DIWA Report

Sub-Activity 3.1: New Technologies

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List of abbreviations

AGV .... *Automated guided vehicle*
AI *Artificial intelligence*
AIS .... *Automatic identification system*
APIs .... *Application programming interface*
AR .... *Augmented reality*
AWS .... *Amazon web service*
CAPEX .... *Capital expenses*
CCNR .... *Central commission for the navigation of the Rhine*
CEERIS .... *Central and Eastern European reporting information system*
DLT .... *Distributed ledger technology*
ETA .... *Estimated time of arrival*
EuRIS .... *European river information services*
GDPR .... *General data procection regulation*
HUD .... *Heads-up display*
IaaS .... *Infrastructure as a service*
ICT .... *Information and communication technologies*
IoT .... *Internet of things*
IWT .... *Inland waterway transport*
KPI .... *Key performance indicator*
LiDAR .... *Laser imaging, detection, and ranging*
MTBF .... *Meantime between failures*
MTTR .... *Meantime to repair*
MVP .... *Minimum viable product*
NIST .... *National institute of standards and technology*
OPEX .... *Operational expenses*
PaaS .... *Platform as a service*
PPP .... *Public private partnership*
RIS .... *River information services*
RPIS .... *Rhine ports information system*
SaaS .... *Software as a service*
SuAc .... *Sub-Activity*
SWOT .... *Strenghts, weaknesses, opportunities, threats*
UAV .... *Unmanned aerial vehicle*
VR .... *Virtual reality*

Executive summary

Under Activity 3 (Technological Developments) of the Masterplan DIWA project, SuAc 3.1 is focused on new technologies in logistics, navigation and traffic management and the potential relevance for fairway authorities and IWT. This study gives an overview of ten technologies which are new and relevant to the abovementioned areas. The authors rated each technology based on a scoring system. Based on the assigned score and the feedback of the DIWA experts, four use cases were developed which utilise some or all of the relevant technologies. They aim at creating a more predictable, plannable, and holistic waterway. To facilitate the development of such use cases, recommendations were given relevant to innovation management. Lastly, a roadmap was developed which gives indications about the optimal order of use cases and their interdependencies. New technologies are an essential part of the effort to digitalise and modernise inland waterway transport (IWT). They can improve the usability and competitiveness of inland waterways in comparison to other modes of transport, which makes them integral to a future-proof IWT concept.

Assessed technologies:

Areas marked in green are highly relevant (3 or 4), yellow marks cases with some relevance (2 or 1).

Technology	Relevance for Logistics	Relevance for Inland Shipping	Relevance for Fairway Authorities
5G	3/4	2/4	1/4
Distributed Ledger	3/4	2/4	1/4
Internet of Things	4/4	4/4	4/4
Cloud Computing	4/4	4/4	4/4
Artificial Intelligence	4/4	3/4	3/4
Big Data Technologies	4/4	4/4	4/4
Virtual Reality	1/4	1/4	1/4
Augmented Reality	3/4	2/4	1/4
Drones	1/4	1/4	2/4
Digital Twin	2/4	1/4	2/4

No immediate conclusion can be drawn from this ranking, as most technologies are used in conjunction with other ones to enable the development of novel applications. Whilst it helps to observe technologies with only low to medium relevance, the following section creates use cases build upon the technologies which are truly relevant to fairway authorities. These four technologies (IoT, cloud computing, AI, and big data) are the cornerstones of the four use cases created within section 4. Whilst digital twins are central in the very late stage of the outlined roadmap, the immediate impact of such a technology is much lower compared to the tangible benefits which the other four provide. Nonetheless, innovation progresses in a non-linear way, which is why authorities should always be aware of technologies deployed in adjacent sectors. In conjunction with concrete innovation

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management procedures (outlined in section 5), fairway authorities can mitigate the risk of being unprepared in the face of change.

Proposed use cases:

Based on the defined technologies, four use cases were developed.

A cross border data exchange platform (Use Case 1) represents the basis for all following endeavours. The platform is the central hub for all activities conducted under national and European initiatives. It serves as an extension of current RIS systems. It incorporates planning tools from private or public logistics stakeholders (such as RPIS) and data based on the actual state of the waterway (i.e. EuRIS). Its open APIs allow external stakeholders to increase planning capacity and transparency.

Smart Infrastructure (Use Case 2) encompasses two main concepts, which are both made possible by the installation of sensors in critical parts of the respective structure. Firstly, the observation and analysis of existing infrastructure (e.g. bridges, locks) for the purpose of predictive maintenance. This allows for a more reliable and efficient waterway management system. Secondly, sensory data can be used to make local infrastructure react to common external conditions (e.g. a vessel approaching) by using simple algorithms, eliminating the need for human assistance in many cases.

The Predictive Traffic Concept (Use Case 3) case builds extensively on the previous two. It requires an extensive pool of data which combines a multitude of different dimensions, such as planned data from shipping companies and accurate real-time data from RIS systems. Using AI systems to recognise patterns in historical and current data, it can make predictions about the state of traffic on the waterway. As such, it provides an increase in accuracy and reliability. In addition to recommendations provided by the system, it can make some basic decisions, thus assisting the vessel operators and others for an optimised use of the IWT.

The holistic digital twin (Use Case 4) is the product of all previous use cases in conjunction with similar applications from other modes of transport (i.e., rail, road, and air). In its ideal state, it represents the consolidation of previously separated but interdependent applications in the logistics sector. Its goal is to harmonise all modalities and create a platform or application which allows the user to find the most efficient and sustainable mode of transport for the respective product. In addition, it allows for a comprehensive, intuitive overview of the entire waterway (and possibly the entirety of all modes of transport).

The use cases require relevant data to work properly. All use cases combined aim to collect the following data (see Figure 1):

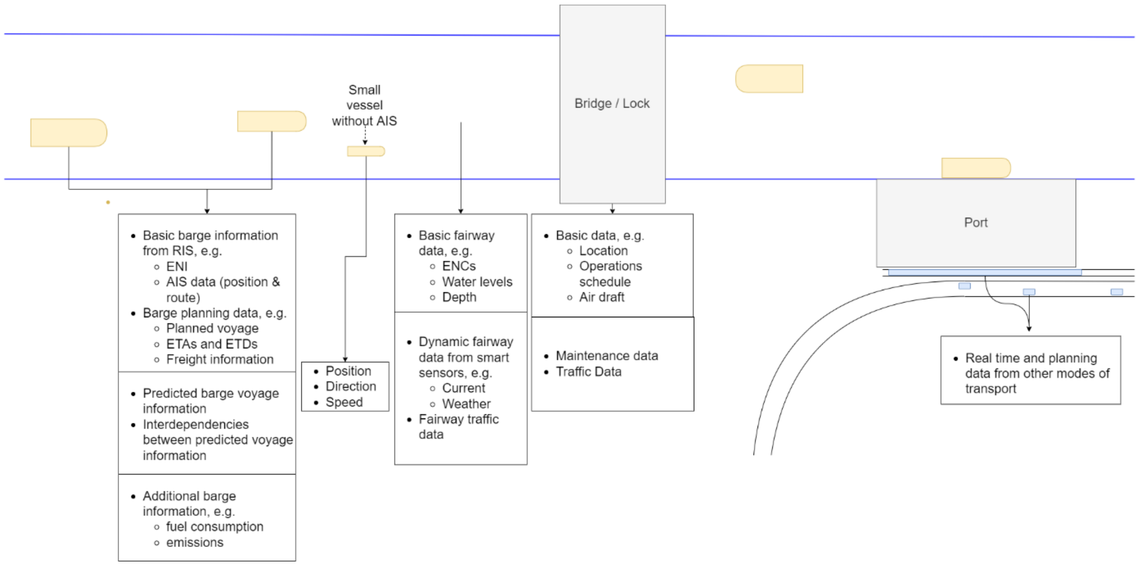

Figure 1: Overview of all use cases

Most data can be collected by fairway authorities either directly or through service providers. Consequently, the authorities can be the main driver in the development of these use cases. Only use case 4 requires considerable external input. However, by ensuring compatibility and extensive cooperation, fairway authorities can still make an important impact.

Actions needed to facilitate the proposed use cases:

Fairway authorities and IWT will benefit greatly from implementing certain innovation management procedures. The list discussed in the report are:

- **Utilise existing cases for new technologies** to save effort and capacity which are spent on pursuing redundant projects.
- **Identify minimum viable products (MVP) for each use case** to provide tangible results through a pilot which can guide further efforts.
- **Initiate and strengthen multimodal and international collaboration** to benefit from the interdependencies between different stakeholders.
- **Cooperate with private and public private partnership (PPP) initiatives** to combine private efforts closer to the market with public initiatives closer to the solution.
- **Create standards and provide data of the waterways/objects/fleet** to harmonise European efforts, helping the development of a more connected and intermodal solution.
- **Establish permanent digital innovation teams** to foster the continuous development of new applications with a focus on advanced technologies.
- **Establish a knowledge management** platform to benefit from the extensive expertise gathered through European fairway initiatives.
- **Establish a collaboration tool for projects and ideas** to decrease the time it takes for an idea to reach relevant stakeholders and potential partners in other fairway authorities.

Roadmap for proposed use cases:

Some of the outlined use cases can be pursued individually, specifically use case 1 and 2. However, use case 2 greatly benefits from a sophisticated platform (use case 1), especially for the harmonised management of smart infrastructure on specific corridors or entire waterway systems. As a result, the platform should be developed first. Due to it being very close to the current EuRIS, it may take less than five years to reach the required level of advancement. Use Case 2 can be developed in parallel, since it uses very different technologies and requires different expertise. The deployment may take more time since such solutions are less established. Nonetheless, expectations are that it is feasible to reach a certain standard on some corridors or waterway systems within the next five years.

The Predictive Traffic Concept requires a high degree of maturity within the two previous use cases because it applies the technologies used for these applications to create a much more advanced and powerful tool. It may be feasible to reach this important milestone within the next ten years if the initiatives are on time and deployed on a large scale. The Holistic Digital Twin is a vision which will be realised once all previous use cases are explored extensively and cooperation between different modes of transport well established. It will most likely take longer than 10 years to realise this vision.

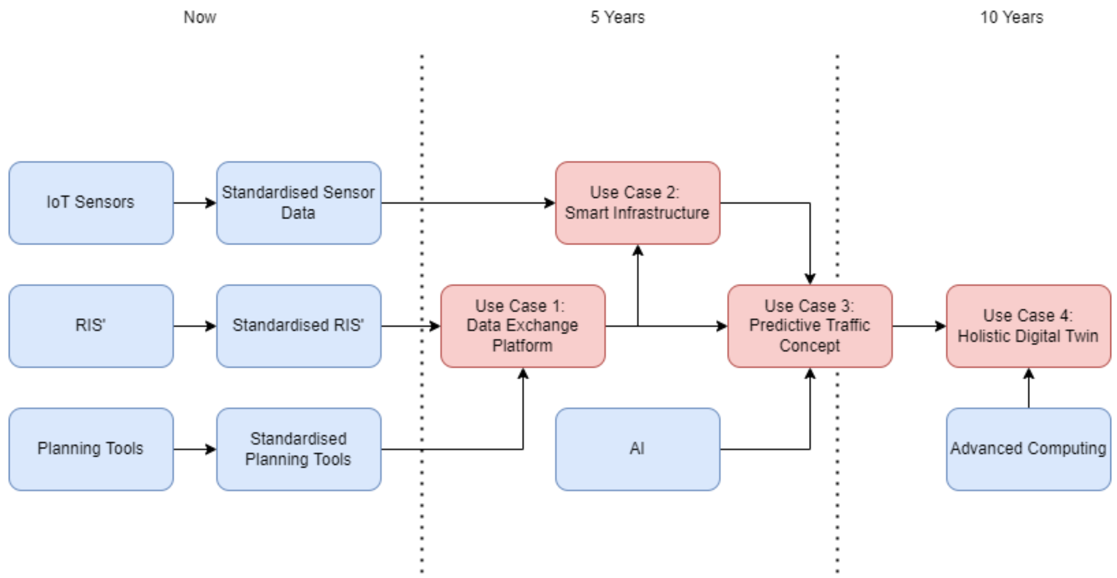

Figure 2: Roadmap overview

Blue: Required technological developments for the successful implementation of the Use Cases

Red: Use Cases

Introduction

This study is part of the DIWA project aiming at the development of a masterplan for the digitalisation of inland waterways and was conducted by bloog GmbH[1] and the DIWA workgroup under the supervision of via donau. It focusses on the question which new technologies are applicable for inland waterway transportation (IWT) and how they can be applied to promote the digitalisation of the fairways. New technologies within the scope of this study are innovations that are not yet proven industrial standards, meaning they have not been established for three years or more.

New technologies play an important role in digitalisation strategies as they are required or at least enabling the use of information technology for the support of business processes.
As inland waterways play a major role in logistics, new technologies that are applicable in logistics have been analysed in detail for this study. Historically, logistics requires physical interconnectivity along the supply chain and between the stakeholders. Digitalisation in logistics also requires a high degree of interconnectivity and thus standardisation. Visibility, transparency, and plannability along the supply chain are key values in logistics. They are decisive factors for the attractiveness of a transport mode.

New technologies do not only enable further optimisation along the supply chains and economic attractiveness. They can also increase service quality, security, and safety as well as ecological sustainability.

Autonomous shipping is a good example to illustrate the role of new technologies in digitalisation and automation projects. Many kinds of sensors are required to capture the environment in real-time to safely navigate the barge through the fairway. Receiving the relevant sensor data requires a sophisticated communication network with the sensors and other surrounding objects. Digitalisation and automation projects often go beyond the one-to-one transfer of manual and physical processes into the digital world. For instance, the integration of holistic fairway information into the routing decisions for autonomous barges will lead to a more economic and ecological use of the autonomous barges.

This kind of generation of added value by means of new technologies is typical for digitalisation projects and will be highlighted in each of the use cases described in this study.

[1] bloog GmbH is consultancy for digital transformation based in Hamburg, Germany. https://bloog.consulting/en/

Objectives of this report

The overarching goal of this study is to allow fairway authorities to meet the anticipated needs of inland waterway users in the future. To enable this, the report is divided into three parts: (1) technologies, (2) use cases and (3) implementation recommendations.

(1) The first part gives an overview of ten technologies that were selected as relevant for inland waterway transport, now and in the future. These technologies were selected by the DIWA workgroup and bloog. They provide a broad overview of current digital trends which might affect the operation of inland waterways transport. While the list is not exhaustive, it covers many of the most influential technologies, such as Artificial Intelligence, the Internet of Things and Digital Twins. It does not cover highly advanced technologies such as quantum computing because they were not deemed relevant by the experts within the DIWA workgroup since they had no influence on the development of specifically fairway authority related applications (but do influence the development of applications and IT in general). Still, many of these technologies are very different in scope and maturity. To make them comparable, they each are subject to the same rating and assessment system, which will be discussed in the respective section.

(2) The second part combines multiple of these technologies into use cases to provide a better understanding about possible applications of the previously selected technologies. These use cases were selected by the experts of the DIWA workgroup in collaboration with bloog. They represent the most effective and efficient combinations of the covered technologies, thus allowing fairway authorities to best meet the requirements of a digital inland waterway.

(3) The third part is practical in nature, providing information on how to best implement these use cases. It was developed by bloog with the help of the DIWA workgroup and other external experts. The last part thus completes the holistic approach which aims at supporting fairway authorities to make inland waterways more digital and thus future-proof.

Scope of this study

This study was conducted by via donau with support of the DIWA workgroup and bloog. Over a period of five months, five fairway authorities participated in the project: via donau (Austria), Rijkswaterstaat (The Netherlands), De Vlaamse Waterweg (Belgium), Voies navigables de France (France), and Bundesministerium für Verkehr und digitale Infrastruktur (Germany).

Work conducted within Sub Activity 3.1. encompassed multiple workshops, interviews, and presentations. Specifically, two workshops were held by the DIWA workgroup (22 February and 18 March 2022). All workshop results can be found in the appendix. In parallel, interviews with experts were conducted to gain additional insights on the demands and technological pursuits of public and private organisations. The results were incorporated in the assessment of the respective technology or use case.

Methodology

Identification of relevant technologies

As stated in the introduction the identification of relevant technologies was driven by the following questions:

- Is there at least one application of the technology in logistics? The area of general logistics was chosen because Fairway Authorities act adjacent to this sector. Consequently, any technology or application that is used by a significant number of logistic companies will be relevant for Fairway Authorities and IWT, even though the authorities themselves might have little use for it. Distributed ledger technologies, for instance, were deemed highly relevant for logistics companies, whilst having a mostly negligible effect on the direct operations of Fairway Authorities. Nonetheless, a future cooperation with a distributed ledger technology user (such as a big logistic firm) might make it necessary for the authorities to implement certain standards. Consequently, it is important to observe such adjacent technological clusters, which is why logistics firms were the focal point during the selection of technologies, not necessarily Fairway Authorities.
- Is the technology "new" in the sense that it is not yet established by many stakeholders in logistics for more than three years? Since the adaptation of new technologies varies across stakeholders, so does the definition of what is "new". Nonetheless, it can be observed that most of these technologies are not established by most actors within the logistics industry. Whilst many applications for big data have been found, many companies and institutions are still using the technology to only a small part of its potential. Thus, it can be described as new in terms of broad market adoption and maturity. This logic applies to all ten identified technologies, even though some of them are more advanced than others.

The selection of relevant technologies has been taken by the authors of this study in close collaboration with the DIWA working group for sub activity 3.1. The following new technologies have been identified:

- 5G communication technology
- Distributed ledger technology
- Internet of things (IoT)
- Cloud Technology
- Artificial intelligence (AI)
- Big data for predictive analytics
- Virtual reality (VR)
- Augmented reality (AR)
- Drones
- Digital twin

As the definition of “new technologies” leaves room for interpretation, the challenge in this categorisation is that the selected technologies are not very homogenous with respect to the scope of applicability. Furthermore, some technologies are interdependent, such as IoT and big data and are therefore difficult to differentiate.

To overcome these challenges and to achieve a comparable and clearly structured assessment of the technologies, standardised scorecards have been developed as well as classifications along the Gartner Hype Cycle. Consequently, each technology review consists of three parts:

(1) An explanation and assessment of each respective technology including some real-world examples
(2) The Hype Cycle (including a description)
(3) The scorecard

The following subsections describe these methodologies in detail.

Explanation and assessment

The explanation for each technology aims to give an understanding about the basic function and logic behind each technology. Most explanations are supported by some real-world examples from an adjacent sector, such as logistics or seafaring. It is important to note that all cases were solely chosen on perceived relevance and merit and are not in any way endorsed by the authors of this report. Their only purpose is to give a better and more detailed understanding about each technology. Based on the description and applications of each technology, an assessment on the importance for fairway authorities is given. Since this report aims to give an overview about the next ten years, assessments may have to be changed in accordance with the technological and organisation advancements in inland shipping. Nonetheless, the authors believe that many of the assessment will remain relevant throughout the following years.

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Hype Cycle

The first metric which was used to analyse a technology was the Gartner Hype Cycle. It displays the maturity of a technology, based on the assessment of either Gartner or other experts. It is divided into five parts, each representing a phase a product or technology usually goes through on the way to market adoption. The five phases are:

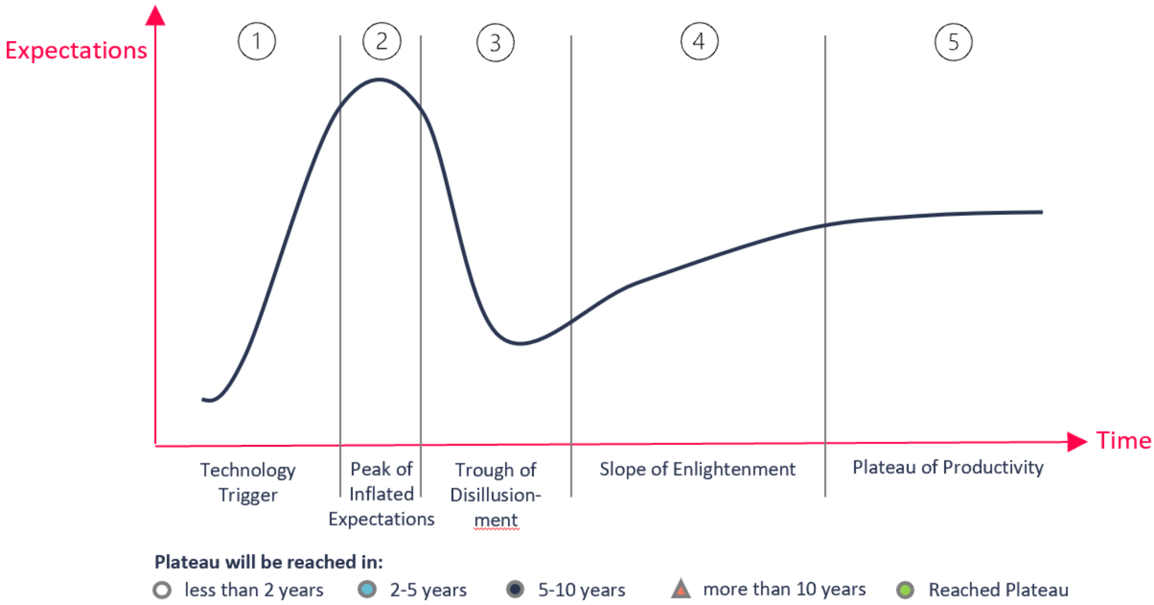

Figure 3: Gartner Hype Cycle

(1) Technology trigger: a significant breakthrough occurs, making technology experts aware of the application or product.
(2) Peak of inflated expectations: early reports about the performance and potential of the application are usually overly enthusiastic, distorting the public opinion in favour of the technology.
(3) Trough of disillusionment: real-world applications of the technology struggle and fail to meet the unreasonably high expectations of the public. Thus, interest in the product declines.
(4) Slope of enlightenment: the technology is understood better, allowing for improved implementation in its proper market niche. As such, performance begins to increase, and expectations become more reasonable and nuanced.
(5) Plateau of productivity: the product features are much clearer and better explored, thereby it makes it easier to assess the proper cases in which it should be used. As such, it can become an established application for specific circumstances on the mass market.

The Gartner Hype Cycle does have the benefit of giving a concise overview of technologies and the expectations users and experts have towards them. As such, it can be used to properly determine the position of a certain technology or application in terms of expectations, which usually coincide with the "readiness" of such product to be used on a wide scale. Fairway authorities usually do not drive the development of technologies. Instead, they are a niche user which must rely on well-established technologies in combination with newer, potentially promising ones. The Gartner Hype Cycle can give a hint on whether a technology is on the track of becoming something to watch or something to ignore (at least for now).

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Scorecards

In addition to the Hype Cycles, scorecards have been developed. They aim to give a holistic assessment of each technology. As many technologies are very different in scope and maturity, a rating system was devised to make them comparable. Each rating consisted of a score from 0 to 4. The rating was conducted by bloog, using the assessment of experts within and outside the company which either work or research in the field of maritime and inland waterway logistics. The aim is to give a better understanding of the relevance based on experience, current developments, and projected trends within each domain. The rating was:

(0) The technology is entirely irrelevant to the respective sector. Either it will most likely have no impact on the industry over the next ten years or the respective industry has no bearing of the development of the technology at all.

(1) The technology is mostly irrelevant to the respective sector. Over the next ten years, it will only have a very marginal effect on the industry in highly specific cases.

(2) The technology is relevant to the respective sector. Over the next ten years, multiple applications will be found which have a noticeable impact on the industry.

(3) The technology is highly relevant to the respective sector. Over the next ten years, multiple, highly influential applications will be launched which have a noticeable impact on the industry and adjacent sectors.

(4) The technology is essential to the respective sector. Over the next ten years, every stakeholder in the respective industry and adjacent sectors will utilise some form of the technology extensively. It will provide unique, highly important benefits to most of the stakeholders.

Each rating of a technology was done thrice, to cover all relevant adjacent sectors. It assessed the relevance of the technology over the next ten years. The three rated categories were:

(1) General logistics: since inland waterways are tightly connected to other modes of transport and the development of logistics in general, it gives an indication on whether a technology is deemed important by the industry. In cases where the importance is high, indications are that it might become relevant for fairway authorities soon or over time.

(2) Inland shipping: users of inland waterways have a very specific set of demands and needs. This rating captures the importance of a technology for such users. Thus, it gives an indication about the value of certain applications within a technological domain for stakeholder such as vessel operators or shipping companies.

(3) Inland waterway authorities: public institutions usually have a very different approach to technologies since their needs differ vastly from those of users and consumers. This rating scale covers the importance of a certain technology to the administrative and supportive capabilities of a fairway authority.

New Technologies

5G Technology

5G is the state-of-the-art technology standard for broadband cellular networks. It is the successor to the previous cellular network standard 4G and 3G, which are still dominant in many areas, especially rural locations. 5G started being deployed internationally in 2019.
In comparison to its predecessors, 5G improved significantly in speed and latency:

Generation	Technology	Maximum Download Speed	Typical Download Speed	Latency
2G	GPRS	0.1 Mbit/s	<0.1 Mbit/s	500 ms
	EDGE	0.3 Mbit/s	0.1 Mbit/s	
3G	3G (Basic)	0.3 Mbit/s	0.1 Mbit/s	100 ms
	HSPA	7.2 Mbit/s	1.5 Mbit/s	
4G	LTE Category 4	150 Mbit/s	15 Mbit/s	50 ms
5G	5G	1,000-10,000 Mbit/s (1-10 Gbit/s)	150-200 Mbit/s	<10 ms

Source: https://kenstechtips.com/index.php/download-speeds-2g-3g-and-4g-actual-meaning

The speed and latency of 5G networks is dependent on the used frequency. The frequency ranges from 1 GHz to over 30 GHz. In general, higher frequency leads to higher speeds, lower latency, and lower range. The most common is sub 6 GHz 5G (mid-band 5G) which usually delivers download speeds of 100-1400 Mbit/s. The high frequency results in ranges of only a few hundred meters compared to 4G, which is why the widespread implementation of 5G is a costly and time-intensive endeavour. Nonetheless, 5G allows for so called “slicing” in which individual frequencies can be used by specific entities in the respective area (such as a terminal operator), which enables individual and separate coverage of demand. This makes 5G useable in small-scale operations, too.
However, for most use cases in logistics the bandwidth and latency of 4G is perfectly suitable. Nonetheless, there are exceptions where the high speeds and low latency play a critical role.

For instance, 5G enables high density IoT-Networks with close to real-time data transfer. Within such networks, it supports 100 times more connected devices per unit area than 4G. Furthermore, 5G lowers the networks energy consumption. Since IoT tracking sensors provide real time data and collect valuable information about supply chain processes, they may create enough benefit to justify individual 5G investments. This is usually done in port or terminal areas, which is why the financial feasibility for broader stretches of water remains questionable.

External projects using 5G

The Port of Barcelona used many new technologies, including 5G, to gather accurate and real time information about vessels in the port area.

https://5gbarcelona.org/pilots/5g-maritime/

The city of Kiel is partnering up with Vodafone to enable autonomous shipping through 5G.

https://captn.sh/en/foerde-5g-englisch/

5G is an essential enabler for other technologies, mostly for those using large amounts of data coupled with the need for low latency. These technologies and use cases are discussed in further parts of this report. As has been pointed out by multiple fairway authorities within the workgroup, the authorities themselves have little to no influence over the distribution and development of the 5G network on a large scale. As a result, the relevance was deemed to be very low. Nonetheless, certain hotspots, like ports, high-frequented locks or bridges and certain sections of the waterway might have to be equipped with 5G to support the usage of advanced data solutions, such as the real-time observation and assessment of traffic. In such cases, local 5G networks will suffice and grant tangible benefits for all stakeholders – fairway authorities might enable such limited 5G networks through purchase or partnerships. However, more distributed 5G applications, such as remote-controlled vessels, seem less feasible for entire waterways in the current state. Yet many future solutions might already use 4G solutions to great effect, e.g. by applying LiDAR or other technologies which utilise less data than traditional camera vision. Alternatively, other technologies such as StarLink and other satellite-based services may become feasible in the future, providing connectivity independent of geographical constraints. Consequently, the availability of connectivity is a highly relevant topic for fairway authorities. Yet 5G itself is likely to be less of a concern in most cases since it is either limited to a few condensed areas or because it may become much cheaper in the future.

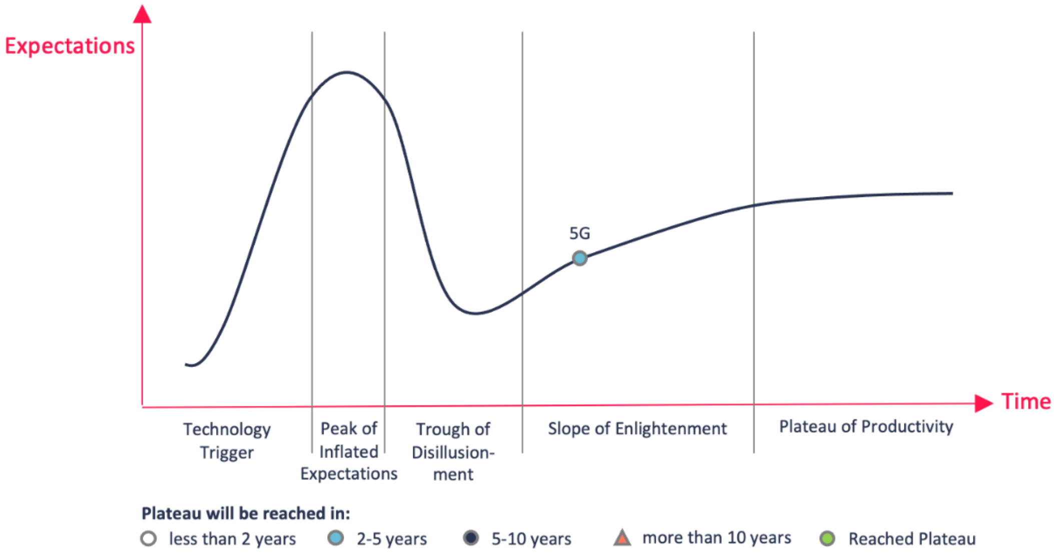

Figure 4: Hype Cycle of 5G

Hype Cycle of 5G:

5G has almost reached its Plateau of Productivity. It is not yet fully established, but the benefits and drawbacks become more apparent. As such, specific use cases can be identified which utilise 5G technology.

5G

Functionality	
	• Technology standard for broadband cellular networks • Provides top-speed of over 1000 Mbit/s with latency at around 30 ms in real-world scenarios (<1 ms in lab test)

Applications	
	• Internet connection for every mobile device • High speeds allow applications like driving vehicles remotely with live video • Facilitates the integration of IoT and other data-driven services

Pros

- High speed
- Low latency for cellular broadband
- Dense connections
- Low error rate
- Individual networks (slicing)

Cons

- Lower range then previous standards for broadband cellular networks
- Due to cost, remote areas are more likely to receive no or little service

Relevance in the next 10 years for:

General Logistics: 3/4

Inland Shipping: 2/4

Fairway Authorities: 1/4

Assessment for Fairway Authorities

- Use cases include dense IoT networks, drone or video surveillance
- Fairway Authorities have little influence over the development of 5G infrastructure
- Low priority for Fairway Authorities over the next ten years

Figure 5: Scorecard 5G

Distributed Ledger Technology

Distributed Ledger Technology (DLT) refers to a consensus of replicated, shared, and synchronised digital data in an immutable manner across a network of multiple entities and/or locations. Unlike a centralised database, DLT does not have a central administrator.

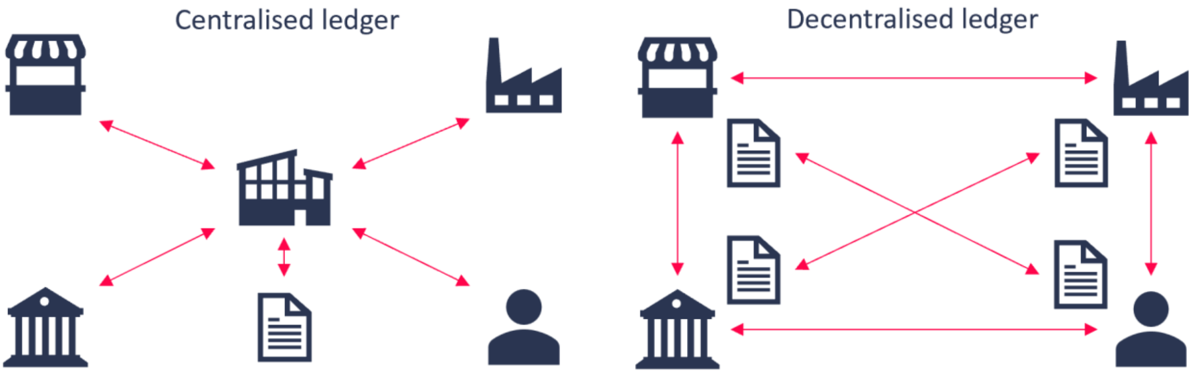

Figure 6: Centralised vs. decentralised ledger

The most prominent form of DLT is Blockchain. The idea of a Blockchain-like protocol stems from the Cryptographer David Chaum in his dissertation in 1982. The idea was revisited multiple times until the first decentralised blockchain was conceptualised in a whitepaper written by the anonymous person or group of people under the name of "Satoshi Nakamoto" in 2009. The whitepaper served as the core concept for the development of the cryptocurrency bitcoin in the following year.

The structure of a blockchain grows by attaching one digital block to another. Thus, each block has one chronological predecessor and one chronological successor. The links to the preceding and following block are unbreakable. This digital concatenation results in a list that documents the values of its users as well as all stored records at any point in time.

The whitepaper of Satoshi Nakamoto served as the core concept for the development of the cryptocurrency bitcoin in the following year.

Blockchain technology has several advantages over centralised databases.

- A blockchain creates a record that cannot be altered and can be end-to-end encrypted. Therefore, blockchain enhances security and prevents fraud. Permissions can be used to prevent access to see anonymised personal data.
- Through the decentralised nature of the blockchain transaction and data are recorded and visible in multiple locations. Thus, transparency is ensured through a consensus mechanism.
- Blockchain creates instant traceability through its record.
- Blockchain helps streamlining transaction by providing a single place for and therefore increases speed and efficiency.

These mentioned benefits lead to blockchain technologies being used by individuals and businesses. There are two types of blockchain catering to different use cases.

- A public blockchain provides access to network and the availability to take part in the consensus for everyone.
- A private blockchain is only accessible by a single organisation. The organisation controls the access and authority over the network. It can be described as a partially decentralised system.

Private blockchains provide higher speeds, better scalability, and lower cost per transaction then public blockchains. Fewer users lead to less time to reach consensus in the network. However, the centralised design and fewer participants lead to trust-issues and makes the network more vulnerable to malicious attacks. Both types of blockchains serve different purposes.

- The first and most prominent use case for blockchain technology are cryptocurrencies which usually run on public blockchains. A cryptocurrency is a digital currency using a medium of exchange and store of value which is not reliant on centralised institutions such as banks or governments. The rise of cryptocurrency started with the invention of Bitcoin in 2009. New cryptocurrencies provide faster transaction times with lower fees then bitcoin. Today the global crypto market cap is at 1.94 trillion USD (21.04.2022).
- Use cases in the logistics sector include the tracking of products through a complex supply chain with many stakeholders and no single authority or institution being able to track and certify the product reliably throughout said chain.

In summary distributed ledger and blockchain technologies provide opportunities for the secure, traceable, and immutable exchange of data. The worth of DLT for industries outside financials still needs to be proven on a large scale. This is especially true for fairway authorities, since they are usually the central authority which provides important documents and certificates, thus rendering much of the DLTs benefits redundant. Nonetheless, cross-industry applications such as waybills, bills of lading or any other document that certifies the origin of a product, might require the cooperation of fairway authorities to be accepted and implemented on a broad scale. However, fairway authorities do not drive this development in any way and play a passive role. Therefore, DLT are deemed mostly irrelevant for the authorities.

External projects using DLT
TradeLens is using blockchain technology for better visibility and control of containers. www.tradelens.com Cargox is using blockchain for document transfer with encryption at the highest confidentiality and the ability to transfer ownership of said documents. www.cargox.io

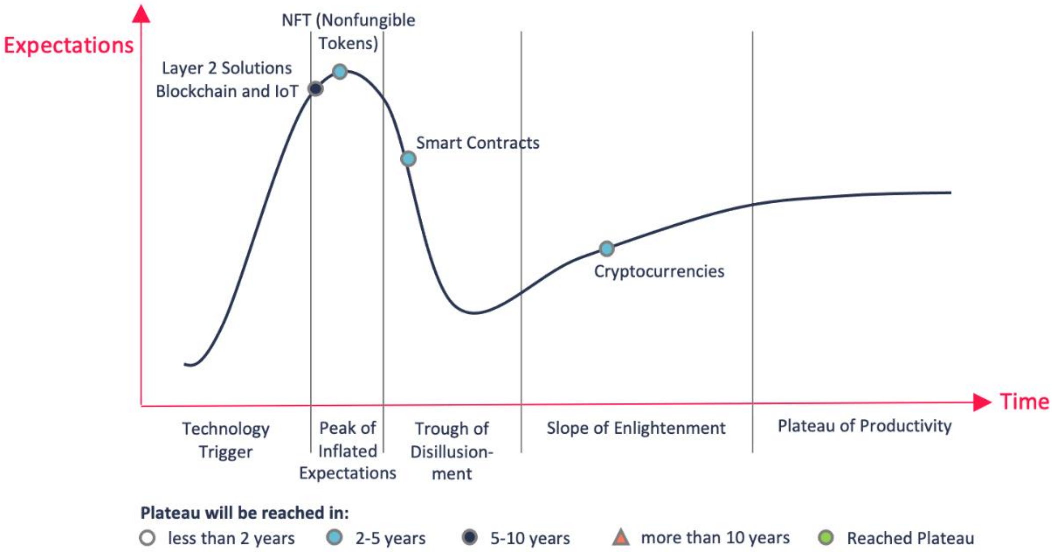

Figure 7: Hype Cycle of Distributed Ledger Technology

Hype Cycle of DLT:

The most famous form of DLT, cryptocurrencies, are almost ready to be adopted by a broad range of users. However, as of now, cryptocurrencies are not widely used (by important entities, such as banks). More sophisticated application, like Smart Contracts and Layer 2 Solutions will have a sizeable impact on the logistics industry but are not yet available to most stakeholders.

Distributed Ledger Technology (DLT)

Functionality

- Digital infrastructure and protocols that allow simultaneous access, validation, and record updating in an immutable manner across a network that's spread across multiple entities or locations

Applications

- Blockchain Technology and Cryptocurrencies (e.g. Bitcoin, Ethereum etc.)
- Cargo-tracking on a blockchain-based platform
- Smart Bills of Lading

Pros

- Secure way of data storage
- Trust through decentralised structures
- Traceability through immutable record
- Transparency through consensus mechanism

Cons

- High development cost
- High maintenance cost

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
3/4	2/4	1/4

Assessment for Fairway Authorities

- Use cases include fraud-proof certificates and bills of lading
- Relevance diminished due central and neutral role of Fairway Authorities
- Low priority for Fairway Authorities over the next ten years

Figure 8: Scorecard of Distributed Ledger Technology

Internet of Things (IoT)

The Internet of Things (IoT) describes a concept whereby one can connect almost any device with an on/off switch to the internet, though it can involve local networks or communication with other devices. Whilst some companies may have used sensors in their own machines and local networks before the 2000's, the term IoT itself was coined in 1999. Throughout the past 23 years, it rapidly increased in popularity, representing one of the most utilised technologies today. According to Cisco, there were only 0.08 devices per person and around 500 million connected devices in 2003. In contrast, by 2020 each person owned 6.58 devices with 50 billion devices being connected throughout the world. There are several factors which contribute to this rapid ascent of IoT.

- A multitude of developments made it possible that a practically infinite number of devices can be connected to the internet whilst retaining a unique ID (via IPv6).
- Sensors are much cheaper and more reliable than in the past. According to Microsoft, the average sensor price fell by 66% between 2004 and 2018. This makes large scale IoT operations much more feasible.
- Cloud computing helped tremendously in the development of IoT, too. Low priced sensors are not enough if the company using them has not the computing power and storage capacity to analyse the data provided by the devices. Cloud solutions allow for a much more seamless integration and scaling of IoT concepts.
- Machine learning enables the rapid collection and assessment of data through algorithms developed to uncover patterns. Without the assistance of computers, the vast amounts of harvested data could simply not be used. More advanced artificial intelligence solutions help in providing more nuanced insights and to act accordingly. Furthermore, AI applications such as Siri help in usability, since they allow the user to directly access smart devices via voice command, making it much more appealing for private users.

As a result of the above-mentioned developments, IoT concepts are nowadays feasible for companies and individual users. Even though private applications become more relevant, manufacturing is still the biggest driver of IoT. Through the concept of Industry 4.0 companies aim to build smart factories, which collect data from operations (such as production, procurement, or maintenance) to make better decisions, increase automation, self-optimise, and allow implementation of predictive maintenance and other predictive modes of operation such as inventory management. Some exemplary applications of IoT are:

- Predictive maintenance is made possible by collecting data from machinery or other infrastructure elements which deteriorate over time. Most items have a specific time after which they are replaced, e.g. after five years. The real depreciation, however, is highly dependent on the actual use. By observing the usage and performance via sensors, parts can be replaced in accordance with their actual state of deterioration, saving money and resources.

- By tracking cargo, companies can identify bottlenecks along the supply chain. This can be useful for different perspectives: shipping companies can optimise their flow of products by using alternative modes of transport in case of inefficiencies. Terminal operators can benefit from tracking by allocating internal resources (such as staff or equipment) according to the actual need.
- Autonomous vehicles are still a far way off in most countries. However, in a more controlled environment with limited external parameters, automation can be achieved by using sensors and the appropriate software. Inside factories, for example, machinery used for the transport of goods on the premise requires very few channels of input. Sensors embedded into the floor and on the vehicle can suffice in a highly controlled environment (e.g. AGVs in a port, transfer trolleys in a factory).
- A smart home is one of the most important private applications which uses IoT. Whilst a decade ago smart homes were merely equipped with remotely controllable devices (such as blinders and lights), the technology has advanced considerably. Today, smart homes utilise IoT and AI technology which grant devices certain autonomy and decision-making capabilities, such as a fridge ordering food once a certain item has been used, or a heater turning on in anticipation of the owner returning from work.
- Just like smart homes, many industrial concepts apply AI technologies to their connected devices. More sophisticated solutions which utilise artificial intelligence are discussed in the respective section of this report.

In summary, IoT solutions provide considerable benefits in many industrial and private settings. Some fairway authorities already use IoT applications, for instance for tracking the deterioration of important parts in the infrastructure, such as locks and bridges. Further, already established solutions are the tracking of traffic on certain hotspots, the tracking of (empty) barges in ports and the monitoring of berthing spots. While many IoT solutions present challenges, from contractual issues to the identification of relevant data, they are deemed highly relevant for fairway authorities. They allow for a significant improvement in many services and most identified use cases apply IoT applications extensively. Other trends, such as Artificial Intelligence, will further increase the importance of such applications in the future. As a result, fairway authorities will benefit greatly from an active role

External projects using IoT
The rail freight company VTG has equipped its fleet of waggons with smart IoT sensors capturing relevant data. https://www.vtg.com/customer-solutions/vtg-connect The port of Rotterdam has implemented an IoT based system for weather and water data. https://www.portofrotterdam.com/en/news-and-press-releases/port-rotterdam-puts-internet-things-platform-operation

in this field, as their access to bottlenecks (i.e., locks and bridges) and other important structures throughout the waterway grant them unique access, which allows for sophisticated IoT solutions.

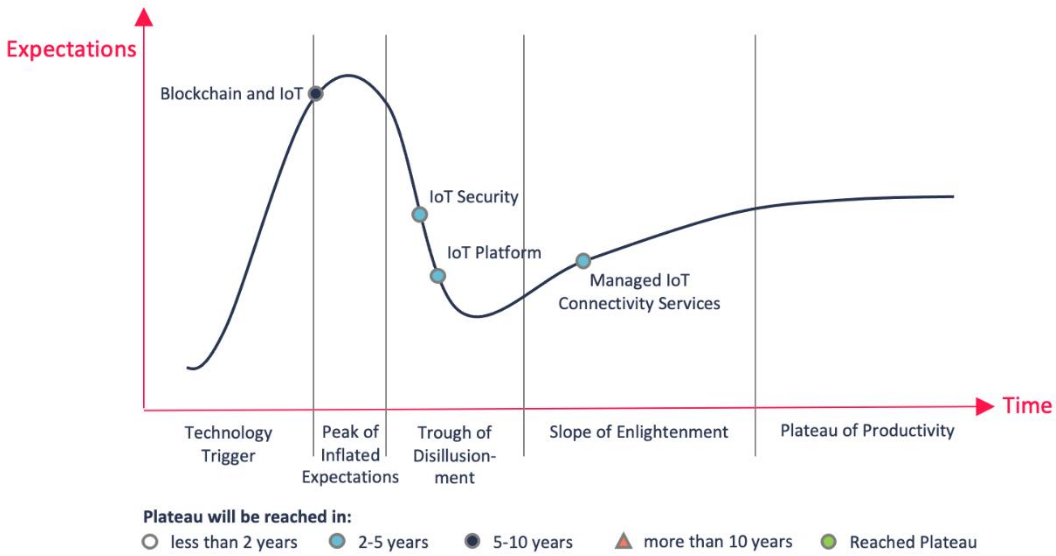

Figure 9: Hype Cycle of Internet of Things

Hype Cycle of IoT:

Many IoT applications are still not yet tested and mass-market ready. However, many will reach maturity in the next 2 to 5 years. More sophisticated applications, such as the combination of Blockchain and IoT, are still farther off and will require significant effort to be feasible.

Internet of Things (IoT)

Functionality

- Physical objects (or groups of such objects) that are embedded with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems

Applications

- End-to-end product tracking
- Wearables for increased safety (e.g. RFID)
- Foundation for big data solutions (e.g. predictive analytics)

Pros

- Large amounts of data that can be utilised for many purposes
- Many sensors are very cheap and widely available

Cons

- Complex IoT Networks are very expensive
- Data analysis can be costly and ineffective when data set isn't purpose driven
- Cyber security

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
4/4	4/4	4/4

Assessment for Fairway Authorities

- Use cases for Fairway Authorities include predictive maintenance and analytics, real-time observation of infrastructure
- Strong interaction with other technologies (e.g. big data and AI)
- Very high priority for Fairway Authorities over the next ten years

Figure 10: Scorecard of Internet of Things

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Cloud Computing

Cloud Technology or Cloud Computing allows the user to access pre-existing infrastructure through the internet on demand. Such infrastructure can include physical and virtual servers, software applications, development tools, data storage solutions and much more. Cloud computing came into being when software providers such as Salesforce started to deliver software applications via websites (1999) and truly took off with the development of large-scale cloud solutions, such as Amazons Web Service (AWS) which was publicly launched in 2006. Other providers, such as Google and Microsoft followed suit. Even though many of these business models vary to some degree, the underlying concept remains the same. The National Institute of Standards and Technology (NIST) identified five essential characteristics of cloud computing. These are as follow:

- On-demand self-service means that any user of the respective cloud solution can access (through a purchase) additional computing capabilities without having to interact with a person.
- Broad network access describes the possibility of accessing the cloud via several different devices (e.g. phones, computers, tablets) through a standardised network (such as the world wide web).
- Resource pooling allows the cloud provider to assign and reassign physical and virtual resources according to the actual need of its customers. The user has no specific knowledge about the physical location of the hardware, though certain parameters (such as country) may be specified by the user.
- Rapid elasticity defines the ability of the provider to adapt to the consumer demand almost instantly. New cloud capacity can be increased by margins which exceed the demand of individual consumers by large amounts, giving them the freedom to act without capacity restraints.
- Measured service describes the ability of the provider to automatically measure, control and optimise resources used for the cloud (e.g. storage capacity, bandwidth, processing power), thus allowing for a high amount of transparency for provider and consumer.

Cloud service models correspond to the typical cloud computing architecture: infrastructure, platform, and application. Many of the big providers (such as Amazon or Microsoft) offer all three services.

- Infrastructure as a Service (**IaaS**) describes the ability of cloud computing to provide a certain infrastructure through storage or computing capabilities. In this service model the user can purchase storage, network capabilities or computing power. Compared to the other models, the consumer has the most control over the deployed applications and software environment, such as the operating system. Examples are the Amazon Web Services or Microsoft Azure.

- Platform as a Service (**PaaS**) provides a virtual platform on which a user can upload his or her own applications, which are then managed by the cloud. The user may not control the operating system or the underlying cloud infrastructure yet has the advantage of handing over more control and responsibility to the cloud provider. Examples are Heroku (by Salesforce) or the Google App Engine.
- Cloud-native applications are provided through the service model of Software as a Service (**SaaS**). This service model gives the least freedom to the consumer. However, it provides any user with a broad array of pre-defined applications which can be utilised without any development necessary on the side of the user. As such, they are attractive to businesses which can rely on standardised applications (such as a website for sales or a storage solution for businesses). Examples are Google Drive, Microsoft OneDrive, or Salesforce.

All three service models provide a considerable amount of flexibility, though the outsourcing of IT-capabilities has certain drawbacks, like a decrease in control and potential data protection issues. Nonetheless, it is a pillar for most software related endeavours since it allows easy scaling and demand driven capacity provision. Currently, many platforms deployed by fairway authorities utilise basic cloud technologies. As such, it serves as an enabler for software- and computer-based solutions. In the future, cloud technology could help to establish practices which would otherwise be hard to implement, for instance using artificial intelligence for analysing large amounts of data. By providing external computing power, it could thus help fairway authorities and other institutions to make the next step in data-centric services. Consequently, fairway authorities can greatly benefit from cloud solutions.

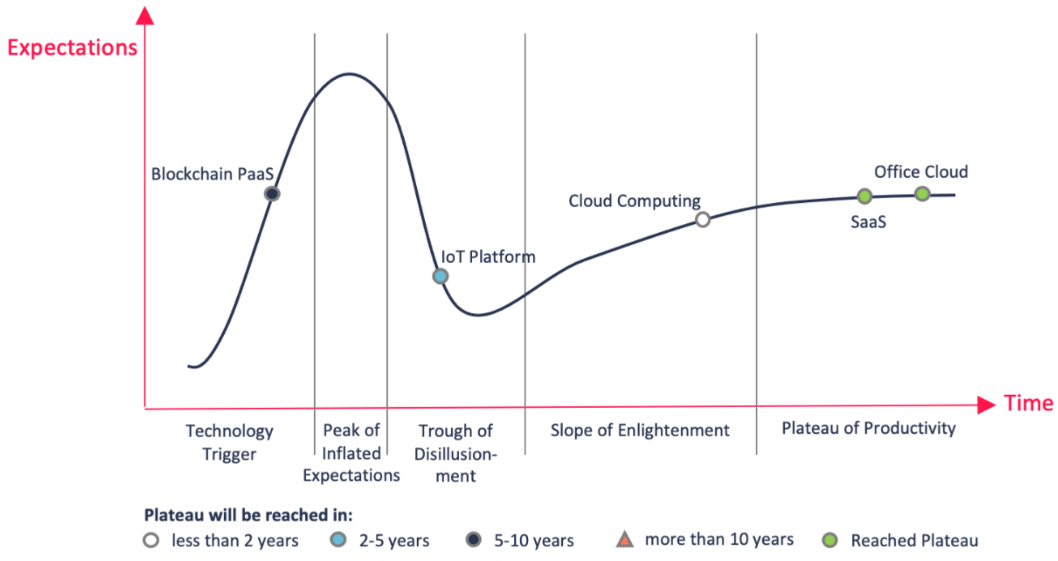

Figure 11: Hype Cycle of Cloud Computing

Hype Cycle of Cloud Computing:

Many forms of the cloud are already available on the mass-market. They provide simple, yet effective measures to increase storage capacity, sharing capabilities and computing power. Nonetheless, more intricate applications have the potential for the mass-market, such as platform-as-a-service solutions with Blockchain or other DLT. These are much more complex than conventional cloud solutions, however, thus they will probably need up to ten years to reach maturity.

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Cloud Computing

Functionality

- On-demand availability of computer system resources, especially data storage (cloud storage) and computing power, without direct active management by the user

Applications

- Harmonised data sets from multiple sources
- AI and big data solutions
- Different service models for the provision of software, platform and infrastructure

Pros

- Reduces internal IT infrastructure
- High availability
- High degree of flexibility and scalability
- Cost-effective and low maintenance

Cons

- High dependency on cloud provider in terms of availability, security, cost
- Limited control over data

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
4/4	4/4	4/4

Assessment for Fairway Authorities

- Use cases include platform hosting and the provision of standardised software
- Almost all application will utilise cloud computing
- Very high priority for Fairway Authorities over the next ten years

Figure 12: Scorecard of Cloud Computing

Artificial Intelligence (AI)

In the past ten years, AI has risen from a rather obscure, niche topic to one of the most anticipated and well-funded research areas on the globe. AI programmes are at the core of many established applications and new inventions, from highly optimised search engines to autonomous vehicles. However, the basic approach to AI has changed dramatically over the past decades and many challenges remain unsolved.

Artificial Intelligence has many definitions, some of which revolve around the understanding and mimicking of human intelligence, whilst others focus on the general ability to solve problems and achieve goals. Regardless, most experts locate the start of true AI-research in the 1950's, when digital computers first became available. During its history, AI struggled to garner enough support and slid into multiple "AI Winters", periods of prolonged inactivity among investors and researchers. Since the 1990's, however, AI research has been gaining momentum and current analyses show that this trend is unlikely to stop. Especially since 2015, many tech giants focus heavily on the development and implementation of AI related projects. There are multiple reasons for this reverse.

Firstly, AI projects have become much more specific. So-called weak or narrow AI focuses on much more distinct questions, thus allowing for the use of tailor-made models and highly concrete statistics to master a particular task. In contrast, developments along the line of artificial general intelligence (AGI) have seen much less success.
Secondly, an increase in computing power and cloud computing have enabled a broad scientific community to engage in the research and application of AI-centred programmes. As such, it has become much cheaper to utilise AI.
Thirdly, new models of data processing and learning have been devised. Recognising the weakness of symbolic AI, most methods utilise a very different approach today. Under the umbrella term of Machine Learning, experts have found ways to teach AI to learn through experience. Such an approach became possible thanks to an ever-increasing capacity in computing power and data storage. Methods such as Deep Learning allow machines to learn almost like humans. Instead of using pre-defined rulesets and hierarchies established by human programmers, AIs using Deep Learning find and process patterns. This can be done either by supervised learning or unsupervised learning.

Using supervised learning, a program learns to link human-given labels (such as "cat") to labelled pictures showing a cat. By weighing different aspects of the image (such as form, colour and many more) through a neural network, the program learns how to best identify an image. Each given data pair increases the accuracy of the prediction. Unlike humans, who can usually recognise a cat after only seeing it a couple of times – or even just once – computers need large amounts of data to be accurate. However, once a program is conditioned to recognise certain patterns it can best human experts in almost any field. For instance, AI can now outperform large teams of trained doctors in the

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recognition of cancer – which is especially valuable in the early phase of the disease. Due to small cues invisible to most human eyes, AI can predict the development of some kinds of cancer from a very early stage.

In contrast, unsupervised learning simply finds patterns in unlabelled data, which requires even less human input. It reduces human bias and can lead to new results, finding hidden patterns which the developers or users were previously not aware of. Among other things, it can cluster data in certain ways, thus detecting anomalies. This can help banks to find fraudulent transactions or companies to identify bottlenecks along the supply chain. Both versions of Deep Learning have many merits. They are used nowadays in plethora of ways. Some simply replace human tasks, such as chatbots. Others recognise patterns, which can help to prevent diseases, bottlenecks or mitigate other risks.

External projects using AI
Blockshipping applies AI to increase the efficiency of container terminals. https://blockshipping.net/ Awake uses AI to optimise berth planning and other port operations. https://www.awake.ai/ AiCON works on a holistic AI-driven solution for terminals. https://avlino.com/solutions/maritime-logistics.html

Alternative learning models provide even more potential use cases for AI applications. Reinforcement Learning, a technique in which an AI agent interacts with a (usually virtual) environment without guidance through trial-and-error implies applications beyond the mere passive optimisation done by programs which aid humans. Mostly known from games such as chess and Go, machines using Reinforcement Learning find strategies totally novel to humans, even in such highly restricted game settings which have been studied for hundreds or even thousands of years. Consequently, such learning strategies are extremely useful in optimising processes already conducted by robots, from simple assembly jobs to highly complex optimisations along a supply chain.

AI applications have already proven to be extremely powerful. They thrive in an environment where data is abundant or can be easily simulated yet struggle in situations where the goals are diffuse, and data is scarce. Nonetheless, an increasingly broad array of learning methods, computing power and data collection will only increase the potential of AI in the upcoming ten years. Being able to collect and analyse large amounts of data about and from relevant stakeholders, such as vessel operators and cargo, is a unique benefit available to the authorities, which further strengthens their position as a driver for more AI-focused solutions. Such solutions can drive many future trends, such as the recognition of complex patterns, resulting in even more accurate traffic forecasts or early-warning systems, change detection of nautical objects (like buoys). Consequently, Inland waterway users, like vessel operators or logistics companies, can benefit considerably from AI-driven application.

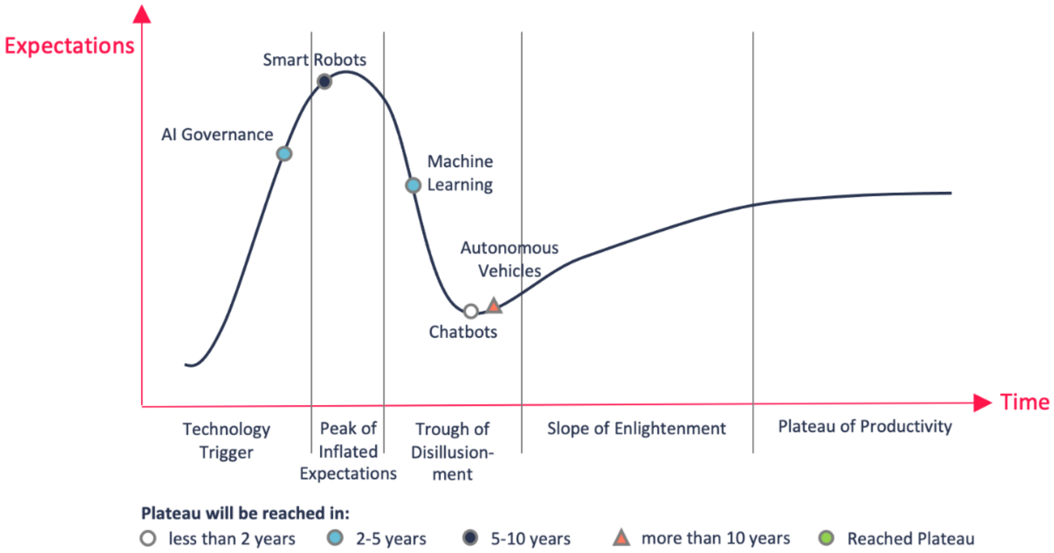

Figure 13: Hype Cycle of Artificial Intelligence

Hype Cycle of AI:

Many AI applications are still in the early phases of development. Simple applications, like chatbots, are already widely used and will be available to the mass-market within the next two years. However, many other applications have proven to be much more complex and intricate than previously thought. For example, Autonomous Vehicles still have a long way to go in the European Region due to many concerns, mostly related to safety and liability. Nonetheless, many Machine Learning Applications relevant to fairway authorities have less pitfalls and will most likely be market ready in the next five years.

Artificial Intelligence (AI)

Functionality

- The ability of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages

Applications

- Visual assistance and chatbots
- Robotics and automated/autonomous vehicles
- Pattern recognition
- Route optimization and predictive analytics

Pros

- Expands the potential of many other technologies drastically
- AI can replace humans in many administrative and repetitive tasks

Cons

- Dependent on good data quality
- High barrier of entrance for custom-made AI solutions

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
4/4	3/4	3/4

Assessment for Fairway Authorities

- Use cases include predictive analytics and smart systems/infrastructure
- Fairway Authorities will have to adapt to the capabilities of AI's and must augment their traffic concept accordingly
- High priority for Fairway Authorities over the next ten years

Figure 14: Scorecard of Artificial Intelligence

Big Data Technologies

Big data technologies describe the tools which allow for the analysis, processing, and interpretation of massive amounts of data. Such processes can be directed at data sets which would be too large, complex, or unstructured to be handled with regular manual tools. The concept of handling such amounts of data is old and dates back centuries. Nonetheless, only modern applications and computing power allow for the processing of such large data sets. Especially the development and proliferation of the internet has helped to increase the importance of big data solutions considerably. Since the early 2000s and beyond, an increasingly large plethora of web applications have brought extremely large data sets to the attention of many influential customer-centric companies. Consequently, "big" is always a relative term, as many online giants like Amazon or Google handle vastly bigger amounts of data compared to a regular production facility. Nonetheless, both activities handle big data and utilise insights gained to optimise their business performance. To harmonise the usage of the term big data, "big" was first described by Gartner as having three essential parameters to it: volume, velocity, and variety. These dimensions have been expanded to also encompass veracity and value. They are commonly known as the five v's of big data.

- Volume is probably the most prominent characteristic of big data. It describes the amount of data which is processed. The volume can differ significantly by company or year. As the number of smart devices increase, so does the potential for big data analysis. Ericsson estimates that the global mobile data traffic by the end of 2021 reached 65 Exabyte (EB) per month, while in 2027 it is estimated to exceed 288 EB per month, more than four times as much. The same growth rate could be observed in the past as well.
- Velocity refers to the speed at which data is generated and transferred. This can be done in real-time for some smart IoT applications but is usually done by transferring it onto a storage which allows the analysis of gathered data. Media channels such as YouTube or Instagram increased the velocity considerably, as did smart devices and the general trend toward a more digitalised world.
- Variety describes the different channels from which data is collected, as well as the way it is structured. Structured data is easily processable, including standardised formats such as email addresses and phone numbers. However, most data are unstructured, i.e., it is not organised according to a pre-set data model which would allow an easy documentation in a database. Unstructured data includes tweets, emails, videos, and photos, among many other things. This huge variety in format and content provide significant opportunities, since it augments and widens the scope for analysis. However, it also makes it considerably more challenging to properly collect such data.
- Veracity refers to the certainty of data, its quality or trustworthiness. The increase in volume, variety and speed makes it more difficult to distinguish high- and low-quality data. As a result, many analyses can be biased or entirely wrong. Data collected inside a controlled setting, such

as a factory, are much more likely to be trustworthy and useable compared to big data approaches which use data generated by millions of users. Nonetheless, such data could generate a much higher yield if it turned out to be correct. Consequently, veracity becomes increasingly important as the potential sources for big data increase.

- Value is by far the most important dimension of big data. All activities within a company or an institution are aimed at generating value, monetary or otherwise.

Examples for the potential usage of big data are plentiful. It has become an established technology in many fields, from healthcare to surveillance. Some use cases are discussed in the following section.

- Business operations benefit greatly from the usage of big data. Many production facilities are highly controllable areas in which data can be collected without external disturbances. As a result, it is much more reliable and thus valuable. Sales or production numbers, customer information and employee records are just some of the many potential sources for performance optimisation.
- Product development relies on the feedback and purchasing behaviour of the customer. Big data helps in analysing large amounts of such data to make reasonable assumptions about which product specific attributes are more valuable to the customer, or which ones can be excluded from the line-up. Consequently, it can enhance the market orientation of the company.
- Fraud detection in financial matters is usually extremely difficult due to the sheer number of transactions conducted every day. Big data technologies can help to mitigate such issues by revealing patterns which are difficult to spot and occur over large timespans, enabling much better fraud detection – an increase in digital payments helps this cause greatly.
- Many IoT applications are only possible because the large amount of data gathered can be processed by dedicated software applications. As such, IoT and big data are intrinsically linked to each other. Whilst big data is also possible for many purely digital cases, sensor information helps to bring big data to the physical world. Consequently, predictive maintenance or the better tracking of goods can help companies to become more efficient and customer orientated.

Many big data applications are tremendously valuable to those who use it. Whilst it may be difficult at first to make sense of the large amount of unstructured data (which is the vast majority), algorithms and artificial intelligence can help to overcome such issues. Consequently, the branch of big data technologies will have a high impact on Fairway Authorities and the users of all waterways.

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Therefore, fairway authorities are already pursuing many big data solutions, mostly to make the waterway more efficient by recognising patterns in the traffic flow. This is especially relevant for bottlenecks such as locks and bridges, where the collection of large amounts of data through IoT or other solutions is relatively easy. Authorities act as a central hub for most actors on the waterway, either in a digital or physical manner. As such, they have the unique advantage of being able to collect large amounts of highly relevant data. Consequently, even without the usage of AI-focused applications, fairway authorities can generate value by analysing patterns through programmed algorithms. This allows them to take a very active stance in this area, actively driving the development of big data solutions in this field.

External projects using Big Data
Marine Digital is using big data to evaluate a ship's energy efficiency. https://marine-digital.com/eeoi ICTSI partnered with Microsoft to create a data platform which spans across its terminals, aiming to improve efficiency and service. https://www.ictsi.com/press-releases/ictsi-powers-unified-global-data-platform-tos-microsoft-azure

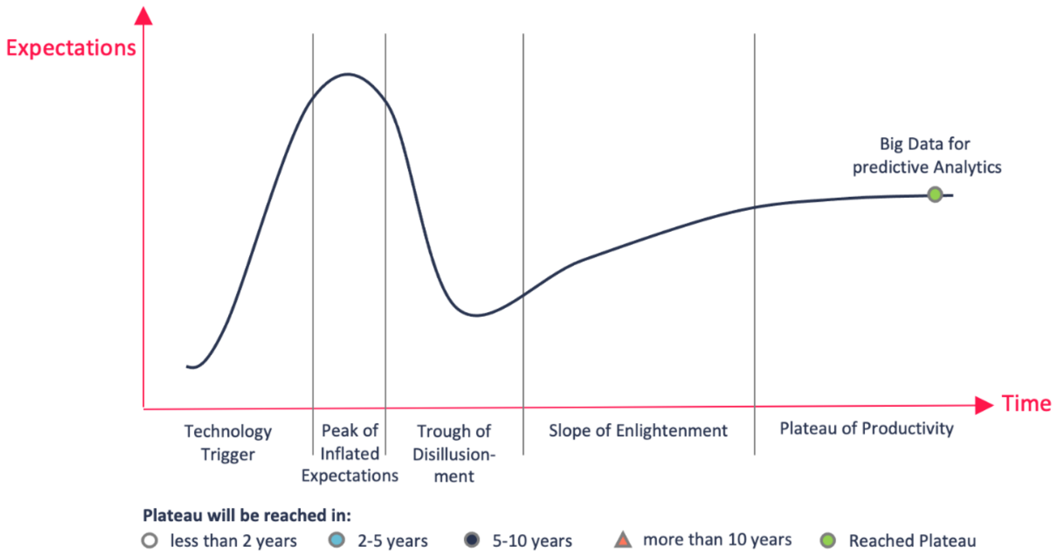

Figure 15: Hype Cycle of Big Data Technologies

Hype Cycle of Big Data Technologies:

Big Data (in the context of predictive analytics) is already well established. Issues mostly arise with adjacent technologies, such as IoT or AI. Consequently, Big Data analytics is closely linked to and dependant on those technologies.

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Big Data Technologies

Functionality

- The use of large amounts of data, statistical algorithms and machine learning techniques to identify patterns

Applications

- Supply chain analytics (e.g. to determine optimal inventory levels or to identify bottlenecks)
- Predictive maintenance of machinery with use of IoT data

Pros

- Recognition of patterns within a complex environment
- Better planning capability
- Better decision making

Cons

- Difficulty of defining relevant KPIs when collecting data
- Incorrect data sets can lead to false assumptions and decisions

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
4/4	4/4	4/4

Assessment for Fairway Authorities

- Use cases include predictive analytics and maintenance
- Dependent on reliable sources for valuable data (which can be provided by IoT), allowing Fairway Authorities to take a very active role in this field
- Very high priority for Fairway Authorities over the next ten years

Figure 16: Scorecard of Big Data Technologies

Virtual Reality (VR)

Virtual reality (VR) is a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment such as VR-headsets and gloves.

Ideas for a "virtual reality" go back to the beginning of photography in the 1800s. The first stereoscope was invented in 1838 which overlayed two images to create one seemingly three-dimensional image. One of the first VR systems was invented 1956. Sensorama was a short-movie experience which connected to all senses of a person including the emission of odours. In 1977, the artist David Em started producing the first navigable world at NASA. The innovation for necessary equipment accelerated in the late 1980 with inventions by the company VPL Research and NASA. Operational headsets and full body suits equipped with sensors got released but were still extremely expensive. Today companies like Oculus offer headsets and additional VR gear at affordable prices for private households.

External projects using VR
CSMART uses virtual training rooms to allow training in a simulation. https://www.csmartalmere.com/about-us/ VR-ME aims to prepare sailors for maritime emergencies on fishing vessels with the use of VR. https://vr-me.eu/

In the early days, only institutions like NASA utilised VR as it was very cost intensive. Today however, as the cost went down significantly, VR is utilised for several purposes:

- The idea for NASAs VR development was the **training** of astronauts in close-to-real-life situations which cannot easily be replicated in the real world. Therefore, VR creates scenarios that would otherwise be very costly or impossible to recreate. This idea has spread into other industries. For example, maritime operators train in VR for their operation with machinery on new ships and general safety training. Surgeons train in VR to prepare for operations on real-life patients.
- The entertainment industry utilises VR for highly immersive **video games**. As a new trend the "metaverse" is a virtual-reality space in which users can interact with a computer-generated environment and other users.
- The automotive industry uses VR for early **design and engineering reviews**. The immersive nature of VR offers a deeper understanding of engineering and design without the need to build early prototypes.

In summary VR is highly effective for training in industries where real-life training would be very important and costly, or the scenario is not replicable. The reduction in cost has led to VR being on the rise as an entertainment device in private households. Some of the functionality and use cases of VR has been taken over and improved by Augmented Reality (AR) in the past years. VR has little benefit for fairway authorities, however, as many training and leisure activities are conducted by other entities. Nonetheless, it remains an important technology for the training of operators in potentially dangerous environments, e.g. on locks, bridges or other moveable heavy-duty infrastructure.

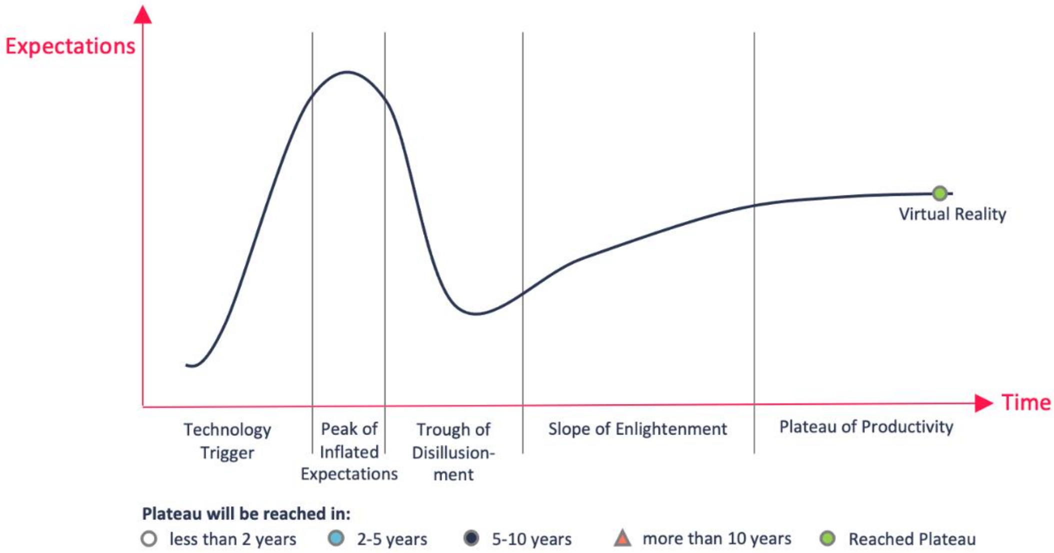

Figure 17: Hype Cycle of Virtual Reality

Hype Cycle of VR:

VR is already very well established. Most applications have been defined, which are in the context of this report a niche.

Virtual Reality (VR)

Functionality

- Computer-generated simulation of a three-dimensional image or environment with which a person can interact in an apparently real or physical way using special electronic equipment

Applications

- Simulations
- Training for real life scenarios (e.g. NASA for astronauts)
- Virtual showroom

Pros

- Hardware widely available and relatively cheap
- Intuitive usage
- Provides close to real-life situations

Cons

- Complexity of real-life situations is broken down and might cause confusion in real situations
- Requires very specific data to simulate the digital equivalent of real objects

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
1/4	1/4	1/4

Assessment for Fairway Authorities

- Training currently the only foreseeable use case, which can be relevant for otherwise dangerous operations (such as on a lock)
- Otherwise, no direct use cases for Fairway Authorities
- Low priority for Fairway Authorities over the next ten years

Figure 18: Scorecard of Virtual Reality

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Augmented Reality (AR)

Augmented reality (AR) describes a technology that superimposes a computer-generated image on a user´s view of the real world, thus providing a composite view. In other definitions AR can also add computer-generated auditory, haptic, somatosensory, and olfactory information. The layered information can be constructive (i.e., additive to the natural environment) or deconstructive (i.e., masking/overlaying of the nature environment). Augmented Reality has the goal to enrich the natural environment by manipulation and making it interactive.

Early AR systems were developed in the early 1990s by the US Air Force. The first commercial AR experiences were introduced in the gaming industry.
The hardware components needed for AR are Display, processor, sensors, and input devices.
Important AR devices and their use cases are:

- The technological advances of **smartphones** and **tablets** have led to a major push in the development of AR applications. Modern smartphones and tablets have advanced computing power, cameras, and sensors such as GPS, accelerometer, compass and sometimes even LiDAR. This makes them suitable devices for AR applications such as Augmented reality games (e.g. Pokémon Go), LiDAR-based high-accuracy digital measuring tape or AR camera filters which are applied in real time.
  Tablets and smartphones are also used in workplaces. Warehouse workers can scan through shelves with the help of AR applications, engineers can visualise the blueprint for components of machinery and doctors can scan the body of a patient.
- **Heads-Up-Displays** (HUDs) are used in vehicles to layer useful information such as speed/traffic signs or fuel consumption on the road/railway/waterway for the driver.
- **Augmented Reality Glasses** are a hands-free alternative for many use cases that can also be achieved by smartphones/tablets. Furthermore, glasses can be integrated seamlessly into everyday life to further enhance the AR experience. AR glasses can also be used for training purposes described in the section on Virtual Reality while adding the possibility of using fragments of the real world. Augmented reality glasses are still in the early stages of development with a lot of room for additional use cases.

Augmented reality applications are increasingly used in many industries and private contexts. The rise of AR glasses will increase the usability to a point where AR is a permanent part of everyone´s sight and therefore everyday life. However, the usage of AR applications for fairway authorities seems mostly irrelevant. Most applications are useful in an industrial setting, or in one where the user is unfamiliar with his/her environment. Such cases might arise while a captain is in an unknown port or waterway section, yet it is questionable whether AR solutions present a tangible benefit when compared to simple guidance systems on a conventional display. While digital traffic signs provide additional input to the user, which is particularly relevant when visibility is low, they have little effect. Most AR solutions seem to result in such quality-of-life improvements, without raising the actual problem-solving capabilities of the individual on the waterway. Consequently, AR applications are deemed relatively unimportant in the context of this report. However, there will most definitely be touchpoints with the technology and the authorities will be in a support role for private parties, especially in providing accurate, AR-ready and detailed data.

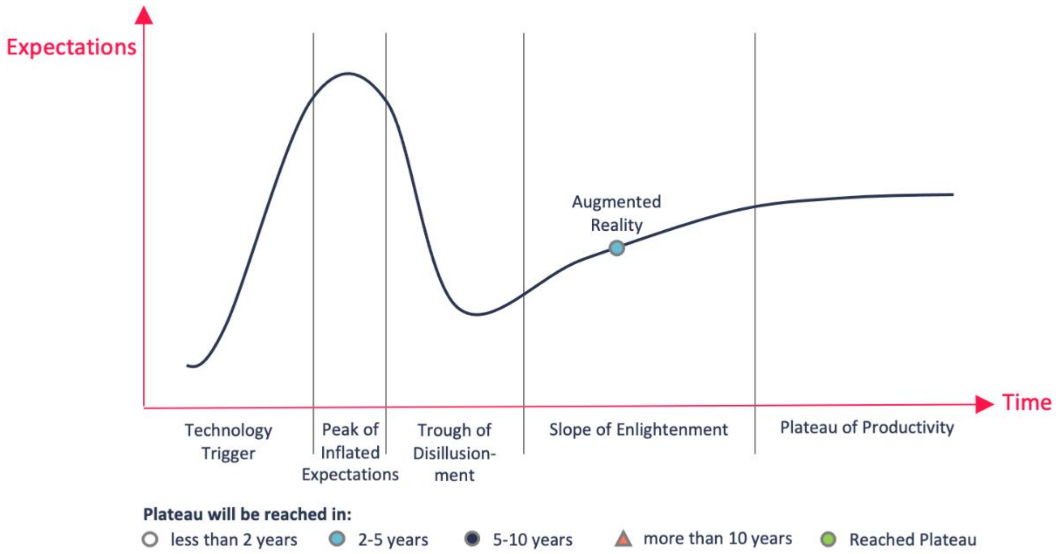

Figure 19: Hype Cycle of Augmented Reality

Hype Cycle of AR:

AR is less established than VR, due to being more complex. However, it is well on its way of becoming a mass-market ready technology which can be widely used.

Augmented Reality (AR)

Functionality	• A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view
Applications	• Head-Up displays in cars or other vehicles • Digital instructions and blueprints for machinery • Guidance system for warehouses or other objects/structures

Pros

- Most hardware widely available (Smartphones)
- Intuitive usage
- Enhanced experience
- Complements smart devices

Cons

- Privacy and security issues
- Can promote risky behavior

Relevance in the next 10 years for:

Assessment for Fairway Authorities

- Possible use cases for Fairway Authorities include maintenance and repair
- Beyond such limited applications, utility is low
- Low priority for Fairway Authorities over the next ten years

Figure 20: Scorecard of Augmented Reality

Drones

Drones describe an unmanned vehicle which can fly, though this definition can be extended to sailing and underwater drones as well. They serve very diverse purposes today but originate from a purely military concept, in which flexible vehicles without personnel inside were a beneficial tactical element. The most famous drone is probably the US-American Predator drone, which was first introduced in 1996 and was deployed extensively in Afghanistan. The first civilian drones were utilised in 2006, as some US-agencies from the deployed them for a variety of different scenarios, from fighting wildfires to surveying border areas. Industrial drones were also first used in that year for the purpose of pipeline inspection. Drones saw a huge boost in demand and research when Amazon considered to use them for delivery in 2013. However, progress in this area has been very slow and many challenges, from regulatory to feasibility, remain. Nonetheless, drones developed quickly after first being adopted in 2006 and are by now a widespread solution for many industrial and commercial purposes. Such are:

- Inspection is by far the most widespread use case for drones. This task can be very diverse. It included visual recording via camera or laser, the surveillance of property or borders, the assessment of infrastructure and specific objects which are difficult to access and the recording of structural elements to create a digital twin. Consequently, drones are used in many commercial settings and by many actors, such as farmers, police agencies, construction companies, or disaster relief agencies.
- Delivery and transport were thought to be very attractive use cases for drones. However, many companies struggled to deploy an efficient, financially, and technologically feasible device. Concepts include solutions to transport good or even people. Some of these ideas were translated into reality, as drones are sometimes used to deliver high-priority light cargo, such as medication. Many start-ups are currently active around drone delivery, however, which could foster a faster development of standard transport drones which might replace some traditional delivery methods.
- Sailing or floating drones (autonomous or remotely controlled) are used for inspections and surveys on the water surface.
- Underwater drones are currently mostly used by military and security agencies for the purpose of inspection and tracking of vessels or in case of search and rescue missions. Nonetheless, commercial applications in the same area are being conducted. Such use cases include the inspection of underwater infrastructure (such as pipelines), safety measurements in ports or the inspection of vessels for the purpose of repair and maintenance.

Drones represent a major development around safety and inspection, where they can be utilised in many scenarios. Their ever-decreasing price and easy usage will make them increasingly attractive for many institutions, including fairway authorities. Fairway authorities already deploy drones for observation of infrastructure and difficult-to-access areas. Other use cases might be semi-automatic general observation drones or underwater drones. The first can be useful in observing remote waterway sectors, analyse vessels for the purpose of inspection or provide real-time information for certain bottlenecks or in the case of an emergency. Nonetheless, there are currently only prototype solutions for the unmanned recharging and maintenance of UAVs, which is why their range will still be limited, at least in the immediate future. Furthermore, legal reasons might prohibit the extensive, long-range utilisation of drones in the air. As for underwater drones, the benefits and drawbacks are explored even less. It is questionable whether fairway authorities can and should pursue a more active stance in this area, since it is very much industry driven.

External projects using drones
The Port of Amsterdam is exploring multiple options for the usage of drones and hosts has a testing ground for new applications. https://www.portofamsterdam.com/en/discover/digital-port/drones Exyn aims to create a 3D model of construction sites with the help of drones. https://www.exyn.com/industries/construction-inspection-drones

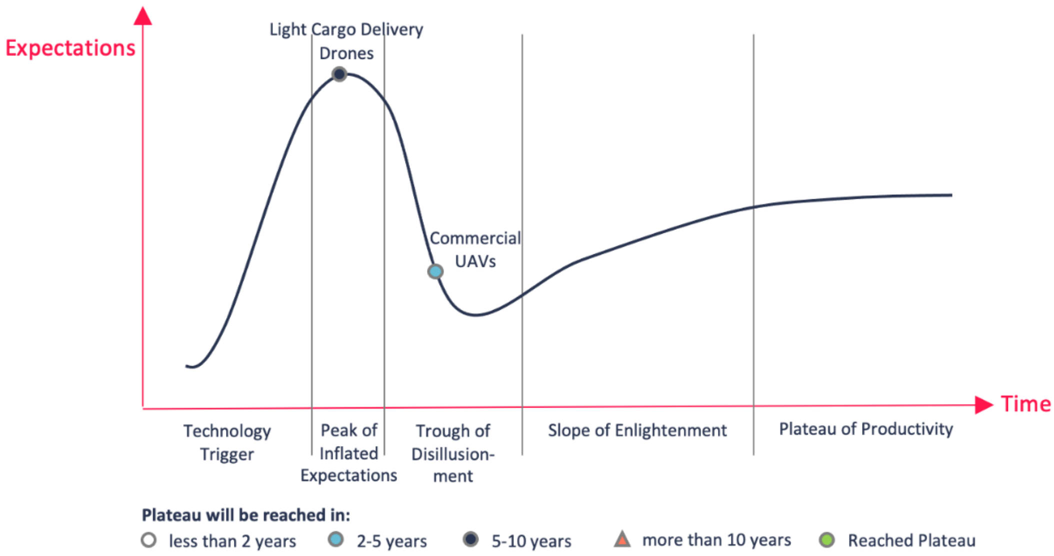

Figure 21: Hype Cycle of Drones

Hype Cycle of Drones:

Drone applications are very diverse in terms of maturity. Commercial UAVs are already in use by some industrial companies or institutions. However, due to many unresolved technical and legal issues they remain a niche application as of now. Other drone concepts, such as Cargo Drones or Underwater Drones have yet to be tested in more detail, as many of them have issues related to feasibility and efficiency.

Drones

Functionality

- Unmanned aircraft or ship that can navigate autonomously or remotely, without human control or beyond line of sight

Applications

- Inspection of infrastructure and objects
- Underwater drones to scan the seabed
- Surveillance + Search & Rescue

Pros

- Very cost effective in comparison to manned alternatives
- Safety issues can be mitigated or eliminated
- Flexible and easy to use

Cons

- Regulatory restrictions (especially in the airspace)
- Complex infrastructure for autonomous operation

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
1/4	1/4	2/4

Assessment for Fairway Authorities

- Use cases include the inspection of infrastructure and vessels
- Fairway Authorities can be a driver in the usage of drones because of the low cost and easy handling
- Medium priority for Fairway Authorities over the next ten years

Figure 22: Scorecard of Drones

Digital Twins

A digital twin is a virtual representation of reality, be it the model of a simple machine, a facility or an entire eco system. It aims at copying all relevant attributes and parameters of any given object or entity and tries to embody them digitally. The idealised digital twin is an exact replica of a real object, with all its intricacies. It thus can be distinguished from a digital model or a digital shadow by the degree of accuracy and information which is required. The first digital twins were used in manufacturing at the beginning of the 2000's and subsequently adopted by other industries and institutions such as NASA (which coined the term "digital twin"). It mostly focuses on physical objects, such as wind turbines, which experience significant stress in the real world through natural forces. A twin helps to accurately simulate and analyse such occurrences. However, more digital twin concepts encompass whole facilities, cities, or complex systems. As a result, IBM distinguishes four types of digital twins:

- Component or part twins are the simplest twins, limited in their functionality but useful when the goal is to digitalise and analyse small units.
- Asset twins consist of two or more components, which is useful for studying interactions between them.
- System or unit twins combine multiple assets, thus allowing for the study of more complex systems and their performance.
- Process twins represent multiple systems, which can be useful in observing them from a high-level perspective to analyse the overall performance and how systems harmonise with each other.

Digital twins provide a host of different benefits. They allow for the testing of components which would otherwise be too expensive to waste. Furthermore, a twin can test a variety of different scenarios which one would not encounter at the same rate in the real world, for example the impact of extreme winds on certain infrastructure objects. Such cases are especially relevant in conjunction with mechanically complex products which can react in a variety of ways to certain scenarios.
However, more sophisticated systems can also greatly benefit from digital twins, though they require much more processing power and better data collection tools to work. Traffic systems, for instance, can utilise digital twin as an alternative to simulations. Whilst simulations are useful for many purposes, they do not allow the freedom and complexity of a digital twin, since the latter represents an actual, digitalised environment.

External projects using digital twins
IBM created a platform to trade and exchange digital twins of equipment and facilities. https://digitaltwinexchange.ibm.com/ Bausch + Ströbel uses a digital twin for mapping machinery 1:1, improving development and commissioning. https://new.siemens.com/global/en/company/stories/industry/the-digital-twin-comes-to-life.html

In conclusion, digital twins are very useful when it comes to managing complex relationships. They may help fairway authorities in the management of local infrastructure through smaller, more localised twins. Alternatively, they can be used to represent whole eco systems, such as the waterway with all its stakeholders, entities, and structures. Such cases, however, require more sophisticated twins not yet available. Fairway authorities need to implement other, more basic technologies before being able to deploy meaningful, holistic digital twins. Such a roadmap will be covered in the next chapter.

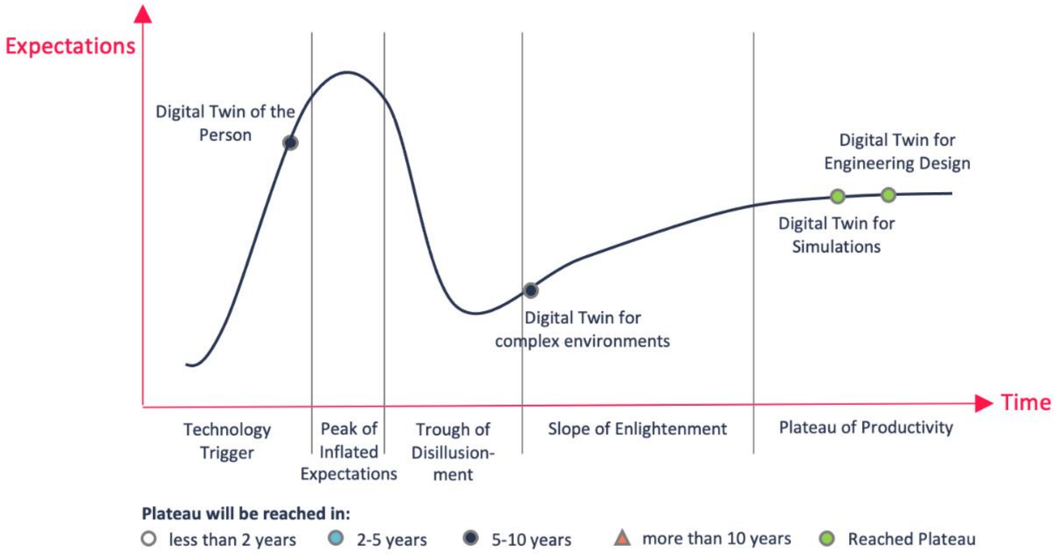

Figure 23: Hype Cycle of Digital Twins

Hype Cycle of Digital Twins:

Digital Twins have the widest range of technological readiness. Simple applications that evolve around one single digitally mirrored device are already used by many stakeholders. However, more sophisticated applications require a significant improvement in data collection and computing capabilities.

Digital Twin

Functionality

- A representation of a tangible or intangible object from the real world in the digital world

Applications

- Product development and maintenance
- Infrastructure and asset management
- Simulation of supply chain

Pros

- Testing of new machinery etc. without cost of material
- Provides overview of real-world assets
- Easier, more flexible and cost-effective simulations

Cons

- Fault in the engineering of the digital twin might only show later in physical testing
- Complex environments difficult to replicate
- Cyber Security (and related IP issues)

Relevance in the next 10 years for:

General Logistics	Inland Shipping	Fairway Authorities
2/4	1/4	2/4

Assessment for Fairway Authorities

- Use cases include a micro level (e.g., stress test of individual bridges or locks) and a macro level (e.g., multi-layered overview of an entire waterway or intermodal supply network)
- Medium priority for Fairway Authorities over the next ten years

Figure 24: Scorecard of Digital Twins

Assessment overview

Areas marked in green are highly relevant (3 or 4), yellow marks cases with some relevance (2 or 1).

Technology	Relevance for Logistics	Relevance for Inland Shipping	Relevance for Fairway Authorities
5G	3/4	2/4	1/4
Distributed Ledger	3/4	2/4	1/4
Internet of Things	4/4	4/4	4/4
Cloud Computing	4/4	4/4	4/4
Artificial Intelligence	4/4	3/4	3/4
Big Data Technologies	4/4	4/4	4/4
Virtual Reality	1/4	1/4	1/4
Augmented Reality	3/4	2/4	1/4
Drones	1/4	1/4	2/4
Digital Twin	2/4	1/4	2/4

No immediate conclusion can be drawn from this ranking, as most technologies are used in conjunction with other ones to enable the development of novel applications. Whilst it helps to observe technologies with only low to medium relevance, the following section creates use cases build upon the technologies which are truly relevant to fairway authorities. These four technologies (IoT, cloud computing, AI, and big data) are the cornerstones of the four use cases created within section 4. Whilst digital twins are central in the very late stage of the outlined roadmap, the immediate impact of such a technology is much lower compared to the tangible benefits which the other four provide. Nonetheless, innovation progresses in a non-linear way, which is why authorities should always be aware of technologies deployed in adjacent sectors. In conjunction with concrete innovation management procedures (outlined in section 5), fairway authorities can mitigate the risk of being unprepared in the face of change.

Use cases for new technologies in IWT

Based on the previously discussed technologies, four use cases have been developed during the workshop sessions within the DIWA workgroup. Additional research and analyses were conducted by bloog beforehand and afterwards. This included interviews with external experts on some of the subjects.

The following use cases can be understood as an "ideal" implementation of a digital, future-proof waterway. Use case one to four can be ordered chronologically, since use case one must meet much less requirements than use case four, which in turn depends on the previous use cases. Thus, the four use cases presented can be seen as modular building blocks within a holistic digitalisation approach. They can be implemented individually, but they benefit greatly from one another. As such, it is highly recommended to understand these use cases as a continuous strive towards a digital waterway, with each new one adding to the old and improving the overall system by more than the mere sum of its parts.

The cross-border "Data Exchange Platform" represents the first use case, and it requires almost no previous systems or applications, save for a sophisticated RIS (like EuRIS) and a planning tool (e.g. RPIS[2]). It would combine the two, allowing for the much-needed fusion of planned data (like ETA) and real-time data (like AIS). Another very important feature is the integration of APIs. This would allow stakeholders to easily extract data, thus enabling their own planning systems to be much more useful.
"Smart Infrastructure" utilises IoT applications installed in locks and bridges along the waterway to make assessments about the required maintenance of infrastructure. It would greatly benefit from the exchange platform, which would serve as a central hub for all collected data points, thus allowing for much more intricate analysis of the waterway.
The "Predictive Traffic Concept" makes use of AI-powered analysis of infrastructure, vessels, and ports to recognise patterns, bundle information and use the two to make accurate predictions about the traffic flow on the waterway. Consequently, transparency and the reliability in planning would increase drastically. To work properly, it would utilise the previous two use cases.
The last use case, a "Holistic Digital Twin", attempts to incorporate all other use cases into one. It is certainly the most futuristic of the four, combining advanced computing capabilities with enormous amounts of data, allowing for extensive collaboration of all stakeholders across the waterway. Thus, it requires all other use cases to be completely implemented. Additionally, extensive information exchange between all stakeholders is a must. If it were to succeed, it would represent a truly digital waterway, with all the benefits it provides to its users.

[2] RPIS – River Ports Planning and Information System; an inland port community system developed by RheinPorts

Co-funded by the European Union

To give a better understanding about the nature of each use case, the following sections each contain the assessment of the respective use case. Like the scorecards for the technologies, each use case has a similar design. However, no rating was given as all use cases were deemed highly relevant to fairway authorities. Accordingly, each use case was instead assigned certain preconditions that have to be met to work properly. To better understand each use case, a depiction is given which shows which kind of data is utilised within each case. In addition, Vision Boards provide a condensed assessment of the demands towards, and values generated by each use case.

Co-funded by the European Union

Use case 1: Data Exchange Platform

This use case focusses on the "currency" in a digitalised environment: data and how to use new technologies for capturing and exchanging data. The idea is to collect relevant digital fairway information in a standardised way and to define ways of exchanging data across border and/or organisations.

The project RIS COMEX already set a solid foundation for a standardised framework for river information services (RIS) and already resulted in the European RIS system EuRIS which went live in Q3 / 2022 in the 13 participating countries. For a centralised reporting, the system CEERIS (Central and Eastern European Reporting Information System) has been developed in close connection to EuRIS. Both platforms already cover basic relevant data and processes covered by the fairway authorities.

This use case covers data exchange beyond the scope of current systems e.g. EuRIS for river information services and logistics planning tools, e.g. RPIS. The idea is to connect two ecosystems and to identify a pilot process for data exchange which is beneficial for both ecosystems.

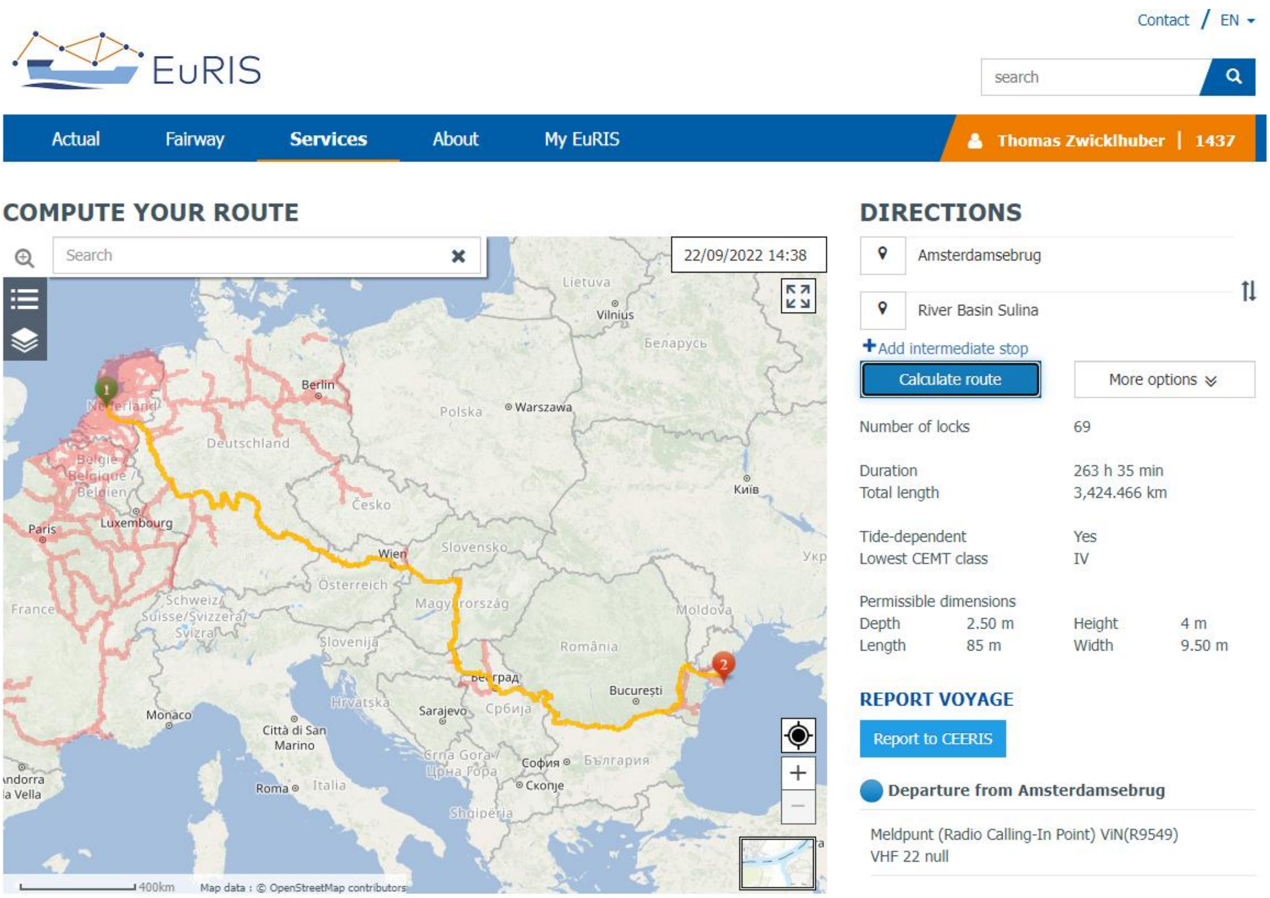

Figure 25: Example of EuRIS' route planning tool

The following ecosystems have been identified as appropriate for a data exchange with fairway authorities:

- Port community systems for inland ports
- Port community systems for seaports
- Maritime single window systems
- Barge planning systems
- Terminal operating systems
- Traffic management systems for other modalities

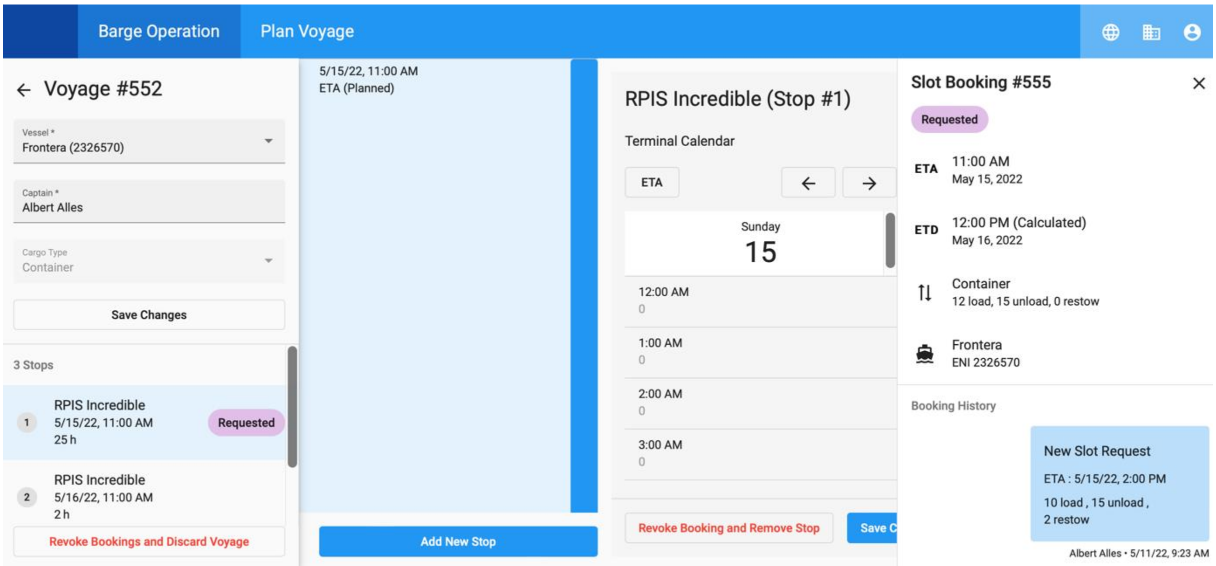

Figure 26: Example of RPIS slot management module for barges

The identification of a suitable pilot process for data exchange will lead to a "minimum viable product" (MVP) which shall prove the concept and feasibility of the data exchange. One example could be to enrich existing information of a barge in EURIS with planning data for the barge from a port community system or a barge planning system. The following systems could be considered as possible integration candidates:

- Interface between EuRIS and RPIS for AIS data and barge voyage planning data
- Interface between EuRIS and one seaport community system like e.g. Portbase in Rotterdam, NxtPort in Antwerp, DAKOSY in Hamburg
- Interface between EuRIS and one barge planning system product (e.g. modility, VEMASYS)

The authors recommend the following steps for an implementation roadmap:

- Identification of pain points in the existing set-up
  - Where are media disruptions today following a barge voyage (e.g. whilst crossing a border and thus having to use different national information systems)?
  - What are obstacles that are time & budget consuming with respect to a data interchange between stakeholders?
  - Prioritisation of pain points
- Identification of suitable partners for an MVP
- Description of MVP(s)

- Implementation of MVP(s)
- Feedback from MPV users and definition of further steps

The following figure provides a schematic, non-exhaustive overview of collected data within this use case.

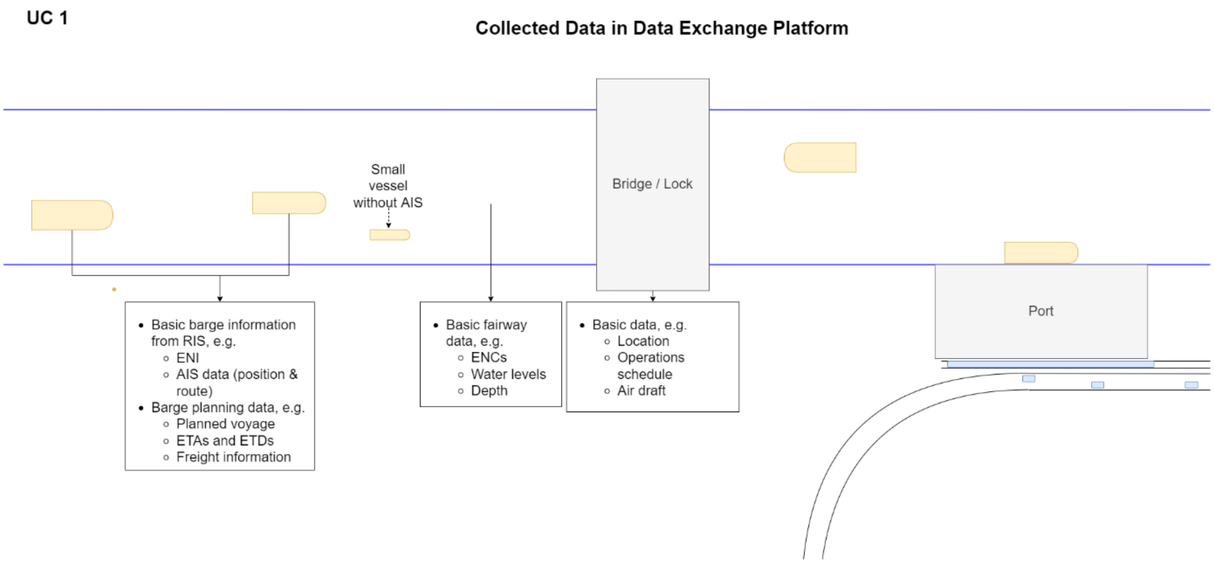

Figure 27: Use Case 1 data collection overview

This figure will serve as a baseline for the following use cases. Each of the four use cases within this section will be equipped with such a schematic overview of collected data. New additions for each subsequent use case will be highlighted in green. These figures shall emphasise the interdependencies between the use cases and the gradual extension of collected data leading to the last use case covering a holistic digital twin.

Vision Board New Technologies Use Case I: Data Exchange Platform

The first use case represents the basis for all following endeavors. The platform is the central hub for all activities conducted under national and European initiatives. It serves as an extension of current RIS systems. It incorporates planning tools from private or public logistics stakeholders (such as RPIS) and data based on the actual state of the waterway (i.e., EuRIS). Its open API's allow external stakeholders to increase planning capacity and transparency.

Used New Technologies

- Big Data
- Cloud Technology

Goal

- **Fairway Authorities**
  Ensure competitiveness of inland navigation as a sustainable mode of transport
- **Terminal Operators**
  Efficient and predictable operations
- **Shipping / Forwarding Companies**
  Transparent and punctual delivery of goods
- **Port Authorities**
  Efficient and safe operations
- **Others**
  Available and usable data

Demand

- **Fairway Authorities**
  Information on the utilisation of the waterway and key infrastructure
- **Terminal Operators**
  Declared ETA of respective vessel & loading information
- **Shipping / Forwarding Companies**
  Declared ETA & real-time traffic data
- **Port Authorities**
  Declared ETA & real-time traffic data
- **Others**
  Access + APIs

Product / Service

- River Information and Planning Service in neutral hands
- Extensive data collection from terminal operators, shipping companies, authorities and waterways
- Real-time information about the utilisation of the waterway
- Information on planned voyages, opening times of locks and bridges and operating times of terminals
- Single window
- Single „source of truth“
- Machine-readable data

Value / Benefit

- Optimisation of the waterway due to the merging of planned and real-time data
- Intermodal transport becomes easier and more efficient
- Increased cooperation between all stakeholders on the waterway and beyond
- Improved competitiveness of inland waterways

Figure 28: Vision Board Use Case I

Co-financed by the European Union
Connecting Europe Facility

Use case 2: Smart Infrastructure

This use case is closely related to the existing physical infrastructure that is under the responsibility of the fairway authorities (e.g. locks, weirs, boat lifts, bridges, waterways, buildings, quay walls, barriers). The aim of this use case is to develop a digital representation of the physical infrastructure for the purpose of improving and optimising the maintenance processes for the infrastructure. Typically, the physical infrastructure is very costly in terms of capital and operational expenses (CAPEX and OPEX). By applying IoT infrastructure the following targets can be achieved:

- Reduction of OPEX
- Improvement of the availability of the infrastructure
- Improvement of the reliability of the infrastructure
- Prolonging the service life and thus reducing the overall CAPEX

For this use case the existing infrastructure will be enriched step by step with digital information about the condition and surroundings.

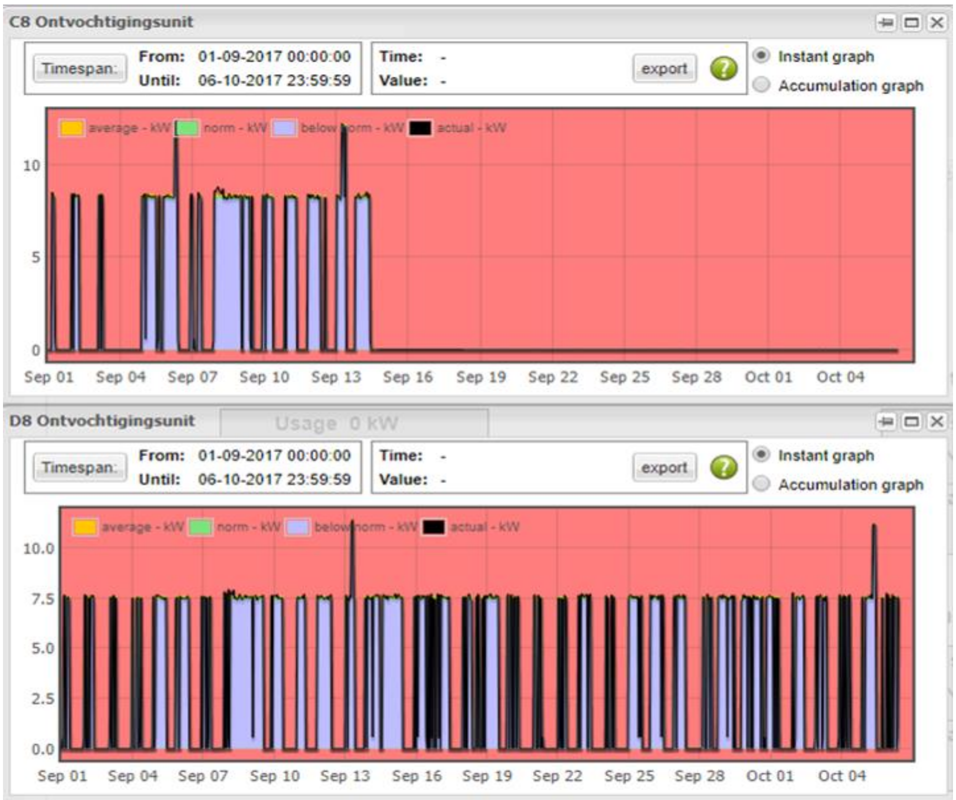

Figure 29: The power consumption inside a lock can be measured through sensors (courtesy of Rijkswaterstaat)

The first step within this use case is to define measurability and the 'right' measures", i.e., meaningful key performance indicators (KPIs). In particular, the following questions should be considered:

- Which KPIs are relevant for the prioritisation of maintenance efforts (e.g. downtime / availability; productivity; meantime to repair (MTTR), Meantime between failures (MTBF))?
- Which KPIs / measures are costly to determine?

In a second step it should be identified how these KPIs could be captured by implementing IoT based measuring devices or by using drones.
In a third step visibility will be created by centrally collecting these data and KPIs and to centralise and visualise the collected data in a meaningful way. This will already provide decision support for maintenance activities within the fairway authorities and lead to a preventive maintenance approach. This step involves technologies for coping with big data as well as augmented and virtual reality.
Once the KPIs are centralised and visualised in a reliable way, technologies towards a decision-making approach can be applied; like AI based predictions that lead to predictive maintenance.

The following figure shows the data added with this use case (highlighted in green) in conjunction with the data from the previous use cases.

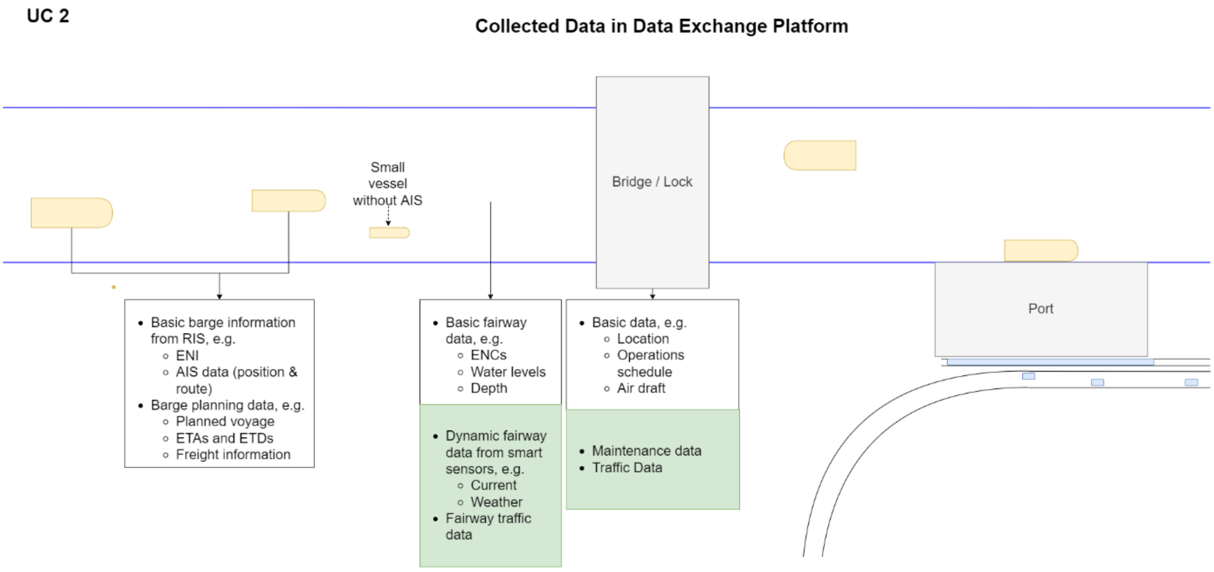

Figure 30: Use Case 2 data collection overview

Vision Board New Technologies Use Case II: Smart Infrastructure

Smart Infrastructure encompasses two main concepts, which are both made possible by the installation of sensors in critical parts of the respective structure. Firstly, the observation and analysis of existing infrastructure (e.g., bridges, locks) for the purpose of predictive maintenance. This allows for a more reliable and efficient waterway management system. Secondly, sensory data can be used to make local infrastructure react to common external conditions (e.g., a vessel approaching) by using simple algorithms, eliminating the need for human assistance in many cases.

Used New Technologies

- All previous
- IoT
- Drones

Goal

- **Fairway Authorities**
  Ensure competitiveness of inland navigation as a sustainable mode of transport
- **Infrastructure Suppliers**
  Competitive products
- **Rail/Road Administration**
  Efficient and safe traffic conditions at intersections between waterways and rail/road infrastructure
- **Others**
  Available and usable data

Demand

- **Fairway Authorities**
  High availability of infrastructure and improved planning capabilities
- **Suppliers**
  Accurate data about their products
- **Rail/Road Administration**
  Data about the utilisation of road/rail infrastructure
- **Others**
  Access + APIs

Product / Service

- Integrated into the Data Exchange Platform
- Data collection through sensors connected to a network
- Provides specific and relevant data about key infrastructure elements and the waterway
- Close to real-time automated notifications in case of anomalies
- Provides predictive recommendations concerning maintenance
- Allows for local automation of infrastructure elements by using sensory input

Value / Benefit

- Less disruption of the traffic on the waterway
- High transparency regarding the condition of the infrastructure
- More cost efficient maintenance
- Improvement in operations due to some automation
- Improved competitiveness of inland waterways

Figure 31: Vision Board Use Case II

Co-financed by the European Union
Connecting Europe Facility

Use case 3: Predictive Traffic Concept

This use case combines data of the two previous use cases. The idea is to apply prediction models to the data within data exchange platforms and from the smart infrastructure. The prediction model can be based on smart algorithms and/or artificial intelligence. By offering predictions within the data exchange platforms the system's focus changes more from a decision supporting tool towards a decision-making tool.

Again, a stepwise approach is highly recommended. The first step is to identify pain points in the existing traffic concept that ideally affect a group of stakeholders, e.g. unforeseeable waiting times of barges at locks. To make use of artificial intelligence it is necessary to have access to a suitable amount of data and to interpret the data in the right way. It is important to define so-called strong designators which can serve as a basis to train AI algorithms.

If the necessary conditions for the use of AI based prediction models is fulfilled an MVP should be identified. An MVP could for example cover predictions for locking processes at locks. This requires actual lock data about the condition and availability of the lock as well as traffic density around the lock. Furthermore, planning data of the barges is required as the positioning data of the barges do not reveal their travel plans. The resulting predicted locking times per barge can be mirrored back to the barge planning system and will lead to a more both, economic and ecological routing of the barge. Thus, this use case will increase the effectiveness of inland waterways as a sustainable transportation mode.

The following figure shows the data added with this use case (highlighted in green) in conjunction with the data from the previous use cases.

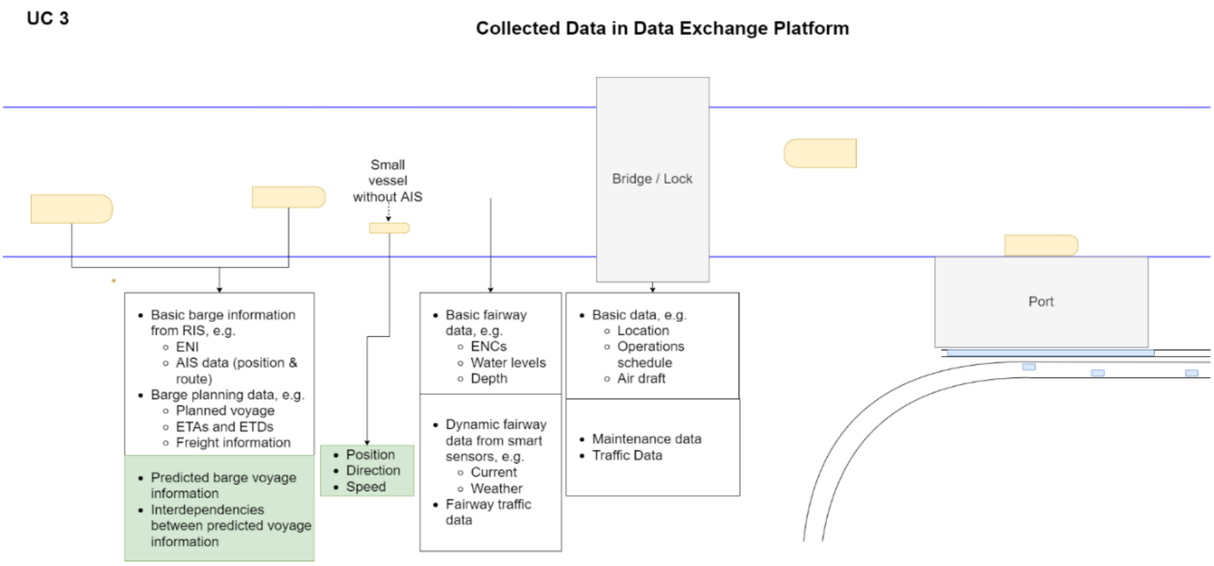

Figure 32: Use Case 3 data collection overview

Vision Board New Technologies Use Case III: Predicitive Traffic Concept

The third use case builds extensively on the previous two. It requires an extensive pool of data which combines a multitude of different dimensions, such as planned-data from shipping companies and accurate real-time data from RIS systems. Using AI systems to recognise patterns in historical and current data, it can make predictions about the state of traffic on the waterway. As such, it provides an increase in accuracy and reliability. In addition to recommendations provided by the system, it can make some basic decisions, thus assisting the vessel operators and others.

Used New Technologies

- All previous
- Artificial Intelligence

Goal

- **Fairway Authorities**
  Ensure competitiveness of inland navigation as a sustainable mode of transport
- **Terminal Operators**
  Efficient and predictable operations
- **Shipping / Forwarding Companies**
  Transparent and punctual delivery of goods
- **Port Authorities**
  Efficient and safe operations
- **Others**
  Available and usable data

Demand

- **Fairway Authorities**
  Information on the predicted use of the waterway and infrastructure
- **Terminal Operators**
  Accurate ETA and freight
- **Shipping / Forwarding Companies**
  Accurate ETA + real-time traffic data and recommendations
- **Port Authorities**
  Accurate ETA + real-time traffic data
- **Others**
  Access + APIs

Product / Service

- Integrated into the Data Exchange Platform
- Uses Smart Infrastructure
- Predictive ETA and waiting times (e.g. at locks)
- Recommendations for efficient usage of the waterway
- Some decisions are made automatically (e.g. booking a lock for a certain time slot depending on predicted ETA)

Value / Benefit

- Improves reliability and speed while lowering emissions and cost of transport on the waterway
- Intermodal transport becomes easier and more efficient
- Improved competitiveness of inland waterways

Figure 33: Vision Board Use Case III

Use case 4: Holistic Digital Twin

As mentioned in the introduction to this chapter, this use case is the most futuristic one as it combines all previous elements of digital infrastructure. The idea is to integrate all previous initiatives and project into one big picture. The aim is not to create one single system covering everything, but to build a standardised framework which allows the integration of modular and scalable solutions. In this sense, this use case can be considered as the technical masterplan for the digitalisation of inland waterways. Most importantly, it aims at bringing together all relevant modalities. This would allow for a much more efficient and effective supply chain management, in which inland waterways should be an integral part. It will gain shape as new technologies emerge and mature, as use cases are implemented and as cooperation with different modes of transport strengthen. However, the holistic digital twin remains a very open concept on purpose. It should serve as a vision for an inland waterway that is adaptive, innovative, and holistic.

The following figure shows the data added with this use case (highlighted in green) in conjunction with the data from the previous use cases.

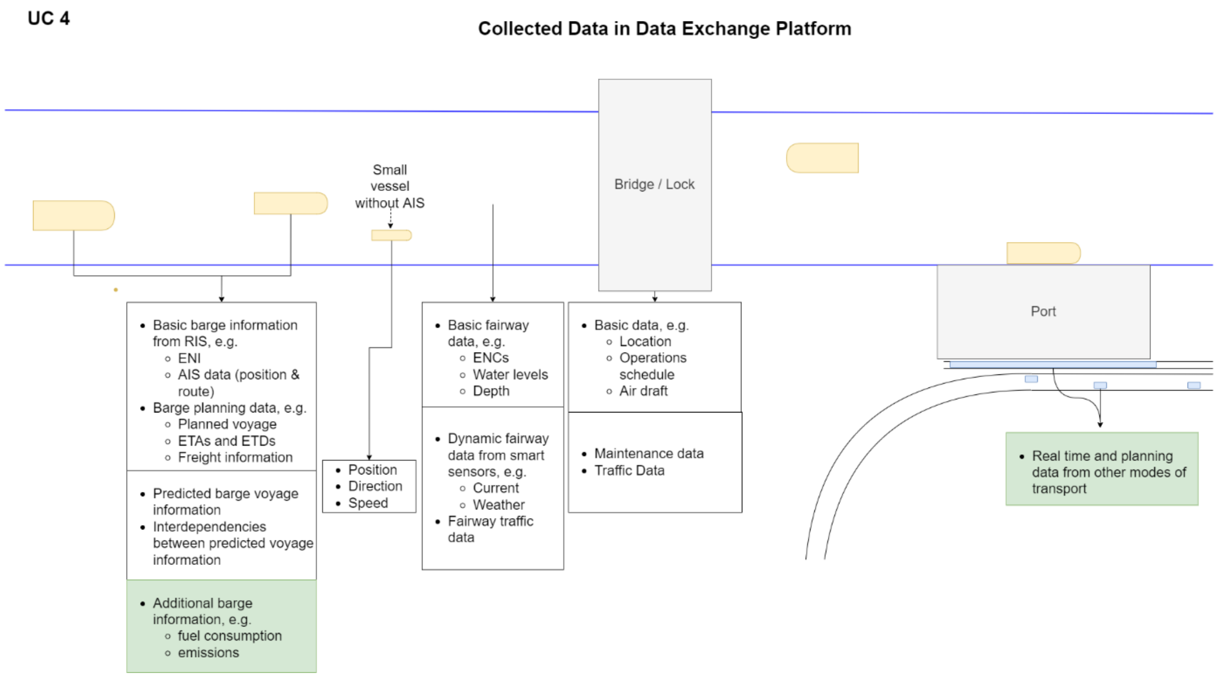

Figure 34: Use Case 4 data collection overview

Vision Board New Technologies Use Case IV: Holistic Digital Twin

The digital twin is the product of all previous use cases in conjunction with similar applications from other modes of transport (i.e. rail, road and air). In its ideal state, it represents the consolidation of previously separated but interdependent applications in the logistics sector. Its goal is to harmonise all modalities and create a platform or application which allows the user to find the most efficient and sustainable mode of transport for the respective product. In addition, it allow for a comprehensive, intuitive overview of the entire waterway (and possibly the entirety all modes of transport).

Technologies

- All previous
- Digital Twin

Goal

- **Fairway Authorities**
  Ensure competitiveness of inland navigation as a sustainable mode of transport
- **Stakeholders in Logistics**
  Efficient, safe and punctual delivery of goods across the entire supply chain
- **Others**
  Available and usable data

Demand

- **Fairway Authorities**
  Complete, failsafe coverage of the entire fairway with data collection tools
- **Stakeholders in Logistics**
  Seamless integration of all modes of transport
- **Others**
  Access + APIs

Product / Service

- One application for all modes of transport
- Set standards for all modes of transport and all involved authorities/ stakeholders
- Redundant data collection across all systems (e.g. ship-tracking done by AIS + another identification system such as 4G/5G)
- Enables autonomous shipping on all parts of the waterway
- Real-time picture of the entire intermodal system

Value / Benefit

- Seemless integration of all modes of transport
- Improves reliability and speed while lowering emissions and cost of transport on the entire supply chain
- Improves competitiveness of inland waterways by means of transparency on an open market

Figure 35: Vision Board Use Case IV

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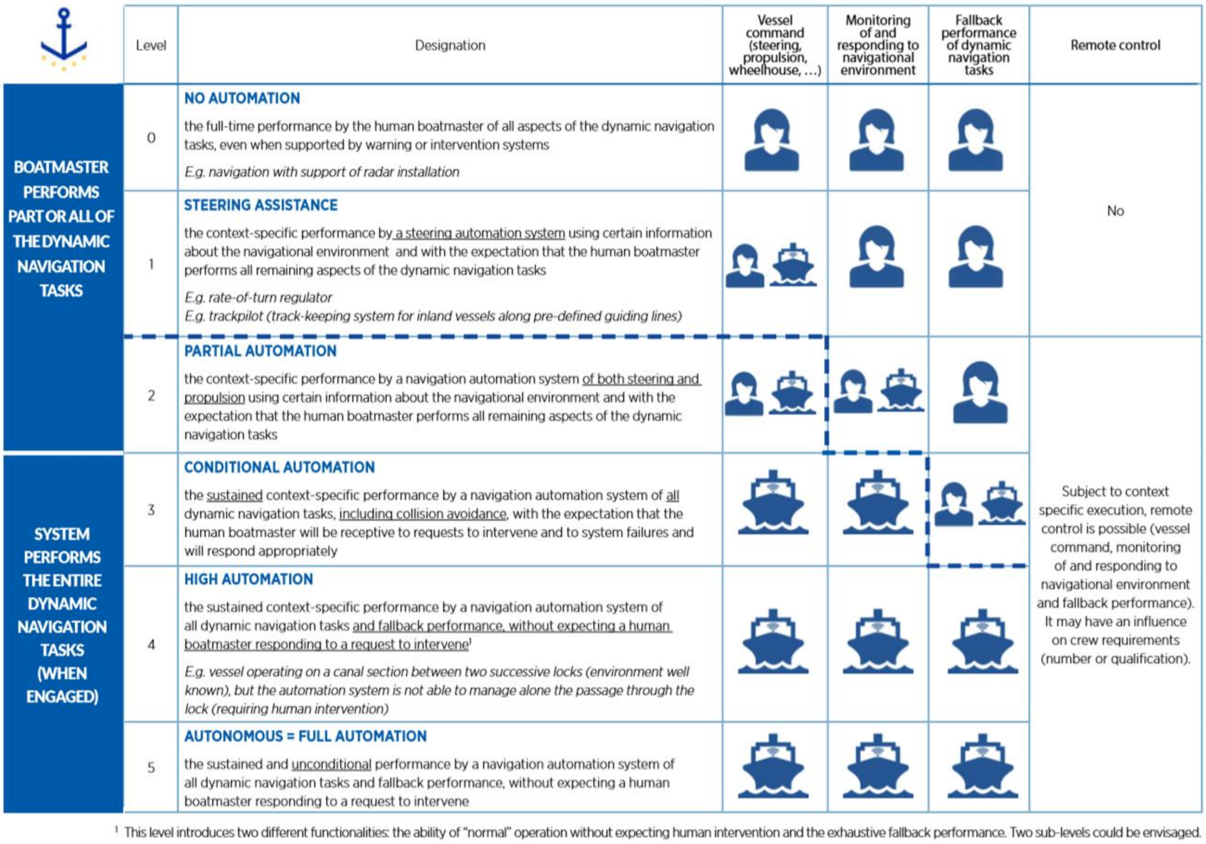
Use Case Excurse Smart Shipping

Sub-activity 2.1 of the DIWA project covers smart shipping. As there is a strong interdependency between smart shipping and new technologies the authors of this study recommend interlinking the findings of this sub-activity with the results of sub-activity 2.1.

Smart shipping refers to the use of new technologies and ICT infrastructure to support shipping operations. It is often linked to automation of shipping; the authors of the report for sub-activity 2.1 refer to the definition of levels 0 to 5 of automation elaborated by the Central Commission for the Navigation of the Rhine (CCNR).



	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.

Figure 36: Levels of automation defined by CCNR;
Source: https://www.ccr-zkr.org/files/documents/cpresse/cp20181219en.pdf

A key question for the automation of shipping on inland waterways is whether to implement smart infrastructure, e.g. equipping inland waterways with sensors and create digital twins of the infrastructure, or to make barges themselves as smart as possible so that they can cope with any kind of physical infrastructure – or both. There are currently several pilot projects investigating in how to create the most practical approach for automation in inland navigation. Thus, this question about the general approach cannot be resolved at this stage.

Among the new technologies discussed in this study, the following are most relevant for smart shipping: 5G technology, IoT, cloud computing, AI, big data technologies, digital twins.

Recommendations on the Implementation of Use Cases

This section covers recommendations in various aspects by the authors for the implementation of the use cases. The recommendations are derived from a SWOT-Analysis conducted by bloog for European fairway authorities.

SWOT Analysis: European Fairway Authorities in the context of innovation

Strenghts	**Opportunities**
• Neutral party • Extensive network of partners • Access to many data sources • Rich pool of experience in many relevant projects	• Collaboration with other stakeholders • Sharing of knowledge and best practices between fairway authorities • Can be the central authority for most inland waterway related issues (public and private)
Weaknesses	**Threats**
• Coordination with many stakeholders • Capacity restrictions (e.g. money, time, …) • Non-aligned goals and priorities of different fairway authorities • Slower than market solutions	• Crowding out by private suppliers • Increase in capacity constraints • Loss of knowledge due to fragmented institutions

Figure 37: SWOT-Analysis of Fairway Authorities

Fairway authorities have many unique strengths, which translate into very important opportunities. The status as a neutral, non-profit institution allows for a much easier collaboration with external stakeholders, since there is no fear of deliberate actions aimed at crowding-out a potential partner or exploiting gathered data. The extensive network of partners provides valuable opportunities in the sharing of knowledge since the pool of expertise across all different authorities is diverse and highly relevant. As a result, fairway authorities become increasingly more important as a provider for holistic solutions on the inland waterway.

Nonetheless, such a complex and extensive network has its drawbacks. The coordination with other actors and the consensus-based approach makes authorities slower than many open market solutions. Capacity restrictions and non-aligned goals may make it more difficult to compete with specialised companies. The loss of knowledge is one of the biggest threats to fairway authorities, especially when confronted with an increasingly international partnership.

Fairway authorities benefit greatly from a structured, long-term approach with a focus on innovation. Consequently, some recommendations are gathered below, to increase innovative capabilities.

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Utilise existing cases for new technologies

Within the participating fairway authorities there are plenty of existing innovative projects that make use of new technologies and that cover or at least touch one of the use cases. The authors recommend making use of this experience and aligning the various activities. Such activities can be pursued on a national level or internationally (i.e., inside the EU in the context of DIWA).

In particular, the following steps should be considered:

- Identification and assessment of existing use cases involving new technologies among the project partners
- Creation of a map with use cases and level of maturity
- Clustering of use cases with similar objectives and technologies
- Definition of standards for the clustered use cases (e.g. definition of a common interface for the exchange of IoT data from the fairway infrastructure)
- Identification of synergies between use cases within each cluster

To allow for such a sophisticated project overview, the authors recommend the creation of a platform which lists all relevant EU projects and the associated parameters. Stakeholders can only learn from projects they know of; thus, visibility is a key aspect. To facilitate the development of such a platform, it will be useful to start with a small, concise tool which only lists the most important aspects (such as stakeholders, technologies involved, outcome).

Identify minimum viable products (MVP) for each use case

The authors recommend identifying at least one minimum viable product (MVP) for each use case as a pilot implementation.

The choice of an MVP should fulfil the following requirements (which in some cases appears to be a balancing act):

- Clearly defined scope
- Focus on the resolution of one pain point
- Create an added value to the stakeholders
- First tangible results after 3-6 months
- Ideally broad coverage of stakeholders
- At the same time low degree of complexity

The benefit of MVPs is to receive quick feedback from stakeholders within a real environment. This allows for an agile way of developing the solutions which follows closely the users' demands.

Initiate and strengthen multimodal and international collaboration

Logistics processes are highly integrated along the supply chain. To follow the overarching goal to strengthen inland waterway infrastructure as environmentally sustainable and reliable for logistics it is important to integrate digital initiatives along the supply chain in the same way. Thus, multimodal and international digitalisation collaboration should be started and strengthened. The following steps should be taken:

- Identification and assessment of existing use cases involving new technologies for other modalities
- Creation of a map with IWT-relevant use cases and level of maturity
- Identification of multimodal pilot projects

Cooperate with private and public private partnership (PPP) initiatives

The authors recommend defining the role of fairway authorities in a digital set-up as enablers and providers of digital infrastructure. This also covers a cooperation with private and PPP initiatives. Private digital initiatives are driven by user and market demands and are often able to develop digital solutions in a quick and agile way. This often creates an added value for the entire IWT ecosystem. As such kind of private initiatives will be developed in any case the recommendation is to actively take part in this development process as fairway authority.

The following aspects shall be considered for cooperation with private and PPP initiatives:

- Compliance with data security policies (like e.g. GDPR)
- Clearly defined data ownership
- Pro-active involvement in the definition of standards
- Compliance with public contract of fairway authorities

Create standards

The creation of standards is a key element in the effort of a harmonised European inland waterway. Standards can be created through legal measures, through dedicated harmonisation efforts or through market pull. The latter is especially valuable since it focuses on the voluntary commitment of all stakeholders which allows for a much faster and harmonious implementation. By creating powerful tools such as EuRIS or other applications, fairway authorities can incentivise private (and public) entities to comply with standards set by the respective authorities. Through the exchange and use of standardised and harmonised data, external stakeholders are pulled towards the standards set within the platform or application. Thus, standards can be created by behavioural incentives. However, this can also be a potential detriment: if other more popular platforms or services do not adhere to standards desired by the fairway authorities, they may pull users towards them, creating a fragmented landscape of different standards and practices. Consequently, legal measures or dedicated harmonisation efforts still play a crucial role in the creation of standards. Nonetheless, the authors believe that all three methods should be applied, with a focus on market pull.

Establish permanent digital innovation teams

Innovative efforts can be facilitated and executed by temporary or permanent entities. Project teams and work group represent an important part in the development and implementation of innovation. However, to foster the continuous strive for a digital waterway, the authors firmly believe that more permanent solutions help greatly in pursuing such goals. A dedicated team can help in establishing more robust, project-independent approaches to innovation and digitalisation. Such a team can be product- and activity-specific or with a more general focus. Specificity for one product or service (like EuRIS) or even more specialised experts responsible for one single activity within that product/service (like lock management) help to foster expertise and innovative capabilities in each respective area. In contrast, general teams help to keep an overview about certain high-level activities (like digitalisation or automation) and thus provide valuable feedback to the more specialised teams and the management. Consequently, both have to work in tandem to provide a holistic approach towards innovation. Whilst there are existing solutions on a national level (such as dedicated departments or workgroups), this is not the case for European efforts aimed at modernising inland waterways. It is highly recommended to create such a structure outside the confines of the traditional day-to-day business, as this might impede the innovative character.

Establish a knowledge management platform

Currently, most best-practices and experiences gained throughout a project are conserved in reports and individual papers. As such, they provide benefits for interested parties outside the respective project team, like universities, service providers and research institutes. However, this solution does not scale well with an increase in innovative efforts. Knowledge management systems (such as wikis) require substantial effort to be user-friendly and effective. Nonetheless, they are one of the most important tools for any large and diverse institution. As the European fairway authorities are very heterogenous in their capacity to innovate, it would greatly help to set up a (international) platform for the management of acquired knowledge. As a result, authorities with a lack of innovative capacity would benefit from insights gained by authorities which are much more engaged in innovation and digitalisation. Furthermore, local pilot projects would have implications for all participating entities, as the lessons learned within these projects are formalised, thus making best-practices more transparent. This would reduce the need of redundant projects among different fairway authorities and create capacity for a more streamlined innovation effort. It is vital that participating authorities provide enough time for the individuals partaking in such activity. Additionally, position within the domain of knowledge-management must be person independent. Many institutions argued that most initiatives today are based on the individual effort of a few employees. If a structured approach is to succeed, it has to be well-established. Knowledge-manager must be a position that is filled once vacant, just like any other key position within an organisation. Furthermore, low-effort solutions are essential to the successful knowledge-management initiative. Applications which were traditionally used in software development projects are increasingly more attractive, since they provide easy but powerful solutions for the management of large, adaptive and scalable solutions. Confluence (with Jira) and GitLab are just two popular examples which combine many features in an intuitive and low-maintenance fashion. Large institutions and projects will require dedicated knowledge management, no matter the platform. However, in the long-term, establishing such a platform within a proper set-up will free up enough capacity as to make it worthwhile.

Establish a collaboration tool for projects and ideas

A knowledge management platform preserves the experiences of past projects and efforts. By doing so, it can foster local innovation efforts since it frees up capacity which would otherwise be spend on possibly redundant projects. In contrast, a collaboration tool (like a forum) would increase the potential for a more coordinated, effective innovation effort among all participating authorities. By allowing for an exchange which is not constrained by projects or fairway authority-specific efforts, it would enable individual actors to collaborate with each other. As such, stakeholders could utilise the shared knowledge of all participating experts within each fairway authority to generate ideas, propose initiatives and increase the development speed of new innovations. Just like the knowledge management platform, the collaboration tool requires free capacity by each fairway authority. Usability and the possibility to partake in such joint exchanges is crucial, and any such platform requires a certain minimum amount of activity to be attractive. Nonetheless, the benefits of pooling knowledge and ideas would help in creating a sustainable, positive, and long-lasting effect on the innovative efforts of European fairway authorities.

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Roadmap

The essential components for each use case and its technological dependencies are depicted in Figure 38. It has to be noted that all fairway authorities are highly heterogenous. As such, there is no "one" roadmap which can be applied to all authorities. Consequently, this roadmap aims to give an overview of what the authors and the workgroup members think feasible for some advanced European fairway authorities. If projects become more international and cooperative, and if innovation is managed in an organised manner, fairway authorities lacking behind may catch up quickly. As a result, this roadmap may become feasible for most European inland waterways in the case of a synchronised, structured approach to innovation and digitalisation.

The data exchange platform is supposed to be an extension of the current EuRIS, thus it can be realised within the next few years if an adequate planning tool is added to its repertoire. Smart Infrastructure is the second use case, though it can be pursued in parallel to the Data Exchange Platform, as it has very little overlap in terms of required technologies or applications. However, collecting IoT data from the fairway infrastructure in a centralised information platform will create an added value which is essential in the long-term. Nonetheless, the implementation order of the use cases will make little difference in the short-term. The next two use cases build upon the previous ones, which is why they need significant advancements within the Data Exchange Platform and all deployed Smart Infrastructure applications. The Predictive Traffic Concept incorporates AI applications, which is why it will most likely not be feasible to establish such application in the next five years. However, if advancements in Use Case 1 and 2 are achieved quickly, this timeline may shift forward. This is mostly because many aspects of the third use case can be achieved with AI solutions already established or in development today. The Holistic Digital Twin relies on the incorporation of applications from other modes of transport in conjunction with hardware and software capable of handling such a sophisticated system. Nonetheless, the authors believe that the cooperation and actual integration of stakeholders from other transport modalities is key and much more important than the advanced computing capabilities required for such endeavour. Such cooperative projects can already be pursued and will ensure a much higher chance of success for the Holistic Digital Twin. Considering the organisational recommendations in sections 6.3 – 6.8. it would be beneficial to create a governance structure for the strategic development towards a digital twin. This could be governed by an international organisation.

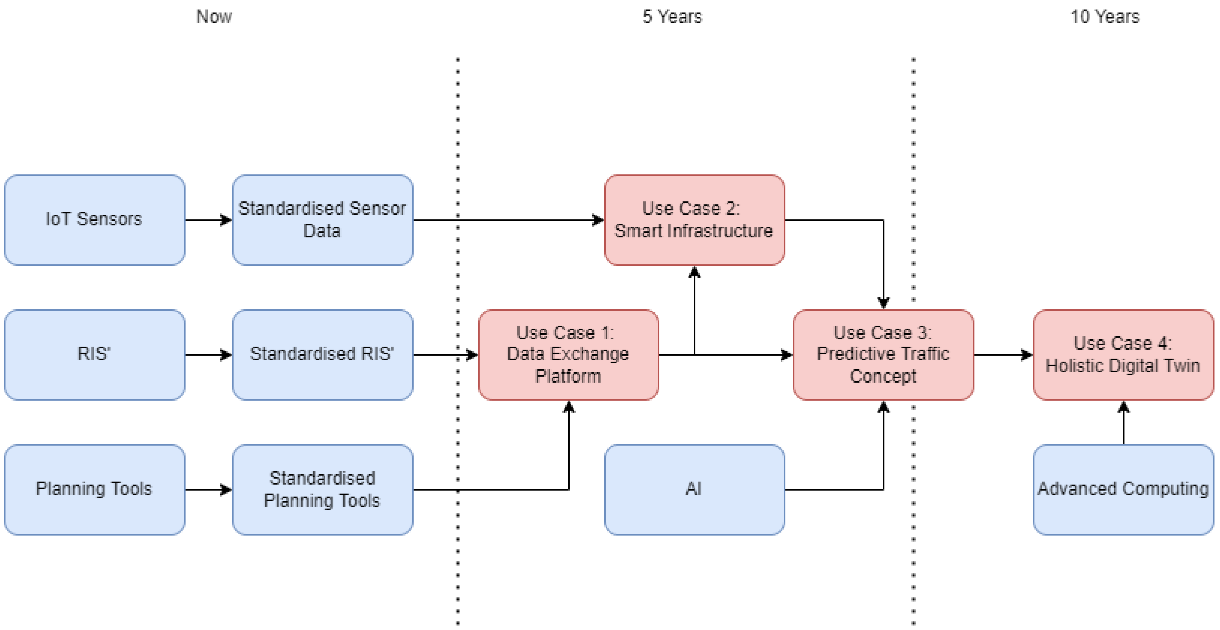

Figure 38: Roadmap overview

Blue: Required technological developments for the successful implementation of the Use Cases

Red: Use Cases

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