EXPLORING POTENTIAL IMPLICATIONS OF AUTOMATED INLAND SHIPPING ON THE DUTCH WATERWAY INFRASTRUCTURE

A scenario analysis

W.J. VAN TERWISGA
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EXPLORING POTENTIAL IMPLICATIONS
OF AUTOMATED INLAND SHIPPING ON
THE DUTCH WATERWAY INFRASTRUCTURE
A SCENARIO ANALYSIS

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Wouter Jeen van Terwisga
Student number: 4513789

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Chair: Prof.dr. G.P. (Bert) van Wee TU Delft T&I
First Supervisor: Dr. J.A. (Jan Anne) Annema TU Delft T&I
Second Supervisor: Dr.ir. J.N. (Jaco) Quist TU Delft E&I
External Supervisor: ir. L. (Lea) Kuiters Rijkswaterstaat

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Preface

Five months of getting to know people, collecting new insights, and continuously developing more knowledge have led to a report that assesses the effects of a still very immature technology. The report in front of you shows the results of a master thesis project, conducted for the Master Management of Technology at the TU Delft; a master programme, where technology is seen as a resource towards a better and more competitive environment. During this master thesis project, I have achieved new knowledge about an upcoming technology which interests me very much. After my bachelor in Maritime Engineering/Naval Architecture, and my youth on board of my parent’s ship, of which the latest can be seen on the cover page of this thesis, it was inevitable for me to do research within the development of the wonderful maritime sector.

This master thesis project started in February 2019 but was initiated by a literature study which started in November 2018 with an internship at Rijkswaterstaat. What seems so logical at this moment was yet so unclear during the start of this thesis. During the trajectory of conducting this research, I have gained not only more knowledge about the inland shipping sector, but also more applied knowledge of the theoretical knowledge that I have gained throughout my Master.

It has been an adventure to combine the amount of knowledge that I already had with the knowledge of experts, into a thesis that hopefully aids Rijkswaterstaat, but also other actors in the inland shipping sector, to prepare for the future of inland shipping. As a result, I want to thank my university supervisor Jan Anne Annema, for his valuable advice at making my thesis academic and his many motivating words after I have sent him another version of my work. Moreover, of course, my supervisors at Rijkswaterstaat; Lea Kuiters, Patrick Potgraven, and Michael Schreuder for their critical advice on my work and the weekly meetings to keep my workflow up to speed. Also, I want to thank my lovely girlfriend, Esther, who has supported me at every step of the way and has always been available for a critical discussion about my work. And, at last, I want to thank my parents for always supporting me and raising me in this exciting sector.

Wouter van Terwisga

Delft, July 18th 2019
Executive summary

Automated shipping is a technology which is highly anticipated by many actors in the inland shipping sector. Rijkswaterstaat, as the manager of the main inland waterways in the Netherlands, wants to be prepared for this technology. As the technology is still very immature, this research has attempted to reduce the amount of uncertainty in the effects and implications of this technology using a scenario analysis approach. As a result, the main research question is as follows: “What are the potential physical and digital implications for the waterway infrastructure of Rijkswaterstaat due to automated inland shipping in the Netherlands by 2050?”.

As little research has been done regarding this topic, this research used literature regarding the diffusion and implementation of high-tech technologies and applied the insights from theory into a scenario analysis. This research used the intuitive logics approach for scenario analysis to develop four scenarios based on drivers, factors, and trends as found during nine expert interviews. Nine interviews were conducted to assess the uncertain trends in the development of automated inland shipping. As a result, technological development and niche development were found as the main trends that highly influence the technology and are both very uncertain. The resulting scenarios were called “Into the roots”, “Fairway bound”, “Business as Usual”, and “Market segmentation”.

When the development of the scenarios was finished, an implication analysis was performed to answer the main research question. This was done by conducting an expert workshop. Six experts from Rijkswaterstaat, in the field of waterway management, and infrastructural design were present during the workshop. The scenarios were validated by the experts, and an open discussion was held to assess the implications per scenario. The results of the workshop were afterwards documented and analysed.

In short, the results show that there are various implications due to automated inland shipping in the Netherlands:

- The physical implications show that automated mooring systems are required to accommodate fully unmanned ships. Rijkswaterstaat should keep track of the development of these systems as they need to be compatible with her infrastructure.

- Regarding the digital infrastructure, automated shipping technology can be facilitated by providing advanced mobile networks, reliable data, and good traffic management on the waterways.
- Rijkswaterstaat already has a lot of data available and can extend this dataset by providing more data to the ships such that ships no longer have to gather all the data by themselves. This implicates an increased responsibility and larger role of traffic management services.

- Maintain international compatibility with data from all actors.

Overall, it can be concluded that no immediate risks arise from the development of the technology. Rijkswaterstaat can, however, facilitate automated shipping technology by providing a good digital infrastructure where international compatibility with the data from all actors is present. Facilitating an advanced digital infrastructure also aids Rijkswaterstaat in achieving her goals: fast, safe, and sustainable waterways. No immediate effects of automated shipping affect the organisation of Rijkswaterstaat. The technology is rather able to aid Rijkswaterstaat in achieving her goals.

Further recommendations are to perform an in-depth analysis of specific problems and challenges that arise with automated ships. Rijkswaterstaat should also keep joining the technological developments of automated shipping in order to stay compatible. Thereby, it is recommended for Rijkswaterstaat to facilitate an advanced digital infrastructure on the waterways to accommodate/facilitate fast, safe, and sustainable flow of cargo over water. Also, it should be made clear of who the responsible actor will be for the data that is shared across the ships and infrastructure. Moreover, more research can be done to investigate the global development of automated shipping instead of just inland shipping.

At last, as the implications are a first attempt at discovering what the effects of automated shipping on the inland waterway infrastructure are, it is, recommended to perform more research into specific implications by performing simulations and case studies for each scenario. Also, backcasting could be a suitable method for defining a normative sustainable future and determining which steps should be taken for Rijkswaterstaat to achieve a desirable future.
Samenvatting [NL]

Geautomatiseerde schepen, of smart shipping zoals het ook vaak genoemd wordt, is een technologie waarin steeds meer mensen zich gaan verdiepen. Rijkswaterstaat als beheerder van de Nederlandse hoofdvaarwegen wil voorbereid zijn op deze technologie. Aangezien deze technologie nog in de kinderschoenen staat, richt dit onderzoek zich op het verkleinen van de onzekerheid op het gebied van de effecten die deze technologie met zich meebrengt. Een scenario analyse en implicatie analyse is uitgevoerd om de hoofdvraag te beantwoorden: “Wat zijn de potentiele fysieke en digitale implicaties voor de vaarweginfrastructuur van Rijkswaterstaat als gevolg van geautomatiseerde binnenvaart in Nederland in het jaar 2050?”

Aangezien er tot nu toe erg weinig onderzoek is gedaan op dit onderwerp, maakt dit onderzoek gebruik van theorie die inzicht geven in hoe high-tech technologieën zich ontwikkelen en verspreiden over de markt. De inzichten uit deze theorieën zijn gebruikt om een betere scenario analyse te doen. De scenario analyse kan in verschillende vormen worden uitgevoerd, maar dit onderzoek heeft gebruik gemaakt van de intuitive logics approach. Deze aanpak zorgt ervoor dat met gebruik van kennis van experts, twee assen worden gemaakt die twee onzekere trends weergeven. De combinatie van deze twee assen zorgen dan voor 4 scenario’s. Negen interviews zijn gehouden met allerlei verschillende experts die zich bezighouden met innovatie in de binnenvaartsector. Het resultaat van de interviews heeft geleid tot de assen ‘technologische ontwikkeling’ en ‘nichevorming’. Deze twee assen hebben daaropvolgend geleid tot vier scenario’s, genaamd: “In de haarvaten”, “Geulgebonden”, “Business as Usual” en “Marktsegmentatie”.

Nadat de scenario klaar waren, is er een workshop uitgevoerd met zes experts van Rijkswaterstaat die gezamenlijk hebben gekeken naar wat de implicaties van elk scenario voor de infrastructuur van Rijkswaterstaat zijn. De zes experts waren elk gespecialiseerd op vakgebieden zoals vaarwegontwerp, sluisontwerp en verkeersmanagement. Tijdens de workshop zijn eerst de scenario’s gevalideerd op hun consistentie en aannemelijkheid. Nadat de scenario’s gevalideerd waren, is er een open discussie gevoerd voor het vinden van de implicaties. De workshop is daarna gedocumenteerd en de resultaten zijn geanalyseerd.

In het kort kan er worden gezegd dat er verschillende implicaties zijn gevonden voor de toekomst van geautomatiseerde binnenvaartschepen:

- De fysische implicaties laten zien dat autonome afmeersystemen nodig zijn om volledig onbemande schepen te accommoderen. Voor Rijkswaterstaat is het hierin
belangrijk om de ontwikkelingen mee te maken zodat de producten ook voor de binnenvaart worden ontwikkeld en in de sluizen van Rijkswaterstaat passen.

- De digitale infrastructuur laat zien dat geautomatiseerde binnenvaart kan worden gefaciliteerd doormiddel van een goede digitale infrastructuur. Geavanceerde mobiele netwerken, betrouwbare data en goede verkeersmanagement zorgen voor een omgeving waarin de techniek goed kan ontwikkelen.

- Rijkswaterstaat heeft al veel data beschikbaar voor het huidige werk. Echter kan dit nog worden uitgebreid om zo de binnenvaart efficiënter te maken. Schepen hoeven dan minder vaak zelf hun informatie te vergaren. Dit zorgt er wel voor dat verkeersmanagement een meer verantwoordelijke en grotere rol krijgt.

- Om compatibel te zijn met alle datastromen, zal Rijkswaterstaat duidelijk mee moeten werken aan internationale ontwikkelingen.

Een conclusie die uit deze implicaties kan worden getrokken is dat er geen directe risico’s volgen uit de ontwikkeling van de technologie. Veel kan echter wel worden gedaan op het gebied van de digitale infrastructuur. Sensoren en actuatoren kunnen worden geïnstalleerd om zo een betere digitale infrastructuur te verzorgen waarop autonome schepen, maar ook huidige schepen beter en efficiënter kunnen varen. Factoren zoals waterdiepte, wind, andere vaarweggebruikers, stroming en actuele brug- en sluisopeningen kunnen allemaal in kaart worden gebracht en naar de schepen worden gecommuniceerd. Er zal hier echter wel moeten worden gekeken naar wie de verantwoordelijkheid voor deze data krijgt en zullen er nieuwe protocollen moeten worden ontwikkeld die data kunnen communiceren. Verder kan corridor management ook verder worden ontwikkeld met deze data, maar ligt er ook een nadruk op het standaardiseren van de datasets die alle kunstwerken leveren.

Al met al kan er worden geconcludeerd dat Rijkswaterstaat geautomatiseerde binnenvaart kan faciliteren door middel van een goede digitale infrastructuur waar internationale compatibiliteit met de data van alle actoren aanwezig is. Het faciliteren van een geavanceerde digitale infrastructuur zal ook helpen bij het behalen van de doelen van Rijkswaterstaat: vlotte, veilige en duurzame vaarwegen. Er zijn als gevolg van de technologische ontwikkelingen geen directe implicaties op het werk van Rijkswaterstaat op dit moment. Echter kan de technologie Rijkswaterstaat wel helpen bij het beter behalen van haar doelen.

Verder onderzoek kan zich nog richten op meer diepgaande implicaties die optreden als daadwerkelijk autonome schepen op de vaarwegen gaan varen. Simulaties en casestudies kunnen op dit moment andere inzichten geven over de problemen die optreden bij de
ontwikkeling van de technologie. Daarnaast is het, zoals reeds aangegeven, belangrijk om de technologische ontwikkelingen bij te houden en te zorgen dat de infrastructuur hiermee om kan gaan. Er liggen ook nog gaten in de kennis over wie de verantwoordelijkheid over de data gaat krijgen. Rijkswaterstaat kan veel data gaan delen, maar als schepen hier volledig op gaan vertrouwen zal de betrouwbaarheid nog veel hoger moeten. Voor Rijkswaterstaat is het hierom aangeraden om een normatieve toekomst te definiëren en de rol van Rijkswaterstaat hierin vast te stellen. Met methodes zoals Backcasting kunnen dan de juiste middelen worden bepaald om deze normatieve toekomst te bereiken.
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List of Abbreviations

AIS Automatic Identification System
AV Autonomous Vessel
BLN Binnenvaart Logistiek Nederland
CBRB Centraal Bureau voor Rijn- en Binnenvaart
CCNR Central Commission for the Navigation of the Rhine
CEMT Conférence Européenne des Ministres des Transports
DI Disruptive Innovation
ECDIS Electronic Chart Display Information System
ECMT European Conference of Ministers of Transport
EICB Expertise- en Innovatiecentrum Binnenvaart
ENC Electronic Nautical Charts
GPS Global Positioning System
ILCM Integrated Logistics Conceptual Model
IWT Inland Waterway Transport
MLP Multi-level perspective
RWS Rijkswaterstaat
TIS Technological Innovation System
Ton-km ton-kilometer
VHF Very High Frequency
VTM Vessel Traffic Management
VTS Vessel traffic services

Glossary

Hybrid Throughout this thesis, hybrid is used to describe a mix between an autonomous and a manually navigated ship.
VHF (radio) Maritime voice communication medium for communication on the waterways
Path dependency “[..] once established some institutions tend to become increasingly difficult to change over time, and so small choices early on can have significant long-term impacts.” (Sorensen, 2015, p. 7)
Groupthink When a cohesive group of people rather wants to conform with each other than to have a critical discussion
Chapter 1: Introduction

The fourth industrial revolution (Industry 4.0) can revolutionise the way ships are designed, manufactured, and operated (Ang, Goh, Saldivar, & Li, 2017). Ang et al. (2017) describe the 4th industrial revolution as “autonomy through cyber-physical systems”, a revolution that introduces disruptive and enabling technologies such as intelligent robots, internet of things, augmented reality, 3D printing, and automated simulations. For shipping, these technologies may bring many changes to the current technological regimes. The technologies can bring increases in efficiency of transport due to better supply-chain integration, but also reduce the amount of required personnel with automated sailing. This could be a way to manage the expected increasing transport volumes (Leeuw van Weenen, Meulen van der, & Geest van der, 2017) and lack of qualified personnel in the inland shipping sector (European Parliament, 2009; Heerschop & van Huizen, 2017; van Huizen, 2018). Stopford (2015) also mentioned the need for ships to become smarter and adapt to the latest technologies in order to better manage the economic cycles in the shipping markets.

The inland shipping sector has especially seen sustainability improvements during the last decades due to changes in regulations for diesel engines (Consuegra, 2016). Technologies regarding the navigation of these ships have been gradually improved. Research does, however, show that innovations regarding the first steps of automation in inland shipping navigation can be expected within the next ten years (Ang et al., 2017; van Cappelle, Chen, & Negenborn, 2018). These innovations make it possible for ships to become more situationally aware and increase the autonomy of the autopilots. This could bring significant changes to the current technologies for navigation. Modern technologies only exist of an autopilot which can keep the ship at a straight course, or in more advanced cases sail a pre-programmed route where the skipper is still in all circumstances responsible for the navigation of the ship.

Increasing interest in more automated shipping in the Netherlands shows that many actors in the inland shipping sector become involved in a future with a more intelligent and automated shipping market. Little is, however, known about what this future will look like. The uncertainty of the future is rising as little research has been done to what extent these upcoming technologies may change the inland shipping sector.

Rijkswaterstaat (RWS), as the executive part of the Dutch Ministry of Infrastructure and Water Management, is the organisation that manages the more than 3000 kilometres of Dutch waterways. These waterways exist of many canals, lakes, rivers, but also many
infrastructural objects such as bridges, locks, and dams. A large part of the +/- 6000 inland commercial cargo ships that sail in the Netherlands (IVR, 2018) encounter these infrastructural objects on a daily basis. Due to the uncertainty of the future effects of more automated inland shipping, the future requirements of inland waterway infrastructure are unclear. When ships are becoming more automated, and computers need to make the decisions during navigation, the ship needs to be compatible with these infrastructural objects to sail on the waterways. A conventional lock, for example, requires a present ship to wait, sail into the lock, moor, change mooring lines during the turning of the lock, and to sail out of the lock. These activities are not easily automated. Therefore, the question arises what the implications are for the infrastructure in case the ships become more automated.

Rijkswaterstaat wants to be prepared for this technology, as the goals of Rijkswaterstaat for its waterways are to contribute to economic vitality, sustainability, and quality of public space. That is why in an internal project at Rijkswaterstaat, preliminary research has been done to explore the future of automated shipping and how that might influence the organisation of Rijkswaterstaat (AEF, 2018b, 2018a). This research did, however, according to multiple sources at Rijkswaterstaat, not fulfil all expectations. Due to the lack of futurists (people who have creative ideas for the future), the research covered very abstract social and economic trends in order to assess whether automation would happen or not. The research did not assess systematic changes to the inland shipping sector caused by automated shipping technology. Hence, the results were not complete. As a result, the research showed ambiguous implications for the organization and the infrastructure of Rijkswaterstaat, providing the need for better research on this topic.

Based on this knowledge gap, more research should be done to create knowledge about the systematic effects of automated inland shipping in the Netherlands, and how that affects the infrastructure of Rijkswaterstaat. Hence, the problem statement is as follows:

There is a lack of knowledge on how automation of inland shipping may change the inland shipping sector and how this change affects the Dutch waterway infrastructure.

1.1 RESEARCH OBJECTIVE AND SCOPE

As a result, the knowledge gap and problem statement found in the previous paragraph will provide the goal for this study. This study aims to explore the effects of automated shipping on the inland shipping sector and its corresponding physical and digital implications on the Dutch waterway infrastructure. This requires knowledge on the status quo of the inland shipping, what the effect of automation will be on the inland shipping market, and what the implications will be on the waterway infrastructure of Rijkswaterstaat. 2050 is used as the timeframe to enable thinking in the long-term but avoiding science-
fiktion ideas. The research is also scoped to assess the effects of a changing way of navigation. Changes in propulsion and fuel-types are not the focus of this research. Therefore, the research question will be as follows:

“What are the potential physical and digital implications for the waterway infrastructure of Rijkswaterstaat due to automated inland shipping in the Netherlands by 2050?”

With the sub-questions:

i. How is the inland shipping sector currently organised?
ii. How can the future of inland shipping be explained?
iii. What will be the effect of automation on the inland shipping sector?

1.1 THESIS OUTLINE

Following upon this introduction, chapter 2 will describe the methodology used in this thesis. Followed by chapter 3, where a theoretical framework provides theories that aid in answering the research questions. Chapter 4 describes the status quo of the inland shipping sector. Chapter 5 will present the results of the scenario analysis based on expert interviews. Accordingly, chapter 6 will feature the analysis of the implications of the technology on the waterway infrastructure. At last, chapter 7 will discuss, conclude and reflect upon the analysis from chapter 6.
Chapter 2: Research methods

This chapter shows which methods and framework were used to answer the research questions of this thesis.

2.1 DESK RESEARCH

First, the research requires theory to explain how technology diffuses over time and how this can aid the answering of the research questions. This is done by writing a theoretical framework that discusses theory about technical transitions and high-tech product diffusion.

When the theoretical framework has been set, desk research defines how the current situation of the inland shipping sector is organised. This *status quo* gives insight into the short-term history as to how the market evolved into the current situation. The status quo also shows which actors are involved in the inland shipping sector and how they interact to provide a sound knowledge base for the remainder of the research.

This desk research answers sub-question i).

2.2 SCENARIO ANALYSIS

Organisations like Rijkswaterstaat experience a lot of incremental changes due to the conservativeness in the shipping sector; this incremental change is also described by the theory of *muddling through* (Lindblom, 1959). There may, however, also be periods where disruption by new technologies can bring fast change and uncertainty within a short timeframe. Scenario thinking as a method within the approach of strategic planning can help to assess the effects of uncertain futures; it promotes early contingency action and early recognition of opportunities for such situations (Cairns & Wright, 2018). For Rijkswaterstaat, this is important in order to redesign the infrastructural objects that have to be renewed in the next decennia. Especially since Willems et al. (2018) state that waterway infrastructure is subject to path dependency. Hence, an analysis of early contingency and recognition of opportunities seems vital.

There are many different ways of performing a scenario analysis (Amer, Daim, & Jetter, 2013). However, the *intuitive logic approach* is the most established version. This approach has been used by many multinational firms to prepare for the future, but also in recent academic literature (Amer et al., 2013; Bradfield, Wright, Burt, Cairns, & Van Der Heijden, 2005; Cairns & Wright, 2018; Milakis, Snelder, Van Arem, Van Wee, & De
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Almeida Correia, 2017; Pernestål Brenden & Kristoffersson, 2017; Tillema et al., 2015; Wright, Bradfield, & Cairns, 2013). Throughout these papers, one of the main reasons to use this method was the uncertainty and long-term character of the problems at hand. The method is also capable of assessing broad scopes. This is useful in this research due to the uncertainty at hand. Little research has been done before on this topic; hence, a broad scope and a wide variety of factors and trends are useful to assess the uncertainty.

As a result, this research will also use the intuitive logic approach. The intuitive logic approach for scenario analysis is a qualitative way of assessing future possible and plausible scenarios, rather than normative scenarios (Cairns & Wright, 2018) without the need for many futurists. Across many applications of this approach, the actual construction of the scenarios may vary, but the sequence is usually the same (Milakis et al., 2017).

This research uses a five-step approach to build and examine the scenarios, based on the basic method mentioned in (Cairns & Wright, 2018) but slightly altered. The altered method merges some steps to reduce the number of interview rounds and group discussions since the number of experts with knowledge and time for the interview are scarce. The same work is done, but more emphasis is put to the analytical skills of the author who develops the scenarios, thereby reducing the need for many interview rounds.

1. **Setting the agenda:** Defining the focal issue of concern and setting the scenario timescale

2. **Individual interviews:** Perform open/semi-structured interview to collect key factors, driving forces and their corresponding impact/uncertainty followed by open questions regarding the effects of such driving forces.

3. **Analysis of interview data:** Desk research based on information collected during interviews; clustering the driving forces, defining the outcomes of these clusters, assigning uncertainty/impact levels to these clusters, and defining the extreme outcomes of the key factors (2 factors/axes).

4. **Framing and scoping the scenarios:** Desk research; build extreme outcomes of the key scenarios and write a narrative describing the scenarios

5. **Review and impact analysis of scenarios:** Check with a workshop at Rijkswaterstaat the plausibility, consistency, utility/relevance, and novelty/challenge of the scenarios and develop the outcomes and impacts on the infrastructure per scenario.

Scenario analysis is usually done by group work, however, due to limitations such as groupthink and the difficulties of getting many experts together on a single date and at a
particular time; individual interviews will be conducted for the gathering of drivers, trends, and factors that define the scenarios. For the interviews, 5 to 15 experts are selected based on their experience in the field of innovations for the inland shipping sector. This includes academics, executives from innovating firms, and highly involved actors on the topic. The search for new experts will stop when the results no longer provide novel information and the ideas converge. The interviews are semi-structured to create an open conversation but structured towards the theory, as is discussed in Chapter 3. The questions for the interviews can be found in Appendix E. The first questions are the basic questions that are required to develop the scenarios. The latter questions are based on theory to get a theoretical basis and better insight on how the technology progresses. These theories can be found in Chapter 3.

The interviews are recorded and transcribed into a summary. When the ideas have been documented and verified by the corresponding experts, a discussion of the results is presented. From this discussion, the most uncertain, though impactful trends and factors are used to develop the scenario matrix. When the two axes of the scenario matrix have been defined, a narrative will be written with the extreme effects of each scenario, which is based on the results of the interviews.

This approach of interviewing single experts and discussing the results of the interviews is chosen because of the time-efficiency. Methods as the Delphi method use multiple rounds of interaction with the experts, where the aim is to get consensus within the group. Due to the limited timespan of this research, a single round of semi-structured interviews is chosen to get a wide overview of the ideas that experts have especially since it is anticipated that it is challenging to speak with a sufficient number of good experts within a short timeframe.

Research shows that three to five scenarios are most suitable for scenario planning (Amer et al., 2013) and recent intuitive logic approach applications in automotive mobility research usually have four scenarios (Engholm, Kristoffersson, & Pernestål, 2019). So, this research will also provide 3 to 5 scenarios. As a result, the scenarios answer sub-question ii.

2.2.1 Implication analysis

After the scenarios have been finalized, step 5 features an expert workshop, where at least five experts from Rijkswaterstaat receive an invitation to discuss the implications of every scenario on the waterway infrastructure of Rijkswaterstaat. The experts are invited based on their expertise regarding shipping and digital/physical waterway infrastructure.

A workshop is chosen because the research is conducted within the organizational boundaries of Rijkswaterstaat, thereby providing a good connection to a variety of experts having knowledge about the interaction between inland shipping and waterway
infrastructure. The workshop will feature an open discussion that enables a variety of ideas to be brought to the conversation.

This workshop follows the procedure of an open discussion:

The discussion followed the following script:

1. Opening and welcome
2. Presentation of the scenarios
3. Validation of the scenarios: Discuss inconsistencies, validity and novelty
4. Present scenario #
   a. Discuss positive and negative physical implications
   b. Discuss positive and negative digital implications
   c. Validate conclusion
   d. Repeat for every scenario
5. Conclude with validation of the overall conclusion

A voice recording of the workshop will be made, the results will then be analysed, and a summary of the full transcript will be presented in the appendices. The results of the analysis are then the answer to the main research question of this thesis.
2.3 OVERVIEW

In Figure 1, an overview is given on the execution of the methodology, where each part of the methodology answers a different (sub-) research question.

![Figure 1: Overview of the research methodology]

2.4 LIMITATIONS

As little information is available regarding the topic of this research, the qualitative method of gathering opinions from experts is used to retrieve the necessary information. There are also some limitations to scenario analysis, as “they are speculative in their nature and sensitive to the pre-conceptions and knowledge of the experts developing the scenarios.” (Engholm et al., 2019, p. 1). By inviting many different experts from different organisations and companies, a broad view is retrieved which attempts to eliminate the pre-conceptions as much as possible.

The intuitive logic approach for scenario analysis is also a qualitative way of assessing future possible and plausible scenarios, rather than normative scenarios. Wright et al. (2013) also mention a limitation of the intuitive logics scenario method, as it does not directly address improved decision making. This is partially solved in this research with use of the expert workshop, where experts from Rijkswaterstaat, who are close to the decision-makers give their input on how their work could change. The analysis of the results of this workshop tries to find implications for how the infrastructure is currently managed and how Rijkswaterstaat could respond to it.
However, the emphasis in this research lies on the reduction of uncertainty in technological forecasting for automated inland shipping and its effects. The objective is not to give policy recommendations. Even though future research on improved decision making could use the results of this research.

Besides, the choice of conducting single interviews with every expert reduces the consensus of the expert opinions; arguments are not discussed with other experts. This has been chosen due to the limited amount of time available for this research. This limitation is solved by a thorough discussion of the arguments in this thesis. The most important and most mentioned factors, trends, and further arguments will be discussed and used as qualitative information for the development of the scenarios.
Chapter 3: Theoretical literature review

Automated shipping as a technology is still very immature. The future is uncertain, technological advances still need to be made, and their effects are yet unclear. Little literature is available regarding the future of automated inland shipping. Therefore, theory is found to give insight in the development and diffusion of technology in technological systems. These theories are then used to build better scenarios and provide improved analyses of the results.

3.1 TECHNOLOGY ASSESSMENT

Technology Assessment (TA) is one of the frameworks that is used across multiple industries to explore the technological advances and the effects of these advances in society. Smit & Oost (1999) describe a framework to perform a technology assessment of which the main four steps are as follows:

1. Explore technological advances
2. Estimate societal/social/environmental-effects
3. Apply normative criticism from multiple perspectives
4. Feedback into the technology development and/or to societal infrastructure to prevent or reduce unwanted effects

These steps each have their methods. Step 1 can be done through an assessment of how technology may progress. By doing this, literature and experts can be utilised to gather information on how the future may look like and what the relevant factors and actors around the technology are and what the history of the technology entails. This is especially relevant in cases where path dependency occurs. As mentioned in Chapter 2, Willems et al. (2018) mention that waterway infrastructure is very path-dependent due to long lifecycles of sometimes exceeding 100 years (Hijdra, 2017).

Step 1 also entails the assessment of technological advances. One way to do this is by trend extrapolation. However, Industry 4.0 is expected to bring disruptive technologies to the shipping industry; causing trends to break in ways that are not yet known. Hence, trend extrapolation cannot be done.

TA attempts to assess the effects of a certain technology. An actor map can help to map the relevant actors and stakeholder that might be affected by the technologies. Interactive sessions with stakeholders and brainstorming using impact/effect trees can assist in analysing the effects of the technologies. Followed by the normative assessment of the effects, multiple perspectives are used to define what should be done to limit the adverse
effects of the technology that is being assessed. These normative statements can be used in the design of the technology or the design of the corresponding infrastructure.

TA is a useful method for assessing adverse effects of certain technologies. For this research, it can be learned from TA that it will be important to also look at the risks that a technology brings. The development of automated inland shipping technology can bring new challenges and problems to the organisation of Rijkswaterstaat. The implication analysis in Chapter 6 will therefore also discuss the risks for Rijkswaterstaat.

3.2 DISRUPTIVE TECHNOLOGIES

As mentioned by multiple authors; upcoming innovations in the shipping market have the potential to disrupt the current markets (Martimo, 2017; Oneto, Anguita, Coraddu, Cleophas, & Xepapa, 2016; Schwab, 2015; Stopford, 2015). But what exactly is disruptive innovation?

A review on disruptive innovation (DI) theory mentioned “a very heated discussion” by scholars, where most agreed with the definition of disruptive innovation by Christensen (1997) (Yu & Hang, 2010). Martimo (2017) summarises the definition of Christensen as: “First, disruptive innovation is inferior by its quality (it underperforms) compared to mainstream products and second, it is usually performed by an entrant firm. Disruption happens when the mainstream market and DI trajectories intersect” (p. 18). Yu and Hang (2010) discussed that other scholars stated that not all disruptive technologies comply with this definition. For example, the mobile phone was inferior at first in terms of quality while high-end in terms of price. It was for the executives of large companies to have these devices despite their lack of reliability and high prices. Only after the mobile phone got more reliability and a lower price, it started to disrupt the landlines. Christensen (2006) responded to this by adding to its framework that disruptive innovation starts either in a fringe-market or detached-market for low-end encroachment. In the case of the mobile phone, this would be the detached market.

The interesting part of the mobile phone market is that most end-users did not know that they would need or want a mobile phone in the future. People were more than happy with the landlines at home. On the other hand, Consuegra (2016) stated that innovations for sustainability in the Dutch inland shipping sector require a large amount of stakeholder support. This would induce only incremental innovation according to (Christensen, 1997), but this also insists that technology developers should perform a technology assessment with the input of many stakeholders. Disruptive innovation contrasts to this statement as it does not listen to stakeholder/end user's needs and wants. Disruptive innovation tries to target new future markets without the input of current actors and stakeholders.
Recently, a study has been done on the potential of smart shipping to disrupt shipping (Martimo, 2017). Martimo (2017) assessed the upcoming smart shipping technologies by the theories of Disruptive Innovation (DI). When looking at theories involving disruption innovation, the popular theory of creative destruction by Shumpeter (2010) usually comes forward. This theory explains how new innovative technologies can destroy and replace the old incumbent technologies. This substitution is usually achieved by an innovative entry of entrepreneurs in an existing market. Martimo (2017) also concludes that “current cargo market situation could be inviting new entrants to join shipping since many of the old actors are facing bankrupts or have too much debt burdening their investing capabilities” (p. 60). As a result, the start of industry 4.0, can bring challenges to the “old actors” since it will require significant investments to implement new IT innovations in an existing organisation.

3.2.1 The innovator’s dilemma

The conclusion of Martimo (2017) also shows that the theory of Christensen (1997) called ‘the innovator’s dilemma’ can be applied to the shipping market. The innovator’s dilemma has two key points. First, developing a new technology takes a lot of time and effort and can be seen as an S-curve when on a value-to-innovation graph. This is comparable to the S-curve of Rogers (2003), which illustrates how innovations develop and diffuse. Within this S-curve, the first iterations of the development will not significantly improve the value of the technology. After a while, as the product gets added value, the value increases much faster per iteration, and the development may pay off. The second key point of the innovator’s dilemma is a result of this S-curve (as seen in Figure 2), as large companies usually have a large customer base, projected sales figures, and an image of quality. These large incumbent firms do not have the resources to put time and effort in products that do not pay off on the short term. Especially since large incumbent firms tend to keep listening to their customers and solve the problems that the current products have; merely achieving incremental innovation. Hence, newcomers have the opportunity to be innovative and design new products which are radically new in existing markets.

Within the inland shipping market, a large part of the firms are small captain-owner shaped firms where the skipper owns a single ship (Hekkenberg, 2013). There is only a small number of large shipping companies. This does however not mean that the sector is innovative. As will be discussed further in Chapter 4, the shipping sector as a whole is notorious for its conservativeness and lack of innovation.

The theory of the innovator’s dilemma applied to the rise of automated shipping could insist that new and more innovative firms could enter the market due to the conservativeness and incrementalistic innovative behaviour. This effect could accelerate the adoption of new
technologies. Therefore, within the scenario analysis experts will be asked during their interviews whether and which new parties (large or small) could enter the market of inland shipping. This knowledge can be used to determine whether the development might accelerate in the near future due to the entrance of new actors.

Figure 2: The S-curve of diffusion of innovations according to Rogers. (Wikimedia Commons, 2019)

### 3.3 SOCIO-TECHNICAL TRANSITIONS

To get more insight into how technological transitions work, Geels (2012) mentions that most radical innovations do not just arise and diffuse. They usually entail a systemic change to transport systems that are shaped as a configuration of technology, policy, markets, consumer practices, infrastructure, cultural meaning and scientific knowledge (Geels, 2012). Geels (2012) calls these systems: socio-technical systems and major changes are called socio-technical transitions.

Geels (2012) discusses the different views that actors in a socio-technical system have. Neo-classical economists see a change in a system as a result of market failures. These economists believe that the market itself will solve these failures by finding the right equilibrium. Psychologists assume that “behaviour change is caused by changes in attitudes; they make policy recommendations that highlight information provision and education campaigns.”. Ecologists see environmental problems as failures of the current politics, capitalism, modernism, etcetera. These ecologists see a change in culture as a solution. Engineers see problems arising in a lack of efficiency and pollution, where science and technology can solve many problems.

At last, political scientists “study the development and struggles over formal goals and targets as embedded international treaties” (Geels, 2012, p. 471). As Geels further discusses, every perspective considers another part of (un)sustainability in the system. This shows that every actor or stakeholder can have its view of how a system may change due to technology.
3.3.1 Multi-Level Perspective

Schwanen et al. (2011) and Geels (2012) both argue that it will have added value to apply methods, concepts, and insight from social sciences in transport studies. Therefore, Geels (2012) applies the Multi-Level Perspective (MLP) framework to analyse the transition to low-carbon transport systems. Geels (2012) states: “Understanding large-scale transitions to new transport systems requires analytical frameworks that encompass multiple approaches in ways that addresses interactions between them. The multi-level perspective (MLP) [...] is one such framework.” (p. 472).

Hence, the MLP framework of Geels (2004) is a way to study system transitions. The framework does this on three different levels, starting with the meso level. On the meso level, the sociotechnical regimes are being built upon the concept of technological regimes of Nelson (1982). According to Rip and Kemp (1998): “A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures” (p. 338). This definition does not entail the presence and interlinkage of different perspectives mentioned by Geels (2012). A sociotechnical regime contrasts to this by explaining more about the dynamics of the various actors in the innovation system.

On the micro-level, technological niches are examined. These niches are protected, bordered environments where new technologies can more easily bring disruptive technologies onto the market. Based on the theory of disruptive technologies, which will be discussed in chapter 3.2, technologies can form a market where they can prove themselves before moving to the mainstream markets. “Niches thus act as incubation rooms for radical novelties.” (Geels, 2005a, p. 450).

When the first steamships were invented, the inland waterways were used as a niche to experiment with this new type of propulsion (Geels, 2002). The success of these experiments caused governments to build more canals, bridges, and deepen the rivers. The inland shipping niche brought an environment where the steamships could prove themselves within certain transport markets. The technological development did not stop within this niche. Moreover, as the technology grew more mature, it first became an assisting propulsion type to the conventional sailing rigs. When also the technology had matured for ocean-going vessels, the acceleration phase towards large-scale diffusion started.

With automated shipping, the case is not very different. The research within this thesis is scoped to investigate the inland shipping market, which could also function as a niche within the development of automated shipping since a lot could be gained by improving the
Exploring the implications of automated inland shipping domestic transport chains. And even in the inland shipping sector itself, a lot of different niches exist. Many different ship types and ship sizes each have their own operational domain and protected space to operate in.

At last, the macro-level examines the sociotechnical landscape “which refers to aspects of the wider exogenous environment, which affect sociotechnical development (e.g., globalisation, environmental problems, cultural changes).” (Geels, 2005a, p. 451).

Considering the three levels of an innovation system, Geels (2002) illustrated the hierarchy of these levels by showing that niches are part of the technological regimes and technological regimes are part of the landscape, as can be seen in Figure 3.

![Figure 3: Multiple levels as a nested hierarchy. (Geels, 2002)](image)

### 3.3.2 Transition phases

Transitions never happen at once; instead, they consist of many different phases (Rotmans, Kemp, & van Asselt, 2001). These transition phases explain the steps that a transition takes from the presence of a niche to a full-scale landscape adopted transition. The first phase is the predevelopment phase, where the status quo does not visibly change. The second phase is the take-off phase. In this second phase, the process of the transition starts to take place, and parts of the system begin to shift. The third phase is the breakthrough. In the breakthrough phase, visible structural changes to the system take place. Socio-cultural, economic, ecological and institutional changes start to react to each other. The breakthrough phase is also the start of the acceleration phase, which is the phase where the development accelerates. The phases are finalized by the stabilisation phase, where the speed of change decreases and a new equilibrium is found. Figure 4 shows an illustration of the trajectory of a transition.
The MLP framework combines these phases into the three levels of the innovation system. First, the technological niche will be established, it will at some point take-off if it is successful, and then it starts to make changes to the sociotechnical regimes and eventually to the full-scale landscape developments. Figure 5 illustrates this trajectory as a path through the three levels of the innovation system.

Figure 5: A dynamic multi-level perspective on Technological Transitions. By Geels (2002).

### 3.3.3 Conclusions and implications

What can be learned from the theory of Geels, is that technology does not suddenly emerge in a large-scale market and expand. It starts with technological niches, which attempt to disrupt the current socio-technical regimes before moving into large-scale landscape developments. Within the inland shipping sector, many niches already exist which will further be elaborated upon in Chapter 4. Radical technologies such as automated shipping could be generated within these niches. It is, however, not known whether the technology will have a radical implementation or that it also becomes incremental as many previous
innovations. Therefore, experts will be asked to think about whether and which niches could be used to generate the technology in.

3.4 UNDERSTANDING THE PRE-DIFFUSION PHASE

Other theories on the diffusion of new high-tech innovations confirm the transition theory by Geels (2002). This paragraph will discuss the various theories regarding the diffusion of technology.

Many years ago, Rogers (1983) developed the mainstream theory of diffusion curves. The theory of Rogers is famous across the world. The third edition of the book ‘Diffusion of Innovations’ has been cited for more than 100,000 times since its publication, according to Google Scholar. The theory can be used for a variety of technologies as the concept stays the same. It all starts with the adoption by the innovators; the actors who invent technological innovation. It is then followed by the early adopters, early majority, late majority, and at last; the laggards. Cumulatively, at the end of the curve, the diffusion of the innovation is 100%.

Ortt (2010) disagrees with the simple theoretical illustration of diffusion. According to Ortt (2010), “mainstream diffusion research seems to imply that large-scale diffusion starts directly after the market introduction of a new high-tech product” (p. 48), while 48% of the technological innovations do not even make it to the mass market (Tellis & Golder, 1996). Ortt (2010), therefore, proposes a more extensive theory of assessing diffusion. Within this theory, there are three phases; the innovation phase, the adaptation phase, and the market stabilisation phase.

The innovation phase is about the time after the invention of a new high-tech product and prototyping the product into a working principle. “The invention of a new high-tech product category is defined to be the first time that the technical principle of this category is demonstrated and mastered.” (Ortt, 2010, p. 51). After the product has been demonstrated and mastered, the adaptation phase starts. In this phase, the product tries to find (niche) markets where it can be used. “The introduction date is defined to be the date at which the product is available for sales or can be transferred to users. In some cases, products are not sold, for example, if a government institute develops a new weapon that is used by the military forces.” (Ortt, 2010, p. 55). Within this adaptation phase, product launches can also fail and be redesigned for another market.

At last, the market stabilisation phase happens after large-product production and diffusion. This is defined using three elements (Ortt, 2010):

- A standard product that can be reproduced multiple times (or standard product modules that can be combined in many ways but are based on the same standard platform);
• A (large-scale) production unit with dedicated production lines (industrial production of a standard product); and
• Diffusion of the product.

Figure 6: The pattern of development and diffusion of high-tech product categories (Ortt, 2010)

Each phase as seen in Figure 6 can have its duration and varies per industry/technology type. On average, across the studied industries by Ortt (2010), the innovation phase takes 10 years ± 13.5 years, and the adaptation phase takes on average 6.7 years ± 7.6 years. The large standard deviations show that there is no real average to be assumed for the pre-diffusion phases. The findings by Ortt (2010) however, implicate “that the diffusion of new high-tech products rarely follows the well-known S-shaped diffusion pattern” (p. 72).

That high-tech products do not follow the mainstream pattern is caused by three groups of factors (Ortt, 2010, p. 66):

1. The main organization(s) responsible for the development, production, supply and use of the new high-tech product;
2. The technological system required to use the new high-tech product; and
3. The market environment, including all the other actors (than the main organizations) and factors involved (e.g. the availability of regulations and standards).

These groups of factors show that innovation cannot just be pushed to the market and be successful without the right organizations, a good technological system, and a sound market environment where the technology can diffuse.

As a conclusion to this theory of Ortt (2010), it requires many barriers to be overcome before large-scale diffusion can happen. Dominant designs are usually not immediately found, and technology has a long pre-diffusion phase. Also, in alignment with the
methodology of the scenario analysis, it will be useful to explore which factors affect the development and diffusion of the technology.

3.5 CONCLUSION

The theory from Ortt (2010) and Geels (2002) overlap in multiple ways. Both theories show that technology does not just enter the market and diffuse. Products may fail, products may learn from the failure and arise in different niche markets. Eventually, when the many pre-diffusion barriers have been overcome, and the dominant design has been found, it can diffuse into the large-scale market. The potential of disruptive innovation in the shipping market also brings the opportunity for new parties to enter the market.

Based on the findings from this chapter, many new insights can be gathered using the theory about things that were yet unknown. The innovator’s dilemma shows the ability for new firms to arise and utilise innovations to enter the market. However, the applicability to the still conservative inland shipping market is questionable. Also, the theory of Geels (2002) shows that radical innovations generate within niches. The inland shipping sector already exists of many different geographical and commodity niches which could be used to incubate the technology. At last, the theory of Ortt (2010) emphasises the many barriers that affect the long duration of the pre-diffusion phase; the phase between invention and large-scale diffusion. Which factors affect the diffusion of automated inland shipping is yet unclear.

Using the insights gathered by the theories, it has become clearer what the concrete lack of knowledge is in the development and diffusion of the technology. This can be used to reduce the uncertainty in the rise of the technology. To do this, the expert interviews will feature a question where they are asked whether there are niches, and which niches that are, where automation in inland shipping can develop initially. Moreover, the question is asked whether the experts can give their opinion on what type of new actors might enter the market due to the development of this new technology. This added knowledge from these theories provides more insight, a better theoretical foundation, and better-quality conclusions regarding the future development of the technology. Table 1 gives an overview of the findings and implications of the theories, as discussed in this chapter.
Table 1: Overview of theory findings and implications

<table>
<thead>
<tr>
<th>Theory</th>
<th>Findings</th>
<th>Research methodology implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology Assessment</strong></td>
<td>Technological development can also entail adverse effects for organisations and society</td>
<td>Implication analysis should also entail discussion about adverse effects</td>
</tr>
<tr>
<td><strong>Disruptive innovation and the innovator’s dilemma</strong></td>
<td>Provides knowledge that in an imperfect market, there may be room for new entrants.</td>
<td>Experts will be asked to answer whether and which new parties they expect to enter the market</td>
</tr>
<tr>
<td><strong>Sociotechnical transitions by Geels</strong></td>
<td>Provides insight that new technologies usually start in a niche. And technology cannot diffuse by itself. It has to become part of the full technological innovation system.</td>
<td>Experts will be asked whether they expect the technology to start in niches and which ones that will be.</td>
</tr>
<tr>
<td><strong>Understanding the pre-diffusion phase by Ortt</strong></td>
<td>Many factors cause the diffusion of new high-tech products to rarely follow the well-known S-shaped diffusion pattern.</td>
<td>Overlap with the theory of Geels provides the added value of asking experts whether they expect the technology to start in niches and which ones that will be.</td>
</tr>
</tbody>
</table>
Chapter 4: Current situation of the inland shipping sector

Before a scenario analysis can be performed, which find the trends for the future, it is essential to get an overview of the status quo. This chapter will show different aspects of the inland shipping sector. First, a composition of the waterways and waterway users is given. After that, the current niches are found to give an overview of the already existing niches in the inland shipping market. As mentioned in the theoretical framework in chapter 3, niches are important in the development of new technologies.

Besides, a short overview is given on how ships navigate and how innovation and digitalisation is currently shaped in inland shipping. And, according to Consuegra (2016), it is important to have a large stakeholder support in inland shipping innovations. Therefore, an overview of the main actors and stakeholders is given to get insight in the stakeholders that are involved in inland shipping innovation.

4.1 THE INLAND SHIPPING SECTOR

The Netherlands is famous for being a strong maritime nation, primarily caused by its central location in Europe at the estuary of the Rhine. The Netherlands contains a lot of maritime companies in different markets; from shipbuilding, to ship services. However, the Netherlands is also famous for its inland shipping sector. The Dutch sector accounts for 314 million tons of cargo per year (CBS, 2018). Moreover, with more than 6700 vessels currently active in commercial cargo transport, combined with cruise ships and other vessels, the Dutch sector represents 55% of the total western-European inland shipping fleet (IVR, 2018).

4.1.1 Ship types

The fleet of the Dutch inland shipping sector is very diverse. Many different ship types are sailing across the rivers, canals, and lakes. In 1992, the European Conference of Ministers of Transport decided to classify all ship types in 10 different categories; CEMT I to CEMT VIII (ECMT-CEMT, 1992). Later, in 2012, recreational ship types were also added to this classification (UNECE, 2019). As a result, waterways and infrastructure could be better designed to accompany a specific range of ship types. Rijkswaterstaat has added extra classes for a more effective and safer waterway in the Netherlands; a summary is given in Table 2.
11,241 commercial ships were active across the Rhine Corridor in 2014 (BCI, Pace Global, & TNO, 2015). To get insight in the sizes of these ships, Figure 7 shows the distribution for most of the CEMT classes.

Table 2 CEMT and RWS classifications of inland ships (Rijkswaterstaat, 2017)

<table>
<thead>
<tr>
<th>CEMT-class</th>
<th>RWS-class</th>
<th>Convoy B x L</th>
<th>Length</th>
<th>Width</th>
<th>Draft</th>
<th>Tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>M1</td>
<td></td>
<td>38.50</td>
<td>5.05</td>
<td>2.5</td>
<td>251-400</td>
</tr>
<tr>
<td>II</td>
<td>M2</td>
<td></td>
<td>50-55</td>
<td>6.6</td>
<td>2.6</td>
<td>401-650</td>
</tr>
<tr>
<td>III</td>
<td>M3</td>
<td></td>
<td>55-70</td>
<td>7.2</td>
<td>2.6</td>
<td>651-800</td>
</tr>
<tr>
<td>III</td>
<td>M4</td>
<td></td>
<td>67-73</td>
<td>8.2</td>
<td>2.7</td>
<td>901-1050</td>
</tr>
<tr>
<td>III</td>
<td>M5</td>
<td></td>
<td>80-85</td>
<td>8.2</td>
<td>2.7</td>
<td>1051-1250</td>
</tr>
<tr>
<td>IVa</td>
<td>M6</td>
<td></td>
<td>80-105</td>
<td>9.5</td>
<td>2.9</td>
<td>1251-1750</td>
</tr>
<tr>
<td>IVa</td>
<td>M7</td>
<td></td>
<td>105</td>
<td>9.5</td>
<td>3.0</td>
<td>1751-2050</td>
</tr>
<tr>
<td>Va</td>
<td>M8</td>
<td></td>
<td>110</td>
<td>11.4</td>
<td>3.5</td>
<td>2051-3300</td>
</tr>
<tr>
<td>Va</td>
<td>M9</td>
<td></td>
<td>135</td>
<td>11.4</td>
<td>4.0</td>
<td>3301-4000</td>
</tr>
<tr>
<td>Vb</td>
<td>1x2</td>
<td></td>
<td>170-190</td>
<td>11.4</td>
<td>3.5-4.0</td>
<td>3951-7050</td>
</tr>
<tr>
<td>VIa</td>
<td>M10</td>
<td></td>
<td>110</td>
<td>13.5</td>
<td>4.0</td>
<td>4001-4300</td>
</tr>
<tr>
<td>VIa</td>
<td>M11</td>
<td></td>
<td>135</td>
<td>14.20</td>
<td>4.0</td>
<td>4301-5600</td>
</tr>
<tr>
<td>VIa</td>
<td>M12</td>
<td></td>
<td>135</td>
<td>17.0</td>
<td>4.0</td>
<td>&gt;5601</td>
</tr>
<tr>
<td>VIb</td>
<td>2x2</td>
<td></td>
<td>185-195</td>
<td>22.8</td>
<td>3.5-4.0</td>
<td>6400-12000</td>
</tr>
<tr>
<td>VIc</td>
<td>3x2</td>
<td></td>
<td>270</td>
<td>22.8</td>
<td>3.5-4.0</td>
<td>9600-18000</td>
</tr>
<tr>
<td>VIIa</td>
<td>2x3</td>
<td></td>
<td>195</td>
<td>34.2</td>
<td>3.5-4.0</td>
<td>14500-27000</td>
</tr>
</tbody>
</table>

Figure 7: Distribution of amount of various ship types in the Rhine Corridor (BCI et al., 2015)

The benefit of having a large ship, sometimes in a convoy combination, is economies of scale. To sail a 10,000 tons vessel, the relative amount of personnel and fixed costs per
ton is much lower than on a 500 tons vessel. The last decades have been known for the economies of scale in inland shipping. Every year, more large newbuild ships were ordered (van Hassel, 2011). Figure 8 shows the growth of the total capacity of the large inland ships. Large in this case is CEMT V and higher. Med represents CEMT III to IV, and small represents I and II.

![built up supply inland ships per ship category](image)

Figure 8: Overview of the total cargo capacity per ship size category (van Hassel, 2011).

**Niches**

The varying sizes and designs of inland ships all give them a different purpose and domain. The chart in Figure 9 shows that the smaller the vessel, the bigger the sailing domain is. Appendix A shows that CEMT II ships, for example, can reach much smaller cities and villages than a CEMT IV Rhine vessel. The exclusive range of the smaller vessels gives them their own niche. On the other hand, the ship design, which is usually linked to the designated cargo type that ships will transport also gives ships their own niches. Most ships just carry dry cargo, while others have the equipment to transport certain types of oil, gas, cement, or dangerous goods. Beelen (2009) shows 10 different vessel types being used to transport cargo in the inland shipping sector:

- Dry Cargo
- Bin
- Container
- Tanker
- Pushed dry cargo barge
- Pushed tanker barge
- Pusher vessel
- Tug and other barges in tow
• Special vessels

However, there are also many other waterway users such as taxis, busses, recreational ships (CEMT 0), ambulances, firefighters, regulatory bodies, and port authorities. Here, each purpose also has a niche. In the case of automated shipping, firefighting ships could, for example, benefit from many safety improvements if they become autonomous because there are no longer people on board.

As a result, niches in the inland shipping sector can form as geographical niches, where only certain CEMT classes are able to sail, and commodity niches, where a certain ship design only allows for the transportation of a limited number of cargo types.

![Figure 9: Waterway length built per CEMT class](image)

(smaller ships can also sail on larger waterways) (CBS, 2019)

A map of waterway network in the Netherlands is given in Figure 10. This map shows the various waterways that the Netherlands has. The other waterways are for ships that are smaller than CEMT Va.
4.1.2 Inland shipping navigation

Currently, inland ships are being navigated by a certified skipper. The ship is steered by a joystick and an engine power control. These are the two main devices which are being used throughout the navigation of a ship on the water. Other devices such as radar, cameras, and electronic charts aid the skipper in deciding during the navigation.

During a trip, from loading to unloading, the ship may encounter several infrastructural objects. Most of these objects are bridges, but also locks and dams are common. When the air draft of a ship is higher than the bridge height, the skipper calls the bridge operator using VHF and needs to manoeuvre the ship into a waiting position before the bridge opens. When the ship encounters a lock, more handling needs to be done. The skipper needs to manoeuvre the ship in a waiting position before the lock opens. Then, when the lock opens, the ship navigates into the lock where it needs to moor. During the turning of the lock, the water level rises or lowers, and mooring lines need to be reset by the deckhand to the new level.
The design of the ship is dependent on multiple factors such as cargo types that it will transport, the operational area, its operational profile, and the type of propulsion that it will feature. Sailing ships were built to carry much cargo while still operating as good as possible under sail and motorised ships are designed to carry as much cargo as possible with the least amount of fuel consumption and construction costs.

The current motorised ships are known for having a diesel engine and a propeller. The diesel engines have been the primary type of propulsion for the last decades. These engines have also been incrementally improved. The efficiency of diesel engines, however, has its limits due to heat dissipation. Even though, engine manufacturers are always looking to find that last piece of efficiency increment.

Other pieces of equipment help the navigation of the ship. Bow thrusters, for example, provide the skipper with better manoeuvrability and are very common for inland ships. Such bow thrusters come in different designs. One of the more advanced designs is the azimuth thruster. An azimuth thruster is different from a conventional propeller since the propeller can provide thrust in every horizontal direction. Azimuth thrusters are usually used for the dynamic positioning of offshore vessels and as bow thrusters for inland ships. However, such thrusters may also provide extra manoeuvrability to inland vessels when they replace the conventional propeller. Especially since manoeuvring a ship in close waters is a skill which must be learned and cannot easily be made explicit. Many factors, such as wind, current, and inertia, can cause the ship to behave in unexpected ways for an inexperienced skipper.

4.1.3 Digitalisation and innovation in inland shipping

Regarding digitalisation and innovation, most (inland) ships that are currently sailing are not very high-tech. Especially older and smaller vessels have little technology on board of the ships. BTB (2017) did research on the implementation of technology on inland ships in the Netherlands. Figure 12 shows, per CEMT class and construction year, the amount of
technology that has been implemented on the average ship in each class. The more colour, the more technology has been implemented. As a result, it can be seen that the newer and larger ships have much more technology than the old and smaller vessels. A lot of technological improvements can still be done with the currently sailing ships.

The long lifecycles of ships and small market size cause technology adoption to be problematic. As can be seen in Figure 12, it is merely the newer and large ships that have more advanced technologies. Unlike the automotive industry, where manufacturers use the technology-push principle to get technology into their cars, inland shipping likes to do it the way it just works. As ships are not made in large scale production lines, there is also a limited amount of ships that are exactly the same. Hence, the economies of scale effects of technology are limited.

Recent initiatives by Rijkswaterstaat, such as the Smart Shipping Challenge in 2017 have contributed to the emergence of start-ups which are commercialising digitalisation and automation technologies in the inland shipping sector. Especially since market dynamics in the inland shipping sector do not immediately invite new firms to experiment and innovate in this sector. Inland shipping, in particular, is famous for its ownership structures. 87% of the inland shipping companies are captain-owner structures (Hekkenberg, 2013). In such a structure, the owner of the ship is also the one who operates the ship. Such companies do not have offices onshore or other staff except for the ones required to operate the ship. Consuegra (2016) explains that these captain-owners are “generally speaking, not innovators, or early adopters of innovation” (p. 119). Consuegra (2016) found a few conditions for the implementation of (environmental) inland shipping innovations which are “in many cases that innovations require few operational changes, that they reduce the fuel consumption and thus fuel costs, and that they are broadly supported by different stakeholders. Some recurring barriers in the adoption of innovations are high investment costs, the lack of regulations, and the innovation’s slow pace of ‘natural’ adoption because of the long service life of components.” (Consuegra, 2016, p. 144). Technology-push principles are, therefore, not very likely and feasible in the inland shipping sector.

The very few companies that are developing technology for automated inland shipping are, for example, Shipping technology and Captain AI. However, also these firms are yet in the early stage of collecting large amounts of data for their future algorithms. No (semi)autonomously sailing ships are yet present on the inland waters.

Figure 12 shows technologies as AIS, radar, ECDIS, autopilot, depth measurement, process monitoring, engine management, and network technology as the first technologies that are installed on currently active ships. The average CEMT VIA ships from 2011-2016
have all these technologies. It should be noted that regarding the autopilot, it represents a device which can keep the ship on a straight or pre-programmed course. Such devices do not have collision avoidance or other advanced functions. A more detailed overview of this figure can be found in Appendix C.

4.1.4 Intermodal freight/modal split

The inland shipping sector also experiences competition from other markets. The Dutch transport system is built up of multiple modalities, such as:

- Rail
- Air
- Road
- Tube
- Inland waterways
- (Short)Sea
- Or a combination of modalities (synchromodal)

These modalities all have their (dis)advantages but have one thing in common; they all depend on the supply and demand of the transport system. From the basics of economics, most of the trade happening around the world is based on supply and demand of goods and resources. A consumer wants a product, which must be shipped across the whole supply chain. Overall, the product starts with the mining of its resources, then it is shipped to the
production facility, then to the retailers and at last to the consumer. This seems very
simplistic and easy. However, many factors influence how this process goes.

Regarding the topic of this research, shipments of goods are central to the supply
chain. The question, however, is: what is the best modality to ship those goods? Many
factors influence the choice of modality (Ortúzar & Willumsen, 2011). Within
Rijkswaterstaat, the following list of factors is used:

A. The Product itself:
   - Value density
   - Package density
   - Preservability
   - Type of goods
   - Vulnerability

B. Logistics in the supply chain
   - Distance between shipper and consignee
   - Required delivery frequency
   - Availability of modes
   - Connectivity between modes in a supply chain

C. Speed, quality, and costs
   - The total lead-time
   - The accessibility
   - Required flexibility in time, reliability
   - Frequency of trips
   - Damage protection
   - Total costs of delivery

Comparing these factors to the various modalities shows the many choices a shipper
has. Figure 13 shows the differences in speed, capacity (in TEU) and costs per capacity.

![Figure 13: Comparison of the modalities in capacity and costs per TEU (courtesy of Rijkswaterstaat)](image)

The current freight transport system in the Netherlands consists of mainly rail, road,
and inland waterways. As inland shipping is seen as one of the most sustainable modalities
for freight transport, it is important to watch the modal split of the freight transport system.
The modal split in the Netherlands during the year 2016 is shown in Figure 14.
4.2 STAKEHOLDERS

The shipowner is quite often also the captain of the ship in the Dutch inland shipping sector. Estimates indicate that about 75% of the inland ships in the Netherlands are family owned and the captain is also the owner of the ship (BVB, 2019). Zooming on this actor can provide a more detailed overview of the actors that become involved during a daily trip of an inland vessel. The key actors involved in a daily trip on an inland ship are as follows:

- Terminal operators
- Authorities
  - Waterway
  - Port
  - Regulatory bodies (e.g. police)
- People living on the canal/river shore
- Bridge men
- Lockkeepers
- Freighters
- Ship crew
- Ship owner
- Vessel Traffic Services
- Information suppliers

When ships become more automated, the functions of these actors will probably change. This does, however, not limit itself to the shipping market or the actors during the voyage. Therefore, a more comprehensive analysis of the total transport system is built to get an overview of the important interactions. Consuegra (2016) studied what the actors and stakeholders of the inland transport network are, which can be seen in Appendix D. This
composition shows the interaction between the various stakeholders in the national/European transport network. It shows across which actors become involved during the transport of cargo across the inland waterway transport network.

The composition starts with the demand for transport. Freight owners want to have their products shipped to another place. So, it starts with the origin of the freight. Here, the freight owners, freight forwarders, and freighters (charterers) become involved. This is followed by the operational hubs, which are the terminals, hubs, ports, etcetera. Then, the vessel operators become involved. The vessel operators are the crew, ship-owners, and other related shipping companies. There is however some competition in this field due to the existence of other modalities such as rail and road, and other inland ships. When the chosen modality has shipped the cargo to the destination, it again encounters the operational hubs such as the terminals and ports. The cargo is then delivered back to the freight owners.

Throughout the voyage, regulating authorities such as the EU, the Dutch government, and municipalities are enforcing their policies. These are policies such as certification of the safety of the ship, safety of the cargo, and traffic rules. Interest groups such as EICB, BLN, and CBRB are also influencing the network by promoting the interests of shipowners and their crew towards the regulating authorities.

Meanwhile, society is also a stakeholder of the inland waterway transport network. The society can, for example, benefit from the more sustainable modality, but also be affected by bridges or locks that are used to let a ship sail through.

What the composition of Consuegra (2016) does not clearly show, is the interaction between the ship and the infrastructure. Rijkswaterstaat is not mentioned within the composition while a ship continuously uses the waterways and infrastructural objects of Rijkswaterstaat during its voyages. Therefore, an updated version of this composition will be used for this thesis. The new actor map will be built using the composition of Consuegra, but also combined with the theory of Tavasszy (2014) concerning the different layers of the freight transport system.

Tavasszy (2014), studies the potential for modelling transport systems. To do this, he places the transport system into five different layers, where each layer has its function and interacts with the other layers through the communication of information. Rijkswaterstaat has adopted this theory for their models with some slight changes. Within Rijkswaterstaat, this model is called the Integrated Logistics Conceptual Model and can be found in Appendix B. This conceptual model clarifies the interactions between actors in the transport market, giving more insight into the world around the inland waterway transport sector and who get affected when technology such as automated shipping arises. In Figure 15, a
composition is developed that uses both the composition of Consuegra and the ILCM model of Rijkswaterstaat to present the actor interaction in the Dutch transport system.

![Diagram of actor and stakeholder overview within the Dutch inland transport system](image)

**Figure 15: Actor and stakeholder overview within the Dutch inland transport system**

### 4.3 CONCLUSION

This chapter has shown many aspects of the inland shipping sector. First, there are more than 6700 commercial cargo ships active in the Netherlands. Together with more than 6000 kilometres of navigable waterways, the operational domain is quite large for some ship types. Additionally, this chapter has shown that there are many different ship types and many different cargo types that such ships can transport. The differences between the ship types give them their own niche market to operate in.

What has also been shown is an abstract discussion of how ships navigate and what kind of waterway structure they encounter on a regular voyage and the communication which is currently still done through VHF. The various actors and stakeholder in the logistical system also show the complexity of cargo and information flow, as illustrated in Figure 15. Regarding the current situation, shipping is still conservative in its innovation adaption. Many ships still lack technology and the implementation of new technology is usually problematic. The technology for automated inland shipping is also in its early stages.

The knowledge gathered throughout this chapter will be used to design future scenarios better and is the answer to sub-question i of this research.
Chapter 5: Scenario development and results

This chapter will discuss the scenario development and the main results. It shows which experts were interviewed, what their ideas are, and how these ideas were combined to development scenarios. The scenarios are presented on a two-axis plot with the most impactful and uncertain trends. The scenarios aim to give new strategic insights on how the inland shipping sector might change due to automated shipping.

5.1 RESPONDENTS

Even though scenario analysis is usually done in a workshop, the qualitative data gathering for the scenario analysis was based on expert interviews due to the difficulty of getting a variety of experts together at a particular time within the limited timespan of this research. These experts were chosen based on their experience in the management of inland shipping innovations. A total of 9 interviews were conducted, as can be seen in Table 3. Interview H had two interviewees but is considered as a single interview as both interviewees work at the same company and are interviewed at the same time.

Table 3: Interviewed experts with their function and expertise

<table>
<thead>
<tr>
<th>#</th>
<th>Expert</th>
<th>Function and Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Marnix Krikke</td>
<td>Direction Human Capital &amp; Innovation at Netherlands Maritime Technology</td>
</tr>
<tr>
<td>B</td>
<td>Rudy Negenborn</td>
<td>Full Professor Multi-Machine Operations &amp; Logistics at TU Delft</td>
</tr>
<tr>
<td>C</td>
<td>Robert Hekkenberg</td>
<td>Associate Professor and Director of Studies BSc. Marine Technology at TU Delft. Specialised in inland and autonomous shipping.</td>
</tr>
<tr>
<td>D</td>
<td>Martin Quispel</td>
<td>Senior Expert Project Manager at Expertise- en InnovatieCentrum Binnenvaart (EICB)</td>
</tr>
<tr>
<td>E</td>
<td>Tom van Dijk</td>
<td>Business Consultant at CGI with three years of smart shipping market research at CGI.</td>
</tr>
<tr>
<td>F</td>
<td>Erik Schultz</td>
<td>Chairman Infra Commission ESO, Chair of Koninklijke Schuttevaer and vice-chair of Koninklijke BLN-Schuttevaer. Previously a commercial director at Damen Shipyards.</td>
</tr>
<tr>
<td>G</td>
<td>Bas Kelderman</td>
<td>Project manager at Expertise- en InnovatieCentrum Binnenvaart/ Stichting Projecten Binnenvaart</td>
</tr>
<tr>
<td>H</td>
<td>Peter van Terwisga</td>
<td>Director Group’s Research at Damen Shipyards</td>
</tr>
<tr>
<td></td>
<td>Jasper Schuringa</td>
<td>Project manager Innovation at Damen Shipyards</td>
</tr>
<tr>
<td>I</td>
<td>Richard van Liere</td>
<td>Project manager STC-Nestra. Expert in the field of transport and logistics.</td>
</tr>
</tbody>
</table>
The methodology prescribed that enough experts were interviewed when no significant new statements were introduced after having interviewed at least five experts. This was also the case after in this interview round as can be seen in Figure 16. The interviewer recognised converging arguments after the first 5-6 interviews into certain directions which will be discussed in the next chapter.

The interviews have been recorded and summarised report of every interview is documented in Appendix F.

![Figure 16: Number of unique factors mentioned during the interviews](image)

**5.2 DRIVERS AND FACTORS**

During the interviews, experts have been asked to give their insight on what the drivers for automation and digitalization are for the inland shipping sector. The intuitive logics method requires these drivers and factors to build the axes for the scenarios. Subsequently, the experts were also asked what the limiting factors were. This paragraph will present the most important drivers and factors in a table and then further discusses the impact of these drivers and factors. First, in Table 4, the most important drivers for the development and diffusion of automated shipping are given.

Table 4: Overview of most important drivers for automated shipping

<table>
<thead>
<tr>
<th>Drivers for automated shipping</th>
<th>Mentioned by experts:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost reduction</td>
<td>All</td>
</tr>
<tr>
<td>Sustainability</td>
<td>A, B, C, E, H, I</td>
</tr>
<tr>
<td>Efficiency (of logistics)</td>
<td>A, B, D, E, F, G, H, I</td>
</tr>
<tr>
<td>Increased safety</td>
<td>A, E, H, I</td>
</tr>
<tr>
<td>Solving the crewing shortage</td>
<td>F, G, I</td>
</tr>
</tbody>
</table>

Exploring the implications of automated inland shipping
Next to the drivers, there is also an array of factors that limit the development and diffusion of the technology. The list in Table 5 shows the various number of factors that affect the market, the technological system, and the organizations in the pre-diffusion phase, according to the interviewees.

Table 5: Overview of limiting factors/barriers mentioned by the experts

<table>
<thead>
<tr>
<th>Limiting factors</th>
<th>Mentioned by experts:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty in investing</td>
<td>A, C, F, H, I</td>
</tr>
<tr>
<td>Regulations</td>
<td>A, B, D, H, I</td>
</tr>
<tr>
<td>Pressure from actors</td>
<td>A, B, D, E, G, H</td>
</tr>
<tr>
<td>Difficult business-case development</td>
<td>C, D, H</td>
</tr>
<tr>
<td>Market entry of multinational shipping firms</td>
<td>D, E, H. But G rather refuted this</td>
</tr>
<tr>
<td>Problematic hybrid situation</td>
<td>A, B, F, G</td>
</tr>
<tr>
<td>Long lifecycle of ships</td>
<td>E, I</td>
</tr>
</tbody>
</table>

The following discussion elaborates on the most important drivers and factors found during the interviews. The statements in the discussion will be linked to their corresponding expert using a superscript identification letter, as shown in Table 3.

The interviews showed that there are a few certain drivers towards the technology. Cost reduction was mentioned by all experts, efficiency (of logistics) by 8 out of the 9 experts, and sustainability by 5 experts as can be seen in Table 4. There are, however, also some complications. Because removing personnel from the ship due to automation does not immediately cause cost-reduction\(^{C, I}\). The tasks of the crew need to be replaced with sometimes more costly alternatives\(^{C}\), such as more costly maintenance-free machinery. On the other hand, cost reduction could also be achieved due to a more efficient logistical system as an effect of the technology, which is also an argument that is mentioned by almost all experts.

It should, however, be noted that not everyone is likely to share their data\(^{A, E}\). Also actors such as charterers may provide pressure against change since their role in the supply chain might diminish due to automated coordination\(^{A, D, G, H}\). The pressure from those actors is an uncertain trend that is yet unknown. The same counts for the willingness to share operational data with others.

Safety is also mentioned in some interviews\(^{A, E, H, I}\) as the driver towards the technology. Safety is primarily achieved by collision avoidance systems which reduce the human error in the navigation of a ship. What also has been mentioned, is that safety should in any case be
higher or equal compared to the current situation in case computers take over the control of a ship. It is however, also a very certain factor, since it is mandatory for the technology to provide safety.

At last, because of the multiple limiting factors, experts were uncertain on how fast the technology would develop and which levels of autonomy we would achieve by 2050. 2050 was used in the interviews as a trigger to get the experts thinking about the future. However, across all interviews, experts argue that looking towards 2050 is difficult since the development is in such an early stage. Some experts also mention that the development will be incremental, just like many previous innovations in the shipping industry. Combined with the difficulty of building business cases around the technology, the investments and hence the development is argued to be slow. The average opinion is that even for the far future, at least one person will stay on board of the vessel. This means that there is room for a reduction of personnel but removing the last man from the ship will be a big barrier. As a result of the uncertainty in future prospects, technological development becomes a key trend in the scenario analysis.

5.3 ASSESSING THE EFFECTS OF AUTOMATED INLAND SHIPPING

In the case that technology development might take up its pace, many experts believe that smaller sized cargo vessels (CEMT II-III) receive a bigger role in the transport system. Economies of scale in the inland shipping sector is seen to be at its end, according to some experts. The economies of scale, which has been the trend in inland shipping, is mainly based on the most cargo per number of crewmembers. As an effect of more automated inland vessels, fewer crew members are needed. Also, because the smaller vessels have a larger domain in which they can sail, the smaller vessels get the larger benefit due to this larger operational domain. This effect seems to be quite certain when the development of automated inland shipping has significantly progressed as many experts mention this effect.

Regarding the theories of Ortt (2010) and Geels (2005b) as discussed in the theoretical framework, many new technologies start within a niche environment in which the technology can mature or fail, before moving to the large scale market. The experts have also been asked whether they see a certain niche as a first opportunity for the technology to prove itself. Some of the experts see containerships as the first ship-type/market-niche where the innovation can develop. Mainly because containerships have point-to-point voyages, giving them a stable environment to sail in, but also due to the shipping companies who have multiple ships in their fleet. Additionally, experts saw canals with little traffic as a more feasible physical niche for autonomous shipping to develop due to the stable
environment that a canal brings. The latter would characterise itself as a protected environment wherein the extreme case; only autonomous ships may sail. In such cases, autonomous ships can communicate efficiently with each other. Especially since experts mentioned that hybrid situations between autonomous and hand-steered vessels would be problematic. Such a hybrid situation would, according to these experts, bring difficulties in communication and trust. Communication difficulties because conventional ships are used to talk by their voice over VHF radio, which is difficult for a computer to understand. Moreover, difficulties in trust, because a conventional skipper does not know where an autonomous ship might go and vice-versa. According to the experts, it can be assumed that autonomous ships respond differently to traffic situations than experienced skippers. Niches could solve these difficulties by providing protected market environments. Even though experts were uncertain on the extent to which niches would be present in the future.

5.4 SCENARIO PLOT

The experts during the interviews showed that there are various certain trends if Automated Vessels (AV) are adopted, such as cost reduction and better integration into the supply chain. On the other hand, more uncertainty lies in the speed of technological AV development and hence, the level of autonomy that ships are going to have in 2050. Many factors affect the speed of technological development and diffusion, as shown in Table 5. This illustrates the amount of uncertainty in the level of autonomy that can be expected in 2050. Moreover, the impact of technological development is also very large due to the effects that automated, or even autonomous ships can have on the sector, as discussed in chapter 5.3.

More uncertainty arose when the experts were asked to think about future niches for the development of the technology since the experts could not easily think about certain niches that would arise. It was mentioned that geographical niches such as canals could create a better environment for autonomous shipping, but also some market niches such as containerships or tankers. However, little consensus was found between the opinions of the experts, indicating the uncertainty for the future. Besides, small but strong bordered niches could significantly impact the sector since some corridors would have to be changed in order to facilitate such niches. An autonomy-ready canal is, for example, not (easily) provided by the market itself. Hence, the impact and uncertainty are large for the trend of niche development.

As a result, the most uncertain and impactful trends as found in the interviews and discussed in the previous paragraph can be used to develop two axes for the scenario analysis. These trends are technological development and niche development.
**Technological development**

Technological development can, herein, be illustrated following the levels of Autonomy by CCNR, as seen in Table 6. The higher levels, such as CCNR level 4, show that technology has evolved significantly, and ships can sail without human interaction, within certain contexts. The lower levels of this trend can be illustrated by CCNR level 2. Here, the human skipper is still managing the ship, while the technology on the ship is only assisting the skipper’s navigation.

**Table 6: CCNR levels of automation in inland shipping. (CCNR, 2018)**

<table>
<thead>
<tr>
<th>Level</th>
<th>Vessel Command</th>
<th>Monitor and respond to the environment</th>
<th>Fallback performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>Human shipmaster is responsible for all navigational tasks of the ship</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Steering assistance</td>
<td>Human shipmaster is aided by a steering automation system for basic navigation</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Partial automation</td>
<td>Context limited awareness of environment by automation system; automation aids a human shipmaster in safer and more comfortable navigation of the ship. Could also be performed remotely</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conditional automation</td>
<td>The ship can sail autonomously within certain contexts, with the expectation that the shipmaster will be receptive to intervene in case of system failure. Could also be performed remotely</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>High automation</td>
<td>Full autonomous sailing including fallback systems without the expectation that a human can intervene, within a certain context.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Full automation</td>
<td>Non-conditional, full autonomous sailing by the automation system.</td>
<td></td>
</tr>
</tbody>
</table>

**Niche development**

Barriers in the market, organisations, and technology affect how the pre-diffusion phase is shaped (Ortt, 2010). That is why most radical innovations start in a niche market before moving into the large-scale market (Ortt, 2010; Geels, 2012). Hence, niche development, as an uncertain trend, can go in two directions. One direction is the development of small niches where the radicality of the innovation is high, and the other direction is broad niche development, which represents a more incremental innovation adoption. For small niches, many barriers are still present in development. The technology is not ready to diffuse in the large-scale market. Therefore, there will be environments where technology arises within a certain context with strong borders. This can be either physical or market contexts. The emphasis within the scenarios on this side of the scenario plot is put on the individuality of markets and physical environments. This means that the technology cannot diffuse everywhere and starts (or stays) within a certain context such as autonomy-ready waterways, or certain market niches.
The broad niches will be characterised by a mix of ships where the level of smart technologies per ship varies within a certain fairway corridor. Certain niches exist, but the physical limitations of niches are much smaller. In this scenario, technology has eliminated barriers such as regulation, trust, and communication in hybrid situations. The factors mentioned by the experts will have found a solution and the technology can find its way to the large-scale market.

As this research is aimed to explore the implications of the technology, the technological development starts at CCNR level 2, which is almost the same as the current situation, or also called Business as Usual (BAU). The effects of a probable diminishing amount of technology on board of inland ships are not taken into account.

Figure 17 shows the developed scenarios. The following paragraphs will further elaborate on each scenario and how they came to be.

5.4.1 Scenario A: “Into the roots”

Scenario A will feature small niches and high technological AV development, which enables ships to sail in CCNR level 4 autonomy. This means that ships can be sailed without people on board and the control could occasionally be taken over by a remote-control station for new instruction. Regulatory, trust and communication problems have been overcome, and autonomous ships are now able to communicate their intentions with non-autonomous vessels (CCNR level 0). Technological development is now in the diffusion phase. Experts mentioned that an effect of such developments would be the diminishing returns to scale. The smaller vessel would get a better position in the market since they are more flexible than...
large ships and hence reach further into the waterway network. Because personnel no longer need to be on the ship in this scenario, the amount of personnel per shipped ton is also smaller. As mentioned earlier, this will bring an influx of smaller vessels to the smaller waterways. Together with more advanced technologies for supply chain integration, the inland shipping sector will be more attractive as a transport modality. A potential effect might be a modal shift from the road to waterways.

Other concepts mentioned during the expert interviews also show the potential for innovative freight concepts such as modular barges which increase port logistics.

As a result, this scenario will be called “into the roots” as a resemblance of the various branches of the Dutch waterway network. The further away from the river’s estuaries, the smaller the canals/branches become. The effect of technology enables more ships to use these branches. Box A will present a narrative in which skipper John resembles a skipper living in the virtual scenario A.

**BOX A: Narrative**

**Year: 2050, Subject: John, 50 years old.**

John’s occupation is ship controller. John used to sail as a skipper on a large ship on the Rhine. However, now that the technology of automated shipping has evolved so far, John can manage multiple ships at a time. Technology has given companies the ability to let their ships sail autonomously, and the ship controllers are now managers of multiple commodities. A lot of smaller CEMT I-III ships have been built, and John is managing the logistics of these ships. Regularly, personnel must be sent to one of the ships to provide maintenance. Also, the assignment of freight contracts has improved significantly. Cargo owners can now track every ship that sails in the Dutch waterways and knows when it is sailing, idle, or in maintenance. Algorithms define the price of cargo transport based on supply and demand. When the algorithm finds a good price, the ship controller can accept the offer and receives the origin and destination of the cargo that must be shipped. With the push of a button, the ship will sail to its destination and pick-up its cargo. During the trip, the ship has innovative ways of communicating with recreational boats in order to provide a safe environment for every waterway user and every waterway user trusts the actions of the ship. Regulation has certified that the ship is capable of sailing autonomously in a certain domain.

Ship Controller John now makes sure all ships are in a good state, get their inspections on time, are insured, and make enough money per trip.
5.4.2 Scenario B: “Fairway bound”

Scenario B’s key characteristics depend on strong niches. Similar to Scenario A, technological development has led to level 4 capable ships. However, the contexts wherein the ship can sail is much smaller. Regulatory, trust and communication problems have not been overcome. Technological diffusion is still in the adaptation phase. Niches are strong since technology has problems with diffusing further due to regulatory, trust, and communication problems. Physical environments are demanded by the market to provide stable environments such as canals or specific waterway-lanes where these problems can be overcome.

The difficulty of further diffusion has led to also a stronger market niche development. Container and tankships are the first to adopt new technologies because of their standardised routes and cargo type. The larger shipping companies, instead of 2-person firms, have more investment space and can optimise their logistics within the company more efficiently. Because technology has not spread across the sector, the benefits of technology are much smaller. Especially since the autonomous ships still require some personnel to be on board when the environment is not fully enclosed from non-autonomous ships. If specific autonomous shipping waterways are present, ships can sail within these waterways with only one person on board or from a remote-control station.

The overall situation on the waterways is similar to the current situation. The difference lies in the ability of skippers to let the automation do the navigation. However, due to various factors, this will be limited to certain contexts such as autonomous-shipping lanes. Moreover, the amount of digitalization has also increased like Scenario A. The logistical chain has been improved, but the amount of data-sharing is limited.

This scenario will be called “Fairway bound” since it refers to the Dutch saying “geulgebonden”, where ships are not able to leave the fairway they are using.

**BOX B: Narrative**

Skipper John’s occupation is a skipper on a large Rhine vessel. His ship is equipped with all the latest technologies for autonomous sailing. Technological and regulatory developments have helped John to require less personnel on the ship, which was already very scarce. On open waters, the ship is allowed to take over the navigation, but on close waters, the skipper has to be present to take over control in case of emergencies. Trust, regulation and communication are still difficult barriers to overcome. Waterway authorities have provided certain autonomy-ready lanes and canals where the ship can and may sail without the expectation that the skipper can intervene. However, due to the problems arising when
leaving such areas, skippers still need to be on board. Logistical coordination has also improved. John can now let the computers do the bidding on the spot market. A minimum price for each type of trip is calculated, and algorithms find the optimal bid and ask price for the voyage. Sailing empty is rarely happening.

5.4.3 Scenario C: “Business as Usual”

This scenario shows the possible situation where technological development has been very slow. The current technologies of autopilots have enabled skippers to let go of the steering on large parts of the river, but the skipper needs to be ready for intervention when needed. Navigation through crowded spaces, locks, and mooring in ports is still manually done by the skipper. On the other hand, improvements have been made to the logistical system. Certain apps and websites have provided better cargo- and data-platforms, which increases the efficiency of the sector. Cargo is better assigned to ships and ship communicate more efficiently with the infrastructure on the water.

BOX C: Narrative

Skipper John is still sailing on his large dry cargo Rhine vessel with the same amount of personnel as 20 years ago. Technological developments regarding navigation have not been around during the last decades. The only change to his ship was the change to a new engine due to emission regulations. However, John can order his cargo easier than he used to. The logistical alignment has improved such that John can just put in a minimum price per cargo per type of trip and an app matches it with a voyage charter.

Internet apps have also enabled John to sail more efficiently. Waterway authorities utilize all the data to provide John with a good lock and bridge planning. He knows at what time exactly he can sail into a lock and can change his sailing speed accordingly.

5.4.4 Scenario D: “Market segmentation”

This scenario shows a potential situation where technological AV development is very slow. The current technologies of autopilots have enabled skippers to let go of the steering on large parts of the river, but the skipper needs to be ready for intervention when needed. Navigation through crowded spaces, locks, and mooring in ports is still manually done by the skipper. Due to the lack of technological development, smaller companies have merged with larger shipping companies to benefit from economies of scale within the fleet of ships. The shipping companies can plan their logistics better within their own fleet but are limited
in sharing data with other actors in the logistical system. This effect can be confirmed using the conclusions found in Hekkenberg (2013): “Captain-owners cannot become more competitive by increasing their market share significantly unless they can set up a cooperation with a large number of other operators.” (p. vii).

Such collaborations between ship owners could also be seen in digital platforms. Platforms such as Uberfreight, where cargo is assigned to available ships automatically.

**BOX D: Narrative**

Since technological development has stayed away from the inland shipping sector, John and most of his colleagues have joined the fleet of larger shipping companies. The bundling of multiple ships with the same characteristics/cargo types has given the skippers an advantage since the logistics can now be smoothly coordinated within the fleet. Cargo biddings can be assigned to every ship in the fleet and maintenance, and management costs can be divided over a larger amount of ships. Logistical alignment is limited to the fleet that the ship sails in.

On the other hand, internet apps have enabled John to sail more efficiently. Waterway authorities utilise all the data to provide John with a good lock and bridge planning. He knows at what time exactly he can sail into a lock and can change his sailing speed accordingly.

5.5 **CONCLUSION**

This chapter has shown how expert opinions can be used to develop two axes for the scenario analysis. *Technological development* in terms of level of autonomy is the first uncertain trend as some are optimistic, and some are pessimistic in the extent to which ships can become autonomous. The other trend is *niche development*. According to the theoretical framework from Chapter 3, it was found that radical technology usually starts in a niche because of many different limiting factors. Based on the interview with the experts, the extent to which niches would play a role in the development of the technology was also very uncertain. However, due to the impact of having broad niches or small niches, the development of niches was the second large uncertain trend for the scenario plot.

These two developments have defined the scenarios which have further been elaborated during this chapter. The results of each scenario show the answer to sub-question ii: “how can the future of inland shipping be explained?”, and sub-question iii: “What will be the effect of automation on the inland shipping sector”. The answers can be summarised as follows:
The future of inland shipping can be explained using theory about the diffusion of technology and the application of a scenario analysis. The application of the theory to the scenario analysis has given insight into four potential scenarios for the future of inland shipping. These potential future scenarios for 2050 show that there is the potential for automated shipping to incrementally become adopted in the large-scale market or by a more radical approach within small and strong bordered niches. Besides, automated shipping technology may also lack in development and cause the inland shipping sector to move into more segmentation or stay in a business as usual scenario.
Chapter 6: Implication analysis

Continuing from the scenario analysis, this chapter will present the results of the expert workshop in which the experts have validated the scenarios, followed by a discussion on the assessment of the implications of each scenario from Chapter 5.

First, the respondents are shown, then the results of the workshop discussions are presented, and at last, the results are analysed.

6.1 RESPONDENTS

For the workshop, multiple experts from Rijkswaterstaat were invited whom all have expertise in the field of shipping and waterways, in either a digital or physical manner. Table 7 shows the six experts who were present during the workshop. Fifteen experts from Rijkswaterstaat were invited but only the six as mentioned in Table 7 could be present during the workshop.

Table 7: Experts present during the expert workshop

<table>
<thead>
<tr>
<th>#</th>
<th>Expert</th>
<th>Function and Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anja van der Sluijs</td>
<td>Senior Advisor waterways</td>
</tr>
<tr>
<td>2</td>
<td>Otto Koedijk</td>
<td>Senior Advisor shipping and waterways</td>
</tr>
<tr>
<td>3</td>
<td>Therry van der Burgt</td>
<td>Solution/IT Architect for the Central Information Services</td>
</tr>
<tr>
<td>4</td>
<td>Anton Huurman</td>
<td>Senior Advisor shipping</td>
</tr>
<tr>
<td>5</td>
<td>Christiaan van der Maarel</td>
<td>System and Integration architect</td>
</tr>
<tr>
<td>6</td>
<td>Wilco Meijerink</td>
<td>Advisor/ Specialist hydraulic structures</td>
</tr>
</tbody>
</table>

Unlike Chapter 5, this chapter will present the results of the workshop discussion and not the individual statements of the experts.

6.2 RESULTS

Two weeks in advance of the workshop, the scenarios were sent to the experts. By doing this, the experts could already assess the scenarios for any inconsistencies or feasibility issues. Then, during the workshop, the experts were able to give feedback on the scenarios. However, no inconsistencies or feasibility issues were mentioned by the experts.

To validate the scenarios, the experts were given a few minutes to ask questions about the scenarios. The only comments were for scenario A and C/D. In scenario A, it was not
fully clear that also on the larger waterways, there would also be a larger number of smaller vessels. Moreover, for Scenario C/D, it would be better if a platform as Uberfreight would be positioned in scenario D instead of scenario C. These comments have been processed in the scenario characteristics. Furthermore, the experts agreed with the validation of the scenarios, and an open discussion was held per scenario to get an idea about the infrastructural implications of the scenarios.

The discussion was led by the author of this thesis and this discussion aimed to assess the physical and digital implications of each scenario. As learned from Technology Assessment, also the negative/adverse implications should be discussed.

The discussion followed the following script:

6. Opening and welcome
7. Presentation of the scenarios
8. Validation of the scenarios: Discuss inconsistencies, validity and novelty
9. Present scenario #
   a. Discuss positive and negative physical implications
   b. Discuss positive and negative digital implications
   c. Validate conclusion
   d. Repeat for every scenario
10. Conclude with validation of the overall conclusion

The discussions have been recorded and afterwards a summary (in Dutch) was written which can be found in Appendix G. Note that all statements in the following paragraphs are built upon the expert opinions during the workshop. Also note that the opinions expressed are those of the experts, not the opinion of the organisation of Rijkswaterstaat. The workshop started with the discussion of scenario A. During this discussion; multiple ideas came forward as to how the full autonomous ships could affect the infrastructure. For each scenario, first the results will be presented whereafter the results are analysed, and the implications summarised.

6.2.1 Scenario A: “Into the roots”

The first thing that came forward was communication. Communication is now usually done through VHF radio, which is a difficult way to communicate with computers. Interestingly, during the workshop, it was mentioned that before the invention of the marine VHF radio, skippers merely communicated with each other through various light and sound
signals. Autonomous ships could also use these ways of communication when they are not sufficiently able to use voice communication.

The main issue during the discussion was the provision of data by Rijkswaterstaat. It could be assumed that autonomous ships can gather all data from their surroundings, but it could also be possible that Rijkswaterstaat provides all the waterway data to the ships. To perform the latter, Rijkswaterstaat would have to know every movement of every waterway user and communicate this data with the autonomous ships. That way, the high-tech hardware could be put onshore instead of on every ship. This does, however, depend on the amount of public expenditure, which is affected by politics and policy. The amount of public expenditure is the key influencing factor to the role that Rijkswaterstaat will have in this matter.

If the choice for Rijkswaterstaat is to provide a digital infrastructure, real-time communication of data should be provided. To achieve a real-time communication of data, the Electronic Navigational Charts (ENC) need to be upgraded to provide real-time information about all the environmental factors that a ship requires to sail with. This could include real-time water depth, bridge-heights, wind speed, currents, locations of other (recreational) vessels, buoy locations, harbour entrances, et cetera. To get this data from the infrastructure to the ships could require new communication infrastructure that enables high bandwidth communication. In the case that Rijkswaterstaat provides the data for the ships to act on, the role of traffic manager also gets larger. Ships will depend on the reliability and availability of data provided by the waterway authority.

As to the physical implications, little change is necessary. An autonomous ship will not require different fairway or lock designs. The difficulty lies in autonomous mooring. Current technologies for automated mooring include suction caps and magnets that stick to the flat hull on the side of the ship. However, due to the vast diversity in ship types in the inland shipping sector, this would require a lot of such – costly – devices. Also, many inland vessels do not have any freeboard when fully loaded. Without freeboard, the automated mooring systems would have to connect to the hull below the waterline, which is problematic. Therefore, there is a demand for more innovation in automated mooring systems. Current technologies do not seem to provide the necessary functionality for autonomous inland shipping.

Overall, the experts put most emphasis on the digital infrastructure of Rijkswaterstaat. Physical adjustments to the infrastructure do not seem vital in this scenario. It is expected that market actors should provide their ships with the necessary adjustments to sail within
the current physical characteristics of the waterways. Rijkswaterstaat can then assist in delivering reliable data on the waterway conditions.

Also, the expected increase in the number of smaller vessels did not cause any new implications. Especially since there is already room for more ships on most of the current waterways.

**Analysis**

Scenario A has discussed how a full breakthrough of automated shipping brings implications to the waterway infrastructure. This implies that a lot of autonomous ships are already sailing on the waterways. However, what are the exact implications for Rijkswaterstaat, and how can they facilitate this technology?

During the expert workshop, it was found that ships are going to rely much more on external data. Radars and cameras could gather much of the data on the ship itself, but Rijkswaterstaat could also facilitate this. If the waterway manager provides all the data for the ships to act on, it will limit the amount of high-tech material on board of the ships. This would, however, implicate that the waterways get more sensors and radars to monitor every part of the waterway. This might be very costly for Rijkswaterstaat.

On the other hand, the infrastructure already has a lot of data available. It would already be capable of communicating the status of all the structures in the waterways which could be combined with data of for example the current water depths, bridge-heights, wind speed, currents, locations of other (recreational) vessels, buoy locations, harbour entrances, et cetera. The question here lies in how far the market is going to retrieve this data by themselves or that Rijkswaterstaat provides it. A large part of the data would already be available at Rijkswaterstaat as a result of their corridor management. It should, however, be researched whether this data can easily be used by autonomous ships.

In any case, it would implicate that new protocols need to be developed which can transfer data to and from the ships. The current Electronic Nautical Charts (ENC) could be fitted with more data. However, with the current digital and physical infrastructure, this could be problematic. Current mobile networks may have some black spots on certain parts of the waterways. Advanced networks with good connectivity on the waterways are needed to transfer the large amounts of data. Also, the new data-protocol would probably have to be made internationally such that ships can also sail into other countries such as Germany and Belgium, as experts mentioned that the ships should never be limited to one country.

Moreover, communication between ships is assumed to be very innovative in this scenario. This would mean that autonomous ships can communicate their intentions in an understandable (digital) format. The current Automatic Identification System (AIS) already
provides the location of every ship which is at least 20 meters in length. However, this is already a quite old protocol which has been developed in the 1990s. This research did not assess the limitations of AIS for the future, but it can be assumed that a new protocol where all the ship and infrastructure data would be shared could also contain an improvement for VHF radio and AIS.

As a result, if new protocols are designed, Rijkswaterstaat would have to join the international design discussions to input their values. The new protocols would have to be able to provide all the necessary data for autonomous shipping, including infrastructure status reports and the location and intentions of every ship. A risk for Rijkswaterstaat lies ahead if compatibility with the new protocols is not guaranteed. It should, therefore, be made clear that compatibility is key.

At last, the physical implications in this scenario were also limited. Experts believe that autonomous ships will be compatible with current lock and bridge designs. The only problem arises in automated mooring. Rijkswaterstaat could work with market parties to accelerate the development of innovative for automated mooring in inland shipping. Also, the innovation would have to be compatible with the locks of Rijkswaterstaat. Therefore, collaboration with the designers of such innovations would be recommended.

Summarised, the following points would be the main implications for scenario A:
- Join international designs of new data protocols and platforms
- Improve mobile data networks and connectivity
- Provide additional sensors and actuators to map and communicate the status of bridges and locks
- Include data for all waterways in ENC with real-time water depth, buoy locations, currents, bridge-heights, actual bridge opening times, et cetera.
- Decide the extent to which Rijkswaterstaat wants to be responsible for the data provision
- Join the (conversation of) design and development of automated mooring systems

6.2.2 Scenario B: “Fairway bound”

The presentation of scenario B involved the demand for autonomous ships to sail in protected environments. However, building waterways specifically for autonomous ships was going to be very unlikely, according to the experts during the workshop. Regulation such as the Mannheim Act demands the equal treatment of sailors and ships and can therefore not exclude certain ships from public waterways. Additionally, with the increasing amount
of buildings, there is already much less space available to build new waterways. One of the alternatives is if private companies started to dig their own canals for autonomous ships.

Another alternative is to provide certain lanes within the current waterways. Such lanes could be separated from the regular ships using buoys. Non-autonomy-ready ships would then not be allowed to sail within these lanes. Within certain geographical niches such as ports or waterways where there is room left, this could become a reality. Therefore, the implications for this scenario can, in designing waterways with additional lanes, specifically for autonomous ships, and digital communication standards that allow the autonomous ships to communicate with each other. However, also for this scenario, it depends on the choices made by Rijkswaterstaat to what extent they can and want to invest in new lanes and waterways for autonomous shipping.

Overall, the implications are not very large in this scenario. Providing autonomous-shipping lanes in certain waterways may not be very expensive and can still help the technology to develop further before moving out of the autonomous shipping lanes. However, the space to provide these lanes is limited. The benefit of providing the autonomous shipping lanes was also not convincing to the experts. Benefits should be made clear before policy might be changed to facilitate additional autonomous shipping lanes.

**Analysis**

Scenario B brought different ideas than scenario A. In scenario B; autonomous shipping lanes would have to be facilitated to let the autonomous ships sail on the public waterways. But full waterways which would in other cases be empty during night-time could also be made compatible for autonomous shipping. Timeslots could be assigned to allow autonomous ships to sail on these waterways. Experts mentioned during the workshop that this might conflict with the Mannheim Act. However, the Mannheim act does not have jurisdiction over all waterways that Rijkswaterstaat manages. The Mannheim act is limited to the Rhine and its estuaries into the open sea (CCNR, 2003). This allows, within national regulation, the opening of waterways for only autonomous shipping. However, to not disrupt the ships which do not have autonomous sailing capabilities, much care should be taken in designing suitable autonomous-only timeslots for the waterways.

As this scenario has the same level of technology as Scenario A, the request for digitalisation of information and infrastructural data would also be present in this scenario. The difference might be that more data is retrieved by the ships themselves and not by the waterway manager, as only a small part of the ships would utilise this data. However, even though the technology is limited to certain niches, the whole sector might benefit from better communication and information. Besides, if Rijkswaterstaat wants to have a facilitating role,
they could assist the technology by providing the autonomous shipping lanes and at the same

time deliver the ships all the data to sail on those lanes. This will also be a policy related
decision.

During the workshop discussion, the most emphasis was put on the large costs of
facilitation. More effort should, therefore, be put in the clarification of the benefits that a
facilitating role could have. In this scenario, geographical niches could be facilitated by
Rijkswaterstaat to enable faster growth of the technology. A technology which could help
RWS in achieving her goals: fast, safe, and sustainable waterways. Moreover, the ships
sailing on the autonomous shipping lanes would be using new communication and data
protocols. So, also in this scenario, it is recommended for Rijkswaterstaat to join the
conversations in the design of new protocols to let them align with their internal processes.

Summarised, the implications for this scenario are, to an extent similar to scenario A
but can be limited to the niches where the autonomous ships will sail in:

- Facilitate niches (autonomous shipping lanes) for the technology to develop
- Join international designs of new data protocols
- Improve mobile data networks and connectivity within the niches
- Provide additional sensors and actuators to map and communicate the status of
bridges and locks
- Include data for in ENC with real-time water depth, buoy locations, currents,
bridge-heights, actual bridge opening times, et cetera.
- Decide the extent to which Rijkswaterstaat wants to be responsible for the data
provision

6.2.3 Scenario C: “Business as Usual”

Even though scenario C is a quite conservative scenario, it brought multiple novel
ideas. The emphasis in this scenario is put on the development of efficient logistics. In this
scenario, technologies provide the ability to become more digitised. However, according to
the experts, it requires a lot of work and collaboration between the waterway authorities and
the waterway users.

The implications from this scenario arise from the goal of Rijkswaterstaat to have a
fast and safe flow of traffic through the corridors that they manage. Currently, some
initiatives already provide corridor management within Rijkswaterstaat, but in this scenario,
this can be improved using data from the ships. If ships more actively communicate their
intentions, traffic management can better anticipate and manage the flow of ships.
Collaboration and assistance of the shipping companies would be required. Also, where the data provision is still lacking, investments should be made to utilise existing technologies better.

During the discussion, it was also mentioned that as a result of this scenario, more emphasis could be put on cost reduction of infrastructure. More standardisation of the structures is demanded in order to reduce the cost of building and maintenance. The standardisation is a trend that has already been put into motion but requires more attention when the sector itself does not improve. The analysis of the results will dive deeper into this result.

**Analysis**

Scenario C saw a more conservative market, where cost reduction should be obtained from the improved flow of traffic and transport and not from technology. This means a request for better corridor management, more data from the ship to the waterway manager, and standardisation in construction and maintenance of waterway infrastructure. The experts mentioned during the workshop that standardisation of lock and bridge designs would get more importance when the technology does not develop. However, for this scenario to get more value, it would be more important to standardise the data sets that the infrastructure delivers. It would be essential to get every lock, bridge, sluice, et cetera, to send their data in a standardised way and be compatible with the ships and the protocols that transmit the data.

More data from ship to the waterway manager is an implication in this scenario because better corridor management, hence better flow of traffic and transport requires more data from the waterway users. Compared to the previous scenarios, the data provision from Rijkswaterstaat for this scenario would entail much less information. To enable a good corridor-management, it will be essential to provide enough data such that ships can efficiently sail through the corridors but also receive enough data from the ships to enable advanced waterway congestion planning. This would hence entail lock-planning, bridge-openings, port-congestion, ship locations, ship’s destination, and ship’s ultimate time of arrival. By building a platform that entails all this data, traffic management could handle the traffic on the waterways more efficiently. Vessel Traffic Management (VTM) could then get a more substantial role since they get a more responsible role in the planning of ships.

In contrast to previous scenarios, no real-time data is required; the current mobile network has enough bandwidth to transceive the necessary data. Certain black spots with low connectivity would, however, have to be solved.
A possible barrier for this scenario may be that not every shipowner wants to share all the required data. This will require active collaboration and involvement with the shipowners.

Summarised, for Scenario C, the implications would be as follows:

- Improve corridor management services
- Standardise data sets
- Request for more data from the ships in terms of location, departure time, destination, and ultimate time of arrival
- Improved provision of lock and bridge planning
- Possible resistance from ship-owners to share data

What can be seen from the results of this scenario is that the development of new protocols and application of large amounts of sensors and actuators into the waterway is not required. Here, the implications show the importance to improve the sector’s effectiveness by better managing the traffic.

6.2.4 Scenario D: “Market segmentation”

In this scenario, the technology of automated shipping has also not advanced. Shipping companies are now collaborating in order to decrease their risk, costs and get a stronger position in relation to other modalities. Experts mentioned during the workshop that this might be a worse situation than it is now. The collaboration of multiple actors into a single conglomeration could put new pressure on the work of Rijkswaterstaat. Platforms such as Uberfreight, where an algorithm combines demand and supply of transport, could bring new business models to the inland shipping market. Such platforms could, according to the experts, also become a powerful actor in conversations and influence decision-making processes along the supply chain, but also in the infrastructural decisions. This could be beneficial because it is easier to gain more insight in the values of the skippers but could also be unfavourable since more critique could come to the work of Rijkswaterstaat.

Such new platforms, where cargo is more efficiently assigned to ships, can increase the efficiency of the transport system. A result could be that there is more transport on the waterways due to this development. In that case, it will be important to align transport with waterway management. Without proper alignment and collaboration with waterway management, more congestion is expected around the bottlenecks (locks, bridges, and ports). Also, if this scenario would become a reality; RWS should attempt to get a good collaboration with the emerging platforms.
**Analysis**

The last scenario, scenario D, could feature more pressure from actors in the inland waterway transport since shipping companies could merge or join larger platforms. Platforms with a large number of ships have a better power position than single ship companies. Rijkswaterstaat would have a new powerful actor to converse with. Such actors could put more pressure on the decision making of Rijkswaterstaat but also be a valuable conversation partner. Hence, increased collaboration with shipping companies/platforms is required in this scenario.

As the experts during the workshop mentioned, it should also be prevented that the collaboration of many ships combined with their improved logistics leads to congestions. Reasons for this effect could be the increased efficiency and hence an increased amount of transported cargo. Corridor management would then also become more important.

At last, the different platforms could create their own protocols for data transfer, which may not be compatible with the current standards of Rijkswaterstaat. Rijkswaterstaat could benefit from the data that is gathered by the platforms. It will therefore, also in this scenario be recommended to emphasise standardisation of data protocols and the collaboration with the platforms to get access to the data that they will produce.

- Added pressure from cargo assignment platforms on waterway management
- Increased collaboration with shipping companies/shipping platforms needed
- Connect logistics chain with ports to prevent port congestion
- Improve corridor management
- Join the development of data protocols and attempt to get access to data from the platforms
6.3 CONCLUSION

This chapter has given an initial answer to the main research question of this research. The question is “What are the potential physical and digital implications for the waterway infrastructure of Rijkswaterstaat due to automated inland shipping in the Netherlands by 2050?”. The answer to this research question has been assessed using an implication analysis, where multiple scenarios were presented to 6 experts during a workshop. Each scenario has its implications and can be subdivided into the two types of implications as defined in the main research question; physical and digital. The following paragraphs will present the main implications as can also be seen in Figure 18.

**Physical implications**

For each scenario, the summarised physical implications can be seen as follows. Little change is required to let autonomous ships, in scenario A and B, sail through the current locks and bridges. Only for the locks, innovations would have to be developed in order to facilitate automated mooring. Inland autonomous ship designs as we know them right now are not capable of mooring to conventional bollards. Rijkswaterstaat could assist in the design of such innovations.

Furthermore, there are some physical implications as a result of more digitalisation. Every scenario features increased data-transfer and scenario A and B even require advanced networks without black-spots to efficiently transfer data from ship to ship or from ship to the

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### Scenario A: “Into the roots” implications:
- Join international designs of new data protocols and platforms
- Improve mobile data networks and connectivity
- Provide additional sensors and actuators to map and communicate the status of bridges and locks
- Include data for all waterways in ENC with real-time water depth, buoy locations, currents, bridge-heights, actual bridge opening times, et cetera.
- Decide the extent to which Rijkswaterstaat wants to be responsible for the data provision
- Join the (conversation of) design and development of automated mooring systems

### Scenario B: “Fairway bound” implications:
- Facilitate niches (autonomous shipping lanes) for the technology to develop
- Join international designs of new data protocols
- Improve mobile data networks and connectivity within the niches
- Provide additional sensors and actuators to map and communicate the status of bridges and locks
- Include data for in ENC with real-time water depth, buoy locations, currents, bridge-heights, actual bridge opening times, et cetera.
- Decide the extent to which Rijkswaterstaat wants to be responsible for the data provision

### Scenario C: “Business as usual” implications:
- Improve corridor management services
- Standardise data sets
- Request for more data from the ships in terms of location, departure time, destination, and ultimate time of arrival
- Improved provision of lock and bridge planning
- Possible resistance from ship-owners to share data

### Scenario D: “Market segmentation” implications:
- Added pressure from cargo assignment platforms on waterway management
- Increased collaboration with shipping companies/shipping platforms needed
- Connect logistics chain with ports to prevent port congestion
- Improve corridor management services
- Join development of data protocols and attempt to get access to data from the platforms

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**Figure 18:** Scenario plot with the key implications per scenario
infrastructure and vice-versa. Physical implications can also be found in the provision of additional sensors and actuators throughout the waterway. For scenario A and B, these sensors could map every variable factor of the waterway such that the ships can sail based on the data of Rijkswaterstaat. For scenario C and D, the sensors could assist in better corridor management due to improved planning and communication of lock and bridge openings.

**Digital implications**

In the case of digital implications, much more implications were found. Scenario A and B, where autonomous shipping technology has been developed, entails various requirements for more digitalisation. Due to the increased demand for data transfer and data gathering, new protocols would have to be developed internationally. The sensors, as mentioned in the physical implications, need to transmit their status in real-time. Protocols should be able to transmit large amounts of data and Rijkswaterstaat is recommended to join the development as it needs to be compatible with their digital infrastructure. An adverse effect of the technology would be caused by incompatibility with new protocols. Besides, current ENCs could, for example, be fitted with more data, and the presentation on the ships would be a nautical map which shows all different kinds of variable factors such as wind, current, actual bridge and lock openings, et cetera. Even though scenario B does not entail a sector where autonomous ships may sail everywhere, the sector could still benefit from this data.

Regarding scenarios C and D, more emphasis is put on better corridor management. Even though this will also be very important in the other two scenarios, scenarios C and D indicate the importance better in case the technology of autonomous shipping does not develop. Also, in scenarios C and D, the emphasis lies on the standardisation of data sets. However, this will be important for every scenario. At last, resistance might occur in the sharing of data by the collaboration platforms in small niches. Rijkswaterstaat would have to actively join the conversations and present the benefit of sharing data with Rijkswaterstaat.

Overall, the conclusion is that there is nothing mandatory to do at this moment regarding the physical infrastructure. Also, for the digital infrastructure, except for staying compatible with the upcoming technologies, no radical changes are required. Little adverse effects of the technology were identified. On the other hand, if Rijkswaterstaat wants to facilitate the technology, preparing for the implications as discussed could help the development and diffusion of technology.
Chapter 7: Discussion

This research has provided a lot of new information. First, the scenario analysis has shown the directions that the inland shipping sector may move into. The scenarios have presented strategic insight into the future, which is useful for Rijkswaterstaat. This chapter will discuss these results and put them into perspective.

7.1 REFLECTION OF THE FINDINGS

As seen from the scenario analysis, there are two axes which are technological development and niche development. Technological development indicates to which level ships will be capable of sailing autonomously. Niche development entails a more theoretical approach as it indicates the radicality of the innovation. On the one hand, broad niches could indicate an incremental innovation adoption and on the other hand, the small niches could indicate a more radical innovation. The small niches show that immature technology needs to mature within a protected environment.

During the implication analysis, the effects and implications of these scenarios were discussed. Many different implications were found, and the most common implications were aimed at building a sound digital infrastructure which is compatible with all of its actors. In three of the four scenarios, it is important to join the development of data protocols and gain access to the data that is generated. Especially since it is the goal for Rijkswaterstaat to provide a fast, safe, and sustainable waterway, it will be important to have access to all the data and provide good traffic and corridor management services. Many specific data types could be integrated in these systems and further research could assess which data is most important to include in the traffic management services. Also, within this topic, it remains the question of who the main provider of data will be. There could be a ship-to-ship connection, where ships communicate their data/findings with each other, or a more ship-to-infrastructure connection where the infrastructure handles the provision and distribution of data. This question arises within all scenarios and is therefore important to investigate in further research.

Furthermore, in all scenarios, little physical change is required. Even in the more advanced scenarios where ships are able to sail autonomously, there is only a need in the future for automated mooring systems. Rijkswaterstaat could join the development of such systems. However, it will be more important to aid the development of the technology of automated shipping as it is expected that this can improve the flow of traffic and cargo, and
Exploring the implications of automated inland shipping

overall the attractiveness of the sector, which aligns with the goals of Rijkswaterstaat, and those of the Minister of Infrastructure and Water management.

Rijkswaterstaat has a lot of data available to fulfil their tasks. This data can be shared with other stakeholders. However, the question is whether this data fulfils the requirements of the sector in terms of reliability and accuracy. Besides, nowadays the skipper is responsible for good navigation. When Rijkswaterstaat provides the data for navigation, who will then be responsible? This question indicates the difficulties in responsibility assignments and provides room for further research.

7.2 MANAGERIAL IMPLICATIONS

Based on the results, Rijkswaterstaat can position itself in different ways; proactive and reactive. The scenarios did not show very radical implications which affect the current way Rijkswaterstaat works. The implications do not indicate that imminent change is needed or that the infrastructure requires significant upgrades. This would indicate that Rijkswaterstaat can position itself as a reactive actor in the development of the technology of automated shipping. However, there is a need for compatibility with data-sources. Rijkswaterstaat cannot just follow the developments and respond to the problems that arise when the technology develops further, because incompatibility with the digital systems of ships may occur.

Besides, as Rijkswaterstaat is the organisation that executes the policy of the Dutch Ministry of Infrastructure and Water Management, it is, therefore, a politically steered organisation. Moreover, the current minister has explicitly mentioned that she wanted to facilitate judicial space for experiments with smart ships and encourages investments and collaboration for more innovation (Rijksoverheid, 2017). Even, during this research, the minister announced a 40 million EUR investment to set goals towards a modal shift to more freight by inland shipping instead of trucks (Rijksoverheid, 2019). Therefore, a more pro-active position better fits the current goals of the minister.

The results show the duality in the choices that can be made in a managerial context. Politics provide the goals to be pro-active and facilitate the development of the technology, while the rationality shows that it may not always be necessary to act pro-actively on the technology. It will, therefore, be most relevant to do further research and define what the desirable future is for the ministry and Rijkswaterstaat. This research did not assess concrete effects to the modal shift, or a level of increased sustainability due to the automation of ships. Further research could take a look at how automation may help the overall economy, the inland shipping sector, and how that aligns with the goals of the ministry.
7.3 PRACTICAL IMPLICATIONS

In the field of the automotive industry, much more research has already been conducted regarding the effects of automated driving. Research as Milakis et al. (2017) also shows that public expenditure and progressive regulatory frameworks could accelerate the transition towards fully automated vehicles. Besides, Lu (2018) mentioned that level 4 automated vehicles require little physical upgrades to the road infrastructure. A more harmonised way of placing road signs, lane marking, HD maps, and an improved vehicle to infrastructure technology would be required. In the case of more public expenditure, the infrastructure can deliver more data and facilitate sensors and intelligent technologies in the road to aid the autonomous cars.

The findings of this research also concur with Lu (2018) as Lu (2018) mentions that there is only a limited of physical and digital change required to let level 4 automated vehicles drive on the road. In the scenario where public expenditure is high, the technology adoption is accelerated due to the facilitation of much more vehicle to infrastructure communication; digitally as well as physically in terms of improved road signs.

The concurrence with research in the field of autonomous cars improves the validity of the results for the inland shipping sector. This research has shown that the adoption can be accelerated by facilitation of a sound digital infrastructure that provides data to the ships for autonomous sailing and receives data from the ships to improve traffic management. The concurrence also shows that the results of this thesis can be generalised across multiple industries. Industries could also learn from each other, especially since the automotive industry is usually faster than the shipping industry in the adoption of innovation.

7.4 THEORETICAL REFLECTION

The results of this research show that there are many barriers before large-scale diffusion can happen. Technology cannot change the landscape by itself. It takes effort from many actors in solving the factors that prevent the large-scale diffusions of the technology. Throughout the research, a list of limiting factors that were mentioned by the experts in the round of interviews was presented. This includes, for example, difficulty in investing, regulation, trust, communication, long-lifecycle of ships. These factors can be compared to the list of factors that affect the pre-diffusion phase by Ortt (2010, p. 22). These factors were summarised in categories as technological system, market environment, and the main organisations. Within these categories, factors found during this thesis can also be placed in the context of the research by Ortt (2010). The problematic hybrid situation could, for example, translate itself as lack of complementary goods that are needed within a technological system, regulation as the regulatory environment within the market.
environment, and difficulty in investing as the lack of resources of the main organisations that need to exploit the technology. Ortt (2010) showed that these categories of factors cause many technologies to have a long pre-diffusion phase. This theoretical knowledge has helped this research in bringing more insight into the development of technology. Niche development has even become one of the main axes of the scenario plot. Moreover, the theory of Geels (2002), as discussed in the theoretical framework in Chapter 3, overlapped with the theory of Ortt (2010) as they both showed that technology rarely immediately enters the large-scale market after invention and usually starts within a niche. Only after the niche has shown the maturity of the technology, it can start to disrupt the socio-technical landscape.

Besides, Martimo (2017) mentioned that “current cargo market situation could be inviting new entrants to join shipping since many of the old actors are facing bankrupts or have too much debt burdening their investing capabilities” (p. 60). However, this theory has neither been confirmed or refuted in this research. The theory of disruptive innovation did provide an additional question to the expert interviews but provided no new insights for this research.

Furthermore, the results of this thesis have given a basis for further scientific research in the field of automated (inland) shipping. No prior scientific research was available as a knowledge base for this research. Hence, the results of this thesis could be used for a variety of further research subjects. Also, more research could be done to assess the development of seagoing ships or other special-purpose ship types using the finding of this research. As Geels (2002) mentioned, it was the inland shipping sector that acted as a niche in the worldwide diffusion of combustion engines as a propulsion method for shipping. It is not yet known whether inland shipping or seagoing shipping will pioneer first in autonomous shipping. It is however known that both sectors have their own pros and cons in terms of technological adoption. Further research could assess where the best opportunities lie for the adoption of autonomous shipping technology.

At last, this research has shown that a different approach to scenario analysis can bring novel scenarios for technological forecasting. The use of theory as one of the axes has diverged from the use of Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) trends, which are commonly used in scenario analyses. The divergence has brought new insights from theory into practice using the scenario analysis and could, after more validation, also be used in further research in the assessment of technological forecasting.
7.5 LIMITATIONS AND RECOMMENDATIONS

The use of scenario analysis has been effective to the extent of this research. By combining uncertainty, it resulted in novel ideas about future scenarios and thereby conveyed an array of implications that could occur in the future. Due to the overlapping implications between the scenarios, the answers get more validity as they occur in multiple scenarios.

As already mentioned in the methodology, in chapter 2, scenario analyses “are speculative in their nature and sensitive to the pre-conceptions and knowledge of the experts developing the scenarios” (Engholm et al., 2019, p. 1). So, the expert’s opinions are bound to have pre-conceptions of the technology. Also, the knowledge of the author of this thesis could affect the development of the scenarios. This research has tried to minimise the effect of this limitation by inviting experts from a variety of companies and organisations without the use of the snowball effect. To further solve the limitations, other industry’s experts have performed research where multiple scenario analyses are compared. Engholm et al. (2019), for example, compared various scenario analyses for the automotive industry to remove the biases and pre-conceptions as much as possible. This is also recommended on the topic of automated inland shipping. If more scenario analyses would be done on this topic, they could be compared to this research and assess the validity of the results. It should be noted that a pre-conception can affect the results, but it could still be a truthful result.

Cairns & Wright (2018) also mentioned that the combination of two uncertain trends could lead to scenarios which have “an infinitesimal likelihood of actual occurrence” (p. 127). Moreover, another limitation shows that there may be multiple high-impact uncertainties, of which a different combination might have led to different scenario’s (Cairns & Wright, 2018). Furthermore, this research was mainly built upon qualitative data. The opinions of experts are used to develop conclusions. This may entail biases such as the availability bias where recently gathered knowledge affects the opinion of a person. Or with cognitive ease, where giving examples during the interviews might influence the way the experts think and react.

The expert workshop for the implication analysis was also an open discussion. A more systematic approach could have produced different and more detailed answers. However, this was not the goal of this research. This research attempts to assess a broad spectrum of implications. For the goal of this research, the open discussion was effective in solving a large part of the uncertainty. As one of the first researches towards the gathering of knowledge about the future of automated inland shipping, the answers are expected to be broad. Scenarios give four directions of how the technology might develop. There is,
however, an endless amount of other possibilities that fall between the four extremes of the axes that have been developed in this research and also a various amount of different implications.

Moreover, the intuitive logic method has been good at retrieving novel trends and factors about the future. That way, challenging scenarios for the future could be built. However, the expert workshop was an extension to this method, and the results during this workshop might have been prone to status quo bias. Some experts during the workshop mentioned that current infrastructure was already very good, and change was not desirable. Such statements may also influence the answers from other experts given during the workshop. Hence, future research could organise multiple workshops with different participants or focus, to reduce the number of biases in the results.
Chapter 8: Conclusions

The aim of this research was to explore the effects of automated shipping on the inland shipping sector and its corresponding physical and digital implications on the Dutch waterway infrastructure using the main research question: “What are the potential physical and digital implications for the waterway infrastructure of Rijkswaterstaat in case of automated inland shipping in the Netherlands by 2050?”.

To get to the objective, a scenario analysis using expert interviews was performed to develop four scenarios for the future of automated inland shipping. These scenarios were used in an implication analysis where an expert workshop was held to develop the implications of each scenario. Based on this scenario and implication analysis, it can be concluded that there are various digital as well as physical implications for Rijkswaterstaat:

- The physical implications show that automated mooring systems are required to accommodate fully unmanned ships. Rijkswaterstaat should keep track of the development of these systems as they need to be compatible with her infrastructure.
- Regarding the digital infrastructure, automated shipping technology can be facilitated by providing advanced mobile networks, reliable data, and good traffic management on the waterways.
- Rijkswaterstaat already has a lot of data available and can extend this dataset by providing more data to the ships such that ships no longer have to gather all the data by themselves. This implicates an increased responsibility and larger role of traffic management services.
- Maintain international compatibility with data from all actors.

Overall, the results show that across all scenarios, no immediate risks arise from the development of the technology. However, international compatibility with the data of the actors on the waterways will be required and it is seen that Rijkswaterstaat can play a significant role in the facilitation of the technology by providing a good digital infrastructure. The goals of Rijkswaterstaat also define that the waterways should be fast, safe, and sustainable. Without good data and advanced technologies, Rijkswaterstaat will not be fully able to achieve these goals. The implications indicate that a facilitating and proactive role could accelerate the adoption of automated inland shipping technology and hence improve the attractiveness of the sector and aid in a modal shift of cargo transport, which is desirable by the Minister of Infrastructure and Water Management.

To get to these results, the scenario analysis has been a rich method to gather broad insights into the future of automated inland shipping. Especially since this is one of the first
attempts at researching how the future of automated inland shipping might look like. Four scenarios were built upon the knowledge of experts. The results of expert interviews indicated two uncertain, yet impactful trends that affect the development and diffusion of automated inland shipping: technological development and niche development. For technological development, it indicates the maximum CCNR level of autonomy that is technologically possible. And for niche development, it represents the level of radical or incremental characteristics of the technology by adoption within small niches or across the whole sector. The implications that followed from these scenarios were built upon an expert workshop with experts in the field of waterway infrastructural design.

This research has also shown how uncertainty in the technological advancements of automated inland shipping can be tackled. Rijkswaterstaat can now strategically prepare for the future based on the combination of the organisation’s goals and the results of this thesis. The goals of Rijkswaterstaat and those of the minister provide the tools and resources for the facilitation of the technology in inland shipping. Future research could also build further upon the results of this thesis and provide the tools for all actors to strategically prepare for the future of automated inland shipping.

8.1 RECOMMENDATIONS

This research shows that many different choices can be made to react to the development of automated inland shipping technology. As a result, the following recommendations are generated as recommendations to Rijkswaterstaat and the scientific community:

- **Determine a normative future**: As a follow-up to this research, it would be wise to make clear what a desirable future is for Rijkswaterstaat and how this future can be achieved. A recommended method for developing normative sustainable futures is Backcasting, as described by Quist (2013). Backcasting makes sure that a desirable/normative future is defined and looks back at what the necessary steps are to get to this normative future. The results of backcasting could help Rijkswaterstaat in better assessing the amount of resources they want to put in preparation for automated shipping in the Netherlands.

- **Learn from other industries**: This research has shown that there is an overlap in the infrastructural requirements for automated cars. As such an industry is usually faster in the uptake of technology, much can be learned from them.

- **Perform more in-depth research**: As the results are potential implications based on the four scenarios, future research is needed to get a more concrete array of problems and implications that arise when an actual autonomous ship sails through the waterways. Current results are based upon predictions of experts.
Future research could dive deeper into the specific implications for policy or infrastructural design. Taking, for example, a single scenario, or a single autonomy level and applying it in a case study, doing a simulation, or letting a semi-autonomous ship sail through a corridor could give more concrete technological demands to the infrastructure. In that case, the smaller, more concrete problems can be identified and solved.

- **Keep joining the technological developments**: Based on the results of the implication analysis, it will be recommended for Rijkswaterstaat to keep joining the international development of the technology and show the role that Rijkswaterstaat wants to play in the development of the technology. Results of this thesis show that standardisation of protocols, improved data sharing, improved corridor management, and advanced mobile networks are key in preparation for this technology. Without the involvement of Rijkswaterstaat, Rijkswaterstaat might lack compatibility with the various datasets that are expected to be generated. Especially since Rijkswaterstaat already has a lot of data available for its current work. Due to the relatively limited amount of required investments, it is recommended to extend the amount of data that is gathered and share this with the waterway users. Besides, little physical adjustments are needed, but an attempt to get involved in the development of automated mooring system is recommended as they need to be compatible with the infrastructure of Rijkswaterstaat.

- **Facilitate a sound digital infrastructure**: As the Minister has announced; there is a need for a modal shift in cargo transport towards inland shipping. The policy of the minister is leading in the decisions that Rijkswaterstaat can make. Also, the goals of Rijkswaterstaat show that a fast, safe, and sustainable waterway is desirable. In concurrence with the results of this thesis, investments should hence be made to improve the digital infrastructure in terms of data provision, improved logistical chains, and improved traffic management.

- **Determine responsibility arrangements**: If more data is shared, who is then responsible for the reliability, validity, and accuracy of this data? Further research could develop an answer to this.

- **Determine the position of inland shipping in the global technology**: This research has assessed how inland shipping may change and which niches there are within inland shipping. Future research could assess how the global transition to automated shipping may look like. More research is needed in areas such as sea-going commercial ships, ferries, water taxis, and offshore maintenance.
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https://doi.org/10.1016/j.futures.2005.01.003


Appendices

Appendix A: Waterway network in the Netherlands
Appendix B: Integrated Logistics Conceptual Model

Figure represents the Integrated Logistics Conceptual model, adopted by Rijkswaterstaat, based on (Tavasszy et al., 2014)
Appendix C: Overview of technology implementation in Dutch inland shipping

Figure represents the average technology implementation per construction year and CEMT class.

<table>
<thead>
<tr>
<th>Year</th>
<th>CEMT I</th>
<th>CEMT II</th>
<th>CEMT III</th>
<th>CEMT IVa</th>
<th>CEMT IVb</th>
<th>CEMT VIa</th>
<th>CEMT VIb</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>2010 - 2011</td>
<td>20</td>
<td>11</td>
<td>23</td>
<td>49</td>
<td>23</td>
<td>49</td>
<td>23</td>
<td>110</td>
</tr>
<tr>
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<td>44</td>
<td>325</td>
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<td>325</td>
<td>44</td>
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<td>88</td>
<td>136</td>
<td>136</td>
<td>136</td>
<td>88</td>
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</tr>
<tr>
<td>1920 - 1915</td>
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<td>33</td>
<td>33</td>
<td>33</td>
<td>58</td>
<td>149</td>
</tr>
</tbody>
</table>
Appendix D: Actor map by Consuegra (2016)

Figure represents the stakeholders in the inland waterway transport network, developed by Consuegra (2016).
Appendix E: Semi-structured expert interview structure

1. Bedankt dat ik langs mocht komen! Om te beginnen wil ik graag vragen of ik dit interview mag opnemen.

2. Mijn naam is Wouter van Terwisga en mijn onderzoek gaat over het in kaart brengen van toekomstscenario’s voor de Nederlandse binnenvaartsector als gevolg van automatisering en digitalisering. En daarmee probeer ik te kijken wat hiervan de implicaties zullen zijn op de infrastructuur van RWS.

3. Kunt u iets vertellen over uw functie, wat u doet en wat uw ervaring is op het gebied van innovatie en ontwikkeling in de scheepvaart/ binnenvaart?

4. Autonome en slimme schepen lijken de toekomst te worden, hoe spelen jullie hierop in? Welke toekomstperspectieven nemen jullie in acht?

5. Hoe ziet u de toekomst van de binnenvaart voor u in 2050?
   a. Gaan we volledig autonome schepen zien? In grote getallen? Of bijvoorbeeld alleen bij een terminal zoals de ECT? Op de ECT-terminal zien we bijvoorbeeld AGV’s, maar de vrachtwagens die daarna komen zijn nog volledig handmatig.
   b. Zal digitalisering hier ook een grote rol in spelen?

6. Wat ziet als belangrijke drivers en factoren voor de ontwikkeling van deze geautomatiseerde toekomst?
   a. Welke trends zullen een rol spelen in de snelheid of in de mogelijkheden van de nieuwe technieken?
   b. Wat zijn de remmende factoren?
      i. Wat als er weerstand komt tegen de nieuwe technieken, komen er dan andere samenstellingen van de techniek? Bijvoorbeeld wel autonoom, niet slim (niet verbonden met de omgeving). Of andersom.

7. Ziet u bepaalde niche omgevingen waar de technologie sneller/makkelijker kan ontwikkelen?

8. Welke partijen zullen hier dan een grote rol in spelen? Komen er nieuwe partijen bij?
   a. Zoals startups, of juist grote bedrijven met veel geld?

9. Is er nog iets anders wat u graag wil vertellen?

10. Bedankt!
Appendix F: Expert interview reports

<table>
<thead>
<tr>
<th>INTERVIEW 1</th>
<th>A</th>
<th>Date: 10-4-2019</th>
</tr>
</thead>
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<tr>
<td>Interviewee</td>
<td>Marnix Krikke</td>
<td></td>
</tr>
<tr>
<td>Interviewer</td>
<td>Wouter van Terwisga</td>
<td></td>
</tr>
</tbody>
</table>

Introductie door Marnix Krikke

A:
Verantwoordelijk voor innovatie en Human Capital bij Netherlands Maritime Technology (NMT). Draagt bij aan nationale maritieme innovatie agenda binnen Nederland Maritiem Land (NML). Autonomie van schepen is 1 van de thema’s, naast emissies, veiligheid, en bijvoorbeeld security. Is binnen NMT verantwoordelijk voor aantal regionale, nationale en Europese samenwerkingsprojecten op het gebied van innovatie.

Niet heel veel kennis qua markt en bedrijfsleven in de binnenvaart. Maar wel qua innovatieve oplossingen.

Q: Hoe zouden we de toekomst in 2030-2050 voor ons kunnen zien?
A: Vervoerscapaciteit zal belangrijk blijven over het water. Belangrijk om binnenvaart te stimuleren vanwege de duurzame karakteristieken van de binnenvaart in termen van emissie per tonkm.

Duurzaamheid is een belangrijke driver.

Demografisch gezien gaat de bevolking niet toenemen, wel meer lokale productie.

Vervoersbewegingen binnen Europa nemen echter niet af. Bijvoorbeeld, briefvervoer afgenomen maar pakketvervoer afgenomen maar pakketvervoer toegenomen.


“Schaalvergroting heeft zijn maximale capaciteit gebruikt”

Kleine kapitein eigenaren verminderen in aantallen. Meer exploitatie van schepen door rederijen.

De afzonderlijkheid van kleine bedrijven zorgen voor beperkte investeringsmogelijkheden maar ook inefficiënte afstemming van de logistieke keten. Grotere rederijen kunnen beter de processen stroomlijnen.

Geen bemanningspool bij kleine bedrijven. Innovatie lastig in te voeren bij zulke bedrijven. Beter inzet van materieel hierin als driver.

Q: Technieken als Internet of Things komen steeds dichterbij. Is het verbinden van schepen een vereiste om autonoom te varen?
A: twee effecten door digitaal en autonoom:

1. Verplaatsen van informatie van het schip naar - en aansturing + monitoring vanaf de wal
2. Intelligente aan de systemen aan boord toevoegen

Schip worden wel echt slimmer. Maar kunnen worden gecoördineerd vanaf de wal. (Vergelijkbaar aan huidige situatie met VTS-stations).

Autonome schepen zullen 4 verschillende categorieën van informatie moeten ontvangen:

1) Het schip zelf (scheepsdata)
2) Wat er direct voor het schip gebeurt inclusief omgevingscondities
3) Ship to infra communicatie (Ship to Infrastructure (S2I))
4) Registratie van andere bewegende objecten (Ship to Ship (S2S))

Schip wordt slimmer, betekent niet dat bemanning er af gaat. Wel dat bemanning beter kan worden ingezet.
Q: Wat zijn volgens u de drivers voor zo’n geautomatiseerde toekomst?
A: Belangrijk om analoog om te zetten naar digitaal., maar die stap is al voor een belangrijk deel gezet. De volgende stap is omzetten van data in bruikbare informatie. Technology push is aanwezig. Markt vraagt betrouwbaarheid, efficiency, veiligheid. Kansen: sterkere industrie, nieuwe businessmodellen,

Maar ook het werk aantrekkelijk maken voor jongeren.
Toeleveranciers van apparatuur zullen het tempo gaan bepalen van de technologie adoptie. Dus vanuit een technology push perspectief.

Q: Wat zijn nog meer belangrijke actoren?
A: Providers van infrastructuur en waterweg data zullen een grote rol gaan spelen. De actuele waterdieptes en brughoogtes moeten precies beschikbaar zijn. Maar ook wind, stroming, etc.

5G zal ook een impact gaan hebben op de binnenvaart. De grote bandbreedte brengt veel mogelijkheden om real-time informatie te vergaren.

Q: Zouden we bepaalde (fysieke) domeinen kunnen gaan zien waar geautomatiseerde schepen als eerste toepassing naar voren komen?
A: Ja dit is zeker mogelijk. In Vlaanderen is dit al te zien op bepaalde rustige kanalen waar getest wordt. Op het prinses-margriet kanaal is dit nog niet aan te raden vanwege de drukte. Bepaalde omgevingen bieden meer kansen dan anderen voor de eerste toepassingen.
En NOVIMAR is een Europees project waarin geïnvesteerd wordt. Vooral gericht op een vessel-train, waar 1 schip de achtervolgende schepen ook bestuurd. Hier kun je sneller stappen maken dan door 1 schip volledig autonoom te maken.

Q: Naast de drivers ben ik ook erg benieuwd wat dan de remmende factoren zijn die deze techniek beïnvloeden.
Het delen van data zal ook niet gemakkelijk gaan. Het openbreken van bedrijfsdata zal niet zomaar gebeuren.
Vertrouwen in de techniek is erg belangrijk. Verzekerringspremies moeten bijvoorbeeld niet gaan stijgen als gevolg van automatisering. Vertrouwen creëren door simulaties en pilots.

Other images provided by interviewee:
CONCLUSION FOR REFERENCE:

Drivers:
- Kostenbesparing
- Duurzaamheid
- Sterkere industrie
- Technology push vanuit toelevanciers d.m.v. technologische ontwikkelingen
- Market pull factors:
  o Reliability
  o Safety
  o Efficiency
  o Flexibility

Future shaping factors:
- Weerstand tegen data deling
- Innovatie lastig in huidige marktconfiguraties waar kleine bedrijfjes individueel werken
- Regelgeving is lastig
- Cybersecurity
- Vertrouwen in de techniek

Other:
- Fysieke, maar ook markt-niches mogelijk. Met name vessel-trains.
Interview #2

Date: 2-4-2019

Interviewee
Prof. Dr. Rudy Negenborn

Interviewers
Erna Ovaa
Wouter van Terwisga

Introductie door Rudy Negenborn:
A: Rudy Negenborn, studie gedaan in Utrecht op het gebied van informatica. Nu full professor “Multi-Machine Operations & Logistics” at TU Delft within the Department of Maritime and Transport Technology, 3mE, TU Delft

→ Synchromodale optimalisatie.

Waarom moeten schepen met elkaar praten? Tot nu toe focus op het individuele schip. Als er niet actief wordt gecommuniceerd kan je capaciteit verliezen door té hoge voorzichtigheid.
(Schepen gaan elkaar langzamer passeren dan nodig)
Elkaar opzoeken, treintje maken naar de sluis door betere informatiedeling. Wel opletten hoe je achter elkaar aan vaart. In elkaars schroefwater zitten is niet efficiënt.

Q: Wat als de waterwegen vol en druk worden? Dus veel innovatie, veel schepen, veel transport. Wat zijn dan de effecten?
“Als het vol en druk wordt, en je loopt tegen verstoppingen aan, dan is het niet handig om enkel individueel te bepalen waar je container of andere vrachtsoort naar toe moet. Juist dan baat bij betere afstemming om de capaciteit die er nog is zo goed mogelijk te gebruiken.”

Q: Dus beter afstemming is een belangrijke driver voor meer automatisering. Wat zouden nog andere drivers kunnen zijn?
A: De driver bij ons komt vanuit de technologische ontwikkelingen: meer rekenkracht, meer sensoren, meer communicatiemogelijkheden— hoe kun je van die ontwikkelingen gebruik maken om transport over water te verbeteren? Vanuit de markt is een driver: hoe kunnen we kosten verlagen (minder personeel mogelijk?). Vanuit de regelgeving: IMO: Emissies van schepen moeten verlaagd worden; is regelgeving voor ingevoerd—om daaraan invulling te geven: Kunnen slimmere besturingssystemen voor schepen en groepen van schepen ervoor zorgen dat er aan die nieuwe emissienormen voldaan gaat worden, zonder schepen helemaal opnieuw te moeten bouwen?

Q: Wat voor communicatiemiddelen kunnen voor zo’n geautomatiseerde toekomst worden gebruikt?
Wetgeving moet wel worden aangepast voordat deze toekomst mogelijk kan worden. Ik zie regelgeving dus als een limiterende factor voor technologische ontwikkeling.
Bijvoorbeeld rijbewijzen nodig voor autonome systemen.
Als het echt druk wordt; dan moeten er wellicht regels worden verminderd.
Verschillende scenario’s voor verkeersmanagement. 1 centraal systeem voor de sturing. Of alle schepen bepalen alles zelf. Of iets hier tussenin. Negenborn verwacht een combinatie van coördinatie met lokale sturing.

Q: 1 centrale zou de schepen juist dommer maken?
A: Schippers etc. willen hun schip niet afstaan aan een centraal systeem.

Q: Wat als de technologische ontwikkeling stagneert maar bedrijven elkaar wel opzoeken voor schaalvoordelen doordat de economie stagneert en er minder transportgroei is? Bijvoorbeeld konvoivaren door grote reders.

Q: Wat dan als de techniek grote weerstand krijgt door een oplaiend maatschappelijk debat? Bijvoorbeeld door slecht nieuws over cybersecurity, aanvaringen, etc.?
CONCLUSION FOR REFERENCE:

Drivers:
- Slimmer afstemmen om bottlenecks te verminderen
- Technologische ontwikkelingen gebruiken om transport beter te maken
- Kostenverlaging /Punctualiteit vanuit de marktpartijen
- Emissieverlaging
- Duurzaamheid

Future shaping factors:
- Regelgeving lastige factor
- Communicatiestandaarden nog niet ontwikkeld
- Omgaan met mogelijk slecht imago
- Zonder nieuwe communicatiestandaarden; inefficiënte verkeerssituatie

Other:
- Nichemarkten kunnen als eerste stap worden gebruikt.
Introductie door Robert Hekkenberg:

A:
Associate Professor bij de TU Delft. Gespecialiseerd op het gebied van autonome schepen en binnenvaart. Momenteel Director of studies van de BSc. Marine Technology.
Veel bezig met onderzoek naar het in kaart brengen en vervangen van taken aan boord d.m.v. automatisering.

Q: Wat ziet u als toekomst voor autonomie en digitalisering in 2050 en hoe speelt u hierop in?

A:
Voor 2050 is te verwachten dat een groot aantal taken zijn vervangen door automatisering. Voor de binnenvaart is het echter lastig vanwege de vele familiebedrijven die zich hier bevinden.
Binnen het JIP autonomous shipping wordt er al onderzoek gedaan voor de eerste proeven met autonome schepen.
Er moet echter wel een goed onderscheid gemaakt worden tussen autonoom en unmanned. Unmanned betekent niet dat het schip ook autonoom vaart. Remote control is ook mogelijk bij een unmanned schip.
In de toekomst zullen er waarschijnlijk wel meer remote control stations komen, waar ervaren stuurmannen vanaf de wal de schepen in de gaten houden.
Uiteindelijk is het de bedoeling om te besparen op het aantal banen. In eerste instantie zal dat echter niet leiden tot minder banen, maar tot een kleinere toename in het aantal banen.

Een effect van autonomie op de binnenvaart kan er ook voor zorgen dat er meer kleine schepen komen. Schaalvergroting zoals dat nu gaande is zal dan afnemen.

Q: Wat zijn dan de drivers voor de ontwikkeling van deze technologie?

A:
De grootste driver kostenbesparing. Daarmee ook economische voordelen voor de sector, maar ook in zekere mate een schonere scheepvaart door hogere efficiëntie.
Veiligheid is hierin een grote factor. Autonomie kan zorgen voor meer veiligheid op het water.
Het autonoom maken van binnenvaart is wel lastiger dan zeegaande schepen qua verkeerstijging, maar biedt weer doordat het schip minder ver verwijderd is van een veilige haven en er dus sneller ingegrepen kan worden als er iets misgaat.
Technology push mogelijk door meer ondersteuning te geven aan de bemanning. Als een collega schipper het heeft, helpt dit ook om dit bij andere schippers te krijgen.

Q: Wat ziet u als de remmende factoren?

A:
Het leveren van een service die periodieke kosten heeft en geen grote initiële investering vraagt kan hierin kansen bieden.

Q: Ziet u namelijk nog bepaalde fysieke- of markt-niches waar digitalisering en autonomie in de binnenvaart als eerste kunnen beginnen?

A:
Nee, ik durf geen niche te identificeren. Op de kleine vaarwegen is het minder druk, dus makkelijker, maar daar zijn de voordelen ook kleiner omdat er minder bemanning op de kleine schepen zit.

CONCLUSION FOR REFERENCE:
Drivers:
- Kostenbesparing
- Schonere scheepvaart
- Betere ondersteuning van bemanning

Future shaping factors:
- Investeringen lastig
- Weghalen van bemanning gaat niet altijd kostenbesparing opleveren
- Eerder slim maken als service in plaats van grote investering
- Banen verplaatsen van schip naar wal. (Remote control)

Other:
- Meer kleine schepen als gevolg van autonomie
- Schaalvergroting afhankelijk van de markt waarin bedrijf zich bevindt.
- Niches onzeker. Kleine vaarwegen makkelijker, maar ook minder voordelen doordat er nu ook al weinig mensen aan boord zitten.
## INTERVIEW 4

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**Introductie door Martin Quispel:**

A:
Senior Expert Project Manager bij het Expertise- en InnovatieCentrum Binnenvaart.
Al vele jaren bezig met economisch onderzoek in de binnenvaart; tarieven, vloot, markt, ladingstromen. Maar ook logistiek; intermodale systemen.
Nu ook veel op duurzaamheid d.m.v. nieuwe motoren, brandstoffen en de financiering hiervan.
Eerst bij STC-Nestra, sinds februari bij EICB voor duurzaamheid en digitalisering van de binnenvaart.

EICB als consultancy voor veel verschillende partijen in de binnenvaart zoals Bureau Voorlichting Binnenvaart en Bureau Telematica Binnenvaart.

Q: Hoe zien jullie de toekomst in 2030-2050 voor jullie en hoe spelen jullie hierop in?

A:
Je ziet dat alles nauwer op elkaar aan gaat sluiten. De keten naar de havens kan worden verbeterd. Veel schepen in havens zorgt voor druk op de infrastructuur en hierdoor is er vraag om hierop slim in te spelen. Op de juiste momenten de schepen aanwezig en afwezig.
Vooral in containervervoer gaat het snel door de standaardisatie en grote belangen die erachter zitten.
Zand en grind markt gaat bijvoorbeeld veel langzamer. Er is veel onderscheid te maken tussen de verschillende deelmarkten qua interesse en snelheid van de ontwikkeling.

Q: Wat zijn dan volgens u de effecten van zo’n autonoom varende en digitale toekomst?

A:
Je ziet dat je nieuwe voertuigconcepten kan gaan gebruiken. Grote kans dat er veel meer kleine modules komen die daarna weer gebundeld kunnen worden. Denk hierbij aan zelf varende pontons.
Schaalvoordelen worden verminderd omdat dit vooral op basis van personeelskosten is, bij autonome schepen valt dit argument weg.

Q: Wat zijn dan de drivers om zo’n geautomatiseerde toekomst te bereiken?

A:
1. Betere benutting van de schepen en dus een kostenverlaging (24/7 operatie)
3. Arbeidskosten; minder personeel.

Q: Wat zijn dan de remmende factoren?

A:
Slecht imago; ongelukken zouden de acceptatie erg kunnen remmen.
Vakbonden die weerstand kunnen hebben tegen het overnemen van menselijk werk door machines
Regelgeving: er moeten nieuwe regels komen die arbeidsreductie kunnen faciliteren.
Risico’s: Verzekeringskwesties, aansprakelijkheid
Q: Ziet u ook weerstand tegen het delen van data tussen bedrijven?
A: 
Ja er is wel veel weerstand en een cultuur tegen het delen van data. AIS was ook een lastig idee aangezien het de locatie van het schip op elk moment zou doorsturen. Echter kunnen regels ook stimuleren. De weerstand tegen datadeling kan worden opgelost door stimulerende wetgeving, zoals het langer mogen varen als je data deelt, of een persoon minder aan boord mag. De komende decennia kunnen we dus wel zien dat er minder mensen aan boord gaan zitten. Maar voordat het volledig onbemand wordt moet er nog heel veel stappen worden gezet.

Q: Zijn er nieuwe marktpartijen die er kunnen gaan ontstaan door deze technieken?
A: 
Kleine familiebedrijven kunnen gaan samenwerken om efficiënter te werken. Meer rederijen die meer schepen binnen 1 bedrijf beheren. Maar ook zeker de huidige partijen die kaarten, autopilots, etc. leveren kunnen een grotere rol gaan spelen doormiddel van technology push.

**CONCLUSION FOR REFERENCE:**

**Drivers:**
- Betere benutting van de schepen en dus een kostenverlaging (24/7 operatie)
- Arbeidskosten; minder personeel.

**Future shaping factors:**
- Slecht imago; ongelukken zouden de acceptatie erg kunnen remmen.
- Weerstand van schippers/eigenaren om data te delen
- Vakbonden die weerstand kunnen hebben tegen het overnemen van menselijk werk door machines
- Regelgeving: er moeten nieuwe regels komen die arbeidsreductie kunnen faciliteren en zodanig de business case mogelijk maken.
- Risico’s: Verzekeringskwesties, aansprakelijkheid
- Ontwikkeling van grotere bedrijven die meer schepen tegelijk exploiteren

**Other:**
- Technology push vanuit toeleveranciers.
Interview door Tom van Dijk:

A
Technisch bedrijfskunde in Enschede gestudeerd. 3 jaar geleden begonnen met het analyseren van de trends in de maritieme wereld. Autonoom varen was één van de belangrijke onderwerpen hierin.
Ook medeauteur van de White paper SmartPort. Expert op het gebied van smart shipping geworden binnen het bedrijf CGI.

CGI lost technologische problemen op voor bedrijven.

Q: Hoe zien jullie de toekomst in 2050 voor jullie en hoe spelen jullie hierop in?

A:
Autonomie is een lastig begrip. Het zal waarschijnlijk stap voor stap gaan zoals de autonomie levels die door verschillende organisaties zijn ontwikkeld.
Vliegtuigen vliegen bijvoorbeeld al jaren autonoom, toch blijven de mensen wel in de vliegtuigen aanwezig. Voordat er daadwerkelijk mensen van het schip af kunnen stappen zal er nog veel moeten gebeuren.
Dull, Dirty, Dangerous (3D) werk als de eerste applicaties voor autonome schepen/robots. Zoals brandblusschepen, olie opruimen en onderzoeksvaartuigen.
Door meer autonomie en minder mensen aan boord kan het ontwerp van de schepen ook veranderen. Hierin zal het scheepsdesign veranderen naar technology first, maar wel gemaakt zodat mensen het nog kunnen monitoren.
Digitaal/software onderhoud en pre-fixed onderdelen kunnen het lastige onderhoud aan schepen veranderen.
Nieuwe vrachtconcepten kunnen er ook voor zorgen dat vracht zijn eigen route gaat bepalen. Hierdoor wordt real-time de beste modaliteit gekozen. Het slim afstemmen van de binnenvaart kan hier grote voordelen bieden.

Q: Zie je dan ook deelmarkten/niches binnen het vrachtvervoer in de binnenvaart waar het eerder kan gaan gebeuren?

A:
Het meest lastige van het varen is het manoeuvreren door de drukke gebieden. Concepten waar de interactie met de omgeving erg klein is, geeft meer kans op autonome schepen.
Pontjes/ferries die weinig interactie hebben zoals in de Noorse fjorden kunnen snel autonoom worden. Autonomie in een drukke haven is niet snel haalbaar.

Q: Wat zie je als de drivers voor een toekomst met autonome schepen?

A:
Een toekomst waar schepen een slimmere rol spelen in het transportsysteem. Daarmee kan een business case ontwikkeld worden door:
- Meer veiligheid
- Minder personeel
- Brandstofbesparing
- Slimmere afstemming in de logistiek

Q: Wat voor factoren zouden dan juist de technologie remmen?
A: Regelgeving zegt nog dat je een x aantal mensen aan boord moet hebben.
Mens naar machine communicatie is een barrière aangezien ze beide slecht weten van elkaar wat ze gaan doen. Een hybride situatie waar door een mens bestuurde schepen en autonome schepen tegelijk varen is lastig.
Regelgeving is niet in alle opzichten een limiterende factor. Er is veel te doen zonder regels aan te passen.
Weerstand door schippers bestaat ook zeker, maar wanneer de voordelen duidelijk en zeker zijn zal dit snel worden opgepakt. De schippers zijn erg belangrijk in de ontwikkeling van de techniek.

Acceptatie zal nooit gemakkelijk gaan, maar als je bijvoorbeeld kijkt naar ongelukken die autonome Ubers hadden dan zie je dat desondanks de ontwikkeling niet stopt.

Q: Zien jullie ook nieuwe actoren die door deze technieken ontstaan?
Maar ook grote partijen zouden hun kapitaal kunnen gebruiken om een slag te maken in de binnenvaart. Er is ook zeker een kans dat de kennis uit de automotive industrie wordt overgebracht naar de binnenvaart.

CONCLUSION FOR REFERENCE:
Drivers:
- Veiligheid
- Kostenbeparing
- Minder personeel
- Brandstofbesparing
- Slimmere afstemming in de logistiek
- Waterwegen hebben nog ruimte voor meer transport

Future shaping factors:
- Mens naar machine interactie is lastig. Hybride situaties van autonome en niet autonome schepen onwenselijk.
- Schippers zijn belangrijke actoren in de acceptatie en implementatie
- Gebieden met veel interactie zijn lastig te automatiseren. Eerder rustige gebieden zonder veel verkeer of Dull, Dirty, Dangerous als niche gebruiken.
- Ontwikkelingen gaan stap voor stap. (incremental)
- De lange levensduur van schepen; schepen moeten zich vaak nog terugverdienen. Een retro-fit is dan vaak niet mogelijk.

Other:
- Automotive kennis kan naar de scheepvaart worden gebracht
Introductie door Erik Schultz:
A:
Tientallen Jaren als commercieel directeur bij Damen Shipyards gewerkt op het gebied van vrachtschepen. Inmiddels met pensioen maar nog aan het werk als vice-voorzitter van brancheorganisatie BLN, voorzitter van de Koninklijke Schuttevaer en enkele werkzaamheden bij Damen shipyards.

Q: Hoe zien jullie bij BLN de toekomst in 2030/2050 van de binnenvaart en hoe spelen jullie hierop in?
A:
Nog veel te weinig. Discussies met leden (schippers) gaan vaak over korte termijn problemen. Zoals ligplaatsen, onderhoud kunstwerken, sluisproblemen, diepgang, etc. Als brancheorganisatie moeten we echter de schippers klaarmaken voor de toekomst. Schippers denken eerder dat organisaties zoals Rijkswaterstaat deze problemen eerst moeten oplossen en kijken daarna wel weer verder. Er is nog steeds weinig geld beschikbaar, schippers zien meer prioriteit om naar de huidige problemen te kijken dan voor te bereiden op toekomstige technieken. Duurzaamheid is een eerste trend die het ontwerp van schepen beïnvloedt.

Maar digitalisering is ook een driver. Er wordt nu nog heel veel papier gebruikt om de logistieke keten te documenteren. Dit kost veel geld en is niet efficiënt. Het digitaliseren en beveiligen van al deze documenten gaat geld opleveren. Dit is de grootste stap in de komende 5 tot 10 jaar. De hele logistieke ketting kan hiervan profiteren. Datadeling wel persoonsgericht. Niet iedereen kan alles inzien.

Weinig mogelijkheden voor Just in time planning. Maar het chippen van containers/vracht kan zeker de planning van vracht verbeteren.

Q: Hoe zien jullie het automatiseren van het varen?
A:
De software/hardware industrie gaat hier de leiding nemen. De uitrusting is niet lastig, er kan een platform worden neergezet. Het gaat erom dat mensen vertrouwen kunnen hebben in die software.

Maar stel dat er wel minder mensen nodig zijn door automatisering, dan kan het personeelsprobleem beter worden gemanaged. De nieuwe generatie jongeren heeft minder belang bij een week lang weg zijn op een schip zonder te weten waar hij/zij precies is op een vrijdagavond. Er liggen wel grote barrières in onderhoud. Wie gaat het onderhoud doen als er minder mensen aan boord zijn. Laagwater geeft bijvoorbeeld ook lastige casussen waar autonome schepen moeilijk keuzes kunnen maken op de rivier. En als we minder mensen nodig hebben, is dan een opleiding wel aantrekkelijk, hoe gaat de volgende generatie dan leren varen?

Hulpmiddelen gaan meer met elkaar communiceren. Computers kunnen sneller reageren en soms de menselijke fout eruit halen.

Q: Wat zouden de effecten kunnen zijn van digitalisering en autonomie? Kunnen we niches gaan zien waar de kansen groter zijn?
A:
Scheepsontwerp kan gaan veranderen doordat andere brandstoffen minder ruimte in nemen. Maar ook doordat minder mensen mee hoeven aan boord. Of veel meer op basis van bakken. Dus meer duwbak combinaties/ rivertrucks. Een effect kan ook zijn dat veel kleine eenheden samen gaan werken tot een grotere eenheid.

Maar veranderingen in klimaat en droogte zorgen er ook voor dat scheepsontwerp verandert. Containervaart zou wel 1 van de eerste markten kunnen zijn waar digitalisering kan beginnen door de standaardisatie. Begin in 1 corridor en kijk daarna verder.

Q: Wat zouden factoren kunnen zijn die de implementatie van automatisering en digitalisering tegenaan?
A: Dat de techniek niet overal tegelijk wordt ingevoerd, neem de tijd om een ontwikkeling geheel door te zetten en te leren. Je krijgt 2 snelheden waar oude schepen bijvoorbeeld niet meer investeren maar de nieuwe schepen wel. De communicatie zal echter lastig gaan tussen de dan nieuwe en oude schepen.

Q: Kunt u een reden geven waarom de investeringen bij scheepseigenaren vaak lastig gaan?
Dat vele schippers na een moeilijke periode eerst de kat uit de boom kijken is duidelijk aanwezig, als de mensen ons vragen waar moeten nu echt in investeren zodat ik dan 10-15jr rust heb en volstaat is het voor ons ook niet duidelijk. De angst leeft dat een investering van vandaag over 5 jaar alweer op de schroothoop moet omdat de ontwikkelingen en eisen van vandaag alweer achterhaald zijn.

Tegelijk zien we dat eisen van investeren nu in een schone motor bijvoorbeeld betekent dat de schipper voor de komende 20jr stil staat en dat terwijl de overheid in een stappenplan gaat naar zero emissie in 2050. Met lange afschrijvingsperiodes in de binnenvaart is een stap nu een stap horizontaal terwijl we eigenlijk in een trappenplan naar zero emissie moeten. De verdiensten zijn helaas niet zo dat een investering van 3-400.000 in een paar jaar is terugverdient, met de opgelopen achterstand in aflossing over de moeilijke jaren eist de bank meestal alle ruimte op en dus blijft er weinig over om te gaan investeren en banken staan daar ook niet direct open voor, eerst maar de lening weer in orde brengen.
CONCLUSION FOR REFERENCE:

Drivers:
- Kostenbesparing
- Reduceren van papierwerk door digitalisering
- Personeelsproblemen oplossen

Future shaping factors:
- Schippers nog niet klaar voor de toekomst
- Hybride situaties erg lastig op het gebied van communicatie

Other:
- Begin in een specifieke corridor (niche)
- Containervaart het meest gestandaardiseerd en kan eerder veranderen
- Meer Duwbak combinaties en kleine eenheden die samen gaan werken
INTERVIEW 7  G  Date: 25-4-2019
Interviewee  Bas Kelderman
Interviewer  Wouter van Terwisga

Introductie door Bas Kelderman:
A:

Q: Hoe zien jullie de toekomst van de binnenvaart in 2050 voor jullie en hoe spelen jullie hierop in?
A:
Veel schepen lopen nog ver achter op het gebied van vernieuwing. De ambitie voor de binnenvaart is emissie loos in 2050. Veel stimulering is nu op basis van duurzaamheid, de ambities liggen bij het schoner maken van schepen. Europese subsidieprojecten zouden ervoor zorgen dat schepen over 5 jaar al autonoom zouden kunnen varen.
Uitgangspunt is dat een schip van punt naar punt wordt laten gevaren, maar er is altijd een persoon die het in de gaten houdt. Dit is technisch en op regelgeving makkelijker haalbaar dan volledig onbemand.
NOVIMAR -> Vessel train als eerste concept waar schepen bij elkaar aansluiten en efficiënter worden ingezet. Echter, als een schip de connectiviteit verliest moet er wel ingegrepen.
De driver is om personeel te verminderen, volledig bemanning loos is nog ver weg.
In 2030 kan je schepen verwachten die van 2 vaste punten geautomatiseerd heen en weer kunnen varen. De lastige momenten zijn dan echter nog dat schepen lastig op zichzelf door een sluis kunnen varen.
De stappen zullen vrij klein zijn. Tussenstapjes nodig, zoals de NOVIMAR vessel train.

Q: Wat zouden de effecten kunnen zijn op de markt, stel dat er veel autonome schepen zijn?
A:
Het kan goed zijn dat er meer kleine schepen komen. Hier gaan nichemarkten veel verder concurreren met de weg.
De kleine vaart kan veel meer profiteren van autonomie doordat zij in mindere mate van schaalvoordelen profiteren.
Het begint met kleine ontwikkelingen die geëxperimenteerd moeten worden.

Q: Wat zijn de remmende factoren voor de ontwikkelingen van de technieken voor autonome schepen?
A:
Het moet duidelijk worden wat de keuzes zijn die een computer maakt (een zelflerend systeem). Het moet snel duidelijk zijn wanneer het systeem niet meer weet wat er moet gebeuren en er een persoon moet ingrijpen. In 2030 zal dit waarschijnlijk al ver gevorderd zijn.
Er moet ook nog een businessmodel worden ontwikkeld. Dit schijnt nog erg lastig te zijn.
Grote investeringen moeten wel opgewegen tegen de voordelen.
Q: In welke niches denkt u dat de techniek sneller/makkelijker ontwikkeld wordt?
A:
Het grote voordeel van containervaart is dat het punt naar punt is. Je weet dan gelijk de vermogensvraag van schepen. Vooral op kanalen, waar het waterpeil geconditioneerd is en de omgeving vrij stabiel. Dus, een omgeving waar de externe factoren vrij stabiel zijn kun je het snelste een vergevorderd systeem implementeren.
Mocht zo’n traject duidelijk zijn, dan kan bijvoorbeeld RWS investeren op dat traject om het bijvoorbeeld 5G-ready te maken en kunstwerken aan te passen aan de autonome schepen.

Q: Wat zijn de drivers om deze technologieën te ontwikkelen en implementeren?
A:
Besparen op bemanning. Het is lastig om goed personeel te vinden, maar ook de kosten worden dan minder.
ADN-schepen zullen een zekere terughoudendheid hebben. Vanwege de gevaarlijke stoffen zullen hier altijd extra mensen aan boord moeten zijn.
Het optimaliseren van het logistieke systeem zal ook een driver zijn om de binnenvaart beter te maken.

Q: Ziet u nog andere partijen die opkomen door deze technologieontwikkelingen?
A:
Vanwege de vraag naar veel connectiviteit zullen telecomproviders zoals KPN ook een belangrijkere rol krijgen. Zoals in het 5G netwerk voor de waterwegen.

Q: Kunnen partijen vanuit andere industrieën zoals automotive ook een intrede nemen in de binnenvaart?
A:
Er zijn zeker mogelijkheden, maar het is toch een kleine markt waar grote partijen wel winst in moeten zien. Vergeleken met de auto-industrie is de binnenvaartmarkt erg klein voor een autofabrikant.

Q: Heeft u nog andere opmerkingen?
A:
Stel dat de industrie meer winstgevend wordt, dan moet wel worden gekeken voor wie dit precies winstgevend is. Er kunnen partijen zijn die juist minder gaan verdienen en daardoor gaan hinderen. Denk hierbij aan bijvoorbeeld bevrachters die door slim afstemmen buiten spel worden gezet.
Dus: zorg ervoor dat de hele keten profiteert zodat er geen barrières door bepaalde partijen worden gemaakt.
CONCLUSION FOR REFERENCE:

Drivers:
- Minder bemanning
  - Kostenbesparing
  - Oplossing voor personeelsschaarste
- Logistieke systeem optimaliseren

Future shaping factors:
- Druk vanuit partijen kan barrières creëren
- Er zal nog lange tijd wel iemand aan boord blijven; minder personeel is wel mogelijk
- Incrementele ontwikkeling van de techniek
- Kanalen geven een stabiele omgeving voor de eerste toepassingen
- Vessel train als mogelijke eerste oplossing richting bemanningsvermindering

Other:
- Binnenvaart is een relatief kleine markt vergeleken met auto’s. Kans op externe grote partijen die intreden is klein.
**Interview 8 H**

**Date:** 30-4-2019

**Interviewees**
- Peter van Terwisga
- Jasper Schuringa

**Interviewer**
- Wouter van Terwisga

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**Introductie:**

**A:**
Peter van Terwisga al meer dan 20 jaar werkzaam in R&D. Op dit moment al 12 jaar Director Research bij Damen Shipyards Group.
Jasper Schuringa Projectmanager Innovation bij Damen Shipyards.

**Q:** Hoe zien jullie bij DAMEN de toekomst van autonoom varen in 2050 en hoe spelen jullie hierop in?

**A:**
Autonomie wordt gezien als een stip op de horizon. Europese subsidies om demonstrators op te zetten die laten zien dat de techniek bestaat en werkt om zo regelgeving en infrastructuur aan te passen (Horizon2020). Maritime Fusion was een project wat meer op de binnenvaart was gericht. Helaas ook niet toegekend aan Nederland, maar heeft wel voorbereidend werk op gang gezet.

Automatisering gaat taken verplaatsen. Minder bemanning aan boord.
Connectiviteit ontwikkeling gaat erg snel. Schepen worden bij de bouw al ontworpen om altijd verbonden te zijn. Autonomie is echter nog in de beginfase.

**Q:** Wat zien jullie als drivers voor deze technieken?

**A:**
Drivers voor connectiviteit:
- Verbeteren van operationele effectiviteit
- Inzicht in prestaties van het schip om het schip te verbeteren
- Verhogen van veiligheid
- Slimmer inzetten van schepen

Kostenbesparing voor klanten
Brandstofbesparing
Functies van het schip naar de wal -> Hoge kostenbesparing
Hogere sociale acceptatie omdat personeel niet meer weken van huis hoeft.
Comfort en luxe als technologie drivers worden gezien. Schippers nemen hun eigen huis mee, hierin is alles vaak netjes afgewerkt en is het comfort hoog. Autonomie geeft ook meer comfort.

**Q:** Damen was in het nieuws bij Code Kilo, wat zien jullie hier voor kansen?

**A:**
Code Kilo zorgt voor standaardisering in data van schepen. Dit is in belang van de werf, toeleveranciers en ook de eindgebruikers.
Hierdoor kostenbesparend door een gestandaardiseerde stroom met gegevens waar de stakeholders op kunnen anticiperen.

**Q:** Wat voor niches zouden autonomie als eerste op kunnen pakken?

**A:**
Dull, Dirty, Dangerous (3D)
Dus autonome brandblusschepen, survey, marineschepen/mijnenvegers, safety standby vessels, et cetera. Dit is echter veel zeegevaar.
Binnenvaart biedt meer kansen door “schaalverkleining”. Dus de kleinere eenheden kunnen meer waarde krijgen.
Point-to-point situaties zoals containervaar zijn ook voordelig en kunnen dus sneller autonomie oppakken.
Q: Wat zien jullie als de remmende factoren?
A:

Q: Wat voor nieuwe partijen zouden er in de markt kunnen toetreden?
A:
Een effect van de autonomie zou kunnen zijn dat schepen meer een commodity worden. Hierin zouden grote partijen zoals Maersk een aantal autonome binnenvaartschepen kunnen exploiteren als aanvulling op de grote zeeschepen. Een effect zou dus kunnen zijn dat schepen meer als vloot worden geregeld in plaats van individueel.
CONCLUSION FOR REFERENCE:

Drivers:
Voor connectiviteit:
- Verbeteren van operationele effectiviteit
- Inzicht in prestaties van het schip om het schip te verbeteren
- Verhogen van veiligheid
- Slimmer inzetten van schepen

Kostenbesparing voor klanten
Brandstoffbesparing
Functies van het schip naar de wal -> Hoge kostenbesparing
Hogere sociale acceptatie omdat personeel niet meer weken van huis hoeft.
Comfort

Future shaping factors:
- Er kan veel druk vanuit actoren ontstaan door het weghalen van bepaalde taken/werk.
- Regelgeving aanpassingen nodig om business cases mogelijk te maken
- Technologie moet zich echter nog wel bewijzen. Voor regelgeving als voor sociale acceptatie.
- Publiek-private samenwerking nodig voor investeringsruimte en kennisdeling.

Other:
- Niches kunnen gevonden worden in de 3D’s van automatisering (Dull, Dirty, Dangerous)
- Goede kans dat kleine schepen van schaalverkleining gaan genieten
- Lange termijn effecten kunnen ervoor zorgen dat grote partijen zoals Maersk kleine autonome schepen gaan exploiteren als verlenging van hun transportdomein.
Introductie door Richard van Liere:

A:
Richard van Liere is projectmanager bij STC-Nestra. NESTRA = Netherlands Expert group for Sustainable TRANsport and logistics.
7 jaar ervaring in Transport and Logistics consultancy.
Onder andere meegewerkt aan subsidieprojecten (HORIZON2020/PROMINENT) voor vergroening van de binnenvaartvloot, zoals nabehandelingssystemen en potentie LNG

Q: Hoe zien jullie de ontwikkeling van autonomie en digitalisering in 2050 voor jullie en hoe spelen jullie hierop in?

A:
De technologie en onderzoek naar autonome schepen is nog erg in de beginfase. River Information Systems (RIS) worden al wel uitgebreid. Er komt steeds meer informatie over de waterwegen beschikbaar die met gebruikers wordt uitgewisseld en gedeeld.
Veel onderzoek wordt gedaan op basis van toekenning Europese subsidieprojecten waar meerdere consortia op inschrijven. Daardoor ontstaan er meerdere losse initiatieven en is er beperkt coördinatie wat betreft ontwikkeling van autonome schepen. In het H2020 Fusion voorstel waren diverse Nederlandse publiek en private instellingen betrokken om autonoom varen in de binnenvaart verder te onderzoeken en te ontwikkelen.
De techniek blijft zich wel ontwikkelen, maar de investeringen remmen het onderzoek. De business cases zijn nog erg lastig om te ontwikkelen.
Grotere rederijen hebben meer capaciteit om te investeren. Container als groeimarkt en tankvaart hebben doorgaans grotere rederijen meer mogelijkheden om te investeren in nieuwe schepen en technieken i.v.m. schepen actief in de vrije vaart.
Er zijn al wel ideeën om havenwachtijden te verlagen voor de container binnenvaart en in te zetten op een systeemvernieuwing door het gebruik van duwbakken (Legobakken). Dit biedt mogelijkheden om de vloot (deels) sneller te vergroenen en te moderniseren. Echter zullen ook drooglading schepen vanuit de bulk (teruglopend vervoer kolen, ertsen) een deel van de groei in containervervoer absorberen.
Wellicht is het mogelijk om kleine bakken die als een trein door de haven heen varen. Dit gebeurt al met duwboten, maar kan ook autonomo. Verder schaalvergroting (in konvooi/combinatie) kan verdere kosten efficiency betekenen, kleinere bakken bieden waarschijnlijk meer flexibiliteit.

Q: Wat zouden de effecten zijn van autonomie in de binnenvaart?

A:
Het is zeker mogelijk dat er kleinere schepen komen. Maar het is vooral dat je slimmer kan plannen met kleinere eenheden. Hub-and-spoke concepten bieden ook meer kansen door grote schepen/konvooi en op grote vaarwegen (kosten efficiency) in combinatie met kleine eenheden op de kleinere vaarwegen.
Digitalisering van binnenvaartinformatie binnen de supply chain is nog laag. Dit vergt verbetering om de sector aantrekkelijker te houden als modaliteit in (multimodale) logistieke ketens.

Q: Wat zijn de drivers voor de ontwikkeling van deze techniek?

A:
De huidige capaciteit van de vaarwegen wordt nog onbenut. De vraag naar transport zal niet afnemen in de toekomst. Maar efficiënter en duurzamer vervoeren over water zal dan een driver zijn om meer over het water te voeren.
Bestaande schepen gaan wel erg lang mee en doorgaans operationele kosten voor oudere schepen laag. Nieuwe schepen zijn relatief duur door hoge CAPEX kosten.
Personeel besparen is een trend voor kostenverlaging. Maar in hoeverre gaat een autonoom systeem echt kostenbesparing opleveren door mogelijke extra investeringen in hardware en software?
Het kan een noodzaak worden om autonoom te gaan varen door een toename van vervoersvraag en een toenemend tekort aan personeel.
Maatschappelijke waarde door meer veiligheid. Verzekeringen en havenbedrijven kunnen bijvoorbeeld gereduceerde tarieven introduceren bij schepen die schoner of veiliger zijn.
Havenbedrijven/gemeentes doen dit al o.b.v. Green Award-certificaat. Andere bonus-/malusregelingen in toekomst zijn goed mogelijk.

Q: Wat zijn de remmende factoren?
A:
Het is nog twijfelachtig of autonomie wel echt voor een kostenbesparing zorgt
- Aansprakelijkheid wetgeving
- Investeringen
- Vervroegde afschrijving van bestaande schepen doordat partijen nieuwe schepen willen hebben
  - Resulteert in actoren die druk gaan uitoefenen tegen verandering
- Communicatie tussen mens en machine. Slechte communicatie kan tot gevolg hebben dat autonome schepen met een slakkengang gaan varen langs (varende) objecten

Q: Zal schaalvergroting ook door blijven gaan in de binnenvaart?
A:
Nee, autonomie kan mogelijk leiden tot een betere inzet van schepen wat kansen biedt aan kleinere concepten. Door de blauwe golf (afstemming van brug en sluis op het schip) en bijvoorbeeld de lego-bakken (kleinere autonome bakken) kan de transportcapaciteit efficiënter worden ingezet.

Q: Moet er dan ook veel worden veranderd aan de huidige infra?
A:
Dat valt mee, huidige auto’s zoals een tesla doen alles op basis van de huidige wegomgeving. Huidige schepen kunnen ook al, bij een stabiele internetverbinding, op afstand worden overgenomen. Echter heeft het besturen van een schip andere uitdagingen, bijvoorbeeld bij wisselende weers- en hydrodynamische omstandigheden op relatief korte afstand (b.v. andere windrichting bij passeren kunstwerk). Vraag is hoe snel en efficiënt een computer hierop kan anticiperen en wat het effect en de interactie zal zijn in een hybride situatie: autonome en niet-autonome schepen. Een schipper heeft vaak veel ervaring en anticipeert vaak vooraf o.b.v. kennis omgeving en over de vaarweg. Vergeleken met een auto is een schip erg lastig te besturen en reageert trager op input.
Kanalen geven de beste stabiele omgeving voor introductie en testen van autonome schepen.
CONCLUSION FOR REFERENCE:

Drivers:
- Better/effectiever gebruik van de capaciteit (meer flexibiliteit)
- Duurzamer vervoer
- Personeelsbesparing
- Personeelstekort oplossen
- Hogere veiligheid

Future shaping factors:
- Wetgeving over aansprakelijkheid opstellen
- Barrières voor nieuwe investeringen
  - Oudere schepen kunnen vaak relatief goedkoop varen (lage kosten)
  - Door overcapaciteit en lange levensduur beperkt ruimte voor vernieuwing/capaciteitsuitbreiding
- Man to machine communicatie lastig

Other:
- Schaalvergroting zal afremmen
  - Meer ruimte voor kleinere geautomatiseerde scheepsconcepten die efficiënter kunnen worden ingepland/ingezet
- Hub-and-spoke netwerken waar kleine schepen op kleine vaarwateren varen en grote schepen/combinaties op grote vaarwateren.
- Container (als voornaamste groeimarkt) en tankvaart als eerste marktniches vanwege grote rederijen die dit beheren
- Modulaire (autonome) bakken binnen havens mogelijk
Appendix G: Expert workshop report

Workshop verslag d.d. 4 juni 2019

1. Introductie door experts


Therry van der Burgt: IT Architect bij het CIV. Werkt ook aan een Europees project waarin vaarwegbeheerders zich voorbereiden op digitalisering en ontwikkelingen daarin.

Christiaan van der Maarel: Architect landelijke brug en sluisstandaarden bij GPO.

Anton Huurman: VWM; Expert op het gebied van brug en sluisbediening, ligplaatsbeleid, sluisplanning.

Anja van der Sluijs: Vaarwegontwerp en inrichting. Ook werkzaam (geweest) bij het projectteam Smart Shipping van RWS.

Wilco Meijerink: Adviseur (hydraulica bij) waterbouwkundige kunstwerken bij RWS.

2. Introductie van het onderzoek

Doel: onderzoeken van de digitale en fysieke implicaties van Smart shipping op de infrastructuur van RWS.

Voorafgaand aan deze workshop zijn er interviews geweest met 9 experts die allemaal kennis hebben van innovatie in de binnenvaart. Hieruit zijn trends en factoren gevonden die de scenario assen hebben bepaald. En aan de hand van de kennis van de experts en de scenario assen zijn de scenario’s A t/m D ontwikkeld.

Deze workshop is bedoeld om meer kennis te vergaren over de digitale en fysieke implicaties van deze scenario’s voor de infrastructuur van RWS.

Opgemerkt werd dat Smart shipping nader zou moeten worden gedefinieerd. Een gangbare definitie is: ‘het in verregaande mate geautomatiseerd varen van schepen’. Echter zullen effecten per niveau van automatisering verschillen, terwijl er sprake zal zijn van een lange transitiefase, waarin de huidige schepen aanwezig zullen zijn, gecombineerd met een groeiend aandeel min of meer geautomatiseerde schepen.

3. Scenario validatie

In een discussie met de experts konden er geen inconsistenties worden gevonden. De scenario’s lijken aannemelijk. Enige opheldering was nodig over wat de assen betekenden en wat er precies met ‘in de haarvaten’ werd bedoeld.

Bij het bediscussiëren van scenario C en D werd nog wel opgemerkt dat uberfreight meer een concept zou zijn voor scenario D in plaats van C.

De factoren zijn wellicht niet volledig de tegenovergestelden van elkaar. Dieper ingaan op de factoren kan andere assen geven en wellicht andere, meer orthogonale, scenario’s.

4. Scenario A discussie

Gezien het feit dat scenario A als eerste werd behandeld, kwam hier ook de meeste input op. De algemene discussie over autonome schepen brak los, maar na sturing wat dit scenario precies voor implicaties zou hebben is de discussie op de volgende conclusies gekomen. Op het gebied van communicatie zal er moeten worden overgegaan op digitale communicatie. Licht en geluidssignalen zoals die nu ook al bestaan zouden hierin mee kunnen spelen om te communiceren met niet digitale waterweggebruikers. Echter kan hierin ook een conservatieve positie worden gekozen, waarin autonome schepen vlot en veilig met de huidige infrastructuur overweg moeten kunnen. De vraag is dus hoeveel investeringsbereidheid en budget er beschikbaar is vanuit de overheid.

In het geval dat budget wel aanwezig is, dan ligt voor Rijkswaterstaat de nadruk op wie de verantwoordelijkheid voor de datavoorziening krijgt. Autonome schepen zouden afhankelijk kunnen zijn van informatie vanaf de wal of informatie die zij zelf vergaren door middel van sensoren. Qua implicaties voor RWS zou een datavoorziening vanaf RWS de meeste impact
hebben. RWS zou dan alle vaarweggebruikers, vaarweginformatie en omgevingsfactoren digitaal in kaart moeten brengen. Object Data Services (ODS) samen met ENC-kaarten zijn hierin al een bestaand concept bij RWS, maar zal nog ver moeten worden uitgebreid. Dit kan in verschillende situaties ook neer komen op digitale peilschalen bij bruggen of een countdown tot de volgende bruggopening. RWS moet zelf gaan bepalen in welke mate zij hierin de voorloper gaan zijn. Er kan ook gekozen worden voor een onafhankelijke ontwikkeling van de techniek waarin de schepen met huidige infra zelf de afstemming met elkaar moeten verzorgen. Er ligt een nadruk op verantwoordelijkheid en betrouwbaarheid. De huidige juridische status quo zal moeten worden veranderd. Zoals het nu gaat is het veilig, maar met autonome schepen zal dit gaan veranderen.

Een implicatie van de vlootverandering werd niet gevonden tijdens de discussie. Dit werd mede veroorzaakt doordat RWS de kleine vaarwegen meestal niet beheert en hier waarschijnlijk wel de aanpassingen moeten gebeuren als er meer kleine schepen komen. Vaak in beheer van gemeentes, en die hebben weinig middelen om zulke vaarwegen radicaal te veranderen.

Een algemene conclusie is dat er altijd een mix zal zijn tussen handgestuurde (recreatie)vaart en autonome vrachtschepen.

Mocht RWS data gaan voorzien aan de schepen, dan moet dit ook Europees worden geregeld. Als dit niet gebeurt zullen de autonome schepen landgebonden zijn, wat onwenselijk is voor de doorstroming van vrachtvaart.


Er is een doorkruisende scenario as waarin de overheid veel investeert of weinig investeert in vernieuwing. Dit gaat veel effect hebben op de ontwikkeling. Sluiswanden worden niet zomaar klaargemaakt voor autonoom afmeren gezien de hoge kosten en ook de diversiteit in schepen. Gevolg van het autonome afmeren is dat remmingwerken soberder –zonder loopvoorziening- uitgevoerd kunnen worden.

Qua fysieke implicaties is de verwachting dat er weinig aan de sluisen moet worden veranderd in het geval van autonome schepen. Een autonoom schip zal echter vragen om nieuwe afmeermogelijkheden. Het in en uitvaren zal niet veel anders gaan dan het huidige ontwerp.

Binnen en buiten de sluis zal er moeten worden geïnvoereerd op het gebied van autonoom afmeren. Technieken als zuignappen en magneten zijn lastig met de diversiteit aan schepen en het feit dat veel schepen afgeladen zijn. Hierdoor ligt de vlakte huid van het schip onder water. Daarnaast werken hoge investeringskosten de integratie van zulke systemen ook tegen.

**Opmerking vanuit de groep:** Duidelijk maken dat er meer kleine schepen komen in dit scenario, die zowel in de kleine als in de grote vaarwegen kunnen varen. Dit kan zich ook uiten als modulaire bakken die deelnemen aan kleinere vaarwegen c.q. havenbekkens en groeperen op grotere vaarwegen.

5. **Scenario B discussie**


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Om dit scenario op de bestaande vaarweg van de grond te krijgen zouden er speciale vaargeulen moeten komen die duidelijk worden afgebakend door middel van fysieke en wellicht ook virtuele boeien. Dit is qua doorstroming alleen mogelijk op vaarwegen waar ruimte over is, of in grote havens. Veel vaarwegen zijn echter ontworpen op het huidige verkeer. Ruimte voor een extra vaargeul past hier vaak niet in. Voor de experts is dit nog lastig om als werkelijkheid te zien. Vooral gezien de hoge kosten die aan dit scenario zitten, de onduidelijke voordelen en het gebrek aan ruimte op de vaarwegen. Veel barrières die dit scenario tegen zitten. Regelgeving zou moeten worden aangepast om dit te faciliteren. Maar bijvoorbeeld het afsluiten van een publieke vaarweg voor slechts autonome schepen is geen mogelijkheid volgens de experts. Remote control zou nog een mogelijkheid kunnen zijn binnen dit scenario. Je loopt dan tegen andere problemen aan, maar het zou misschien zonder speciale vaargeulen kunnen. Daarnaast is digitaal infrastructuur minder belangrijk dan bij scenario A.

6. Scenario C discussie

In dit scenario zal de binnenvaartmarkt niet veel veranderen t.o.v. nu. Hierdoor begin het wel meer druk om op kostenverlaging van infrastructuur. Meer standaardisering/ uniformering van bouw van infrastructuur kan zorgen voor hogere kwaliteit en lagere kosten van de infrastructuur. Infrastructuur vraagt hierin om meer data van de scheepvaart. Informatiesystemen kunnen worden geoptimaliseerd met de huidige beschikbare technieken om kostenreductie te behalen, maar hiervoor is wel medewerking van, en datadeling door, de schippers nodig. De infrastructuur gaat in dit scenario de scheepvaart helpen door een betere doorstroming te faciliteren op basis van meer data-uitwisseling. Corridormanagement zal dus nog belangrijker worden en beter moeten om ook te concurreren met het wegvervoer. Vanuit RWS vraag naar contractuele datadeling/ eigenaarschap van data. Voorkomen dat RWS moet betalen om initieel zelf ingewonnen data te verkrijgen van derden. Schepen en infra realisator onder contract datadelen, zodat niet alleen de scheepsbouwer of infrastructuurboerner de performedata terugkrijgt maar ook RWS alle informatie mag gebruiken. Om doorstroming ook nog verder te verbeteren zou er kunnen worden gekeken naar hoe schepen sneller door slui zen en bruggen heen varen met de huidige technieken. Schippers verleiden ’s nachts te varen, betere aanvaarroutes, etc. Er moet wel opgelet worden dat de hele keten wordt verbeterd en dat niet RWS zo snel mogelijk alle schepen door haar corridors laat varen en uiteindelijk de havens overbelast raken. Samenwerking met havens en buitenland.

7. Scenario D discussie

Dit scenario laat meer zien dat bedrijven samen gaan werken om schaalvoordelen uit samenwerking te halen. Dit scenario is niet erg gekoppeld aan techniek, maar meer aan marktontwikkelingen. Uberfreight, zoals dit in scenario C staat, kan wellicht beter in Scenario D. Dit omdat schippers zich makkelijk kunnen aansluiten bij zo’n platform. Dan zit de schipper niet vast aan een rederij, maar aan een digitaal platform. De bevrachter als actor valt er dan tussenuit. Vraag gaat directer van aanbod naar vraag. Het samenvoegen van vele bedrijven/schepen kan wel tot conglomeraties gaan leiden die een volwaardiger gesprekspartner zouden kunnen zijn en mogelijk meer druk uitoefenen op Rijkswaterstaat. Daarnaast kan de logistieke keten volledig worden geoptimaliseerd, of de doorstroming volledig optimaliseren. Hierin zal een tussenweg moeten worden gevonden. Echter zal RWS hierin vooral voor de doorstroming zorgen. Als puur de logistiek wordt geoptimaliseerd kan het zijn dat een schip met een late deadline langer voor de sluis moet wachten dan een schip wat snel ergens moet zijn. Duurzaamheid kan ook nog een belangrijke factor zijn in de ontwikkeling van slimme technieken. Er wordt erkend dat dit belangrijk is, maar dit is niet de scope van dit onderzoek.