on the Danube lead major navigational bottlenecks and lower travel speeds.

To be able to implement innovations in smart shipping, it is crucial that they are economical feasible: the investment can only be done if it will be a profitable investment. To calculate the effect of implementation of smart shipping technology in inlands shipping, the advantages on the business operations of inland shipping companies can be divided into:

- Cost reduction
- Extra revenue

Cost reduction

Inland shipping is quite a labour intensive activity, about one third of operational costs are related to the manning of the ship. That makes reducing manning is a logical target for automation. With the labour market becoming more challenging in the coming years with the aging of the current profession, the relevance will even grow in the near future. This raised the question what kind of automation an inland ship will need to become less labour intensive.

In two different studies carried out in the Netherlands and Belgium, outlooks were made based upon existing business models of inland shipping companies.

The research carried out by Panteia en Ecorys[34] is based on three development paths, all aiming to reduce manning to a larger extent:

1. Partially automated sailing on certain (easy) stretches in the waterway.
2. A second scenario where the passages of locks was included.
3. A third scenario where it was also possible to sail on smaller waterways including automated docking at the destination. For each of the scenarios the cost for investments on board of a ship and on the side of the fairway authority where estimated for a period of 30 years. The cost included the initial investments and the maintenance cost in the years that follow the initial investments.

Based on information of stakeholders, the cost for investments in the necessary equipment on board can roughly be estimated to be €100.000 in scenario one, €200.000 in scenario two and €1.000.000 in scenario three additionally.

The investments that need to be done by the fairway authorities in the Netherland (for the whole network including the network of other fairway authorities besides Rijkswaterstaat) where calculated as well. Development path 1 requires a total expenditure of 114.2 million euros. This consists of 33 million euros in initial investments and 81.2 million euros maintenance cost up to 2050. The total expenditure for development path 1 and 2 amounts to 856.8 million euros, consisting of 114.2 million euros in investments and 742.6 million euros maintenance cost up to 2050. Compared to development path 1, the required additional expenditure for development path 2 is estimated at €742.6 million. The total expenditure for development path 1, 2 and 3 amounts to 1,024.4 million euros, consisting of 154.6 million euros in investments and 873.8 million euros maintenance cost up to 2050. Compared to development path 2, the required additional expenditure for development path 3 is estimated at €171.7 million. The social benefits and benefits for users where calculated as well. Examples of social benefits of smart shipping are: less emissions (by reducing the use of fuel), less congestion on the road (modal

[33] "A comparison of the application potential of waterborne platooning for the Danube and the Rhine corridors": Colling et al.; 2022 European Transport Research Review

[34] Panteia and Ecorys (2021). Economische effecten smart shipping.

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shift towards IWT) and increased safety. Which in total contributes to a sustainable and competitive transport system. The overall impact is shown in table 3.3.

Table 3.3. Economical effect per scenario

Type of effect	Effect (Million EUR)		
	Scenario 1	Scenario 2	Scenario 3
Economical effect Dutch IWT-sector	841,1	1.378,6	1.419,8
Balance investment authority	-94,9	-591,3	-656,1
External effects	177,2	277,7	368,3
Overall balance	**923,3**	**1.064,9**	**1.132,0**

Source: Panteia and Ecorys (2021). Economische effecten smart shipping

The table describes:

- The total economic effect on the Dutch IWT-sector: the financial benefit of investments regarding smart shipping and is a combination of increased transport and savings on crew cost and fuel.
- The balance of investments by authorities: the amount of investments done by authority in each scenario.
- External effects: the monetisation of external effects such as lowering of emission's and modal shift towards IWT.

The research concluded that smart shipping could be beneficial to society and that certain investments will pay off. Socially speaking but for the commercial users as well. Table 3.4. shows the potential market uptake of developments in the Dutch IWT sector, based on the economic effects shown in table 3.3. The table shows how many ships of the total Dutch fleet are expected to invest in smart shipping development in each scenario (after investments by the authorities are made). This table shows that the combination of investments by authorities and the benefits leads to the biggest market uptake in scenario 2. This has to do which the increased cost of investments on board of the ship in scenario 3 which make the investments less profitable.[35]

Table 3.4. Potential market uptake per scenario

	Scenario 1	Scenario 2	Scenario 3
Amount of ships	463 (19%)	67 (3%)	104 (4%)
Amount of ships	0	687 (28%)	558 (23%)
Amount of ships	0	0	36 (1%)
Total	463 (19%)	754 (31%)	698 (28%)

Source: Panteia and Ecorys (2021). Economische effecten smart shipping

Extra revenue

In Flanders in 2021[36], there was also research done concerning the financial and economic impact of smart shipping. This research was led by EY and fully based upon the scenario of implementing remote sailing on inland waterways by controlling the ship from a shore control centre.

The difference in cost was calculated between 12 kinds of "regular" ship and their smart shipping equivalent on 7 different trajectories. Difference was made between the way of exploitation (sailing during day versus continuous sailing), CEM-T class and type of goods.

The conclusion of the research was that the possibility of reducing costs with smart shipping varies for the size of the ships, the type of exploitation and the type of freight carried, thus more or less confirming the Panteia survey outcome.

However, automation gives the ship-owner the possibility to sail continuously, giving small ships now sailing only during day hours or semi continuously the possibility to sail continuously at limited extra

[35] Panteia and Ecorys (2021). Economische effecten smart shipping.
[36] EY Consulting (2021). Wat is het potentieel voor Smart Shipping in de Binnenvaart?

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costs. The extra revenue made contributes largely to the profitability of using smart shipping techniques.

Business case evaluation NOVIMAR project
Within the H2020 project NOVIMAR several case studies were conducted investigating the business values of a smart vessel platooning concept, where a number of follower vessel with a reduced number of crew members are guided by a lead vessel equipped with navigation and control systems taking over the situational awareness and navigation responsibility while sailing in the platoon. The main intended cost benefit is reduced cost through a reduction of the size of the crew. This should not only lead to a modal shift from road to inland waterways and short sea shipping, but also allow inland navigation to become profitable in small waterways and urban areas, where it now often cannot compete with other modes. Additional expected benefits are improvement of safety and reduction of emissions. Potential business cases for the application potential of waterborne platooning were elaborated for the Rhine and the Danube corridor as well as for short sea shipping.

In the Danube region several key parameters for the profitability of a smart shipping system were identified in the investigation of the ship-platooning concept. The following success factors can be highlighted:

- An implementation of Smart Shipping is more attractive in areas with high traffic and cargo density because the investments and required improvements of infrastructure are more cost-effective there due to economy of scale.
- A low demand of interactions between the vessel and the infrastructure can facilitate a successful implementation of a smart shipping concept. This would significantly reduce the costs of potential infrastructure improvements. For vessel platooning concepts passing locks means that a decoupling and subsequent recoupling process is required resulting in delays as well as waiting times and an increased complexity.
- The implemented concept also has to have the effect the operation costs by reducing crew costs. Mayor reductions can be realised when expensive crew members can be reduced. For the Danube use case it turned out that the potential savings are lower compared to the Rhine corridor due to lower wages.
- Due to longer sailing hours the overall transport duration can be reduced for highly automated vessels resulting in substantial time savings with a positive impact on the economic viability of the business cases.
- Positive effects can be generated especially for larger modern vessel, where potential fuel saving due to an optimized travel speed and fuel consumption are particularly cost-effective.

The use of the vessel platooning concept for the Danube has to cope with some major challenges:

- A high percentage of cargo is transported by large pushed convoys, where only the main vessel is propelled. Implementing concepts for autonomous sailing for pushed convoys is much more complex than for smaller self-propelled vessels.
- The traffic density is not high. An economically favourable implementation of a vessel platooning concept would require 30 to 50 vessels that sign up for the concept and the formation of 1 vessel train with 3 to 4 vessels per day. This could be realised if large shipping companies would change to the platooning concept using own vessels.
- The relatively low wages of crew members further reduce the attractiveness of a smart shipping concept on the Danube.
- The passing of the many regular locks is also an additional obstacle for the platooning concept.

In certain conditions, the use of the vessel platooning concept on the Danube is quite useful. Like already mentioned before, Smart Shipping is more economical in areas with high traffic density. A legal basis shall allow longer sailing times per day. The transport of goods shall be performed with the newly designed inland vessels instead of push barges. In this case, the transhipment process can be executed with the corresponding handling equipment as well.

3.6 Regional status

Regional differences, in all the topics that are mentioned in the paragraphs above, are defining for the speed and direction in which smart shipping products develop. In general, services and product development by commercial parties are theoretically speaking available for use over the entire

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network. But this is just theoretically. This all depends on individual conditions that must be met for a good functioning of the products.

A large amount of IWT crosses international borders. This means that when a product or services is depending on external input, regardless of who provides that input, this input needs to be available in all countries, in a standardised and harmonised way and preferably with the same service levels. This might pose some challenges. As for example, fairway information is available in all countries but the refresh rate, or the number of locations where this information is available differs.

Economic feasibility is also depending on the characteristics of a corridor. For example: a concept such as a vessel train is depending on a corridor without locks to be economic feasible. Other systems that support skippers in navigating a lock are only feasible in region with many locks (for example the Mosel). If not, the investments cost is too high to make the investment economical feasible. So, local differences in geography, services and conditions are important. Some of the regional characteristics are described below per country.

Germany

Germany has the largest inland waterway network in Europe with more than 7300km of waterways. For 7300km inland waterway the investment of technology is much higher than in other countries. For example the digital network to get information from shore to ship is very difficult. There is no area-wide mobile internet along the inland waterways[37]. So the authority has to invest in other technology to send the information to the skipper, for example AIS. Germany has built up about 120 AIS land stations along the inland waterways and there are more than 40 new land stations planned to cover most of the corridors. The landscape of some inland waterways varies. There are rivers, rivers with locks, canals with locks, trails through valleys or cities.

Germany has about 315 locks where the investment of the authority for lock passing technology is enormous. On the other hand the investment for an entrepreneur is more economical feasible for the German inland waterways due to the high number of locks. So the development for such systems for companies can be a benefit when the authority can deliver the needed information from shore.

The next problem is to collect the information and make sure that the data quality (availability, completeness and accuracy) is high enough. To reach a level of nearly 100% you need redundancy for every information and a lot of personnel for maintenance. For example the latest update of an ECDIS map (Inland ENC) needs very high frequency of sounding. For 7300 km it's nearly impossible to get this actual information in the map especially in terms of low or high water. Another example is the information about the bridge clearance. There are more than 1.300 bridges above the German inland waterways. For the authority it is impossible to capture the actual clearance and send this information on board. In fact of this the vessel needs an on-board system.

Another problem is the legal and regulatory which is mentioned above. Germany is part of the CCNR, DC, MC, UNECE and the European Union and as well we there are national legislations. It is very difficult to get a German-wide regulation for smart shipping and technology.

Conclusion: In Germany there can be a high benefit for the entrepreneurs to develop and invest in smart shipping technology on the shore side. The German authority supports smart shipping technology and has a lot of testing areas but to implement new systems will need some time in fact of the large area of inland waterways.

The Netherlands

The Dutch waterway network is a dense network, with free flowing rivers and canals. Waterway management is divided between Rijkswaterstaat, provinces and municipalities. 80 percent of the routes, travelled on the inland waterways start at a waterway not under the management on Rijkswaterstaat. Although the majority of the use by IWT is concentrated at the big waterways under the management of Rijkswaterstaat.

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[37] https://www.breitband-monitor.de/mobilfunkmonitoring/karte

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Rijkswaterstaat is actively sharing quite some information though the development of EuRIS and national development to share more information generated by the infrastructure. Examples are elaborated in paragraph 3.3.4.

Rijkswaterstaat is actively participating in partnerships such as the Dutch Forum for Smart Shipping to drive development further. Parties can apply for permission on the Dutch Inland Waterways that are not part of International conventions.

Belgium
In Belgium in the Flanders region the law has been adapted in order to make more space for experimenting with automated vessels. Since 2019 vessels are allowed – after a thorough safety analysis – to test with reduced crew or no crew on board. Tests can last for 1 year and can be extended five times.

In the Walloon region, the government is working on a similar change in the law in order to promote innovation in inland navigation and to make possible the tests on the whole territory of Belgium

France
France has a total of 8500 km of navigable waterways, of which 2400 km of CEMT IV+. 6700 km of these waterways are managed by Voies Navigables de France (VNF, the national waterway authority). VNF has installed 90 AIS base stations, ensuring a full coverage of the major waterways, just like inland electronic navigation charts ("ECDIS" charts).

Mobile internet is fully available around built areas, but many waterways in the countryside are in poorly covered sectors. 64% of the smaller waterways (CEMT 0-III) have sufficient mobile signal to access internet.

VNF manages 1700 locks, and all of these situated on the major waterways use internet to access our national IT applications (AIS data, lock keeper's software, electronic reports…) and shall be remotely operated in a near future (to optimize the work of lock operators) – this is already fully the case on the Rhône. On the smaller waterways, most locks have DSL internet connection through phone lines.[38] By 2027 VNF intends to connect them by optical fibres; in addition VNF is preparing a national deployment of remote controls for skippers to operate the small locks themselves.

On all waterways in France, electronic reporting is mandatory for all cargo transportation vessels: loaded (for the waterway dues) or empty (for statistics). Most waterways have hydrologic measurement stations, interconnected with a national database, even though on the smaller water waterways do not have fully reliable data (lack of gauge calibration and maintenance, vandalism).

Austria
No large shipping industry is situated in Austria and there are no active smart shipping initiatives. Beginning of 2022 no test area for smart shipping is available for projects and there are no pilots in preparation.

The Austrian Danube stretch with a total length of 378 river kilometres is characterized by 2 free flowing section and a total of 10 locks with a usable lock chamber length between 230 and 275 and a width of 24m. In the Danube corridor a total number of 20 locks are in operation. The Austrian Danube stretch further includes 41 bridge objects. Between Kelheim and Sulina, a total number 129 bridges must be passed along the international Danube waterway, 21 are bridges over locks and weirs (Manual on Danube Navigation, 2019). Due to the high density of locks and bridges a high number of interactions between vessel and infrastructure is required implying a need for advanced protocols in ship to ship and ship to shore communication. Furthermore, a high infrastructure density required a higher level of accuracy in positioning. In Austria DGPS is available. More accurate position data might be obtained via mobile communication data but would require a permanent data stream. Additional burdens on AIS should be avoided. 5G-coverage is available in and around urban areas. However, in rural areas there are still some gaps with regard to 5G. 4G-coverage is available almost everywhere. [39]

[38] https://monreseaumobile.arcep.fr/
[39] https://www.a1.net/hilfe-support/netzabdeckung

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In some parts of the free-flowing sections complex flow situations with high cross flows occur especially in river bends. The lower Danube shows a very dynamic morphology. Complex flow situations on the Danube pose a challenge for the development of automated and autonomous vessel.

3.7 Conclusion

General conclusions

- The potential business value of smart shipping solutions is not yet fully recognized by the logistical sector. This has to do with the relative high cost of investments and uncertainty on the business case.
- Although there is a need for digitalisation of information coming from the fairway authority, the main issues in the current situation are not especially related towards the services delivered by authorities.
- Current developments focus on the current situation and try to develop solutions that fit the current status of the infrastructure and digital services.
- A lot of uncertainty has to do with organizational issues, related to legal challenges and data standardisation / quality. Eventually these challenges impact the economic feasibility of the further development of smart shipping. Uncertainty about the speed in which regulations will be in place could impact the adoption of developments.

Figure 3.2. DIWA Maturity Model

Reactive	Organized	Digitized	Connected	Intelligent
No overarching vision Requires heroics to change Management sceptical about digitalisation Unfocused digital initiatives	Specialists deliver changes using established process Traditional digital features Building digital capabilities	Advanced digital features in silos Overarching vision established Digital information exchange possible Limited real-time situational picture digitally available	Advanced digital features aligned with partners Digital information exchange by default Full real-time situational picture digitally available	Digital transformation established A.I. assisted process optimization Predictive digital capabilities Automated response to standard situations

Current level of digitalisation in the logistic sector

- Level of digitalisation with regard to smart shipping is still very low in the sector. In the current situation the development and the use of smart shipping is mainly of interest to a small part of the total sector (some pioneers).
- Overarching visions on the side of the logistic sector, purely focusing on the business value that smart shipping can have, are very limited.
- There is still discussion on the need and the added value of smart shipping. The business value is partly recognized but it feels that the current experiments and their outcomes are not always well known thought out the whole sector.
- Initiatives and research are done on many different aspects. There is no real guidance or roadmap made by the sector on which aspects are most important to focus on.
- That said, there are multiple initiatives, fuelled mainly by European funds. The first commercial parties have products ready for market implementation. These products are making use of advanced digital features. Although it looks like there is no real overarching vision on information exchange between the couple of developers.

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- Developments are pushed by a few pioneering companies and adopted by the first users. Besides this, there is no clear overarching demand that is clearly stated by users.

Conclusion on the current level of digitalisation in the logistic sector
Based on the information gathered and the aspects mentioned in figure 3.4. the level of digitalisation, related to smart shipping developments in the logistical sector, is estimated by the working group to be heading towards organized. Again, this is an estimation for the topic of smart shipping. Differences exist between countries as well.

Current level of digitalisation related to smart shipping on the side of the fairway authorities

- Fairway authorities in Western-Europe acknowledge the potential of smart shipping solutions in helping to overcome the challenges that face the sector.
- Authorities are working to get the legislation in place to facilitate developments on the inland waterways.
- Authorities try to create the necessary space to experiment with systems.
- Research is conducted on the role that authorities can play in facilitating the developments further
- Authorities are reserved in investing in new services or adjustments in infrastructure because of the current uncertainty in the needs.
- This reserved position on the other hand can slow down developments because market uptake might need a 'flywheel'.
- Focus seems to be on organizational & legal challenges rather than on the development of (new) digital features or infrastructure. That said, specialists are researching the possibilities to use or adapt existing (information) services to facilitate further development.
- Systems are in place for certain services to exchange digital information.
- Not all fairway authorities in (Western)-Europe act as active on smart shipping. This is mainly related to the amount of initiatives that are deployed by commercial parties and research institutes in their specific area. That said, all participating fairway authorities recognize the potential of smart shipping developments.

Conclusion on the current level of digitalisation of the fairway authorities
The level of digitalisation, related to smart shipping developments on the side of fairway authorities is estimated to be organized.

4 Future state smart shipping

This chapter describes how the future related to smart shipping could be in 10 years from now (2022). It refers to a situation where none of the current boundaries or restrictions are present. Therewith making it possible to define the needs for smart shipping to develop. This chapter does not reflect the current roadmap for authorities. It is an overview of the expressed 'wishes' in a situation with no boundaries. In the next chapter this situation is used for a gap analysis with the current situation. Making it possible to develop a roadmap to overcome the identified gaps.

10 years from now, in 2032, the inland waterways are fully part of the logistic process. It is not expected that level 5 automation will be implemented widely on the waterways. A mixed traffic situation is more likely, were highly automated ships (CCNR level 4) use the waterways together with less automated ships. The Dutch forum for smart shipping for example expects that 25% of the Dutch fleet will reach this level of automation before 2032[40].

The highly automated ships will only function without human intervention in specified conditions, including certain locations.[41] This means that when these conditions are not met, the ship needs human-controlled. This can be on shore (in a shore control centre) or on board of the ship. Future business value

In 2032 staff shortage will still be a challenge for IWT.. In 2032 some business cases will have shown that they work while others will have disappeared. Depending on the type of inland shipping entrepreneur (1 ship, several ships or push barges, willingness to invest) a choice is made between fully manned voyages, reduced crew on board, remotely controlled or fully autonomous sailing (in combination with staff on board). All these different new types of sailing will exist at the same time. Some of the business cases that are working well in 2032 are (if all needed conditions are met):

- Remotely controlled ships with no crew on board on specific waterways and/or on fixed routes. For example, waterways where there is a guaranteed depth so this business case could further develop. This is also made possible because the infrastructure was automated. This kind of ships sail next to the smaller manned vessels on the same small rivers and canals.
- Push barges sail in convoy. 1 ship manned and the other ships/barges can then be picked up from a distance.
- On some stretches bigger ships will sail with reduced crew on board. The captain is sometimes located in a shore control centre.

It is expected that the need for digital/automated systems, to assist the skipper, is recognized more by the logistic sector. Maybe even pushed by shippers in their effort to optimize the use of different modalities and to push transparency in the whole transport chain. Smart shipping solutions proved to be a solution for the staff shortages. D, dangerous and dull work is done in a more automated way as well. Inspections of infrastructure, survey or waste collection are done with highly automated sailing drones.

4.1 Legal framework

In 2032 sailing with less crew on board of an inland waterway ship is possible in an operational environment. This means that on an international level the relevant authorities developed a regulatory basis for autonomous vessels as well as their interaction with conventional vessels. This legislation is non-ambiguous and covers the whole European region. Authorities implemented the necessary modifications in their legislation so that sailing with a reduced crew is possible. This could still mean that in certain places of situations it is obligated that a human preforms certain tasks. But this is clearly demarcated using for example the concept of operational envelopes that is based on Operational Design Domain (ODD) such as suggested by Rødseth, Wennersberg and Nordahl (2021).[42] This could mean that the domain in which specified systems can be used is demarcated by several parameters. For example: geographical aspects, the quality of expected connectivity in an area, the traffic intensity and so on.

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[40]Expectation of the Dutch Forum for Smart Shipping

[41] Rødseth, Wennersberg and Nordahl (2021). Towards approval of autonomous ship systems by their operational envelope.

[42] Rødseth, Wennersberg and Nordahl (2021). Towards approval of autonomous ship systems by their operational envelope.

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Next to that, crew standards are adapted to the new situation. It is also known which services should be implemented on board to sail with a reduced crew. Next to that:

- Clear rules and regulations are in place related to traffic rules, traffic rules are especially important in a hybrid situation.
- Requirements for shore control centre (personnel) is in place including competencies. Including specific requirements for example related to the work duration, needed knowledge of the navigating area.
- Requirements related to the human – machine interface are clear. If a system perforce tasks on board, it was to be clear when and how a skipper needs to take over control and if this can be done safely.
- Liability in case of an accident is clear. The responsibilities are known for crew, ship-owner, technology supplier and authorities in several different use cases.

4.2 Technical development

In 2032, developments in automation and connectivity have led to a more cooperative system. This can be an explained with the figure below. This figure (4.1) is inspired by the European roadmap for Connected and automated driving (CAD).[43] The figure highlights three tracks in the roadmap towards the future of smart shipping on Inland Waterways. :

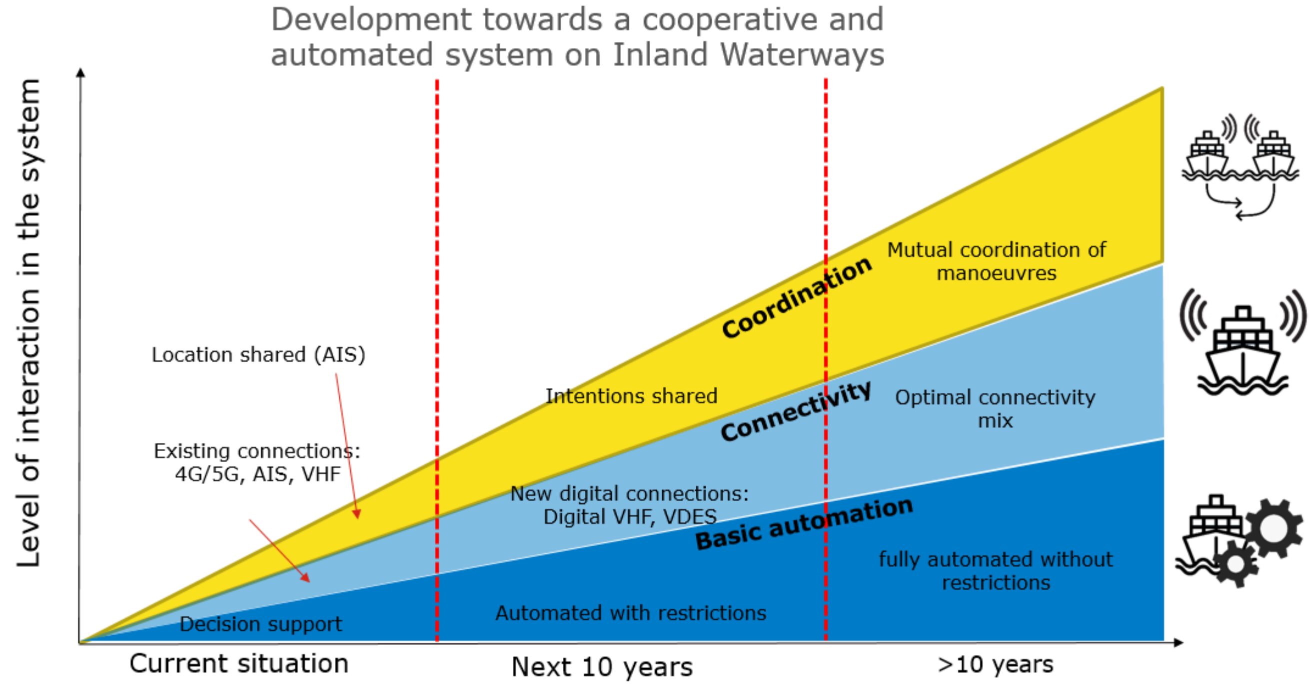
Basic automation: the systems that are used to automate the ships processes, mainly related to navigation. Therewith assisting the user in decision-making processes or in later stages taking over control and becoming fully automated.;

Connectivity: the need for connectivity between ships and there surrounding. A connected system of ships is depending on the ability to communicate. Connectivity is needed to transfer the data for example on intentions of other ships or information on the status of the fairway.

Cooperation: the ability to use coordinate mutual behaviour between ships. The tracks do not have the same starting point. Automation on board of ships already started years ago. Automated ships do not have to connected. And the other way around: ships that are connected do not have the be automated. In line with the EC it is believed that connectivity together with the basic need for automated will be an important driver for smart shipping and contribute to the safe, sustainable and smooth development of smart shipping.

[43] See appendix 4 for the picture of the European Commissions roadmap on Connected and Automated Driving (CAD).

Figure 4.1. Roadmap smart shipping on Inland Waterways



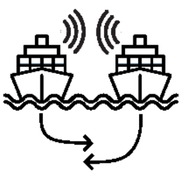
Source: own creation inspired by the EC-roadmap for Connected and Automated Driving (CAD) – Appendix 4

The increase in connectivity and automation will reach some stages of cooperation between ships. A stage where ships are able to share their intended manoeuvres for the next minutes. This information can be used by the automated systems for decision-making processes and eventually lead to 'coordination of manoeuvres between ships'. The first examples of this concept is 'Silent VTS'. A concept in which the skipper receives the short-term route of other ships directly on his ECDIS.[44]

In 2032:

Basic automation: the maturity of automation enables ships to sail highly automated on specific part of the waterway without human back up. Systems on board are integrated to be able to share information that is needed for decision-making and actuation of those decision within the defined space.

Connectivity: the majority of the fleet is connected, so able to at least receive information of other ships, although the level of connectivity does not enable sufficient coverages for all mission critical processes. Which means that it can't be expected that coverages by any means is enough for all automated systems on the whole European Waterway. Bottlenecks are identified.
A uniform data exchange standard is in place to ensure that systems development by different companies are able to communicate with each other. Making it possible to reach a coordinated transport system. All parties in the supply chain agreed on a common data architecture and governance structure to data exchange between relevant parties. To be able to share information in a way that all other ships are able to receive and produce this information, standardized data models are in place. Making it possible to represent knowledge about the dynamic environment. Authorities are able to share the information that they have and that is relevant for automated ships, in a reliable way. More on this in the paragraph on data quality.



Coordination: information about the short term intentions of smart ships is send out and received by other users in the near surrounding of the ship. Other smart ships can use this information for their state estimation and decision-making process. Other, less automated ships, can receive this information as well as input for the skippers decision-making process.

[44] Bongaertz et al. (2021). Meta studie Informatie Havengebied

As an indicative example, some expressed wishes of needs that are addresses in a workshop with the industry are shown below. These needs for the future give insight in some practical aspects and are translated to functional requirements in chapter 5. For example the gap related to AIS. The wish of the sector to extend the AIS carrying obligation can be translated to the need for a more comprehensive and complete situational awareness. How this can be obtained and what the role is of the fairway authority is input for chapter 5 and 6.

Table 4.1. Operational, organizational and technical requests identified by the industry[45]

Gaps	Description of the gap
Rules and regulations	Non-ambiguous and clear traffic rules are often not available. Lanes to be used are varying. Currently there are too many exceptions for non-ambiguous decision-making for autonomous vessels. A regulatory basis for autonomous vessel and their interaction with conventional vessels is missing. Moreover, the use of partial or full automation systems should allow to reduce e.g. crew size in order to create an actual benefit that compensates for the higher investment costs.
Faster implementation time	In general, a faster implementation of service should be aimed at.
AIS	An extension of the AIS carrying obligation also for class B vessels would improve safety (object detection) for vessels sailing partially and fully autonomous.
Collision avoidance	A collision avoidance approach similar to the direct communication between aircrafts would increase safety for autonomous sailing. First steps in this direction be to ensure track/path adherence for a certain time, the use of a "virtual" blue board, followed by the implementation of cooperative avoiding action.
Proof of increased transport safety	Incentives for the use of navigation assistance systems and technologies can be generated by ensuring and capitalizing a proven safety gain for transports. EBIS for tanker vessel lead to stricter controls and increased trust.
Infrastructure for automatic berthing, fixing in locks	Solutions for automatized vessels required

4.2.1 River Information Service

The EuRIS portal as important result of the project RIS COMEX will provides harmonised RIS services accessible through web services at the level of European inland navigation corridors (e.g. Rhein Corridor, Amsterdam-Antwerp-Brussels Corridor and Danube Corridor) and up-to-date information on water levels (and gauge predictions), Inland ENCs with bIENC overlay (depth contour lines updated regularly based on riverbed characteristics), vertical bridge clearances and shallow sections. The platform poses an important step towards offering RIS services at a harmonised quality level across borders to the IWT sector, with a standardised interface. Thus providing the basis for further advantageous developments in smart shipping. The central access point for web services is an important step forward, but towards the future the need for harmonised information services across boarder with the same service level will be needed. Most of the information described below is based on the current state on the waterway. For smart shipping, the need for predictions will grow. In 2032 EURIS should be the information platform for IWT in Europe. Therefor the web services should mature further. One important need towards the future is the development of a feedback loops which allows users to help in raising the level of data quality. In 2032 there is a raised awareness in the whole sector the data quality is a combined responsibility of the whole sector, not only the waterway authorities. Below the needed services are elaborated.

Central access point for web services

[45] Innovative Navigation, ARGONAV: Workshop Smart Shipping Requirements AT/DE 2020

An important aspect for development of smart and autonomous sailing applications is the availability of reliable, accurate, and up-to-date basic input data. In addition to data obtained from sensors, European waterway authorities can support these developments through a central access point with further relevant information concerning the infrastructure of inland waterways as e.g. current water levels, Inland ENCs with bIENC overlay (including depth contour lines) and actual bridge clearances as well as traffic information as for example the status of locks. Correct, complete and up-to-date information about bottlenecks is of outmost importance for navigating on rivers with free-flowing sections, to allow for safe navigation (e.g. avoid groundings), support route planning / voyage planning, and to optimise vessel draught (increase utilisation).

Traffic overview and density
For vessels navigating at a high level of autonomy, it is particularly important to have comprehensive and forward-looking overview of the traffic situation, especially concerning encountering traffic and locking times to ensure safety and optimise energy consumption. With a dense network of AIS base stations, a reliable traffic image can be provided. In addition to senor data, smart vessel might also observe buoy positions transmitted by AIS to assist dynamical determination of fairway boundaries for manoeuvring operations in the future. Furthermore, traffic restrictions such as one-way traffic, with signals communicated by AIS could be incorporated in the decision process of speed control.

Passage durations and waiting times at locks and bridges
Based on the evaluation of position data in relation to a developed RIS reference data network model, current travel times for all waterway sections can be queried to optimize vessel speed and voyage planning.

Obstacles in the fairway
Obstacles in the waterways are reported via central endpoints so that the skipper and/or the logistics party can adjust its planning accordingly. Lock planning is optimized facilitating predictable travel times with reduced waiting times.

bIENCs
Inland ENCs with bIENC overlay provide bathymetric riverbed information visualised as depth contour lines updated regularly based on riverbed characteristics. Together with supplementary up-to-date collaborative depth data (shared by other vessels), the bIENC overlay with riverbed contour lines will provide and optimal overview enabling the selection of a safe path for navigating along the route. Due to the fact that the initial purpose of the IENCs focused on safety of navigation the accuracy and reliability requirements for the services (e.g. production of IENCs) need to increase in order to meet the requirements of autonomous sailing. For IENCs relevant quality parameters are composed of accuracy, correctness, punctuality, and completeness and require an increased level of transparency.

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 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.

Bottleneck identification
Prior to voyage planning and loading of autonomous vessels, information on actual vertical bridge clearances is needed for a safe passage of critical bridges. The lowest value determines the possible air draught.
Furthermore, a supplementary service providing information on the "least fairway depth" along a calculated route, this service will be available as web service and supports smart vessels in the preparation of their voyage (especially with regards to loading) with information on the least fairway depth also considering water level forecasts.

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Data and services for logistics
Entrepreneurs and logistics parties can access data sharing platforms based on granted access rights (ship insights provided by vessel operators) and the principle privacy by design enabling them to optimize their logistics processes.
Economic operators provide data required by the eFTI regulation that can be retrieved by competent authorities by pull-mechanisms. Data is also correctly shared across borders so that start and end points in the logistics chain do not contradict each other.

The logistics party can retrieve data from a platform where ships are located and in what condition (full or empty) (each party must be able to decide for itself whether it wants to participate or not). This way, the logistics party knows which ships are in a corridor and he can use them to optimize his transports. The data platform is run by a neutral data manager.

Berth availability
As for infrastructure like berths, unloading and loading places, data is available that ensures that the infrastructure can be used as optimally as possible.

As an indicative example, some expressed wishes of needs that are addresses in a workshop with the industry are shown below. These needs for the future give insight in some practical aspects and are translated to functional requirements in chapter 5.

Table 4.2. Potential information and data gaps provided by the industry[46]

Information	Description of the gap
Depth information in ECDIS	Full coverage of depth information in Inland ECDIS 2.4 with a raster width of 5m, accuracy level of 10cm, resolution of 10cm and a sufficient update frequency based on criticality of river bed characteristics.
Level of accuracy in ECDIS	Not for all relevant object's information on the accuracy level of the provided object dimension is available. Additional information on accuracy required. For lock entry/exit, positional accuracy of ECDIS should be 1-3 cm; Realistic contours in ECDIS would allow an autonomous ship to identify its position and heading by matching with measured lidar/radar data
ECDIS	Add bridge contour lines for all bridge objects in ECDIS; add information on radar/lidar visibility of objects
Buoy positions	More frequent updates of buoy positions
Laser scans of objects	If objects need to be passed with a distance below 15 meters, ECDIS accuracy needs to be improved e.g. by using laser scanner measurements
Absolute height / altitude	Reference to absolute altitudes not reference levels and absolute height for all objects is required
AIS overlay	With an increased level of autonomy, highly reliable and high-quality information is required. Control mechanisms for the correctness of AIS data are thus required. This controls could be executed by authorities. A further possibility would be the implementation of an AIS overlay.
AIS track evaluation for path optimization	AIS data often include an incorrect sensor position. Should be guaranteed that the track information is correct. Should be controlled by authorities.
AIS ATONs	AIS ATONs are required covering all stretches and relevant situations.
Current	Currently there is a big gap regarding data on currents. Depending on the purpose, the respective situation and on related reference water levels 1D-2D-3D flow model would be required especially for high levels of autonomy. Above a certain threshold (depending on the allowable displacement of the vessel) data on cross flows (distribution of flow velocities in cross-sectional profiles, average flow velocities related to all relevant statistical water levels) should be provided by authorities. A workaround is possible for parallel longitudinal flow lines.

[46]Innovative Navigation, ARGONAV: Workshop Smart Shipping Requirements AT/DE 2020

	Definition of critical situation and parameters would be helpful. For path/track optimization further weighting between different factors is required.
Voice communication	For autonomous vessels machine-readable information is required. Rules for a mixed situation (autonomous and conventional vessels) need to be elaborated.
Additional sensor for critical objects	The most critical objects (e.g. critical bridges should be equipped with additional sensors (e.g. for actual bridge clearance)
Reliable position information around critical objects	In case of position reception problems, anticipatory interpolations of the path are possible up to 30 seconds. However, that initially used position information for the calculation must be reliable and precise.
Infrastructure for automatic berthing, fixing in locks	Solutions for automatized vessels required
GNSS correction data service	With increasing level of automation, the requirements for position accuracy are increasing as well. Thus, an affordable correction data service for high-precision GNSS (~2cm) should be available for all vessels in relevant situations. As an alternative, a very good mobile coverage (5G) is required.

4.2.2 New Technologies

Smart Shipping can lead to a largely autonomous operation of inland vessels. As already mentioned in the previous chapters, automated operations can increase safety but also reduce the number of crew members on board. New technologies support the fulfilment of these objectives.
The use of smart ships increases the amount of generated and used data to optimise ship operations and meet processing requirements. Infrastructure and systems equipped with new technologies enable, facilitate or even create new opportunities for the implementation of smart shipping concepts. New technologies are reshaping inland waterway transport to some extent. Nearly every New Technology has somehow a value for Smart Shipping, perhaps some more than others. For example, the use of IoT (Internet of Things), AI (Artificial Intelligence) and 5G technology are important components for a smarter shipping. More details you can find in Sub Activity 3.1 New Technologies.

4.3 Cyber security & privacy

(Cyber) security

- Safety of systems on board of the ship and systems used for communication between ship and shore can be trusted
- Security protection is always in place. The PIANC WG 210 refers to several safety protection functions that should be implemented within automated systems: anti-interference, anti-blocking, anti-eavesdropping, data encryption, anti-tampering, data recovery and hardware reinforcement[47]
- Companies are able to demonstrate that all safety measures are in place. Including the external hard- and software that is used to let products function.
- Safety requirements are specified in a quantitative way for example: requirements regarding the need for a safety shutdown system, introduction of two or three factors authentication
- Performance standards (related to reliability and redundancy) for communication and cyber security systems are up-to-date for usages in automated a shore-controlled ships.[48]

Privacy

A legal framework for sharing data across borders, including all necessary standards is in place.

[47] PIANC (2022) WG 210 report on smart shipping
[48] Bolbot, V. et al. (2019). Safety related cyber-attacks identification and assessment for autonomous inland ships.

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4.4 Data quality

The role of human on board of ships will change. Being less involved in actively sailing the ship the whole trip. AS a result of the changing role, the dependence of systems on data to sail the ship will increase. For systems to perform on a desirable level, knowing which data has which quality is essential. Only then, this data can be used for the right purposes. In first instance, knowing the quality of data could be even more important than high quality data. Within ten years, user can verify the quality of external received data because the meta-data is available, complete and up to date.

In ten years' time, not all available data is available on every stretch of the waterway. What is known is where every service is available on the waterway network. To achieve that, the Infrastructure Support Levels for Automated Driving (ISAD)[49] are translated to the inland waterway network and information on the support levels is available for all relevant transport corridors in Europe. This categorization, describes:

1. The level of digitalisation of the infrastructure
2. The digital information that is provided on certain part of that infrastructure
3. Gives an indication what services can be expected from a fairway authority in the support of automated driving.

Figure 4.3. gives an example on how this information in described. With this information, authorities give insight in the support that is available on certain stretched of the waterway. Combined with the operational envelopes, this gives clarity towards users where smart shipping products. Other topics related to data quality that are fixed in 2032 are:

1. All data that is shared by the authorities is available in a machine-readable way.
2. Authorities make sure that the way in which the data is shared, is truly harmonized.
3. Raw data can be shared as well.
4. Platforms for data sharing are used.
5. Data and information available on the EURIS portal can be retrieved by external systems.

Figure 4.3. Example of the information described with the ISAD levels

	Level	Name	Description	Digital information provided to AVs			
				Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance: speed, gap, lane advice
Digital infrastructure	A	Cooperative driving	Based on the real-time information on vehicles movements, he infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow	X	X	X	X
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time	X	X	X	
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs	X	X		
Conventional infrastructure	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs	X			
	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs				

Levels of the Infrastructure Support for Automated Driving (ISAD Levels).

Source: ERTRAC (2019). Connected Automated Driving Roadmap

4.5 Vessel traffic management services (VTS)

In the near future, VTS will provide more services that are adjusted to the use of smart shipping concepts. Services provided are both available for highly automated ships and less automated ships. VTS will play a role in a coordinate system. Providing more tactical and strategic traffic information that is otherwise hard(er) to get by individual users. Meaning, information that can be used by systems

[49] ISAD is a categorization that is proposed in the EU project INFRAMIX to describe the support levels for automated transport on the road.

to predict and include future situation that may influence travel plans. This process is already started with the implementation of corridor management in the Netherlands and the development of EURIS in the COMEX project

The way in which information is shared in adapted so that system to system communication is possible. For example by sharing information not only by VHF but also though digital messages that can be received in an electronic map. To provide the needed services, authorities were able to convince users to share their available information as well.

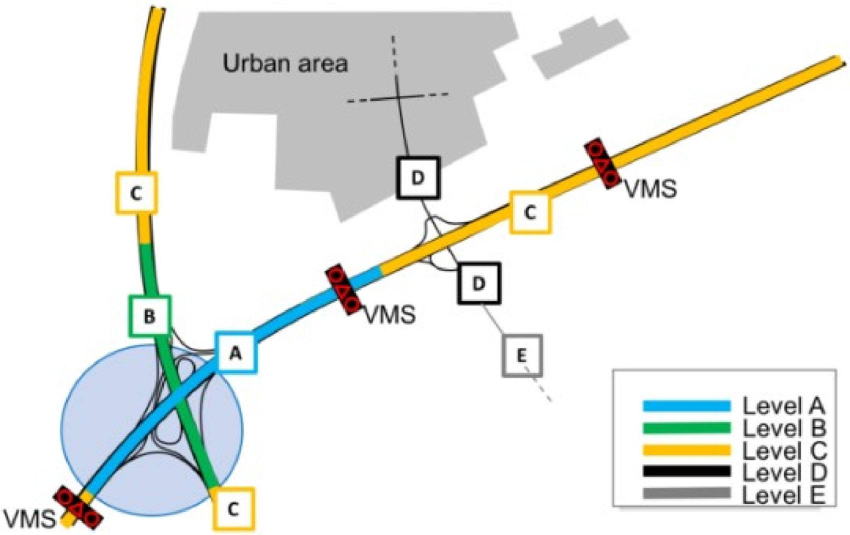
In the future, VTS will be more connected in the transport system. Maybe sharing information that is now only availed for the operator (radar images). And on the other hand making use of data that is generated on ships. With this, VTS can help in the process of state estimation creating a more situational awareness. By combining all this information the decision-making processes on board of ships and that of the VTS operator will be supported even more.

4.6 Regional status

Even in the Greenfield situation, differences if smart shipping development will appear. For example, it can be assumed that on waterway where there is less traffic, less recreational traffic, a fix waterway, less obstacles around or on the waterway, fixed transport routes automation will be higher faster than on stretches of fairways where the complexity is much higher.

Therefore, the need for support from the waterway authority will differ between waterways. The proposed Infrastructure Support Levels of Automated Driving and the operational envelopes will give inside in the needs and the challenges for certain stretches. For one part of the waterway, challenges will occur on connectivity needs for other waterways the needs for more reliable data will be the main challenges. Locally not everything might be the same because some navigational environments require more sensors than others in order to navigate safely. Furthermore, the business case will not be the same on every waterway, which also means that there will be differences in use of technology.

Figure 4.4. Examples of ISAD Levels assigned to a road network



Source: ERTRAC (2019). Connected Automated Driving Roadmap

5 Gap analysis

This chapter provides a gap analysis between the desirable future (chapter 4) and the current situation (chapter 3). These gaps are described and combined with different future roles of fairway authorities. The chapter concludes with integrated functional requirements for the safe, smooth and sustainable development of smart shipping towards the future.

5.1 Technical gaps

For a gap analyses on the technical aspects, the framework introduced in figure 4.1 is used. The desired future is a connected and cooperative transport systems. Gaps exist on the three aspects of the framework: basic automation, connectivity and coordination.

*Basic automation: o*ne of the main gaps it that the majority of the current technical developments, especially the ones that are market ready, focus on the automation of the that are used for sensing, state estimation, decision-making and (in some cases) the actuation of these decisions. These products are used for assistance of the skipper on board, or controlling the ship from shore. These applications enable more data sharing within the ship, combining input from different systems. Paving the way for more digitalisation on board of the ship.

An important sub-development is the systems that are used for sensing. Creating a picture of the surrounding environments around the ship. Systems that are used for this are for example bridged height detection software/sensors, LIDAR, radar and cameras. All these sensor generate data that is used to determine what other users or links in the infrastructure (locks, bridge) are doing. RIS corridor management and -information is a useful information platform to gather information and create redundancy by using the information to verify the input that is gathered by other sensors.

Application possibilities

These systems can be used on some part of the waterway, but the usages is limited. Due to limitations of the systems itself but mainly because the commercial use without a human in the loop is not allowed yet on most waterways in Europe. There are not many 'of the shelf systems' because of the big differences between systems on board of ships. The degree of digitalisation on board of many ships is still relatively lows (see picture 2.2. for a Dutch example). Therefor the investment cost are high.

The level of automation will increase, the adoption of systems on board of ships will increase and the Operational Design Domain (ODD) in which the systems can be used will be increased as well. It is expected that the amount of ships that will be automated to level 4 of the CCNR definition of automation was grown, across all waterways. Depending on the characteristics of the waterway, the users and the transported goods and routes that are taken. This will lead to a more mixed use of the waterway by automated and less automated ships. It is expected that within the current scope of 10 years the human will stay in the loop as a back-up.

Further on in the development of smart shipping, other tasks in the logistical process regarding IWT will be automated as well. Examples of these kind of development are already presented but in a limited way. Example are: automation of the (un)loading process, automated mooring, maintenance, cargo planning, loading schemes etc.

Because of all this, the amount of data and information will increase. Although the human might be still in the loop to monitor the automated processes, the higher the level of automating is, the more important becomes the quality of the data. Verifying the correctness of data gather by sensors (on board of the ship) will increase in importance to maintain the current safety levels. Information on the fairway authority is used in the current situation but towards the future, this use can increase and will enable further development of smart systems. Real-time information on the intentions of other is not the only data need where there is a difference between the current and the Greenfield situation. The amount of data that is used for sensing and state estimation will changes as well. When the level of automation increases, the role of a human will be more on monitoring. Therefor the certainty on the correctness of the data has to be higher than in the current situation where the human is constantly monitor the sailing process. The current data provision though RIS services has developed towards more information for planning purposed. For this need, the information doesn't have to be real-time. If the same information is used for navigational support, the need for real time information increases. For example on current, velocity or actual bridge clearance. This information is not available on the whole waterway network, if it is available at all. Especially if it concerns real time information. More of this in the next paragraph.

Connectivity

One of the conditions to be able to share information between ships, logistic parties and the authority is connectivity. Connectivity consists of two parts:

1. Ships need some form of connection with enough bandwidth to exchange the necessary information.
2. Ships (and systems used by logistic parties of authorities) should be able to communicate with each other (speak the same 'language'). For this, a common communication standards and data architecture, should be agreed on and in place. Including a governance structure that allows for safe (cyber secure) communication and making sure that all privacy aspects taken care of.

Connection

In the current situation, not all smart shipping systems need input for external sources. In this situation full connectivity when sailing a ship is not necessary. That's convenient because broad band coverages on the whole European network does not exist.[50] On waterways in close proximity of habitation, for example in the Netherland or Flanders, connectivity is generally more available than on more vast stretches of waterways though hilly terrain. Even if there is connectivity, this does not guarantee a connection that is good enough for transmitting the necessary data. Besides the connection, other factors such as the quality of the transmission and the receivers or the amount of people using the connection might limit the capacity to transmit data.

Still, there is a gap between the connectivity needed in the future and the current availability. Instead of trying to get coverages though the whole network, focus should be on bottlenecks. Bottlenecks could be infrastructure such as bridges and locks or selections of the waterway that are known to be difficult to navigate because of high traffic density of geographical factors. This could be sections where efforts can be made to achieve better connectivity if needed. Waterway authorities aren't responsible for the connection itself, services providers are. Nevertheless there is a role for fairway authority to stimulate better connections. Besides this, the importance on information where certain coverage is expected to be present becomes more important. More on this in the next paragraph.

Poor connections will occur in places where the usages of connections is limited. Services providers will not offer connections there because they do not generate enough revenue. If the bottlenecks occur around objects that are under the control of a fairway authority, they could provide land, an energy connection towards the transmission tower. Making the investment far less expensive and there for more attractive for a service provider.

Communication standards

The current developments do not focus that much on the connectivity between ships, standards for communication between vessels are not specifically developed for smart shipping purposes. Although it is suggested that VDES could be useful as a standard for communication between ships and authorities. Technical needs, related to the safe (cyber secure) use of communication systems should be in place. PIANC WG 210 suggested some technical solutions that could be implemented.[51] Besides this, when sharing information between different users, privacy should be guaranteed at any time. At least making sure that the data owner can determine who can see which information at which moment. For this, existing frameworks such as I-Share might be used.

When speaking about connectivity, the connection between highly automated ships and VTS-operators is an important aspect. Because of the fact that within the timeframe of 10 years, a mix traffic situation ask for VTS-services for automated and less automated ships. The role that authorities take can vary.

[50] Example for Dutch 4G/5G coverages in the Netherlands: https://www.kpn.com/netwerk/dekkingskaart.htm
Example for Berlgium: https://www.bipt-data.be/nl/projects/atlas/mobile
Information on the networks in Germany, France and Austria are included in paragraph 3.6.

[51] PIANC (2022). InCom WG Report 210. Smart Shipping on Inland Waterways. Version 1.0

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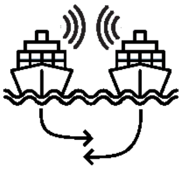
In the current situation, experiments are undertaking in the Netherlands to share VTS information digitally with ships, instead of speech. This can be beneficial for both automated and less automated ships.



Cooperation

In the current situation the focus on cooperation between ships or ships and infrastructure is limited. Information that is needed for cooperation is shared (for example AIS-information), but this isn't done with smart shipping development is mind. This is a gaps with the foreseen future. A cooperative system is seen as a possible way to reduce the complexity of functions such as sensing of surroundings, state estimation and decision-making. Reducing the possible input sensors on board of a ship to calculate the possible intentions of other users. In this way, maintaining safety in a mix traffic system (highly automated and less automated ships) and making development easier and less expensive.
It is not expected that the whole IWT-system will be cooperative towards Decision-making processes, including how to react on the intentions of other users will still be done on board of each ship but it is foreseen that ships will actively share the intentions for the upcoming minutes the first steps towards coordination are. Especially because, the first experiments are already completed with intention sharing and coordination (within the NOVIMAR project). Within ten years is should be possible that smart ships share their intentions with other ships (smart or not smart).

Besides sharing information between ships, sharing information with authorities about the intentions could be beneficial for traffic management purposes as well. Giving the traffic manager more real time information about the intention of a ship without having to ask the skipper. Therewith limiting the amount of spoken words. The shared information and the fact that the amount of spoken words can be reduced can contribute to more safety.

Towards the future, more integration of the IWT in the total transport chain is expected as well. Data and information that is produced by smart ships and their sensors on board will help to further develop the IWT into a more connected and cooperative system and with that a more integral part of the transport chain.

5.2 Operational and organisational gaps

The above analysis revealed several technical gaps. In additions to the gaps, several operational and organizational gaps are identified as well. These gaps are preconditions to make the technical developments possible. If these preconditions are not met, the technical developments are probably not reaching an operational status.

1. *A regulatory framework to make navigation with less crew possible*
   A legal framework that allows for navigation with less crew is a precondition for a return of the investment on the needed automation for smart shipping. A lot of work is already done of these aspects. Based on the steps that the CCNR takes, the needed frameworks for the Rhine River is expected to be there in a few years. Other River Commission will need to do the same.

   Afterwards, any legal framework (that allows for navigation with less crew) needs to be implemented on a national level. Without the necessary legal framework, developments are hard to implement safely in an operational environment.. From the perspective of the logistical sector is has to be clear where this regulations are in place. Both conditions do not exist in the current situation. As suggested in chapter 4, the work that is done in the automotive industry and the maritime industry on operational envelopes can be of useful here.[52] The operational envelopes concept can be helpful in determine the locations where sailing with less crew can be allowed and under which circumstances. Local circumstances, such as the availability of services, the complexity of the waterway or the amount of other users can be taken into account.

2. *Clarity on the presence, availability and quality of services offered by fairway authorities*

[52] Rødseth, Wennersberg and Nordahl (2021). Towards approval of autonomous ship systems by their operational envelope.

In the future situation the need for information from external sources (including data and information provided by a fairway authority) will grow. Due to the fact that more and more data will be needed to verify sensing by sensors and further integration into the supply chain.

In the current situation services and services levels vary between waterway, countries and transport corridors (see paragraph 3.6). The quality of the data is also not always clear. This makes it more difficult to agree on harmonisation and standardisation of information for the purpose of smart shipping.

Nevertheless, harmonisation and standardisation of services would be beneficial for the usages. Although this might be a process of many years. Therefor another step that might be taking less effort is suggested first.

Related to the quality of the data, one of the gaps that was found, was that the quality of the data is not always know. Besides the fact that it isn't clear where every service is available. A clear overview of the available (digital) services on the whole European waterway network is helpful for the further development and implementation of smart shipping services. It is proposed to translate the ISAD levels for road infrastructure to the waterway network and use this levels to describe the availability and quality of services. Giving clarity towards users and developers of systems where the can use digital services that are provided by the fairway authority.

3. *Harmonisation and standardisation of the available data and information across whole corridors*
   A third gap relates to the quality of the data provided by the authorities. Although the implementation of corridor management services with the RIS COMEX project and the development of EuRIS platform is a giant step forward in the harmonized disclosure of RIS-information throughout the main inland waterway corridors in Europe, this doesn't mean that al information in delivered with the same data quality of service level.

   Gaps in standardisation are unbeneficial for the use of this information for smart shipping solutions. It is important to notice that smart shipping developers (or users) are not the main users of information provided by authorities. The needs that arise from smart shipping development are therefore not taken into account yet. Towards the future, a clear feedback process should be implemented to allow users to share feedback to improve the quality of the data services and take into account specific needs that arise from further automated transport. Towards the future this needs should be taking into account so that the information that is provided stay useful for the purpose that is has been created, namely allow smooth, safe and sustainable navigation for all users.

   A kind of feedback loop can also provide additional information to ensure that data quality increases with help of the users.

5.3 Business value and financial situation

There is no gap between the current situation and the future regarding the business value of smart shipping systems. Smart shipping product can help in maintaining the position of IWT in the transport sector. Making sure that the same amount of goods (or even more) can be transported in a safe, sustainable and smooth way, despite a growing staff shortage.

To harvest this business value, entrepreneurs should be able to invest in innovative (smart shipping) systems. There is a gap between the needed investment capabilities and the current possibilities. This gap is twofold. The current market structure in the IWT-sector results in low margins and dependence on external capital for investments. The incentive to invest isn't there yet for most companies due to the uncertainties about possibilities to use the current systems in a commercial way. Economic gains depends on the possibility to reduce the crew on board of the ship. If this is still prohibited by law, the business case is hard to find for most entrepreneurs. Current development already give insight in operational performance, enhance safety by adding decision-making support systems or claim to reduce emissions. But these advantages are not enough for most shipping companies to invest.

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The other side of the medal is that authorities are reserved to invest in services or (digital) infrastructure as long as the developments stay relatively limited and there is limited research on the social benefits of smart shipping developments. This attitude causes uncertainty as well and with that lowering the willingness to invest. Studies in Flanders and the Netherland provided useful input in showing that investment made in smart shipping on the side of the IWT and authorities should go 'hand in hand'. By doing that, a positive business case, for both sides is possible. Making sure that enough companies are able to invest in smart shipping solutions that it enables an investment by the authorities. Because investments in smart shipping solution could not be only commercially feasible, they have social value as well (see paragraph 3.5).

5.4 Conclusion on an integral and harmonized services

What the future will bring is uncertain. There are many variables that will influence if and how smart shipping systems will be introduced in IWT. Based on the current situation and the expectation on how the IWT-sector can benefit from smart shipping, some conclusion are drawn from the gap analysis. These findings are the basis for the suggested functional requirement in this paragraph. The services will be described in functional requirements which will be input for the strategic roadmap in the next chapter. The conclusions and related functional requirements for services are categorized based on (figure 4.2).

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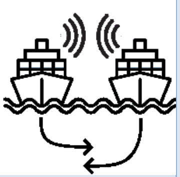
Table 5.1. Conclusions and suggested functional requirements

Topic	Conclusion	Functional requirement	Efforts[53]	Cost[54]	Role fairway authority
Basic automation 	With the increase in automation on board of the ship, the need for external data and information to created redundancy and allow for safe navigation will grow.	1. Increase the quality of the data by investing in quality of existing data instead of a focus on sharing new types of data. A solution might be to build a digital twin of the waterway with the possibility for users to add or suggested changes.	High	High	Intermediate
	In the near future, the need for new data or information might be less than getting insight in the quality and availability of the data that is present for the whole European inland waterway network.	2. Need for more clarity on the quality (meta data) of existing data. This allows users to verify on critical functional parameters.	High	Low	Basic
		3. Need for insight in the levels of support for automated navigation (ISAD). Give automated systems and their operator's guidance on the "readiness" of the waterway network for (further) automation.	High	Low	Intermediate
	A legal framework that allows for navigation with less crew is a precondition for a return of the investment on the needed automation for smart shipping.	4. Need for a legal framework that allows for navigation with less crew.	High	low	Basic
	Without the necessary legal framework, developments are hard to implement safely in an operational environment.	5. Need for non-ambiguous digitalised traffic rules to allow for safe navigation (especially in mix traffic situations).	Medium	Medium	Advance
		6. Need for a clear demarcation where navigation with smart shipping systems is allowed and under which circumstances. Create parameters and apply them on the waterway. The operational envelops concept may be used.	Medium	Medium	Intermediate

[53] This is a first expert judgment without any comprehensive analysis. To make a substantiated analysis , the needs should be further elaborated in DIWA activity 3 and 4.
[54] This is a first expert judgment without any comprehensive analysis. To make a substantiated analysis, the needs should be further elaborated in DIWA activity 3 and 4.

		7. Need for more clarity of responsibilities and liability issues in case of an accident when using smart shipping systems.	Medium	Low	Not applicable.
Connectivity 	Connections between users and the infrastructure will increase. Connections will grow to make sure that the safety on the waterway can stay as it is today with a mix of highly automated and less automated ships.	8. Need for reliable connection on the waterway – especially on critical sections.	Medium	High	Advance
	There should be a common language to communicate between highly automated ships and highly automated ships and shore with attention for cyber security and privacy.	9. Need for agreement of a common language to share information between users (like C-ITS) on the road following the work of CESNI.	High	Medium	Advance
		10. Need for a governance structure that allows for safe (cyber secure) communication and making sure that all privacy aspects taken care of (like e.g. Ishare).	High	Medium	Medium
Coordination 	A cooperative network where highly automated ships (and VTS) are connected and share intentions is seen as possibility to reduce complexity and allows for a safe (and easier) implementation of smart shipping.	11. Need for increase in system to system communication – sharing data not by voice but with digital messages.	Medium	Medium	Advance
		12. Need for harmonized data.	High	Low	Basic
		13. Need for coordination on the way in which a cooperative network should work.	High	Medium	Advance

5.5 Role of the fairway authority

Smart shipping has commercial and social value. The implementation of smart shipping systems can contribute to policy goals concerning sustainability, safety and competitiveness of the inland waterway sector. Taking the current development is mind, it can do this in a relatively short term.

Automation in IWT is ongoing and will be there regardless of the role that the fairway authorities take. Although elaborating a clear role regarding this development, the way in which smart shipping will develop itself can be guided. In fact, it should be guided to make sure that the safety of the waterways is ensured. For highly automated users and for less automated users as well. By facilitating smart shipping, the full potential can be used so that the IWT stays a strong, competitive, sustainable part of a well-functioning integrated transport system. On the other hand, authorities have a role to play to make sure that the use of this systems, especially in a hybrid situation where automated systems and less automated systems will have to work together is guaranteed. A cooperative system will to develop without the help of fairway authorities. This related among others several aspects:

- Guidelines regarding non-ambiguous and clear traffic rules, especially in mix traffic situations
- Guidelines and protocols for information sharing
- Guidelines for a common languages for system to system communication
- Clarity of available information services and a feedback process in place
- Harmonisation and standardisation of information services across corridors including clear services levels

The role of fairway authorities is important to ensure safety but also to and speed up the developments and stimulate the uptake of developments, or to broaden the business value.

Because the level of uncertainly concerning smart shipping, three different scenarios and corresponding services are elaborated below. This levels can build on each other. So when 'choosing' the intermediate level the responsibilities and services described in the basic level are applicable as well for the next level.

<u>Basic</u>

The main effort of authorities will be to implemented legislation to make sure that it is able to navigate with less crew.

Related to technical challenges, the main focus will be on harmonisation of data across countries and corridors. No new information in collected of shared for use of smart systems. The focus in on increasing the awareness that there is already a lot of data available that can be used for the purpose of smart shipping.

Vessel traffic management and services will not change. Services are provided in the same as they are provided now using the EURIS portal. The implementation of corridor management will not take smart shipping systems into account as potential users of the information.

<u>Intermediate</u>

In an intermediate scenario focus will be on investing in the quality of existing information. Making sure that the quality of the data in known and developing an ISAS for the whole (west-European) waterway network. Creating clarity on the available information across corridors. Effort on harmonizing communication standards is part of this as well.

Authorities will map the potential bottle necks that limit the use of automation. By mapping the bottle necks, clarity is giving towards the users of the product about the geographic scope where they can use the product. Based on the, the business case can be made. If the bottle necks are identified, authorities can, based on the investments that are needed, discuss the needs with the developers of products.

In this scenario VTS should focus on providing traffic information in such s format that it can be used by machines. So next to speech, the services of the VTS post are becoming more comprehensive. With this, VTs becomes a more integrated part of the IWT.

<u>Advance</u>

In the advanced scenario, authorities take the lead in making investments to ensure that smart shipping development can develop further. This investments will target on collecting more data on strategic point/bottle necks in the network by adding sensors to objects. Also, authorities can support the further development of connectivity in the sector.

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Actively participating in the process to come to common standards regarding the exchange of data and the standards to do so. Actively helping to reach some form of cooperation, in a safe and sustainable way. And actively process input from smart shipping users to improve information services.

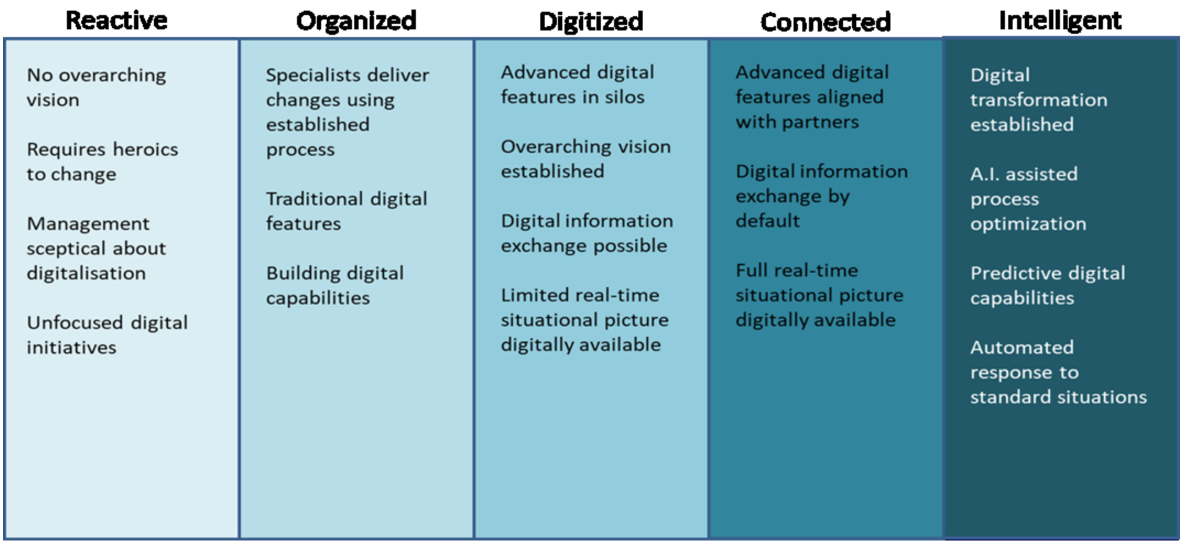
6 Strategic roadmap

Chapter five concluded with functional requirements that are necessary to take into account regarding development of smart shipping. These recommendations are used as a basis for the next steps to take towards a next level of digitalisation on the inland waterways related to smart shipping. Including some general remarks on the consequences for implementation. Further elaboration of these consequences should be done in the related activities (3 and 4).

6.1 Steps to next level of digitalisation (for the fairway authority)

The DIWA Maturity Model was introduced earlier in this report. Based on the analysis of the current situation, it was concluded that generally speaking the digital maturity level of IWT related to smart shipping is 'organised'. With a slight differences between the governments and the logistic sector and differences between countries. The IWT sector looks slightly less mature related to smart shipping than several authorities. Mainly because smart shipping applications are developed and used by a small group of early adopters without a clear overarching vision of the total sector.

Figure 6.1. DIWA Maturity Modal



Source: Masterplan DIWA project

This would mean that the next steps to push the development of smart shipping forward are steps towards a digitised, connected and intelligent level. Within the scope of DIWA (2032), reaching the intelligent level doesn't seem to be realistic. The required steps to reach that level of digitalisation are not foreseen within a ten year timeframe. Investments for the next level of digitalisation go hand in hand with investments making sure that overall policy goals related to an integrated, climate-neutral transport are reached. Smart shipping is a means to cope with the challenges ahead. Activity 5 should bring all recommendations together and see which measures might have the biggest impact on the overall goals for IWT. A general roadmap for the suggested functional requirements related to smart shipping is given in figure 6.2.

Figure 6.2 General roadmap for the implementation of smart shipping requirements

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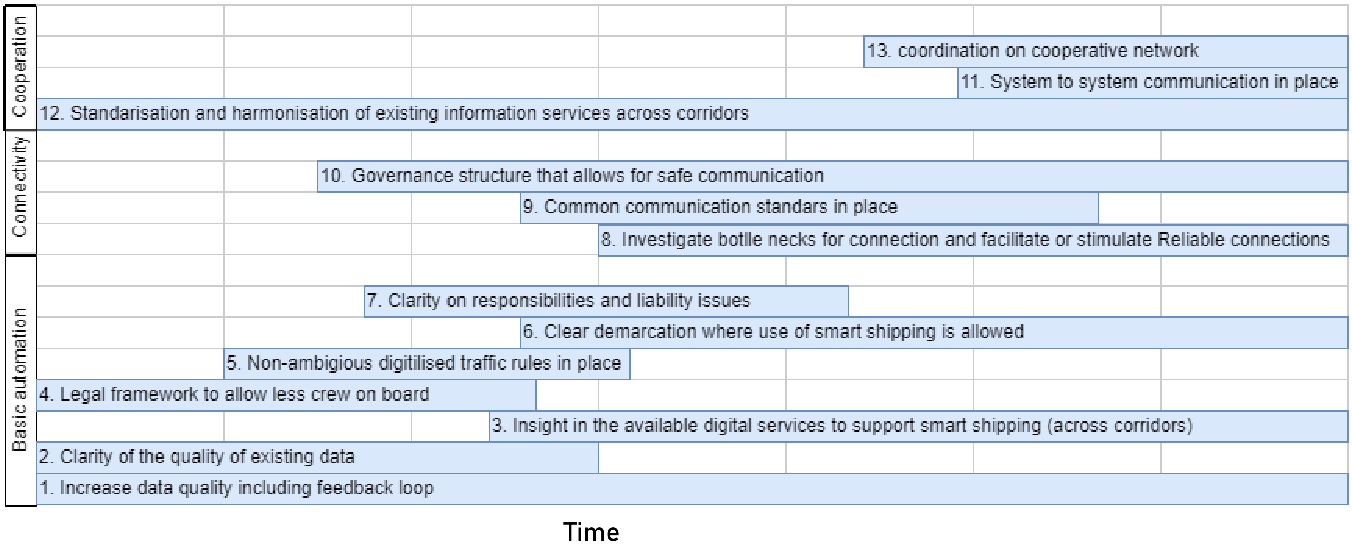

The functional requirements are categorised into three tracks: requirements related to basic automation, connectivity and cooperation. The timeline of the horizontal axis is the scope of DIWA: 10 years.

The basic assumption is made that smart shipping with less crew on board of the ship is allowed in the beginning of this timeframe (requirement 4). This will create the possibility to use smart shipping products in an operational environment, creating a mixed traffic situation. In general: ships, regardless of the level of automation, need to be able to navigate the waterway as it is ,in a safe and sustainable way. To do so, and to facilitate the development to ensure a competitive and future-ready sector, the functional requirements are drafted.

The roadmap shows which requirements are essential to make sure the developments continue (1, 2, 4, 6,12). Other requirements become more essential to ensure safe use in a mix traffic situation (3, 5, 7, 10). Some requirements continue to be important although the development: ensuring sufficient data quality never stops. The same goes for harmonisation and standardisation of data. When existing data is shared in a harmonised and standardised way, new data needs will occur and the process starts over again. That said, the fulfilment of the above mentioned requirements will make the next step in the maturity level possible. Other requirements become more important to facilitate the further development of a cooperative system (8, 9, 11 and 13), making a step forwards to the 'connected' level in the maturity model.

6.2 Consequences for implementation

6.2.1 Technical

Chapter 5 gives some technical needs for existing services. Although these are mentioned, the way in which technical developments will lead is still uncertain. These technical needs should therefore be seen as examples for further investigation.

It is suggested to focus on operational and organizational recommendations first. But exploring the technical needs on how they would benefit the different business developments and the 'traditional' ships as well should be encouraged. If this is the case, investing in these services can be seen as 'no-regret' solutions.

6.2.2 Operational and organizational

Table 5.3 indicates the requirements. The main operational and organizational requirements will allow the operational introduction of smart shipping systems on the European waterways.

The main condition to do so is to get the legal framework in place, and adjust national legislation to allow for sailing with less crew on board. Because the necessary legislation is adjusted, exemption can be granted as well. Without this, the next step in digitalisation of smart shipping in an operational environment would be hard.

The further development of the operational envelopes concept might help in getting a better understanding what is needed for safe navigation and where fairway authorities are able to grant permission.

At the same time, other operational and organizational needs should be addressed to make sure that possibilities and the business value for both users and society is clear.

6.2.3 Financial

For the financial implications, some first research is done in Flanders and the Netherlands. In general, the financial impact of investments of digital services and infrastructure is relatively limited in comparison to possible physical modifications what might be needed to ensure that smart ships can secure themselves in locks and a berth when the mooring process is automated.

On other aspects that are relevant for the whole transport process, such as automation of loading and unloading processes, receiving and processing of new travel details and creating of loading plans, no information was obtained during this research.

One other important financial aspect is that existing services, systems and infrastructure will be needed, even when a substantial amount of ship will be equipped with smart shipping products. Not only for less digitalised ships, but also for redundancy reasons as well. Making sure that navigation can take place in a smooth and safe manner in a scenario where digital systems would fail. This means that investments for the purpose of making smart shipping possible will be in addition to operational cost for existing systems. Adding to the total amount of cost for authorities. From a macro economic standpoint this doesn't mean that the investments are not economical feasible. Investments for the purpose of smart shipping can be used for other purposes as well. More information on the status of objects can be used for predictive maintenance, possible lowering the cost for maintenance of objects. More sustainable IWT lowers the social cost that come with emissions etc. The economic research that was quoted earlier in this report[55] concluded that investment in digital infrastructure for the purpose of smart shipping will be beneficial for society.

6.2.4 Business value

Regardless of the level of digitalisation of the sector and the infrastructure, the challenges for IWT are there. Implementing the necessary measures to contribute to climate-neutral transport in 2050 while at the same time coping with staff shortages and a possible increase in transport volumes due to modal shift.

Smart shipping could be a short- to medium-term solution for some of the challenges. Investments in digital solutions on board of the ship are, in comparison to investments in other ways of propulsion relatively inexpensive, making it possible to cope with the challenges earlier.

Authorities and the logistic sector are in this together, facing the same challenges ahead. The economic impact study that was carried out in the Netherlands showed that investments in digital solutions have a social value too.

6.2.5 Regional

There are regional differences, not even especially related to smart shipping but in general. Not only between countries but on international corridors and between different waterways within countries as well. These differences have to do with many different aspects ranging from the nature of the goods that are transported, types of entrepreneurship, use of the waterways, specific rule and regulations, the geography of the waterway, the services that are available and the service levels.

All these parameters have impact on the way in which smart shipping will develop itself from country to country and from corridor to corridor.

[55] Panteia and Ecorys (2021). Economische effecten smart shipping

The level of digitalisation and the related services should take the regional differences in mind when looking towards (higher) levels of digitalisation for the purpose of smart shipping.

This report gives an indication of the parameters which can influence the adaptation rate of smart shipping developments. Accordingly, authorities can decide which recommendations fit their regional situation best, taking in mind the general transport routes and corridors, and making sure that on major (intentional) corridors the same rules are applicable to ensure safe and smooth sailing.

It is for this reason that the concept of automation support levels is introduced and recommended. With this concept, the main focus is not on applying the same services with the same service level on each part of the waterway, but to give insight in the available services and expected quality. This is the basis for potential investments in other services or services with better quality. To do so, different (technical) solutions might be needed.

6.3 Fall-back scenarios

Extensive fall-back scenarios were not discussed or elaborated in this study.

Redundancy is one of the main fall-back scenarios. In general this means that for any operation or (critical) system, one is not depending on system, sensor or input parameter.

Within the timeframe of this study, on board of vessels and with regards to the VTS the human is the main fall-back scenario. Therefore systems should be able to cope with different input sources e.g. digital communication but also the ability to cope with spoken word. For the services of authorities this means that many services would need to have a physical and digital version, for example digital ATONs and physical buoys.

7 Appendix

7.1 Appendix 1. Literature list

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7.2 Appendix 2. Abbreviations

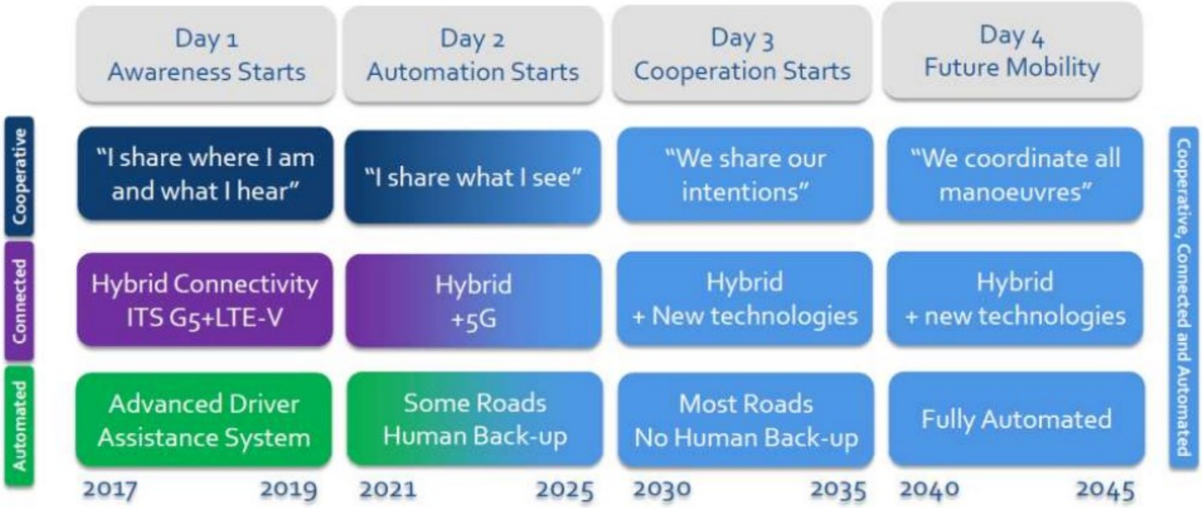
AI	Artificial Intelligence
AIS	Automatic Identification System
API's	Application Programming Interface
ATON	Aid to Navigation
CAD	Connected and Automated Driving
CCNR	The Central Commission for the Navigation of the Rhine
CEM-T	European Conference of Ministers of Transport - Classification of European inland waterways
CESNI	European committee for the elaboration of inland waterway standards
COMEX	Corridor Management Execution
DC	Danube Commission
DIWA	Digital Inland Waterways
EC	European Commission
ECDIS	Electronic Chart Display Information System
ES-TRIN	Technical regulations for inland vessels
ETA	Estimated time of arrival
EU	European Union
EURIS	Name of the RIS-platform that is developed within the COMEX project
E.g.	For the sake of example
IENC	Inland Electronic Navigational Charts
IALA	International Association of Lighthouse Authorities
IMO	International Maritime Organization
IWT	Inland Waterway Transport
MC	Moselle Commission
NOVIMAR	Novel Inland Waterway Transport and Maritime transport concepts
PIANC	World Association for Waterborne Transport Infrastructure
RCC	Remote Control Centre
RIS	River Information Service
RN	Small Navigation Committee (CCNR)
RPNR	Règlement de police pour la navigation du Rhin
RWS	Rijkswaterstaat – Dutch fairway authority
SC	Sava Commission
SRL	Stakeholder readiness level
SuAc	Sub Activity
UNECE	United Nations Economic Commission for Europe
VDES	VHF Data Exchange System
VHF	Very high frequency
VNF	Voies Navigables de France
VTS	Vessel Traffic Services
WG	Working Group
WSV	The Federal Waterways and Shipping Administration (Germany)
TCA	Track control assistants
TEN-T	Trans-European Transport Network
TRL	Technology readiness level

7.3 Appendix 3. Glossary: an overview of terms and definitions

Term	Definition
Actuation	Sub function of motion control (operational task on board of the ship) which described the actual forces that is applied to move the vessel for example by using the rudders or propulsion.
Automated shipping	Certain processes on board of the ship are automated in such way that they can perform task without or with less human assistance.
Autonomous	On a fully autonomous ship, every aspect (including for example maintenance, power management unto the communication and fire extinguishers) is developed in such way that they can perform in any circumstance without the need of a human in the loop.
Degree of automation	A description of the level of automation.
Decision making	Sub function of motion control (operational task on board of the ship) which described the process of deciding how to respond on a situation.
Drone	A small remotely operated ship that isn't equipped to have a person on board of the ship. These sailing drones are often used for tasks such as inspections or surveys.
Mixed fleet	A future situation in which automated and less automated ships will both use the waterways at the same time.
Operational design domain	The operational design domain is a description of the conditions (including the physical, digital and environmental conditions) in which a given automation system or feature is designed to function.
Remote control	A ship can be controlled from a location that is not on board of the ship. For example for a shore control centre. A remotely controlled ship, can have a skipper on board on the ship. The skipper on board can take over control at any moment.
Sensing	Sub function of motion control (operational task on board of the ship) which described the process of acquiring information (for example on the position and orientation of the ship).
Smart Shipping	Smart interaction of intelligent and sustainable vessels, intelligent infrastructure, communication technology and regulations'. Waterway infrastructure is an integral part of smart shipping. Intelligent information services, information exchange technologies and high-quality data are required.
State estimation	Sub function of motion control (operational task on board of the ship) which described the process conceptualize information into a picture of the current situation.
Unmanned	No persons on board of the ship.

7.4 Appendix 4. Connected and Automated Driving (CAD) roadmap – European Commission

Figure 7.1. Connected and Automated Driving (CAD) roadmap – European commission



Source: used in several presentation of the EC – 2018 onwards