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Innovative Green Inland Waterway Shipping Developments in Ghent and Le Havre

- Learning Outcomes for Sweden

Master's thesis in Supply Chain Management

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Abstract

Sweden is looking to be free from fossil fuels by 2045 and create sustainability in the transportation sector. One approach is to utilize the underdeveloped inland waterways of Sweden, since inland waterway shipping has been proved to be more environmentally friendly compared to other transportation methods such as road transportation. Thus, the purpose of this study is to investigate innovative green inland waterway shipping cases in leading European countries, such as Belgium and France, to identify key learnings for the Swedish case in order to facilitate a modal shift from land to inland waterways transportation network.

The study uses a qualitative approach to conduct interviews with industry and governmental stakeholders in four different case settings, namely Gothenburg, Stockholm, Ghent and Le Havre. The case settings along with the findings are then compared to each other and current theory regarding topics related to new technology and innovation, such as government policies and stakeholder collaboration, but also technical aspects such as crane operations, automation and other industry 4.0 related topics.

This study provides valuable insights for Sweden and other regions in how new technologies and innovation can benefit a modal shift to inland waterways. Moreover, the aspects which affect and are affected by new technologies and innovation are also investigated to form a holistic viewpoint. The study resulted in two main conclusions, the first of which is related to the importance of not only considering technical aspects, but also other aspects which affect the technical such as governmental policies and stakeholder collaboration. The second key conclusion is related to the maturity and complexity of the different settings, and how it affects the learnability for the different settings.

Keywords: Inland Waterways, Inland Waterway Transportation, Freight Transportation, Modal shift, Innovative Technologies, Industry 4.0, Waterway Infrastructure, Waterway Development.

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Shortening and Terminology

Barge	A flat-bottomed vessel primarily used for transporting goods through inland waterways and canals.
EoS	Economies of scale. The reduction of cost per unit the output volume increases.
Hinterland	The land behind coastal areas and river shorelines.
Intermodal transportation	Transport movement where the goods are stored within the same loading unit and carried by two or more transport modes.
IWMO	Inland Waterway Management Operation. The administration and maintenance of navigable rivers, canals, and lakes.
IWS	Inland Waterway Shipping. Vessels transporting goods on inland waterways, e.g. lakes and canals.
IWW	Inland Waterway. A navigable route such as a river, canal, or lake used for transporting goods and passengers.
Last-mile delivery	The final stage of the logistics process where a package is transported from a distribution center to the customer's doorstep.
Modal shift	Transfer road freight to other modes of transport.
Supply chain	The system of actors, resources and information involved when a product or service is distributed from a supplier to a customer.
Tow-boat	A boat designed for pushing or pulling barges and other vessels, typically used on rivers and canals.
Transshipment	The process of unloading cargo from one vehicle/ vessel/train/plane and loading it onto another during the same transport route.
Vessel	A ship or boat designed for transporting goods or passengers over water.

1. Introduction

In this chapter, the study is presented in accordance with the relevant background to the research study. The purpose of the study is presented along with the research questions. Lastly, the limitations of the study are described.

1.1 Background

The landscape of goods transportation is witnessing a transformative shift driven by multiple factors (Engström & Abrahamsson, 2019). The escalating congestion and rising costs associated with road transportation in Sweden, in combination with an increased emphasis on sustainability commitments, have pushed companies to explore alternative ways of transporting goods. Considering sustainability, the exploration of the advantages and disadvantages of an intermodal change towards inland waterway shipping is comprehensively addressed by Grauers and Persson (2016). This imperative has also received attention from the Swedish government, prompting a focus on promoting sea transport as a viable and sustainable solution (Regeringen och Regeringskansliet, 2023). Therefore, it is of high importance to study what technologies can be implemented in order to reduce the environmental impact on Inland Waterway Shipping (IWS) further (Marinò & Bucci, 2018).

As Sweden navigates a path towards becoming the first country free from fossil fuels by 2045 (Regeringen och Regeringskansliet, 2023), the government's plan emphasizes the significance of increasing transport efficiency, reducing and eliminating emissions, by developing new fuels, transport modes and solutions. In an effort to achieve this goal, the Swedish government implemented legislation from the European Union in 2014, in which sea transport is encouraged. Additionally, the Swedish Transport Agency, Transportstyrelsen, has evaluated the classification of several water areas as inland waterways, showcasing a commitment to fostering an environment which encourages waterway transport development (*Zoner Inlandssjöfart - Transportstyrelsen*, n.d.). However, the vast majority of shipping companies in Sweden have yet to change with reasons such as high investment and running costs, which are further explained by Otterström and Torpfält (2016).

Currently, inland waterways in Sweden play a marginal role in national shipping, accounting for merely 3% of goods transported via sea routes and a mere 0.7% utilizing inland waterways (Garberg, 2016). This underutilization represents a significant opportunity for a substantial upswing in waterway transport. To comprehend the potential for such a shift, it is essential to examine the experiences of other European countries that have made efforts in implementing efficient inland waterway shipping solutions. Why this shift has yet to be

implemented is explained by Rogerson et al. (2019), where the main barriers of a modal transition towards inland waterway shipping in Sweden are investigated.

Countries such as France and Belgium have already implemented or are in the process of establishing effective inland waterway shipping solutions (Specht et al., 2022). In 2022, the two mentioned countries, together with Germany and the Netherlands, were responsible for more than 99,5% of the total EU flow of goods shipping though containers on inland waterways (Ec Europa, 2023). Thus, the current developments of the leading countries mirror what Swedish development lacks. In Ghent and Le Havre, several companies are using innovative technologies and practices in inland waterway transportation that enhances efficiency and effectiveness. Therefore, there is a huge learnability potential for green solutions in which a modal shift is encouraged.

1.2 Purpose

The purpose of the study is to investigate innovative green inland waterway shipping cases in Belgium and France to identify key learnings for the Swedish case in order to facilitate a modal shift from land to inland waterways transportation network.

1.3 Clarification of Questions

In alignment with the study's objectives, two distinct research questions have been formulated to guide the investigation. In order to understand the study, it is necessary to have a question related to the current situation and identify some key characteristics for the setting of the Inland Waterway Shipping (IWS) when comparing Gothenburg, Stockholm, Ghent and Le Havre. The first question is designed to compare the setting considering innovative technologies, techniques, and operational methodologies. Therefore, the first question of the study is phrased as following:

1. *What similarities and differences can be found when comparing the green and innovative development of barge transportation on inland waterways with the settings in Gothenburg, Stockholm, Ghent and Le Havre?*

Moving to the second and last question, the primary objective is to use the characteristics found in the first question and identify key learnings to facilitate a modal shift. Since a significant shift is underway and inevitable, it is important to study how it can be used to enhance and optimize the efficiency, effectiveness and sustainability of the inland waterway transport system in Sweden, specifically between Gothenburg and Stockholm. The last question of the study is therefore phrased as following:

2. *What learnings from similarities and differences between Gothenburg, Stockholm, Ghent and Le Havre's inland waterway shipping can be used to facilitate a modal shift to the inland waterway shipping network?*

1.4 Limitations

The primary limitation of this study relates to its geographical scope. Specifically, the research will concentrate on the realization of inland waterway shipping (IWS) within the urban region surrounding both Gothenburg and Stockholm in Sweden by comparing with the urban IWS environment in Ghent and Le Havre. Considering the different settings, the findings are not directly applicable. However, the learnings might be helpful in the development of the respective inland waterways (IWWs).

Furthermore, the study's data and insights, which entails innovative technologies, techniques, and operational methodologies, will predominantly be derived from companies situated in Sweden, Belgium and France. These nations host some of the partner companies associated with the InnoWatr project. Consequently, it is crucial to acknowledge that the study might assume a direct applicability of its findings to the context of Sweden. The geographical concentration and affiliations with RISE imply that the results may be most directly relevant to the specified regions and organizations, potentially limiting the generalizability of the findings to a broader context. In addition, it is also noteworthy that a focal point of the InnoWatr project is innovations and new technologies.

1.5 Outline

This subsection presents the outline of the report, which is a concise description of all major sections in the study. Some smaller descriptions of relevant subsections are also presented under the outline.

1. *Introduction*

A general description of the background for the study is presented followed by the purpose, clarification of the research questions and limitations that are of scope for the study.

2. *Method*

The method section of the study explains how the study was conducted by partly presenting a description of the research strategy, research design and the process of the research. Additionally, a description of the literature study and the data collection are also presented under this chapter.

3. *Frame of References*

In the section frame of reference, relevant scientific articles are studied as a means to gain knowledge about IWS and its transport system in particular to be able to compare the qualitative research and the previously established frameworks.

4. *Empirical data*

This chapter presents information gained by the interviews conducted related to the research questions presented in the introduction.

5. *Analysis*

The analysis of the report discusses how the empirical findings are related to previous studies presented in the frame of reference.

6. *Discussion*

The interview results from all respondents are discussed in this section based on several topics that were mainly presented by the stakeholders.

7. *Conclusion*

The conclusion presents clear answers to the research questions which are discussed in accordance with it.

8. *Recommendations*

In this chapter, recommendations for future studies based on the current research are presented.

9. *References*

All references used in the study are listed under this section.

10. *Appendix*

Relevant appendices are presented at the end to enhance the understanding of the study.

2. Methodology

This chapter presents a detailed description of the methodology that is used to study this thesis. The research strategy, research design and research process are described at the beginning of the chapter. Then, the literature study and data collection are presented followed by the selection of interviewees. At the end of the chapter, dimensions such as reliability, validity, trustworthiness, ethics and morality are described.

2.1 Research Strategy

The chosen method for this thesis is a qualitative approach. The qualitative method is the collection of data that is made when conducting interviews in order to be able to answer the research questions provided by the students (Fleetwood, 2023). The answer from the interviewees creates the foundation for the findings. Furthermore, the interviews are semi-structured, meaning that most questions are sent to the interviewees in advance in order for the respondents to be prepared for their interview. All questions that were sent to each respondent in advance are presented under appendices I-X. The rest of the questions are not prepared and can be asked spontaneously during the ongoing interview. These types of interviews are normally around 30 minutes to one hour and are only conducted once (Flick, 1998). The reason for choosing semi-structured interviews as a research method is that it combines both a structured and an unstructured interview, therefore offering advantages from both methods. A semi-structured interview allows for a more flexible and spontaneous exploration of topics and themes that can be of high importance for both the specific interviewee and for a successful report (Jamshed, 2014).

Given the open format of a semi-structured interview approach, it is recommended to utilize recording tools during the interviews due to unexpected tangents that can arise, which makes it difficult for the interviewers to take notes simultaneously. By recording the ongoing interview, it will enhance the efficiency of gathering all data coming from the interviewees while also eliminating the risk of missing any relevant information (Flick, 1998). However, asking for the respondents consent of recording the semi-structured interview in advance is essential for the interviewees to feel safe, open and have the opportunity to familiarize themselves with boundaries of what the stakeholders can discuss during the interview or not.

2.2 Research Design

Since the case already was pre-defined by RISE (Research Institute of Sweden), the design of the research can therefore be classified as a case study. A case study is described as a detailed study of a specific event and is commonly used in business research (McCombes, 2023). Considering that a case study encompasses

a specific instance, the necessity to do a comprehensive examination and analysis from a theoretical perspective is required (Bryman & Bell, 2015). By having a pre-defined case where the aim is to investigate innovative green IWS cases in leading European countries to identify key learnings for the Swedish case, using a qualitative method to make this study is essential. The qualitative research strategy can enable a deeper understanding of intricate relationships in the study and can therefore afford a nuanced comprehension of the situation characterized by depth rather than width (Peterson, 2019). Additionally, the qualitative research strategy facilitates the examination of factor behavior in diverse social contexts. Since the study focuses on the IWS in Gothenburg, Stockholm, Ghent and Le Havre, it is inevitable that the diversity of the social contexts can affect the outcome of the study as well. In order to facilitate a comprehensive analysis of the collected data, a literature review has been employed in order to create a theoretical framework as the foundation for the analysis.

2.3 Research Process

This section focuses on the research process, which entails information in an organized way of how this study was made, from starting point to presentation (Singh, 2021). The research process can also be presented as a figure, as shown in Figure 1 which illustrates the process of this study.

During the initial meeting with RISE, the subject and scope of the study were already pre-defined. This enabled a more seamless start of the project through discussions of the scope and the introduction of the project. The supervisors from RISE also presented some relevant academic literature during the start-up meeting in order to dive into the scope, which made it feasible to begin with the next part of the process along with finding other related articles and books as well. An initial background could then be made and written based on the articles both found and provided. When studying the literature, an introduction to the case study was written and a choice of method was determined. During the study of the literature, some limitations for the study were also determined. After studying the literature, an initial frame of references for the case was created. However, additional relevant data was researched during the literature study process, which gave more context and was therefore included. During the project, the supervisors provided essential stakeholders from Gothenburg, Stockholm Ghent and Le Havre that could participate in interviews for the study. When finding out which stakeholders were going to be interviewed, a study of the organization and their projects was made in order to ask relevant questions depending on the stakeholder's area of expertise. Data about the different settings and stakeholders that the interviewees represented was collected to have a deeper understanding of the different contexts. Interview questions were sent to relevant stakeholders, and interviews were scheduled before visiting the stakeholders. During the interviews, transcriptions and recordings were made in order to, more

seamlessly, start writing the empirical findings from the interviews. An initial analysis could then be made with support from the frame of references through sorting and categorization of data as well as triangulation of sources (Thurmond, 2001). After the analysis, a discussion was presented where focal topics were handpicked and discussed based on the findings. Then, conclusions were drawn after the study. The presentation of the study was held after the report was finished followed by an opposition.

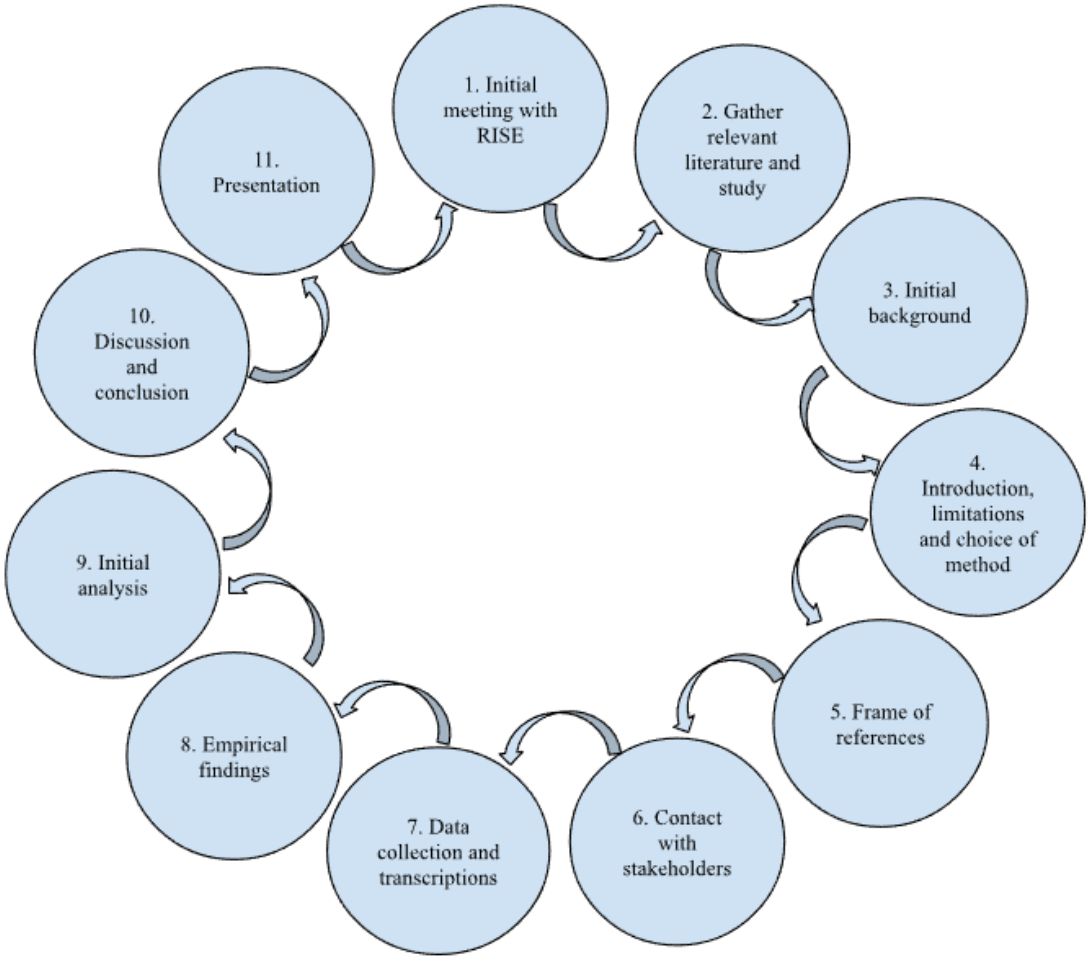

Figure 1 A visualization of the research process

2.4 Literature Study

In order to address the research questions and objectives of the study in an optimal manner, a literature review was conducted. Through a literature review, the study's significance is enhanced since the authors obtain greater knowledge concerning the selection of relevant literature (Bryman & Bell, 2017). Due to this, it is essential that the studied literature is scholarly in the form of original articles that are published in scientific journals. As mentioned, the literature review was partly provided by RISE and recommended by the supervisor of this study. More literature was found through different tools, such as Google Scholar, OneSearch, DiVa Portal and Chalmers Library. When searching for scientific data regarding

the Swedish IWS, the search was mainly done in both Swedish and English, and only in English for international IWS. Through a comprehensive review of the current literature and several bibliographies, essential references were identified and carefully studied, which were then used as a major source of crucial information to support the initial stages of the study (Bryman & Bell, 2015).

In order to find relevant articles and books for the study, keywords were configured. When the need to delimit the literature further, multiple keywords were employed simultaneously (Bryman & Bell, 2017). Examples of keywords that were configured for this study are: inland waterway shipping, inland waterway shipping, type of modal, shipping, transportation systems and transportation in Sweden.

2.5 Data Collection

An interview guide was created containing relevant subjects prior to all meetings with the respondents. The sequence of the questions was adjusted during the interviews. The interviews achieved high quality since the respondents could combine their reality of the questions all while maintaining flexibility in their answers, which is essential for a successful study (Dalen et al., 2015). Due to the fact that interview questions were sent to key stakeholders in advance, it was essential to ensure that the questions were written and could be answered in a feasible way. Therefore, the interview guide underwent evaluations with the authors of the study, the supervisor from the university and the supervisors from RISE, before being presented to the stakeholders. Lastly, all interviews were conducted in place, and if not, they were conducted using the Microsoft Teams application which serves as a digital meeting space. Through Microsoft Teams, both authors and respondents could see and hear each other which created an inviting environment to achieve optimal results for the objective (Shukla et al., 2022).

Other actions taken to avoid any upcoming errors during the interviews included not specifying any ending time, which provided the respondents space to speak more freely without stressing over a limited time. However, some interviews included strict time limitations resulting in a potentially more stressed environment. Therefore, it was essential to keep focus on the subject during the interviews and not have discussions that were outside of scope of the study (Pettersson, 2012). In order to do this, the ‘area principle’ presented by Dalen et al. (2015) was used, which is a method where the authors initiate the interview with questions centered around the study’s main themes, which subsequently will lead the interview into the key aspects of the study.

2.6 Selection of Respondents

Since the study was pre-defined by RISE, the selection of respondents was already decided and provided. At the beginning of the study, it was planned to interview key stakeholders from Belgium, France, Germany and Netherlands, which are a part of the Interreg project and partners with RISE. Therefore, the selection of interviewees were specific companies within the established network. However, since the stakeholders from Germany and Netherlands could not participate, the stakeholders from Ghent and Le Havre were chosen.

In order to obtain consent from each stakeholder, an information letter was sent by email. The email briefly described who the authors were and what the participation of the interview would entail for the study. The email also informed how the stakeholder's personal information would be handled, which was recommended by Dalen et al. (2015). The information letter served as the initial contact email to the respondents and should be easy to read to enhance respondent understanding and avoid any misunderstandings.

Table 1 presents a compilation of the selected respondents' titles and experiences. In total, seven interviews were conducted where three were from Sweden, five from Ghent, Belgium and two from Le Havre, France. All respondents hold experience of working within the shipping industry and work with shipping related questions on a daily basis.

Tabell 1. A list of all interviewees with their role and experience.

Interviewees	Data Collection	Role and experience
Interviewee 1: Peter Årnes	Study visit and one conducted interview	A supporting function with development questions for stakeholders in Gothenburg. He is also responsible for contracting between the municipality and specific private actors. Has a background in the waste industry since 1979 and has recently worked with operational and work management related questions at "Kretslopp & Vatten" for 11 years, which is a governmental administration for water based in the province of Västra Götaland, Sweden.
Interviewee 2: Amanda Baumgartner	One digital interview.	Employed as a strategist at Trafikkontoret for the City of Stockholm where the responsibilities entail advancing sustainable transportation solutions within the systemic framework of Stockholm Municipality. Historical focus has also revolved around freight transportation. Has 7 years of experience in total.

Interviewee 3: Johan Lantz	One digital interview.	CEO of 9 years for Avatar Logistics in Stockholm, Sweden, which is a company which develops solutions for IWW. The CEOt has 42 years of work experience within the transportation industry.
Interviewee 4: Danny Vanrijkel	Study visit and one conducted interview.	Founder and main responsible for Fabriek Logistiek in Ghent, Belgium. Contain a background as a project manager. Has 15 years of experience within the development agency POM in East Flanders.
Interviewee 5: Erik Doets	Study visit and one conducted interview.	CEO of Thienpont, a company repurposing waste from demolitions to building material located in Ghent, Belgium. Has 4 years of experience in the industry.
Interviewee 6: Bart Peeters	Study visit and one conducted interview.	Urban lighting advisor for the City of Ghent. Works for the municipality with questions regardings the IWWs. Has 11 years of experience.
Interviewee 7: Tom Pauwels	Study visit and one conducted interview.	Project manager at POM in East Flanders and holds 9 years of experience. Is involved in the InnoWatr project as a project partner since the beginning. Previous experiences as a postdoctoral research associate regarding transportation, mobility and waste transportation for over 20 years.
Interviewee 8: Peter Geirnaert	One digital interview.	Consultant and project manager for Urban Waterway Logistics. Works with sustainable solutions for inland waterway logistics, last mile solutions and energy applications. Has over 30 years of experience in the field.
Interviewee 9: Muriel Andurand	One digital interview.	European Project Manager for CIRCOÈ. Focuses on gaining and leading mostly french projects for the organization. He has 3 years of experience in the field.
Interviewee 10: Peyrot Gilles	One digital interview.	Managing Director at Sogestran and holds around 25 years of experience in the industry. The organization is mostly focusing on inland navigation and maritime transport solutions.

2.7 Reliability

Reliability refers to the extent to which measurements are conducted in a consistent and dependable manner, and the degree to which the results can be achieved if the study were to be conducted again in the future. Reliability can also involve whether the study is influenced by temporary or miscellaneous conditions (Bryman, 2018). The reliability of this study can be strengthened by conducting multiple interviews with experts in the field, which in this case is the green

shipping industry. The prepared interview questions were formulated in a simple and understandable manner in order to avoid any potential misinterpretations. As mentioned before, the interview questions were also sent to all participants in advance in order for them to be prepared with answers.

2.8 Validity

Validity refers to the measurement of only using that is intended to be measured. It is about the relevance of measurements, specifically the extent to which a study truly measures what it intends to measure (Bryman, 2018). Within this study, there is a risk associated with incorporating interviews with stakeholders from the same city as it involves opinions and experiences from stakeholders working in the same setting. However, since the purpose of the study is to investigate innovative green inland waterway shipping cases in leading European countries to identify key learnings for the Swedish case, thus mitigating concerns of threats affecting the validity. Also, while a qualitative research strategy can provide greater insights, it is essential to be aware of potential biases that can affect the results (Leung, 2015). The author highlighted this issue by arguing that if a specific stakeholder expresses strong opinions during an interview, it could be related to a personal bias. This should then be taken into consideration when conducting the analysis and be treated cautiously.

2.9 Trustworthiness

Trustworthiness in a qualitative study is imperative in order to support the study. This can be done by looking at four different criteria that were taken into consideration in order to ensure a high level quality and trustworthiness of the research. These criteria are credibility, transferability, dependability and confirmability (Norman et al., 2020). Table 2 presents these criteria with a short description of them and the activities that were done in order to achieve the purpose.

Tabell 2. The four criterias to achieve trustworthiness in a study.

Criteria	Purpose	Activities
Credibility	Establishing credibility ensures that the findings and interpretations of the research are accurate and trustworthy.	Conducted interviews with several key stakeholders in the field along with studying previous literature and scientific studies. Data triangulation. Doing research on how to conduct appropriate interviews for the study. Doing research of relevant theories that can support the empirical findings.
Transferability	Transferability assesses the extent to which the findings of the study can be applied or transferred and generalized to other contexts and studies.	Providing an exceptional background description of the field and research context
Dependability	Dependability ensures that the research findings are consistent and reliable over time and under various conditions.	Providing a detailed description of the chosen method Presenting a track record of the data collected by the respondents
Confirmability	Confirmability aims to maintain objectivity and ensure that the findings of the research are based on the data collected rather than the biases or perspectives of the researcher.	Ensuring that weekly journals and meetings were conducted with supervisors and partners from RISE.

2.10 Ethics and Morality

Ethics and morality play a vital role in research studies when involving external participants in interviews. Ensuring anonymity, confidentiality and informed consent of the participants is essential in order to create a safe space for the participants during the study (Ifariyike, 2020). Due to this, the authors carefully considered the potential harm of stakeholders. This study puts emphasis on investigating innovative green IWS cases in leading European countries to identify key learnings for the Swedish case in order to attract goods flows from land to inland waterways transportation network. If the stakeholders had controversial opinions on the subject, it was handled with consideration. The interview questions were formulated in a manner that ensured that all participants were not

harmed psychologically or did not potentially have a negative impact on one's career.

The interviews started with an introduction to the study by illustrating the purpose of the case and the objectives of the interviews. All participants were informed about the consent, with the option to retract statements and conclude the interview if needed. Lastly, the interviewees were asked to provide consent for recording the ongoing interviews in order to feel safe, as mentioned by Flick (1998).

3. Frame of Reference

This chapter includes a literature study of relevant areas related to inland waterways and inland waterway shipping. Benefits and challenges are presented along with the infrastructure and management operations related to inland waterways as well with several dimensions taken into consideration such as industry 4.0 and innovative technologies.

3.1 Inland Waterways

IWS is the act of transport using lakes, canals, rivers, watercourses, inlets and bays within the territory of a state. The transportation can either be done during one part of the transportation process or during the whole process (Roso et al., 2020). Waterways within a mass of land are used to transport goods, mostly within the country, in contrast to sea transportation where goods are transported from one land mass to another via seas and oceans, usually between countries (Asean AFFA, 2021).

When it comes to IWS, there are several studies that present different benefits and challenges. A summary of all the relevant benefits and challenges for the study are presented in Table 3. To begin with, the first benefit shows that freight transport is an environmentally friendly way of transport compared to the other transportation modes (Sihn et al., 2015). One reason is because of the high fuel efficiency and that maritime transport pollutes significantly less harmful particles into the air (Fu et al., 2010). In comparison with road transport, inland waterway transport could cause a significant reduction in CO_2 emissions with approximately 920 tons of CO_2 emissions per kilometer (Mako et al., 2021).

Moreover, a significant majority of organizations studied within the field mention environmental sustainability as one of the most beneficial dimensions when using IWWs (Roso et al., 2020). However, using the inland waterways to transport goods has been used in a significantly smaller manner when compared to other freight transportation modes, such as maritime-, road-, rail- and airfreight. This is shown in Figure 2, where IWW only was used for 1,8% of transportation in the EU during 2021 (Freight Transport Statistics - Modal Split, 2023).

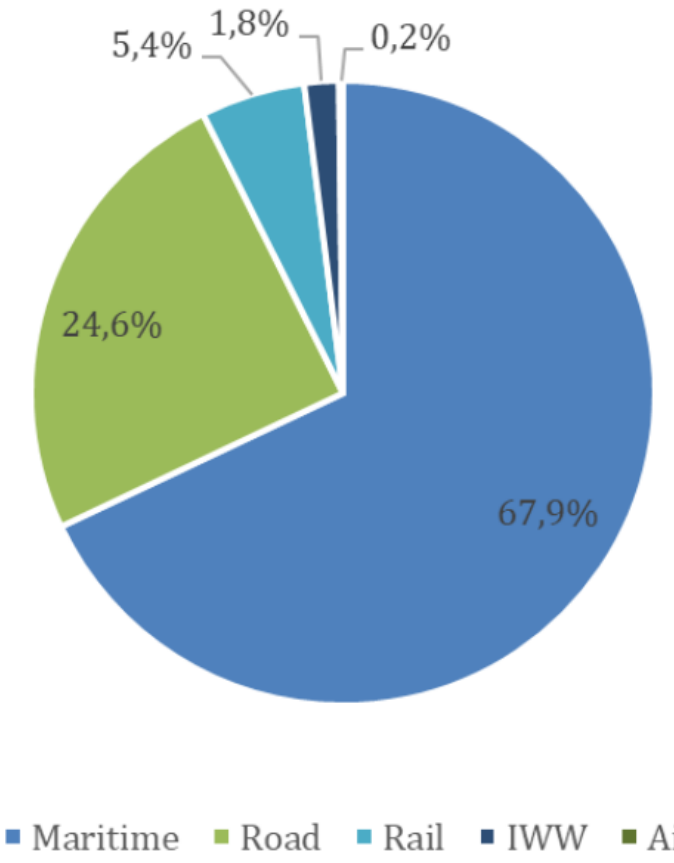

Figure 2 Freight transportation modes used in the EU during 2021 in percentage (Freight Transport Statistics - Modal Split, 2023).

Moreover, low cost appears to be one the greatest benefits when using IWW transportation due to two main reasons (Fan and Nachtmann, 2021). The first reason is Economies of Scale (EoS), since loading multiple containers onto the barge results in more room for goods to get transported compared to other transport modes. By doing this, decreased shipping costs can also be achieved due to EoS. The article mentions that shipping costs can decrease between 20% and 50% when using maritime transport compared to using road or rail. The second reason is that truck container transportation is incurred between 40-80% when it comes to inland destinations. Thus, increasing the market share could significantly diminish the share of expenses when it comes to IWWs (Fan & Nachtmann, 2021).

Another benefit of IWS is that it can decrease the amount of road traffic density and congestion by mitigating goods from the road network to the waterway network. Since the traffic density is smaller in IWW compared to road transportation, the reliability of deliveries arriving on time increases, resulting in higher customer satisfaction (Fan & Nachtmann, 2021). An example of this is the collaboration of three different Self-Propelled Container Barge (SPCB) operations between port of Cikarang and to Port of Tanjung Priok, which decreased the road

traffic congestion with 18.6% after utilizing the IWWs of Indonesia (Achmadi et al., 2018). Lastly, IWS is considered to generally be a transport mode with high safety due to several reasons, such as low number of accidents (Liu et al., 2016; Caris et al., 2014).

One of the disadvantages when operating on IWWs is the decreased navigational safety (Suhrab 2023). Collisions with infrastructure are one of the most common types of IWW accidents since most of the ships used to pass through the route are unfit most of the time. The reason for this is that operators and shippers either go against the rules or lack adequate training for the job (Uddin et al. 2017; Sulaiman et al. 2011). Although technology has developed, most operators are still limited to daytime operations when working with vessels in order to prevent accidents occurring during nighttime when vision is low (ibid.). Another disadvantage is the elongated transportation time due to the increased transit time from one destination to another in comparison with other transportation modes (Wiegmans & Konings, 2019). The elongated transportation time can also be related to a less flexible way of working when it comes to IWW due to the inadequacy of the modern "door-to-door" transportation conditions that are applied for road transport (Caris et al., 2014). The solution for IWWs lies in the synergy between road and waterway transport, since the last-mile deliveries usually cannot be facilitated via water routes. Another dimension that creates a challenge is the lowering of transportation costs by creating synergies between stakeholders, as the waterway transportation industry is embossed with high transportation costs (Roso et al., 2020). Moreover, the product characteristics can arguably be a barrier for organizations when using inland waterway shipping (Roso et al. 2020). All products have different sizes, and this can be a challenge for organizations when trying to fit the products into the barge without experiencing any difficulties and damage. In order to avoid these risks, multiple transshipments become the solution. However, this solution becomes time consuming and creates increased costs and inefficiencies.

Furthermore, the investment costs tend to become higher when utilizing IWS as a transport route (Roso et al., 2020). As an example, the diesel engine itself is a major dimension of the investment cost. Since the ships are also expected to be used for around 60 years, the investment costs become higher in comparison with other transport modes. Poor hinterland connectivity is another challenge for organizations working with IWS since it can impede the integration of IWS in the logistics chain. Limitation in the connectivity can then affect the efficiency of the transport flow of goods going back and forth from ports and therefore affect the overall efficiency of IWS negatively (Roso et al., 2009). One of these limitations consists of nature reserves, also called Natura 2000, which often have heavy regulations surrounding which vessels can pass and what infrastructure can be built to support the transportation activities. The nature reserves thus create

complexity for passing through these waterways (Maiorano et al., 2007). Besides this challenge, the limited hinterland connectivity can also affect the reliability of ports. Lastly, extreme weather conditions and climate change can affect the IWS negatively since ice jams can paralyze the IWW traffic during winter season (Caris et al. 2014; Roso et al. 2020). Even if this challenge may be seen as short-term, the long-term consequences need to be considered. Poor weather conditions can result in a reduction of maritime transport in IWW, resulting in an increase in transport by road and rail. This increase would then lead to higher congestion levels and therefore increase the CO_2 emissions since IWS is more environmentally friendly compared to road and rail transport (Jonkeren et al., 2011).

Tabell 3. Summary of some benefits and challenges with IWS with relevant sources

Benefits	**Reference(s)**	**Challenges**	**Reference(s)**
Environmentally friendly	Sihn et al. (2015), Fu et al. (2010), Jonkeren et al. (2011), Mako et al (2021)	Lack of navigational safety	Suhrab (2023), Sulaiman et al. (2011), Uddin et al. (2017)
Low costs	Fan and Nachtmann (2021)	Longer transportation time and less flexibility	Wiegmans and Konings (2019), Roso et al. (2020), Caris et al. (2014)
Reduces road traffic congestion	Achmadi et al. (2018)	Product characteristics	Roso et al. (2020)
Higher reliability of deliveries	Fan and Nachtmann (2021)	High investment costs	Roso et al. (2020)
Higher customer satisfaction	Fan and Nachtmann (2021)	Poor hinterland connectivity	Caris et al. (2014)
High safety	Liu et al. (2016), Caris et al. (2014), Fan and Nachtmann (2021)	Bad weather conditions	Caris et al. (2014), Roso et al. (2020), Jonkeren et al. (2011)

Furthermore, it is important to note the four major barriers to a modal shift to IWS in Sweden (Rogerson et al., 2019). The first barrier is the regulatory barrier, consisting of fees and legislation. This barrier is heavily dependent on governmental policies and decision making to enable changes. The second barrier is the financial barrier and constrains the modal shift to IWS by requiring heavy

investments in the development of ports and quays, as well as a high risk for the ship operator related to the vessel. The financial barrier can be overcome by committing to partnerships, ensuring high volumes of goods and continuous transportation. The third barrier is related to the service quality and is directly impacted by frequency and reliability of the transportation. To enhance this, communication between the different actors is heavily emphasized to increase time efficiency, and back-up plans were made in case it was needed. Market characteristics is the fourth and last barrier to a modal shift to IWS in Sweden, where the importance of establishing continuous goods flows were highlighted in order to conduct businesses. The market for IWS in Sweden however is very limited, thus it is needed to conduct proof-of-concept runs and engage with various actors in the industry, including ports, shippers, shipping companies, forwarders, and haulers (Rogerson et al., 2019).

3.2 Inland Waterway Infrastructure and Management Operations

This subsection is in turn divided into two separate subsections where the first one presents a general description of the inland waterway infrastructure. The second subsubsection focuses on inland waterway management and its operations (IWMO). Here, the technology perspective is also in focus where a digital transformation is presented.

3.2.1 General Inland Waterway Infrastructure

The infrastructure related to inland waterway shipping can be defined as intermodal terminals, canals, bridges and locks, and involves dimensions such as designing, building, financing and maintaining. (Lannemyr & Sommar, 2020; Wiemans & Van Duin, 2017). The management of the infrastructure is often handled by some kind of ministry, which in Sweden is Sjöfartsverket. (Engström & Abrahamsson, 2019).

A challenge regarding the infrastructure lies in the finite capacity of canals, bridges and locks. As an illustration, canals can become too narrow if larger vessels or an increased traffic volume are situated. Moreover, locks often serve as bottlenecks since skippers need to decelerate or wait for passage. In order to overcome these challenges, construction efforts are needed in order to decrease the capacity constraints (Wiemans & Van Duin, 2017). However, these investments can be challenging to implement due to their large scale and lack of political support (Wiemans & Van Duin, 2017; Mirčetić et al., 2017). When it comes to attention for the transportation modes, it is common that decision-makers prioritize fundings for road- and railways rather than waterways. The infrastructure related to inland waterways also needs maintenance and financial support. As a result, sea transportation faces market challenges and reduced competitiveness (Berechman, 2018; Wiemans & Van Duin, 2017).

The dimensions of the IWW affect the dimensions of the vessels. According to Achmadi et al. (2018), the ship's draft must be adequate to be able to operate under full load at the lowest water level. The width of the river determines the maximum breadth of the ship that can pass through the river, as well as the curves of the river affect the length of the ship. The height of the ships also has a maximum height due to the height of the bridges as well. In 2015, the latest version of the Classification of European Inland Waterways (CEMT) was released by the European Union. The classification guides stakeholders in dimension and vessel types of the classified waterway (Inland Waterway Transport in Europe, 2015). The maximum beam refers to the length from the port side to the starboard side of the vessel, the maximum length refers to the length between the bow and the stern, while the draught refers to the length of the ship which is below the waterline. The different classifications and their limitations are presented in Table 4 below. The CEMT classification gives an indication of the permitted dimensions of these waterways, but it is needed to look at the exact properties of the waterway for correct data (VISURIS, n.d.).

Tabell 4. Classification of European inland waterways according to Resolution No 92/2 of the European Conference of Ministers of Transport (Inland Waterway Transport in Europe, 2015).

Type of inland waterways	Classes of navigable waterways	Motor vessels and barges						Pushed convoys						Minimum height under bridges
		Type of vessel: General characteristics						Type of convoy: General characteristics						
		Designation	Maximum length	Maximum beam	Draught	Tonnage		Length	Beam	Draught	Tonnage			
			L(m)	B(m)	D(m)	T(t)		L(m)	B(m)	D(m)	T(t)			H(m)
1	2	3	4	5	6	7	8	9	10	11	12			13
Of regional importance	I	Barge	38.5	5.05	1.80–2.20	250–400								4.0
To west of Elbe	II	Kampine-Barge	50–55	6.6	2.50	400–650								4.0–5.0
	III	Gustav Koenigs	67–80	8.2	2.50	650–1 000								4.0–5.0
To east of Elbe	I	Gross Finow	41	4.7	1.40	180								3.0
	II	BM–500	57	7.5–9.0	1.60	500–630								3.0
	III		67–70	8.2–9.0	1.60–2.00	470–700		118–132	8.2–9.0	1.60–2.00	1 000–1 200			4.0
Of international importance	IV	Johann Welker	80–85	9.5	2.50	1 000–1 500		85	9.5	2.50–2.80	1 250–1 450			5.25 or 7.00
	Va	Large Rhine vessels	95–110	11.4	2.50–2.80	1 500–3 000		95–110	11.4	2.50–4.50	1 600–3 000			5.25 or 7.00 or 9.10
	Vb							172–185	11.4	2.50–4.50	3 200–6 000			
	Via							95–110	22.8	2.50–4.50	3 200–6 000			7.00 or 9.10
	Vlb		140	15.0	3.90			185–195	22.8	2.50–4.50	6 400–12 000			7.00 or 9.10
	Vlc							270–280 195–200	22.8 33.0–34.2	2.50–4.0 2.50–4.50	9 600–18 000 9 600–18 000			9.10
	VII							285	33.0–34.2	2.50–4.50	14 500–27 000			9.0

Furthermore, each and every country has different ship characteristics of inland waterway transport. These characteristics can even differ from river to river (Achmadi et al., 2018). This means that a wide range of vessels are in place and are categorized into different classifications, as presented in Table 4. Highlighting the variety of vessel sizes, some vessels have the capacity to carry just a few tons while others can carry several thousand tons (Wisemans and Van Duin, 2017). By having a wide range of classifications, the characteristics of the goods transported affect what type of vessel is used for transportation. In Sweden, inland waterway shipping is not differentiated with sea shipping by law in contrast to the rest of the EU. Instead, the rules of sea shipping and rules from IWS are applied in Sweden, making the navigation in inland waterways complex (Garberg et al., 2019). Regulations are also formulated without stating how the regulations should be achieved to create a higher flexibility for boat owners (Transportstyrelsen, 2019). However, this could also be confusing and create difficulties for single operators to understand how the regulations should be followed (Garberg et al., 2019).

3.2.2 Inland Waterway Goods Transportation

There are three different main categories of load types consisting of bulk cargo parcel, specialized parcel and general cargo parcel (Stopford, 2009). The loads are further classified into subcategories with a specific type of characteristic. Consequently, a specific type of vessel is required depending on the load subcategory. Bulk cargo consists of the subcategories of dry bulk, such as waste and building material, and liquid bulk, such as fuels. Specialized parcels entail for example motor cars, forest products, refrigerated products, chemicals and liquified gas. Lastly, general cargo can be subcategorized into loose cargo, containers and pallets (Stopford, 2009).

The operation system between dry bulk, liquid bulk and container transport are diverse (Wisemans and Van Duin, 2017). It is mentioned that the majority of freight transport in IWW is dry bulk. Regarding dry bulk, both its transport and terminal operations are characterized as a structured transport flow with easy operations. The export of dry bulk mainly begins in the hinterland where it is loaded into a vessel waiting to be transported to a deep-sea port. When arriving at the deep-sea port, the dry bulk gets stored in a terminal waiting for as many IWW vessel loads as needed to fill a deep-sea ship. When the dry bulk is shipped to the next terminal, cargo in the terminal starts to load and unload the material (ibid.). The loaded material is then transported further inland, which for instance can be to a burning plant.

3.2.3 Inland Waterway Management Operations and Technology

Inland Waterway Management Operations (IWMO) is the involvement and interactivity between several transport actors. These actors are for instance

shippers, IWS operators, skippers, logistics service providers (LSP), road operators, and inland port and terminal operators (Wiemans & Van Duin, 2017). The previously mentioned actors compose the industry when considering the triple helix model of innovation, which is defined as the interaction between the industry, the government and the academy. The universities are supposed to provide research on which industry will build upon to produce and distribute commercial goods, while the government's role is to regulate the market (Leydesdorff, 2012). The benefits of collaborations through the triple helix model are a synergy which bridges the gap between science and industry, thus providing the market with better innovation and solutions (Petrović et al., 2018).

The management of Inland Waterway Operations (IWO) is essential in order to manage the balance between having a well-functioning infrastructure and avoiding risks. Infrastructure and risks can interact in two different ways: (1) infrastructure may face threats from emerging risks, and (2) risks can arise from infrastructure (Wehrle et al., 2022). The emerging risks are classified into (a) natural disasters, (b) terrorist attacks and (c) human-technical failure. When it comes to inland waterway shipping however, terrorist attacks are considered as unlikely while natural disasters are particularly being taken into consideration when the infrastructure is deteriorated and vulnerable. Consequently, greater attention is being put on human-technical failure. Risks can also emanate from the infrastructure itself by design, condition or operational aspects that can impact its functionality or cause threats to other interconnected systems (Wehrle et al., 2022).

To establish a successful logistics chain using intermodal transport, having a section that focuses on IWMO is essential. This is done by having an infrastructure that puts emphasis on the administration, which is of higher complexity compared to other administrative tasks since it involves excessive controls, more inspections and paperwork (Medda & Trujillo, 2010). Since the sizes of the vessels vary, the administrative work becomes of higher complexity. For instance, smaller vessels need to transport more times than larger vessels and since the sizes can vary, the loading degree of the barge varies as well (Wiemans and Van Duin, 2017).

Due to the high complexity of IWMO, many seaports are undergoing a digital transformation that can offer several benefits to simplify the process for the stakeholders involved in the logistics chain. For instance, the Port of Rotterdam had a strategic opportunity where the digital design was focusing on container data. This digital platform enables users to get data directly from the suppliers (Laas, 2020). The terminals for ports of Rotterdam and Antwerp have also undergone a digital transformation where the actors have enabled paperless container transfers. This has encouraged the authorities to facilitate the administration and decreased the complexity for the stakeholders involved (The

Editorial Team, 2016). Another example related to the topic, Engström and Abrahamsson (2019) mentioned that the Netherlands has offered an online route planning software named the Blue Road Map where the focus is to offer shippers navigational help in urban environments (Route Search Engine, n.d.). Offering online route planning software for the shippers makes it possible for organizations to increase their efficiency and optimize their supply chain (Wiegmans et al., 2015).

3.2.4 Loading and Unloading Operation

The loading and unloading operation is referring to the activity in which goods are loaded or unloaded from the vessel and onto another vessel, vehicle or dry land for storage, which can be seen in Figure 3. This activity, which is usually done by the dock personnel, takes place after the vessel has navigated in the port, docked and secured mooring (International Maritime Organization, 1992). A vessel is only profitable when it is moving cargo, meaning that the overall profitability of a vessel can be improved by implementing an efficient way to load and unload goods (Thomas, 2023).

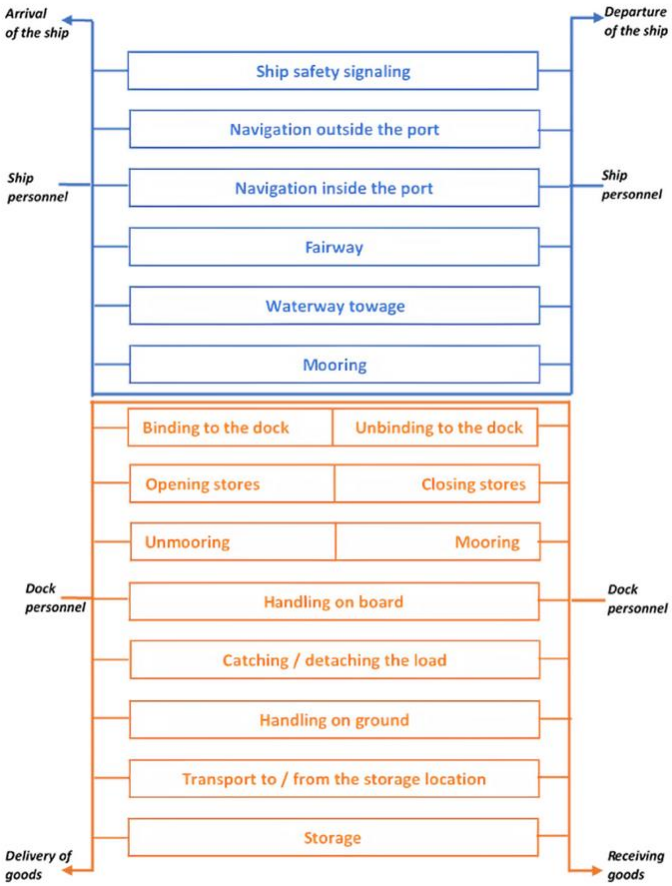

Figure 3: The arrival/departure flowsheet of the ship in and out of the harbor (International Maritime Organization, 1992).

There are many ways to conduct the loading and unloading operations depending on the context of a number of variables such as the ship, quay and goods characteristics (North Sea Region, n.d.). The ship characteristics determine which quays and waterways the vessel can make use of, and vice versa. The quay characteristics affect which cranes can be used. Some cranes are stationary, while others are movable or semi-stationary, meaning they can move within a specific path range. The goods' characteristics also influence which cranes can be used, i.e. a lifting crane for palletized goods. More examples of this can be found in POM Oost-Vlaanderen (2019).

3.3 Industry 4.0 and Innovative Technologies

As the industry is rapidly evolving into a new era, industry 4.0 is enabling more solutions to be conformed (Restrepo-Arias et al., 2022). Industry 4.0 refers to the ongoing trend of automation and data exchange in manufacturing technologies, such as 3D printing, robotics, Unmanned Aerial Vehicles (UAVs), Internet of Things (IoT), blockchain, and artificial intelligence. The aim of industry 4.0 can be concluded as to work with a higher level of automatization achieving a higher level of operational productivity and efficiency, connecting the physical to the virtual world (Alcácer & Cruz‐Machado, 2019).

First, industry 4.0 creates a more efficient fleet management. Technologies in industry 4.0 enable real-time monitoring of vessel performance, fuel consumption, and engine health through sensors and IoT devices. This data can be analyzed to optimize routes, reduce fuel consumption, and minimize maintenance downtime, leading to more efficient fleet management (Cotteleer & Sniderman, 2017). Furthermore, industry 4.0 allows for enhanced prediction rate in maintenance for maritime assets. By analyzing data from sensors and equipment onboard vessels, maintenance issues can be identified before they lead to costly breakdowns, ensuring optimal vessel uptime and safety (Agrawal et al., 2020). As for safety and security onboard vessels and in ports, it can be increased when implementing innovative technologies. IoT sensors and connected devices are two types of technologies that enable real-time monitoring of environmental conditions, equipment status, and crew activities, thus allowing for early detection of potential hazards and dangers (Biiak & Lindskog, 2022).

In addition, the management of the supply chain can be optimized through industry 4.0. The reason is that industry 4.0 technologies facilitate the integration and automation of supply chain processes in the maritime industry. From automated cargo handling at ports to blockchain-based logistics management systems, these advancements streamline the movement of goods, reduce transit times, and enhance supply chain visibility and transparency (Sullivan et al., 2020). Lastly, industry 4.0 would unlock access to remote operations and autonomous vessels. Autonomous vessels equipped with AI and advanced sensors can navigate

autonomously, optimize routes, and make real-time decisions which leads to increased efficiency, lower operating costs and reduced environmental impacts (Sullivan et al., 2020). As the high investment costs are one of the main challenges of a modal shift to IWS, automation would lead to a decrease in demand for skippers. Automation may be implemented in parts of the operation, such docking and undocking, or for the whole transportation distance (ibid.).

As for implementing innovative technologies, either a new vessel could be built with technologies, or an old vessel could be retrofitted. Retrofitting is the activity of providing a machine with a part, or a place with equipment, that it originally did not have when it was built (Retrofit, 2024). Ship owners retrofit to upgrade the vessels' operational standards as technology and new innovations reach the market. For instance, only by changing the fuel type from diesel to LNG, the CO_2 emissions can be cut by 10% (European Inland Barging Innovation Platform, 2018). More examples of retrofitting can for instance be related to the power system of the ship and adjusting the fuel consumption. However, retrofitting is still seen as very costly for ship owners and is instead justified through public interest in energy and emission reduction (Cordis, 2011).

4. Inland Waterway Shipping in Gothenburg

This section presents a description of the setting in Gothenburg by providing insights in how the city works with the significant growth in goods turnover, with a focus on inland waterway shipping and sustainable waste management initiatives. The recycling waste barge and Kretslopp & Vatten (KoV) are two cases that are also presented under this section.

4.1 The Setting in Gothenburg

As the largest harbor of Scandinavia, the port of Gothenburg has seen immense growth since its establishment in the 17th century. The port experienced an annual turnover of 40.5 million metric tons of goods in 2022 (Larsson, 2023). However, this number represents a 6% decrease compared to 2010, a year which witnessed a 29% increase compared to the year of 2000 (WSP Sverige AB & Knape, 2013). The apparent stagnation in growth suggests that the port of Gothenburg has reached its maximum capacity. Consequently, the challenge created by the plateauing of the growth has been recognized by the government and other key stakeholders, which have unveiled plans to modernize and expand the port's infrastructure. The first part in addressing the challenge is to deepen the harbor's current depth from 13.5 meters to 16.5 meters (Trafikverket Region Väst, 2017). This upgrade to the fairway sets out to increase the capacity of the port by enabling larger ships to dock, thus creating a more efficient process in which less vessels have to dock and undock for the same amount of goods. Secondarily, the port of Gothenburg will see an increase in the number of quays, which boats can dock to, within the fairway, thus increasing the capacity of the port by increasing the volume of ships which the port can handle (Persson & Vuorenmaa Berdica, 2017).

In general, it is evident that sea transport has received less governmental financial support compared to land transport (Baird, 2007). Paradoxically, carriers and forwarders argue that the primary catalyst for encouraging actors to switch from land transportation modes to waterway transportation is the need for government subsidies. Specifically, subsidies are needed when it comes to equipment for handling transshipments at intermodal hubs (Flodén et al., 2017). Thus, the lack of subsidies and governmental support has impeded the progress of sea transport infrastructure, ultimately increasing the gap in developmental disparity between the two transportation modes.

Gothenburg's inland waterway consists of a main river called Göta Älv, which splits into branches such as lakes, canals and other smaller waterways, as illustrated in Figure 4. One of these smaller waterways is the moat which surrounds the most central point of Gothenburg. There are fifteen bridges around the moat where some of them which connect the landmasses between the moat

are low. Currently, the lowest bridge on the moat is Stora Bommens Bro which has a maximum free height of 1,8 meters ("Stora Bommen," 2023).

Figure 4. A map of the waterways surrounding central Gothenburg (Google Maps, 2024c).

4.2 Stakeholders Case Descriptions in Gothenburg

This subsection presents two cases that participated in the study, one of them being the recycling waste barge that stops at several locations around Gothenburg to collect waste from visitors. The second one is the organization is Kretslopp & Vatten, also known as sustainable waste and water in English and puts emphasis on finding sustainable solutions with several innovative techniques in the city.

4.2.1 The Recycling Waste Barge

The invention of the recycling barge began as a project in DenCity where the purpose of the project was to investigate the conditions for transferring a variety of flows to waterways and study what effects it has on the road network. The citizens of Gothenburg were highly positive of the concept and since the project proved that it is possible to use the IWWs in Gothenburg for container transportation, the seven-week long project resulted in a continuous operation where further investigations were made on possibly becoming a permanent addition to waste and recycling management in the city (DenCity & Bakosch, n.d.). This encouraged DenCity to develop the barge for waste flow instead of goods flow and the goal was then ultimately set to reduce the usage of cars and trucks and increase the usage of IWWs. The Swedish government has introduced the recycling waste barge as a strategic measure to optimize waste collection processes in Gothenburg. This initiative serves as a comprehensive solution for disposing various waste types, including burnable waste, hazardous materials, electronics, non-recyclable items, and even textile waste (Göteborgs stad, n.d.).

However, certain restrictions apply, as the disposal of appliances, dirt, garden waste, and packaging are not permitted on the barge (Olofsson, 2020).

The waste barge was developing and put into use in 2019 and a number of stakeholders were involved in the start-up. The most important stakeholders can be summarized into the municipality, DenCity, DHL, Renova, Sandinge Transport and Sustainable Waste and Water (known as Kretslopp & Vatten in Swedish). Sustainable Waste and Water is however today the most essential stakeholder to the waste barge together with workers on the waste barge and a transporting actor which moves the waste from the barge to a recycling center (Årnes, 2024).

As of today, the recycling waste barge travels through Göta Älv from Frihamnen and the waste barge normally stops at five different locations as presented in Figure 5 which are Sannegården, Eriksberg, Lindholmen, Stigbergskajen and Skeppsbron (Göteborgs Stad, 2024). Due to current work of extending the quay in Skeppsbron, the waste barge travels to the other four destinations and collects the waste. Unlike conventional recycling centers in Sweden, there is no need for a special recycling center card to use the recycling waste barge. Moreover, individuals can access the barge an unlimited number of times, in contrast to the specified number of times that visitation is allowed at traditional recycling centers (Olofsson, 2020).

Figure 5. Map of the city of Gothenburg with red location pin spots of where the recycling waste barge stops (Google Maps, 2024b, edited by authors).

Lasty, the waste barge itself can carry six lighter or four heavier containers depending on the weight. Furthermore, the waste barge is being pushed around

the city with a towboat, a hybrid towboat as presented in Figure 6. The waste barge is designed to have more room for visitors that want to travel around the city. The number of visitors can vary depending on the season but the average number of visitors per year is 6 000 people and the average person disposes of around 10 kg per year.

Figure 6. Photographs of the recycling waste barge in Gothenburg (Morcos, 2024b).

4.2.2 Kretslopp och Vatten

Kretslopp & Vatten (KoV), also known as Sustainable Waste and Water in English, is a municipal organization within the city of Gothenburg where the organization is dedicated to sustainable waste and water management by finding sustainable solutions with different innovations and techniques. By interviewing KoV, it will give the study more insights into how the organization works with their strategies and methods to promote environmentally friendly solutions in terms of waste management in Gothenburg. Since the organization also collaborates with other stakeholders in the development of the recycling waste barge, having an interview with KoV will give the study an understanding in how the processes can be integrated into inland waterway shipping and its future in the city. Furthermore, conducting an interview with KoV can provide insights into some success factors and challenges that the organization has faced when implementing the recycling waste barge in the city. This experience can then be used to identify potential obstacles and opportunities for implementing a similar barge in the future, both in Gothenburg and the other cities involved in the study.

5. Inland Waterway Shipping in Stockholm

This segment introduces an overview of the setting in Stockholm by providing insights into the origins of the implementation of inland waterway shipping. Two case descriptions are also presented: one focusing on Trafikkontoret and another on Avatar Logistics. Lastly, the inland waterway waste and construction material flow in the city is also presented.

5.1 The Setting in Stockholm

Stockholm city is currently paving the way to become fossil fuel free by 2040. The driver for this project entails road congestion, air pollution, noise pollution and an increase in public transport. Three main goals have been formulated in guiding and realizing this vision (Stockholms Stad et al., 2018). The first goal is to increase availability and predictability for goods transportation. This goal is carried out through easier access to distribution points, allowance of night transportation and increased collaboration in freight loading. The second goal revolves around finding solutions which lead to less environmental impact by minimizing the total number of freight trucks. The third and last goal is to create solutions in high collaboration with the triple helix model, meaning the academy, private and public actors.

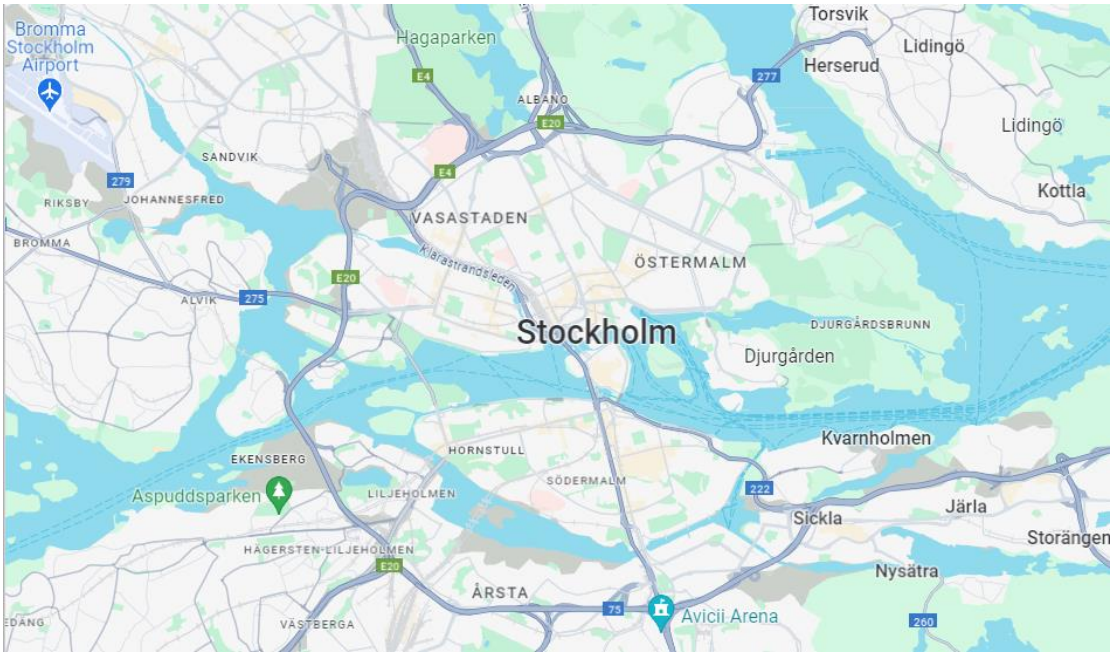

Figure 7. A map over the waterways in central Stockholm (Google Maps, 2024a).

Furthermore, there are no CEMT classifications of the waterways in the city of Stockholm, or Sweden in general. However, another classification system is used from the EU-directive where four different zones are taken into consideration called zone 1, zone 2, zone 3, and zone 4, as presented in Figure 8. These zones differ depending on the height of the wind waves. In a zone 1 classified zone for

instance, the wind waves can rise up to two meters. For zone 2, the wind waves can rise up to 1.2 meters while zone 3 area entails maximum wind waves up to 0.6 meters. The last zone area however is considered to not have any wind or waves that occur. As shown in Figure 9, Stockholm has a zone 3 classification.

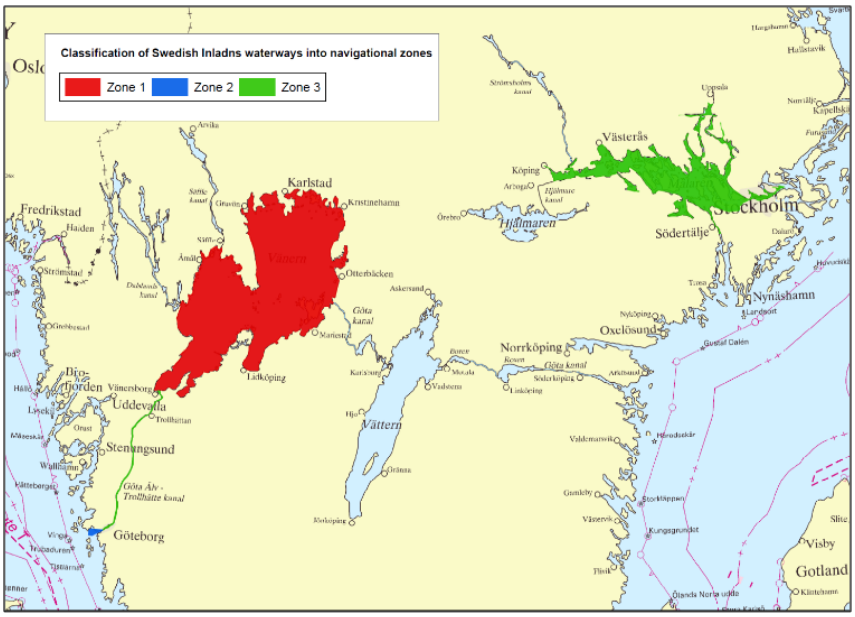

Figure 8. A map of the different inland waterway zones in Sweden (Transportstyrelsen, 2018).

Considering waste flow in Stockholm related to glass, paper, general plastic and metal, the main mode of transportation is through trucks where the waste is first collected from pickup points to regional distribution centers (Sjöstrand et al., 2021). After that, the waste is shipped to one of eleven national recycling centers where none of which have optimal placements near a waterway. However, the waste flow related to aluminum and PET could potentially be shipped to Västerås, but the current volumes are not sufficient enough.

The transportation of dirt and stone masses is also being conducted in Stockholm, which is estimated to compose every fourth truck transportation. The outcome was an estimated 12% reduction in the carbon footprint and 80% less transport cost for the specific scenario (Energimyndigheten, 2017). It is also worth mentioning that the break-even point of the truck and vessel transportation versus only truck was calculated to be 40 kilometers. One challenge to continue developing this has been the amount of available loading docks.

5.2 Stakeholders Case Descriptions in Stockholm

This section highlights two cases that participated in the study. One involves Trafikkontoret, also known as Stockholm Traffic Administration in English who are responsible for planning, maintenance and development of the city's traffic and transportation systems. The other stakeholder is Avatar Logistics, which is an

organization that develops solutions for inland waterways in Sweden and other countries in Europe.

5.2.1 Trafikkontoret

Conducting an interview with Trafikkontoret is beneficial when studying the inland waterway shipping in Stockholm since they are responsible for ensuring that the public spaces are both safe and attractive with efficient and sustainable transport solutions. Having good accessibility in a dense city like Stockholm is essential for both citizens and companies and Trafikkontoret works with this by doing several investments for streets and roads, coordination and development of the district councils' urban environment activities. By conducting an interview with a stakeholder from Trafikkontoret can provide more insights into how the organization works with these aspects and also inspire other cities to work with inland waterway shipping for several reasons.

Recently, the organization started investigating the conditions of implementing several barges in the inland waterways for reasons such as becoming more environmentally friendly and reducing road congestion. One idea is implementing a recycling waste barge that will travel to selected berths in areas that are easily accessible to residents and located in areas where many people live (Dencity & Bakosch, n.d.). By letting the stakeholder present these implementations and suggestions for the study, it is easier to map both obstacles and opportunities for future implementations.

5.2.2 Avatar Logistics

Avatar Logistics is a Swedish company which develops solutions for inland waterways by using the Swedish inland waterways as a base when creating solutions for their customers (Lantz & Avatar Logistics, 2024). Interviewing Avatar Logistics in Stockholm for a study on inland waterway shipping will provide valuable insights in terms of new innovative technologies and aspirations that they have for Stockholms inland waterway shipping. Avatar Logistics is also in close collaboration with the Interreg Project which is funded by the European Union. The solutions that Avatar Logistics provide are focused on sea transportation, terminal handling, storage and pre/on carriage by road or rail. They operate in and around the two biggest Swedish lakes, Lake Mälaren and Lake Vänern, with focus in the cargo segments bulk, container, liquid fuels and recycling products, but mostly transport construction material within the concrete industry (Lantz & Avatar Logistics, 2024).

Figure 9. Photograph of the IWW vessel Jehander1 used in Stockholm (Avatar Logistics & Lantz, 2022).

5.3 Waste and Construction Material Flow in Stockholm

In 2020, the municipality for water and waste (Vatten och Avfall) in Stockholm formulated a plan for the upcoming years in how the waste flows in Stockholm will be developed ("Avfallsplan För Stockholm 2021-2024," 2024). One of the goals is to collect 70% of food waste with the help of a sorting facility. Another goal is to develop the waste collection system by collecting industrial waste locally with electrified vehicles and transport to centralized regional loading centers where a more extensive waste collection takes place. The purpose of the solution is to create a more efficient waste collecting system. However, there are no current plans on how to integrate the usage of inland waterways in the proposed solutions. It is also important to note that the formulated goals are mostly plans on what to do, but not how to do, meaning there is still potential to make use of the waterways in the future solutions ("Avfallsplan För Stockholm 2021-2024," 2024). One initiative is the DenCity project, which previously mentioned it started in Gothenburg. Ultimately, the implementation of a floating waste barge, which stops at 10 different quays around the city, is being investigated (Dencity & Bakosch, n.d.). The purpose of the waste barge is, similar to the waste barge in Gothenburg, to help residents of Stockholm with the disposal of waste without the need for a car, thus reducing road congestion and increasing overall waste flow efficiency by offering more alternatives for waste disposal.

Considering the construction material flow in Stockholm, the formulated plans are similar to the waste flow plans in regard to the composed goals not having a concrete solution. The plans are instead formulated to encourage a more sustainable way of handling the flows related to building and demolition ("Avfallsplan För Stockholm 2021-2024," 2024). One example is the goal to repurpose, recycle or upcycle at least 70% of the waste material that is produced when constructing or demolishing buildings.

6. Inland Waterway Shipping in Ghent

This section presents a description of the setting in Ghent by describing the city's infrastructure, water levels and architectural history. Some key stakeholders are also presented under this section and the stakeholders are POM, Urban Waterway Logistics, Fabriek Logistiek, Thienpont and City of Ghent. Lastly, the inland waterway waste and construction material flow in the city is also presented.

6.1 The Setting in Ghent

The rivers and canals in Ghent have been the city's vital arteries in centuries due to the high share in European barge freight transport (Li & Notteboom, 2012). Recognizing their significance, the Belgian government is actively encouraging the development of the waterways by offering subsidies to construction companies. For quays built on inland waterways, government funding is available, and can potentially reduce 80% of the infrastructure costs or 50% of the total expenses (Vlaamse Waterweg, 2018). The private actor which wishes to utilize the infrastructure then pays a fee to the government, thus closing the economic circle. However, there is a requirement for one specific volume of goods per euro invested.

Looking at the city of Ghent, the waterways are CEMT classified. As presented in Figure 10, the waterways of class I and II are common in the inner center of Ghent. Larger Va-classified vessels are allowed in the outer waterways which encapsulate the city. The low classification value of the waterways in the inner city is a consequence of low canal depths, low bridges and narrow passages (VISURIS, n.d.).

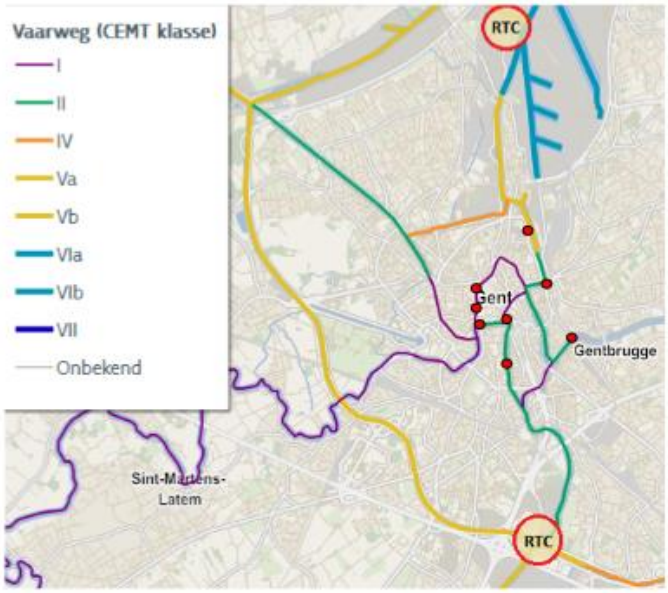

Figure 10. Map overview of CEMT classifications for Ghent's waterways with marked out spots for regional transshipment centers (RTC) and urban transshipment points (UTP) as red dots (VISURIS, n.d.).

There are two water levels taken into consideration in the city of Ghent, the low level which is the sea level, and the normal level which is 1 meter higher (City of Ghent & Peeters, 2024). In this dynamic environment, the city of Ghent is working with a set of broader ambitions which are developed into action plans depending on the context of each of the areas within Ghent. One ambition is to create an economy through the waterways. To do this, two regional transshipment centers (RTC) as presented in Figure 11 are being developed with transshipment possibilities where the waterways converge (City of Ghent & Peeters, 2024). The idea is to complement the RTCs with eight smaller decentralized urban transshipment points scattered around the city.

Another noteworthy point is that the inner city of Ghent is defined as the old town of the city and has a distinct medieval theme (City of Ghent & Peeters, 2024). This theme needs to be taken into consideration before building or rebuilding of the infrastructure is approved, creating a challenge in modernizing the area, including the waterways and surrounding infrastructure. The old town can be approximated to around the orange area in Figure 11 below. To cross the waterways surrounding the old town, low pedestrian bridges are incorporated. Many of these bridges have a clearance of less than 2 meters.

Figure 11. Map overview of the innermost part of Ghent (Howell-Jones & Global Cycling Network, 2024).

The drivers for increased usage of waterways in Ghent are considered to mainly consist of noise pollution from road vehicles, environmental pollution and also limitations in infrastructure capacity which leads to road congestion (Tom, 2024).

6.2 Belgian Stakeholders

This subsection presents five different cases that participated in the study. The five different case companies are POM in East Flanders, Urban Waterway Logistics, Fabriek Logistiek, Thienpont and City of Ghent. A description of why these stakeholders is choosing is also presented under each and every company description.

6.2.1 POM in East Flanders

Provinciale Ontwikkelingsmaatschappij Oost-Vlaanderen (POM) is the Provincial Development Company located in East Flanders, Belgium and is an organization that is established by the regional government to foster both a financial development and a healthy environment within East Flanders, specifically in Ghent and Antwerp. POM works with various responsibilities in order to foster the economic vitality of East Flanders. Sustainability, technology, innovation, future orientation and a healthy climate are topics that are of high importance for the organization and POM works with it in several ways. For instance, the company is involved in several projects related to the presented topics by participating, motivating and developing as partners with other organizations that work with the projects. Other than collaborations, the projects are being tackled by identifying economic needs and opportunities and making challenges become groundbreaking achievements (Wat Doet De POM? - Pomov, 2023).

One of the EU projects that POM is involved in is the Interreg North Sea Region where POM has undertaken a role as a project coordinator. Another main project that the organization is involved in is the AVATAR Project, where stakeholders are focusing on how to use water instead of roads to transport goods in order to cherish the environment. The AVATAR project has focused on these possibilities by experimenting with autonomous prototypes of vessels, implementing a zero-emission inland vessel for city distribution and developing suitable technologies (AVATAR - Pomov, 2023).

Another vessel that is involved in the AVATAR-project is the Green Wave vessel which is fully electric and has been used as a research vessel in the AVATAR-project. During 2022, a new vessel in the AVATAR-project was under construction and the developers borrowed the Green Wave vessel in order to put the project partners' ideas to reality by doing tests (Interreg North Sea, 2022). One of the tests involved loading the vessel at the border of the city with construction materials which then got unloaded at a wharf in the city center, as shown in Figure 12.

Figure 12. The Green Wave vessel being unloaded in the city of Ghent (Interreg North Sea Region, 2022).

As of now, there are three different AVATAR-vessels called AVATAR 0, AVATAR I and AVATAR II which all have different characteristics yet look similar. as presented in Figure 13 which presents the vessels AVATAR I and II.

Figure 13. Photograph of AVATAR I and II (Morcos, 2024a).

Since POM are involved in various projects related to inland waterway shipping in Ghent and are continuously working on several solutions in order to move forward and become more efficient and environmentally friendly, it is essential to conduct an interview with a stakeholder that is as involved as POM are in the development of the vessels. By conducting several tests and continuously developing the current technology related to inland waterway shipping, POM will provide valuable insights to the study by presenting what kinds of new innovations and technologies have been implemented so far and why has that been successful or not.

6.2.2 Urban Waterway Logistics

The organization Urban Waterway Logistics (UWL) works in the research and innovation center as a project manager for several projects. These projects put emphasis on the development of inventive and sustainable logistic solutions and transport concepts, predominantly in urban environments. Private companies in the region of Flanders are involved in order to get goods in and out of the city by using IWWs. Since the organization has previous experience in autonomous sailing, UWL is involved in the setup of developing and testing autonomous sailing in the urban boats, which is being tested in the AVATAR vessels (Geirnaert & Urban Waterway Logistics, n.d.).

6.2.3 Fabriek Logistiek

Fabriek Logistiek is the first logistic testing space in Belgium tailored to the needs of organizations seeking to assess and compare existing and new innovative warehousing methodologies in a realistic operational environment by using their own staff and commodities. Fabriek Logistiek has been co-developing the AVATAR vessels with focus on testing solutions such as the loading and unloading operation with a specific grapple. The warehouse is located in Ghent and is supported by multiple logistics organizations such as Moore, Logisol Pro, BRIX advice, Zelco and LogFlow (About Fabriek Logistiek - Fabriek Logistiek, 2022).

6.2.4 Thienpont

The container service organization Thienpont is situated in Drongen, Ghent where the company's customers can either be other companies or private individuals seeking to rent a container. Thienpont has different kinds of containers depending on the disposed material, the quantity and the chosen waste flow. One of the activities at Thienpont is to upcycle waste into building material for road construction. The organization is a partner of Urban Waterway Logistics, and the organization has recently developed an interest in moving waste via water. The company has two container parks situated in Drongen and Wetteren where private individuals can deliver their disposables directly to the industrial park. However, all of the assortment is being handled by the organization (Thienpont, 2024).

6.2.5 City of Ghent

The City of Ghent is a municipal governmental organization that is tasked with the governance and management of the city's affairs. Environmental policies, public services, cultural events, urban planning and transportation are some of the administrative functions that the organization oversees. Furthermore, the City of Ghent focuses on improving the quality of life for its residents by promoting economic development and ensuring sustainable growth for the city (Welcome to the City of Ghent, 2019).

6.3 Waste and Construction Material Flow in Ghent

The city of Ghent is on the path of becoming more sustainable and faces its own challenges considering the city's own characteristics. The current strategic plans push for a city which develops with a view to the future, has opportunities, creates unity and serves the residents by the residents (SDGS & De Clercq, 2022) To achieve these goals, a transition from the current linear economy to a circular economy through innovation in reusability of products and raw material, as well as a reduction in raw material usage, has been advanced. One step in actualizing a circular economy, a sorting line was opened in the North Sea Port in 2022, ensuring that 35% of the incoming bulk industrial waste is recycled into new raw material (Circular Economy, n.d.). Currently, the main collector of waste in Ghent is IVAGO, but there are also private stakeholders on the market.

The goal of a circular flow is not only limited to the waste flow, but is also implemented for building material (Stad Gent, n.d.). The initiative is calculated to have major benefits in terms of reducing the carbon footprint of Ghent (City of Ghent & Bats, 2023). Moreover, a case study found that Ghent was the second most active region when considering transportation of building materials on waterways (Interreg North Sea Region et al., 2021). The reason for choosing the waterways as a means of transportation is to reduce the negative impacts of road transportation, such as road congestion. Similarly, the waterways are also used for transporting agriproducts from the production site directly to stores in Ghent's city center (CCNR, 2022).

7. Inland Waterway Shipping in Le Havre

A description of the setting in Le Havre is presented under this section by providing a description of the infrastructure and the waste- and construction material flow in the city. Two main stakeholders in Le Havre are also presented. Lastly, the inland waterway waste and construction material flow in Le Havre is also presented.

7.1 The Setting in Le Havre

The main waterway channel in Le Havre is an extension and the outlet of the river Seine which flows through Paris (Map of the European Inland Waterway Network, 2018). It is a major transport artery, which links Paris to the English Channel, and is navigated by vessels such as high-capacity barges, tow-boats and river cruise ships (French Waterways & Edwards, 2023). In the waterway between Le Havre and Paris, the dimension of the waterway allows for a draught of 4 meters, while all bridges on the waterway allow for a minimum headroom of 7 meters above water level. The ports of Le Havre, Rouen and Paris have created a joint coalition called HAROPA, thus increasing collaboration and synergies between the ports situated on the river Seine (Circular Flanders, 2023). One of the main ambitions of the coalition is to strengthen the Seine corridor by improving the transport infrastructure and taking strategic decisions.

7.2 French Stakeholders

This section highlights two cases that participated in the study. One of the stakeholders is CIRCOÈ and the other one is Sogestran. A description of the two stakeholders is presented in this subsection followed by an explanation of their relevance to the study.

7.2.1 CIRCOÈ

CIRCOÈ is a logistics consulting and innovation center where the focus in the organization is to provide businesses with improvements in their logistics and transport performance (CIRCOE, 2023). Several methodologies and tools are being used when working with the suggested implementations and ideas, both in the upstream and operational phases. The organization is based in Le Havre, Normandy and collaborates with several partners in the region consisting of the industry, the academy, and lastly the government, ultimately collaborating within the triple helix. International stakeholders are also a main partner of the organization, and many projects are conducted abroad to push modern logistics further by integrating the latest technological advances in the projects (CIRCOE, 2023).

Conducting an interview with CIRCOÈ can provide valuable insights into innovative green inland waterway shipping developments by focusing on for

instance the vessels, ports, cranes and quays. Since the organization is also involved in several projects abroad, it signifies their experience in facing diverse logistical challenges and how the innovative green inland waterway shipping developments can be adapted and implemented in different settings.

7.2.2 Sogestran

The Sogestran Group is an organization that puts emphasis on inland navigation and maritime transport solutions (Mediaction, n.d.-a). The organization uses their expertise in four areas of business: (1) river transport, (2) maritime transport, (3) multimodal transport and (4) services to industries in order to provide tailor-made solutions to customers. Sogestran has over 200 units consisting of self-propelled barges, push boats and seagoing vessels and operates a fleet of inland waterway vessels for transporting goods in primarily France and neighboring countries (Mediaction, n.d.-b). One of these vessels is the Zulu-vessel which transports all types of goods like bulk, container and palletized cargo on the 300 kilometers long route from Le Havre to Paris (Gilles, 2024). Having an interview with The Sogestran Group can provide examples of how the organization operates in terms of new technologies and innovations when comparing the setting with the other cities related to the study.

The Zulu-vessel is 50 meters in length and 7 meters in width and has an integrated crane. The radius of the crane is only 12 meters, but since the crane is situated on rails, it can be moved along the complete length of the vessel (Gilles, 2024). The vessel started with a diesel engine, but since it has recently undergone its 6th generation of development, a new type of fuel source has been implemented, namely hydrogen fuel cells.

Figure 14. The Zulu 6 vessel (Fuel Cells Works, 2023).

7.3 Waste and Construction Material Flow in Le Havre

Currently, the city of Le Havre intends to create a circular economy in waste logistics (HAROPA PORT, 2023). To achieve this objective, the HAROPA port has created two goals. The first goal is to consume sustainably and to facilitate positive uses for waste. For example, dredged material from the canals and rivers can be converted into filling material for waterlogged quarries with the purpose of ecological redevelopment. In another initiative, the purpose is to convert the dredged material into building material such as bricks and tiles. In a third initiative, a methanisation plant is under construction until 2025 which has the purpose of converting food waste into gas for heating and fuel. The second goal is about fostering and assisting the focus on industrial and regional ecology. This goal is worked towards through implementing low carbon industrial zones, economic support of non-profit organizations and waste treatment and recycling plants.

8. Findings from Interviews

This subsection presents the findings from all conducted interviews. The findings are divided into the different settings in Gothenburg, Stockholm and Ghent. Interviewee 1 represents the findings from Gothenburg, Interviewee 2 and 3 from Stockholm, Interviewees 4-8 from Ghent and lastly, Interviewees 9 and 10 from Le Havre. To summarize the findings, three tables divided into the categories of benefits, challenges and a vision of the future state have been presented under findings from each respective city. The bullet points presented in the tables represent the key aspects which have been brought up by the interviewees during the interviews. The analysis is built on, but not limited to, the foundation of these bullets.

8.1 Findings from Gothenburg

General information and barge usage

As for the usage of inland waterways in Gothenburg, the municipality worker from Kretslopp & Vatten (KoV) highlighted the importance of utilizing the inland waterways as a transportation alternative in order to become more environmentally friendly. Seeking other transportation modes is, according to the municipality worker, of high importance in order to preserve and maintain the environment for future generations. The benefits of using the inland waterways in the city are many. Other than becoming more environmentally friendly, the municipality worker mentioned that the number of customers visiting the waste barge currently is 6 000 visitors per year. Beyond this, the number of customers visiting the recycling waste barge via a passenger car has decreased and the customers have started visiting the barge by more environmentally friendly transportation modes, such as by bus, bike or walking. The objective of DenCity, which ultimately was to increase sustainability, has been fulfilled by reducing vehicular usage through the establishment of five strategically positioned stops across various locations, as shown in Figure 5. The municipality worker emphasized the significance of having the waste barge readily accessible to customers within specified time slots. While visiting the different quays, the waste barge is parked for a few hours at every stop in order for customers to visit the barge and sort out the waste and material in a non-stressful manner. The time slots for each stop at the quays are visible for the customers, making the availability for the customers easily accessible and ensuring efficient planning of their visits. However, the timing of waste arrival at the recycling center in Marieholm is less critical and can even arrive one to two days later if needed. As for the staff working at the waste barge, the municipality worker mentioned that the staff are handpicked and are present to welcome customers and talk to the visitors to increase customer satisfaction. The staff is also present to bring up the reason why the waste barge exists in order to spread awareness and influence customers' decisions on becoming more environmentally friendly.

Challenges and limitations

While the municipality worker at KoV mentioned that there are many benefits of implementing the recycling waste barge in Gothenburg and utilizing the IWWs more, some drawbacks were also presented during the interview. For instance, the municipality worker mentioned that the staff decides whether it is safe to drive the waste barge or not due to weather conditions. Wind speed and wave heights are aspects that make it unpleasant for both staff and visitors to drive the waste barge. The same applies for deviations in water levels since the staff will then experience problems with ramps or gangways. Despite these potential issues, the municipality worker mentioned that the operations for the waste barge have still not faced any significant issues due to weather conditions and that the operation needed to be interrupted once since the establishment in 2019. Another aspect that has interfered with the movement of the waste barge is the Hisingen Bridge. During the construction and development of the waste barge the Hisingen Bridge was under construction until 2021. Consequently, the waste barge encountered some periodic obstacles, unable to pass beneath the bridge on certain days of the week for an extended period of time. This resulted in some difficulties in route planning for the waste barge. Nonetheless, the municipality worker contended that they were fortunate that the disruption did not significantly impact them. However, it emphasized the critical necessity of effective planning in order to mitigate any potential disruptions.

During the development of the waste barge, it was planned to take the barge to Säveån in order to load more waste in the vessel that would result in more efficient work. The plan needed to be adjusted since the journey to the incinerator facility in Säveån from Frihamnen has many low bridges, a variety of water levels and many areas that are protected by the Natura 2000 network. The expenses of rebuilding many of these bridges and dredging Säveån would result in high investment costs, which the municipality worker did not see as feasible. Moreover, since the area is classified as Natura 2000, current regulations do not allow for infrastructure development in the area regardless.

When considering the infrastructure in Gothenburg, there are some setbacks that limit the usage of inland waterways in the urban environments of the city. One proposed concept that was taken into consideration involved the introduction of a new recycling waste barge operating several times per week within the city's moat. The barge would collect waste from various companies and restaurants around the moat before proceeding to Marieholm for unloading. However, the municipality worker argued that this idea is difficult to implement in Gothenburg as a result of the low bridges around the moat. Having a well-functioning and well-developed waterway system in a city like Amsterdam, where they have worked with waterway related questions and issues for over 100 years, the municipality

worker argued that it is more feasible to implement this in their urban environment than in Gothenburg. Consequently, considering existing technology and infrastructure in Gothenburg, the municipality worker believes that it is impractical to implement a waste barge in the urban environment.

As for management operations, the municipality worker mentioned that the organization has experienced some obstacles on the way that has prevented the waste barge from moving around the city in a feasible way. One of the main aspects that was highlighted is about finding available quays with the purpose of loading and unloading. The municipality worker at KoV mentioned that despite the abundance of quays around the city and along the canal, it is assumed that there are no issues with finding quays. However, this is not the case. There are many actors involved in the quays that prevent the waste barge from loading and unloading. One actor can own the quay, another can own the property itself and a third actor can be responsible for managing the quay. Having multiple stakeholders involved in the quay's ownership makes it difficult according to the municipality worker to find quays for barges to operate in the city.

New Technologies and Innovation

Considering new technologies and innovation, the municipality worker mentioned that the waste barge utilizes solar energy to power lights and utilities on the barge. Another dimension that is relatively new is the electrification of the towboat which pushes the waste barge around the city. Furthermore, the municipality worker showed that previous ideas have been fulfilled by presenting a relatively new waste barge that was finished in 2023. The main idea was to increase the efficiency in the waste management process for incoming waste material by developing the sorting process on the barge.

Even if the recycling waste barge operates as planned, the municipality worker argued that there are some innovative plans and suggestions being discussed for a future recycling waste barge that will operate in the city. For instance, it is being considered to implement an integrated weighing system in the barge for the containers, making it easier to account for statistical records in Renova's digital system. However, it was argued that the financial dimension is a vital factor that constrains the ability to implement new suggestions and that the issue lies elsewhere than finding new innovative suggestions.

In the context of technological innovation for the future, the municipality worker highlighted the potential for automating the tow boat, which could reduce the reliance on workers and enable operations during inconvenient working hours, such as during the night. Moreover, the municipality worker mentioned the existence of plans to introduce a camera system at the inland recycling center, used to analyze the waste that is being left to identify misallocated waste, thus

increasing the accuracy of sorting. As for retrofitting, the municipality worker discussed that the tow boat has been partly electrified to use electric propulsion for inland waterways while retaining the diesel engine for sea movement. In a separate case, a ferry that is not related to the waste flow has also been retrofitted to utilize hydrotreated vegetable oil (HVO) instead of diesel fuel, leading to reductions in carbon emissions.

Lastly, the municipality worker emphasized the need for a crane solution suitable for urban environments in the city, thus enabling loading and unloading operations. Standardized quays and barges are also essential to create efficiency in the waste flow. However, the municipality worker at KoV believes that there has to be a commercial interest in the development to find these solutions.

Tabell 5. The benefits propagated by the interviewee in Gothenburg.

Respondent	Stakeholder	Benefits
Interviewee 1	Kretslopp & Vatten	• Enhances environmentally friendliness and generational sustainability • Increased sustainability awareness • Reduced reliance on cars • Reduces car and truck usage • Increased accessibility to waste disposal facilities • Electrification of waste transport leads to improved sustainability

Tabell 6. The challenges propagated by the interviewee in Gothenburg.

Respondent	Stakeholder	Challenges
Interviewee 1	Kretslopp & Vatten	• Weather conditions including wind, waves and water level • Reconstructions in the waterways can lead to halts in waterway operations • Low bridges • Protected areas such as Natura 2000 • Finding appropriate quays • High investment costs • Stakeholder collaboration

Tabell 7. The future state propagated by the interviewee in Gothenburg.

Respondent	Stakeholder	Future state
Interviewee 1	Kretslopp & Vatten	• Integration of new technologies for efficiency • Integration of a weighing system for statistics • Automation for increased flexibility and reduced dependence on workers • Camera system at recycling centers for sorting improvements • Alternative fuels such as HVO • Crane solution suitable for urban environment and low bridges • Standardized quays and barges for efficiency in waste flow

8.2 Findings from Stockholm

General information and barge usage

As for the usage of inland waterways in Stockholm, the strategist from Trafikkontoret mentioned that the opportunities for using the inland waterways as a transportation tool are high due to the historical use of the waterways. Since the city is also located on several islands, it makes it easier, according to the strategist, to use the inland waterways. Consequently, the interviewee argued that the aspiration is to optimize the utilization of all available infrastructure, thus reducing road congestion as much as possible. Other than arguing that the usage of inland waterway shipping would result in reduced road congestion, the strategist highlighted that another benefit is the amount of goods that can be transported on a barge compared to road transportation. This volume increase would result in a reduced usage of trucks in the city, which is a main goal for the city of Stockholm according to the interviewee. Building upon this perspective, the interviewee argued that this truck reduction would result in increased traffic safety where less accidents will be situated.

Moreover, the strategist highlighted that the inland waterways are not used as much as there is potential for. Building upon this perspective, the CEO of Avatar Logistics claimed that although the prerequisites are very satisfactory, there is no incentive on the larger scale from the government to increase the activity on the waterways. Instead, one main driver supported by both interviewees is the current need to mitigate the goods flow from the road network to prevent problems such as road congestion, air pollution and overall sustainability. Noise and visual pollution are two other dimensions that were discussed by the interviewees, who both argued that implementing barges as a transportation

mode will result in less trucks being utilized in the city center, therefore causing less unnecessary noise in the city. The CEO asserted that new regulations have banned trucks from certain areas or certain times, which is also a driver for increased usage of the waterways, especially since the barges can operate around the clock. Moreover, the city wants to make use of all the available infrastructure, and the waterways are no exception. To make this practical, both interviewees claimed that the waterways are evaluated as a transportation path in all the construction projects in the city since it is more likely to win contracting negotiations with the municipality as the more environmentally friendly solution is presented. The barges in particular mostly transport construction materials such as limestone and sand from Gotland to Stockholm, but the strategist highlighted that the barges are also used as temporary land for projects related to developments in the waterway infrastructure. This barge can load up to 1000 tons of material, and it is estimated that around 400 truck transports a week has been reduced as a result of the barge's activities.

Challenges and limitations

The strategist mentioned that to increase the efficiency of the transportation activity, and therefore the profitability of the barges, empty transports must be reduced as much as possible. As of today, however, there are some empty transports considering the barges situated. However, empty transport is currently not considered a challenge by the CEO, who claimed that the transportation distances are too short, but can see the benefit of reducing the empty transport as the activities increase on the waterways. Both interviewees explained that there are ideas of solutions in which there is an increased collaboration between stakeholders such as package deliveries, but the solutions are yet to be implemented since most private companies see huge risks in taking the first step in changing their ways of transportation. The strategist highlighted that the city is only able to provide the necessary regulations or infrastructure such as quays, and that the first step must come from the company stakeholders themselves. On the other hand, the CEO thought that many quays in the city are being rebuilt into promenades to host businesses such as restaurants, which makes finding quays for loading and unloading more challenging than it already is. The CEO elaborates that a solution to this could be by building a centralized transshipment terminal. However, the interviewee noted that while the concept has been deliberated upon, it is not currently under active consideration for implementation.

Moreover, the strategist asserted that the inland waterway infrastructure in Stockholm is not limited by natural reserves, narrow passageways or low bridges. There are shallow waters in some areas, but they are not regarded as limitations to the overall infrastructure. However, there is a lock which separates the waterways around the coast from the inland waterways. The strategist believes that this lock could be considered problematic and complex by stakeholders. The

CEO, however, looks at it differently. The CEO claimed that a city like Ghent has many narrow passageways, locks and bridges, while the waterways in Sweden are uncomplex. Despite the relative simplicity, usage of the waterways in Sweden are taxed while usage of the waterways in Ghent are subsidized through many ways, one of which is receiving a bonus for each container that is moved from the road network to the waterway network. Therefore, the CEO emphasizes that a cultural and political shift is of high importance if the modal shift is to be implemented. Another difference between Sweden and a majority of countries in the European Union (EU) mentioned by the CEO is that Sweden's inland waterway network is disconnected to the EU. This has in turn led to Sweden creating its own legislations and regulations surrounding the IWW, with one difference being that captains for the sea and IWW need two different qualifications, thus fueling the already existing manpower issue.

New Technologies and Innovation

Considering new technologies and innovation, the daily work and responsibilities of the strategist are not directly related to the topic. However, the strategist had some opinions from the organization's perspective. Automation and electrification of the vessels are not yet implemented, but it is thought that it will develop in that direction in the future. The CEO of Avatar Logistics, however, mentioned that the electrification of the vessels has recently started, but is very slow in development. Considering automation of the vessels, the CEO thought that it is very beneficial with autonomous vessels since there are manpower shortages related to sailors and captains. This statement is supported by the strategist who claimed that automated vessels could be applied where the routes are static. Another way to deal with the manpower related issues is by remote controlled vessels. This idea is expressed by the CEO, who gave an example of captains which remote control multiple vessels simultaneously from an office in Antwerpen. Lastly, the CEO mentioned that the internet of things (IoT) could help with a much needed increase in communication between vessels, customers and other stakeholders in the value chain. Through IoT, real-time updates of schedules, estimated times of arrivals, and many more parameters would be improved, ultimately leading to enhanced cash flow. Another parameter that would be improved was thought to be navigation, where the strategist thinks AI could have a benefit in the planning of dynamic routes. To implement these solutions however, the CEO does not think that retrofitting is a viable solution since many vessels are outdated, and the cost of retrofitting is high. Instead, it is more viable to buy new vessels with these functions already implemented.

Tabell 8. The benefits propagated by the interviewees in Stockholm.

Respondent	Stakeholder	Benefits
Interviewee 2	Trafikkontoret	• Less road congestion • Mix usage - transportation and temporary land • Increased volume compared to road transportation • Increased sustainability • High connectivity • Less accidents • More likely to win contracting negotiations • Reduced noise and visual pollution
Interviewee 3	Avatar Logistics	• Less road congestion • Reduced noise pollution • Increased sustainability • Can operate 24 hours a day • More likely to win contracting negotiations • Reduced noise and visual pollution

Tabell 9. The challenges propagated by the interviewees in Stockholm.

Respondent	Stakeholder	Challenges
Interviewee 2	Trafikkontoret	• Difficult to minimize empty transports • Implement right regulations to encourage modal shift to IWW • The usage of the lock can be seen as complex • Collaboration between stakeholders
Interviewee 3	Avatar Logistics	• Implement right regulations to encourage modal shift to IWW • Collaboration between stakeholders • Finding available quays • Manpower scarcity

Tabell 10. The future state propagated by the interviewees in Stockholm.

Respondent	Stakeholder	Future state
Interviewee 2	Trafikkontoret	• Electrification of vessels • Automated vessel operations • Route planning with AI
Interviewee 3	Avatar Logistics	• Centralized transshipment terminal

		• Electrification of vessels • Automated vessel operations • Remote controlled vessels • Increased communication between stakeholders in the value chain

8.3 Findings from Ghent

This subsection presents the findings from the conducted interviews which were conducted in Ghent in Mars 2024 where the project manager from POM joined all the interviews and could therefore provide more intel to the subject by also presenting some aspects from their perspective as well.

General information and benefits of barge usage

Initially, all stakeholders from Ghent shared that inland waterway shipping have emerged as a significant component of urban logistics in the city by offering solutions that will mitigate congestion and reduce the environmental impacts. The interviewees showed this by providing various examples of current practices and outlining their visions for future implementations. For instance, the municipality worker in Ghent mentioned that the city of Ghent is investigating the potential of distribution hubs (regional transshipment points), combined with intra-city transshipment points. According to the municipality worker in Ghent, the implementation of the intra-city transshipment points would create an economy through the waterways, meaning it will optimize the efficiency of the city's inland waterway shipping network and thereby reduce costs for businesses. The project manager from UWL supported this notion by highlighting the potential for increased utilization of inland waterways for deliveries and waste flows by emphasizing the importance of raising awareness that could lead to a greater volume of goods being transported via the inland waterways. This would, according to the project manager, in return make IWS more financially viable. By implementing these urban transshipment points all over Ghent, as the municipality worker in Ghent presented, the result would imply a reduced usage of trucks operating in the city and thereby reduce traffic congestion, noise pollution and visual pollution. The interviewee also emphasized that last mile deliveries carried out by fossil-free driven vehicles are also being considered as a part of the transshipment point logistical system, leading to a further reduction of CO2 emissions.

Related to costs, the founder of Fabriek Logistiek emphasized the importance of identifying financially viable solutions when implementing new solutions to increase the usage of inland waterway shipping in Ghent. Interviewee 4 mentioned that organizations need to determine whether a suggestion should be implemented or not by analyzing the number of operations a solution entails. By minimizing the number of operational actions, the solution will be scalable later

on later on. The CEO of Thienpont agrees with this dimension and presented an example of how to lower the operational cost, which can be done by implementing an integrated weighing system for easier statistical analysis of the waste. Meaning, instead of weighing the waste as a separate activity, it is weighed as a part of the truck transportation process. The founder of Fabriek Logistiek also emphasized the criticality of efficiency by articulating that transportation with empty cargo is a wasteful expenditure of resources and thus inefficient. Optimizing the use of transport capacity involves ensuring that the barge is fully loaded whenever transport is being operated. The municipality worker in Ghent supports this argument by emphasizing the importance of having viable volumes in order to get greater profits. The founder of Fabriek Logistiek presented a suggestion to achieve this efficiency by combining two distinct flows of goods. For instance, by coordinating the delivery of construction materials to one destination and collecting waste on the way to the final destination point at once. Building upon this perspective, the project manager from UWL highlighted a specific initiative aimed at reducing empty waste transport within the concept of the AVATAR vessel project. The initiative involves collaborating with farmers to transport food into the city while simultaneously transporting waste out of it. However, it emerged that implementing the suggestion posed a challenge due to existing business behaviors. Despite efforts related to presentations to farmers, the project manager from UWL mentioned that the integration of this transport method remains unrealistic to implement in the near future since the resistance stems from the difficulty of ending long-lasting logistics flows. However, the idea is beneficial since it creates opportunities for substantial CO_2 savings associated with the implementation.

Challenges and limitations

Furthermore, the interviewees shared some initial perspectives related to some benefits and challenges when using the inland waterways in Ghent. For instance, the CEO of Thienpont emphasized that because of the excellent connectivity and the viable volumes of transporting goods via the inland waterways, low-cost opportunities are created for many organizations to utilize it while also becoming more environmentally friendly. It was also highlighted by the CEO of Thienpont that the scalability in terms of volume is also a major driver in order for organizations to shift their transportation mode from road to waterway transportation in order to handle larger volumes and therefore enhance cargo efficiency. Related to becoming more environmentally friendly, the CEO of Thienpont highlighted the significance of environmental sustainability for an organization's market competitiveness. The more environmentally friendly a solution that an organization can present, the more likely it is to be chosen by the government for a given project. Therefore, prioritizing sustainability is, according to the CEO of Thienpont, a key driver for shifting transportation towards waterways. Building on this insight, the project manager from POM argued that it

is possible that a regulatory approach wherein the government incentivizes and even forces organizations to use inland waterways by linking it to several business opportunities. The project manager from POM continued by saying that by implementing regulations and demands that support companies employing environmentally friendly transportation methods, the government can effectively encourage organizations to adopt inland waterway shipping.

Even if the interviewees presented several benefits when using the inland waterways in Ghent, some challenges are also in place. The founder of Fabriek Logistiek began the interview by expressing that it is difficult to make people become interested in waste transportation since it is perceived as low value. From an economic standpoint, the founder of Fabriek Logistiek argued that individuals and organizations are unwilling to invest in a modal shift for waste management if the finances are too high. Another obstacle that can prevent the inland waterway shipping of bulk waste to be situated are the weather conditions, specifically wind, which the founder of Fabriek Logistiek highlighted as an important dimension to consider since bad weather can make the products and waste get lost in the river. The CEO of Thienpont highlighted a key challenge hindering the organization's utilization of inland waterways despite the well-established connections. The presence of bicycles, rocks, and sludge in the river is the main obstacle, which creates less space for the vessels to pass through the river.

Infrastructure

The stakeholders expressed various concerns regarding the infrastructure associated with inland waterway operations in Ghent, particularly focusing on the city's bridges and the use of cranes. Regarding the bridges, the CEO of Thienpont emphasized that the current dimensions of the containers make it infeasible for the containers that Thienpont currently has to pass through the bridges. Therefore, it was argued by the CEO that in order to implement their operations in the inland waterways, having smaller containers is an important aspect to consider in order to navigate under the bridges effectively. As for the loading and unloading operation related to the smaller containers, the CEO of Thienpont presented some significant challenges due to the placement of hooks which can only be fixed to the short side of the containers. This limitation creates restrictions in terms of flexibility as containers can only be loaded from the short side, despite vessels typically docking at the quay on the long side. Consequently, containers must undergo rotation, adding an additional operation step. However, the CEO of Thienpont proposed a solution involving the integration of a crane to facilitate the container rotation during the unloading operation, aiming to enhance the operational efficiency. While this is seen as redundant, the CEO of Thienpont emphasized that as the volume increases, the impact of this development becomes more relevant and will have greater impact in the long run.

Furthermore, the project manager from POM highlighted that the CEMT I vessels face constraints navigating the CEMT I classified waterways within the inner city of Ghent due to a combination of low bridges and shallow canal depth caused by sedimentation and debris, including sludge, bicycles and rocks. The presence of bicycles and rocks poses a significant challenge by affecting the depth of the canals, which the municipality worker in Ghent argued is another negative impact since it interferes and makes it infeasible for the vessels to pass through the bridges. Building upon this perspective, the project manager from UWL argued that a significant challenge of the AVATAR-vessel was ensuring its navigability through the city of Ghent due to the low bridges. The project manager mentioned that the city has 34 bridges, some of which are particularly low. However, it was reassured that the vessel's current design allows it to navigate throughout the city, which is aligned with the primary vision of the vessels. With the vessel capable of operating at a depth of only 50 centimeters below the waterline, while Ghent's lowest bridge offers a clearance of 70 centimeters, the project manager argued that adjustments like ballasting are necessary for passage under certain bridges. Although it remains feasible to navigate through the bridges successfully, the total height of cranes, containers and goods on the vessel should not exceed this limitation.

Due to the low bridges, the interviewees mentioned that the low bridges pose more challenges related to crane operations along the inland waterways in Ghent. For instance, the founder of Fabriek Logistiek emphasized that these low bridges have made it incapable to have cranes which can pass under the low bridges in Ghent. Furthermore, due to special constraints related to vessel dimension, integrated cranes that are suitable for such conditions have not been developed yet. Additionally, as ships on small canals are narrow in width, loading and unloading cargo with a crane on the ship will cause instability with risk of tilting of the vessel. Building on this argument, the project manager from UWL claimed that despite new innovative technologies loading and unloading operation from the ship to the quayside poses significant challenges, especially regarding stability and safety.

According to the project manager, tests have shown that the use of cranes on ships will not be feasible due to imbalance which can result in the vessel collapsing. However, efforts are being made in order to explore other alternatives for loading and unloading solutions. One solution that the project manager brought up involves utilizing loading ramps and roll-on-roll-off lift truck systems which will offer both greater stability and safety. This solution will, according to the project manager, have the capacity to transport goods directly from the vessel to the city center. Building upon this perspective, the municipality worker in Ghent mentioned that due to sedimentation and debris caused by the quantity of bicycles that get thrown in the river by citizens and rocks, some restrictions are in place

related to the loading and unloading operations. These restrictions cause the execution of the loading and unloading operations needed to be done outside of the city's lower bridges. According to the municipality worker in Ghent, such alternative destinations need to meet two key criterias: they should be financially beneficial and be situated in areas requiring minimal transportation mode adjustments to reach the final destination.

During the interviews, it was noted that despite challenges posed by low bridges restricting crane operations, certain cranes are capable of navigating under these structures. For instance, the municipality worker in Ghent mentioned a vessel with an integrated crane called Zulu, which can pass through some of the low bridges in Ghent. Additionally, the founder of Fabriek Logistiek discussed the feasibility of implementing cranes related to waste flow management, which has not been implemented yet. However, the project manager from POM mentioned that the existing Zulu vessel is not designed to tail into the deep city center of Ghent where there are low bridges, while also emphasizing that putting a crane on a vessel lowers the capacity of the vessel, where less cargo can be shipped. However, foldable cranes are currently utilized in inland waterway activities which facilitate the delivery of food and drinks to the restaurants located in the city that both fit in the vessel and under the bridges.

There is a divergent opinion regarding the impact of architecture and urban themes on the feasibility of implementing cranes within Ghent. The project manager from POM disagrees with the notion expressed by the municipality worker in Ghent regarding that the city's architecture and theme dimension presents significant challenges for integrating cranes and other infrastructure close to the waterways which can result in a visual pollution. Instead of this, the project manager argued that it can be feasible to implement a solution where their cranes do not create visual pollution, such as placing the loading and unloading zone inside a building which hides the crane. It was also considered by the project manager of creating an architectural crane as a landmark for the city.

New Technologies and Innovation

In terms of innovative technologies, the interviewees revealed various concepts and studies concerning potential implementations in the inland waterway operations. For instance, the project manager from POM mentioned that pilots are carried about, and studies are being made into utilizing a remote control for vessel navigation. It was highlighted by the interviewee that the AVATAR-vessel for instance can be remotely controlled but is not being entirely utilized for a few reasons. The project manager from UWL elaborated on this by highlighting that while experiments are being conducted on how to use a remote control to steer the vessels, it still remained in the testing phase due to safety reasons. Despite successful tests conducted in the Netherlands and other research and innovations

centers abroad, the integration into the daily operations has not been implemented because of safety reasons. Although tests with a remote-control system are in this state feasible across Flanders, the current national legislation prioritizes safety protocols which is hindering the implementation. As of now, there is always a skipper on board while conducting these tests. The project manager from UWL also noted that Flanders is a frontrunner in navigating these legislative difficulties, yet specific regulations concerning automated sailing through remote control systems are yet to be established.

Concerning innovative technologies related to the vessels, the founder of Fabriek Logistiek and 8 presented some insights in how this could be implemented. For instance, the founder of Fabriek Logistiek has studied magnets for mooring remotely. This will remove the need for, and thus the cost, of staff on site. Yet, the solution needs to allow the vessel to move up and down as payload is increased or decreased. Having the magnet make the ship stuck to the pier makes it easier to load and unload the vessel. According to the founder of Fabriek Logistiek, it would also use magnets to control the height of the vessels since unloading leads to higher buoyancy, ultimately leading to a difference in height between vessel and quay. Yet, this solution needs to be financially beneficial to implement. As for the mooring, there is an automated mooring system being developed by other partners involved in a project within the organization. The project manager from UWL presented another docking and undocking solution that is conducted concerning innovative technologies. The utilization of three different thrusters for a new propulsion system on the vessel were highlighted, including one for main propulsion and the other two propulsions for bow and stern thrusters respectively. With these two thrusters, the project manager emphasized that horizontal movement towards the quay is achievable without needing to physically dock the ship. The project manager argued that this new technology enables station keep mode, which is highly advantageous when it comes to remote control sailing since it eliminates the necessity for a skipper to be on board when handling the mooring operations. This implementation is according to the project manager being tested together with a Dutch company to further explore the technological dimensions.

Moreover, the project manager from UWL presented several innovative technologies related to the AVATAR-vessel. Firstly, the advancements in communication technology were presented, specifically regarding the integration of GNSS (Global Navigation Satellite System) with GPS and Galileo for enhanced navigation accuracy which is especially suited for urban environments. Thereafter, the project manager from UWL outlined the developments related to the propulsion system and emphasized the efforts made to optimize efficiency and reduce energy consumption. This development involved designing specialized propellers and increasing the engine performance. The project manager from

UWL mentioned that these developments could be made during the construction of the Green Wave vessel. However, the organization is currently working on these implementations for the next AVATAR-vessel by having adapted propellers to increase efficiency and lower the energy needs. Moreover, the project manager mentioned that ongoing researchers are focusing on enhancing the battery technology to prolong the operational capacity, with focus on finding alternative energy sources such as hydrogen and methanol. One example would be using swappable hydrogen fuel-cell packs when the technology becomes commercialized. Currently, however, the project manager is co-operating with multiple companies to create a standardized swappable battery pack used for the propulsion of the vessels.

Lastly, the founder of Fabriek Logistiek presented a crane called Sennebogen which has undergone many tests for potential future deployment. This crane is engineered to be capable of reaching into the negative, meaning below the ground, which is not a common characteristic for crane vehicles. However, a grapple for this specific crane is still in development, and its purpose is to minimize waste loss and pollution by enabling the cutting of waste outside of the grapple. The grapple is also used to collect the waste and prevent it from falling on the ground or water when loading from the quay to the vessel and vice versa. The founder of Fabriek Logistiek emphasized that the grapple is currently designed for handling plastic and household trash only, as cardboard and paper can damage it. However, the interviewee mentioned that cutting metal still remains untested and emphasized that it is going to be tested in the future. Building upon this perspective, the project manager from POM mentioned that the grapple has been tested in woods and the results were not satisfactory since the material damaged the grapple. However, the project manager intends to utilize this grapple for loading and unloading vessels, which is expected to be operational within 2-3 years from now depending on the testing time.

Industry 4.0

Regarding industry 4.0, the interviewees revealed a diversity of visions and thoughts related to the subject in relation to inland waterway shipping. For instance, the CEO of Thienpont believes that AI is the future and that if the organization works as they do now, the organization will not exist in 5-10 years. Due to the technological revolution that is taking place, the CEO of Thienpont believes that these changes will significantly benefit the company and help the organization to move their operations to water transportation. Moreover, the CEO of Thienpont anticipates that the segregation of various waste flows will become more efficient through the transition from manual manmade separation to AI-driven separation techniques. This separation is, according to the CEO of Thienpont, essential for a country like Belgium due to the current scarcity of manpower in the waste transportation industry.

Furthermore, the project manager from UWL highlighted the organization's involvement in several projects related to industry 4.0 by specifically mentioning their work with IoT and the legal aspects. For instance, the project manager from UWL mentioned that the organization has provided insights into a recent project involving a smart terminal, which embeds automated sailing, mooring and loading processes. The presented automated functionalities are integrated into a digital twin framework that the organization uses to leverage machine learning to optimize the various equipment operations at the docking stations. Another initiative related to industry 4.0 that the project manager mentioned is the ongoing testing operations related to smart navigation, where the ships are equipped with decision-making capabilities on the ship itself. This navigation includes the ability to autonomously adjust or deviate like a car in response to safety concerns such as avoiding collisions.

Moreover, the project manager from UWL emphasized the ongoing evolution within ports and quays and its integration of technologies related to Artificial Intelligence (AI) and Internet of Things (IoT) across Europe. Drawing inspiration from the port of Singapore and Shanghai, the project manager mentioned that automated connections with the port upon entry are already established. The ports of Singapore and Shanghai have the biggest container ports in the world. There the loading and unloading operations of the containers are fully automated and therefore do not need any staff working with the activities, which according to the interviewee, is the final goal if it is financially beneficial.

Furthermore, the project manager from UWL expressed the complexity surrounding the pursuit of full automation. Even if it is seen as something great, the field is very big and highly complex, resulting in many investments that need to be made in order to conduct future research and development. Building upon this perspective, the project manager from POM expressed some concerns related to full automation and highlighted the potential impact of innovative technologies on employment by raising concerns about labor shortages. In the context of Ghent's existing staff shortages, the project manager argued that the implementation of autonomous sailing appears to be an intriguing solution. However, the project manager views autonomous sailing as something complementary rather than a replacement of human labor.

While some of the interviewees see industry 4.0 as a useful tool to implement IWS operations, the founder of Fabriek Logistiek has other opinions. Automation in inland waterways might not be particularly interesting. The founder of Fabriek Logistiek mentioned that robots, if introduced into the transport operations, are many times programmed to operate at deliberately slower speeds in order to minimize the risk of any damage in accidents. However, the founder of Fabriek

Logistiek mentioned that notable changes can be useful to implement within the waste sorting system. For instance, the implementation of camera inspection integrated with AI is something that the founder of Fabriek Logistiek thought could be implemented in the future, thus visually distinguishing the waste due to its characteristics. The reason behind this innovation was discussed by the founder of Fabriek Logistiek who mentioned the challenges associated with manual waste sorting processes and the unpleasant work environment related to waste management, such as odor and soilage.

By implementing AI-driven camera inspection systems, the founder of Fabriek Logistiek argued that it becomes feasible to remove these specific jobs and thereby enhancing the efficiency and eliminating manpower related issues. This is something that the project manager from UWL also expressed concerns about, particularly the trend towards fewer job opportunities. While the project manager expressed concerns related to AI-driven separation, cited examples were presented from other ports in Barcelona and Valencia where the focus has been on balancing employment opportunities with the automated system.

Retrofitting

The concept of retrofitting existing vessels is a subject that both of the project managers from POM and UWL discussed. The project manager from UWL mentioned that it is possible for smaller vessels to be retrofitted and is a practice that can be used in the future. However, the interviewee expressed that the only dimension that can be retrofitted in a feasible manner is another type of propulsion or battery. Furthermore, the project manager from POM acknowledged the feasibility of retrofitting the vessel by expressing some concerns and skepticism regarding the practicality and the economic benefits related to it. From previous observations, the project manager from POM mentioned that it is more common for organizations to construct new autonomous vessels rather than retrofitting existing ones. Despite the economic advantages that are theoretically associated with retrofitting, the project manager from POM highlighted a paradox. Although vessels require higher investment cost and have a longer lifespan compared to other transportation modes, retrofitting should be more beneficial than creating a new vessel. This is a consequence of new vessels being subsidized by the government, while retrofitting old vessels are not.

Tabell 11. The benefits propagated by the interviewees in Ghent.

Respondent	Stakeholder	Benefits
Interviewee 4	Fabriek Logistiek	• Reduced road congestion • Reduced environmental impact
Interviewee 5	Thienpont	• Reduced road congestion • Reduced environmental impact • High connectivity leading to many opportunities • Higher scalability than road transportation • Increased chance for government to choose your solution, and thus company as a partner
Interviewee 6	City of Ghent	• Reduced road congestion • Reduced environmental impact • Facilitate economical flow • Reduced noise and visual pollution
Interviewee 7	POM	• Reduced road congestion • Reduced environmental impact • Increased chance for government to choose your solution, and thus company as a partner
Interviewee 8	UWL	• Reduced road congestion • Reduced environmental impact • Facilitate economical flow

Tabell 12. The challenges propagated by the interviewees in Ghent.

Respondent	Stakeholder	Challenges
Interviewee 4	Fabriek Logistiek	• Minimize operational actions • Minimize empty transportation • Build interest in waste transportation • High investment costs • Difficult weather conditions • Low bridges • Cranes integrated in the vessel • Automation leading to slower operations • Manpower scarcity
Interviewee 5	Thienpont	• Minimize operational actions • Less available space as a result of bikes, rocks and buildup of sludge in the canals • Low bridges • Manpower scarcity
Interviewee 6	City of Ghent	• Finding viable volumes • Less available space as a result of bikes, rocks and buildup of sludge in the canals • Low bridges

		• Finding appropriate quays • The architectural theme of the city
Interviewee 7	POM	• Implement right regulations to encourage modal shift to IWW • Less available space as a result of bikes, rocks and buildup of sludge in the canals • Low bridges • Economic benefits of retrofitting • Manpower scarcity
Interviewee 8	UWL	• Change in existing business behavior • Low bridges • Implement right regulations to encourage modal shift to IWW • Cranes integrated in the vessel • Full automation of vessel operations • Manpower scarcity

Tabell 13. The future state propagated by the interviewees in Ghent.

Respondent	**Stakeholder**	**Future state**
Interviewee 4	Fabriek Logistiek	• Automated mooring • Magnetic mooring and height adjustments • Grapple for crane which cuts waste as it closes • Separation of waste through AI
Interviewee 5	Thienpont	• Change container type to liftable • Integration of a weighing system for statistics • Automated sorting of waste • AI influence in waste logistics
Interviewee 6	City of Ghent	• Stimulated waterway economy by regional and urban transshipment points • Fossil-free last mile delivery • Increased logistics flow on waterways
Interviewee 7	POM	• Cranes which do not create visual pollution • Remote control for vessel operations • Autonomous sailing
Interviewee 8	UWL	• Navigation system for urban environment • Adapted propellers for propulsion efficiency • Energy source alternatives • RoRo lift truck systems • Automation of loading and loading operation

		• Smart terminal with automated functions • Automated navigation • Automated sorting of waste • Implementation of retrofitting on IWW vessels

8.4 Findings from Le Havre

General information and benefits/challenges of barge usage

Initially, both stakeholders from Le Havre argued that inland waterway shipping has emerged as a significant component of logistics both inside the city center and outside. Using the inland waterways is something that both of the stakeholders argue is beneficial for several reasons, one of the reasons being less road congestion. According to the project manager at CIRCOÈ, the scalability difference between trucks and inland waterway vessels is largely significant, resulting in less congestion being polluted when transporting goods on water instead of road. Considering the future perspective, the project manager mentioned that larger cities will in a short manner of time implement low emission zones in several areas of the city center, meaning that solutions need to be found related to transporting goods to the city center. Using this transportation mode now is, according to the project manager, also beneficial for the organization in order to create a competitive advantage than using it in the future, since the project manager sees this transportation as something that companies need to utilize due to future regulations. Furthermore, the director general of Sogestran argued that using the inland waterways would also result in less accidents being situated since there is less traffic density in the water compared to road transportation. Lastly, both the project manager AND the director general argued that using inland waterway shipping would result in less noise pollution due to the operation not being situated in the city center.

Although the stakeholders presented some benefits, one major challenge was discussed by the project manager. According to the interviewee, high costs associated with new technologies stem from limited market adoption concerning inland waterway shipping. The interviewee elaborated this perspective by arguing that as more organizations will start using the inland waterways, the costs will decrease, which is, according to the interviewee, being situated in the near future.

Infrastructure

As for the infrastructure, the director general mentioned that Le Havre has great possibilities for shipping operations as the city is a coastal town. The challenges, however, are related to the shipping destination of Paris, where the infrastructure is not sufficient. The project manager elaborated that there are lesser developments for waterway operations. For example, there are no extensive

developments for dockers, cranes, terminals and workforce. Simultaneously, loose regulations for inland waterway shipping as of today create very little formalities for the usage of quays. Instead, loading and unloading can take place anywhere deemed suitable, as long as it only takes minutes to do, and the quay is left in its original shape. The director general explained that the municipality has focused on pedestrian walkways and roads for cycling instead of the development of quays along the waterway.

New Technologies and Innovation

Considering innovative technologies, the propulsion system of the Zulu vessel has been highly developed. The project manager mentioned that the Zulu vessel started with a diesel engine for its first generation. Currently, the Zulu is in its 6th generation of development and uses swappable hydrogen fuel cells. The project manager continued to explain that this type of fuel is a very recent innovation, and that there are still high regulations that have not yet developed with the market. The high regulations stem from safety concerns since hydrogen is highly reactive, and the Zulu vessel conducts operations in urban areas.

Industry 4.0

Regarding the question of autonomous sailing, there are no current plans or needs to develop this system for IWS on the Seine River. The project manager and the director general claim that automation of vessels entail slow moving vessels, and because of the length of the waterway from Le Havre to Paris, automation would not be a feasible solution. For shorter routes however, it could be a possibility for the future. Considering IoT, the project manager gave an example of multiple vessels navigating by platooning, lowering drag and thus increasing efficiency. Another use could be remote troubleshooting of maintenance, which would ultimately result in lower costs for the vessel. The challenge stated related to industry 4.0 comes from ensuring cybersecurity, as the more digitized the operations become, the more susceptible they become to being targeted for hack. The director general mentioned the ability to track both goods and vessels. By implementing a tracking system, the activity of organizing multimodal logistics is simplified and made more efficient. The project manager supported this claim and elaborated that an increase of organization between stakeholders in the supply chain is essential for better synergies and further developments.

Retrofitting

As for retrofitting, the interviewees argued that there are no vessels that are retrofitted as of now in Le Havre. Even though the stakeholders are familiar with the concept of retrofitting from previous transportation projects, the interviewees argued that retrofitting within the inland waterway shipping vessels is not something being considered. Building upon this perspective, the project manager argued that there is a certain risk in place when retrofitting a vessel whether the

project will be successful or not. Building a new vessel is, according to the project manager, sometimes the best option rather than retrofitting an existing vessel since the costs are considered to be the same in the end. This is because government incentives are usually distributed to new vessels with new technologies rather than old vessels with new technologies.

Tabell 14. The benefits propagated by the interviewees in Le Havre.

Respondent	Stakeholder	Benefits
Interviewee 9	CIRCOÈ	• Less road congestion • Higher scalability than road transportation • More likely to win contracting negotiations • Reduced noise pollution
Interviewee 10	Sogestran	• Less road congestion • Less accidents • Reduced noise pollution

Tabell 15. The challenges propagated by the interviewees in Le Havre.

Respondent	Stakeholder	Challenges
Interviewee 9	CIRCOÈ	• High investment costs • Cyber security • Finding appropriate quays • Alternative fuel - hydrogen fuel cells
Interviewee 10	Sogestran	• Automation leading to slower operations

Tabell 16. The future state propagated by the interviewees in Le Havre.

Respondent	Stakeholder	Future state
Interviewee 9	CIRCOÈ	• Automated navigation • Platooning vessels
Interviewee 10	Sogestran	-

9. Analysis

In order to answer to the first research question, which again is "*What similarities and differences can be found when comparing the green and innovative development of barge transportation on inland waterways with the settings in Gothenburg, Stockholm, Ghent and Le Havre?*", focal topics have been chosen that the stakeholders mainly discussed. Since the focal aspect of the study has been new technologies and innovation, it has been equally important to analyze all topics which it affects or is being affected by. As a result, the interviews with the stakeholders have resulted in three different topics which directly affect the new technologies and innovation aspect, namely navigation on the inland waterway, profitability, and business behavior and market characteristics. In turn, the focal aspect affects the environmental impact. The five different topics are further expanded below in more detail.

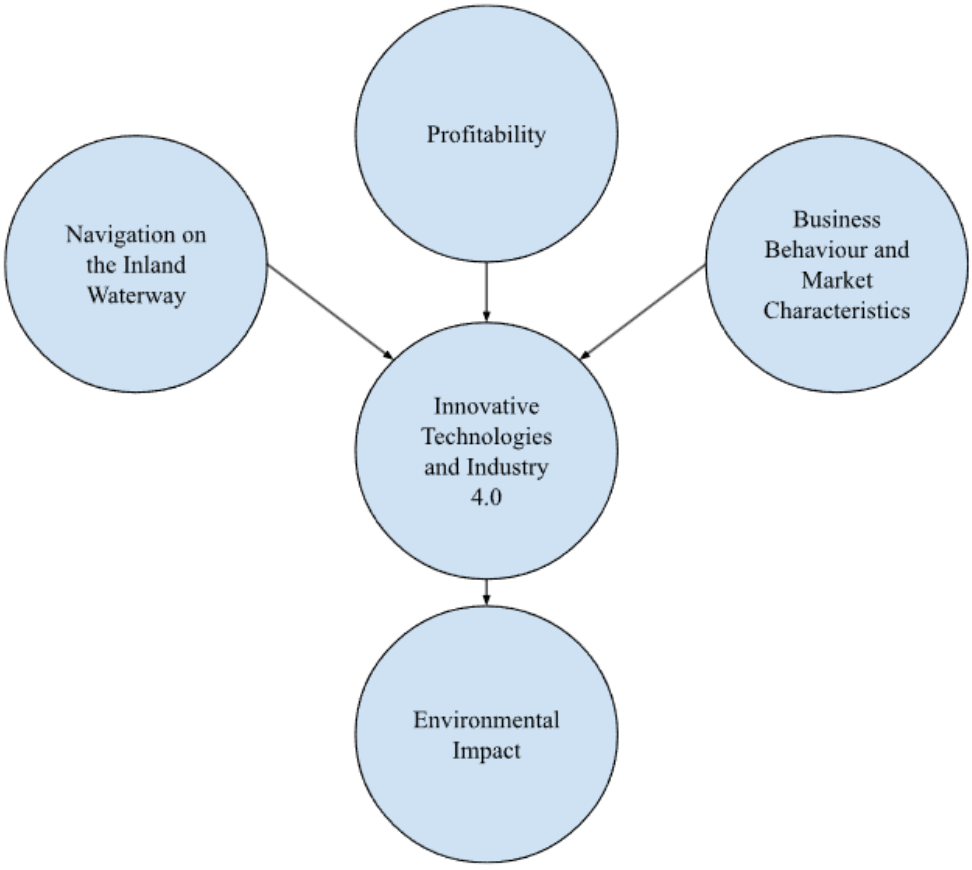

Figure 15. Contexts affecting innovative technologies and industry 4.0

The topics are divided into different subsections and their respective subjects based on the stakeholders' answers. Firstly, the perspective of the environmental impact is presented with focus on road congestion. and visual pollution. Then, profitability is discussed from three different perspectives: (1) minimization of operational actions, (2) increased volumes, and (3) creation of synergies between

stakeholders. Subsequently, the business behaviors and market characteristics are presented. In this subsection, the main focus is on the limited market and raising awareness and governmental incentives. Innovative technologies and industry are then analyzed from four different settings: automation of the barges, automation of waste sorting systems, Internet of Things (IoT) and retrofitting. Lastly, navigation in terms of safety, infrastructure and connectivity is analyzed. Figure 16 presents a general description of how the topics are connected. Subsequently, each subsection in the analysis presents a table consisting of the topics and whether the stakeholders view them as a benefit or a challenge. However, nearly all challenges can be perceived as benefits, but if it is regarded as a challenge to achieve for the stakeholder, it is classified as a challenge in the table.

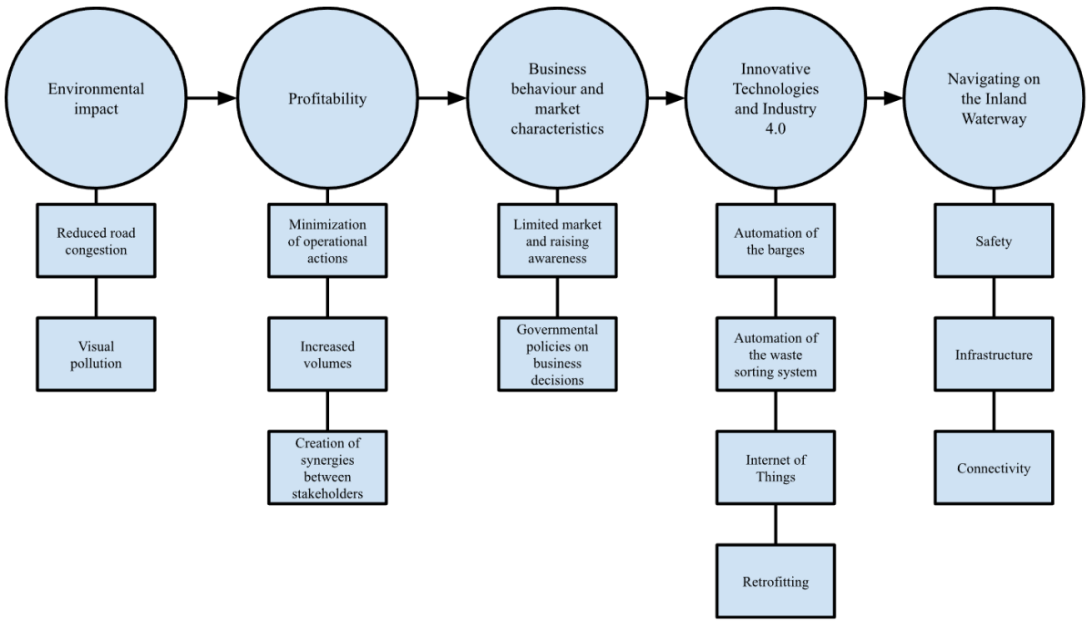

Figure 16: Content map of analysis.

9.1 Environmental Impacts

The environmental impacts have been analyzed mostly from a perspective where reduced road congestion has been discussed. The section presents a Table with the stakeholder's vision and perspective based on the subjects below related to benefits and challenges.

Tabell 17. A compilation of benefits and challenges on environmental impact and reduced road congestion from the stakeholders.

	Gothen-burg	Stockholm		Ghent					Le Havre	
Sub-topics	Kretslopp & vatten	Trafik-kontoret	Avatar Logistcs	POM	UWL	Fabriek Logistiek	Thien-pont	City of Ghent	CIRCOÈ	Soge-stran
Reduced environ mental impact and road	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit

congestion										
Create solutions to reduce road congestion	Benefit		Benefit					Benefit		
Reduced noise pollution when reducing traffic density		Benefit	Benefit					Benefit	Benefit	Benefit
Reduced visual pollution		Benefit	Benefit					Benefit		

9.1.1 Reduced Road Congestion

After conducting the interviewees, it is clear that all stakeholders see the increased usage of inland waterways as beneficial due to the reduction of road congestion. For instance, Stockholm is working towards becoming free from fossil fuels and minimizing the usage of freight trucks. Sign et al. (2015) explains that freight transport is more environmentally friendly than other transportation modes. One benefit is that the barge in Stockholm has eliminated 400 truck transports a week, ultimately reducing road congestion. The strategist at Trafikkontoret emphasized that it is vital to make use of all available infrastructure to reduce road congestion. One example is mentioned by Achmadi et al. (2018) who claimed that the implementation of IWS in Indonesia led to a 18.6% decrease in road congestion. In addition, since (Energimyndigheten, 2017) mentioned that every fourth truck transport in Stockholm is composed of dirt and stone, there is a huge opportunity for reduced road congestion.

As a result of the floating recycling barge in Gothenburg, less people find the need to take the car to drive to recycling centers located remotely. Instead, the customers use low carbon methods such as bus, bike or walking as a means of transportation to the recycling waste barge. Since the recycling waste barge moves to five different locations using the push-barge, the waste barge travels to the customers instead of requiring the customers to travel a longer distance to the waste barge, thus increasing the accessibility and minimizing the usage of road transportation. However, in Ghent, one solution is the transportation system in which goods are transported from centralized regional transshipment points to decentralized urban transshipment points via the waterways, to later be shipped by fossil free vehicles considering last mile delivery. As for the vessel itself, there are many fossil free solutions that could be implemented depending on the route characteristics. The Zulu-vessel offers capacity, the AVATAR-vessel offers flexibility, and the recycling waste barge offers simplicity. Not only does high usage of road transportation lead to more emissions and road congestion, but also noise pollution. Stakeholders in Ghent, Stockholm and Le Havre all mentioned that

another benefit of IWS would be the implication of less noise pollution as a result of less trucks being utilized in the city centers. As Roso et al. (2020) stated, IWS has been used to a significantly smaller extent than other transportation modes, thus promising great opportunities for development.

Lastly, noise and visual pollution was briefly mentioned by the stakeholders in Stockholm and Ghent. In Stockholm, both stakeholders argue that both pollution types are expected to decrease in the case of a modal shift since less trucks will be utilized on the roads inside the city. This is also mentioned by the municipality worker in Ghent, who argues that a reduced number of trucks in the city will result in less noise and visual pollution. The municipality worker also mentioned the problems with conducting crane operations in Ghent's inner city, as the cranes also cause visual pollution. This is however further expanded upon in the subsection crane operations.

9.2 Profitability

The question and solutions surrounding profitability was another major topic that was discussed frequently by the stakeholders. Ultimately, the topic could be divided into three subcategories of solutions, namely minimization of operational actions in the value chain, increased volumes and lastly, the creation of synergies between stakeholders. The subcategories are presented below, followed by Table 18 with the stakeholders' vision and perspective based on the subjects below related to benefits and challenges.

Tabell 18. A compilation of benefits and challenges on profitability from the stakeholders.

	Gothen-burg	Stockholm		Ghent					Le Havre	
Sub-topics	Kretslopp & vatten	Trafik-kontoret	Avatar Logistcs	POM	UWL	Fabriek Logistiek	Thien-pont	City of Ghent	CIRCOÈ	Soge-stran
Minimi-zation of operation al actions	Benefit					Benefit	Benefit			
Econom-ies of Scale	Challenge	Benefit		Benefit		Benefit	Challenge	Benefit	Benefit	Benefit
Minimizin g empty cargo transport-ation		Challenge	Benefit		Benefit	Challenge		Benefit		
Stakehold er collabo-ration				Benefit	Benefit		Benefit	Benefit	Benefit	

9.2.1 Minimization of Operational Actions

The International Maritime Organization (1992) established that a vessel is only profitable when moving cargo. Thus, by minimizing the number of operational actions in the value chain, meaning that by making the overall process more efficient, profitability is increased. This benefit is also strengthened by the founder of Fabriek Logistiek who highlighted the importance of finding holistic solutions

with minimal number of operational actions. The findings have shown different practical approaches in achieving this. Considering Gothenburg, the stakeholder at Kretslopp & Vatten (KoV) discussed a solution for an integrated weighing system. In the weighing system solution, an integration of a scale on the recycling waste barge would lead to enabling statistical data as the containers are being filled with waste, thus eliminating the need to weigh the waste as a separate action. However, the financial dimension is currently constraining the ability to implement this solution, as presented in Table 18 where the stakeholder from Gothenburg views EoS as a challenge. Nonetheless, as the volumes in the waste flow are increased, the financial investment would become more defendable. Considering Ghent, the CEO of Thienpont agrees with the idea of an integrated weighing system and that it would lead to the benefit of less operational actions. However, the CEO notes that this is already in use for their waste collecting activities by truck, as the trucks are weighed before and after emptying the load by driving onto a scale for trucks. Another opportunity to reduce operational actions was brought up by the CEO, who claimed that containers in Ghent must first be unloaded from the vessel onto land, and then be rotated from the long side to the short side, before being able to be picked up by a truck. The reason for this is that trucks in Ghent have a hook system for loading containers onto the truck. Thus, by changing the hook system into a system where the container can be directly lifted from the vessel onto the truck, an operational action is eliminated. The CEO emphasized that as the volume in the waste flow is increased, the elimination of one operational action has a major impact on the profitability in the long run, as shown in Table 18.

9.2.2 Increased Volumes

In this subsection, both EoS and minimization of empty cargo transportation are discussed. Fan and Nachtman (2021) emphasize that EoS can be reached by loading more goods on the barge, meaning increasing the load percentage, thus decreasing shipping costs. This strategy is being utilized at Thienpont which is currently increasing waste volumes by expanding the company through acquisition of competitors. However, the CEO viewed EoS as a challenge and explained that it is not feasible to reach EoS by using a continued waste collection method with trucks and must instead implement the usage of barges. The CEO mentioned that the barges have a much bigger capacity than the trucks, and in combination with the excellent waterway connectivity of Ghent, a low-cost opportunity is created while also becoming more environmentally friendly. The significant difference between road and waterway transportation in scalability and capacity was also highlighted by the project manager at CIRCOÈ in Le Havre, and the strategist at Trafikkontoret in Stockholm respectively, who both agreed that it would result in less environmental impact.

Another way of improving the overall load percentage would be to minimize transporting empty cargo. The founder of Fabriek Logistiek also mentioned that the challenge of empty cargo transportation is a wasteful expenditure of resources, thus creating inefficiencies. However, the project manager from UWL suggested a method to reduce empty cargo transportation by collaborating with farmers by bringing food to the city while simultaneously transporting waste out of it. The municipality worker for the City of Ghent also highlighted that a current solution is smaller vessels that deliver beer bottles from breweries directly to bars and restaurants, while simultaneously collecting empty bottles back to the breweries, thus minimizing empty cargo transportation. Additionally, the strategist at Trafikkontoret in Stockholm emphasized that this specific inefficiency is important as it is related to the profitability of the barges. However, the CEO of Avatar Logistics, who mainly transports construction material, claims that empty transports are not considered a challenge since their transportation routes are currently on the shorter side, but that he can see the benefits as the activities are increased on the waterways. Thus, it can be argued that high volumes and the reduction of empty cargo transportation is vital for reaching EoS. This is also argued by Rogerson et al. (2019), who claims that the financial barrier can be overcome by ensuring high volumes of goods and continuous transportation. Fan and Nachtmann (2021) are also in support of this claim by explaining that an increase in market share would diminish the expenses for IWS since 40-80% of the market is dominated by truck container transport regarding inland destinations.

9.2.3 Creation of Synergies between Stakeholders

The last method of increasing profitability is related to the creation of synergies. Rogerson et al. (2019) highlighted that committing to partnerships is one way to deal with the financial barrier, which constraints the modal shift to IWS. To create synergies, different efforts are being made by different stakeholders. The first effort is through the triple helix method, in which private and public actors, as well as the academy collaborate to push through new solutions. This beneficial type of collaboration is one of the goals of Stockholm as mentioned in Stockholms Stad et al (2018), but evidently, it is not currently practiced. However, the organization CIRCOÈ in Le Havre is collaborating through this method which is showcasing satisfactory results by being in the forefront in fuel development considering their development of hydrogen fuel cells.

Beyond the triple helix method, three ports on the river Seine have formed the joint coalition of HAROPA with the ambition to strengthen the Seine corridor by both improving transport infrastructure and taking strategic decisions together. This inter-city solution can also be compared to the intra-city solution in Ghent where the regional and urban transshipment points are being developed to create an economy through the waterways and a more efficient IWW transportation

network, thus leading to reduced costs for businesses, as mentioned by the municipality worker for the City of Ghent. As Stockholm also has a goal of implementing a solution where waste is collected locally with fossil free vehicles, to later be transported to more centralized collection centers, a solution similar to that of Ghent's could also be of interest. The project manager at CIRCOÈ also mentioned that the costs of using IWS will decrease as more organizations start making use of it. This is strengthened by Roso et al. (2020) who claims that synergies between stakeholders can result in lower transportation costs, while Wiegmans & Konings (2019) explain that this type of solution can result in increased transit time. Thus, it can be argued that there is an ad-hoc trade-off between economy and transportation time. Moreover, it was also discussed that increased collaboration would result in transportation becoming more financially viable, which is supported by Rogerson et al (2019). Moreover, Table 18 shows that the project managers from UWL and CIRCOÈ see the stakeholder collaboration as something beneficial since costs will decrease as more organizations begin utilizing the inland waterways. However, Freight Transport Statistics (2023) argues that the usage of inland waterways is still not being used to the extent as wanted, which results in a limited market that causes high transportation costs.

In addition, one challenge is to address the flexibility issue brought up by Caris et al. (2014), who claims that door-to-door services cannot be facilitated via waterways and need to be complemented with an additional last-mile delivery solution. This is also the case for Stockholm where the collection of waste is done by truck and is first transported to regional distribution centers and then to national recycling centers, as mentioned by (Sjöstrand et al., 2021). Since none of the recycling centers have optimal placements near waterways, a waterway transportation solution would require a complementary last mile delivery solution. However, there is an opportunity in the waste flow related to aluminum and PET, which can be shipped to Västerås if volumes are increased to an amount which is economically defendable. Fan and Nachtmann (2021) argue that the reliability of deliveries arriving on time would increase when the transportation is conducted through the waterways.

Another way of creating synergies between stakeholders is with the implementation of a circular economy. As for Ghent, the new sorting line from 2022 will help with recycling 35% of incoming bulk waste from the industries into raw material, which is mentioned by (*Circular Economy*, n.d.). The goal is not limited to only waste flow however, as Ghent is seeking to create a circular flow for building material since there are major opportunities to reduce carbon footprint in that industry. Repurposing demolished building material is the operational work of Thienpont. Therefore, it could be argued that it is in the interest of Ghent to create synergies and accelerate the development of these

types of businesses, ultimately reaching Ghent's stated goals. As stated by "Avfallsplan För Stockholm 2021-2024," (2024) the goal in Stockholm has been set to repurpose 70% of the incoming waste from demolished buildings. Thus, there should be a similar interest in supporting waste repurposing businesses.

Lastly, another example in implementing a circular waste economy is related to the sludge buildups in the canals. As mentioned by HAROPA PORT (2023), Le Havre is taking initiatives to create two different solutions. The first is by converting the dredged material into filling material for waterlogged quarries with the purpose of ecological redevelopment. In the second initiative, the dredged material is instead reconverted into building material such as bricks and tiles. In Ghent, The CEO of Thienpont and the project manager from POM, stated that the canals in Ghent need to be maintained for rocks, bikes and sludge. By selling the repurposed dredged material, it could help finance the maintenance and dredge collection. Due to this, both of the stakeholders argue that stakeholder collaboration is essential. However, it is also important to note that this will cause transportation disruptions on the waterways, which the stakeholder from KoV emphasizes can be overcome by effective planning.

9.3 Business Behavior and Market Characteristics

Business behavior and market characteristics are dimensions that were discussed by the interviewees based on the respective cities. The section presents a Table with the stakeholder's vision and perspective based on the subjects below related to benefits and challenges.

Tabell 19. A compilation of benefits and challenges on business behavior and market characteristics from the stakeholders.

	Gothen-burg	Stockholm		Ghent					Le Havre	
Sub-topics	Kretslopp & vatten	Trafik-kontoret	Avatar Logistcs	POM	UWL	Fabriek Logistiek	Thien-pont	City of Ghent	CIRCOÈ	Soge-stran
Change Customer Mindset		Challenge	Challenge		Challenge					
Raising Aware-ness	Benefit				Benefit					
Govern-Mental policies on business decisions	Challenge	Challenge	Challenge	Benefit	Challenge		Benefit		Challenge	Challenge

9.3.1 Limited Market and Raising Awareness

(Rogerson et al., 2019) argue that in a country like Sweden that has a very limited market for IWS, it is needed to conduct a proof-of-concept and engage with various stakeholders within the industry for new types of shipping operations, which Wisemans and Van Duin (2017) presents. Although the stakeholders from Gothenburg and Stockholm discussed the usage of inland waterways in the respective cities, the usage of inland waterways cannot be compared to the usage

in Ghent and Le Havre. While "Avfallsplan För Stockholm 2021-2024," (2024) presented that it has been discussed how to utilize the inland waterways in the city of Stockholm, Li and Notteboom (2012) argued that the rivers and canals in the city of Ghent have been historically used extensively. This reveals that while Ghent has conducted their operations on water as usual, the implementation for operating on inland waterways is relatively new for Gothenburg and Stockholm. This was discussed by the CEO from Avatar Logistics who argued that one major reason why the inland waterway operations are being conducted significantly more in a majority of the countries in the EU compared to Sweden are the inland waterway network connections.

Furthermore, it was argued by the stakeholders that competitive forces play a significant role in shaping business behavior when conducting businesses on inland waterways. Despite the disconnections previously mentioned, the stakeholders from Sweden emphasized the importance of countries increasing the usage of inland waterways in the country to reduce road congestion and become more environmentally friendly. This refers to a broader market dynamic driven by the need for organizations to differentiate themselves from competitors, thus exceeding customer expectations. In order to do this, the first step is to change the current business behavior from operating businesses as usual. As discussed by the stakeholders from Stockholm, the initiative of operating on water must come from the company stakeholders themselves. As presented in Table 19, this can be seen as a challenge since stakeholders in Stockholm are used to operating on the road and might want to continue conducting businesses as usual. Therefore, raising awareness to other stakeholders can increase the collaboration between the stakeholders, thus increasing the volume of goods being operated on water, as stated by the project manager from UWL. Raising awareness and changing customers' mindset is something that the stakeholder from Gothenburg has emphasized by having staff on the barge greeting the customers and explaining the purpose of the waste barge traveling around Gothenburg. However, it was argued that despite efforts to raise awareness, the utilization of inland waterways remains unrealistic for some organizations. This challenge was raised by the project manager from UWL due to the initiatives involving farmers in the IWS. Although presentations were made by the stakeholders from UWL, the farmers were not interested in conducting operations on water to transport food to the city.

9.3.2 Governmental Policies on Business Decisions

The interviews and settings illustrate the crucial role subsidies play in incentivizing the adoption of inland waterway shipping, which can guide companies to conduct businesses on water, hence shaping business decisions. A comparison was made by the strategist from Trafikkontoret who argued that while the usage of waterways in Sweden are taxed, the usage of waterways in

Ghent can be subsidized by companies receiving a bonus for containers being moved from the road network to the waterway network, as stated by Vlaamse Waterweg (2018) who argued that subsidies can potentially cover the total expenses with 50-80%. These subsidies can effectively encourage businesses to consider operations on inland waterways since the city of Ghent has, from an historical point of view, utilized the waterways to transport goods. Additionally, it was stated by the CEO from Thienpont and the project manager from POM that conducting operations on water is beneficial since it can create opportunities for organizations to be handed projects by the government and win contracting negotiations, therefore continuing to encourage companies to operate on water. Hence, the influence of governmental policies on business decisions is high which therefore exerts a significant influence on business behavior. Another way of encouraging extensive solutions is the requirement of a specific volume of goods per euro invested by the government, explained by Vlaamse Waterweg (2018).

Additionally, the stakeholders from France mentioned that it is more common for organizations to conduct new and improved vessels rather than modifying the existing ones since it is seen as something more advantageous. For instance, the European Project Manager mentioned that the Zulu vessel has been developed by starting with a diesel engine to the usage of swappable hydrogen fuel cells in the latest generation. While this is being implemented, the regulations around usage of hydrogen as fuel has not yet been developed to the same extent as the safety concerning hydrogen fuel has, which was discussed by the stakeholder from CIRCOÈ as a challenge. One reason can be related to the uncertainty of the unknown and the fear of not being successful, which can result in wasteful investments in cost and time. Another reason for it being situated might be caused by the governmental incentives provided for building new vessels with new technologies rather than old vessels with new technologies, as stated by the European Project Manager from CIRCOÈ. This is connected to the setting in Ghent, where the project manager from UWL presented that while efforts were made to optimize the efficiency and reduce the energy consumption, the Green Wave vessel was still under construction. Hence, a change in mindset for governments should be considered.

Related to subsidies, Persson and Vuorenmaa Berdica (2017) emphasized that the port of Gothenburg will see an increase in the number of quays to increase the capacity of the port. As presented in Table 19, KoV sees governmental policies on business behaviors as something challenging. Although the implementation of more quays is based in a desire to change the current business behavior in the country, the stakeholder from Gothenburg argued that despite the abundance of quays available in the city, the involvement of multiple stakeholders with varying interests and responsibilities around the quays complicate the process of securing access to the quays. When ownership and management of quays are divided, it

causes inefficiencies and hinders businesses' ability to utilize quays for barge operations. Simultaneously, the CEO of Avatar Logistics mentioned that the quays in Stockholm are being repurposed into promenades, thus limiting the availability of the quays. This highlights the importance of dealing with governmental issues and fostering collaboration among the stakeholders, hence can be done by offering subsidies to the stakeholders. The stakeholders from Sogestran and Avatar Logistics elaborated this perspective by mentioning that the municipality in Le Havre has put emphasis on pedestrian walkways and roads for cyclists rather than developing the infrastructure and the lack of quay along the waterway. Although the situation is similar to the problem with finding available quays in Gothenburg, the waste barge has five main stops that are used daily for collecting waste from customers. Berechman (2018), Wisemans and Van Duin (2017) and Baird (2007) state that it is common for decision-makers to prioritize fundings for road- and railways, hence waterways need maintenance and financial support. The stakeholders from Le Havre agree with this by arguing that one essential challenge that is situated when conducting operations in Le Havre is that there are no extensive developments for dockers, cranes and terminals due to lose regulations, which is stated by Mirčetić et al (2017).

9.4 Innovative Technologies & Industry 4.0

This chapter aims to present the innovative technological aspects, as well as the findings regarding crane operations and retrofitting. Thus, the topics are divided into automation of the barges, automation of the waste sorting system, internet of things, crane operations and lastly retrofitting. A Table is presented with the stakeholder's vision based on the subjects below related to benefits and challenges.

Tabell 20. A compilation of benefits and challenges on Innovative Technologies & Industry 4.0 from the stakeholders.

	Gothen-burg	Stockholm		Ghent					Le Havre	
Sub-topics	Kretslopp & vatten	Trafik-kontoret	Avatar Logistcs	POM	UWL	Fabriek Logistiek	Thien-pont	City of Ghent	CIRCOÈ	Soge-stran
Auto-mated navigation		Benefit	Benefit			Challenge			Chall-enge	Challenge
Auto-mated mooring					Benefit	Benefit				
Fully Auto-mated Vessels	Challenge			Chall-enge	Challenge					
Auto-mation of the waste sorting system					Benefit	Benefit	Benefit			
Internet of Things		Benefit	Benefit	Benefit		Benefit			Benefit	Benefit
Crane Opera-tions				Benefit	Challenge	Challenge		Chall-enge		
Retro-fitting	Benefit		Challenge	Chall-enge					Chall-enge	

9.4.1 Automation of the Barges

In the development of a full automation of the IWS operations, different solutions and challenges were discussed in different operational areas. The first area is the navigation of the vessel. As for Stockholm, the strategist at Trafikkontoret anticipates an automated future, however there is no current progress in Stockholm in this area. Sullivan et. al. (2020) motivates that industry 4.0 will play a key role in unlocking automation through AI and advanced sensors. Currently, the founder of Fabriek Logistiek argues that automation might not be feasible with current technologies and regulations. This is because automated vessels must operate at much slower speeds to minimize the risk of accidents. Both stakeholders in Le Havre agree that navigational automation is not currently feasible because of the same reason.

The idea of navigational automation is however seen as positive from both stakeholders in Stockholm, who claim that it can be used as a way of dealing with current manpower related issues for sailors and captains. Sullivan et al. (2020) agrees that automation would lead to a decrease in demand for skippers, but also claims that another way is by remote controlling vessels instead of automating. This is already in use in some places such as Antwerpen, where one captain controls multiple vessels remotely, as claimed by the CEO of Avatar Logistics. However, the project manager from UWL mentioned that Flanders is a frontrunner in navigating these legislative difficulties and are soon expecting to find new regulations concerning automated sailing through remote control systems while the other cities are still focusing on previous obstacles that the stakeholders from Ghent needed to face. Another way of lowering the need of manpower is through automated mooring. There were two ideas brought up for automated mooring. The first idea was brought up by the founder of Fabriek Logistiek, and entailed magnetic mooring, while the second idea was brought up by the project manager of UWL and included mooring by continuous thrusting against the dock. The second idea is currently in its testing phase.

Considering full automation, Table 20 presents that the project managers of POM and UWL emphasized the complexity and thus the need for huge investments. However, it is deemed possible, as the latter project manager exemplified with the ports of Shanghai and Singapore which have fully automated their container operations. In addition to huge investment costs, another drawback of a fully automated system mentioned by the stakeholder at KoV, is paradoxically the lack of staff. This is however related to the fact that the staff on the recycling waste barge offer service and sustainability awareness to the customers, which in turn has increased customer satisfaction. It could therefore be argued that automation is more relevant for operations which do not provide any service.

9.4.2 Automation of the Waste Sorting System

To sort the waste into different waste flows, the founder of Fabriek Logistiek argued that an AI system together with cameras could be beneficial. From the findings, there was no current solution for a system like this, but it is anticipated for the future. The reason for why an automated separation system is needed is because of manpower related issues, brought up by the CEO, but also the CEO of Thienpont and the project manager at UWL. This is because it is becoming less and less popular to work in that environment as a result of odor and soilage. Moreover, the process is anticipated to be more efficient, as explained by the CEO of Thienpont. An AI system could play a vital role in reaching the goal for Stockholm, which was mentioned by "Avfallsplan För Stockholm 2021-2024," (2024), of separating 70% of the good waste from domestic waste. Another way of separating the waste was discussed by the stakeholder at KoV. The solution entails manual sorting by the customer on the waste barge by discarding waste into the respective container. Since the vision of the waste barge in Gothenburg is to have customers visiting the barge and sorting the material themselves, implementing an automated waste sorting system is unnecessary. However, it was mentioned that there are plans to introduce a camera system at the recycling centers in Gothenburg which notices the customer if the waste has been misallocated. This system could potentially be of benefit to the waste barge itself.

9.4.3 Internet of Things

The topic of internet of things was discussed in two different ways, maintenance and tracking respectively. Considering maintenance, Cotteleer & Sniderman (2017) stated that industry 4.0 enables real-time monitoring of the vessel in parameters related to performance and health through IoT and sensor devices. This is in line with the thoughts of the project manager at CIRCOÈ who thinks that this type of digital troubleshooting can benefit by reducing the costs of the vessel. Agrawal et al. (2020) strengthens this theory by claiming that data from IoT and sensor devices can be used to identify maintenance issues before they lead to costly breakdowns. The CEO of Avatar Logistics in Stockholm also thought that IoT could help with much needed communication between vessels, but also between other stakeholders in the value chain. This might however not be of high relevance for the recycling waste barge in Gothenburg since the municipality worker at KoV mentioned that the barge can arrive at its unloading destination with a couple of days delay without problem.

Considering communication between vessels, the project manager at CIRCOÈ elaborated that as vessels are connected, navigation by platooning can be used to increase efficiency. The project manager from UWL highlighted that autonomous navigation is currently being developed and tested using IoT and sensor devices. As for the increased communication with stakeholders, such as real-time tracking information, the CEO of Avatar Logistics thinks that the overall cash flow would

be improved through many different parameters. The director general from Sogestran and the project manager from CIRCOÈ argue that the tracking ability is needed to organize multimodal logistics in a beneficially efficient manner. Rogerson et al. (2019) argue that the frequency and reliability of the transportation is directly impacting the service quality.

The importance of prioritizing administrative tasks for a successful logistics chain using intermodal transportation is also emphasized by Medda & Trujillo (2010). This is because of the high complexity of IWMO, which has resulted in many ports digitizing many of their processes, which is mentioned by Laas (2020), The Editorial Team (2016) and Sullivan et al (2020). Thus, improving communication between different stakeholders is an emphasized part of creating efficiency in the system. It is evident that IoT can have a central role in enhancing communication and thus the service quality and more parameters. However, the project manager for UWL explained that navigation systems with higher accuracy are needed for navigation on IWWs, in contrast to sea transportation. One example could be The Blue Road Map, as mentioned by Engström & Abrahamsson (2019). By offering online route planning, the efficiency can be further increased, which is explained by Wiegmans et al. (2015). The project manager at Trafikkontoret also agrees that the navigation could be improved, but the idea mentioned was through AI for the planning of dynamic routes.

9.4.4 Crane Operations

The municipality worker for the City of Ghent mentioned that the medieval theme of the inner city is a challenge, and that it is impossible to operate cranes on the quays without creating visual pollution. At the same time, the founder of Fabriek Logistiek argues that there is no current solution to utilize an integrated crane on the barge as a consequence of the challenge with low bridges either. Because of the narrow dimensions of the canals, the project manager from Urban Waterway Logistics stated that an integrated crane would result in a high risk of unbalance for the vessel, thus compromising the safety. The Zulu vessel developed in Le Havre, which has an integrated crane is according to the project manager at POM, not fit for the tight dimensions of the waterways of Ghent's inner city. However, it shows that the principle of an integrated crane is possible. In addition, the project manager mentioned that there are other vessels with integrated cranes currently in use in Ghent's inner waterways but related to smaller flows of food and beverages. Moreover, the project manager argued that there could be solutions of cranes on the quayside which do not create visual pollution. Another problem related to utilizing cranes on land is that most cranes cannot go below ground level, thus requiring specialized cranes that enable this functionality, such as the Sennebogen crane. For this crane, the CEO from Fabriek Logistiek is also developing a unique grapple which cuts the waste as the grapple is closing, thus

minimizing waste which could fall and pollute the area nearby, especially when it is windy.

9.4.5 Retrofitting

As for retrofitting, Table 20 presents that only Gothenburg has a positive experience when considering retrofitting. Although the stakeholders are familiar with the context of retrofitting, no vessel is being operated as of now that has been retrofitted to a larger extent. This was emphasized by the project manager from UWL, who argued that it is a beneficial possibility for smaller vessels to be retrofitted in a feasible manner where the only dimension that can be retrofitted is another type of propulsion or battery. Retrofitting has been a success for the waste barge in Gothenburg since it was modified by implementing solar energy to power lights on the recycling waste barge and electrifying the tow boat which pushes the barge around the city. While Gothenburg has modified the waste barge and the tow boat, the vision of conducting more operations on water is not something being considered as of now for Stockholm since it is more viable to buy new vessels with new functions already implemented, thus creating a challenge. In addition, the project manager from CIRCOÈ explained that government incentives encourage organizations to produce new vessels with new technologies instead of retrofitting existing vessels.

Cordis (2011) argued that the ultimate costs between retrofitting an old vessel and creating a new one is considered to be the same, hence the environmental investments should be of higher importance than the investment costs, which Roso et al (2020) supports. Furthermore, Roso et al (2020) states that one of the reasons concerning the high investment costs is that the vessels have a longer lifespan compared to other transportation modes. A paradox was discussed by the project manager from POM who argued that despite the environmental and economic advantages that are associated with retrofitting in the long run, there are concerns of it.

9.5 Navigating on the inland waterways

The analysis that can be made related to navigation of inland waterways can be divided into two separate focuses, one being related to safety concerns and the other one on infrastructure in terms of locks and the low bridges in respective cities. Connectivity is also a topic analyzed from the interviews conducted. A Table is presented with the stakeholder's vision based on the subjects below related to benefits and challenges.

Tabell 21. A compilation of benefits and challenges on navigating the inland waterways from the stakeholders.

	Gothen-burg	Stockholm		Ghent					Le Havre	
Sub-topics	Kretslopp & vatten	Trafik-kontoret	Avatar Logistcs	POM	UWL	Fabriek Logistiek	Thien-pont	City of Ghent	CIRCOÈ	Soge-stran

Less Accidents		Benefit	Benefit						Benefit	Benefit
Nighttime Opera-tions	Benefit	Benefit	Benefit						Challenge	Challenge
Weather Condi-tions	Challenge					Challenge				
Cyber Security									Challenge	Challenge
Locks		Challenge	Challenge							
Low Bridges	Challenge			Challenge	Challenge	Challenge	Challenge	Challenge		
Connect-ivity	Challenge	Benefit					Benefit			

9.5.1 Safety

After conducting the interviews, three main safety concerns were raised by the stakeholders: (1) less accidents, (2) uncertainty of weather conditions, and (3) cyber security. Concerning accidents, the stakeholders from Trafikkontoret and Sogestran argued that using the inland waterways would result in less accidents being situated due to lower traffic density, as supported by Caris et al (2014) and Fan and Nachtmann (2021). Since the city of Stockholm has a main goal to become fossil free by 2040, the stakeholders argued that reducing the number of trucks transporting goods in the city center is essential, as Stockholms Stad et al. (2018) also emphasizes, which has been made by asserting that new regulations have banned trucks from certain areas and times in the city. Although the strategist at Trafikkontoret and the CEO of Avatar Logistics emphasized that the new regulations which have banned trucks from certain areas and times are a driver for the increased usage of waterways, the strategist was also considering the conduction of nighttime operations as a benefit which is mentioned previously. Furthermore, the regulations were also emphasized by the stakeholder from CIRCOÈ who argued that other larger cities in Europe will implement these regulations in the future as well. However, this regulatory barrier is according to Rogerson et al (2019) something that is dependent on governmental policies.

Furthermore, ensuring that a reduction in road transportation is situated is according to the interviewees a major driver for increasing traffic safety, which Caris et al (2014) also emphasizes. Additionally, Stockholms Stad et al. (2018) emphasizes that one of the main goals to reduce the number of accidents being situated when transporting goods in Stockholm is to conduct transportation during nighttime. Although Sulaiman et al (2011) argue that most operators are still limited to daytime operations in order to prevent any accidents to be situated during the nighttime, which is one of the main subgoals that the CEO from Avatar Logistics are working with in order to increase the availability and predictability for goods transportation. This is not something that the stakeholders from Le Havre are considering since their operations extend to Paris. However, since the waste barge in Gothenburg stops at several locations during its daytime operations to collect waste from customers and then being transported to Marieholm, the necessity to implement nighttime operations is low. Since the

waste barge only operates in a restricted area, Liu et al (2016) argue that the probability of risks and accidents being situated decreases. Although KoV is considering implementing a new waste barge that will operate within the moat of the city, concerns related to safety and accidents are being studied in order to prevent it from happening.

Furthermore, Table 21 presents that the stakeholders from Gothenburg and Fabriek Logistiek see weather conditions as something challenging that can prevent operations being conducted on the inland waterways. While the founder of Fabriek Logistiek argued that wind could cause products and waste getting lost in the river, the stakeholder from Gothenburg mentioned that the wind and waves are two aspects that can make it unpleasant for staff and visitors to drive the waste barge around the city. Although the stakeholder from Gothenburg mentioned that the weather conditions have not yet prevented the operations from being conducted, the possibility of it still exists, especially from a geographical and climate setting. It was also stated by the interviewees that the weather conditions can result in transportation not being able to operate on water, resulting in an increased usage of road and rail as stated by Caris et al (2014) and Roso et al (2020).

Lastly, safety concerns in terms of cyber-attacks have been discussed by the stakeholders from Le Havre. As the more digitized the operations become, it was argued that the more susceptible they become to being targeted by hackers. Although Wehrle et al (2022) mentioned that terrorist attacks are one of the emerging risks that can be situated when managing the inland waterway operations, cyber-attacks is one aspect that should be taken into consideration since the technology is still developing. When stakeholders consider safety in terms of less accidents being situated by using innovative tools to be implemented, cyber-attacks should also be considered. For instance, while the project manager from UWL mentioned that tests are being made on how to use remote controls for vessel navigation, it could be argued that the risk of cyber-attacks being situated should also be considered. Hence, Biiak and Lindskog (2022) argue that safety and security onboard vessels in terms of implementing IoT to enable real-time monitoring for potential hazards and dangers.

9.5.2 Infrastructure

Related to infrastructure, Wisemans and Van Duin (2017) state that some challenges are in place concerning infrastructure where locks for instance can serve as a bottleneck since skippers need to decelerate or await for passage. While the stakeholder from Trafikkontoret supports this statement by Wisemans and Van Duin (2017) since it creates problems and increases the complexity, the CEO from Avatar Logistics claims that the setting in Stockholm is significantly less complex than Ghent since the city has many narrow passageways. Although Ghent

has narrow passageways and low bridges, the stakeholders from Ghent have clearly expressed what solutions have been implemented or will be implemented to avoid these issues. The CEO from Avatar Logistics presented a solution to avoid the issues stated by Wisemans and Van Duin (2017), which consists of implementing a centralized transshipment terminal. Even though this suggestion has not been under active consideration, it is clear that the stakeholders from Stockholm and Ghent have a similar goal of working around the issues stated by Wisemans and Van Duin (2017).

Another main aspect that is of high importance in order to conduct operations on water is the dimensions of the bridges. As supported by Wehrle et al (2022), all stakeholders argued that the management of inland waterway operations are essential in order to manage the infrastructure without being in a harmful situation causing risks to occur. While the stakeholders from Le Havre and Stockholm did not see the dimensions of the bridges and the narrow passageways as an issue since the bridges are high enough to not interfere with the goods, it is imposing less complexity on the barge department. However, the other stakeholders from Gothenburg and Ghent need to take these dimensions into consideration since both of the cities need to conduct operations in areas where low bridges are stationed, which Wisemans and Van Duin (2017) states. As an example, the CEO of Thienpont mentioned that the current dimensions and design of the containers makes it infeasible for the organization to conduct business in the inland waterways, thus needing to adjust the dimensions of the containers. Moreover, the stakeholder from Gothenburg mentioned that one idea is to implement a waste barge that can operate within the moat.

Since the stakeholder was comparing the operations in Gothenburg with Ghent that have conducted these operations for over 100 years, thus having more expertise in the subject, it should be easier for these cities to implement a barge in Ghent. Moreover, managing operations despite low bridges is something that the stakeholders from Ghent have accomplished. For instance, the project manager from UWL mentioned that the Green Wave vessel and the AVATAR-vessels are designed to be operated in the city center by the vessels being capable of operating at a depth of 50 centimeters below the waterline since the lowest bridge in Ghent has a 70 centimeter clearance. By conducting operations in areas with low bridges, the project manager argued that adjustments like ballasting are necessary. When comparing the bridges between Ghent and Gothenburg, the lowest bridge in Gothenburg is lower than the lowest bridge in Ghent. Hence, it is logical to assume that the Zulu vessel in its current shape is not suited for IWS around the moat in Gothenburg but is possible to operate on the main canal - the Göta Älv.

As stated by Achmadi et al. (2018), the dimensions of the vessel need to be adequate to the dimensions of the IWWs. While the waterways in the city of Ghent

and Le Havre are CEMT-classified as supported by (City of Ghent & Peeters, 2024), the waterways of Gothenburg and Stockholm use a different system. (Garberg et al., 2019) argue that a differentiation in systems can create confusions and complexities for skippers which increase the safety risk. Especially when considering that the different classification systems need supplementary information of the waterway conditions before operations. For example, it is argued by Uddin et al. (2017) and Sulaiman et al. (2011) that collisions are one of the most common types of IWW accidents since most of the ships used to pass through the route are unfit most of the time because operators and shippers either go against the rules or lack adequate training for the job. Furthermore Achmadi et al. (2018) claimed each and every country has different ship characteristics of inland waterway transport which can even differ from river to river.

9.5.3 Connectivity

As for connectivity, the project manager from Trafikkontoret argued that beneficial opportunities for using the inland waterways as a transportation tool in Stockholm are high since the city is situated on an archipelago, as presented in Figure 8. Moreover, the stakeholder from Thienpont argued that Ghent is a city with high connectivity that would result in beneficial low-cost opportunities when transporting goods via water. The connectivity in the city would, according to the interviewee, result in an organization becoming more environmentally friendly due to efficient transportation. The high connectivity can also be related to the competitive advantage mentioned above since it will show how organizations are working with becoming more environmentally friendly. Although the connectivity perspective was mentioned by the stakeholder from Thienpont from a positive point of view, the stakeholder from Gothenburg had other visions concerning the connectivity in the respective city. For instance, the stakeholder from Gothenburg argued that it is needed for the stakeholders to work around this issue since many nature reserves prevent the operations to be conducted in an optimal manner, which has been situated for setting in Gothenburg when the initial plan for the barge was conducting operations in Säveån. This is supported by Maiorano et al. (2007) who argued that the regulations can cause poor hinterland connectivity which also affects the overall logistics efficiency. However, the operations have, according to the stakeholder from Gothenburg, not affected the overall operation significantly.

10. Discussion

The study confirmed existing findings about benefits and challenges but also added more complexity to the overall understanding, especially regarding how new technologies and innovation could affect the modal shift process. Previous research identified several challenges and barriers to modal shift, such as regulatory, behavioral and financial aspects. The study, however, concentrated on how new technologies and innovation have benefitted different settings, and what is needed to overcome the remaining challenges. In doing this, it was shown that the benefits and challenges regarding new technologies and innovation not only are technical, but also that other factors such as governmental policies, stakeholder collaboration and maturity all play a vital role in addressing the contextual challenges.

Although a major part of the study was focusing on innovative technologies and industry 4.0, other dimensions such as environmental impacts and creating synergies were mentioned by the stakeholders as essential subjects for several reasons. Firstly, the environmental impacts that are addressed in this study reflect a global concern for sustainability practices in the transportation industry. The stakeholders recognize the importance of minimizing the environmental footprint when arguing for the implementation of the inland waterways for the transportation industry. Furthermore, some new technologies and other suggestions have been introduced which can help reduce the environmental impact in direct and indirect measures. Direct measures, such as switching fuel from energy sources such as diesel to battery or hydrogen fuel cells, are concrete ways of reducing the environmental impact. However, the more interesting aspects are the indirect measures which result in reduced environmental impact. Every setting is defined by its own challenges, but through stakeholder collaboration, new technologies and innovation can be created to overcome the challenges. Evidently, the role of governmental support is also important in fostering this environment, which is further elaborated in the following sections. Thus, the overall feasibility of IWS is improved, resulting in a natural modal shift.

10.1 Broader learnings

In order to answer the second research question of the study, which again is “What learnings from similarities and differences between Gothenburg, Stockholm, Ghent and Le Havre's inland waterway shipping can be used to facilitate a modal shift to the inland waterway shipping network?”, the subtopics presented in the tables of the analysis were further elaborated upon. To consolidate the subtopics into learnings, two challenge types were identified, challenges that are related to all cases and challenges that are related to specific case settings respectively. Considering the first challenge type, all cases can draw benefits and learnings from what has been presented. As for the second challenge type, benefits and learnings

can be collected depending on if the challenge is related by multiple case settings. In the challenges related to all cases, we identified two main topics, governmental support and stakeholder collaboration.

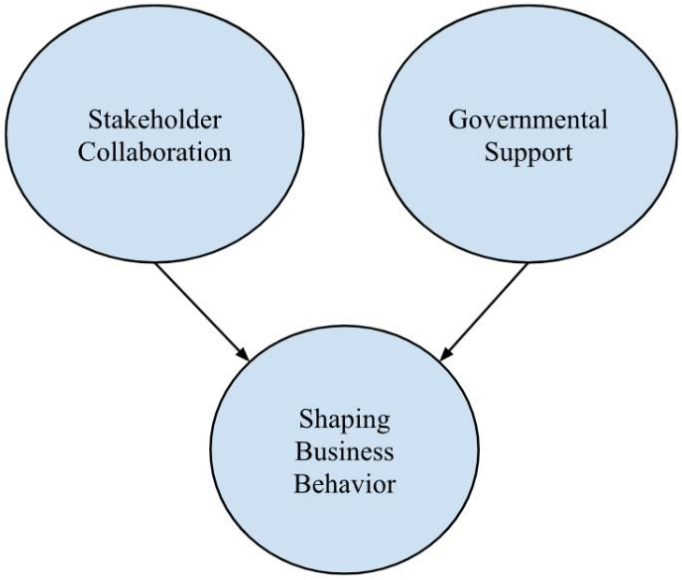

Figure 17: Identified key learnings that shape business behavior.

The first main takeaway that was obtained after conducting the interviews is the importance of collaboration between stakeholders in order to attract stakeholders to use the inland waterway shipping network. For instance, one of the stakeholders from Ghent discussed that instead of stakeholders letting road transportation operations be conducted when collecting waste from the restaurants, organizations around the canals have accepted these operations to be conducted in the inland waterways instead. Although Gothenburg and Stockholm are only conducting operations when it comes to waste and construction material as of now. However, the increase in collaboration can also result in other flows being operated. Furthermore, the stakeholder from Gothenburg also mentioned that operating within the moat to collect waste from organizations is something that they strive for. Although the restrictions preventing the operations from being conducted are related to the infrastructure, it is essential for organizations around the canal to collaborate with the waste barge operations.

The reasons for why inland waterways are used to different extents can be explained through different reasons. As shown for Le Havre, the usage of inland waterway shipping can be related to the unproblematic connectivity and accessibility of the waterway network. As for Ghent, there are many limitations from the waterway characteristics. Although, the usage of inland waterways is high as a result of a business behavior which fosters new technologies and innovation in trying to overcome the limitations.

Furthermore, the main difference in usage can also be due to the encouragement and financial support provided by the countries' government. For instance, the stakeholders from Gothenburg and Stockholm experienced that the lack of support from the government has hindered the stakeholders from executing and developing the operations on the inland waterways further. The subsidies provided by the government have shown to be of high success for the settings in Ghent and Le Havre since the support of the development has created opportunities for the stakeholders to actually go through with the implementations.

As for the effect of business behavior, companies' knowledge of using inland waterway shipping can significantly change before knowing its benefits. Increased knowledge of its utilization could create opportunities such as increased turnover and easier transportation, while also creating solutions for any existing challenges. As stated by the stakeholders from Stockholm and the project manager from UWL, changing current business behaviors is something seen as challenging since the initiative must come from the company stakeholders themselves. Therefore, if this mindset is being brought up during the beginning of the younger generations' careers, people might approach the view on new solutions and innovations differently compared to the older workers. Since Roso et al. (2020) mentioned that a majority of organizations consider the vessels being a greater investment due to the longer lifespan, it is more beneficial to educate younger generations on how the usage of inland waterways can create opportunities and minimize challenges. Although both of the cities in Sweden together have one waste flow and one construction material flow, educating people on the opportunities while providing examples of the usage is essential to spread knowledge and increase the usage in Sweden as well. Since Ghent and Le Havre are utilizing the inland waterways to a greater extent compared to the settings in Sweden, this particular education might not be seen as relevant to Ghent and Le Havre as to Gothenburg and Stockholm. However, educating younger generations regarding the opportunities that the IWS can contribute to is essential in any setting-

10.2 Narrow learnings

In order to address the second challenge type, which is challenges related to the specific settings, a model is presented with maturity and complexity regarding the development of IWS. We argue that settings with similar complexity can more easily relate to one another, and thus draw learnings more effectively. However, it is important to note that learnings can still be collected by cases with different complexities. As for maturity, it can be argued that case settings with less maturity can draw more learnings from case settings with high maturity than inversely.

Figure 18 presents how the separate cases can be demonstrated in relation to the degree of maturity for new technologies and innovation.

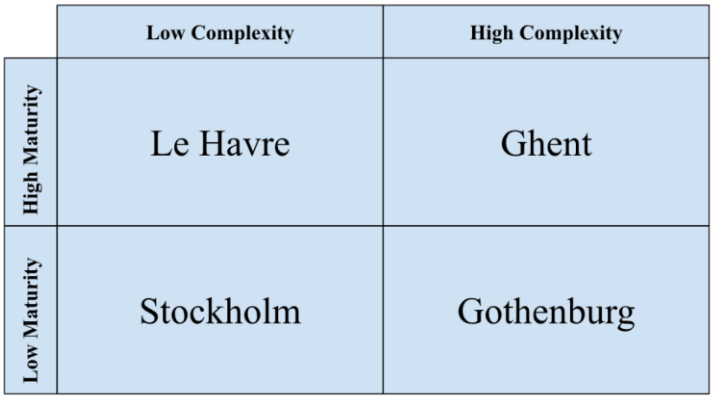

Figure 18: Maturity vs. Complexity between settings.

When it comes to the maturity level for Gothenburg, it is similar to Stockholm yet contains higher complexity. One reason for the maturity level being lower in Gothenburg can for instance be related to the fact that Gothenburg does not have a developed goods transportation flow for the inland waterways. If a city does not operate on the inland waterway to a greater extent and is not using any new technologies, the maturity level can be considered as low. Although the usage of inland waterways is seen as something beneficial and the usage of it can create many opportunities, the barriers can be interpreted as more complicated and need to be confronted when investing in the implementation. For instance, it was argued by the stakeholder from Gothenburg that the reason for that there are no inland waterway vessels that operate in the moat of the city is due to the low bridges. For this implementation to be successful, greater commitment between many shareholders is required, which is also argued by the stakeholder from Gothenburg. Another barrier can be due to governmental limitations that indirectly restrict new technologies to be developed, such as subsidies, which is another reason for the setting in Gothenburg being interpreted as less mature than the settings of Ghent and Le Havre.

Although the setting of Stockholm entails usage of the inland waterways regarding construction material flow, there are practically no new innovations and technologies that have been implemented, resulting in the setting to be interpreted as less mature. Mainly, the reasons can be explained in two different ways. The first reason is that the city does not have any specific limitations concerning the waterway characteristics. Due to this, it enables operations to be conducted more easily and the stakeholders using the inland waterways do not need to consider the waterway limitations as much as the other cities need to do. Hence, the complexity scale for the setting in Stockholm is considered low. The other reason for the lack of new innovations and technologies can be explained by

the absence of developed flows related to IWS. In turn, this can be explained by the low maturity in factors mentioned in the key learnings, namely stakeholder collaboration and governmental support, but also to settings related challenges such as low availability of quays. Although the low development is affecting the operations on inland waterways, there are not any current projects working on either working around the issue or solving it. Hence, the setting in Stockholm concerning new technologies and innovation is considered to be less mature than any other studied settings.

As for Ghent however, the maturity level is considered to be high while also dealing with high complexity when comparing it to the other settings. Although the infrastructure in the city is very limited due to the dimensions of the canals, bridges and locks, the stakeholders in Ghent have shown many solutions and opportunities related to new technologies and innovation in order to work around these issues. The stakeholders have developed solutions to not only transport goods between other cities within the hinterland, but also within the most complicated areas to operate in Ghent. Furthermore, another reason for the setting of Ghent being highly mature is due to the synergies between shareholders and stakeholders within the city center to use the barges as a tool to transport glass bottles and other products needed to be transported to and from the city center. This collaboration between stakeholders creates opportunities for the operations to continue growing within the city, hence increasing the opportunities to develop the vessels further. Additionally, the maturity level can also be connected to the subsidies offered by the government to continue encouraging businesses to develop transportation operations. Another reason for setting in Ghent being highly mature while also being more challenging can be shown in the stakeholder's explanation of the issues related to the position of cranes on land. Although the stakeholders are trying to find solutions, it is shown that the stakeholders still haven't found solutions related to integrated cranes either, due to the tight dimensions of the waterways.

As for Le Havre however, who showed themselves as being highly mature and lower in the challenging scale as shown in Figure 18, there were no issues related to implementing an integrated crane on the barge for operations. However, this observation raises some critical considerations regarding the factors contributing to the successful implementation in Le Havre. One critical consideration is what the situation would have been if Le Havre had faced the same waterway characteristics challenges as Ghent. This thought digs into whether Le Havre's perceived rather maturity is only a result of greater opportunities due to its waterway characteristics or if their ability to implement an integrated crane without issues is simply due to the fact that they do not encounter any low bridges similar to Ghent's.

11. Conclusion

The conclusions of the study provide valuable insights into the learnings that Sweden can collect from Northern Europe's developments in sustainable inland waterway shipping. While the study confirmed existing findings about benefits and challenges related to the modal shift, it also expands the current viewpoint by introducing new challenges and solutions related to new technologies and innovation.

The study takes a holistic approach in understanding the overall and contextual challenges of each case setting to maximize the chances of a successful implementation of sustainable inland waterway shipping practices in Sweden and other regions. The first key conclusion of the study is the importance of considering not only technical aspects but also governmental policies and stakeholder collaboration, which affects the technical solutions that solve contextual challenges related to green inland waterway shipping. The second key conclusion is that different cases can draw learnings from one another more effectively by comparing the degree of maturity and complexity. For example, as the complexity between Gothenburg and Ghent is similar, meaning both cases face similar challenges, it is evident that they can learn more from each other than the other cases.

Furthermore, the study's findings from interviews with stakeholders in different cities, including Gothenburg, Stockholm, Ghent, and Le Havre, emphasizes on the diverse perspectives and experiences regarding the benefits, challenges, and future visions of green inland waterway shipping. By taking this viewpoint, the risk of inefficiently redeveloping existing solutions is minimized. Instead, Sweden can identify best practices directly and receive a boost to the sustainable development of the inland waterways. The findings and recommendations presented in the thesis serve as a valuable guide for policymakers, industry stakeholders, and researchers seeking to drive innovation and sustainability developments in the inland waterway shipping sector.

12. Recommendations for Future Research

This chapter presents the author's recommendations for future research that can be made after reading this thesis.

For future studies it would be of interest to evaluate the technological advancements used in IWS. How has the use of autonomous vessels, sustainable propulsion systems, and digitalization for efficient operations affected the transportation in the inland waterways? Have respective settings matured further or have new challenges emerged? And if not, how come? That study would not only provide us with answers in regard to what followed, it would also be valuable when investigating if the new technologies and innovations have improved and affected the operations on the inland waterways.

In this study, a selection of project managers, CEOs and other stakeholders highly involved in the development of inland waterways were selected for the interviews. It could be that a different selection of respondents would provide different findings for the study and highlight other topics of high significance.

Over the course of this study, dimensions such as innovative technologies, retrofitting, limited infrastructure, governmental support, stakeholder collaboration and navigation have been mentioned and discussed by the stakeholders to some extent. In future studies, it would be of further interest to investigate these topics more closely, and perhaps separately, in order to provide a more in-depth analysis of their individual impacts on the development and implementation of innovative green inland waterway shipping initiatives.

References

About Fabriek logistiek - Fabriek logistiek. (2022, May 31). Fabriek Logistiek. Retrieved March 27, 2024, from https://www.fabrieklogistiek.be/en/about-fabriek-logistiek/

Achmadi, T., Nur, H. I., & Rahmadhon, L. R. (2018). Analysis of inland waterway transport for container shipping: Cikarang to Port of TanjungPriok. IOP Conference Series: Earth and Environmental Science, 135, 012015. https://doi.org/10.1088/1755-1315/135/1/012015

Agrawal, M., Eloot, K., Mancini, M., & Patel, A. (2020). Industry 4.0: Reimagining manufacturing Operations After COVID-19. In McKinsey.com. McKinsey & Company. Retrieved February 19, 2024, from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/Industry%204%200%20Reimagining%20manufacturing%20operations/industry-4-0-reimagining-manuacturing-ops-after-covid-19.pdf

Alcácer, V., & Cruz‐Machado, V. (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing systems. Engineering Science and Technology, an International Journal, 22(3), 899‐919. https://doi.org/10.1016/j.jestch.2019.01.006

Årnes, P. (2024, March 11). Interview with Peter Årnes. Interview, Gothenburg, Sweden.

Asean AFFA. (2021). Inland waterways transport [Slide show]. Presentation. https://asean.org/wp-content/uploads/2023/02/2.-FN_Inland-Waterways-Transport.pdf

AVATAR - Pomov. (2023, April 19). Pomov. https://pomov.be/project/avatar/ Avatar Logistics, & Lantz, J. (2022). Photograph of the IWW vessel Jehander1 used in Stockholm. Stockholm, Sweden.

Avfallsplan för Stockholm 2021-2024. (2024). In Stockholm Vatten Och Avfall. Stockholm Vatten och Avfall. Retrieved April 22, 2024, from https://start.stockholm/globalassets/start/om-stockholms-stad/politik-och-demokrati/styrdokument/avfallsplan-for-stockholm-2021-2024.pdf

Baird, A. (2007). The economics of Motorways of the Sea. Maritime Policy & Management, 34(4), 287–310. https://doi.org/10.1080/03088830701538976

Berechman, J. (2018). The infrastructure we ride on: decision making in transportation investment. https://openlibrary.org/books/OL27744473M/The_Infrastructure_We_Ride_On

Biiak, A., & Lindskog, Y. (2022). Leveraging Technologies of Industry 4.0 for risk management in Sea Freight Forwarding Operations [MA thesis, Univeristy of Gothenburg]. https://hdl.handle.net/2077/77649

Bryman, A. (2018). Samhällsvetenskapliga metoder.

Bryman, A., & Bell, E. (2015). Business research methods. Oxford University Press, USA.

Bryman, A., & Bell, E. (2017). Företagsekonomiska forskningsmetoder.

Caris, A., Limbourg, S., Macharis, C., Van Lier, T., & Cools, M. (2014). Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges. Journal of Transport Geography, 41, 126–136. https://doi.org/10.1016/j.jtrangeo.2014.08.022

CCNR. (2022, May 11). 2. INLAND WATERWAY TRANSPORT EMBEDDED IN URBAN LOGISTICS - CCNR - Observation du marché. CCNR - Observation Du Marché. https://inland-navigation-market.org/chapitre/2-inland-waterway-transport-embedded-in-urban-logistics/?lang=en

Circular economy. (n.d.). Stad Gent. https://stad.gent/en/city-governance-organisation/city-policy/ghents-climate-actions/circular-economy

Circular Flanders. (2023, November 1). Haropa - Le Havre - Circular Flanders. https://circularports.vlaanderen-circulair.be/portfolio/haropa-le-havre/

City of Ghent, & Bats, A. (2023, June 21). URBCON - By-products for sustainable concrete in the urban environment. Interreg NWE. Retrieved April 24, 2024, from https://vb.nweurope.eu/projects/project-search/urbcon-by-products-for-sustainable-concrete-in-the-urban-environment/

City of Ghent, & Peeters, B. (2024, March 19). Interveiw with Bart Peeters from City of Ghent. Interview, Ghent, Belgium.

Cordis, C. (2011, December 27). RETROFITting ships with new technologies for improved overall environmental footprint. CORDIS | European Commission. Retrieved February 18, 2024, from https://cordis.europa.eu/project/id/285420/reporting

Cotteleer, M., & Sniderman, B. (2017, December 17). Forces of change: Industry 4.0. Deloitte Insights. Retrieved February 18, 2024, from https://www2.deloitte.com/us/en/insights/focus/industry-4-0/overview.html

Dalen, M., Kärnekull, B., & Kärnekull, E. (2015). Intervju som metod (2nd ed.). Malmö: Gleerups utbildning.

DenCity, & Bakosch, A. (n.d.). Återvinningspråmen - ett test som blev verklighet. DenCity. Retrieved April 3, 2024, from https://dencity.se/berattelser/atervinningspramen-ett-test-som-blev-verklighet

Dencity, & Bakosch, A. (n.d.). Flytande återvinningscentraler en möjlig lösning i Stockholm. DenCity. Retrieved April 20, 2024, from https://dencity.se/berattelser/flytande-atervinningscentraler-en-mojlig-losning-i-stockholm

Ec Europa. (2023, June). Inland waterway transport of containers, EU, 2012-2022. Retrieved January 18, 2024, from https://ec.europa.eu/eurostat/statistics explained/index.php?title=Inland_waterways_statistics_on_container_transport

Energimyndigheten. (2017). Energieffektivt logistiksystem för transport av jord- och bergmassor på Södertörn. In Energimyndigheten. Retrieved April 12, 2024, from https://www.optimass.se/wp-content/uploads/2019/07/slutrapport-eels-2015-2017.pdf

Engström, E. M., & Abrahamsson, A. (2019). Inland Waterway Transportation in Northern Europe What Sweden could Learn from a Modal Shift Process in the Netherlands. https://odr.chalmers.se/bitstream/20.500.12380/256481/1/256481.pdf

European Inland Barging Innovation Platform. (2018, August 14). Breakthrough LNG Deployment in Inland Waterway Transport - EIBIP. EIBIP. Retrieved March 14, 2024, from https://eibip.eu/publication/breakthrough-lng-deployment-in-inland-waterway-transport/

Fan, B., & Nachtmann, H. (2021). Literature review and comparative analysis of inland waterways transport: "Container on Barge." Maritime Economics & Logistics, 25(1), 140–173. https://doi.org/10.1057/s41278-021-00195-6

Fleetwood, D. (2023, November 27). Quantitative Research: What It Is, Practices & Methods. QuestionPro. https://www.questionpro.com/blog/quantitative-research/

Flick, U. (1998). An introduction to qualitative research. http://ci.nii.ac.jp/ncid/BB14980167

Flodén, J., Bärthel, F., & Sorkina, E. (2017). Transport buyers choice of transport service – A literature review of empirical results. Research in Transportation Business & Management, 23, 35–45. https://doi.org/10.1016/j.rtbm.2017.02.001

Freight Transport Statistics - Modal split. (2023, February). Eurostat Statistics Explained. Retrieved February 14, 2024, from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Freight_transport_statistics_-_modal_split

French Waterways, & Edwards, D. (2023, June 8). River Seine (Lower) | Detailed Navigation guides and maps. French Waterways. https://www.french-waterways.com/waterways/seine/lower-seine/

Fu, Q., Liu, L., & Xu, Z. (2010). Port resources rationalization for better container barge services in Hong Kong. Maritime Policy & Management, 37(6), 543–561. https://doi.org/10.1080/03088839.2010.514955

Fuel Cells Works. (2023, July 31). "Zulu 6." https://fuelcellsworks.com/subscribers/zulu-6-a-significant-leap-forward-for-hydrogen-powered-river-vessels/

Garberg, B. (2016, December). Regeringsuppdrag Analys av utvecklingspotentialen för inlands- och kustsjöfart i Sverige. Sjöfartsverket. Retrieved January 18, 2024, from https://www.researchgate.net/publication/324423179_Particle_sources_and_transport_in_stratified_Nordic_coastal_seas_in_the_Anthropocene/fulltext/5acd703d0f7e9b1896559359/Particle-sources-and-transport-in-stratified-Nordic-coastal-seas-in-the-Anthropocene.pdf

Garberg, B., Bengtsson, M., & Martini, V. (2019). Åtgärder för ökad andel godstransporter på järnväg och med fartyg. In Trafikverket (TRV 2018/93267). Retrieved March 6, 2024, from https://bransch.trafikverket.se/contentassets/00340eec2ef8460ba6b2423b7e5d4468/svar-och-aterrapportering-fran-trafikverket-2020/02-rapport-atgarder-for-okad-andel-godstransporter-pa-jarnvag-och-med-fartyg-2018-93267-justerad.pdf

Geirnaert, P. & Urban Waterway Logistics. (n.d.). Urban Waterway Logistics, Interreg VB North Sea Region Programme. Interreg North Sea. Retrieved March 29, 2024, from https://northsearegion.eu/avatar/project-partners/urban-waterway-logistics/

Gilles, P. (2024, May 6). Interview with Peyrot Gilles. Interview.

Google Maps. (2024a). A map over the waterways in central Stockholm. Sweden. https://www.google.com/maps/@59.3292116,18.0606086,12z?entry=ttu

Google Maps. (2024b, April 7). Map of the city of Gothenburg with red location pin spots of where the recycling waste barge stops. https://www.google.se/maps/@57.7081108,11.9059566,7679m/data=!3m1!1e3!4m6!1m2!10m1!1e1!11m2!2swlol6pGHSVulcOZnkrm-wA!3e3?entry=ttu

Google Maps. (2024c, April 17). A map of the waterways surrounding central Gothenburg. https://www.google.se/maps/place/Inom+Vallgraven,+G%C3%B6teborg/@57.7035861,11.9522855,3229m/data=!3m1!1e3!4m6!3m5!1s0x464ff368a2410f03:0x71b0c1e1cef80fe1!8m2!3d57.7022551!4d11.9615896!16s%2Fg%2F11dyll9z6?entry=ttu

Grauers, H., & Persson, E. (2016). Vänersjöfartens miljönytta? En studie av miljöeffekterna av inlandsjöfarten i Västsverige [Master thesis]. Chalmers University of Technology.

Göteborgs stad. (n.d.). Så fungerar det på återvinningspråmen. Göteborgs Stad. Retrieved February 16, 2024, from https://goteborg.se/wps/portal/start/bygga-bo-och-leva-hallbart/avfall-och-atervinning/har-lamnar-hushall-avfall/atervinningspramen/sa-fungerar-det-pa-atervinningspramen

Göteborgs Stad. (2024, March 4). Här stannar återvinningspråmen. Retrieved April 3, 2024, from https://goteborg.se/wps/portal/start/bygga-bo-och-leva-hallbart/avfall-och-atervinning/har-lamnar-hushall-avfall/atervinningspramen/har-stannar-atervinningspramen

HAROPA PORT. (2023, June 14). To manage resources sustainably and foster the circular economy. Retrieved April 29, 2024, from https://www.haropaport.com/en/manage-resources-sustainably-and-foster-circular-economy

Howell-Jones, J. & Global Cycling Network. (2024, May 1). How to halve car usage in less than a decade – a tour of Gent. Global Cycling Network. Retrieved May 3, 2024, from https://www.globalcyclingnetwork.com/lifestyle/interviews/how-to-half-car-usage-in-less-than-a-decade-a-tour-of-gent

Ifariyike. (2020, June 25). Ethical Guidelines for online interviews | Virtual Ethnographic Methods | Class Research portfolio. https://voices.uchicago.edu/202003sosc20224/2020/06/25/ethical-guidelines-for-online-interviews/

Inland waterway transport in Europe: No Significant Improvements in Modal Share and Navigability Conditions Since 2001 : (pursuant to Article 287(4), Second Subparagraph, TFEU). (2015).

International Maritime Organization. (1992). International Convention for the Prevention of Pollution from Ships (MARPOL). Retrieved April 18, 2024, from https://www.imo.org/en/about/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

Interreg North Sea. (2022, October 10). Let's North Sea: the Green Wave. Retrieved April 12, 2024, from https://www.interregnorthsea.eu/our-news/lets-north-sea-the-green-wave

Interreg North Sea Region. (2022, July 13). AVATAR - Test Green Wave in Ghent, Interreg VB North Sea Region Programme. Retrieved April 12, 2024, from https://northsearegion.eu/avatar/news/avatar-test-green-wave-in-ghent/

Interreg North Sea Region, Brauner, T., Kahle, M., & Pauwels, T. (2021). Market review on city freight distribution using inland waterways. In Interreg North Sea Region. In the framework of AVATAR, a project co-funded by the INTERREG North Sea Region programme 2014-2020. Retrieved April 24, 2024, from

https://northsearegion.eu/media/17515/210521_avatar_wp4_market-review_v1_final.pdf

Jamshed, S. Q. (2014). Qualitative research method-interviewing and observation. Journal of Basic and Clinical Pharmacy, 5(4), 87. https://doi.org/10.4103/0976-0105.141942

Jonkeren, O., Jourquin, B., & Rietveld, P. (2011). Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterway transport in the river Rhine area. Transportation Research Part A: Policy and Practice, 45(10), 1007–1019. https://doi.org/10.1016/j.tra.2009.01.004

Laas, B. (2020, July 16). The new port infrastructure: strategic design of a container data platform for Port of Rotterdam. TU Delft. Retrieved February 14, 2024, from http://resolver.tudelft.nl/uuid:570b377a-d99b-4be6-b119-317ddd2d36a1

Lannemyr, R., & Sommar, R. (2020). Torrhamnar och omlastningskajer för ökad sjöfart på inre vattenvägar. Trafikverket, 1–46. https://bransch.trafikverket.se/contentassets/00340eec2ef8460ba6b2423b7e5d4468/framjandeuppdrag/forstudie-analys-torrhamnar-och-andra-omlastningsytor.pdf

Lantz, J. & Avatar Logistics. (2024, April 25). Interview with Johan Lantz from Avatar Logistics [Slide show]. Interview, Stockholm, Sweden.

Larsson, C. (2023, February 10). Årsredovisning för räkenskapsåret 2022 (By C. Magnusson, B. Ling Fransson, R. Ljungh, & L. Johansson). Göteborg.se. Retrieved February 16, 2024, from https://goteborg.se/wps/PA_Pabolagshandlingar/file?id=45338

Leung, L. C. (2015). Validity, reliability, and generalizability in qualitative research. Journal of Family Medicine and Primary Care, 4(3), 324. https://doi.org/10.4103/2249-4863.161306

Li, J., & Notteboom, T. (2012). The development of the inland waterway transport system in Flanders (Belgium) : an institutional analysis. INSTITUTE OF TRANSPORT MARITIME MANAGEMENT ANTWERP(ITMMA). https://repository.uantwerpen.be/docman/irua/df3c16/6406d609.pdf

Liu, K., Zhang, J., Yan, X., Liu, Y., Zhang, D., & Hu, W. (2016). Safety assessment for inland waterway transportation with an extended fuzzy TOPSIS. Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 230(3), 323–333. https://doi.org/10.1177/1748006x16631869

Maiorano, L., Falcucci, A., Garton, E. O., & Boitani, L. (2007). Contribution of the Natura 2000 Network to biodiversity conservation in Italy. Conservation Biology, 21(6), 1433–1444. https://doi.org/10.1111/j.1523-1739.2007.00831.x

Mako, P., Dávid, A., Böhm, P., & Savu, S. (2021). Sustainable transport in the Danube region. Sustainability, 13(12), 6797. https://doi.org/10.3390/su13126797

Marinò, A., & Bucci, V. (2018). Technology and science for the ships of the future: Proceedings of NAV 2018: 19th International Conference on Ship and Maritime Research.

McCombes, S. (2023, November 20). What is a case study? | Definition, examples & methods. Scribbr. https://www.scribbr.com/methodology/case-study/

Medda, F., & Trujillo, L. (2010). Short-sea shipping: an analysis of its determinants. Maritime Policy & Management, 37(3), 285–303. https://doi.org/10.1080/03088831003700678

Mediaction. (n.d.-a). Fluvial, maritime & intermodal transport, services to industries. https://www.sogestran.com/en/

Mediaction. (n.d.-b). Sogestran news: The Sogestran Group in video. https://www.sogestran.com/en/news.php?id=15

Mirčetić, D., Nikoličić, S., Bojić, S., & Maslarić, M. (2017). Identifying the Barriers for Development of Inland Waterway Transport: a Case Study. MATEC Web of Conferences, 134, 00039. https://doi.org/10.1051/matecconf/201713400039

Morcos, M. (2024a). Photograph of AVATAR I and II. Ghent, Belgium.

Morcos, M. (2024b). Photographs of the recycling waste barge in Gothenburg. Gothenburg, Sweden.

Norman, A., Stahl, & King, J. R. (2020). Expanding Approaches for Research: Understanding and Using Trustworthiness in Qualitative Research. Department of Education. Retrieved January 24, 2024, from https://files.eric.ed.gov/fulltext/EJ1320570.pdf

North Sea Region. (n.d.). Overview Transshipment Methods for Inland waterways, Interreg VB North Sea Region Programme. https://northsearegion.eu/iwts20/e-library/overview-transshipment-methods-for-inland-waterways/

Olofsson, P. (2020, September 15). Återvinning flyter på. Recycling. Retrieved February 16, 2024, from https://www.recyclingnet.se/article/view/739551/atervinning_flyter_pa

Otterström, V., & Torpfält, S. (2014). Inlandssjöfart - från teoretisk möjlighet till potentiellt utförande [Bachelor Thesis]. School of Business, Economics and Law, University of Gothenburg.

Persson, K., & Vuorenmaa Berdica, K. (2017, March 24). Kapacitetshöjning av farled och hamn – Göteborg Tekniskt PM om behov, åtgärder och samhällsekonomiska effekter (TRV 2014/73014). Sjöfartsverket; Sjöfartsverket. Retrieved February 16, 2024, from https://www.sjofartsverket.se/contentassets/47e056f1120340ed923354e93620cc8d/sammanfattande-huvudrapport---kapacitetshojning-av-farled-och-hamn---goteborg-2017-03-24.pdf

Peterson, J. S. (2019). Presenting a Qualitative Study: A Reviewer's perspective. Gifted Child Quarterly, 63(3), 147–158. https://doi.org/10.1177/0016986219844789

Petrović, T., Račić, D., & Sigur, Z. G. (2018). The benefits and Limitations of Triple-Helix Collaboration: the case of Zagreb. https://hdl.handle.net/10419/179981

Pettersson, M. (2012). Litteraturval : Valet av skönlitteratur i svenskundervisningen. DiVa Portal. http://liu.diva-portal.org/smash/get/diva2:19760/FULLTEXT01

POM Oost-Vlaanderen. (2019). Overview transshipment methods for inland waterways, Interreg VB North Sea Region Programme. Interreg North Sea Region. Retrieved April 18, 2024, from https://northsearegion.eu/iwts20/e-library/overview-transshipment-methods-for-inland-waterways/

Regeringen och Regeringskansliet. (2023, June 16). Vägen till nettonoll tema på nationella klimatmötet. Regeringskansliet. Retrieved January 18, 2024, from https://www.regeringen.se/artiklar/2023/06/vagen-till-nettonoll-tema-pa-nationella-klimatmotet/

Restrepo-Arias, J. F., Bedoya, J. W. B., Zapata-Cortés, J. A., Paipa-Sanabria, E., & Garnica-López, M. A. (2022). Industry 4.0 Technologies Applied to Inland Waterway Transport: Systematic Literature Review. Sensors, 22(10), 3708. https://doi.org/10.3390/s22103708

retrofit. (2024). https://dictionary.cambridge.org/dictionary/english/retrofit

Rogerson, S., Santén, V., Svanberg, M., Williamsson, J., & Woxenius, J. (2019). Modal shift to inland waterways: dealing with barriers in two Swedish cases. International Journal of Logistics: Research and Applications, 23(2), 195–210. https://doi.org/10.1080/13675567.2019.1640665

Roso, V., Vural, C. A., Abrahamsson, A., Engström, M., Rogerson, S., & Santén, V. (2020). Drivers and barriers for inland waterway transportation. Operations and Supply Chain Management, 13, 406–417. https://doi.org/10.31387/oscm0430280

Roso, V., Woxenius, J., & Lumsden, K. (2009). The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography, 17(5), 338–345. https://doi.org/10.1016/j.jtrangeo.2008.10.008

Route Search engine. (n.d.). https://www.blueroadmap.nl/#/

SDGS, & De Clercq, M. (2022). Ghent 2022 Sustainability Report - Focus on Prosperity. In SDGS. Retrieved April 23, 2024, from https://sdgs.un.org/sites/default/files/vlrs/2023-08/vlr_ghent_2022.pdf

Shukla, A., Arora, V., & Kumar Reddy, G. (2022). Virtual Meeting Platforms for Online Activities during Covid-19: An Empirical Evidence. The Indian Journal of Industrial Relations, 57(4), 54–56. https://www.researchgate.net/profile/Lrk-Krishnan/publication/359971910_Case_Study_Ford_Debacle_Derails_Make_in_India_Plans/links/6258f2b39be52845a904b863/Case-Study-Ford-Debacle-Derails-Make-in-India-Plans.pdf#page=54

Sihn, W., Pascher, H., Ott, K., Stein, S., Schumacher, A., & Mascolo, G. (2015). A green and economic future of inland waterway shipping. Procedia CIRP, 29, 317–322. https://doi.org/10.1016/j.procir.2015.02.171

Singh, A. (2021, March 29). Significance of research process in research work. SSRN. Retrieved January 23, 2024, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3815032

Sjöstrand, H., Merkel, A., & Vierth, I. (2021). Hållbar inlandssjöfart i Sverige - Offentlig upphandling som effektivt styrmedel? In VTI Rapport. Trafikverket. Retrieved April 12, 2024, from https://vti.diva-portal.org/smash/get/diva2:1548210/FULLTEXT01

Specht, P., Bamler, J., Jović, M., & Meyer-Larsen, N. (2022). Digital information services needed for a sustainable inland waterway transportation business. Sustainability, 14(11), 6392. https://doi.org/10.3390/su14116392

Stad Gent. (n.d.). Circular materials management within the city organisation. Retrieved April 24, 2024, from https://stad.gent/en/city-governance-organisation/city-policy/ghents-climate-actions/circular-materials-management-within-city-organisation

Stockholms Stad, Baumgartner, A., & Billsjö, R. (2018). Förslag till handlingsplan för godstrafik i Stockholms stad. In Stockholms Stad. Retrieved April 12, 2024, from https://edokmeetings.stockholm.se/welcome-sv/namnder-styrelser/hagersten-liljeholmens-stadsdelsnamnd/mote-2018-04-19/agenda/remissunderlag-handlingsplan-for-godstrafik-i-stockholms-stad-pdf-1?downloadMode=open

Stopford, M. (2009). Maritime Economics. Taylor & Francis US.
Stora Bommen. (2023). In Stora Bommen. Retrieved March 10, 2024, from https://sv.wikipedia.org/wiki/Stora_Bommen

Suhrab, M. I. R. (2023). NAVIGATIONAL SAFETY OF INLAND WATERWAY TRANSPORT SYSTEM (IWTS) IN SARAWAK: RAJANG RIVER. Journal of

Sustainability Science and Management, 18(4), 102–118. https://doi.org/10.46754/jssm.2023.04.008

Sulaiman, O., Saharuddin, Kader, S. A., & Laily, R. N. (2011). Safety and Environmental Risk and Reliability Model for inland waterway collision accident frequency. International Journal of Energy and Environment, 4(3), 461–477. https://www.researchgate.net/publication/260002581_Safety_and_Environmental_Risk_and_Reliability_Model_for_Inland_Waterway_Collision_Accident_Frequency

Sullivan, B. P., Rossi, M., Desai, S., Solé, J., & Terzi, S. (2020). Maritime 4.0 – Opportunities in digitalization and advanced manufacturing for vessel development. Procedia Manufacturing, 42, 246–253. https://doi.org/10.1016/j.promfg.2020.02.078

The Editorial Team. (2016, June 23). Rotterdam implements paperless container transfers. SAFETY4SEA. Retrieved February 14, 2024, from https://safety4sea.com/rotterdam-implements-paperless-container-transfers/

Thienpont. (2024, March 21). Containerdienst Thienpont: Plaatsingsservice en Containerparken - Thienpont. Retrieved March 28, 2024, from https://thienpont.be/

Thomas, P. (2023, March 29). Efficient vessel turnaround times make commercial sense. Marinetraffic. https://www.marinetraffic.com/blog/efficient-vessel-turnaround-times-make-commercial-sense/

Thurmond, V. A. (2001). The point of triangulation. Journal of Nursing Scholarship, 33(3), 253–258. https://doi.org/10.1111/j.1547-5069.2001.00253.x

Trafikverket Region Väst. (2017). Farleden Göteborgs hamn, SVA1801. Trafikverket, 1, 1–36. https://bransch.trafikverket.se/TrvSeFiler/Samhallsekonomiskt_beslutsunderlag/Region_Vast/Region%20V%C3%A4st/3%20Investering/SVA1801%20Farleden%20G%C3%B6teborgs%20hamn/sva1801_farleden_goteborgs_hamn_ua1_seb_170220_g.pdf

Transportstyrelsen. (2018, January 8). Transportstyrelsens föreskrifter och allmänna råd om fartyg i inlandssjöfart. Retrieved April 12, 2024, from https://www.transportstyrelsen.se/sv/Regler/ts-foreskrifter-i-nummerordning/2018/details?RuleNumber=2018:60&ruleprefix=TSFS

Transportstyrelsen. (2019). Regler för nationell sjöfart - Transportstyrelsen. Retrieved March 6, 2024, from https://www.transportstyrelsen.se/sv/regler/Regler-for-sjofart/regler-for-nationell-sjofart/

Uddin, M. I., Islam, M. R., Awal, Z. I., & Newaz, K. M. S. (2017). An Analysis of Accidents in the Inland Waterways of Bangladesh: Lessons from a Decade (2005-2015). Procedia Engineering, 194, 291–297. https://doi.org/10.1016/j.proeng.2017.08.148

VISURIS. (n.d.). FAIRWAYS BASED ON CEMT CLASS. Retrieved May 22, 2024, from https://www.visuris.be/cemt?KL=en

Vlaamse Waterweg. (2018). PUBLIEK-PRIVATE SAMENWERKING VOOR DE BOUW VAN LAAD- EN LOSINSTALLATIES - HANDLEIDING VOOR DE AANVRAGER. In Vlaamse Waterweg. Retrieved February 14, 2024, from https://www.vlaamsewaterweg.be/sites/default/files/download/2018-0603_handleiding_pps_kaaimuren_remake.pdf

Wat doet de POM? - Pomov. (2023, September 26). Pomov. https://pomov.be/over-pom/

Wehrle, R., Wiens, M., & Schultmann, F. (2022). A framework to evaluate systemic risks of inland waterway infrastructure. Progress in Disaster Science, 16, 100258. https://doi.org/10.1016/j.pdisas.2022.100258

Welcome to the city of Ghent. (2019, October 1). Stad Gent. Retrieved March 29, 2024, from https://stad.gent/en

Wiegmans, B., & Konings, R. (2019). Inland waterway transport: Challenges and Prospects. Routledge Studies in Transport Analysis.

Wiegmans, B., Witte, P., & Spit, T. (2015). Characteristics of European inland ports: A statistical analysis of inland waterway port development in Dutch municipalities. Transportation Research Part A: Policy and Practice, 78, 566–577. https://doi.org/10.1016/j.tra.2015.07.004

WSP Sverige AB, & Knape, U. (2013). Godskartläggning i Västra Götaland. Trafikverket, 978-91-7467-542–9. https://www.diva-portal.org/smash/get/diva2:1363943/FULLTEXT01.pdf

Zoner inlandssjöfart - Transportstyrelsen. (n.d.). https://www.transportstyrelsen.se/sv/sjofart/fartyg/inlandssjofart/Zoner-inlandssjofart/

Appendices

Appendix I. Interview Guide for Sustainable Waste and Water

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

Background and Introduction

- Tell us about your background and what you do in your workplace.
- How many years of experience do you have in the industry?
- Why did the recycling waste barge start?
- How did the recycling waste barge arise?
- Were there any obstacles with implementing the recycling waste barge or was there a smooth flow?
- What was your role in the start-up of the recycling waste barge?
- Which actors were involved in the barge's start-up and what did they do?
- Which actors are still involved in the barge's daily work?

Communication and Collaboration

- What logistics stakeholders do you collaborate with in IWW waste transportation?
- How does the collaboration and communication look like between the actors involved in IWW waste transportation?
- Have there been any issues when it comes to communication and collaboration between the stakeholders working with IWW waste transportation?
- Do you use any digital system to communicate between the actors?

As-is situation

- What does the use of IWWs look like in Gothenburg?
- What does the use of IWS look like in Gothenburg?
- Name some significant advantages and disadvantages regarding IWS.
- What are we doing well about IWS in Gothenburg?
- What do we need to improve in order to expand the use of IWWs in Gothenburg?
- Have you or your organization experienced pressure to develop inland waterway transport from stakeholders? In which way?
- What are the rules for adding to the dock?
- How much waste is transported on inland waterways in Gothenburg compared to road transport?

New Technologies and Innovation

- Does the recycling waste barge in Gothenburg use any new technologies or innovation?
- Where can new technologies be implemented?
- How can new technologies be implemented?
- Has the recycling waste barge in Gothenburg been developed since its inception? If so, how?
- What opportunities do you see with Industry 4.0 on inland waterways in Sweden?
- Is there already something of Industry 4.0 that has already been implemented on IWWs in Sweden?

- Is retro-fitting relevant to the recycling waste barge in Gothenburg in its current state?
- Do you use Blue Road Map (google maps for waterways) or any similar technology to navigate the waterways?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?
- Are you available for an online meeting in the future if needed?

Appendix II. Interview Guide for Trafikkontoret

Before the interview

- Is it okay for you if we record this interview?
- Would you prefer to remain completely anonymous in our work, or is it acceptable for us to mention your role and company?

Background and Introduction

- Could you please provide some insights into your role and responsibilities at your workplace?
- How many years of experience do you have in the industry?
- What motivated the decision to start utilizing the inland waterways in Stockholm?
- How were these barge projects initiated in Stockholm?
- What commodities do the barges in Stockholm transport?
- Did you encounter any barriers that made it challenging to implement the barges in Stockholm, or was everything relatively smooth?

As-is situation

- What is the current utilization of the inner waterways in Stockholm?
- Do the barges in the city ever run empty?
- How do you work with preventing empty transportations with the barge in Stockholm?
- Could you mention some specific advantages and disadvantages of using the inner waterways in Stockholm?
- We came across an article from Intelligent Logistics written in 2019 where you, Sandra Frosth (investigator at Ecoloop), and the CEO of Avatar Logistics mentioned that you had identified some risks but hadn't found any direct obstacles to choosing maritime transport. Could you elaborate on this response? Have you encountered any direct obstacles since then?
- Does the current infrastructure limit the transportation activity on inland waterways in Stockholm?
- What needs to be developed and improved to continue expanding the use of the inner waterways in Stockholm?
- Have you or your organization experienced any pressure from other stakeholders to develop the inner waterways? In what ways?
- How much less are road transports used now that you've been working with the inner waterways in Stockholm?

New Technologies and Innovation (Barge)

- Have the barges in Stockholm adopted any new technology and innovation lately?
- Where can new technologies be implemented?
- How can new technologies be implemented?
- Have there been any developments or advancements in the barges since their inception? In what ways?
- What opportunities do you see with Industry 4.0 on the inner waterways in Stockholm?
- Is retrofitting something you consider when working with the barges in Stockholm currently?
- What is the next step for the barges in Stockholm?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?

Appendix III Interview Guide for Avatar Logistics

Before the interview

- Is it okay for you if we record this interview?
- Would you prefer to remain completely anonymous in our work, or is it acceptable for us to mention your role and company?

Background and Introduction

- Could you please provide some insights into your role and responsibilities at your workplace?
- How many years of experience do you have in the industry?
- What motivated the decision to start utilizing the inland waterways in Stockholm?
- How were these barge projects initiated in Stockholm?
- What commodities do the barges in Stockholm transport?
- Did you encounter any barriers that made it challenging to implement the barges in Stockholm, or was everything relatively smooth?

As-is situation

- What is the current utilization of the inner waterways in Stockholm?
- How do you work with preventing empty transportations with the barge in Stockholm?
- Could you mention some specific advantages and disadvantages of using the inner waterways in Stockholm?
- Does the current infrastructure limit the transportation activity on inland waterways in Stockholm?
- What needs to be developed and improved to continue expanding the use of the inner waterways in Stockholm?

New Technologies and Innovation

- Have the barges in Stockholm adopted any new technology and innovation lately?
  - Where can new technologies be implemented?
  - How can new technologies be implemented?
- Have there been any developments or advancements in the barges since their inception? In what ways?
- What opportunities do you see with Industry 4.0 on the inner waterways in Stockholm?
- Is retrofitting something you consider when working with the barges in Stockholm currently?
- What is the next step for the barges in Stockholm?

Concluding

Do you have any questions you personally would like to be answered when finishing the report?

- What do you feel needs to be developed in order to increase (or improve) transport on IWW?

Appendix IV. Interview Guide for Fabriek Logistiek

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

Background and introduction

- Can you provide us with a short description of your role and what do you do in your workplace?
- How many years of experience do you have in the industry?

Communication and collaboration

- What logistics stakeholders do you collaborate with in IWW waste transportation?
- How does the collaboration and communication look like between the actors involved in IWW waste transportation?
- Have there been any issues when it comes to communication and collaboration between the stakeholders working with IWW waste transportation?
- Do you use any digital system to communicate between the actors?

As-is situation

- What type of cranes are used for waste loading/unloading? Why are those specifically used?
- How are cranes used for loading/unloading in waste transport in Ghent?
- What type of cranes are used for loading/unloading waste in Ghent?
- What type of drivers have you experienced when developing cranes in Ghent?
- Do Ghent use specific cranes in canals with low bridges? (2 m clearance)
    - Are these cranes used in an urban environment?

New Technologies and Innovation (Cranes)

- Did you use any new technologies and innovations for the cranes developed for waste transport?
    - Where were new technologies implemented?
    - How could new technologies be implemented?
    - How has or could new technologies and innovation help with the loading and unloading?
- What opportunities do you see with industry 4.0 on the crane operation for waste transportation?
- Is there anything from industry 4.0 that is already implemented on cranes and its operation?

New Technologies and Innovation (Ports and Quays)

- Do you use any new technologies and innovation in IWW ports and quays in Ghent?
    - How could new technologies be implemented?
    - How has or could new technologies and innovation help with the IWW transportation in Ghent related to waste transport?
- What opportunities do you see with industry 4.0 on IWW ports and quays in Ghent?
- Is there anything from industry 4.0 that is already implemented on IWW ports and quays in Ghent?
- Is it necessary to have different transshipment facilities depending on the cargo type?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?

Appendix V. Interview Guide for Thienpont

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

Background and introduction

- Can you provide us with a short description of your role and what you do in your workplace?
- How many years of experience do you have in the industry?

New technologies and innovation pt 1: Vessels

- Did you use any new technologies and innovations for the vessels developed for waste transport?
    - Where were new technologies implemented?
    - How could new technologies be implemented?
    - How has or could new technologies and innovation help with the loading and unloading?
    - How has or could new technologies and innovation help with the docking and undocking?
- What opportunities do you see with industry 4.0 on IWW waste transport vessels in Ghent?

New technologies and innovation pt 2: Ports and quays

- Do you use any new technologies and innovation in IWW ports and quays?
    - Where can new technologies be implemented?
    - How can new technologies be implemented?
    - How has or could new technologies and innovation help with the IWW transportation?
- What opportunities do you see with industry 4.0 on IWW ports and quays in Ghent?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?
- Are you available for an online meeting in the future if needed?

Appendix VI. Interview Guide for City of Ghent

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

Background and introduction

- Can you provide us with a short description of your role and what you do in your workplace?
- How many years of experience do you have in the industry?
- Why is the development of IWW important to you?
- How can you in your role or your municipality in general facilitate IWW transport? Give us some concrete examples

As-is situation

- What are the regulations around loading/unloading process in an urban environment?
    - Do you use specific quays?
- What are the dimensions of the canals?
- Are there any maps of the canal dimensions and quays that we could use?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?
- Are you available for an online meeting in the future if needed?

Appendix VII. Interview Guide for POM

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

As-is situation

- What type of drivers have you experienced when developing IWS in Ghent?

AVATAR Vessel

- What CEMT classified waterways can the AVATAR vessel use?
- Did you experience any setbacks during the development of the AVATAR vessel?
- In hindsight, is there anything you would change about the vessel or the project?

New Technologies and Innovation (Vessels)

- Is it possible to retrofit a vessel into autonomy?

Other questions

- Was there something mentioned from the other interviews that you fully agreed with or not agreed with?
- Previous interviewees mentioned some innovative techniques that are close to be implemented in IWWs. How close are we to actually implementing these techniques?
- How are customers and water logistics companies in Ghent working together?

Appendix VIII. Interview Guide for Urban Waterway Logistics

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study? This is just for research purposes so we will not use your name.

Background and Introduction

- Can you provide us with a short description of your role and what do you do in your workplace?
- How many years of experience do you have in the industry?

AVATAR-vessel

- Why did the AVATAR-project start?
- What benefits does the vessel provide compared to before?
- Did you experience any setbacks during the development?
- In hindsight, is there anything you would change about the vessel or the project?
- What do you think went very well considering the development of the vessel?

As-is situation

- Can you explain the docking and undocking activity for the AVATAR-vessel?
- What type of drivers have you experienced when developing the AVATAR-vessel for IWW transportation in Ghent?
- Is it feasible for the AVATAR-vessel to travel through the city of Ghent – despite any (dimensional) limitations of canals, bridges and locks
- Can the AVATAR-vessel conduct IWS in canals with low bridges (2m clearance)

New technologies and innovation pt 1: Vessels

- Did you use any new technologies and innovations for the AVATAR-vessel?
    - Where were new technologies implemented?
    - How could new technologies be implemented?
    - How has or could new technologies and innovation help with the loading and unloading?
    - How has or could new technologies and innovation help with the docking and undocking?
- What opportunities do you see with industry 4.0 for the AVATAR-vessel?
- Is there anything from industry 4.0 that is already implemented for the AVATAR-vesselt?
- Is retro-fitting a used practice for the AVATAR-vessel?

New technologies and innovation pt 2: Ports and quays

- Do you use any new technologies and innovation in IWW ports and quays?
    - Where can new technologies be implemented?
    - How can new technologies be implemented?
    - How has or could new technologies and innovation help with the IWW transportation?
- What opportunities do you see with industry 4.0 on IWW ports and quays in Ghent?
- Is there anything from industry 4.0 that is already implemented on IWW ports and quays in Ghent?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?
- Are you available for an online meeting in the future in order for both parties to ask questions?

Appendix IX. Interview Guide for CIRCOÈ

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

Background and introduction

- Can you provide us with a short description of your role and what you do in your workplace?
- How many years of experience do you have in the industry?

As-is situation

- What type of flows do you have in the city?
- What type of vessels are used?
    - Why are these vessels used
    - How many of these vessels are autonomous?
- What type of drivers have you experienced when working with IWS in Le Havre?
- How do you conduct IWS in canals with low bridges?

New Technologies and Innovation

- Did you use any new technologies and innovations for the vessels developed for waste transport?
    - Where were new technologies implemented?
    - How could new technologies be implemented?
- How has or could new technologies and innovation help with the loading and unloading?
- What opportunities do you see with industry 4.0 on IWS vessels in Le Havre?
- Is there anything from industry 4.0 that is already implemented on IWS vessels in Le Havre?
- Is retro-fitting a used practice?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?
- Are you available for an online meeting in the future if needed?

Appendix X. Interview Guide for Sogestran

Before the interview

- Is it okay for you if we record the interview?
- Do you want to stay anonymous for the study?

Background and introduction

- Can you provide us with a short description of your role and what you do in your workplace?
- How many years of experience do you have in the industry?

As-is situation

- What type of flows do you have in the city?
- What type of vessels are used?
    - Why are these vessels used
    - How many of these vessels are autonomous?
- What type of drivers have you experienced when working with IWS in Le Havre?
- How do you conduct IWS in canals with low bridges?

New Technologies and Innovation

- Did you use any new technologies and innovations for the vessels developed for waste transport?
    - Where were new technologies implemented?
    - How could new technologies be implemented?
- How has or could new technologies and innovation help with the loading and unloading?
- What opportunities do you see with industry 4.0 on IWS vessels in Le Havre?
- Is there anything from industry 4.0 that is already implemented on IWS vessels in Le Havre?
- Is retro-fitting a used practice?

Concluding

- Do you have any questions you personally would like to be answered when finishing the report?
- What do you feel needs to be developed in order to increase (or improve) transport on IWW?
- Are you available for an online meeting in the future if needed?

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