Design methodology for sustainable urban freight distribution via waterways

A case study of het Wallengebied in Amsterdam

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Preface

As I conclude this thesis report, I mark the end of my journey through the master's program in Complex Systems Engineering and Management at TU Delft. This research venture unfolded in collaboration with the City of Amsterdam, where I delved into sustainable transport options and their viability in a bustling urban landscape like Amsterdam's. Looking back, this period has been a rollercoaster, laden with challenges that have truly contributed to my personal growth. This milestone isn't just about acquiring knowledge in my research field, but also about uncovering my own strengths and areas for improvement.

However, it's crucial to acknowledge that reaching this point wouldn't have been possible without the guidance and support of numerous individuals. This is why I'm grateful for the opportunity to express my appreciation.

A huge debt of gratitude goes to my thesis committee. Marcel, your adept guidance through the subject was invaluable. Your expertise and feedback provided the foundation for my deep exploration of this complex topic. To Alexander and Lori, I extend my thanks for your involvement in the thesis committee and for offering constructive insights during our milestone meetings.

Lastly, but certainly not least, I want to extend heartfelt thanks to my parents, brothers, and friends. Their unwavering love and support have been my driving force throughout this master's thesis journey.

Lisa van Velzen
Rotterdam, 2023

Summary

Urban areas in Europe play a crucial role in driving economic growth, knowledge production, innovations, and employment. However, the existing urban freight transport system is inefficient and hinders sustainable development, resulting in negative impacts such as traffic congestion, air and noise pollution, and road accidents. The city of Amsterdam is facing various challenges in managing urban freight transport within its historic and densely populated inner city. With a rapidly growing population and increasing number of trips to, from, and within the city, Amsterdam is facing pressure on accessibility, road safety and quality of life. Furthermore, Amsterdam needs to renovate a significant portion of its historical quays and bridges, which will have a major impact on urban freight transport. In response to these challenges, the municipality of Amsterdam has implemented various measures to improve transport, including environmental zones, initiatives for emission-free traffic, time windows, no-entry zones, and weight restrictions. The city's commitment to maintaining accessibility and liveability, combined with its ambitious goals, has led to advancements in urban freight transport, with one notable initiative being waterborne transport. This initiative aims to utilize the city's canals as a distribution system for the city centre, harkening back to their original purpose.

While many initiatives of waterborne transport showed success in pilot projects and demonstrations, large-scale or long-term implementation could give rise to unexpected side effects. Challenges also persist due to government policies and the cooperation of key stakeholders. In this context, the objective of this thesis is to develop a design methodology that assists Dutch municipalities and decision-makers in governing urban waterborne freight transport. The design statement of this thesis is as follows: *Design of a methodology for sustainable urban freight distribution via waterways.*

The design methodology offered a stepwise approach for designing, evaluating, and generating implementation guidance for waterborne freight transport, enabling a thorough understanding and assessment of impacts. The thesis combined the designed methodologies proposed by Dym et al. (2004) and Johannesson and Perjons (2014) in the development of the design methodology. The design approach encompassed five stages: problem definition, defining the design requirements, creating the design process, demonstrating the design process, and evaluating the design process.

In the thesis, the problem definition stage addressed three topics: (sustainable) urban freight transport, urban waterborne freight transport, and a stakeholder analysis. These chapters looked at the current situation regarding (sustainable) urban freight transport, their implementation challenges, and, from there, success and failure factors of previously implemented initiatives in the field of urban waterborne freight transport in Europe and cities in the Netherlands. Next, a stakeholder analysis was performed to determine which stakeholders were involved in this transport system and what their objectives were in the field of urban waterborne freight transport. This information was then translated in the second stage, defining the design requirements, into requirements for the design of sustainable urban waterborne freight distribution. These requirements served as the foundation for the design of sustainable urban waterborne freight distribution.

During the next phase, creating the design process, the steps to be performed when designing a new design were understood. A morphological chart was used to support this process, allowing decision-makers to explore the design space, identify key criteria and parameters, and evaluate trade-offs between different solutions based on multiple criteria. Morphological analysis broke down the complex system into smaller components, simplifying the identification of potential solutions. Once drawn up, the alternatives were assessed and evaluated against criteria set by stakeholders involved in urban waterborne freight transport. These criteria were derived from the objectives of the

stakeholders involved that were previously defined and included affordability, sustainability (including emissions), noise, road safety, efficiency, reliability, and flexibility. The design process used a scorecard, where criterion values were scored using smart coloring techniques. This involved creating separate scorecards for each stakeholder based on the criteria important to that stakeholder. To provide effective implementation guidelines for urban waterborne freight transport, it was crucial to identify and address trade-offs, as well as critical success and failure factors associated with the implementation process. Collaborative sessions with stakeholders played an important role here. Implementing urban waterborne freight transport required navigating complexities and taking into account the different perspectives and interests of stakeholders.

The design methodology was applied to the case study of het Wallengebied in the fourth stage, where the steps of the design methodology were followed. During these steps, several alternatives were prepared and scored for all stakeholders involved based on the criteria important to them. Possibilities to turn certain alternatives with a poor score on a criterion into a more positive score were considered. This was also something to be done in the final step during the collaborative sessions. However, due to time constraints, the final step, the execution of collaborative sessions, was not conducted.

The fifth step was a validation where self-validation was chosen to see where the design methodology met. The design methodology met all the requirements that had been set up, but on the other hand, the design methodology also had some limitations worth mentioning. One important limitation was its dependence on data availability and quality. To address this, efforts should be made to improve data collection methods and ensure data quality to improve the performance of the methodology. Another limitation related to the scoring of alternatives within the methodology. The evaluation and scoring process could be influenced by subjective judgments and preferences of stakeholders, which introduced the possibility of bias and resulted in different outcomes depending on the evaluators involved. To reduce this limitation, it was important to explore and develop objective evaluation criteria and methods that reduced subjectivity and increased the reliability of method evaluations. Finally, to maintain usability and user-friendliness, the methodology might use simplifications and assumptions that did not fully reflect the complexity of real scenarios. While this approach promoted usability, it might result in less accurate results or outcomes that might not perfectly match practical implementations. Future research should focus on refining the methodology by including a more comprehensive representation of real-world complexity while ensuring usability.

To address the limitations of the design methodology for sustainable urban waterborne freight transport, several recommendations for further research were made. First, it was important to improve data collection methods and data integration processes. Second, it was recommended to conduct sensitivity analyses and further validate the methodology. Validating the methodology's predictions and recommendations through multiple case studies would enhance credibility and demonstrate applicability in real-world scenarios. Third, it was recommended to organize collaborative sessions specifically for the case study of het Wallengebied. Involving stakeholders in this process could lead to a better understanding of their needs and concerns, leading to more informed decision-making and the development of effective strategies tailored to the unique context of het Wallengebied. Overall, these research recommendations aimed to address the limitations of the design methodology and improve its potential in designing sustainable urban waterborne freight distribution.

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1. Introduction

1.1. Problem background: Unsustainable cities

Europeans are urbanites: in 2018, 72 percent of the total European population lived in urban areas (Clark et al., 2018). Urbanisation is an ongoing trend and the urbanisation rate in Europe is expected to increase to around 83.7 percent by 2050 (European Commission, n.d.). Behind these numbers are differences between the European countries. The Netherlands leads Europe in terms of urbanisation. In relative terms, the share of built-up areas in relation to the total territory, the Netherlands tops the European list with a percentage of 21 percent, just behind Malta and Belgium (European Commission, n.d.). Cities are often described as engines of economic growth. In almost all European countries, urban areas are the main producers of knowledge and innovation. The European Union has 271 metropolitan regions, which in 2013 counted 59 percent of the population, were responsible for 62 percent of all employment and generated 68 percent of GDP, underlining the important role as centres of population, economic activity and employment (European Commission, 2017a). The functioning of the economy is highly dependent on urban transport systems as they keep goods and commuters accessible and ensure the well-being of the population through accessibility to all social activities (European Commission, 2017b). With the increase in urban population and continued economic growth, the demand for freight transport is rising. The current way of transporting goods in cities is inefficient and does not contribute to sustainable development (Quak, 2011). Urban freight transport is responsible for a number of social, environmental and economic impacts that threaten the quality of life in these urban areas, such as traffic congestion, air pollution, noise pollution and the consequences of road accidents (Browne et al, 2012). Despite these negative impacts, urban areas continue to have demand for freight transport services and depend on the distribution of goods. The need to examine how to improve mobility while reducing congestion, road safety and pollution has therefore increased significantly.

1.2. Problem statement: Urban freight transport in Amsterdam

Amsterdam's inner city is one of the most beautiful urban areas in the world with its history, unique structure and countless monuments. But the area is also under considerable pressure. Amsterdam is growing and thriving and is becoming increasingly crowded with residents, visitors, homes and jobs. It is expected that by 2032 the city will have grown to more than one million inhabitants. In 2040 it is expected that there will be 290.000 new homes, the number of jobs will increase by 30% and there will be 4% more tourists visiting the city (Gemeente Amsterdam, Verkeer & Openbare Ruimte, 2019). Increasing crowding in the city is accompanied by a huge increase in the number of trips to, from and within the city. By 2030, the number of daily trips will have increased by 20-39% compared to 2015. If no action is taken, accessibility, road safety and equal opportunities for accessible and affordable mobility will come under pressure. The increase in mobility also puts pressure on the city's liveability. Traffic in the city increases the proportion of CO_2 and particulate matter in the air and deteriorates air quality (Gemeente Amsterdam, 2019).

In addition to these problems caused by the increased levels of urban transport, the city of Amsterdam faces a major challenge in renovating a large part of its historical quays and bridges. Amsterdam is characterised by its canals and the bridges and quay walls are historical and essential connections in the city. For a long time, little attention was paid to the management and maintenance of the infrastructure and thus the historical inner city. The result is that 80 to 125 bridges and 60 kilometres of quay wall are currently in poor condition and in need of maintenance. The large and complex task will take a long time and have a major impact on urban freight transport. It therefore offers opportunities to look for alternative transport possibilities to reduce the nuisance of heavy freight traffic on the bridges and quays (Gemeente Amsterdam, 2020b).

In order to deal with the current challenges and to organize transport in the area more efficiently, cleaner and lighter, the municipality of Amsterdam has drawn up various ambitions to change the transport movements in the city. The ambitions have resulted in several measures that have an impact on transport in the inner city. Traffic is a major polluter of the air, which is why the municipality of Amsterdam is working towards a city with only emission-free traffic by introducing environmental zones and emission-free zones (Gemeente Amsterdam, 2020c). The environmental zones are intended to keep the most polluting passenger cars, trucks, delivery vans, taxis, buses and mopeds and motorbikes out of the city. The measures will not only reduce emissions, but also reduce noise since emission-free vehicles make no engine noise and only the sound of the tyres can be heard (Gemeente Amsterdam, 2020c). In order to further reduce the number of freight vehicles the municipality has introduced time windows and no-entry zones in some parts of the inner city and the current weight restrictions are strengthened. Previously, trucks of 7.5 tonnes or more were only welcome in the inner city with an exemption. The new policy concerns new additional rules for heavy vehicles, as a result of which vehicles heavier than 30 tonnes no longer have access within the S-100, stricter requirements apply to route exemptions (exemption Zone Heavy Traffic) and a maximum length of 10 metres applies within the zone (Gemeente Amsterdam, 2022b). Lastly, in December 2023, the speed limit in Amsterdam will go to 30 kilometres per hour on 270 kilometres of busy city streets. This means that from then on, 80 per cent of the roads will be 30-kilometre roads. This will make traffic safer and quieter (Gemeente Amsterdam, 2022e).

The increasing drive to keep the city accessible and liveable, combined with the municipality’s ambitions, generates developments in urban freight transport. Urban freight transport initiatives aim at improving distribution by making changes in freight transport operations or the freight transport context (Quak, 2008). Several initiatives have been implemented in Amsterdam, such as the introduction of a sustainable freight hub on the outskirts of the city at an easily accessible location where goods can be transferred to clean (electric) onward transport into the city. To further encourage the use of electric delivery and freight vehicles, pilots are being conducted where exemptions are given to electric transport. This will ensure that transporters spend less time looking for a suitable unloading point and have less administrative burden. Another initiative that the municipality of Amsterdam wants to revive is waterborne transport (Litjens, 2017). This initiative stems from the idea of using the canals again for what they were once intended: as a distribution system for the city centre. In theory, urban water lends itself well as an alternative to road freight transport.

Several urban waterborne distribution concepts have already been established in the Netherlands and other places in Europe. Multiple authors recognise the potential for a shift of distribution from road to waterways and indicate that waterborne transport can contribute to a more sustainable transport system (Konings, 2009; Lowe, 2005; Rohács & Simongáti, 2007). In the Netherlands, there have been successful concepts in Utrecht with the beer boat and in Amsterdam with the City Supplier and the DHL Floating service centre (Maes et al., 2015). In Europe, there are also a number of cities with many waterways that use waterborne deliveries, such as Paris, Lille and London (Taniguchi & Dablanc, 2014; INE/EFIP, 2008). Despite these promising findings, waterborne distribution has not yet been implemented on a significant scale.

1.3. Thesis project objective

The emergence of new concepts is driving the adoption of urban waterborne transport. While many initiatives have proven to be successful in pilot projects and demonstrations, unexpected side effects can occur with large-scale or long-term implementation, and challenges remain due to government policies and the cooperation of key stakeholders. This thesis aims to contribute to the sustainable objectives of municipalities and improve the liveability and accessibility of urban areas by minimizing transportation-related disturbances. In order to facilitate sustainable urban freight distribution through waterways, an innovative design methodology is being developed. This methodology aims to provide valuable support to Dutch municipalities and policymakers. By incorporating various essential elements, it will effectively guide the design process for urban freight distribution via water. Through its implementation, different crucial aspects of water-based freight distribution within urban areas will be carefully addressed and taken into consideration. In order to respond to the object, a design statement is formulated. The design statement is as follows:

Design of a methodology for sustainable urban freight distribution via waterways.

With this design statement in mind, the thesis can be divided into two parts: an analysis of urban (waterborne) freight transport and the development of a design methodology that provides guidance on designing urban waterborne freight transport.

Analysis of urban (waterborne) freight transport
The first objective of this study is a comprehensive analysis of urban freight transport. This means first understanding how urban freight transport works and what elements are involved. It will look at what sustainable urban freight transport and urban waterborne freight transport means, insights from previous urban waterborne freight transport initiatives, key stakeholders and critical success and failure factors.

Design framework
This information can be used for the development of a design methodology that provides guidance on designing urban waterborne freight transport. The design methodology will be applied to a specific case study, "Het Wallengebied" in Amsterdam, to determine its effectiveness.

1.4. Case: “Het wallengebied” in Amsterdam

Het Wallengebied is located in the middle of Amsterdam’s historic centre in the Burgwallen-Oude Zijde district (see figure 1-1). It has one of the most beautiful neighbourhoods in the world, but the area is under great pressure. As in the rest of Amsterdam, population and employment are growing, bridges and kilometres of quay wall need to be repaired and the logistical flows are increasing while public space is not growing with them. A large part of the logistic flows come from het Universiteitskwartier, which is located in het Wallengebied (see figure 2-1). Het Universiteitskwartier lends itself to the activities of the University of Amsterdam. The UvA has plans for the development of the Universiteitskwartier. It must become a place where students, employees, knowledge institutions, companies and residents can form a valuable knowledge cluster with developments that are beneficial for the university, the city and the residents (Gemeente Amsterdam, 2021). The UvA is a major party that provides a large flow of logistical movements due to the number of pedestrians, cyclists and the supply of goods into and removal of waste from the area. After commissioning the renovated UvA buildings, the demand for logistics in the area will further increase, such as the delivery of facility products, catering, packages, books, technical equipment and waste collection on campus. Besides the UvA, there are also many other functions in this area, such as hotels,

Figure 1-1. Het Wallengebied

Figure 1-2. Het Universiteitskwartier

restaurants, shops, businesses and homes that generate logistics flows. With a total of 1.965 businesses, het Wallengebied is well above the average for Dutch neighbourhoods. The area has 608 offices, 234 shops, 323 facilities, 387 horeca establishments, 194 businesses and 219 other businesses (Gemeente Amsterdam, n.d.-c). The combination of these flows and the deteriorating condition of the bridges and quays put pressure on liveability and accessibility in the area. Consequently, the government is placing increasing demands on the logistics sector. One of the ambitions for het Universiteitskwartier is to design and evaluate waterborne freight distribution. The project is unique because of its location, vulnerable infrastructure, congestion and the huge diversity of interests of the area's users (Balm, 2022).

1.5. Scoping

In the context of developing a design methodology, scoping holds significant importance. This section explores the decisions made concerning system demarcations and the rationale behind those choices.

1.5.1. Geographical scope

The first system demarcation is formed by a geographical boundary. This thesis focuses on urbanised regions, which are high-density areas characterized by a diverse ring of activities (van Binsbergen & Visser, 2001). This thesis examines the inner city of Amsterdam, namely het Wallengebied. It should be noted that the fact that the study is conducted in Amsterdam does not limit the applicability of the findings solely to this municipality, given the numerous generic aspects that Dutch municipalities share in their processes and resources. While the conclusions of this thesis may not be universally generalizable, they can be adapted to other urban areas with minor modifications.

1.5.2. Time scope

The fifth delineation concerns the timeframe. The design for waterborne freight transport must be able to be implemented in the short term, between 2023 and 2025, because most of the municipality's measures will be tightened between 2025 and 2030. This places certain requirements on the design. The design needs to be logistically, physically and technologically feasible in the coming years. This period gives an opportunity to implement new possible constructions and design changes.

1.5.3. Supply chain scope

Geographical locations, the origin of the logistics flow and its destination, form the next demarcation. To analyse the supply chain process, it must be structured and decomposed. The overall supply chain perspective deals with the activities from the manufacturing to the final delivery to the end user. The focus of this thesis is further delineated and concentrates on the last part of the supply chain known in academic literature as urban logistics, urban goods distribution, urban freight transport or the last mile. The reason for this focus is that this part of the supply chain is the least economically efficient. Moreover, the last mile places a burden from both an environment and social perspective. Improving this last part of the supply chain has potentially the greatest impact on as many stakeholders as possible.

1.5.4. Type of goods flow scope

The fourth demarcation concerns the flows of goods included in this study. Different types of goods flows can be distinguished in high-density urban areas. According to the municipality of Amsterdam municipality, the logistics sector can be divided by activity, products to be delivered and end customer into the following segments (see figure 1-3): construction, horeca (hotel, restaurant, catering), supermarket and wholesale, retail, services, home delivery (formerly parcel delivery) and waste processing (Gemeente Amsterdam, 2022a).

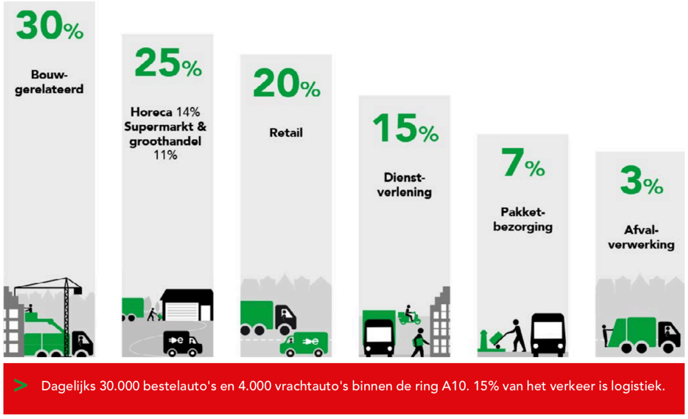

Figure 1-3. Segments (Gemeente Amsterdam, 2022a)

A large part of logistics movements consists of supplying horeca (hotel, restaurant, catering), supermarkets and wholesale. In Amsterdam, this comprises a quarter of all movements, but in some areas this share is much higher. Many of the products in this segment are perishable goods and are transported conditioned (chilled or frozen) (Gemeente Amsterdam, 2022a). The horeca sector generally contains a homogeneous market sector, but the commercial activities offered to end users entail very different logistical and organisational constraints. Distribution channels are characterised by unpredictability, which can mean that companies hold significant stocks, but also that just-in-time (JIT) deliveries are often needed in small quantities, leading to frequent and inefficient deliveries (MDS Transmodal Limited, 2012). According to the Hogeschool van Amsterdam a catering establishment has an average of six different suppliers, with an average of 12.7 deliveries per week. About 80% of the products come from the region, up to about 30 km from the city, whether through a regional distribution centre or not (Gemeente Amsterdam, 2022a). There is still much to be gained here in terms of frequency and efficiency. Larger and better organised horeca businesses, such as large hotel and restaurant chains, are more likely to achieve economies of scale through centralised purchasing and more consolidated and less frequent deliveries. Smaller companies can also get these benefits by making the required deliveries transparent and alerting the supplier to joint purchasing opportunities, so that deliveries can be bundled and transport movements reduced (MDS Transmodal Limited, 2012). At the same time, new trends are focusing on fresh, available and local products, changing demand more frequently. This results in smaller volumes and more frequent deliveries (Gemeente Amsterdam, 2022a). The collection of waste from households and businesses, despite its limited share of 3 per cent share of logistics mileage, has a major impact on the city. Waste disposal is inextricably linked to the segment of horeca. Growth and trends in this segments are automatically reflected in waste flows. In Amsterdam, the commercial waste stream is collected by a large number of collectors, each with their own heavy vehicles. Consequently, there are many different waste collectors operating in some neighbourhoods, sometimes driving several times through a street because customers individually agree on collection times (Gemeente Amsterdam, 2022a). The optimisation of municipal waste management can contribute to the sustainability of cities. The trend towards privatisation and consolidation in the sector can lead to operational economies of scale that can lead to greater efficiency (MDS Transmodal Limited, 2012). In the case study of the het Wallengebied, these percentages may exhibit slight variations compared to other areas in Amsterdam. This district comprises a larger concentration of catering establishments, making it even more evident why the flow of horeca goods is a key consideration in this thesis.

1.5.5. Scope of the sustainability perspective

The fifth demarcation relates to the sustainability perspective. This means that economic efficiency has been taken into account, but also environmental and social objectives. The rationale for this premise is based on three reasons. First, the problem owner and client of this study is the Municipality of Amsterdam. The municipality aims to be a sustainable, healthy, liveable and vital city (Gemeente Amsterdam, 2022d). These values are best achieved through a sustainable approach.

Secondly, there is a growing interest from scientific research and practitioners for innovations in sustainability in the field of urban freight distribution systems. Finally, the global trend towards sustainable processes and trends changing the demand for urban freight distribution create the need to solve urban freight distribution problems from a sustainable perspective.

1.5.6. Logistic and technological developments

The final demarcation focuses on logistics and technological developments and opportunities to improve the efficiency of urban goods distribution. The focus is on the feasibility of a modal shift in short-haul freight distribution, made possible by new logistics concepts. The new logistics concepts are intermodal and based on new freight transport technologies, the effective use of specific infrastructures (road and water) and the application of specialised systems within the urban environment.

1.6. Deliverable

The deliverable of this thesis consists of two parts. First, a design methodology that provides guidance on designing urban waterborne freight transport. The methodology describes how alternatives can be designed and how they can be scored based on various established criteria. It also includes an implementation guidance on how to implement the chosen waterborne freight transport solution, including considerations for regulatory compliance, stakeholder engagement and operational management. Overall, the design methodology would provide a structured approach to the entire process of designing, evaluating and generating an implementation guidance for urban waterborne freight transport, aiming to improve efficiency, sustainability and integration of water-based transportation within urban logistics networks. The design methodology should be easy to use by non-experts and should also be applicable in other urban areas with the same characteristics. Secondly, the design methodology is applied to a particular case study, namely het Wallengebied. The purpose of this case study is to serve as a medium for showcasing, evaluating, and practicing the design methodology. By utilizing this case study, the design methodology's effectiveness is demonstrated, illustrating how it operates in practice.

1.7. Thesis outline

This section provides an overview of the format of the thesis. Chapter 1 provides the background information problem description, research objective and scope of the research. Chapter 2 elaborates the approach of the thesis. The third chapter discusses the concept of urban freight transport. Chapter 4 consists of an explanation of urban waterborne freight transport and the findings of relevant examples from the literature. Next, chapter 5 conducts a stakeholder analysis. Chapter 6 contains the design requirements. Chapter 7 deals with the development of the design process based on the previously drafted requirements. Chapter 8 consists of the design verification by the application of the design process in het Wallengebied in Amsterdam. Chapter 9 consist of a validation of the design process. Next, chapter 10 contains the discussion, conclusion and recommendations for further research.

2. Thesis project methodology

This thesis project aims to create a design methodology that provides guidance on designing sustainable urban waterborne freight transport. The objective of this chapter is to present the way in which the methodology of this research is executed. In order to do this, first the general methodology is described, after which the research methods are explained.

2.1. Thesis approach

To find the appropriate design methodology, several existing methodologies are considered. These serve as a guideline for preparing the flowchart for this thesis project.

2.1.1. Selection of suitable design methodology

Dym, Little & Orwin's (2004) design methodology has been widely adopted by students at TU Delft's Technology, Policy, and Management faculty. The model provides a well-structured, yet flexible approach that includes various design tools to enable designers to create a broad design space. The methodology consists of five phases: problem definition, conceptual design, preliminary design, detailed design, and design communication. Each phase's output serves as input for the next, allowing designers to learn a systematic approach to design. The methodology's spiral structure promotes feedback and iteration, with feedback occurring both internally during the design process and externally after a design has entered the market and received user feedback. Iteration involves repeatedly applying a common method or technique throughout the design process, keeping the original goals in mind to get closer to the final design (Dym et al., 2004).

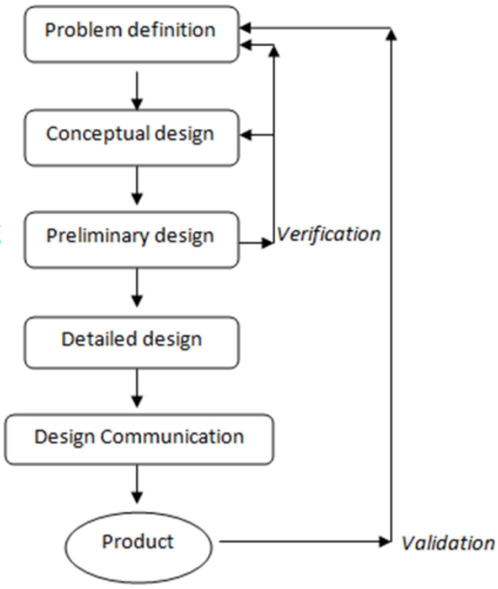

Figure 2-1. Dym, Little & Orwin's (2004) design methodology

Johannesson and Perjons (2014) proposed a comprehensive Design Science Research (DSR) framework, which is discussed in their book, "An Introduction to Design Science." This framework, shown in figure 2-1, serves as a reliable guide for both the design process and research methods, including questionnaires, surveys, and interviews. The framework comprises five primary stages: Explicate Problem, Define Requirements, Design and Develop Artefact, Demonstrate Artefact, and Evaluate Artefact. Despite its apparent sequential order, Johannesson and Perjons (2014) emphasize the iterative nature of the design process, and the arrows in the framework denote input and output relationships.

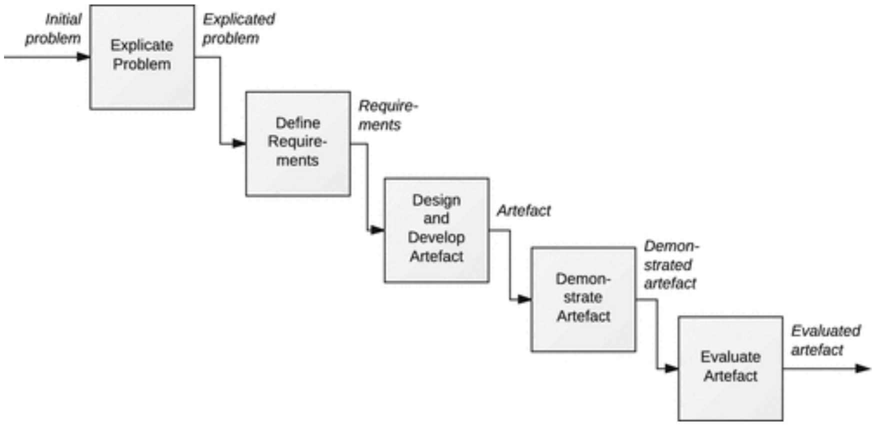

Figure 2-2. Design Science Research Framework (Johannesson and Perjons, 2014).

The combination of the design methodologies proposed by Dym et al. (2004) and Johannesson and Perjons (2014) can aid in the development of the design methodology for urban waterborne freight transport. Dym et al.'s methodology provides a systematic approach to the design process, while Johannesson and Perjons' DSR framework offers a reliable guide for conducting research and designing artefacts. By integrating the two approaches, designers can develop a comprehensive design methodology for designing urban waterborne freight transport systems. The methodology for this thesis incorporates elements from both Dym et al.'s methodology and Johannesson and Perjons' DSR framework. The process starts with identifying an initial problem, followed by formulating a problem definition. This definition aids in assessing the current urban logistics situation and establishes clear goals and objectives to be accomplished through the implementation of urban waterborne freight transport. The problem definition incorporates all pertinent information and sets the essential requirements for the design. This step draws from both methodologies. In the next step, the requirements are defined, utilizing Johannesson and Perjons' methodology. These requirements serve as the foundation for the design of urban waterbørne freight transport. This step is present in both methodologies.

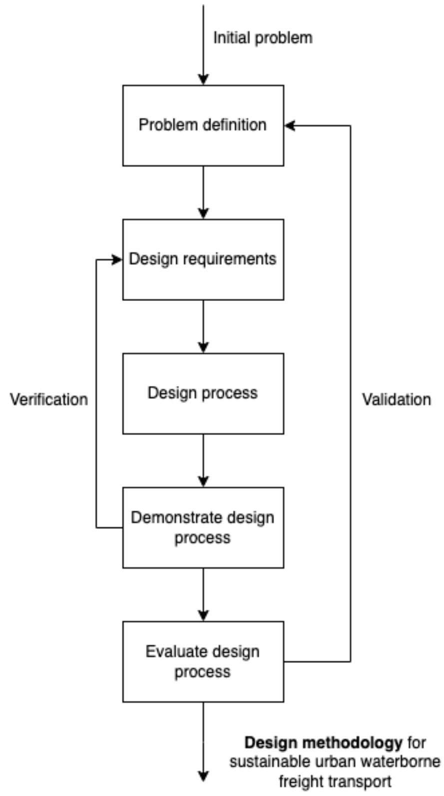

Figure 2-3. Overall methodology

The design process consists of three main components: design, evaluation and implementation guidance for urban waterborne freight transport. The design methodology incorporates a user-friendly design function that allows users to create and modify various aspects of urban waterborne freight transport. This functionality encompasses all the relevant components and factors related to urban waterborne freight transport. Users are empowered to explore different design scenarios, make adjustments and evaluate their impact on the efficiency and effectiveness of freight transport, facilitating iterative design processes and informed decision-making.

Moreover, the design methodology includes an evaluation function that enables users to assess the performance and impact of urban waterborne freight transport initiatives. A comprehensive set of metrics and indicators is provided to measure criteria. Users can input specific data and parameters relevant to their context, facilitating evaluation of different scenarios. The methodology generates reports or visualizations summarizing the evaluation results, enabling users to make well-informed decisions and prioritize actions for improvement effectively.

Furthermore, the design methodology offers implementation guidance to assist users in effectively implementing urban waterborne freight transport. The design methodology provides guidance on monitoring and evaluating implementation progress, identifying potential challenges, and proposing solutions to overcome them. It serves as a comprehensive guide, supporting users in successfully translating their designs and evaluations into real-world implementation of urban waterborne freight transport initiatives. Throughout these phases, the design methodology shall take into account the interests of the stakeholders involved.

Following the design of urban waterborne freight transport, the next step involves demonstrating the design, following the approach outlined by Johannesson and Perjons (2014). During this stage, the design is applied to a real-life case to verify its correctness and ensure it fulfills the requirements. After the demonstration, the design undergoes evaluation to validate its effectiveness and alignment with the stakeholders' needs. This validation process aligns with the principles found in both methodologies. The combination of Dym et al.'s methodology and Johannesson and Perjons' DSR framework provides a robust approach for developing a comprehensive design methodology that facilitates the design, evaluation, and generation of implementation guidance for urban waterborne freight transport. The overall methodology is shown in figure 2-3.

2.1.2. Research questions

The objective of this thesis is to develop a design methodology for achieving sustainable urban freight distribution using waterways. To accomplish this, several aspects must be investigated, leading to the formulation of sub-questions. Urban waterborne freight transport is a complex subject. To gain a comprehensive understanding, the initial sub-question "***SQ1. What is the current status of the system in which urban waterborne freight distribution will be implemented?"*** is introduced. This question serves as a broad introduction to the problem definition and will be further broken down into more specific sub-questions.

Urban waterborne freight transport is part of the broader context of urban freight transport. Therefore, it is essential to provide background information on urban freight transport and sustainable urban freight solutions. Addressing the question ***"SQ1.1. What is the current status of urban freight distribution and what are the key challenges in implementing sustainable transportation solutions?"*** will shed light on potential challenges in implementing urban waterborne freight transport. Subsequently, the focus will shift to urban waterborne freight distribution. Understanding the components of this transportation system is crucial for its effective design. Hence, the next sub-question is: ***"SQ1.2. What are the main functions of urban waterborne freight distribution?".*** By addressing these two questions, a theoretical understanding of urban waterborne freight distribution is achieved. However, real-world insights can be gained from existing initiatives where urban waterborne freight distribution has already been implemented. These initiatives hold valuable lessons for design purposes. Hence, the subsequent question is: ***"SQ1.3. What urban waterborne freight transport initiatives have been implemented, and what are the critical success and failure factors for large-scale implementation in urban areas?".*** To complete the picture, it is crucial to consider all stakeholders involved in the transportation process. Their interests are pivotal in the design phase, as they influence the feasibility of various options. Consequently, the next sub-question is: ***"SQ1.4. What are the interests of the main stakeholders in urban waterborne freight distribution?".*** By addressing these four sub-questions, the main question "What is the current status of the system in which urban waterborne freight distribution will be implemented?" is adequately answered.

With this information at hand, the next step is to explore the requirements for designing urban waterborne freight distribution. For this purpose, the question ***"SQ2. What are the requirements for the design of sustainable urban waterborne freight transport?"*** has been formulated. Insights from previous initiatives, together with stakeholder input, will contribute to establishing these design requirements. With a clear understanding of the design requirements, the next crucial step is to explore the methods that can be employed for designing urban waterborne freight transport. This involves examining various approaches for designing and evaluating alternatives, as well as strategies for implementation. To address this, the question **"SQ3. What methods can be used to design urban waterborne freight transport?"** has been formulated.

2.1.3. Thesis flow diagram

Figure 2-4 presents the flow diagram of the thesis, which combines the stages from overall framework with the chapters, methods, and main and sub-questions. The design phase is indicated on the left-hand side of the framework for each phase. In the middle, the chapters are depicted with the methods employed in the chapter. On the right-hand side, the objective of the thesis and the sub-questions that will be addressed in one or more chapters are presented.

The thesis flow diagram commences with the **Introduction**, which is part of the "Initial problem" phase and provides a background of the topic while analysing the relevant domain. Chapter 2, **Thesis Methodology**, explains the approach and methods employed in the thesis. Chapters 3, 4 and 5 address ***SQ1: What is the current status of the system in which urban waterborne freight distribution will be implemented?*** And are part of the "Problem definition" phase. The methods utilized in these chapters primarily include desk research and semi-structured interviews conducted with experts during a workshop. Chapter 3, **Urban Freight Distribution**, explores the concept of urban freight distribution and sustainable urban freight distribution. It examines possible solution concepts for mitigating negative impacts and ensuring sustainable urban freight transport, along with the implementation challenges associated with these solutions. This chapter provides an answer for ***SQ1.1 What is the current status of urban freight distribution and what are the key challenges in implementing sustainable transportation solutions?.*** Chapter 4, **Urban waterborne freight distribution**, focuses on current activities in urban freight distribution and the role of waterborne transport in making urban distribution sustainable by answering ***SQ1.2 What are the main functions of urban waterborne freight distribution?.*** The chapter then presents various cases from Europe and the Netherlands where waterborne distribution has been implemented, along with the success and failure factors associated with large-scale implementation in urban areas to answer ***SQ1.3 What urban waterborne freight transport initiatives have been implemented and what are the critical success and failure factors for large-scale implementation in urban areas?***. Chapter 5 comprises of a **Stakeholder analysis** to identify relevant stakeholders, their interests, and views, which answers ***SQ1.4 What are the interests of the main stakeholders in urban waterborne freight distribution?***. This analysis translates stakeholder interests into criteria that are important in waterborne distribution. Chapter 6, **Requirements**, is part of the "Design Requirements" phase, utilizing input from the "Problem definition" phase. This chapter presents a list of requirements for the design of urban waterborne freight distribution, answering ***SQ2 What are the requirements for the design of sustainable urban waterborne freight distribution?***. Chapter 7, **Design of urban waterborne freight distribution**, is part of the "Design process" phase and discusses different design methods and gives an answer to **SQ3.** ***What methods can be used to design sustainable urban waterborne freight distribution?***. The information obtained is processed and translated into the most appropriate design methodology for urban waterborne freight transport. Chapter 8, **Design verification: Case study,** is part of the "Demonstrate design process" phase and involves applying the design methodology to a specific case, Het Wallengebied in Amsterdam, to verify whether the methodology is suitable to design, evaluate and implement urban freight distribution by water as a solution for a sustainable and economically efficient supply of Het Wallengebied. Furthermore, chapter 9, **validation of design process**, is part of the "Evaluate design process" and is conducted to ensure that the design methodology meets the specific needs and expectations of the stakeholders who will utilize it. The **Discussion and Conclusion** will be presented as part of Chapter 10.

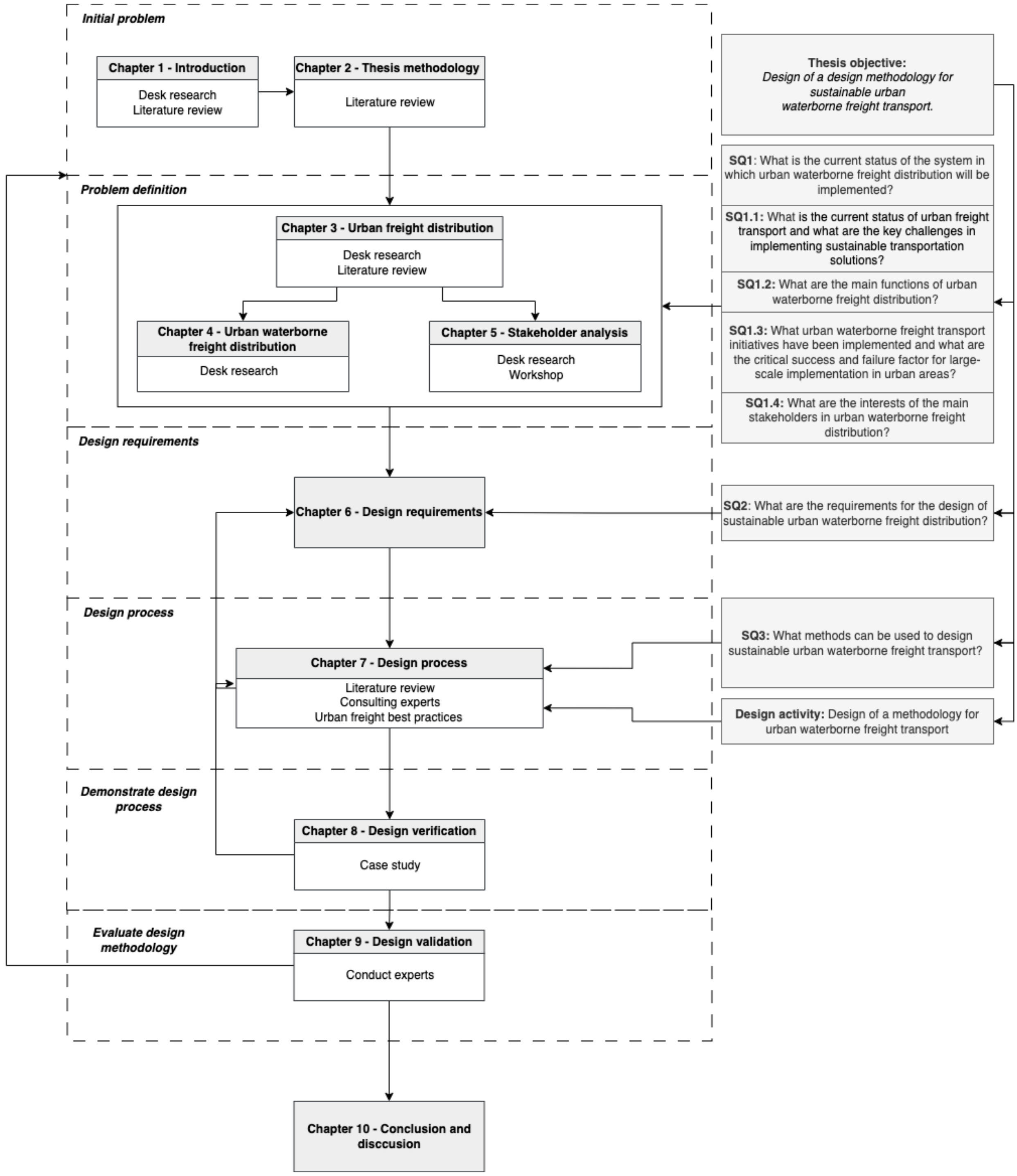

Figure 2-4. Thesis flow diagram

2.2. Research methods

This thesis uses several qualitative research methods separately and in combination. The research methods consist of a literature review, desk research, semi-structured interview sessions and a case study. The ways in which the methods are used are explained below.

2.2.1. Literature review and desk research

A literature review is a comprehensive and critical evaluation of existing research and literature related to a specific topic. In the context of this thesis, the literature review serves various purposes, including providing background information for the introduction, informing the methodology, analysing urban freight transport and urban waterborne freight transport, conducting stakeholder analysis, and contributing to the design of a design methodology. The process of conducting a literature review involves systematically reviewing academic articles, books, and other relevant sources to gather and summarize the current state of knowledge on the chosen topic. By analysing the existing literature, it is possible to define relevant concepts, establish the scope of the research, identify gaps in knowledge, and gain a preliminary understanding of critical factors (Wee & Banister, 2016). To ensure a comprehensive and up-to-date overview of the literature, a variety of sources have been used, including academic databases such as Scopus, Science Direct, and Google Scholar. The search has been conducted using English and Dutch languages, and the timeframe for the literature review spans from 1990 to 2023. The selection of relevant literature has been based on the examination of abstracts, introductions, and conclusions.

In addition to peer-reviewed studies, the search strategy also includes the exploration of references in previous research on waterway transport concepts in Europe. Forward and backward snowballing techniques have been employed to expand the list of relevant literature. The main search strings and Boolean operators used include terms like "Urban waterborne freight transport," "Urban waterway transport," "Urban freight transport," "Stakeholder urban freight transport," "Stakeholders urban waterborne freight transport," "Design urban freight transport," "Evaluation urban freight transport," and "Implementation guidance urban freight transport." Different combinations of these strings have been utilized to retrieve relevant literature. Due to the limited availability of peer-reviewed studies, insights from grey literature, student theses, conference papers, and policy reports have also been included. The literature review and desk research have played a vital role in deepening the understanding of urban freight transport, urban waterborne freight transport, the stakeholders involved, and acquiring information on the design methodology.

2.2.2. Semi-structured interviews

To gain an even better understanding of the interests of the stakeholders, a stakeholder workshop will be held to evaluate different solutions that can reduce nuisance in het Wallengebied and ensure quality deliveries. During the workshop, semi-structured interviews will be conducted with stakeholders to understand their interests. This includes a series of open-ended questions based on the topics to be covered and allows both the interviewer and the interviewee to go into more depth where necessary (Mathers et al., 2002). Questions are asked about their use of urban freight transport and their views on the possibility of doing so by water. Together, this forms an in-depth analysis of the current issues and complexities behind urban waterborne freight transport. Based on all this information, key criteria are identified that can be verified with the criteria used for the established design methodology.

2.2.3. Case study

Once the design methodology for the design of sustainable urban waterborne freight distribution is established, it will be applied to a Case study. The case study approach allows for in-depth, multifaceted explorations of complex issues in their real-world settings (Crowe et al., 2011). The case study method embraces the full set of procedures needed to do case study research. The tasks include designing a case study, collecting the study’s data, analysing the data and presenting and reporting the results. Case study research is not limited to a single data source. A good case study benefits from having multiple sources of evidence (Yin, 2012). Therefore, the data for the case study will be collected using direct observations, interviews, archival records and documents. In the case study of het Wallengebied, several documents containing relevant data will be included in the discussion. This comprehensive approach will shed light on the intricacies of the area and provide a clear understanding of its current situation.

3. Urban freight distribution

To establish a design methodology for sustainable urban waterborne freight transport, it is necessary to understand what urban freight distribution is and what sustainable urban freight distribution looks like. Therefore, a literature review is conducted on various aspects related to sustainable urban freight distribution answering the research question: “*What is the current status of urban freight distribution and what are the key challenges in implementing sustainable transportation solutions?”.* The structure of Chapter 3 is as follows; first, an explanation of urban freight distribution is given. Next, It examines how trends reduce the efficiency of freight transport and consequently negatively affect urban areas. The area of sustainable urban freight distribution is then highlighted. The chapter ends with an explanation of the different implementation problems associated with sustainable freight distribution solutions.

3.1. Urban freight transport

Urban freight transport (UFT) and urban freight distribution (UFD) are some of the commonly used terms that appear in literature around city logistics. In this thesis, these terms – which will be filled in by the definitions below – will be used interchangeably. The exact definition of urban freight distribution varies among authors. According to Dablanc (2007), urban freight distribution can be defined as a large number of different types of freight flows crossing an urban environment. Another definition is by Ogden (1992) who defines urban freight distribution as "the movement of things (as distinct from people) to, from, within and through urban areas". This definition is consistent with that of Muñuzuri et al. (2005) who define urban goods transport as "those movements of goods that are affected by particularities associated to urban traffic and morphology". This definition may be perceived as incomplete and therefore Ambrosini and Routhier (2004) argue that this definition should be extended to include "household purchasing trips, urban road maintenance and building, waste collection, etc", and not just the movement of goods between premises. For a comprehensive explanation of urban freight distribution, this study refers to the definition of Allen et al. (2020). His definition is broader in terms of the types of vehicles, the range of freight vehicle movements and the other vehicle activities covered, and includes:

1. All types and sizes of goods vehicles and other motorised vehicles used to pick up and deliver goods to locations in the urban area;
2. all types of movements of goods vehicles to and from urban premises, including goods transfers between premises, ancillary goods deliveries to urban premises, money collections and deliveries, waste collections and home deliveries made from urban premises to customers;
3. service trips and other vehicle trips for commercial purposes which are essential to the functioning of urban premises.

3.2. Current situation of urban freight distribution

The current situation of urban freight distribution of horeca goods has several options. There is a distinction between goods delivered directly from the supplier and goods consolidated at an Urban Consolidation Centre (UCC) near urban areas. For goods delivered directly from the supplier, there are several options. The goods can be delivered directly to one receiver, without further intermediate stops. Another option is for multiple receivers to be delivered in one round. In both cases, the road vehicles must comply with laws and regulations set by the municipality. A third option is that the goods are delivered from the supplier to a micro-consolidation centre (MCC) such as a pick-up point or a local distribution facility. An example of a pick-up point is a locker where the end customer can collect the products themselves (MDS Transmodal Limited, 2012). From the local distribution facility, the products can be collected or delivered to the final receiver over a short distance. With consolidation, the goods are delivered to the UCC by (multiple) suppliers. At the UCC, the goods are bundled and transported to the city by traditional road transport using advanced road vehicles, such as the urban distribution truck and electric vehicles (MDS Transmodal Limited, 2012). Once in the city, there are several options to deliver the goods to the receivers. The products can be delivered directly to the receivers or to a micro-consolidation centre (MCC). A schematic representation of the current situation is shown in Figure 3-1.

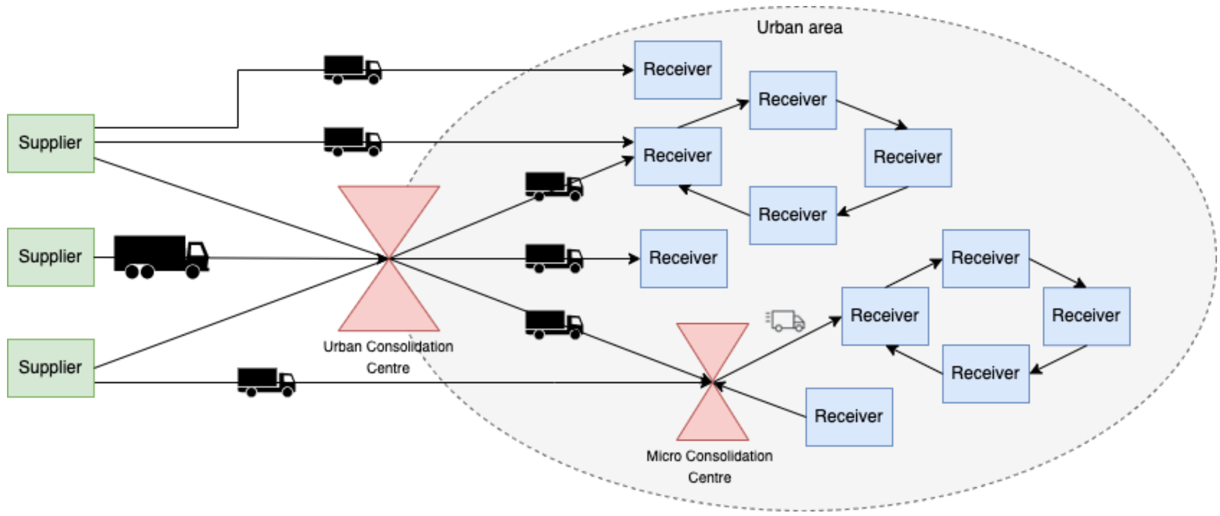

Figure 3-1. Current situation of UFT

3.3. Impact of freight distribution in urban areas

An anticipated rise in urban transport movements can be attributed to various trends, which are detailed in Appendix 1 - Trends and Statistics in Urban Freight Transport. These trends are expected to ensure that the challenges with urban freight distribution will only increase in magnitude. The problems can be divided into three main categories, namely economic, environmental and social impacts (Quak, 2011). First, the increase in freight transport creates negative economic impact. Many cities face congestion because the current infrastructure is not sufficient to handle the large volumes of freight transport. In addition, a lack of loading and unloading areas causes trucks to block the road because they have to double park while stocking shops. Both congestion and blocked roads cause higher transport costs. This translates into lower profits, which has negative economic consequences. An abundance of trucks in city centres also reduces the attractiveness of cities, especially in shopping areas (Ambrosini and Routhier, 2004). Finally, many European and Dutch cities are characterised by historic city centres with narrow streets and monumental structures. In these areas, freight transport problems are even worse because the system can easily be blocked by a single truck and monumental structures can be damaged by the vibrations of heavy vehicles.

The second problem category is environmental impact. Compared to cars, trucks produce disproportionately large amounts of hazardous particles. In part, this is caused by the fact that trucks used for urban distribution are generally older and more polluting than trucks travelling longer distances (Dablanc, 2007). Statistics show that freight transport accounts for 20-30% of vehicle kilometres, corresponding to 16-50% of air pollutant emissions, depending on the pollutant in question, from transport activities in a city (Dablanc, 2007). The emissions have local impacts that can affect both health and the environment. Other environmental impacts of freight transport include noise and vibration from trucks. These have a much greater impact relative to cars.

The last problem category is the social impact and this involves effects that reduce the quality of life of urban residents. The impact of the above emissions on people's health is a major concern. Moreover, a significant proportion of traffic accidents can be attributed to excessive goods transport (van Essen et al., 2011). Noise pollution has a negative impact on residents' daily lives, and the presence of trucks creates congestion and barriers in the neighbourhood that can be perceived by residents as a nuisance. These are all effects that affect the quality of life of urban residents.

3.4. Sustainable Urban Freight Distribution

While urban freight distribution is essential for the functioning of cities and its economic growth, it has significant long-term impacts upon sustainability. The sustainability problems are twofold. On the one hand, freight transport contributes to a decrease in liveability in urban areas through localised traffic accidents or incidents, noise pollution, greenhouse gas emissions and local air pollution (Browne et al., 2012). On the other hand, it reduces the accessibility of urban areas for passenger and freight traffic in certain places and at certain times due to traffic congestion and vehicle restrictions (Binsbergen en Visser, 2001). Despite the fact that freight transport has the most negative impact on urban sustainability, it is not a priority in urban planning (von Wieding et al., 2008). Sustainability is a concept with many subjective interpretations and this section will provide a definition of sustainable urban freight distribution (SUFD). According to Brundtland (1987), sustainable development is development that meets the needs of the present without compromising the ability of future generations to foresee their own needs. This definition emphasizes three fundamental components of sustainable development: (1) economic growth; (2) social equity; and (3) environmental protection. A sustainable transport system should meet the needs of the current generation by contributing to social equity and economic growth, and it should meet the needs of the present and future generation by protecting the environment. Figure 3-2. provides an overview of the three dimensions of sustainability in their interrelationships with the 'three pillars' or 'three circles model' (Dréo, 2006). The most common examples of such impacts at the three dimensions of sustainability are: air pollution (environmental sustainability), fatalities, noise disturbance and local traffic safety (social sustainability) and journey unreliability, delivery delays and transport costs (Macharis & Melo, 2011).

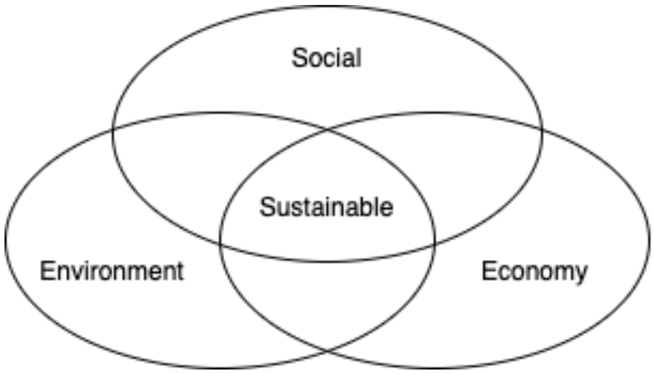

Figure 3-2. Overview of three dimensions of sustainability

3.5. Implementation challenges

Innovative concepts to improve efficiency and combat the hazardous effects of urban freight transport are accompanied by several implementation challenges. For governments and local administrators, policies must balance the negative impacts of urban freight transport with the performance of the local economy (Ambrosini and Routhier, 2004). In times of economic turmoil, economic objectives take precedence over social and environmental concerns. In addition, budget cuts, legal constraints and lack of political will and specific knowledge create obstacles for local administrators to analyse and address the problem.

A major barrier preventing transport companies to successfully innovate are high capital expenditure, relatively conservative attitudes and reluctance to share information. High costs are often problematic given the industry's low profit margins. Moreover, innovative solutions are not easily adopted by the conservative mindset and this is exacerbated by the complexity of the sector. Innovations rarely emerge without extensive coordination with external parties. Finally, strong competition and high fragmentation makes companies reluctant to share information that could benefit their competitors, which slows down development (Wiesenthal et al., 2011).

The receiver initiates the transport flow by placing an order. Based on the order, a delivery time is agreed with the shipper. After this step, the receiver is no longer involved in the logistics planning process (Verlinde et al., 2012). The shipper can deliver the order itself or hand it over to a professional carrier. There is no contractual obligation between the receiver and the carrier which limits the contact, besides track-and-trace systems, to the delivery moment. This leads to inefficiencies that remain unresolved in most cases. Receivers have no insight into how their ordering patterns affect transport flows, so they feel no financial incentive to change this pattern. Therefore, getting recipients to change their behaviour is a challenge.

One of the biggest challenge in achieving sustainable urban freight transport solutions is the involvement of multiple stakeholders. According to the Macharis, Milan and Verlinde (2012), stakeholders can be divided into five relevant groups in the field of urban freight transport: shippers, receivers, logistics service providers, local authorities and citizens living and consuming in the urban area concerned. A stakeholder can have multiple roles, for example a resident who is also a receiver. The objectives of the different stakeholders are generally different (Bektaş et al., 2015). This creates a challenge to find solutions that are beneficial for all actors involved.

It can be concluded that there is no single solution to make transport more efficient and address environmental, social and economic impacts. Urban logistics takes place in a complex environment, with multiple stakeholders pursuing their own objectives, making it no easy to implement and enforce solutions. Solutions for urban freight transport should therefore be based on a solid business case that takes into account the objectives of all actors involved.

3.6. Conclusion

This chapter sought to explore how goods distribution can be carried out in a sustainable manner and what are possible implementation problems. A sustainable way of supply meets the needs of the present without compromising the ability of future generations to meet their own needs. This highlights three fundamental components that will emerge throughout the thesis: economic growth; social justice; and environmental protection. Sustainable goods distribution must meet the needs of the present generation by contributing to social justice and economic growth, and it must meet the needs of the present and future generations by protecting the environment. There are several solutions that can contribute to sustainable distribution. It is important to understand the possible implementation problems so that these can be avoided when introducing a new concept. A key barrier is high capital expenditure, relatively conservative attitudes and reluctance to share information. Another barrier is the challenge of persuading receivers to change their behaviour because they do not understand how their ordering pattern affects transport flows. A major challenge in achieving sustainable urban freight transport solutions is the involvement of multiple stakeholders. Finally, it can be concluded that there is no single solution to make transport more efficient and address environmental, social and economic impacts. Solutions for urban freight transport should therefore be based on a solid business case that takes into account the objectives of all stakeholders involved.

4. Urban waterborne freight distribution

One of the possibilities to organize urban freight distribution in a clean, economical and safe way is to make use of urban waterborne distribution to replace trucks in environmentally sensitive or highly congested areas. According to He & Haasis (2019) urban waterborne distribution can be defined as the use of ships to transfer the goods to the transit points by the inland waterway of a city. Research into waterborne transport is fairly limited. Therefore, this chapter focuses on answering two research questions. The research question "*What are the main functions of urban waterborne freight transport"* ensures that all key components of urban waterborne freight distribution are identified and understood. The research question "*What urban waterborne freight transport initiatives have been implemented and what are the critical success and failure factors for large-scale implementation in urban areas?"* gives insight into previously implemented initiatives and the associated success and failure factors. The purpose of this chapter is to provide information for design requirements that can be found in Chapter six. Before anything can be said about the opportunities and obstacles in switching to a new way of handling urban distribution, it is important to identify what the changes are between the current and the desired situation. Therefore, this chapter describes the components and activities of waterborne goods distribution. There are a number of cases in Europe and the Netherlands were waterborne distribution is applied and demonstrated that the use of inland waterways can be a viable alternative for freight distribution in urban areas. These will be discussed in the next section, as will the sectors for which inland navigation can be used, the conditions under which the concept was developed, the main success and failure factors and the role of local government.

4.1. Desired situation of urban freight distribution

A good alternative for urban freight distribution by road is transport by water. This reduces the number of road transport movements, relieves quays and bridges and uses electric transport. Distribution via inland waterways offers high reliability due to the large capacity on waterways that allows congestion-free transport and a high level of safety (Konings, 2009). According to Lowe (2005), inland waterways are the safest of all transport modes because of the low accident and fatality rates. If inland waterways are used effectively, the environment can benefit from distribution of goods by water because they are an energy-efficient and less polluting means of transport (Konings, 2009; Lowe, 2005).

The essence of waterborne distribution consists of five main steps, namely pre-transport, transhipment from pre-transport to the vessel, waterborne transport, transhipment from the vessel to on-carriage and on-carriage. The goods that need to enter the city are delivered to a urban consolidation centre where they are transferred to a vessel after possible storage or handling. The goods are then transported by a vessel across the water network and delivered into the city centre where they are unloaded at a transhipment facility. Some distribution still needs to take place once the goods leave the vessel. This last leg can be completed in various ways and it depends on the used vessel, the available loading and unloading zones, the possibilities for transloading the products and the amount and location of receivers. The vessel may stop at only one or several loading and unloading points per delivery. In both cases, transport is required from the quay to the final destination. The final destination may be directly at the receiver or at a micro-consolidation centre, after which they are further distributed to several receivers (Maes et al., 2015). There does not seem to be one standard solution for cities. It should be a combination of modalities and making better use of existing infrastructure. Figure 4-1 illustrates the distinct concepts, differentiating between a scenario where the transhipment location in the city can be viewed as a micro consolidation centre or simply a transhipment location without additional facilities.

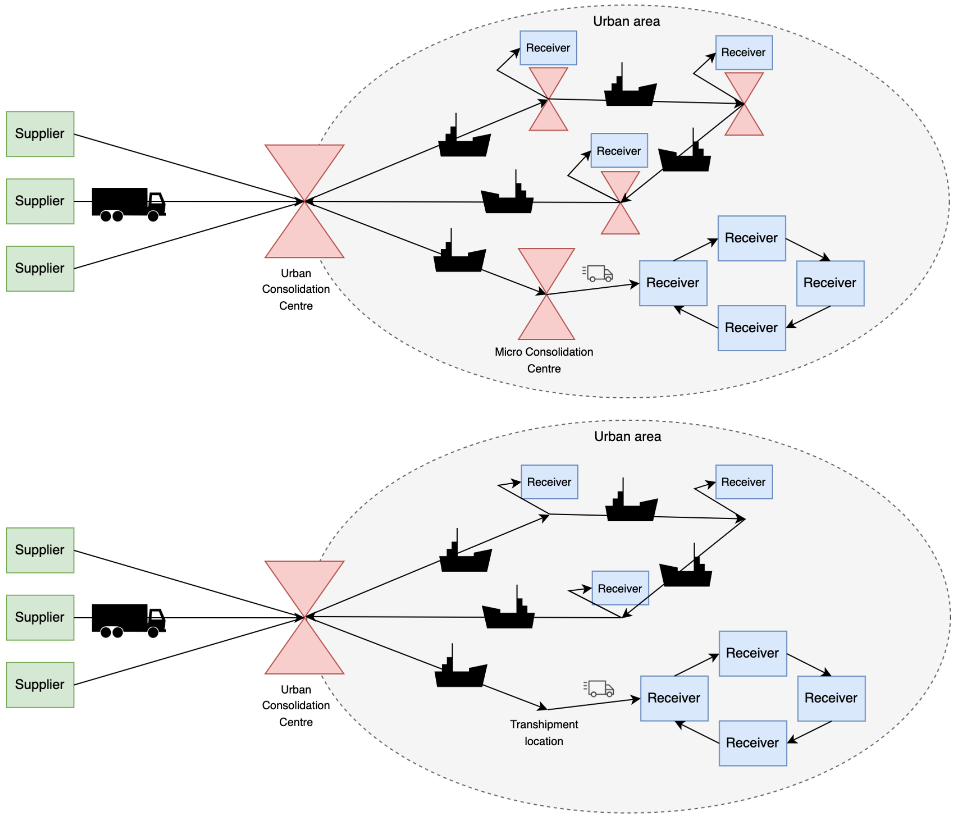

Figure 4-1. Schematic representation of desired situation

In addition to the five main steps of urban waterborne cargo distribution, there are several other crucial components that require examination, namely vessel characteristics, transshipment equipment, cargo carrier, and cargo units. All these components are discussed in detail in Appendix 2. These different components of urban waterborne freight transport play a vital role in determining the outcomes of initiatives. The following section elaborates on the substantial influence of these components on the success or failure of such initiatives.

4.2. Critical success and failure factors of initiatives in Europe and the Netherlands

Europe and the Netherlands have witnessed the establishment of several concepts for urban cargo distribution by water. For a comprehensive understanding of these concepts, Appendix 3 and 4 can be consulted. The analysis of various initiatives in the Netherlands and the rest of Europe has unveiled several critical success and failure factors. These factors pertain to the external environment in which they are implemented, as well as factors related to the specific implementation context. Success factors can be seen as factors that increase the potential for implementation and are vital for the achievement of a goal. Failure factors are the reasons that can hold back implementation and can be defined as a limited number of areas in which risks, problems and barriers may arise (Mehrabioun Mohammadi et al., 2021). To systematically examine critical success and failure factors, a pragmatic framework is needed. For this purpose, Feitelson and Salomon's (2004) Political Economy Framework and the PESTEL classification framework (Sammut-Bonnici & Galea, 2015) can be used. Feitelson and Salomon's (2004) framework conceptualises the interaction between different feasibility factors and argues that the adoption of transport innovations is determined by technical, social and political feasibility. This framework is complemented by the PESTEL classification framework, which also includes economic and legal factors (Sammut-Bonnici & Galea, 2015). Thus, success and failure factors can be divided into technical, social, political, economic and legal factors. To be characterised as technically feasible, an innovation must work and it must be technically possible to facilitate waterborne freight distribution.

To be politically feasible, policymakers must support waterborne transport and be willing to develop favourable policies. This relates to social feasibility, which looks at the extent to which waterborne transport is accepted by the public. Economic feasibility refers to the factors that determine the distribution of monetary costs and benefits. Finally, legal factors are established or missing rules or regulations. Together, these factors determine the likelihood of urban waterway transport being introduced (Feitelson & Salamon, 2004; Sammut-Bonnici & Galea, 2015). Table 4-1 summarise the factors examined in the literature.

4.2.1. Technical success and failure factors

The first technical success factor is related to external conditions and concerns the density of waterways. According to Quak (2011), waterborne transport is only feasible in specific circumstances and for a limited part of the transport flow in cities with a very high density of waterways. In many cities, waterways are not dense enough to account for a significant share of urban freight volume. Small-scale solutions such as parcel delivery or distribution to local shops and restaurants are particularly dependent on the density of waterways. Under the right conditions, water transport can improve accessibility and reduce negative environmental impacts.

The location of cargo receivers along the waterway network can be considered the second technical success factor. The location is very important for the success of the initiative and this is also reflected in the initiatives. The beer boat in Utrecht and Mokum Maritiem in Amsterdam are only possible because of the location of their customers at the quay. However, the examples of Vert Chez Vous and Franprix in Paris show that the use of road vehicles, such as tricycles and CNG trucks, can increase the radius of action of the solution. For example, Franprix could deliver to shops located up to 4 km from the quayside. In this way, the density and location problem can be overcome to some extent (Taniguchi & Dablanc, 2014).

A third technical success factor concerns the location of shippers along the waterways or the presence and location of platforms that allow transhipment and bundling of goods. Waste processor Syctom's success factor is the location of its centre and storage facilities along the water (Janjevic & Ndiaye, 2014). Mokum Maritiem in Amsterdam has a cooperation agreement with Binnenstadservice, a logistics service provider for retail in city centres. They offer a service centre on the edge of the city to facilitate the bundling of goods for transhipment at the waterfront. From there, the goods go by water to the final receiver (De Binnenvaartkrant, 2011).

Amsterdam municipality’s policy report "Nota Varen Deel 2" acknowledges the lack of transhipment locations. The most suitable locations can only be used for a maximum of 15 minutes, while transhipment takes longer (Gemeente Amsterdam, 2020a). To successfully implement waterborne transport, transhipment of cargo along waterways must me made possible. In fact, at a small number of transhipment locations in the urban area of Amsterdam, according to van Duin et al (2018), waterborne transport can compete with truck deliveries based on logistical performance of both modes.

The fourth technical success factor enabling urban goods distribution by water is the use of special vessels and equipment and specific loading units. This can be seen in both Dutch and European initiatives. Johnsen et al. (2019) investigated whether a fleet of autonomous floating vessels could promote the adoption of urban waterborne transport in Amsterdam. They looked in detail at the development of autonomous floating technology. Although the article does not provide specific research results, it argues that there is a real potential for the successful delivery of autonomous floating technology that can be used for goods transport in the near future. In the case of Vert chez Vous, the Bierboot and Mokum Maritiem, transhipment is facilitated by the use of self-loading and unloading vessels with a loading crane and all the equipment available on the vessel. The impact of these solutions on the landscape is reduced. At Vert Chez Vous, it ensures a seamless transition between the boat and the bikes, increasing the range (Taniguchi & Dablanc, 2014). The use of dedicated intermodal loading units was previously mentioned by Nemoto et al (2006) as one of the key factors enabling intermodal urban logistics. The Syctom example uses a new type of swap body (Intermodal Transport Units or UTI) that made it possible to implement the concept because paper rolls could be transported in this way. The loading unit previously used, conventional sea containers, was not suitable for transporting these products (Janjevic & Ndiaye, 2014). The loading units also determine which flows can be used. There are flows that depend on external conditions and need to be transported in the right way. These are the chilled and frozen products. This is because of the requirements for conditioned transport and to comply with food safety. The right loading unit can solve this problem (Logistiek.nl, 2016). Strongly standardized packaging makes the distribution process easier and leads to lower costs and faster and reliable service (van Binsbergen & Visser, 2001).

4.2.2. Social success and failure factors

Social acceptance is based on how society perceives the effects of waterborne transport. There are several factors influencing social acceptance. The literature shows that inland waterway solutions for urban freight transport are only competitive if there are significant accessibility problems in the area. This is especially true for small-scale solutions. Accessibility problems may be related to the physical environment in which distribution takes place and to traffic density and can be seen as a social success factor. Accessibility problems related to the physical environment can be seen in the initiatives in Utrecht and Amsterdam. In Utrecht, the cafés and restaurants are located on the canal quay, which is lower than the road. The premises in this area are difficult to reach by truck because the driver has to deliver the drinks one level below via a staircase. In contrast, the water is at the same level, making waterborne distribution less of a problem (Quak, 2011). In Amsterdam, the inner city infrastructure is characterised by many small streets, narrow and fragile bridges and many obstacles when transporting by road. On the water, these factors are less of a problem. In terms of traffic service, this is reflected in the initiative in London. The concept in Sainsbury has shown that freight in central London can be transported faster by river than by roads because there is no traffic congestion (INE/EFIP, 2008). Besides increasing accessibility problems, other factors driving a shift to waterborne transport are increasing levels of environmental pollution, infrastructure damage, noise pollution and visual intrusion (Jandl, 2016).

4.2.3. Legal success and failure factors

Accessibility problems may also be related to low accessibility due to traffic and access restrictions for freight vehicles. Avoiding these restrictions can be seen as a legal success factor. In both Amsterdam and Utrecht, freight vehicles face traffic and access restrictions, such one-way traffic, weight and length restrictions, time windows, environmental zones and 30-kilometres roads. These policy restrictions prevent the logistics sector from functioning optimally. Vessels are not subject to the measures, which means they are not constrained by these measures (Maes et al., 2015).

4.2.4. Economic success and failure factors

All initiatives are in fact public-private partnerships involving the government in the form of financial participation. This is because the total cost of an urban waterborne freight transport including transhipment is often challenging (Diziain et al., 2014). This is partly because the start-up phase is often difficult and the cost per load can only compete with road transport if there is sufficient volume (Maes et al., 2015). Financial support can be seen as an economic success factor. In Utrecht, the local government funded €400.000 for the purchase of the zero-emission boat. Together with an amount from the exploitation of the first beer boat, the €800,000 boat was bought (Maes et al., 2015). Mokum Maritime received punctual funding from Doen Foundation, Secretary of State for Transport and North Holland Province (Janjevic & Ndiaye, 2014).

Both Rohács and Simongáti (2007) and Quak (2011) conclude that a distorting factor is the extra costs incurred by the additional transhipment and associated administrative work. This increases total transport costs and makes it difficult to make waterborne transport cost-effective enough to become an attractive mode of transport. Cargo consolidation can achieve economies of scale, but the initiatives show that this requires financial support from the government. In addition, a critical service frequency determines whether or not multimodal freight transport can compete with cheap road transport. To maintain this critical frequency , the service must attract a sufficiently large cargo volume. It can also be said that the volume of multimodal freight must exceed a "critical mass" (Sunde, 2002). To achieve this, shippers need to cooperate and consolidate their freight. Research shows that shippers are not always willing to transfer their cargo. The local government can play an important role by providing financial support and a restrictive transport policy for road transport (van der Meer, 2012). This allows the break-even point to be reached faster.

4.2.5. Political

When implementing an innovation, such as urban waterborne freight transport, it is important to distinguish between two different groups that can change urban freight transport. According to Anderson et al. (2005), changes can be made by governmental authorities and by businesses. Government involvement can be seen as a political success factor. Most examples are driven by the private sector, e.g. DHL's floating distribution centre, Franprix and Mokum Maritime. There are also initiatives, such as the beer boat in Utrecht, that are driven by the public sector. It cannot be concluded that the origin of the initiative affects its success, and in some cases, such as the Beer Boat and Mokum Maritiem, the concepts are very similar but driven in a different way. By intervening, public authorities can play an important role in providing infrastructure for transhipment activities in urban areas and efficiently incorporating port and storage facilities into the urban landscape. This can be seen as a political success factor. For French supermarket Franprix, the riverside facility La Bourdonnais was rehabilitated by the Paris port and designed to be fully integrated for distribution by water (Taniguchi & Dablanc, 2014).

4.3. Conclusion

Based on the experience of inland waterway transport for urban distribution, several critical success and failure factors have been identified which can be divided into technical, social, political, economic and legal factors and are shown in table 4-1. It can be concluded that waterborne transport can only compete with road transport if significant accessibility problems exist. If this is the case, the importance of a dense waterway network, the location of receiver of goods, the location of an urban hub of the shipper and the availability of sites that allow transhipment and bundling of goods are emphasised for its successful operation. The use of special vessels, equipment and specific loading units has a positive effect on the implementation of waterborne transport. The technologies facilitate the process and enable intermodal logistics. It can be concluded from the initiatives that distribution by water is possible for several segments, ranging from parcel delivery to waste transport for return flows, and that the use of road vehicles for the last-mile transport also allows this solution to be applied in cities with a less dense waterway network. Waterborne transport is driven by growing accessibility problems, increasing environmental pollution, infrastructure damage, noise pollution and visual intrusion. The distribution of goods via water has a positive impact on these factors. However, this is offset by many different costs incurred in waterborne transport. This is a very important failure factor that should be included in the analysis. Local authorities play an important role in managing innovative successful transport concepts. The involvement of both private and public stakeholders is a fundamental factor for the success of existing urban freight waterborne transport concepts. They can remove failure factors, such as the additional costs associated with initial investment and transhipment and the lack of infrastructure capacity. In most cases, cooperation came down to financial support and facilitation of sufficient loading and unloading facilities in urban areas by public authorities.

Tabel 4-1. Critical succes and failure factors

Categories		Critical success factors	Critical failure factors
Technical	T1.	High density of waterway network	
	T2.	Sufficient availability of transhipment locations	
	T3.	Strategic location of receivers	
	T4.	Well-placed location of urban hubs (shippers)	
	T5.	Special vessels and equipment	
	T6.	Intermodal loading units	
	T7.	Autonomous technology	
	T8.		Low availability of loading stations for electric vessels
Social	S1.	Accessibility problems for UFT due to physical environment	
	S2.	Accessibility problems for UFT due to traffic density	
	S3.	Environmental pollution by regular UFT	
	S4.	Noise pollution by regular UFT	
	S5.	Visual intrusion by regular UFT	
	S6.	Damages to road infrastructure by regular UFT	
Legal	L1.	Traffic and access restrictions for regular UFT	
Economic	E1.	Financial support for waterborne freight distribution	
	E2.		High initial investment costs for waterborne freight distribution
	E3.		Transhipment costs for waterborne freight distribution
	E4.		Administrative costs for waterborne freight distribution
	E5.		Obtaining critical mass for waterborne freight distribution
	E6.		Cost-effectiveness of regular UFT
	E7.		Cheap road transport for regular UFT
	E8.		Failing cooperation logistics actors for waterborne freight distribution
Political	P1.	High involvement of local government	
	P2.	Inclusion of stakeholders for waterborne freight distribution	

5. Stakeholder analysis

This chapter analyses the different stakeholders involved in urban freight distribution and, in particular, urban waterborne freight distribution. The stakeholder analysis is a crucial component of the preliminary research conducted for this master's thesis, which aims to develop a design methodology. This design methodology serves as a decision support system, where stakeholders play a significant role in shaping its functionality and effectiveness. Understanding the stakeholders and their roles and interest is essential for determining the requirements and design of the design methodology. The purpose of conducting the stakeholder analysis is to identify and analyse the various stakeholders involved in urban waterborne freight transport. This chapter therefore seeks to answer the following research question: "*What are the interests of the main stakeholders in urban waterborne freight distribution?"*. By conducting a comprehensive stakeholder analysis, we can gain insights into who the key stakeholders are, what their roles and interests entail, and how they may be affected by the implementation of urban waterborne freight transport. This knowledge will help in shaping the design methodology to effectively address the needs and concerns of different stakeholders. Moreover, the stakeholder analysis helps in determining the appropriate engagement strategies for involving stakeholders in the decision-making process. It assists in identifying the stakeholders who should be invited to working sessions, from whom information should be collected, and who may have different perspectives on the arrival of urban waterborne freight transport. This information is vital for fostering collaboration, gathering valuable input, and ensuring that the design methodology caters to the diverse stakeholder needs.

5.1. Stakeholders

Literature (Macharis et al, 2014) gives different definitions of the term stakeholder. The meanings vary minimally and all demonstrate that regardless of the definition, urban freight initiatives and policies must take into account the different stakeholders in the decision-making process. Firstly, there is Freeman (1984) who defines a stakeholder as an individual or a group of individuals who can influence the objectives of an organisation or can themselves be influenced by these objectives. This definition can be characterised as organisational and business oriented. Secondly, there is Banville's et al. (1998) definition, who state a stakeholder is someone who is interested in an issue in one of three ways: 1) by primarly affecting it, 2) by primarly being affected by it and 3) by both affecting it and being affected by it. Finally, there is the definition of Macharis et al. (2015) who believe that a stakeholder should rather be defined by his/her stake in the issue, as this determines whether he/she can influence or will be influenced by the final outcome. They see stakeholder as any group of people, organized or not, who have a common interest or stake in a particular issue or system.

In the literature, roughly the same stakeholders are distinguished for urban freight transport. Witlox (2006) divides these stakeholders into three groups: trade and industry, society and public policy makers. Trade and industry consists of suppliers, carriers, receivers, wholesalers and distribution companies. Society are inhabitants, employees, commuters, consumers and tourists. Public policy include local, regional and national governments. In this research, based on the STRAIGHTSOL project, the stakeholders will be divided into five relevant groups in the field of urban freight transport (Macharis, Milan & Verlinde, 2012):

- The shippers
- The receivers
- The logistics service providers
- The local authorities
- The citizens living and consuming in the urban area under consideration.

The upcoming sections will delve deeper into the stakeholders involved in urban freight transport, highlighting their specific objectives and interests.

5.1.1. The shipper

The shipper refers to the company or entity that owns the goods being transported. This can include manufacturers, wholesalers, or retailers. Shippers have the responsibility of delivering the goods to the intended receivers. They may have their own fleet of vehicles for transportation or may rely on logistics service providers to carry out the delivery on their behalf (Anand et al., 2014). In situations where logistics service providers are involved, the shippers act as customers of the carriers (Macharis et al., 2014). Shippers aim to meet their customers' expectations by providing excellent service quality. They prioritize environmental sustainability and emphasize the importance of mutual accessibility (Behrends, 2011). The primary objective is to minimize costs, while also emphasizing secondary goals such as ensuring the safe, timely, and damage-free handling of goods, which are vital considerations for shippers (Macharis et al., 2014).

In urban waterborne freight transport, shippers play a crucial role in facilitating the movement of goods through waterways. They are responsible for preparing goods for transport, which involves selecting appropriate packaging materials to ensure protection and support during transit. Shippers also ensure proper documentation to comply with regulatory requirements, including transportation regulations, safety standards, and specific regulations for the type of goods being transported. Shippers optimize efficiency and reduce costs by consolidating shipments from various sources into a single cargo load, maximizing the utilization of waterborne vessels. They handle the arrangement and booking of transportation with waterborne carriers or logistics providers, negotiating rates, determining routes, and coordinating logistics operations to ensure timely and reliable delivery. Managing risks associated with waterborne freight transport is a key responsibility of shippers. They assess and mitigate potential disruptions, weather conditions, and safety concerns. This may involve securing insurance coverage and implementing risk mitigation strategies. Overall, shippers act as the vital link between goods suppliers and waterborne carriers in urban waterborne freight transport. They handle coordination, documentation, cargo handling, and ensure a smooth and efficient flow of goods through the waterborne transport network within urban areas.

5.1.2. The receiver

The receivers of goods play a vital role in urban freight transport as they initiate the transportation process through their orders. They have the decision-making power to determine when to place orders, the quantity of goods needed, and the preferred delivery timeframe (Anand et al., 2014). Receivers can vary from individual consumers awaiting personal parcels to professionals such as retailers, restaurant owners, hotel managers, factory owners, contractors, or office managers (Macharis et al., 2014). Receivers have specific expectations regarding delivery times, aiming to receive goods at the right time and location (Balm et al., 2014). They also seek cost-effective delivery and a high level of service, which entails real-time information updates and the ability to receive deliveries during less busy periods, reducing the risk of theft or customer complaints. Retailers, in particular, desire an appealing urban shopping environment with minimal truck presence. However, they also require just-in-time operations and low stock levels in their stores, which often leads to an increased number of trucks (Macharis et al., 2014). Furthermore, receivers express concerns about the environmental impact of truck transportation, emphasizing the importance of sustainable freight practices (Macharis et al., 2014).

5.1.3. The logistics service provider

Logistics service providers play a vital role in facilitating door-to-door transport services as requested by shippers and/or receivers. They act on behalf of the shipper, who holds contracts with the carrier and the retailer. These logistics service providers include carriers, express delivery services, and other companies specializing in logistics services. Freight forwarders may also be involved, organizing logistics and outsourcing transportation, while drivers determine delivery routes and handle goods (Macharis et al., 2014).

Logistics service providers differ in the context of road and waterborne freight transport. They possess different types of assets, such as trucks for road transport and vessels for waterborne transport, reflecting the unique infrastructure requirements of each mode. For urban waterborne freight transport they facilitate the physical movement of goods through waterways. Their main responsibility is to provide transportation services by operating and overseeing the waterborne vessels used for freight transport. They are in charge of loading, unloading, and handling the cargo on and off the vessels, ensuring that the goods are securely and safely transported to prevent any damage or loss. They also take on the task of arranging and scheduling the transportation of goods, which includes determining the optimal routes, departure and arrival times, and managing various logistics operations. Logistics service providers are responsible for complying with relevant regulations and standards while delivering high-quality service to their customers.
The primary objective of logistics service providers is to achieve a positive return on investment and generate profit by delivering efficient logistics services. They strive to optimize vehicle utilization and provide the desired quality of transport service requested by customers, shippers, and receivers, particularly under just-in-time pressure. Logistics service providers aim to offer high-level services that meet the delivery requirements of both shippers and receivers, emphasizing visibility, punctuality, and damage-free delivery. Some providers also prioritize environmental concerns, focusing on reducing emissions, noise levels, visual disturbances, and congestion (Macharis et al., 2014). Employee satisfaction is another important consideration for logistics service providers. Introducing new initiatives or measures can significantly impact the working conditions of their employees and bring about substantial changes in their work processes (Macharis, Milan & Verlinde, 2012).

5.1.4. Local government of Municipality

The municipal government holds the administrative authority in the city and wields influence over urban freight activities through policy implementation, measures, and regulations (Anand et al., 2014). Elected by citizens, the local government is responsible for shaping and managing the physical environment, representing the interests of various stakeholders, including citizens, employees, residents, and shopkeepers (Dablanc, 2011). Financing public infrastructure such as roads and waterways, as well as subsidizing select public services, falls under the purview of local authorities. They also assume responsibility for land-use planning and regulation, encompassing factors like parking times, time windows, and zones for loading and unloading freight (Macharis et al., 2014).

The municipality bears the responsibility for the city's economic and environmental sustainability and thus must consider the impact of policies on both businesses and citizens. With a multitude of users, the municipality must navigate and reconcile differing perspectives and occasionally conflicting interests. Striving for an appealing and livable urban environment, the municipality aims to enhance citizens' quality of life. Simultaneously, they seek to foster a positive business climate and create an attractive setting for diverse companies. The municipality's objective is to strike a balance between economic and environmental objectives by formulating policies that cater to both (Anand et al., 2014).

5.1.5. The citizens

Citizens in urban areas, including residents, consumers, and commuters, are not directly involved in freight transport operations. However, they play a significant role as end users of goods and are deeply concerned about their living and working environment. They experience negative impacts of transportation, such as traffic congestion, accidents, noise, and pollution. Improving accessibility and reducing these nuisances are their key priorities. The municipal administration represents residents and works towards achieving these objectives (Macharis et al., 2014).

5.1.6. Additional stakeholders

Furthermore there also exist more fragmented stakeholders associated with urban freight transport. These stakeholders can either have an interest in the topic or can influence it in other ways. Some examples include vehicle manufacturers, public transport operators and landowners. According to Lindholm (2012), vehicle manufacturers have an impact on urban freight transport due to the of technological innovation of vehicles to enable efficient urban freight transport solutions. Public transport operators are an important stakeholder because the goal of more efficient public transport in urban areas is often more important than creating optimal mobility for freight transport (Cherrett et al., 2012). Landowners set requirements on where, when and to what extent urban freight transport should be allowed (Lindholm, 2012). Their interest is usually triggered by the requests and demands of tenants living in urban areas (MDS Transmodal Limited, 2012).

5.1.7. Stakeholder relationships

The diversity of stakeholders with different and sometimes conflicting objectives introduces challenging trade-offs in urban logistics policy-making. Numerous policies have failed or have had a limited uptake because of their inability to properly acknowledge this aspect. Each stakeholder, in its own role, would like to see their objectives achieved, independent of its neighbours interests. This generates problems and conflicts in the achievement of consensual initiatives to be implemented in a limited space and infrastructure within an urban area. Trade-offs have to be made between the different objectives. In order to make these trade-offs, the different relationships between the stakeholders need to be mapped out. This will be done by means of a power, attitude and interest analysis.

With the help of this analysis, the informal stakeholder relationships are identified. For an inventory of stakeholder relationships, a stakeholder grid or map is often used. There are many versions, most of which are one-dimensional or two-dimensional, with the axes labelled with characteristics of stakeholder status or behaviour. Frequently used grids are the power/interest matrix and the interest/attitude matrix (Murray-Webster & Simon, 2006). The power/interest matrix aims at identifying, mapping and prioritising the stakeholder based on their power and interest in the project. By mapping the stakeholders on the matrix you can determine who has a lot or little power to influence the project and who has a lot or little interest. This makes the concept easy to understand, but that is also the limitation of the matrix. It does not show what their attitude is towards the project. The interest/attitude matrix does show the attitude and interest of the stakeholders. This is also easy to understand, but it does not give any information about whether an active backer or active blocker is influential or not. For this reason Murray-Webster & Simon (2006) came up with a new three-dimensional stakeholder grid that makes it possible to identify all the things that need to be considered and provides some useful labels that can be checked during the overall process of stakeholder analysis and stakeholder management. Let's further elaborate on each element of the matrix and how it relates to the stakeholders in this thesis:

- **Power**: Power represents the stakeholders' ability to influence decisions and outcomes. In the case of urban waterborne freight transport, stakeholders such as shippers, receivers, logistics service providers, local authorities, and citizens hold varying degrees of power. Shippers have the power to determine the requirements for freight transport and can influence the practices of logistics service providers. Receivers, on the other hand, can influence how goods are delivered by setting specific delivery preferences. Local authorities, including municipalities, hold a comprehensive position of power as they can establish regulations and policies that stakeholders must adhere to. Their decisions can have a significant impact on distribution practices and sustainability initiatives in the urban area. Citizens, as consumers and residents, also hold power through their influence on local decision-making processes and their ability to support or resist changes in freight transport practices.

- **Interest**: Interest reflects the stakeholders' level of engagement and involvement in the project or program. All stakeholders considered in the study demonstrate a strong interest in sustainable practices for urban waterborne freight transport. They recognize the need to address environmental, economic, social, and transport-related challenges associated with freight distribution in urban areas. The interest of stakeholders may vary depending on their specific roles and responsibilities. Shippers and receivers are directly involved in freight transport and have a vested interest in improving efficiency and cost-effectiveness while reducing environmental impacts. Logistics service providers have a professional interest in meeting the needs and requirements of their clients, the shippers and receivers. Local authorities are interested in promoting sustainable and efficient urban transportation systems. Citizens, as consumers and residents, have an interest in a clean, accessible, and liveable urban environment.
- **Attitude**: Attitude refers to the stakeholders' overall support or resistance to the project or program. Stakeholders' attitudes towards sustainable urban waterborne freight transport can vary based on their individual perspectives and priorities. The municipality and local citizens generally have positive attitudes toward sustainable distribution practices. They view these practices as beneficial for reducing environmental pollution, noise, and congestion in urban areas. On the other hand, shippers, receivers, and logistics service providers may prioritize factors such as efficiency, profitability, and competitiveness. However, this does not mean they are resistant to sustainable practices. These stakeholders recognize the importance of sustainable distribution and may be willing to adapt their operations to meet sustainability goals. It is crucial to acknowledge that stakeholders often have multiple objectives and must make trade-offs to align their interests with sustainable urban freight transport initiatives.

By analysing stakeholders using the power/interest/attitude matrix, we can gain insights into their roles, influence, interests, and attitudes. This analysis helps in understanding the complexity of stakeholder dynamics and enables the development of strategies to engage and collaborate with stakeholders effectively. It ensures that the design methodology for sustainable urban waterborne freight transport considers the diverse perspectives and needs of stakeholders and promotes sustainable and efficient freight distribution practices in urban areas.

5.2. Criteria

To assess a specific initiative, it is crucial to understand the goals of different stakeholders, which can often be diverse and conflicting. Evaluating these goals requires translating them into specific criteria that each stakeholder group assesses. A criterion represents an objective that a stakeholder aims to achieve. It should be precise, unambiguous, and universally understood and accepted by all decision-making actors (Macharis, Milan & Verlinde, 2012). To fulfil these requirements, a distinction is made between the overall objective and the means to achieve it, as there are often interconnected measures taken to reach these objectives. Additionally, certain measures may contribute to multiple objectives. Based on the stakeholders and their objectives described earlier, a set of criteria has been identified. Table 5-1 provides an overview of the criteria and sub-criteria for all stakeholders discussed in chapter 5.1.

Tabel 5-1. An overview of the criteria and sub-criteria of all stakeholders

Stakeholder	Criteria	Sub-criteria	Description of criteria
Shipper	Sustainable operations		Positive attitude towards environmental impact
	Accessibility		Accessibility of the area
	Low cost deliveries		Low out-of-pocket costs for transport
	High level of service	Punctual deliveries	Receiver satisfaction
		Damage free handling	Receiver satisfaction
		Safe deliveries	Receiver satisfaction
Receiver	Low cost deliveries		Low costs to receive goods
	Attractive shopping environment		Nice and liveable surroundings
	Low stock		Low stock at location
	Sustainable operations		Positive attitude towards environmental impact
	High level of service	Certain delivery times	Deliveries that do not compromise the receiver operations
		Just-in-time operations	Deliveries that do not compromise the receiver operations
		Visibility	Deliveries that do not compromise the receiver operations
The logistic service provider	Viability on investment		Positive return on investment
	Profitable operations		Making a profit by providing logistics services
	Sustainable operations		Positive attitude towards environmental impact
	Employee satisfaction		Employees are satisfied with their work and working environment
	High level service	Efficiency	Receiver and shipper satisfaction
		Punctuality	Receiver and shipper satisfaction
		Visibility	Receiver and shipper satisfaction
		Damage free delivery	Receiver and shipper satisfaction
Local government	Network optimization		Optimal use of existing infrastructure
	Quality of life of citizens		Attractive environment for citizens
	Positive business climate		Attractive environment for companies
	Enforcement		Easiness of compliance
	Low cost measures		Low costs to implement the measures
	Social acceptance		Citizens support for measures
Citizens	Accessibility		Reduce freight transport, less congestion
	Attractive urban environment	Low emissions	Reduce emissions of CO_2, NO_x, PM2.5, PM10.
		Low noise nuisance	Reduce noise nuisance
		Low visual nuisance	Less space occupancy by trucks
		Road safety	Positive impact on road safety

In order to select the most important criteria for the design methodology, a thorough understanding of each stakeholder's objectives is necessary. This involves reviewing existing literature and analysing relevant policies and regulations. The criteria should be selected based on their relevance to the stakeholders' goals and their potential impact on the success of urban waterborne freight transport. In some cases, criteria can be bundled together as sub-criteria under broader categories to provide a comprehensive and organized framework for evaluation. This grouping allows for a more efficient and systematic assessment of the initiatives. The selection process aims to capture the key considerations and priorities of each stakeholder group while ensuring that the criteria are measurable, understandable, and acceptable to all parties involved in the decision-making process. It is important to note that due to limitations and practical constraints, it is necessary to prioritize the most important criteria and make choices accordingly. To achieve this, workshops were conducted with real stakeholders and experts in Amsterdam's logistics chain. Each participant was asked to draw up a set of criteria for evaluating innovative supply concepts. Participants engaged with each other to discuss the desirability, feasibility and other criteria of the concepts. One by one, participants were asked to elaborate on their criteria, allowing participants to reflect on each other's vision. Most of the criteria were widely shared, but are inherently broad and can be interpreted differently.

One key aspect that all stakeholders consider important is sustainability. They emphasize that freight transport should be clean and emission-free, with a strong link between sustainability and the liveability of the area. Currently, the density of traffic movements causes inconvenience for many residents. To improve the liveability, it is necessary to reduce the number of logistics movements entering the city and ensure that the movements are cleaner, quieter, and lighter. However, there is a complexity in finding the right balance between light, clean transport and its impact on the liveability. Affordability is also a critical criterion for many stakeholders. High transport costs negatively affect carriers, as well as receivers and citizens who face increased product prices. It is crucial to ensure that transport services remain affordable. Although new transport modes often have high implementation costs, these initial expenses should not be an immediate reason to reject them. In the case of waterborne transport, it is important to carefully consider how value can be added, as simply adding extra links and transfer points can lead to significant costs in the logistics concept. Efficiency in the distribution of goods is another essential criterion. This involves avoiding the wastage of resources such as time and energy. It can be achieved through the bundling of freight when necessary and maximizing load factors by combining freight from different shippers and utilizing shared means of transport. For waterborne transport, efficient transhipment and final road transport organization are of paramount importance. Reliability is a widely recognized requirement for freight transport in terms of logistics performance. It encompasses aspects such as delivery speed, meeting customer requirements, and ensuring product quality. Timely and uninterrupted delivery is crucial, as an excessive number of links and transfer points can introduce errors into the system. Seamless delivery, where customers receive their orders with minimal interruptions, is essential. Furthermore, ensuring the quality of freight and minimizing losses or damages is important, particularly for products that are sensitive to certain conditions, such as temperature. Customers must have confidence that products are handled correctly during transport, with on-time delivery and adherence to recipient requirements. Flexibility is a crucial characteristic of the concept in three respects. Firstly, it should be adaptable to changes in the environment, enabling it to respond to shifts in city policies or visions. Secondly, it should be capable of scaling up to accommodate multiple receivers or carriers interested in joining the concept. Lastly, it should exhibit delivery flexibility, as modern customer expectations often involve receiving deliveries within a specific time frame, typically within 24 hours of placing an order. The concept should be equipped to meet these demands. In summary, the selection of criteria was a collaborative and iterative process that involved meticulous analysis and consideration of stakeholder perspectives and objectives. The aim was to create a comprehensive framework for evaluating sustainable urban waterborne freight distribution. The final selection of criteria includes affordability, sustainability, noise, road safety, efficiency, reliability, and flexibility.

5.3. Impact areas

The previous sections identify the stakeholders involved in the urban freight distribution and their criteria. This information can be used for the design methodology by classifying them into impact areas discussed in chapter 3.4. The reason for designating impact areas is twofold. First, it helps enable cross assessments and second, it ensures that the required data is collected in an efficient, coordinated and consistent manner. The problem of collecting the same data several times is thus avoided. Stakeholder criteria are multifaceted and can be categorized into different dimensions of sustainability and mobility. Both mobility and sustainability rely heavily on a negotiated balance between private interests (operational efficiency) and public interests (economic costs, environmental pressures and social equity). The ideal mobility is one in which economic and social activities can be carried out with minimal external costs to society. The expected sustainability consists of distribution of goods with reduced environmental impacts within the city, minimal costs for the city and business, and minimal externalities for society (Melo & Costa, 2011). Three sustainability impact areas are distinguished: environment, economy and society. Mobility is defined in this thesis as the transport impact area. The choice of impacts areas for urban waterborne freight transport is substantiated by their relevance and significance in addressing the specific challenges and opportunities associated with this mode of transportation in an urban context.

Environment
The environment impact area recognizes the importance of minimizing the environmental footprint of waterborne freight transport in urban areas. Environmental impact evaluation relates to the global greenhouse effect and energy consumption and those of local air pollution. Pollutants are attributed to their place of emission based on the journey that caused them. This allows emission rates to be estimated per km (and per area) within the city (Melo & Costa, 2011). Urban waterborne freight transport has the potential to offer environmental benefits compared to other modes of transport, and focusing on the environmental impact area ensures that sustainability considerations are properly addressed.

Economy
The economic impact area acknowledges the role of urban waterborne freight transport in supporting local and regional economies. Criteria within this area may focus on enhancing trade and commerce, reducing transportation costs, improving supply chain efficiency, attracting businesses and investments, and supporting job creation. In an ideal approach, economic impact evaluation would analyse the total cost of the urban freight distribution system. Due to technical limitations and the fact that such an analysis is not a goal of this study, the economic indicators will focus on operational and internal costs of the community as a whole and of the different stakeholders. Indicators related to environmental pollution, such as air pollution, can also be included in the economic indicators. However, this has not been done to avoid including the same element, environmental and economic, twice in the same target analysis (Melo & Costa, 2011).By promoting economic sustainability, urban waterborne freight transport can contribute to the growth and competitiveness of urban areas.

Social
The societal impact area recognizes the social aspects of urban waterborne freight transport. For the social impact evaluation, it was considered what constraints and benefits would be achieved for which stakeholders, at a time when issues of social justice are receiving much attention. Social indicators include both mobility and sustainability aspects and are used as inputs to characterise the problem and as outputs to evaluate the effects of an initiative (Melo & Costa, 2011). By considering societal impacts, urban waterborne freight transport can contribute to creating a more liveable and inclusive urban environment.

Transport
The transport impact area specifically addresses the challenges and opportunities associated with waterborne freight transport in urban areas. It assesses the performance of a (freight) transport system. It involves understanding the extent to which the measure contributes to more efficient and reliable freight transport (Balm & Quak, 2012). Focusing on the transport dimension helps address the unique considerations and complexities of urban waterborne freight transport.

These impact areas provide a holistic framework for evaluating the sustainability and effectiveness of urban waterborne freight transport. By considering criteria within these areas, stakeholders can address the environmental, economic, societal, and transport-related challenges and opportunities to promote sustainable and efficient waterborne freight transport in urban areas.

5.4. Conclusion

To answer the research question *"What are the interests of the main stakeholders in urban waterborne freight distribution?"* first, the stakeholders were divided into five relevant groups: the shippers, the receivers, the logistics service providers, the local governments and the citizens living and consuming in the considered urban area. These stakeholders each have their own objectives related to urban freight distribution. To assess a given initiative, these objectives have been translated into criteria. These criteria can be further divided into the impact areas: environmental, economic, social and transport. Based on all the information, a selection of criteria was made for the waterborne freight transport evaluation framework. The most important criteria have been classified according to the defined impact areas. This is shown in Table 5-2. The impact area economy looks at the affordability of waterborne transport. Affordability refers to the cost of production. These are the costs of setting up the transport system, including the costs of maintaining the transport system at the desired performance. These costs relate to all stakeholders. The environmental impact area environment relates to the sustainability performance of waterborne transport. Sustainability consists of emissions of greenhouse gases and air pollutants. Greenhouse gas emissions are CO_2 emissions and air pollutant emissions are NO_x, SO_2 and PM_{10} emissions. Emissions have negative impacts on the earth's climate, human health and nature. The impact area society relates to noise pollution and road safety. Noise pollution is the noise caused by goods transport that people perceive as a nuisance. Road safety is traffic safety which can be defined as accidents and material damage. These impacts mainly concern citizens and local government. Lastly, there is the transport impact area. This involves the shipper, the logistic service provider and the receiver and is about efficient, reliable and flexible transport. Efficient transport is about operational utilization and describes the capacity utilization of the transport system. Transport system reliability is the probability that the system can perform the desired function at an acceptable level. This refers to on-time performance and the quality of goods. Flexibility is the ability of the system to adapt to external changes while maintaining system performance that meets customer requirements.

Tabel 5-2. Criteria classified according to impact areas

	Shipper	**The Logistic service provider**	**Receiver**	**Local government**	**Citizens**
Economy					
Affordability	X	X	X	X	
Environment					
Sustainability	X	X	X	X	X
Society					
Noise pollution				X	X
Road safety				X	X
Transport					
Efficiently	X	X	X		
Reliability	X	X	X		
Flexibility	X	X	X		

6. Design requirements

The purpose of this chapter is to describe the design requirements based on the analysis and discussion in the previous chapters. The information from these chapters lead to important information that can be used to answer the research question: "*What are the requirements for the design of sustainable urban waterborne freight transport?*". These requirements are of great importance as they determine which requirements the design from the design methodology should meet. The design methodology to be developed aims to support decision-makers in designing, evaluating and implementing urban waterborne distribution and identifying critical areas and opportunities. This can contribute to analysis and implementation of waterborne supply. However, sustainable distribution is a broad and complex objective and any design and evaluation methodology must be able to adequately provide decision-makers with informative signals on the multitude of issues involved. The design of urban waterborne freight transport should comply with a set of requirements. To collect requirements, it is important to know what requirements are and how they are defined. According to Bahill and Dean (2009), a requirement can be defined as a statement that identifies a capability or function required by a system to meet a customer need. It involves converting inputs into outputs to meet customer needs. The importance of making good requirements is the beginning of the design phase and thus the foundation of the design. According to Dick et al. (2011), one of the three reasons for project failure is requirements and more specifically, poorly organised, expressed, overly changed, not related to the right stakeholders and incomplete. Having a good list of requirements can contribute significantly to a successful project and hence design.

6.1. Types of requirements

According to Bahill and Dean (2009) there are two types of requirements: mandatory and trade-off. Mandatory requirements specify the necessary and sufficient capabilities a system must have to be acceptable; use the words must; are passed or failed with no in between (do not use scoring functions); and should not be included in trade-off studies. After identifying the mandatory requirements, systems engineers propose alternative designs, all of which satisfy the mandatory requirements. Trade-off requirements are then evaluated to determine the best designs. Trade-off requirements set conditions that would make the customer happier and are expressed with the words should or could (often a significant or incentive is attached to how well a performance or trade-off requirement is satisfied); should be described by scoring (utility) functions or measures or effectiveness; should be evaluated with multi criterion decision-making techniques, as none of the feasible alternatives is likely to optimize all the criteria; and there will be trade-offs among these requirements (Bahil & Dean, 2009).

Next, mandatory and trade-off requirements can be distinguished into functional requirements and non-functional requirements and the constraints (Sommerville, 2011; Robertson & Robertson, 2006). According to Sommerville (2011), functional requirements can be defined as, "Statements of services that the system should provide, how the system should respond to certain inputs, and how the system should behave in certain situations". Robertson and Robertson (2006) add: "Things the product should do". Non-functional requirements can be defined as, "Limitations on the services or functions provided by the system. They include time constraints, limitations on the development process and constraints imposed by standards" (Sommerville, 2011). Robertson and Robertson (2006) specify it with "Qualities that the product must have". Non-functional requirements do not affect the operation of the system, but can be classified to structure the requirements more precisely. A constraint is more of a global issue that shapes the requirements and is usually created by the researcher. The constraints must apply for the design and cannot be part of a trade-off. Using this classification, an overview of requirements can be created.

6.2. Requirements for the design of urban waterborne freight transport

The requirements for the design of urban waterborne freight distribution are shown in table 6-1.

Tabel 6-1. Requirements for the design of sustainable urban waterborne freight distribution

Nr.	Type	Explanation	Reference
Mandatory requirements			
	Functional requirements		
1.	The design must transport freight.	The transport system must be capable of transporting freight within the scope of the study, i.e. from the starting point at the UCC to the final receiver, including transhipment and on-carriage.	Chapter 1.5.3 Supply chain scope
2.	The design must have the desired capacity.	The waterborne freight transport system should be able to handle the expected amount of freight to be transported within the urban area.	Chapter 1.5.4. Type of goods flow scope
	Non-functional requirements		
3.	The design must be scalable	The transport system must be able to scale up or down in response to changes in demand, such as during peak periods or changes in freight volumes.	Appendix 1. Trends and statistics in urban freight transport
4.	The design must be interoperable	The transport system must be able to integrate with other transportation systems, as with pre-transportation.	Chapter 4.1 Desired situation of urban waterborne freight transport
	Constraints		
5.	The design must comply with the physical characteristics of the waterways.	The physical characteristics of waterways influence the design of the transport system, such as the maximum vessel size that can be used due to passage profiles and the location of bridges, locks and other obstacles.	Chapter 4.4.1. Technical (Critical success and failure factor)
6.	The design must comply with the physical characteristics of the surrounding infrastructure.	The transport system must be designed to operate within the physical characteristics of the surrounding infrastructure , such as the availability of transhipment facilities and the need for coordination with other modes of transport and infrastructure.	Chapter 4.4.1. Technical (Critical success and failure factor)
7.	The design must comply with all applicable laws and regulations.	The transport system must comply with all applicable laws and regulations, such as environmental regulations, safety requirements and permits for the use of waterways and facilities.	Chapter 4.4.3. Legal (Critical success and failure factor)
8.	The design must take into account the availability and capabilities of technology	The availability and capabilities of technology, such as vessel design and propulsion system, can affect the design of the transportation system. The design must be technological feasible to implement in the coming year.	Chapter 4.4.1. Technical (Critical success and failure factor)
9.	The design must be cost-effective.	The transport system must be designed to provide cost-effective transport services, for example through the use of efficient operations and the optimisation of resources.	Chapter 4.4.4. Economic (Critical success and failure factor) and Chapter 5.2 Criteria and Chapter 5.3 Workshop criteria
Trade-off requirements			
	Non-Functional requirements		
10.	The design should be as affordable as possible.	Minimizing the total cost of all transportation system components is crucial to ensure affordability. This aspect holds significant importance for the shipper,	Chapter 5.2 Criteria and Chapter 5.3 Workshop criteria

		logistics provider, receiver, and local government. However, the citizens are the only stakeholder who might not prioritize this aspect as highly.	
11.	The design should be as sustainable as possible.	The transport system should emit as few greenhouse gas emissions and air pollutants as possible because of the negative impacts on the earth's climate, human health and nature. This can be done by using low-emission ships, efficient engines and using clean energy sources. This aspect holds utmost significance for all stakeholders involved in the process.	Chapter 5.2 Criteria and Chapter 5.3 Workshop criteria
12.	The design should ensure high road safety.	The transport system should be designed to maximise road safety. This criterion holds significant significance for both the local government and citizens.	Chapter 5.2 Criteria
13.	The design should comply with local noise regulations.	Minimizing noise and vibration levels is crucial to adhere to local noise regulations. This criterion holds paramount importance for both the local government and citizens. Efforts to reduce noise and vibration contribute to creating a more peaceful and comfortable environment for residents, improving overall well-being and quality of life.	Chapter 5.2 Criteria
14.	The design should be as efficient as possible.	Designing the transportation system to maximize capacity utilization is of paramount importance. This aspect holds significant significance for the shipper, logistics service provider, and receiver.	Chapter 5.2 Criteria and Chapter 5.3 Workshop criteria
15.	The design should be as reliable as possible.	The transport system should be designed to operate with a high level of reliability and availability. This refers to the probability that the system can perform the desired function at an acceptable level, with respect to on-time performance and quality of goods. This aspect holds significant significance for the shipper, logistics service provider, and receiver.	Chapter 5.2 Criteria and Chapter 5.3 Workshop criteria
16.	The design should be as flexible as possible.	The transportation system should be designed to adapt to external changes while maintaining system performance that meets customer requirements. This aspect holds significant significance for the shipper, logistics service provider, and receiver.	Chapter 5.2 Criteria and Chapter 5.3 Workshop criteria

6.3. Conclusion requirements

The requirements for the design of sustainable urban waterborne freight distribution were formulated by using the chapters that form the problem statement, namely chapters 3, 4, and 5. These chapters provided the necessary information to identify key aspects and considerations for the design of sustainable urban waterborne freight distribution. Through a comprehensive analysis of the content within these chapters, the requirements were derived to ensure that the design adequately addresses the objectives and challenges outlined in the problem statement. Once the requirements have been established, the subsequent phase involves the creation of the design process. Drawing upon the identified requirements, the design process focuses on designing and implementing urban waterborne freight distribution that effectively supports the desired functionalities and capabilities. The design methodology is tailored to facilitate activities related to design, evaluation, and implementation guidance specific to urban waterborne freight transport. It serves as a resource to enable efficient decision-making and assessment of potential solutions. This design methodology serves as a valuable asset for stakeholders involved in urban waterborne freight transport, providing them with the necessary support in designing, evaluating, and generating implementation guidance for sustainable and economically efficient solutions.

7. Design of sustainable urban waterborne freight distribution

This chapter builds upon the previously chapters and outlines the key elements to consider when following the design methodology for urban waterborne freight distribution. This chapter builds upon the previously formulated requirements and outlines the key elements to consider when developing a design for sustainable urban waterborne freight transport. The following sections provide a detailed analysis of each element, including a general explanation of the step, the tasks involved, and the methods that can be utilized.

7.1. Phase 1: Problem description

The design methodology should consist of a comprehensive problem description. This problem description should assess the existing urban logistics situation and provide a clear understanding of the goals and targets to be achieved through the implementation of urban waterborne freight transport. To create such a comprehensive problem description and establish goals and targets, the following steps can be followed:

7.1.1. Defining the current urban situation

In the problem description, a critical aspect is the analysis of the overall city situation, which involves identifying the problems within the city and establishing the reasons for investigating waterborne freight transport. Therefore, it is vital to gain a comprehensive understanding of the city's context in terms of mobility, transport, and logistics. This analysis aims to identify the specific problems and concerns that need to be addressed in the implementation of urban waterborne freight transport measures.

The task involved in this phase include providing a detailed description of the city and its existing challenges, aiming to identify the current situation accurately. This process mainly relies on desk-based activities, such as analysing existing documents prepared by municipal administration services and other relevant stakeholders. These data sources are instrumental in identifying critical areas of concern and highlighting gaps where solutions in the field of urban logistics are currently lacking and can be implemented. By conducting a thorough review of these materials, a clearer understanding of the existing urban logistics landscape can be gained, enabling the development of effective strategies and measures to address the identified issues and improve overall urban freight transport.

7.1.2. Setting the objectives

Clear definition of goals is crucial for the successful implementation of sustainable logistics measures in urban waterborne distribution. These targets should align with the criteria discussed in Chapter 5, figure 5-2, and can be categorized under the impact areas of economy, environment, society, and transport. However, it is important to note that the specific objectives may vary depending on the stakeholders involved and their level of interest in urban waterborne freight transport.

The tasks to be carried out involve identifying the specific stakeholders involved in urban waterborne freight transport, as outlined in Chapter 5. These actors include shippers, receivers, logistics service providers, local authorities, and citizens residing and consuming in the urban area under consideration. It is essential to involve these stakeholders in the process. Activities should be organized to ensure their active participation and cooperation. This involvement fosters a shared understanding of the challenges and encourages collective responsibility in the implementation of urban waterborne freight transport.

The utilization of focus groups is valuable when it comes to setting objectives for urban waterborne freight transport as it enables high-level discussions, promotes collaboration, enhances stakeholder engagement, incorporates diverse perspectives, and ensures an efficient and time-bound process. It is a valuable tool for creating meaningful and inclusive objectives that can drive sustainable and effective urban logistics initiatives.

7.1.3. Analysing the logistics context and processes:

The analysis of the logistics context and processes involves a series of tasks aimed at understanding the urban situation from the perspectives of city logistics and freight transport. The following tasks are involved:

- Analysis of transport regulations and measures: This task entails analysing transportation regulations and measures, specifically those mentioned in Table 4-1, which can be deemed as legal success factors. These factors include time windows, weight restrictions, environmental zones, speed limits, and noise restrictions (L1). Through this analysis, a comprehensive understanding of their impact on freight transportation can be obtained.
- Analysis of road and water network characteristics: This task centers on evaluating the characteristics of road and water networks to assess their suitability for freight transport. It involves analyzing technical success factors from Table 4-1, such as studying waterway profiles, assessing network utilization (T1), locating transshipment points (T2), and identifying urban hubs (T4). Through this analysis, valuable insights into the accessibility and efficiency of the transport network are gained.
- Overview of logistics flows: This task involves gaining an understanding of the characteristics and main types of logistics flows within the area. It includes analyzing the type, volume, and delivery locations of goods (T3) being transported. This information helps identify the patterns and requirements of freight transport in the urban area.

Methods for conducting these tasks include:

- Desk activities: Gathering information on existing logistics processes and infrastructure through research and analysis of available documents and data sources.
- Interviews with local stakeholders: Conducting interviews with key stakeholders involved in logistics and freight transport to gain insights into their needs, challenges, and perspectives. These stakeholders may include local authorities, transport operators, logistics companies, and other relevant parties.
- On-field data collection: Collecting data directly from transport operators and conducting surveys on the road during specific time windows. This data collection method provides first-hand information on traffic patterns, volumes, and other relevant factors.

7.1.4. Conclusions phase 1

The combination of these methods enables a comprehensive analysis of the logistics context and processes, allowing for the identification of specific issues and concerns in urban freight transport. The problem description thoroughly assesses the current urban logistics situation and establishes clear goals for the implementation of urban waterborne freight transport. Moreover, the problem description incorporates the objectives of various stakeholders.

7.2. Phase 2: Designing alternatives

According to the design methodology, the design process should include a design function that enables users to create and modify various aspects of urban waterborne freight transport. This functionality should encompass the components and factors discussed in the previous chapters. Users should have the capability to explore different design scenarios, make adjustments, and evaluate their effects on the efficiency and effectiveness of freight transport.

The term "design" here emphasises the need to develop a detailed analysis of each identified service so that a practical assessment can be carried out in the next phase. Therefore, the main tasks at this level relate to the analysis, identification and specification of the key features and/or elements of the service. There are several tools and techniques that engineers and designers use to explore and generate innovative freight distribution solutions.

7.2.1. Methods for designing alternatives

Morphological analysis is a problem-solving technique used to explore all possible solutions to a complex problem by breaking it down into its component parts or attributes. The structured approach ensures that the combinations of these attributes can be examined to generate potential solutions (Börekçi, 2018). Morphological analysis can help decision-makers explore the design space for potential solutions, identify key design criteria and parameters, and evaluate trade-offs between different solutions based on multiple criteria. The morphological analysis breaks down the complex system into smaller, more manageable components, making it easier to identify potential solutions. Moreover, it can be a participatory process, allowing different stakeholders to be involved in the evaluation process. This can help ensure that the solutions found are acceptable and supported by different groups (Pahl and Beitz, 2013). The technique is highly flexible and adaptable to different problem domains. They can be used to explore a wide range of options and to identify and evaluate trade-offs between different design choices. Both methods are visual and interactive, which can facilitate stakeholder engagement and communication. The use of visual representations and interactive tools makes it easier for decision-makers to communicate complex ideas and involve stakeholders in the evaluation process, enhancing the transparency and credibility of the evaluation process. This can be especially important for the creation of urban waterborne freight transport, which may involve multiple actors and decision-makers (Pahl and Beitz, 2013).

The steps to be followed to create a morphological chart are as follows (Pahl and Beitz, 2013):

1. Define the problem: The first step in morphological analysis is to clearly define the problem that needs to be solved. This involves identifying the objectives, constraints and other factors that are relevant to the problem.
2. Identify the components: The next step is to identify the components or parameters that are relevant to the problem. This involves breaking down the problem into smaller parts or components that can be examined individually. The components should be independent of each other and collectively cover the problem space.
3. Generate solutions: The next step is to generate a list of potential solutions for each component. The constraints that are listed in chapter 6 play a crucial role in deciding which solutions can be generated because they narrow down the range of possible solutions. By incorporating constraints into the morphological analysis process, the range of possible solutions is reduced to those that are realistic and viable. This helps to ensure that the final solution is effective and implementable within the given constraints.
4. Create a morphological chart: The next step is to create a morphological chart, which is a table that shows all the possible combinations of solutions for each component. Each row of the chart represents a different potential solution, and each column represents a different component. This allows you to see all the possible combinations of solutions for the problem.
5. Evaluate the solutions: The next step is to evaluate the potential solutions using criteria. This can be done using morphological analysis scoring, which assigns scores to each potential solution based on the evaluation criteria.
6. Select a solution: The final step is to select a solution that meets the objectives of the problem and satisfies the evaluation criteria. This can involve further refinement of the solution or testing to ensure it is feasible and effective.

7.2.1. Designing alternatives for urban waterborne freight transport

The components for urban waterborne freight distribution are based on the scope of this thesis and are explained in detail in Chapter 4 of this thesis. The components consist of transhipment from pre-transport to the vessel, waterborne transport, transhipment from the vessel to on-carriage and on-carriage. The components are divided into smaller sub-components that collectively cover the problem space and provide an alternative to urban waterborne freight transport. Table 7-1 shows the morphological chart with all components identified. The next step is to create a list of potential solutions for each component. The potential solutions should be specific to the case and explained in detail. Once all solutions have been drawn up, the morphological chart should be completed to show an overview of all possible combinations.

Tabel 7-1. Morphological chart for urban waterborne freight transport

Urban waterborne freight transport		Solutions			
Components	*Sub-components*	*Option 1*	*Option 2*	*Option 3*	*…*
Transhipment from pre-transport to the vessel	*Location of transhipment facility*				
	The transhipment equipment				
	Storage and consolidation of goods				
Waterborne transport	*Vessel type*				
	Vessel size				
	Vessel equipment				
	Propulsion type				
	Operating method				
	Route				
Transhipment from the vessel to on-carriage	*Location of transhipment facility*				
	The transhipment equipment				
	Storage and consolidation of goods				
On-carriage	*Vehicle type*				
	Vehicle size				
	Propulsion type				
Freight	*Loading units*				
	Time of day delivery				

The upcoming sections will delve into the various components of urban waterborne freight transport and explore the potential options associated with each component. Each section will involve a detailed discussion of these options, taking into consideration their feasibility and potential limitations. It is important to note that there may be additional options beyond those presented, or certain options may not be viable in specific circumstances. The options discussed are derived from literature and insights obtained through consultations with experts in the field, including employees at the Amsterdam municipality and professors at TU Delft.

7.2.1.1. Location of transhipment facility

The location of a transhipment facility is a critical factor in determining the efficiency and effectiveness of urban waterborne freight transport. Transhipment facilities are intermediate points where goods are transferred between different modes of transport to complete the journey from origin to the destination. The location is very important for different reasons. The location should be easily accessible to both the waterway network and the inland transportation network, such as highways or railways. This will ensure that the transfer of goods between the different modes of transport can be done quickly and efficiently. Moreover, transhipment facilities should be located close to the markets they serve so that the distance goods have to travel by water to their final destination is feasible.

The locations for transhipment can be classified according to the area's restrictions. The two measures considered here are environmental and weight restrictions zones. These measures place restrictions on emissions, length and weight of vehicles. If a location is chosen within the area with one of these restrictions, the rules applicable there will apply. If a location is chosen where neither measures applies, no restrictions on pre-transportation apply and all possible forms of transport are possible.
There are thus three different options for the location of the transhipment facility:

1. Outside the environmental zone (green zone) and weight restriction zone: no restrictions apply here.
2. Inside the environmental zone (green zone) but outside the weight restrictions zone: only the environmental restrictions apply here.
3. Within the environmental zone and the weight restriction zone: here the environmental and weight restrictions apply.

7.2.1.2. The transhipment equipment

Transhipment equipment for urban waterborne freight transport typically includes specialized infrastructure and handling equipment designed to facilitate the transfer of freight between different modes of transportation, such as from a truck to a vessel. The type of equipment may vary depending on the type and volume of goods being transported, the size and the capacity of the vessel and the facilities available at the port. In this thesis, the focus is on the cranes used to transfer the goods from the quay to the vessel. This crane may be present on the vessel itself or on the quay. The type of crane used will not be specifically addressed in this section. Therefore, there are two options for the transhipment equipment of the transhipment facility:

1. The transhipment facility has a crane for transhipment operations
2. The transhipment facility does not have a crane for transhipment of the goods

7.2.1.3. Storage and consolidation of goods

Transhipment facilities can store and consolidate goods that are being transported from one location to another. The purpose of these facilities is to facilitate the transfer of goods between different modes of transportation. The transhipment facility may have a warehouse and space for consolidation. A warehouse may store goods for a certain period of time. The facility may have various storage options, including space for perishable and perishable goods that need to be transported conditioned (chilled or frozen). This storage ensures minimal damage to the products. Consolidation of goods in a transhipment facility involves combining multiple shipments for transport in a single vessel. This process helps reduce costs by maximising space utilisation and minimising the number of shipments to be transported. In general, the storage and consolidation of goods in a transhipment facility are critical parts of the logistics supply chain, helping to ensure that goods are transported efficiently and cost-effectively. There are four different options for transhipment facility facilities:

1. The transhipment facility has a warehouse and space for consolidation
2. The transhipment facility has a warehouse
3. The transhipment facility has space for consolidation only
4. The transhipment facility does not have a storage area and space for consolidation

7.2.1.4. Vessel type

There are different types of vessels that can be used for waterborne transport:

Barge:
A barge (see figure 7-1) is a type of vessel mainly used for transporting goods by water. It is a flat-bottomed vessel with a large cargo space and limited draught, making it suitable for sailing on shallow waters such as canals and rivers. The name "barge" comes from the fact that the vessel has a spacious, open cargo space that is easily accessible for loading and unloading goods.


Figure 7-1. Barge (Zoev City / City Dock, 2019a)

Deck barge:
A deck barge (see figure 7-2) is a type of vessel used for transporting goods by water. It is a flat-bottomed vessel with an open cargo area and no propulsion of its own. It is usually pulled by a tug or pusher. The name "deck barge" comes from the fact that the vessel has a flat deck used to protect the cargo from the weather. Deck barges are used to transport all kinds of goods, from building materials and machinery to vegetables and fruit.


Figure 7-2. Deck Barge (Zoev City / City Dock, 2019a)

Tug/pusher:
A tug or pusher (see figure 7-3) is a type of vessel specially designed to pull or push other vessels. They are often used on waterways to enable the transport of goods and people. It is usually a relatively small and powerful vessel with a powerful engine and a large tractive force. Tugs are used to manoeuvre large vessels through narrow waterways or ports, while pushers are used to push barges in a convoy. The name "tug" comes from the fact that the vessel "tows" other vessels, while the name "pusher" comes from the fact that the vessel "pushes" other vessels. This results in the following vessel type options:


Figure 7-3. Tug/pusher (Zoev City / City Dock, 2019a)

1. Barge
2. Barge with tug/pusher
3. Deck barge with tug/pusher

7.2.1.5. Vessel size
The size of ships used for transporting goods in waterways is influenced by the clearance profiles, which define the maximum dimensions allowed for vessels to pass through. Clearance profiles typically include restrictions on parameters such as vessel height, width, and draft to ensure safe navigation and prevent obstructions or damage to infrastructure. In some cases, ships that exceed the clearance profiles may be granted exemptions or special permissions to operate. These exemptions are usually granted after careful evaluation of the specific circumstances and potential risks involved.

7.2.1.6. Vessel equipment
The vessel may have transhipment equipment to facilitate freight transfer between the vessel and the quay in the city centre. The type of equipment may vary depending on the type of volume of goods being transported, the size and the capacity of the vessel. In this thesis, the focus is on a type of crane used to transfer the goods. As mentioned, a crane can be present on the vessel, but also on the quay itself. This section looks at the types of cranes that may be present on the vessel. The type of crane can be divided into:

1. Electric moveable platform: A moveable platform can be used to get the goods to the quay. The idea is basically the same as that of a truck. The goods are placed on the platform from the vessel. The platform extends to the quay to drive the goods to the quay from there.

2. Electric loading crane: The electric loading crane is used for loading and unloading cargo. The crane is usually mounted on the deck of the vessel and can be moved to reach different parts of the deck.
3. No transhipment equipment on the vessel.

7.2.1.7. Propulsion type

When it comes to choosing a propulsion type for a vessel in urban waterways, there are several factors to consider such as the size of the vessel, speed requirements, noise pollution, emissions and regulations. Some common types of propulsion for vessels in urban waters are:

1. Electric propulsion: Electric motor are becoming increasingly popular for vessels operating in urban waterways due to their quiet operations, zero emissions and low maintenance costs. Electric propulsion is ideal for vessels that operate at lower speeds and have shorter operating ranges.
2. Hybrid propulsion: Hybrid propulsion systems combine an electric motor with a traditional diesel or gasoline engine to provide more power and longer operating ranges. Hybrid systems are ideal for larger vessels that need to operate at higher speeds and cover longer distances.
3. Diesel propulsion: Diesel engines have long been the standard for marine propulsion, and they continue to be a popular choice for vessels operating in urban waterways. Diesel engines are powerful and efficient, making them ideal for larger vessels that need to cover longer distances at higher speeds.

It is important to note that local regulations and restrictions limit the types of propulsion systems that are allowed in certain urban waterways.

7.2.1.8. Operating method

The operating method of vessels for urban waterborne freight transport can involve different levels of automation, depending on the specific needs and characteristics of the transport system. Here is a brief description of the three types of handling:

1. Manual handling: In this approach, the handling of vessels for urban waterborne freight transport is done entirely by human operators. This includes the loading and unloading of cargo and navigation of the vessel. Manual handling requires a skilled workforce and may be more susceptible to errors and accidents.
2. Automated handling: In an automated handling approach, the handling of vessels is done using a fully automated system. This includes automated cargo handling and navigation of the vessel. Automated handling reduces the need for human intervention, which can increase efficiency and reduce the risk of errors and accidents.
3. Semi-automated (remotely) handling: In a semi-automated approach, the handling of vessels is done using a combination of human operators and automated systems. The human operators can remotely control and monitor the vessel using advanced navigation and communication technologies, while automated systems handle cargo handling and navigation. This approach combines the benefits of human expertise.

7.2.1.9. Location of transhipment facility

There are several options for locations of transhipment facilities for waterborne goods transport in urban areas, each with its own advantages and disadvantages. In general, the choice of location for a transhipment facility depends on several factors, such as available space, location of receivers and the cost of on-carriage. It is important to consider these factors when choosing a location for the transhipment facility for waterborne goods transport in an urban area. The following options can be chosen:

1. On the edge of the city at a location with space for loading and unloading: An advantage of this option is that more space is available for the transhipment facility and the loading and unloading of goods. This can lead to more efficient and faster transhipment of goods. However, the distance to the centre of the city may mean that more on-carriage is needed, which may lead to additional costs and delays.
2. In the city with space for loading and unloading: An advantage of this option is that there is less distance from the centre of the city, which may lead to shorter journey times and less on-carriage. However, space for loading and unloading can be limited in the city and can lead to traffic congestion and delays.
3. In the city at multiple transhipment locations: The advantage of multiple transhipment locations along the quay is that it ensures better distribution of transhipment capacity and accessibility of transhipment facilities. This can lead to less traffic congestion and delays in the city. Moreover, it can lead to more efficient and faster transhipment of goods as there is less congestion at one location. However, it may also mean that the transhipment facilities operate less efficiently because the capacity of the facilities may be limited.

7.2.1.10. The transhipment equipment

The quay in the centre of the city can have transhipment equipment to facilitate the transfer of goods between the vessel and the quay. This thesis focuses on the cranes used to transfer the goods from the quay to the vessel. This crane may be present on the vessel itself or on the quay. This means that there are two options for the transfer equipment of the transhipment facility:

1. The transhipment facility has a crane for transhipment operations
2. The transhipment facility does not have a crane for transhipment operations

7.2.1.11. Storage and consolidation of goods

When transhipping goods from the vessel to the quay in the centre of city, it may be necessary to temporarily store and consolidate the goods before transporting them further. When choosing a storage and consolidation method, it is important to consider factors such as the nature of the goods, the space available on the quay and the safety measures required. It is also important to ensure good communication between the various parties involved in the transhipment, such as the shippers and the drivers for the on-carriage, so that the transhipment process runs smoothly and efficiently. There are various options for storage and consolidation of goods during transhipment, such as:

1. Storage and consolidation of goods in warehouses: Several warehouses can be available in the city centre for the storage of goods. This can be useful when there is temporarily no space available on the quay for loading or unloading goods. The facility can have various storage options, including space for perishable and perishable goods that need to be conditioned (chilled or frozen). If there are multiple deliveries for different locations, the goods are consolidated at this location before being transported further. This enables more efficient operations and reduces transport costs. The facility may also have space for return flows that can be delivered to the vessel from these locations. In this way, the vessel can take the return flows back to the transhipment facility outside the city where it will be further processed.
2. Temporary storage: another option is to temporarily store the goods in the means of transport standing at the quay used for on-carriage. This allows immediate transfer from vessel to the means of transport, which can lead to shorter reporting times.
3. No storage and consolidation: there is no storage and consolidation of goods, but the goods are delivered directly from the quay to the receiver.

7.2.1.12. Vehicle type for on-carriage

There are several sustainable ways of on-carriage from a transhipment facility for urban waterborne goods transport in the city centre. Here are some options:

1. Cargobikes: Cargobikes are becoming increasingly popular for last mile distribution. They are electric or pedal-powered bikes with a large cargo capacity, and they can navigate easily through the city's narrow streets and bike lanes. They are emission-free, cost-effective, and efficient for small to medium-sized deliveries (Nürnberg, 2019).
2. LEFV: Low Emission Freight Vehicles (LEFV) are delivery vans or trucks with low carbon emissions. They run on electric or hybrid engines, compressed natural gas, or biofuels, reducing their carbon footprint and air pollution. They are a sustainable alternative to traditional delivery vehicles, especially for larger deliveries (Balm & Hogt, 2017).
3. Road train: Sligro, a Dutch food wholesaler, has introduced a road train for their last mile distribution in Amsterdam. The road train consists of a small electric vehicle pulling several cargo trailers. It is an innovative and sustainable solution that reduces traffic congestion and emissions while delivering goods efficiently (Sligro, n.d.).
4. On foot: walking is a sustainable option for on-carriage of goods, especially for small deliveries with a short distance within the city centre.

7.2.1.13. Vehicle size for on-carriage

The size of the vehicle for on-carriage will depend on the mode of transport and the number of roll container being transported at a time:

1. Only one roll container: for modes of transport where only one roll container is transported at a time, the vehicle size may be smaller and more agile.
2. Multiple roll containers: for modes of transport where several roll containers are transported at a time, the vehicle size may be larger to accommodate the additional containers.

7.2.1.14. Propulsion type

The choice of propulsion type for onward transport must take into account the strict environmental regulations, including the use of motorised vehicles, that apply to city centre. To comply with these regulations, transport within the city limits must be electrically or manually powered.

1. Electric propulsion: Battery- or fuel-cell-powered electric vehicles are allowed in the inner city. These vehicles produce no emissions, making them a good choice to reduce air pollution and noise levels in urban areas.
2. Manual drive: Another option for further transport within the inner city is manual drive, such as bicycles, cargo bikes or handcarts. These vehicles do not use motorised propulsion and are a sustainable and environmentally friendly option for short distances and lighter loads. They are also often faster and more manoeuvrable than motorised vehicles in densely populated urban areas, and can be parked and manoeuvred more easily.

7.2.1.15. Loading units

Loading units refer to the standardised transport units used to transport goods in urban freight transport. These units are designed so that they can be easily handled, transported and transhipped between different modes of transport, in this case road vehicles and ships.

The choice of loading unit for catering goods depends on several factors, including the type and quantity of goods transported, the available transport infrastructure and the requirements of the cargo owner or shipper. In the city of Amsterdam, transporting goods with roll containers is common, as they are easy to manoeuvre and compatible with different modes of transport. Roll containers can contain different types of special loading units, depending on the specific requirements of the transport. Here are some examples of special loading units that can be used with roll containers:

- Special crates: Crates are sturdy boxes made of wood or plastic used to protect goods during transport. They can be stacked on roll containers for efficient use of space and reducing the risk of goods getting damaged.
- Boxes: Boxes are rectangular containers made of cardboard or other sturdy material used for transporting a wide variety of goods, from small parts to clothing and household items. They can be loaded on roll cages or into trucks for transport.
- Loading units for transporting waste: Special loading units are used for transporting different types of waste, such as paper, cardboard, plastic, glass, metal and organic waste. These loading units can range from large containers to smaller bags and boxes, depending on the nature and quantity of the waste.
- Loading units for the transport perishable goods that need to be conditioned (chilled or frozen): To safely transport perishable and conditioned goods, such as horeca goods, special loading units that are conditioned are required. These can range from small cool boxes and insulated bags to large refrigerated containers or trucks equipped with refrigeration systems and other equipment to control and maintain temperature during transport.

7.2.1.16. Time of day for delivery

The urban water freight delivery schedule in the city center is influenced by the time windows set by the city authorities. These time windows specify the periods during which deliveries can be made in the designated areas. The purpose of time windows is to manage traffic congestion, reduce noise pollution, and ensure the smooth flow of goods and services in urban areas. In the context of water freight delivery, there are three scenarios regarding time windows:

- Deliveries can be made at times when both water and road time windows apply: In this scenario, the city center has specific time slots designated for deliveries, considering both water and road transport. This allows for coordinated scheduling and efficient utilization of both modes of transport.
- Deliveries can be made at times when time windows do not apply to water and road: In certain cases, the city center may have areas or time periods where time windows do not restrict water and road freight deliveries. This provides more flexibility in scheduling and allows for deliveries to be made outside of peak hours or restricted periods.
- Deliveries can be made at times when only time windows apply to the road, but not to the water: In this scenario, there may be specific time restrictions imposed on road freight deliveries due to traffic management or other considerations. However, water freight deliveries are not subject to the same time restrictions, allowing for deliveries to be made during those periods using the waterways.

The components and their corresponding options are presented in Table 7-2, showcasing the morphological chart.

Tabel 7-2. Morphological chart with options

Urban waterborne freight transport		Solutions			
Components	*Sub-components*	*Option 1*	*Option 2*	*Option 3*	…
Transhipment from pre-transport to the vessel	*Location of transhipment facility*	Location 1	Location 2	Location 3	
	The transhipment equipment	Crane on location	No crane on location		
	Storage and consolidation of goods	Warehouse and space for consolidation	Warehouse	Space for consolidation	No warehouse and space for consolidation
Waterborne transport	*Vessel type*	Barge	Barge with tug/pusher	Deck barge with tug/pusher	
	Vessel size	4,5 x 20 meter			
	Vessel equipment	Electric moveable platform	Electric loading crane	No transshipment equipment	
	Propulsion type	Electric	Hybrid	Diesel	
	Handling	Manual handling	Automated handling	Semi-automated handling	
Transhipment from the vessel to on-carriage	*Location of transhipment facility*	On the edge of the city	In the city at one stop	In the city at multiple stops	
	The transhipment equipment	Crane on location	No crane on location		
	Storage and consolidation of goods	Storage and consolidation in warehouse	Temporary storage	No storage or consolidation	
On-carriage	*Vehicle type*	Cargobikes	LEFV	Road train	On foot
	Vehicle size	One roll container	Multiple roll containers		
	Propulsion type	Electric propulsion	Manual drive		
Freight	*Loading units*	Special crates	Boxes	Loading units for waste	Loading units for perishable and conditioned goods
	Time of day delivery	Between 7:00 and 10:00	Between 10:00 and 20:00	Between 20:00 and 7:00	

From the range of possible components and solutions identified in the problem description, it is necessary to narrow down the options to a few alternatives that are both feasible and realistic. This selection process takes into account the factors and constraints outlined earlier, ensuring that the chosen alternatives align with the objectives and limitations of the project. The identified factors, such as the urban context, logistics processes, and stakeholder considerations, play a crucial role in defining the boundaries for feasible solutions. These factors help in assessing the practicality, viability, and impact of each alternative. By considering these factors, the number of potential alternatives is streamlined, eliminating options that are impractical or incompatible with the given constraints. The process of choosing the alternatives is not made in isolation. It involves active consultation and engagement with stakeholders who have a vested interest in the outcomes of the project. Stakeholders, including shippers, receivers, logistics service providers, local authorities, and citizens, provide valuable insights, perspectives, and expertise that contribute to the selection of viable alternatives.

7.2.2. Conclusion phase 2

By utilizing the morphological chart during the design phase, users are able to create and modify various aspects of urban waterborne freight transport. The morphological chart serves as a comprehensive framework that encompasses the components and factors discussed in previous chapters. It empowers users to explore different design scenarios, make adjustments, and evaluate their impact on the efficiency and effectiveness of freight transport. The mandatory design requirements (requirement 1 to 9 form table 6-1) have been taken into account during the design process.

7.3. Phase 3: Evaluating alternatives

Once the alternatives have been drawn up, they should be assessed and evaluated according to the criteria drawn up by the various stakeholders involved in urban waterborne freight transport. The evaluation process and the methods chosen to evaluate the performance of a measure are a complex matter. Morphological analysis scoring is a technique used to evaluate the potential solutions generated during a morphological analysis process. There are different scoring methods that can be used, but the basic idea is to assign score to each potential solution based on certain criteria (Pahl and Beitz, 2013).

7.3.1. Methods for evaluating alternatives

Effect table, score card, and weighted scoring model are decision-making tools used to evaluate and score alternatives based on multiple criteria. The effect table is a matrix that lists the potential effects of each alternative on each criterion. The table allows decision-makers to compare the alternatives against each criterion and to identify any trade-offs between them. Each cell in the matrix is filled with a score that represents the degree of impact that the alternative has on the criterion. The scorecard is a tool that summarizes the scores from the effect table into a single, easily understandable chart. The scorecard displays the overall score for each alternative and criterion, allowing decision-makers to see at a glance which alternative performs the best overall. The weighted scoring model is a tool that assigns weights to each criterion based on their relative importance. Each criterion is then scored based on the degree to which each alternative meets that criterion. The scores are multiplied by their respective weights and then added together to calculate an overall score for each alternative. These tools are commonly used in decision-making processes where multiple criteria need to be considered. They help decision-makers to evaluate alternatives objectively and to make informed decisions based on the criteria that matter most (Parnell et al., 2023).

The choice of evaluation method for scoring alternatives depends on several factors, such as the nature of the problem, the context of decision-making, available resources and the preferences of decision-makers. In the case of urban waterborne freight transport, the use of an effect table and scorecard may be more appropriate than a weighted scoring model for several reasons. First, the evaluation criteria for urban waterborne freight transport are complex and multidimensional. They can be divided into the impact areas of environment, economy, social and transport. An effect table and scorecard can provide a more comprehensive and transparent representation of the trade-offs between these criteria and the potential impacts of the alternatives. Second, stakeholders involved in the decision-making process have different values and preferences regarding the assessment criteria. In a weighted scoring model, the different criteria are weighted according to stakeholders' preferences. A requirement is that stakeholders agree on the relative weighting of each criterion, which is not feasible as there are differences in stakeholders' opinions and values.

An effect table and score card can be used to assess and evaluate all alternatives. The effect table shows the expected impact of each alternative by indicating the expected value of each criterion. The unit in which this is displayed depends on the type of criterion and can be either quantitative or qualitative. Quantitative measurements focus on numerical data (numbers), while a qualitative score is based on words and meanings. Both types of measurements are essential to collect different types of knowledge. A qualitative is mainly used when it is not possible to express the value of a criterion in a standard unit or predict its value accurately enough. Once the effects for all alternatives have been determined, the score card can be used. The scorecard is a coloured effects table. Based on smart colouring, the criterium values are scored. The colouring is based on the "traffic light metaphor", where the colour green is associated with "go" while the colour red is associated with "stop". Colours in between green and red, such as orange or yellow, give an intermediate value. The colours make it possible to see at a glance which alternative or alternatives are most beneficial. However, it does not yet directly answer the question of which alternative is preferable. Indeed, a red cell in a column does not mean that the alternative cannot be chosen. Nor does a scorecard indicate whether certain criteria have more weight than others. However, it is common to rank the criteria so that the most important criterion is on the left. It should be noted that the assessment and evaluation process should be transparent and open to discussion and feedback from stakeholders. Moreover, the score should not be the sole basis for decision-making, but should be used in combination with other factors such as feasibility and stakeholder preferences (Multicriteriamodel, 2020).

7.3.2. Evaluation of alternatives for urban waterborne freight transport

Once compiled, the alternatives should be evaluated. To do this, the evaluation criteria should first be identified. The criteria for evaluating the alternatives are drawn up in chapter five of this thesis and are based on the objectives of the stakeholders involved. The criteria can be divided into the impact areas: environmental, economic, social and transport and consist of affordability, sustainability, noiseless, road safety, efficiently, reliability, flexibility (see table 5-2).

To assess these alternatives effectively, an impact table and scorecard will be utilized, incorporating established criteria. However, the implication is that these criteria are not uniformly weighted by the diverse stakeholders involved in the urban waterborne freight transportation process. Due to differing opinions and values among stakeholders, reaching a consensus on the relative importance of each criterion may not be achievable. To address this challenge, a separate table will be created for each stakeholder involved in urban waterborne freight transportation (see table 7-3). Each table will evaluate the alternatives using the criteria from Table 5-2 that hold significance for that particular stakeholder. As different criteria are used in scoring the alternatives, this may lead to variations in how well an alternative performs for each stakeholder. The tables not only aid in evaluating the alternatives but also take into account the dynamics of power, interest, and attitude among stakeholders, as discussed in Chapter 5. By analysing these factors, the tables provide valuable insights into how each stakeholder perceives the different alternatives and their attitudes toward them. This comprehensive approach highlights the varying perspectives and priorities among stakeholders, ensuring a more nuanced and holistic evaluation of the alternatives. By considering the different perspectives of stakeholders and acknowledging their diverse interests and attitudes, this evaluation process enhances the decision-making process for urban waterborne freight transportation. It enables stakeholders to have a clearer understanding of how each alternative aligns with their goals and priorities, and ultimately leads to more informed and collaborative decision-making for sustainable and effective freight transportation solutions in the urban environment.

Tabel 7-3. Tables of alternatives and impact areas

Shipper, Logistic service provider, receiver					
Impact area	*Economic*	*Environmental*	*Transport*		
Criteria	*Affordability*	*Sustainability*	*Efficiently*	*Reliability*	*Flexibility*
Alternative 1					
Alternative 2					
Alternative 3					
…					

Local government				
Impact area	*Economic*	*Environmental*	*Social*	
Criteria	*Affordability*	*Sustainability*	*Noise pollution*	*Road safety*
Alternative 1				
Alternative 2				
Alternative 3				
…				

Citizens			
Impact area	*Environmental*	*Social*	
Criteria	*Sustainability*	*Noise pollution*	*Road safety*
Alternative 1			
Alternative 2			
Alternative 3			
…			

The stakeholder criteria and Table 7-3 demonstrate that the shipper, logistic service provider, and receiver share a common perception of the important criteria. However, this does not imply that their power, interest, and attitude are identical, leading them to assign the same scores to each criterion. Each stakeholder group may prioritize and weigh the criteria differently based on their specific perspectives and interests, resulting in varied scores for the different criteria. On the other hand, both the local government and the citizens value the social criteria. The distinction between these two stakeholders lies in the fact that, in addition to the social criteria, the local government also considers cost as an essential factor in their evaluation process. This differentiation in criteria evaluation underscores the importance of understanding the unique perspectives and priorities of each stakeholder group. By recognizing and considering these divergent viewpoints, decision-makers can make more informed and inclusive choices that balance the needs of all stakeholders involved in urban waterborne freight transportation. The collaborative consideration of various criteria allows for the development of more effective and sustainable solutions that address the interests and concerns of all parties in a balanced manner.

When evaluating urban waterborne freight transport, a combination of qualitative and quantitative data can be used to measure the criteria of affordability, sustainability, noise pollution, road safety, efficiency, reliability, and flexibility. Affordability, sustainability, and efficiency are quantitatively measured, while noise, road safety, reliability, and flexibility are qualitatively measured. The assessment is conducted on a predefined scale with a range of values for each criterion, and the values are linked to the colours of the traffic light metaphor. The metaphor includes five options: very negative, negative, neutral, positive, and very positive (see figure 7-4). The final step involves selecting a solution that scores the best on each criterion and meets the objectives.

Figure 7-4. Scoring

Affordability
Measuring the affordability of urban waterborne freight transport requires considering various costs, including initial investment costs, transhipment costs, and personnel costs. Initial investment costs refer to the capital required to acquire or upgrade infrastructure, equipment, and vessels. This includes the cost of building loading/unloading facilities, as well as the cost of purchasing or leasing vessels, cranes, and other equipment needed for waterborne freight transport. Transhipment costs refer to the costs associated with the movement of goods from one mode of transportation to another, such as from a vessel to a truck for further delivery to their destination. These costs can include handling fees, storage fees, and other expenses associated with the transfer of goods between different modes of transport. Personnel costs refer to the expenses related to the workforce needed to operate and maintain the waterborne freight transport system, including crew members, engineers, and administrative staff. This can include salaries, benefits, training costs, and other related expenses. By considering these different costs, it is possible to evaluate the affordability of urban waterborne freight transport systems and compare them to other modes of transport, such as road. This can help to identify the most cost-effective solutions.

Sustainability
Assessing the sustainability of urban waterborne freight transport involves evaluating its environmental impact, which includes measuring the emission of greenhouse gases, mainly CO2, and air pollutants such as SO2, NOx, and PM10 (Demir et al., 2015). CO2 emission is a significant factor as it contributes to the rise in the earth's temperature, leading to severe climate problems. Meanwhile, air pollutants have negative impacts on human health, the building environment, and nature.

When evaluating CO2 emissions for waterborne transport, emissions can be categorized based on transport mode and operation cycles, including payload, utilization degree, loading factor, and types of commodities transported (Kim, 2010). For waterborne freight transport, it is essential to consider the source of generating electricity for electric-powered vessels to compare CO2 emissions accurately. To estimate the CO2 emissions of urban waterborne freight transport, the system is divided into three components: main haulage, pre- and post-haulage, and transhipment operations, with the distance of pre- and post-haulage affecting the total emissions. Terminal emissions are also incorporated, considering the electricity consumption of the equipment used (Kim, 2010).

Air pollution has negative impacts on society, including human health effects, material damage, crop losses, and biodiversity losses (CE Delft, 2019). Emission calculations for air pollutants are based on transport activity and performance, which depends on the transported volume and distance.

Efficiency
Efficiency in urban waterborne freight transport is determined by the operational utilization, which describes the capacity utilization of the transport system on a roundtrip basis. In this context, efficiency is defined as the ability to use resources effectively and minimize waste, which can include fuel, time, and other inputs. However, it's important to note that calculating the utilization degree can only be done ex-post, meaning it cannot be calculated in advance for this specific case. Therefore a qualitative assessment can be made based on observations of the transport system’s performance and the extent to which it is effectively using resources and minimizing waste. Factors that can be considered include fuel efficiency, route optimization and load capacity utilization.

Noise pollution

Freight transport causes noise pollution, which is the disturbance of noise for people. This pollution is caused by both the sound of the vehicle engine and the sound of the vehicle rolling over the infrastructure (Demir, Huang, Scholts & van Woensel, 2015). Factors that affect the amount of noise emissions include the type of vehicle, vehicle speed, type of area (population density), type of infrastructure, cargo payload, time of day, existing noise levels and population density near hubs (CE Delft, 2019). However, due to the non-linear nature of noise pollution and the many indicators that affect it, quantifiying noise emission and estimating its monetary costs is rather complex (Demir et al., 2015). Therefore, this thesis will consider qualitative criteria for estimating noise pollution.

The type of vehicle is an important factor affecting noise emissions, as a vessel is generally quieter than a truck on the road. Vehicle speed also plays a crucial role, as higher speeds results in higher emissions. Population density refers to the number of people exposed to noise, and the closer people live to an emission source, the more nuisance they will experience. Noise emissions are more severe in urban areas than in rural areas, making noise emissions for transport in urban areas higher. Additionally, higher payload leads to higher noise emission. Finally, the time of day is another crucial factor, as noise-induced health effects are higher at night due to sleep disturbance. As a result, noise pollution at night will have a bigger negative impact than during the day (CE Delft, 2019). Al these aspects will be considered to give a score to noise pollution.

Road safety

Freight transportation activities lead to an increase in accidents, which is a negative externality. The increased traffic on the road raises the likelihood of accidents, which is detrimental to society (CE Delft, 2019). In addition to injuries, accidents result in property and freight losses, as well as delays for other traffic. The type of area is important in determining traffic safety. In areas with low accident risks, both the immaterial and material losses are reduced. Urban areas have a higher chance of accidents and a greater impact. Although marginal accident costs can be calculated, this thesis considers traffic safety as a qualitative factor in the transport system's performance due to the complexities of estimating these costs. The non-linear nature of accident costs and the influence of several factors make it challenging to estimate these costs accurately. Therefore, the study uses qualitative indicators, such as the number of vehicles on the road and the type of area, to estimate traffic safety.

Reliability

The transport system's reliability refers to its ability to perform its desired function at an acceptable level of performance. Travel time reliability is the probability that a trip can reach the destination within a specified time interval and is determined by two indicators: on-time performance and disruptions and delays. On-time performance is defined as the percentage of vehicles that remain on schedule, and is a crucial measure of a system's effectiveness and reliability. The calculation of on-time performance is done ex-post.

Disruptions and delays have a significant impact on a transport system's on-time performance and, therefore, its reliability. Disruptions are stochastic in nature and disrupt the normal operations of a system. Delays are the consequence of disruptions that take place in this system. Example of an disruption are traffic accidents on the road or weather conditions causing ice on the canals. While disruptions and delays are taken into account qualitatively for the reliability criteria, they are less common on waterways compared to roads, where capacity constraints cause disruptions. Compared to roads, waterways generally have wider space and can accommodate more vessels, which reduces the probability of congestion and capacity constraints. However, disruptions caused by weather-related events such as freezing must be taken into account as they can significantly impact the reliability of water transport systems. When waterways freeze, vessels are unable to navigate and transport goods, which can cause supply chain disruptions and affect timely deliveries.

The presence of ice can also increase the risk of accidents and damage to vessels, further compromising the reliability of the transport system. Therefore, it is crucial to consider the impact of ice in assessing the reliability of water transport systems in urban areas with colder climates.

Flexibility
The flexibility of a transportation system refers to its ability to adapt to external changes while still meeting customer requirements and maintaining satisfactory system performance. This can be measured through indicators such as capacity, level of service and profitability. External changes can include variations in demand, infrastructure loss and degradation, price changes, and resource availability.

There are multiple definitions used to determine the flexibility of freight transportation systems: availability of products or services to meet individual customer demand, flexibility of the delivery system to meet specific customer demand, and ease of adjustment to unexpected time demands. These definitions can be translated into indicators such as frequency of service and demand adaptability. Demand adaptability refers to the system's ability to accommodate changes in traffic demand while maintaining satisfactory performance. It deals with changes in traffic quantity, commodities and spatial patters or traffic flows (Morlok & Chang, 2004). The higher the demand adaptability score, the higher the flexibility of the system. Since it's difficult to quantify, scores are used for relative comparison of transportation systems. The frequency of the service is a measure of how often a transportation system operates, whether it's a truck or a vessel. A higher frequency of service indicates that the transportation system is more flexible because it can accommodate more demand and respond more readily to changes in demand. Assessing the frequency of service is important when evaluating the flexibility of a transportation system. It can be qualitatively assessed by considering factors such as the number of daily departures, the consistency of the schedule and the number of routes served. By looking at these factors, it can be determined how well a transportation system is able to adapt to changes in demand and maintain a satisfactory level of performance.

7.3.3. Conclusion phase 3
The utilization of the scorecard and effect table within the developing includes an evaluation function enabling users to assess the performance and impact of urban waterborne freight transport initiatives. These evaluation methods facilitate the scoring and assessment of different alternatives, allowing users to compare and evaluate their effectiveness based on predefined criteria. By incorporating these evaluation mechanisms, the design methodology fulfils the requirement for an evaluation function. Moreover, when evaluating urban waterborne freight transport, there are specific design requirements (requirement 10 to 16 from table 6-1) that need to be taken into account. These requirements are defined by the criteria affordability, sustainability, efficiency, noise pollution, road safety, reliability and flexibility.

7.4. Phase 4: Implementation guidance
In order to provide effective implementation guidance for urban waterborne freight transport, it is crucial to identify and address trade-offs and critical success and failure factors associated with the implementation process. Implementing urban waterborne freight transport involves navigating various complexities and considering the diverse perspectives and interests of stakeholders. To ensure successful implementation, it is important to delve deeper into the concept of trade-offs and critical success and failure factors.

Trade-offs refer to the compromises or sacrifices that need to be made when pursuing a particular course of action. In the context of urban waterborne freight transport, trade-offs can arise when attempting to balance the needs and preferences of different stakeholders. For example, prioritizing environmental sustainability might require compromising on certain economic factors or vice versa. By understanding these trade-offs, decision-makers can make informed choices that maximize the benefits while minimizing negative impacts. Moreover, policymakers can explore strategies to turn negative impacts into positive outcomes. This involves identifying ways to mitigate or offset any adverse effects associated with an alternative. By taking a proactive approach and considering how negative impacts can be addressed, policymakers can turn challenges into opportunities for sustainable development. Chapter 4.4 discusses critical success factors and failure factors in the context of implementing urban waterborne freight transport. Critical success factors can be considered as enablers that enhance the potential for implementation and are essential for achieving the desired goals. Conversely, critical failure factors can be seen as showstoppers that impede implementation and give risks, problems and barriers (Mehrabioun Mohammadi et al., 2021). Both factors can be categorized in technical, social, legal, economic and political aspects.

By understanding and leveraging enablers and mitigating or overcoming showstoppers, decision-makers and stakeholders can create an environment that supports the successful implementation of the chosen alternative for urban waterborne freight transport. Categorizing these factors provides a comprehensive view of the potential risks, challenges, and opportunities associated with the implementation process. To make this information insightful, there are two approaches. Firstly, trade-offs and success and failure factors can be clarified based on literature and existing knowledge from previous pilot projects. However, to effectively utilize this information, stakeholders must be actively involved. This is achieved through collaborative sessions, where stakeholders can express their perspectives, requirements and concerns. These sessions provide a platform for valuable insights, open dialogue, and contribute to the decision-making process. Given that stakeholders may have varying criteria reflecting their respective interests, concerns, and priorities, open and collaborative discussions enable stakeholders to articulate their criteria and work together to refine the alternative solution. This iterative process allows for adjustments, incorporating feedback, and addressing specific requirements. Stakeholders play a significant role in confirming existing trade-offs and critical success and failure factors or identifying new ones, ensuring that the alternative solution aligns with their needs and expectations. Overall, these collaborative sessions foster dialogue, collaboration, and knowledge-sharing among stakeholders. They enable a comprehensive exploration of trade-offs and identification of critical success and failure factors. Actively involving stakeholders increases the likelihood of achieving broad support and successful implementation of urban waterborne freight transport. The municipality also plays a vital role in facilitating implementation by creating a conducive environment for sustainable freight transport practices. They can set regulations and polies, coordinate stakeholder efforts, facilitate partnerships, and provide the necessary resources and support for successful implementation.

7.4.1. Set up of collaborative sessions

To determine the necessary adaptations and adjustments for the alternatives, collaborative sessions should be conducted with the stakeholders. These sessions follow the initial assessment of the alternatives and provide an opportunity for stakeholders to discuss and establish the boundaries and constraints. The solutions need to meet the established requirements while taking into account any emerging considerations. Stakeholders can also contribute insights on areas where further adjustments can be made and suggest actions to achieve desired outcomes.

After the initial round of assessments and sessions, the pain points and challenges become evident. These findings should inform the improvement of the alternatives, taking into account the main solution directions to enhance sustainability: logistics, policy, and technological solutions. It is important to consider and coordinate all three directions in order to successfully implement urban waterborne freight transport.

Conducting collaborative sessions with stakeholders is a crucial step in the implementation process of urban waterborne freight transport. There are multiple steps to facilitate productive and effective collaborative sessions:

1. Identify the stakeholders: Determine the key stakeholders who have an interest or are affected by the implementation of urban waterborne freight transport.
2. Define the session objectives: Clearly define the objectives and desired outcomes of the collaborative sessions. Determine what specific topics, issues, or decisions will be addressed during the sessions. This will provide focus and direction to the discussions.
3. Plan and prepare the sessions: Develop an agenda for each session, outlining the topics to be discussed and the activities or exercises to be conducted. Prepare any necessary materials, such as presentations, case studies, or reference documents, to provide information and context to the stakeholders.
4. Create a collaborative environment: Ensure that the sessions are conducted in a neutral and inclusive environment that promotes open and respectful communication. Encourage active participation and ensure that all stakeholders have an opportunity to voice their perspectives and concerns.
5. Facilitate the discussions: Assign a skilled facilitator who can guide the discussions, manage time, and ensure that all stakeholders have an equal opportunity to contribute. The facilitator should encourage dialogue, ask probing questions, and ensure that different viewpoints are heard and considered.
6. Use participatory techniques: Incorporate participatory techniques such as group discussions, brainstorming, SWOT analysis, role-playing, or scenario planning to encourage active engagement and generate innovative ideas. These techniques can help stakeholders explore trade-offs, identify enablers and showstoppers, and contribute to the decision-making process.
7. Document and synthesize outcomes: Take detailed notes during the sessions to capture the key points, agreements, disagreements, and any action items or recommendations. Summarize the outcomes of each session and share the information with the stakeholders to ensure transparency and accountability.
8. Follow-up and feedback: After the sessions, provide stakeholders with an opportunity to provide feedback on the process and outcomes. This feedback can help improve future sessions and address any concerns or issues that may arise.
9. Iterative approach: Collaborative sessions should be conducted iteratively, allowing for ongoing engagement and refinement of the alternative solution based on stakeholder feedback. The process may involve multiple sessions to address different aspects or stages of the implementation.

After Step 9, which involves conducting collaborative sessions iteratively and refining the alternative solution based on stakeholder feedback, there are several key actions to take:

10. Analyze and synthesize the feedback: Review and analyse the feedback received from stakeholders during the collaborative sessions. Identify common themes, concerns, and suggestions that have emerged throughout the process. Synthesize this feedback to gain a comprehensive understanding of stakeholder perspectives and priorities.
11. Update and refine the alternative solution: Incorporate the feedback and insights gathered from stakeholders into the alternative solution for urban waterborne freight transport. Make necessary adjustments, modifications, or enhancements to address the identified trade-offs, enablers, and showstoppers. Ensure that the updated solution aligns with the stakeholders' criteria and requirements.
12. Develop an implementation plan: Create a detailed implementation plan that outlines the steps, timelines, responsibilities, and resources required to execute the alternative solution. Consider the logistical, policy, and technological aspects of implementing urban waterborne

freight transport. Collaborate with relevant stakeholders, including the municipality, to ensure alignment and coordination in the implementation process.

13. Communicate and engage stakeholders: Share the updated alternative solution and the implementation plan with stakeholders. Provide clear and transparent communication about how their feedback and input have been incorporated. Engage stakeholders in ongoing communication and dialogue to keep them informed about the progress and address any further concerns or questions that may arise.
14. Monitor and evaluate progress: Implement a robust monitoring and evaluation framework to assess the progress and effectiveness of the implemented urban waterborne freight transport solution. Regularly track key performance indicators, measure outcomes against predefined goals, and collect data to inform future decision-making and continuous improvement.
15. Adapt and iterate: Remain open to further refinements and adaptations as the implementation progresses. Continue to engage stakeholders and seek their input throughout the implementation process. Stay responsive to emerging challenges and opportunities, adjusting strategies and actions accordingly.
16. Celebrate successes and share best practices: Acknowledge and celebrate milestones and achievements along the way. Share success stories, lessons learned, and best practices with stakeholders and the wider community to foster knowledge exchange and inspire further sustainable transportation initiatives.

By following these steps, you can ensure that the collaborative efforts with stakeholders result in a well-informed and effective implementation

7.4.2. Trade-offs and critical success and failure factors

As previously mentioned, the critical success and failure factors can be categorized into five main areas: technical, social, legal, economic, and political. These factors, outlined in Table 4-1, serve as a guide during the sessions and will be briefly explained in terms of their potential to enable or hinder the implementation of urban waterborne freight transport. Understanding and effectively addressing these factors is key to ensuring a successful implementation.

7.4.2.1. Technical Success and failure factors:

One of the technical success factors for urban waterborne freight transport is **the density of the waterway network** (T1). The density refers to the number and interconnectedness of waterways within an urban area. A higher density of waterways can significantly contribute to the success of waterborne freight transport by providing more efficient and convenient routes for freight movement. A dense waterway network allows for better connectivity between various points within the urban area. It offers flexibility in route planning as it provides multiple options for navigating through the urban area, allowing for efficient detours in case of congestion, maintenance or other disruptions. The flexibility enhances the reliability and resilience of waterborne freight transport.

The location of receivers (T4) in urban waterborne freight transport is influenced by the choice of **transshipment locations** (T3). The proximity of transshipment locations to receivers plays a vital role in optimizing the overall efficiency and effectiveness of freight operations. When selecting transshipment sites, it is essential to strategically consider their proximity to receivers. By locating transshipment sites close to receivers, the distance and travel time between the transshipment point and the final destination are minimized. However, finding suitable space for transshipment sites within the city center can be challenging. Urban areas often face limited available land. As a result, identifying suitable locations for transshipment sites within the city center requires careful planning and consideration of factors such as available space, infrastructure requirements and zoning regulations. In order to overcome these challenges, it is important to explore creative solutions. Two potential approaches include repurposing existing infrastructure and utilizing transhipment methods that do not require dedicated transhipment sites.

1. Reusing Existing Infrastructure: One solution is to repurpose and adapt existing infrastructure within the urban area. This could involve using underutilized docks, piers, or waterfront facilities that are already present. By retrofitting and upgrading these spaces, they can be transformed into efficient transhipment points. This approach maximizes the use of existing resources and minimizes the need for additional land allocation.
2. Transhipment from Boats: Another solution is to explore transhipment methods that do not rely on dedicated transhipment sites. For example, certain types of boats or vessels may have built-in capabilities for direct loading and unloading of cargo, eliminating the need for a specific transhipment location. This approach allows for greater flexibility in choosing delivery points along the waterways, without being constrained by the availability of transhipment infrastructure.

By considering these creative solutions, urban waterborne freight transport can overcome the limitations of space and infrastructure within the city center. Repurposing existing infrastructure and utilizing alternative transhipment methods help optimize efficiency and ensure seamless goods movement, even in areas where dedicated transhipment sites may be challenging to establish.

The location of urban hubs is a crucial technical success factor in urban waterborne freight transport. These hubs serve as key point of origin and destination for goods, facilitating efficient consolidation and distribution processes. Urban hubs strategically located in areas with high concentrations of businesses and industries enable efficient consolidation of goods. Shippers act as central points where various shipments from multiple suppliers are gathered and organized for transportation via waterborne vessels. This consolidation optimizes cargo loads, reduces empty trips, and maximizes the capacity utilization of vessels, leading to cost savings and improved operational efficiency. The establishment of urban hubs enables the optimization of waterborne freight transport systems. By strategically locating shippers near waterways, the efficiency of cargo transfer between land-based transport and water vessels is enhanced. This allows for seamless integration of different transportation modes, reducing transshipment times, minimizing handling costs, and improving overall operational efficiency.

Special vessels and equipment (T6) play a crucial role in the success of urban waterborne freight transport. These specialized assets are designed specifically to meet the unique challenges and requirements of transporting goods through urban waterways. One key advantage of these vessels is their efficient cargo handling capabilities, enabling quick and safe loading and unloading of goods. This reduces turnaround times at transshipment locations, enhancing operational efficiency.

Moreover, special vessels for urban waterborne freight transport are designed with sustainability in mind. They often incorporate environmentally friendly propulsion systems, such as electric or hybrid engines, to minimize emissions and reduce their ecological footprint in sensitive urban environments. Additionally, these vessels may incorporate noise and vibration reduction technologies, ensuring minimal disruptions to nearby communities as they navigate through urban areas. In the context of electric vessels, they offer a sustainable solution for urban waterborne freight transport. The **availability of loading stations equipped with charging infrastructure** (T8) is crucial for their success. These stations provide the necessary power supply to recharge the vessels, ensuring continuous operations without interruptions. A well-developed network of loading stations supports the adoption and utilization of electric vessels, reducing emissions and promoting environmentally friendly transport. However, the limited availability of charging infrastructure poses a challenge, as it restricts the range and operational capacity of electric vessels and may discourage their use in urban waterborne freight transport.

Furthermore, the integration of **autonomous technology** (T7) holds promise for enhancing efficiency, safety, and reliability in waterborne freight transport. Autonomous vessels have the ability to optimize routes, improve navigation accuracy, and reduce the risk of human error. Achieving successful implementation of autonomous technology requires advanced sensors, robust communication systems, and reliable control algorithms. By embracing autonomous technology, urban waterborne freight transport can achieve higher productivity and operational efficiency.

Intermodal Loading Units (ILUs) (T6) are essential technical success factors for urban waterborne freight transport. These units facilitate the seamless transfer of goods between different modes of transportation, such as water vessels and trucks. Their standardized design, compatibility with multiple modes of transport, enhanced security, and streamlined documentation procedures contribute to the efficiency, reliability, and effectiveness of goods movement in urban areas. By utilizing ILUs, stakeholders can optimize urban waterborne freight operations, improve intermodal connectivity, and promote sustainable and efficient logistics solutions.

7.4.2.2. Social Success factors

One important aspect of social success factors is addressing **accessibility problems** related to **physical environment** (S1) This includes overcoming infrastructure limitations and navigating challenges to ensure smooth and efficient waterborne freight transport operations. By improving infrastructure, maintaining proper waterway depth and width, and enhancing navigational aids, the accessibility of waterways can be ensured, facilitating the movement of goods and promoting sustainable transportation solutions. Another critical social success factor is reducing **traffic density** (S2) in urban areas. By shifting freight transport to waterways, it becomes possible to alleviate traffic congestion and overall traffic density. This not only improves accessibility and mobility for residents and businesses but also mitigates congestion-related issues, leading to more efficient transportation networks.

Urban waterborne freight transport offers environmental benefits by reducing emissions and pollutants compared to road-based alternatives. Minimizing **environmental pollution** (S3) through the implementation of emission control measures, the promotion of cleaner fuels, and the adoption of sustainable practices helps improve air and water quality. This contributes to a healthier urban environment and enhances the overall quality of life and public health.

Managing and minimizing **noise pollution** (S4) generated by waterborne freight transport operations is crucial for maintaining the well-being of residents living near waterways. Employing noise reduction technologies, enforcing noise regulations, and implementing appropriate operational practices help mitigate noise impacts and ensure a peaceful environment for communities.

The **visual intrusion** (S5) caused by transport infrastructure can also be addressed in urban waterborne freight transport. Designing infrastructure to harmonize with the urban landscape and minimizing visual intrusion helps preserve the aesthetic value and character of the city. By integrating infrastructure with architectural and environmental considerations, public acceptance can be enhanced, leading to a positive urban environment.

Shifting freight transport to waterways also reduces the **damages on urban road infrastructure** (S6) caused by heavy vehicles. By diverting freight traffic from roads, waterborne transport helps preserve the quality of roads and reduces the need for frequent maintenance. This not only benefits road users but also results in cost savings for the community by reducing infrastructure repair and maintenance expenses.

7.4.2.3. Legal Success factors:

Clear regulations and policies (L1) regarding traffic and access restrictions are crucial legal success factors for urban waterborne freight transport. By establishing these guidelines, authorities can ensure the safe and efficient movement of goods through waterways. Implementing appropriate restrictions and guidelines helps integrate waterborne freight transport into the existing legal framework, promoting its effectiveness and compliance with regulatory requirements. Integrating waterborne freight transport into the existing legal framework requires aligning regulations with the specific needs and characteristics of urban areas. This involves working closely with local governments, transportation authorities, and relevant stakeholders to develop appropriate policies and regulations that consider the unique challenges and opportunities of urban waterborne freight transport.

7.4.2.4. Political Success factors:

Active involvement and engagement of local government (P1) authorities play a vital role in the successful implementation of urban waterborne freight transport. Here's an elaboration on the significance of the involvement of local government in achieving success in this domain:

- Regulatory Support: Local governments can provide regulatory support by developing and implementing policies, regulations, and guidelines that promote and facilitate urban waterborne freight transport. This includes addressing legal and administrative barriers, streamlining permit processes, and establishing clear rules and standards for operations. Regulatory support from local governments creates a favorable environment for the growth and sustainability of waterborne freight transport in urban areas.
- Infrastructure Planning and Development: Local governments play a crucial role in infrastructure planning and development for urban waterborne freight transport. They can identify suitable waterway routes, determine optimal locations for transshipment points, and allocate resources for infrastructure investments. By actively participating in the planning and development of waterborne infrastructure, local governments ensure the availability of necessary facilities to support efficient and reliable freight operations.
- Coordination and Collaboration: Local governments can facilitate coordination and collaboration among various stakeholders involved in urban waterborne freight transport. They can bring together government agencies, private sector entities, industry associations, and community representatives to create partnerships and forums for dialogue. Such coordination helps align the interests and efforts of different stakeholders, promoting collective action and enabling effective problem-solving.
- Funding and Financial Support: Local governments can provide funding and financial support for urban waterborne freight transport initiatives. This may include grants, subsidies, or incentive programs to encourage the adoption of sustainable transport solutions. Financial support from local governments helps offset the initial costs of infrastructure development, vessel acquisition, or technology adoption, making waterborne freight transport more economically viable.
- Public Awareness and Education: Local governments can play a crucial role in raising public awareness and educating the community about the benefits of urban waterborne freight transport. By conducting public campaigns, organizing information sessions, or integrating waterborne transport education into school curricula, local governments can help build public support and understanding of this mode of transport. Increased awareness fosters a positive perception of waterborne freight transport, which can lead to greater acceptance and utilization.

In conclusion, the involvement of local government authorities is crucial for the successful implementation of urban waterborne freight transport. Their regulatory support, infrastructure planning, coordination efforts, funding support and public awareness initiatives contribute to the growth, efficiency, and sustainability of waterborne freight transport in urban areas. Collaborative efforts between local governments and stakeholders pave the way for effective and holistic solutions that address the unique challenges and opportunities of urban freight transport.

7.4.2.5. Economic success and failure factors:

The successful implementation of urban waterborne freight transport can face economic challenges related to **high initial investment costs** (E2) **and transhipment expenses** (E3). The substantial initial investment required for infrastructure development and the acquisition of specialized vessels and equipment can create financial barriers for stakeholders considering waterborne transport alternatives. Comparatively lower upfront costs associated with other transportation modes may discourage the adoption of waterborne freight transport. Another economic factor that can hinder the cost-effectiveness of urban waterborne freight transport is the impact of transhipment costs. Transhipment operations involve various expenses, such as terminal usage fees, equipment rental, labour, and administrative charges, incurred during the handling, storage, and transfer of goods between different transport modes. Inefficiently located transhipment facilities or suboptimal processes can increase transportation costs, reducing the overall economic viability of waterborne freight transport.

To address these economic challenges, providing **financial support** (E1) through subsidies, grants, or incentives emerges as a significant success factor. Such assistance offered by local governments or relevant authorities can encourage the adoption and implementation of waterborne transport alternatives. By offsetting high initial investment costs, stakeholders are motivated to invest in infrastructure and specialized assets, making waterborne freight transport more economically feasible. Financial support plays a crucial role in promoting the economic viability of urban waterborne freight transport. Subsidies, grants, or incentives can directly alleviate some of the financial burdens associated with initial investment costs, making waterborne transport more competitive with other modes of transportation. Through the provision of financial support, urban waterborne freight transport can overcome economic barriers, ensuring its financial feasibility and fostering its successful implementation. This approach promotes economic growth, efficiency, and sustainability in urban freight transportation systems, contributing to a more effective and environmentally friendly transportation landscape.

7.4.2.6. Trade-offs

During step 6 of the implementation process, trade-offs are thoroughly discussed and examined. While specific trade-offs can be identified during the collaborative sessions with stakeholders, there are also well-known trade-offs that are commonly associated with urban waterborne freight transport. These trade-offs represent the inherent challenges and considerations that decision-makers must navigate in order to find an optimal solution. By acknowledging and addressing these trade-offs, stakeholders can make informed decisions that strike a balance between conflicting factors and achieve the desired outcomes of urban waterborne freight transport.

- *Environmental Impact vs. Economic Viability*: One of the key trade-offs is balancing the environmental benefits of waterborne freight transport, such as lower emissions and reduced traffic congestion, with its economic viability. While waterborne transport is generally more sustainable, it may require higher initial investments or longer transit times, which can affect its economic feasibility compared to other modes.
- *Reliability and Frequency vs. Capacity*: Achieving high reliability and frequent service in urban waterborne freight transport may require allocating sufficient capacity and resources. However, trade-offs can arise between providing more frequent services with smaller vessels, which may have limited carrying capacity, and using larger vessels with less frequent services.
- *Efficiency vs. Local Community Concerns*: Increasing the frequency of waterborne freight transport operations to improve efficiency may lead to increased noise or disturbance for

nearby residents. Finding a balance between operational efficiency and minimizing community impacts is essential.

- *Scalability and Volume Capacity vs. Initial Investments*: Expanding urban waterborne freight transport operations to accommodate increased volumes may require significant initial investments in infrastructure, vessels, and equipment. Trade-offs can arise between scalability and volume capacity on one hand, and the financial investments required to support such expansion on the other.

These examples illustrate the complex nature of implementing urban waterborne freight transport and the need to carefully consider trade-offs, leverage enablers, and mitigate showstoppers to ensure successful implementation.

7.4.3. Conclusions

The various sections in the implementation guidelines help in effectively implementing urban waterborne freight transport. Collaborative sessions help identify trade-offs and success and failure factors and can help propose solutions to overcome them. The methodology serves as a comprehensive guide to support users in successfully translating their designs and evaluations into actual implementation of urban waterborne freight transport initiatives. Moreover, this step also takes great account of stakeholders' interests to ensure their involvement throughout the process.

Met de laatste stap is de design methodology overview zoals deze te zien is in figure 7-3 compleet.

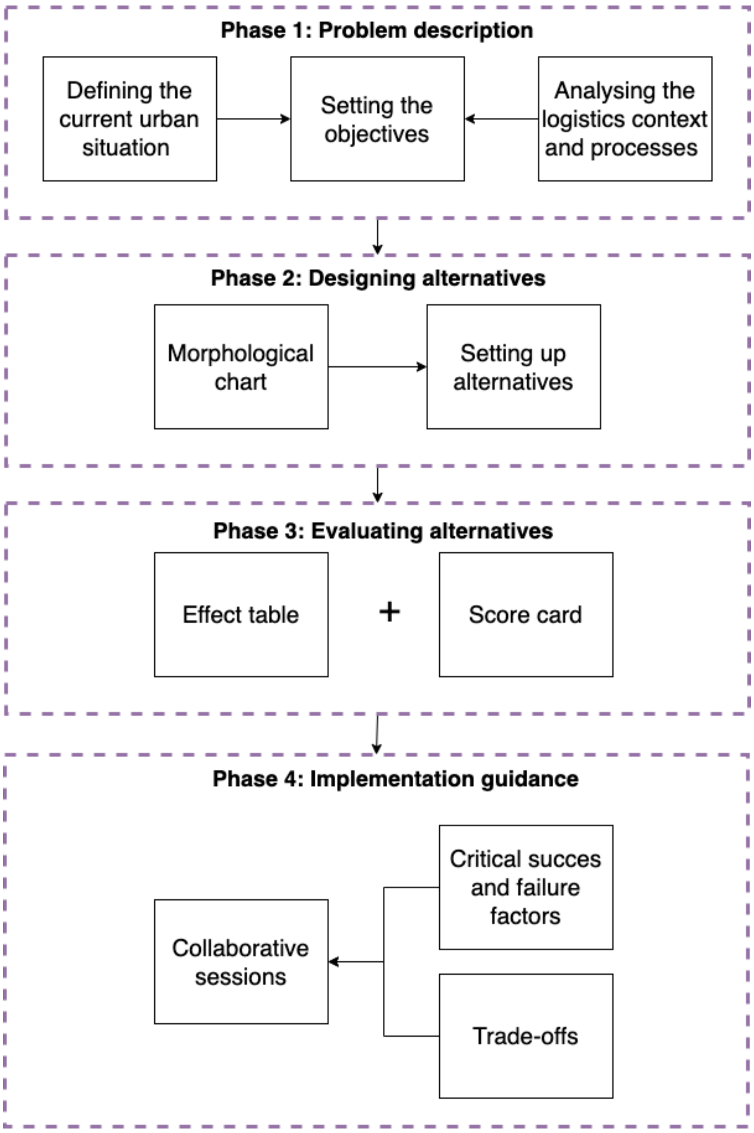

Figure 7-3. Design methodology overview

8. Design verification: case study

Following the design methodology, the next step is the demonstration phase, where the design methodology is put into action through the case study of het Wallengebied. The application of the design methodology to the case study of het Wallengebied, involving all the steps outlined in the methodology, is a crucial aspect of this research. However, obtaining specific and accurate data directly related to the selected case study was not feasible within the scope of this study. As a result, alternative approaches were employed to conduct the evaluation of the designed model. In order to overcome the data limitations, rational simplifications were made, and reliable estimates were generated through various means. This involved interviewing experienced experts who possess valuable insights and knowledge in the field, as well as conducting a thorough examination of similar case studies. By leveraging the expertise of these individuals and drawing from existing research, a suitable basis for evaluating the model was established. This chapter serves as a practical demonstration of the design methodology's implementation and its role in designing, evaluating, and providing guidance for urban waterborne freight transport in the specific area under investigation.

8.1. Phase 1: Problem description

The problem description consists of three steps: defining the current urban situation, setting the objectives and targets and analysing the logistics context and processes.

8.1.1. Defining the current urban situation

Amsterdam is a big city and on 1 January 2022, the city had a population of 881,933. Almost 9,500 more than a year earlier. This number is expected to rise to 1,070,000 by 2050, a growth of 21 per cent (Gemeente Amsterdam, n.d.-a). Het Wallengebied is located in the oldest part of Amsterdam in the Burgwallen Oude Zijde district. The area is bounded by Damrak, Dam, Rokin, Amstel, Kloveniersburgwal, Nieuwmarkt, Geldersekade and Prins Hendrikkade (see figure 8-1) and has a rounded total area of 40 hectares and a population of 4,550 people in 2022 (Statistieken wijk Burgwallen-Oude zijde, n.d.).

Figure 8-1. Het Wallengebied

It has one of the most beautiful neighbourhoods in the world. Its history, unique structure and numerous monuments give it a unique character. However, the area is under great pressure. The high concentration of attractions, shops, restaurants, sex-related functions and coffee shops attracts tourists from home and abroad (Gemeente Amsterdam, 2021). In addition, logistics forms the bloodstream of the city centre. It is essential for the quality of living, working and staying in the city. More and more logistics will be needed in the coming years. Logistics take up a lot of space and have a major impact on traffic safety, air quality, liveability and accessibility. New solutions are needed to maintain a good balance between liveability and supply (Gemeente Amsterdam, 2022a). Besides the increase in tourism and logistics, the city of Amsterdam faces a major challenge to renovate a large part of its historic quays and bridges. Amsterdam is characterised by its canals, and the bridges and quay walls are historical and essential connections in the city. For a long time, little attention has been paid to infrastructure management and maintenance. As a result, 80 to 125 bridges and 60 kilometres of quay walls are currently in poor condition and in need of maintenance. This large and complex task will be time-consuming and have a major impact on freight transport in the city (Gemeente Amsterdam, 2020b).

In addition, Amsterdam has plans to renovate and redevelop het Universiteitskwartier, located in het Wallengebied in Amsterdam. This area is in the middle of Amsterdam's historic centre. The area is characterised as the vibrant historical heart of Amsterdam with a square kilometre of knowledge and culture. Het Universiteitskwartier lends itself to the activities of the University of Amsterdam. The plans for developing the area stem from the desire to cluster the University's accommodation. The university wants to move from several buildings scattered across the city to four open urban campuses, including het Universiteitskwartier. For both parties, thanks to its central location with a wide variety of functions, the area can serve as the ideal location to further develop the synergy between city and university. It should become a place where students, employees, knowledge institutions, businesses and residents can form a valuable knowledge cluster with developments that are beneficial for the university, the city and the residents (Gemeente Amsterdam, 2020).

Figure 8-2. Het Universiteitskwartier (Gemeente Amsterdam, 2021)


Figure 8-3. Het Universiteitskwartier (Gemeente Amsterdam, 2021)

The UvA is a major party that creates a large flow of logistical movements due to the number of pedestrians, cyclists and the supply of goods to and removal of waste from the area. Besides the UvA, there are also many other functions in this area, such as hotels, restaurants, shops, businesses and homes that provide logistical flows. After commissioning the renovated UvA buildings, the demand for logistics in the area will further increase, such as the delivery of facility products, catering, parcels, books, technical equipment and waste collection on campus. The combination of these flows with the logistical problems discussed earlier, the deteriorating condition of the bridges and quays and the measures taken mean that the Municipality of Amsterdam, together with the University of Amsterdam, is looking for innovative ways to supply the area. Waterborne transport should contribute to the city's ambition to be an attractive, liveable, healthy, safe and accessible city for all.

8.1.2. Setting the objectives and targets

The objectives have been defined in Chapter 5 and are grounded in literature, workshops, and data provided by the Municipality of Amsterdam. They are presented in table 5-2.

8.1.3. Analysing the logistics context and processes:

8.1.3.1. Analysis of transport regulations and measures

To meet the current challenges and organise transport in the city more efficiently, cleanly and lightly, the Amsterdam municipality has drawn up several ambitions to change transport movements. This has led to several measures affecting transport in the city centre.

Environmental zones

Traffic is a major air polluter, which is why the municipality of Amsterdam is working towards a city with only emission-free traffic by introducing environmental zones and emission-free zones (Gemeente Amsterdam, 2020c). The environmental zones are designed to keep the most polluting passenger cars, trucks, vans, taxis, buses and mopeds and motorbikes out of the city. The measures not only reduce emissions, but also noise as zero-emission vehicles make no engine noise and only the sound of the tyres can be heard (Gemeente Amsterdam, 2020c).

Passenger, freight and delivery vehicles, buses and taxis

Figure 8-4 shows the environmental zones within the Amsterdam ring road in which passenger, freight, and delivery cars, buses and taxis that do not meet the requirements of the environmental zone are not welcome (Municipality of Amsterdam, n.d.-g).

Figure 8-4. Environmental zone (Gemeente Amsterdam, n.d.-e).

Delivery vehicles

Currently, a green environmental zone applies within Amsterdam. This means that diesel delivery vans can only enter the environmental zone if they have a mission class 4 or higher. Non-diesel delivery remain welcome, but diesel delivery vans with an emission class of 3 or lower are not allowed to enter the zone. However, there are special cases where exemptions apply or where it is possible to apply for an exemption. From 2025, the rules for vans will become increasingly strict. In the period 2025-2030, the emission class will keep going up so that eventually in 2030 only zero-emission vehicles will be allowed (Gemeente Amsterdam, n.d.-e).

Freight vehicles

Since 1 January 2022, a purple environmental zone has applied within Amsterdam. This means that diesel trucks can only enter the environmental zone if they have an emission class of 6 or higher. All diesel-engined trucks with an emission class of 5 or lower are not welcome. All non-diesel trucks are allowed to enter the environmental zone. However, there are special cases where exemptions apply or where it is possible to apply for an exemption. From 2025, Amsterdam will introduce an emission-free zone for truck traffic with a number of agreements. For example, new trucks registered from 1 January 2025 must be emission-free, trucks must have at least emission class 6, rigids may be no more than 5 years old and tractors no more than 8 years old, and only emission-free vehicles will be allowed from January 2030 (Gemeente Amsterdam, n.d.-f)

Vessels

The City of Amsterdam has also set ambitions for waterborne transport to improve air quality. All forms of transport must be emission-free and have quiet propulsion within 10 years. So this also applies to waterborne transport. The measures will gradually increase. For instance, the measures will apply to the inner city as early as 2025. In addition, emission-free boats can currently benefit from a 70% discount on inner harbour fees (Gemeente Amsterdam, n.d.-d)

Weight restrictions

Due to the deteriorating condition of bridges and quay walls in the city centre, a new heavy traffic zone policy is applicable from October 1, 2021 (see figure 8-5). Previously, cargo vehicles of 7.5 tonnes or more were welcome in the city centre only with an exemption. The new policy involves new additional rules for heavy vehicles. For instance, vehicles over 30 tonnes no longer have access within the S-100, there are stricter requirements for route waivers (Zone Heavy Traffic Waiver) and there is a maximum length of 10 metres within the zone (Gemeente Amsterdam, n.d.-b).

Figure 8-5. Weight restrictions (Gemeente Amsterdam, n.d.-b)

Time windows

In Amsterdam has time window on (parts of) streets, (pedestrian) areas, squares and separate loading and unloading locations. City districts have the authority to set window times. The times vary by city district and area, and are often in the morning. In het Wallengebied, which includes het Universiteitskwartier, it is possible to load and unload from 07.00 - 11.00 without an exemption. Between 11.00 - 20.00, the area is only accessible via a requested vezippas (retractable pole pass). Het Wallengebied is closed daily for loading and unloading between 20.00 and 07.00 and all Sunday (Gemeente Amsterdam, n.d.-i).

To ensure proper distribution of water use, time windows apply for waterborne transport requiring an operating license. Within the central zone (within the Singelgracht including the Singelgracht itself) waterborne transport is in principle not allowed from 10:00 to 20:00, unless with obtained permit or permission. There is then space to cross traffic flows on the water and there is a possibility to transport goods further over the bank (here the window times apply until often 11:00 in the morning). Outside the city centre, window times do not apply, but where necessary for smooth and safe passage, prescribed shipping routes can be established. In addition, permit holders for waterborne transport outside the city centre zone are given priority when using designated loading and unloading locations (Gemeente Amsterdam, 2020c).

Maximum speed

In December 2023, the speed limit in Amsterdam will go to 30 kilometres per hour on 270 kilometres of busy city streets. This means that from then on, 80 per cent of the roads will be 30-kilometre roads. This will make traffic safer and quieter (Gemeente Amsterdam, 2022e). On a number of roads, the speed remains 50km/h or higher. Here, however, this speed limit is still an appropriate exception because of the use, layout and/or environment. Within Amsterdam, a speed limit of 6 kilometres per hour applies on most waterways. There are a few exceptions where the maximum speed is 7.5 kilometres per hour, namely on de Kostverlorenvaart, het Oosterdok, de Nieuwe Herengracht, de Amstel in de richting van Ouderkerk aan de Amstel (Gemeente Amsterdam, n.d.-h).

Noise restrictions

All new urban developments must comply with national noise legislation. The Noise Abatement Act assumes a preferred limit value and a maximum limit value for road traffic, railways and industry. A noise load below the preferred limit value is considered permissible and a noise load above the maximum limit value is not considered permissible. In the new directive, the guide value for road traffic noise has been lowered to 53 dB. This is a substantial tightening of the guide values from the earlier 1999 directive. For a liveable and economically vital Amsterdam, it is therefore of great importance to limit serious noise pollution and sleep disturbance as much as possible. This value applies to the 24-hour period. In addition, a value of 45 dB applies at night (Gemeente Amsterdam, 2020d).

8.1.3.2. Analysis of road and water network characteristics

Street characteristics

Only limited traffic is allowed on public roads in het Wallengebied. Many streets are one-way, accessible only to loading and unloading traffic or designated for cyclists. To limit access to these streets, multiple bike barriers and retractable poles have been installed. Some streets are accessible only on foot or by (moped or scooter) bike during the day. During evenings on Thursdays to Saturdays, only authorized residents and businesses with valid parking permits may access the streets. Most streets that are accessible to cars during the day have one-way traffic. The Grimburgwal and Oudezijds Achterburgwal may become shared spaces or car-free streets in the future. The area is very busy with residents, students but also tourists. This has implications for the layout of future transport. Especially in certain places shown in figure 8-6, this should be taken into account (Nijhuis & Balm, 2021):

1. Oudemanhuispoort - Oudemanhuispoort is the street that provides access to the main entrance of the UvA location Oudemanshuispoort. In addition to being heavily frequented by UvA staff and students, the street is also a popular destination for tourists visiting the street and the Books 4 Life Amsterdam company that is typically displayed there. Consequently, it is not recommended to use Oudemanshuispoort as a logistics route.
2. Slijkstraat - Slijkstraat is situated at the rear of the Oudemanhuispoort site, and is a narrow street that is occupied by residents. Furthermore, after the renovation, this street will provide entrance to the underground bicycle storage at the Oudemanh uispoort location. To minimize disruption, it is advisable to limit the use of this street for transport.
3. Entrance to the Future University Library Bicycle Parking Facility - At the intersection of Kloveniersburgwal and Vendelstraat, there is a narrow tunnel that is currently (June 2021) occupied by a bike path. After the reconstruction, the entrance to the University Library's bike shed will be located just behind the tunnel. However, given the combination of the narrow tunnel and the high volume of cyclists, this passage is not an ideal route.

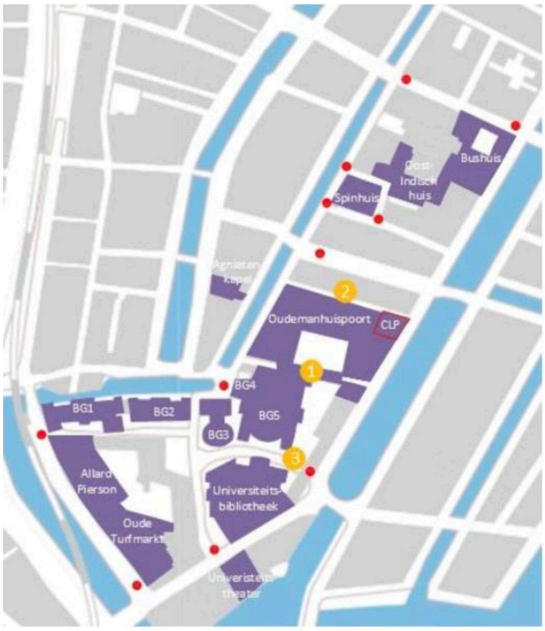

Figure 8-6. Busy places in het Universiteitskwartier (Nijhuis & Balm, 2021):

Waterway characteristics

This section discusses some key features of the waterways in the city centre of Amsterdam.

Passage profiles waterways

Amsterdam has an extensive water network: the canals, numerous other inland waterways and various transit routes such as the Amstel and the IJ. Leading the description of Amsterdam's inland waterway network are the passage profiles. These are the profiles for which, based on nautical requirements, the maximum passage width, length and depth for all shipping has been established. Each waterway/canal in the city is categorised. These are shown in figures 8-6 and 8-7. The vast majority of canals in the city centre have passage profile B (blue canal). This also applies to the main waterways in het Wallengebied, namely Geldersekade, Kloveniersburgwal, Rokin and Oudezijds Voorburgwal. That is, ships are allowed to sail here if they have a maximum length of 20 metres, a maximum width of 4.25 metres and a draught of no more than 2.20 -NAP. The Oudezijds Achterburgwal has a more rescrictive character with profile E (yellow canal). Here, vessels with a maximum length of 14 metres, a maximum width of 3.75 metres and a draught of a maximum of 1.80 -NAP are allowed. An exemption allows vessels with dimensions outside the passage profile to use the canals. This means that larger vessels with greater carrying capacity can be used for waterborne transport. It should be noted that these are specific exemptions (Gemeente Amsterdam, 2020d).

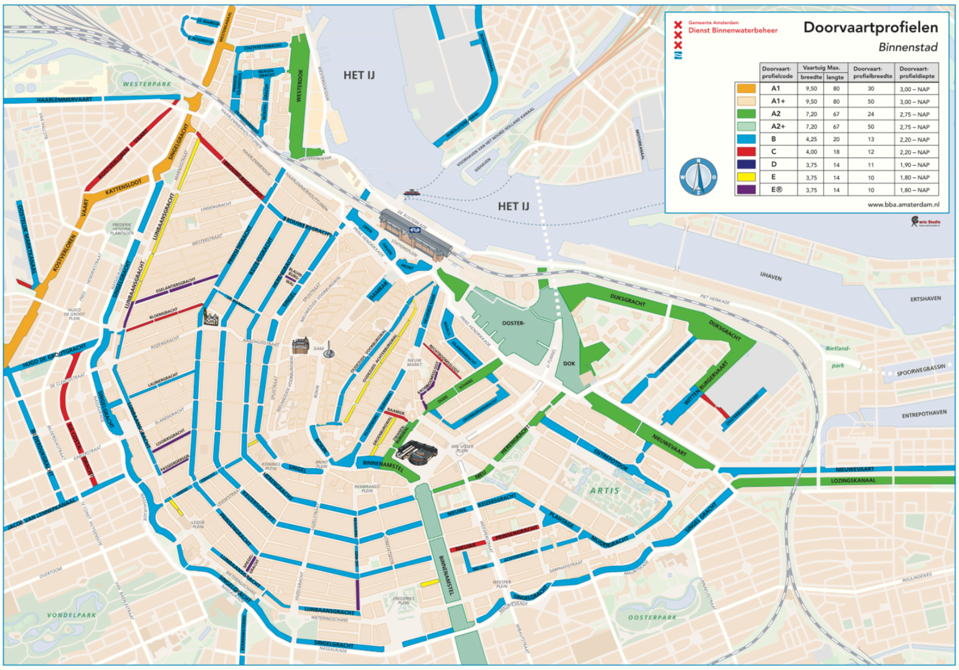

Figure 8-8. Passage profiles for the city of Amsterdam(Gemeente Amsterdam, 2020d)

Figure 8-7. Passage profiles for het Wallengebied (Gemeente Amsterdam, 2020d)

Use of water network

Amsterdam's inland waterways and canals are intensively used. In recent years, various measurements and counts have been carried out to map the number of shipping movements at the various locations. Based on the insights, it has been established that the water is frequently used especially between 10 am and 10 pm. For waterborne transport to grow, it is important to create space on the water. That means looking within the crowds on the canals to see where and when this transport can best take place. Based on the crowds on various canals at peak times, it can be seen that before 10 am, there are fewer boat movements. Only in the evening, from about 8pm onwards, the number of boat movements decreases. This means there are restrictions between 8 pm and 10 am. Laying the capacity profiles on the passage profiles creates figure 8-9. For the rampart area, this means that for profile B, there is mainly room for waterborne transport on weekdays (Monday to Thursday) from 8 pm to 10 am. Fridays are significantly more popular for pleasure and passenger shipping and are taken together with weekends. Profile E have an additional restriction. These are only accessible for waterborne transport in the morning or evening throughout the week (Gemeente Amsterdam, 2020d).

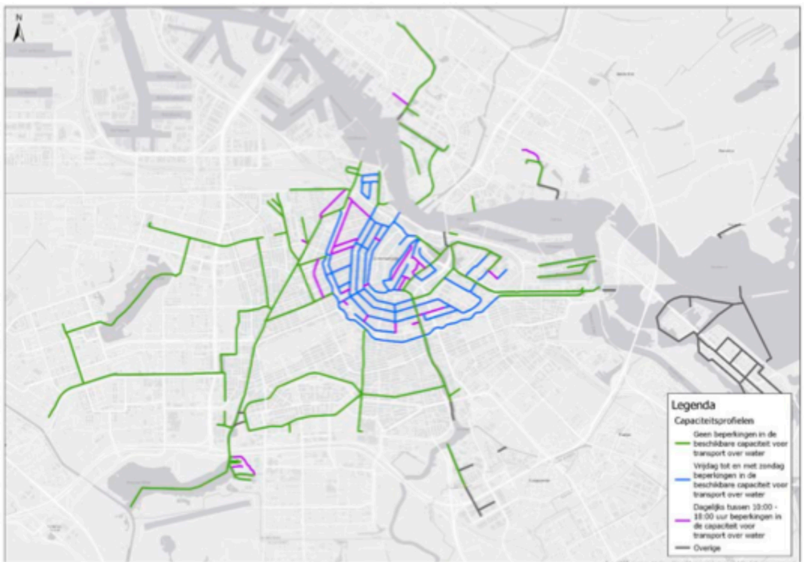

Figure 8-9. Capacity profiles (Gemeente Amsterdam, 2020d)

Loading and unloading points

The municipality has designated around 120 embarkation/disembarkation locations for passenger shipping. Many of these locations are actually in commercial use, sometimes only short (max 15 min) embarkation/disembarkation is allowed. At about 30 of these embarkation/disembarkation locations, loading and unloading of goods is allowed. Often also with a restriction of max 15 min. Important conditions for facilitating transport by water are space on the quay, length of the berth, obstacles in the vicinity and facilities such as shore power.

Current loading and unloading facilities are not adequate to accommodate the growth of waterborne transport. Working with window times for waterborne transport, the network can be expanded by, among other things, making public loading and unloading locations available for transport for pleasure and passenger shipping. As a result, the current number of loading and unloading locations can be expanded by several dozen. This will create an efficient network of loading and unloading facilities for waterborne transport. Conditions regarding the use of loading and unloading facilities will be included in the permit. Information on specific site conditions for loading and unloading will be made accessible. Locations for loading and unloading are:

4. Recognisable for which they are suitable (not all sites are suitable for all forms of transport);
5. Accessible to holders of an operating licence for waterborne transport;
6. Within city centre zone use permitted within window times, outside window times only with permission;
7. Maximum loading time is in principle 1 hour (Gemeente Amsterdam, 2020c).

8.1.3.3. Overview of logistics flows

For this thesis, it has already been indicated that horeca goods will be looked at. To specify this in more detail for this case study, the supply of horeca goods for the University of Amsterdam and a number of large hotels in het Wallengebied will be considered.

Figure 8-10. Buildings of het Universiteitskwartier (Gemeente Amsterdam, 2021)

There are several reasons why the goods flows of the University of Amsterdam and hotels were chosen for this thesis. Hotels and the UvA are both organizations that consume and use a large quantity of horeca goods. However, there are many different suppliers for the delivery of these goods resulting in many transport movements in the area that are not always delivered in the most efficient way. There are opportunities to bundle these goods and transport them via water. The bundling of goods flows is important to make transport by water economically viable. This will take a large part of the transport movements off the road, contributing to the municipality's objectives. Cooperation between the different stakeholders is essential for waterborne transport. Hotels and the UvA are both large organizations that have opportunities to collaborate with other parties and promote transport by water. If these large parties see a future in transport by water, it is easier for small organizations to get involved.

Het Universiteitskwartier consists of several UvA properties with different functions. Figure 8-10 and 8-11 shows these properties, their location and their function. A number of UvA premises contain horeca establishments where deliveries are made. A total of eight different establishments are supplied. The horeca establishments consist of a food court with four different food stands, a kiosk, a restaurant and two coffee bars. These venues are located in BG5, the bus shelter, the UB and the OMHP. Data on the number of deliveries per week and per day are known for these venues.

Figure 8-11. Buildings of het Universiteitskwartier (Gemeente Amsterdam, 2021)

BG5 is located at Oudezijds Achterbrugwal 233 - 237 and consists of study areas, classrooms and the central catering area. Four different food stands and a kiosk are located here. The kiosk accounts for 17 roll containers (RC) per week and the four food stands together for 18 RC. This location sees about 17 unique suppliers per week and 23 delivery moments per week. Converted to days, 7 roll containers are delivered per day through 5 delivery moments per day. The bus house is located at Kloveniersburgwal 48 and consists of research cluster, offices and start-ups. There is one small restaurant here which accounts for 8 Roll Containers per week. There are 3 unique suppliers at this location and 4 delivery moments per week. Converted, this is 2 roll containers per day through 1 delivery moment. The UB is located at Vendelstraat 2-8 and consists of the university library and study areas. The OMHP is located at Oudemanhuispoort 4-6 and consists of offices, teaching rooms, study places, auditorium and logistics point. Both locations have a coffee bar which accounts for 2 roll cages per week in both cases. There are 2 unique suppliers at both locations and 2 delivery moments per week. Converted, this is 1 roll container per location per day through 1 delivery moment.

A total of 47 roll containers of horeca goods are delivered per week for the University of Amsterdam, representing 9 to 11 roll containers per day. There are 8 different receivers at 4 different addresses. There are 31 delivery moments per week which amounts to 6 delivery moments per day. The goods are delivered by 18 unique suppliers. It is important to note that not all suppliers come weekly. Some come every 2 or 4 weeks. In addition to these volumes and delivery frequencies, around 3 roll containers are delivered per week for vending. This is spread across all UK sites. This brings the weekly total to 50 roll containers.

Besides the horeca flows of the University of Amsterdam, the horeca flows of a number of major hotels in het Wallengebied are examined. For the number of deliveries for the hotels, it is important to distinguish between 3 types of hotels:

- Hotels with a restaurant
- Hotels without a restaurant (only breakfast or a kiosk)
- Star hotels with (star) restaurant.

For hotels without a restaurant, far fewer deliveries are made compared to hotels with a restaurant, as no or fewer catering supplies are needed. Star restaurant have 2-3 times more deliveries compared to regular restaurants because they order a lot from local suppliers. Therefore, more different suppliers come with small delivery trucks than regular restaurants.

For star hotels, a volume of 0.46m3 is delivered 70 times a week by 40 different suppliers. Converted, 32.2m3 of goods are delivered weekly by 40 different suppliers. In this case, the volume is calculated in m3 because not everything is put on roll containers. A roll container with the standard dimensions of 0.81m x 0.72m x 1.62m has a volume of:

Volume = Length x Width x Height
Volume = 0.81m x 0.72m x 1.62m
Volume = 0.963 m3

So, the maximum amount of m3 that can fit on a roll container with these dimensions would be approximately 0.936m3. However, the actual amount of m3 that can fit on the container will depend on the shape and size of the items being loaded, as well as any weight restrictions. It's important to follow any guidelines or restrictions provided by the manufacturer to ensure safe and efficient loading. If the number of m3 is converted to roll containers with the above volume, this means that approximately 34 roll containers are delivered weekly by 40 different suppliers. For regular hotels, this number is slightly different. For regular hotels, a volume of 1.2m3 is delivered 26 times weekly by 15 different suppliers. Converted, 31.2m3 of goods are delivered weekly and converted to roll containers, approximately 33 roll containers are delivered weekly by 15 different suppliers. For hotels without catering, the volumes are slightly less known. Possibly this volume is around 1 m3 per delivery. This would mean that for hotels without catering facilities, a volume of 1m3 is delivered 12 times weekly by 4 different suppliers. Converted, 12m3 of goods are delivered weekly and converted to roll containers, approximately 13 roll containers are delivered weekly by 4 different suppliers.

For this study, a number of hotels in het Wallengebied will be examined. The following hotels have been chosen for this purpose, namely hotel De L'Europe, hotel Residence Le Coin, hotel NH Collection Amsterdam Doelen and Radisson Blue hotel and hotel Sofitel Legend the Grand Amsterdam. Both hotel De L'Europe and hotel NH Collection Amsterdam Doelen and hotel Sofitel Legend the Grand Amsterdam can be scaled as a star hotel with (star) restaurant. The Radisson Blue hotel is scaled under a regular hotel with restaurant and the hotel Residence Le Coin is a hotel without a restaurant.

Figure 8-12 shows for the University of Amsterdam and the various hotels how many, how often and where in the area the horeca goods have to be delivered.

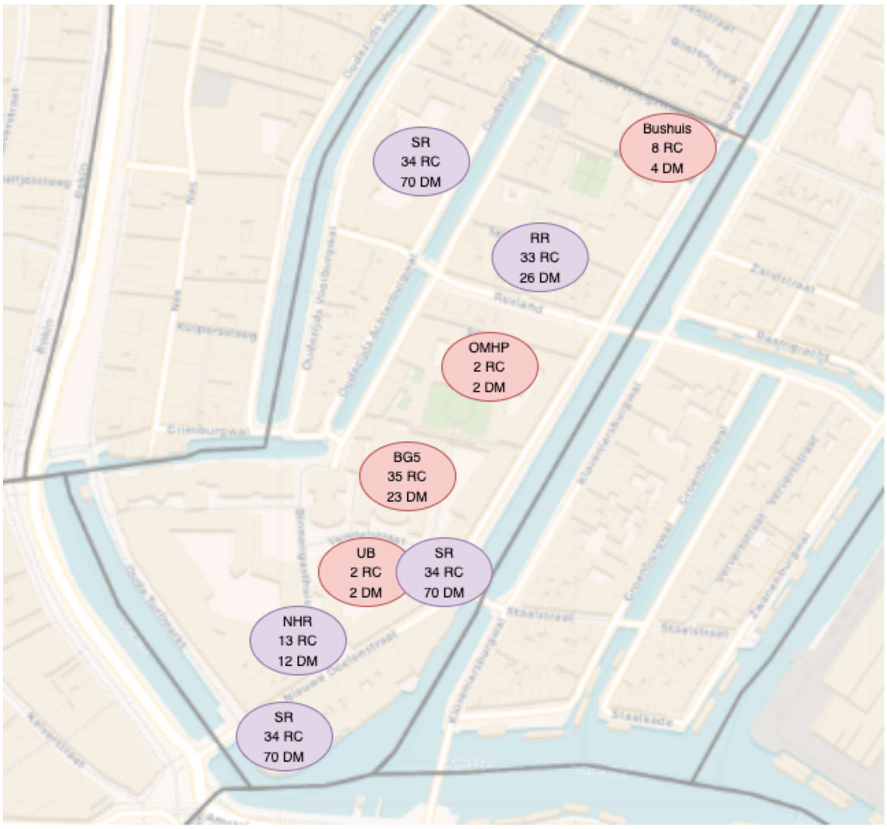

Figure 8-12. Locations and amount of freight

8.2. Phase 2: Designing alternatives

The design process is based on the morphological chart that was developed in Chapter 7. This chart outlines the main components of urban waterborne freight transport, serving as a foundation for the design phase. In the design process, the options for each component will be presented and described in order to populate the morphological chart and generate feasible alternatives. This will allow for a comprehensive exploration of various options and facilitate the creation of practical solutions for urban waterborne freight transport.

8.3. Choosing alternatives

First, the choice of transhipment facility has to be made. As the design must be able to be implemented within a short time, existing transhipment locations should be used. Amsterdam has several transhipment facilities. For all these facilities, the different components are discussed: the location, the transhipment equipment and what facilities, such as storage and consolidation, they have.

CTPark Amsterdam City (see figure 8-13) is located on the North Sea Canal, 1 kilometre from Amsterdam's A10 ring road and just 7 minutes by boat from the city centre. This gives the hub a unique location, in the port area, by the water, close to arterial roads and the city centre. The location is outside Amsterdam's ring road and therefore also outside the environmental zone. This means there are no restrictions on pre-transportation. The site covers 9.5 hectares and has a sheet pile wall creating a 180-metre quay. This allows ships to be loaded and unloaded. The hub has a warehouse area of as much as 125,000 m², 10,000 m² of office space and 1,600 parking spaces. Besides storage, the warehouse space can also be used for pallet storage and value-added services (VAS) such as packing, labelling or sorting. The site does not have a crane for transhipment (CTPark Amsterdam City, n.d.).

Figure 8-13. CTPark Amsterdam City

CityDock is located in the Westelijk Havengebied on Papierweg in Amsterdam. The hub is strategically located on the edge of the city right next to the motorway and on the waterfront. It is a construction hub specialising in construction, waste and goods handling. In total, CityDock has 3,500 m2 of outdoor space and 1,000 m2 of covered storage, spread over three locations on the outskirts of the city of Amsterdam. At this location, several cranes are available for loading and unloading goods from trucks and boats, and goods can be stored and consolidated. The location is within Amsterdam's ring road, but just outside the environmental zone. As a result, there are no restrictions on pre-transportation (Zoev City / City Dock, 2019b). For both options, the boats sail from the site across the IJ towards the city centre. Here, they enter the Oosterdok after which they sail via the Oostertoegang towards het Wallengebied.

Both transhipment locations in the case study of het Wallengebied are strategically positioned outside the environmental and weight restriction zone. Consequently, no restrictions are imposed on operations conducted at these locations. To provide a visual representation, Figure 8-14 depicts the precise locations of the two transhipment sites on the map.

Figure 8-14. Transhipment locations

From here, the vessel proceeds to the transhipment facility in the city. The route depends on where the transhipment can take place. There are 3 options for transhipment facilities. The options will be specified for the case. In the first option, goods are taken by vessel to a location close to het Wallengebied, but still just outside the area so there is more space for transhipment. Zoev City has a hub near the Oosterdok (see figure 8-15). This location has no crane or long-term storage. However, there is enough space for transhipment and temporary storage and consolidation before the goods go further into the city. There is also a cardboard press and pallets to put the cardboard waste back on the boat.

Figure 8-15. Oosterdok transhipment facility

The second option is the central logistics point, located in the Oudemanhuispoort in het Wallengebied (see Figure 8-16). This location is designed to receive bundled deliveries internally for further distribution. The idea is for vessels to dock at the quay in front of the CLP and for roll containers to be transported to the point from there. The distance involved is about 10 metres, requiring crossing a car park, a stretch of road, a step and a pavement. The site itself does not have a crane for the transfer. However, the CLP does provide space for storage and consolidation. The CLP can play an important role for return flows. Waste in het Wallengebied can be brought to this site so that the waste can be returned by vessel.

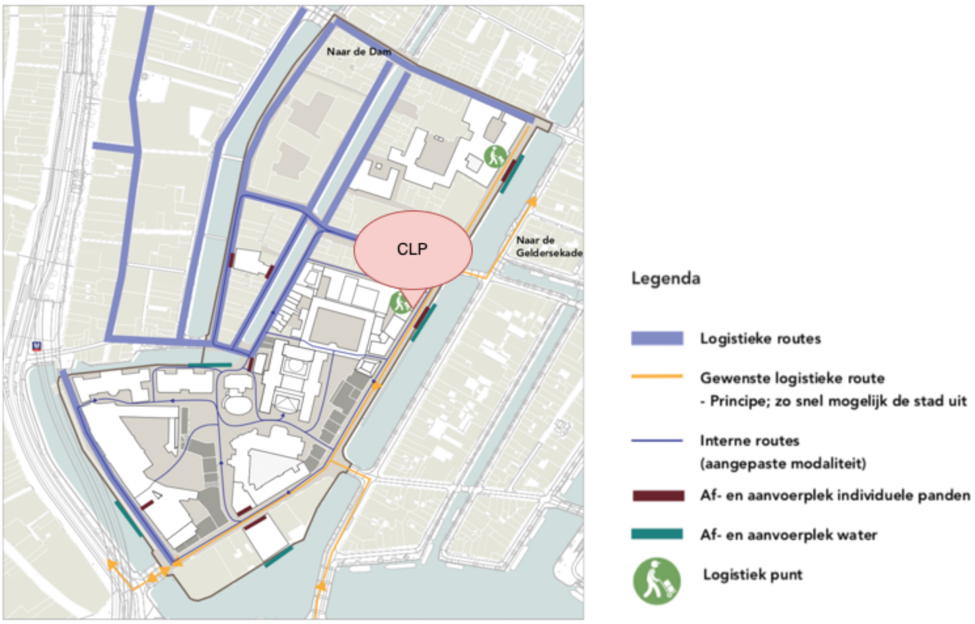

Figure 8-16. Centraal Logistiek Punt Universiteitskwartier

Finally, there is the possibility of stopping at different places where delivery is needed. These places do not have a crane or space for storage or consolidation. In these cases, the goods must be taken directly to the consignee. The place to stop depends on the capabilities and location of the receiver. At the same time, unnecessary stops should not be made and, where possible, goods for different locations that are close together should be unloaded at the same time. Looking at the location of UvA and the hotels included in the case and the possible stops determined for het Wallengebied, a number of stops can be defined. From these stops, only a short distance of less than 75 metres needs to be covered to the receiver. This is the maximum distance acceptable for the drivers to cover workload and time. The stops are shown in Figure 8-17.

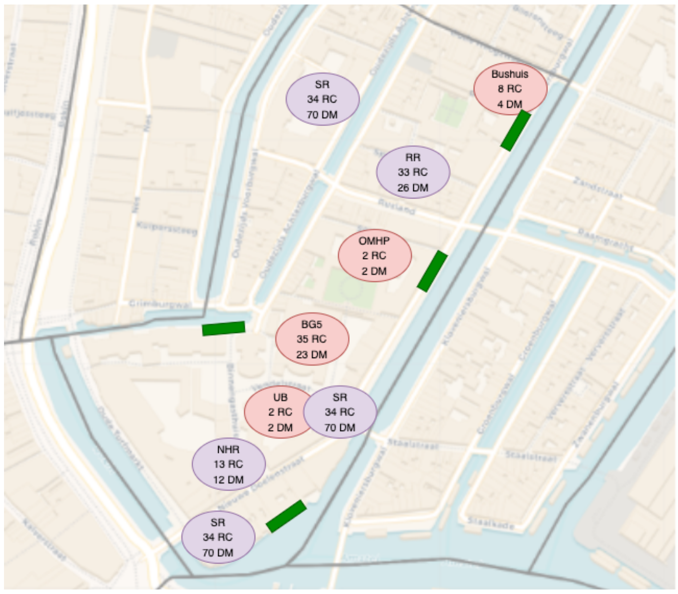

Figure 8-17. Stops for transhipment

For the vessel options, an electric vessel with manual operation is used in all cases. According to current and future regulations, the boat must be electric. Because the alternative has to be implemented in the relatively short term, it is not possible to look at autonomous boats. However, this could be possible in the future. All three options for a transhipment location in the city do not have a crane on the quay. So this must be present on the vessel. In this case, a crane or a movable platform could be used. This depends on the type of boat used. A tow/push boat is used. Finally, the size of the boat depends on how often and how many roll containers are delivered to the area. This case study considers vessel with a size of 20 x4.5 meter and a load capacity of 20 roll containers. This results in two options of boats, namely an electric tow/push boat, manually operated with a load capacity of 20 roll containers and a moveable platform for transhipment and an electric tow/push, manually operated with a load capacity of 20 roll containers and a crane for transhipment.

Next, the on-carriage from the transfer point to the receiver should be considered. The choice of on-carriage depends on the location of the transhipment facility. At a transhipment facility outside the city on the Oosterdok, the roll containers cannot be transported on foot. In that case, the Cargobikes, the LEFV and the road train remain. These can all cover the distance of 1,5 km to get to the CLP in het Wallengebied. If stopped at several points, the distance to the receiver is limited and can be covered on foot. The maximum distance carriers can walk is 75 metres. By using a Movexx-brand electric container puller, roll containers can be transported more easily. However, a container puller is not always the ideal tool, as these devices have difficulty going up and down the pavement when a container is attached. The hinge point potentially creates a dangerous situation, as the container puller hinges at a different angle to the roll cage. This could cause the load to fall off the container or be seriously damaged. This must be taken into account when choosing this mode of post-transportation. At the CLP point, containers can be transported over a distance of about 10 metres on foot.

To evaluate the impact of different factors on the alternative's score, two variables that can be modified are the type of load carrier and the time of delivery. The type of load carrier can vary from special crates, boxes, loading units for waste, and units for perishables. The time of day can be categorized into three options: morning delivery between 7 am and 10 am, daytime delivery between 10 am and 8 pm, or night-time delivery between 8 pm and 7 am.

Simultaneously, there is an alternative where water transport is not utilized, and only road transport is used. This option serves as the reference alternative, wherein consolidation of goods is applied wherever possible, and electric trucks are primarily used to transport them into the city.

The available choices result in the following alternatives for waterborne freight transport for several hotels and the University of Amsterdam in het Wallengebied.

1. The first alternative for urban waterborne freight transport includes moving goods from the Papierweg hub to the Oosterdok hub situated outside the city center via an electric tug/pusher boat. The boat, which can hold up to 20 roll containers, is operated manually. Upon arrival at the Oosterdok hub, the goods are unloaded from the boat with the assistance of a crane on the boat, bundled together, and conveyed by electric vehicles directly to their final destination in the city center. The goods are delivered straight to the receiver.
2. The second alternative is almost identical to the first alternative, except for the use of a movable platform instead of a crane on the boat for the transfer of goods.
3. The third alternative for urban waterborne freight transport involves the transportation of goods from the Papierweg hub to the Central Logistic Point (CLP) located in het Wallengebied using an electric tug/pusher boat. The boat, which can carry up to 20 roll containers, is operated manually. After reaching the CLP, the goods are unloaded from the boat with the help of the crane on the boat and transported by foot to the CLP, which is situated less than

10 meters away. The CLP provides storage space for goods and facilitates consolidation, and any waste generated can be stored and transported back to the Papierweg by vessel.

4. The fourth alternative is almost identical to the third alternative, except for the use of a movable platform instead of a crane on the boat for the transfer of goods.
5. The fifth alternative for urban waterborne freight transport involves using an electric tug/pusher boat to transport goods from the Papierweg hub to het Wallengebied. The vessel, which has a capacity of 20 roll containers, is manually operated. The vessel stops at various locations along the quay to ensure the shortest possible on-carriage, and the goods are unloaded from the vessel using the crane on the boat. From there, the goods are transported on foot to the receiver.
6. The sixth alternative is almost identical to the fifth alternative, except for the use of a movable platform instead of a crane on the boat for the transfer of goods.

In addition to considering waterborne transport alternatives, it is also important to take into account the current situation of transporting goods by road and the possibility of slightly modified options where electric vehicles are used to transport bundled goods into the city.

7. The seventh option entails using trucks fuelled by diesel to transport goods to an urban consolidation centre located on the outskirts of the city. From there, the goods are then delivered into the city using electric vehicles. The evaluation does not include any options where goods are transported directly into the city using diesel or petrol trucks, due to upcoming environmental zone regulations that will restrict their entry into the area. Only solutions that are future-proof and comply with these regulations are being considered.

8.4. Phase 3: Evaluation of alternatives

Various alternatives undergo evaluation based on distinct criteria that determine the performance of waterborne freight distribution in a given scenario. These criteria are used to determine how each alternative scores in terms of performance from the standpoint of different stakeholders. It's important to recognize that the scoring derived from these criteria is not a one-size-fits-all metric. Given the array of stakeholders, each with their own perspectives and concerns, the assessment of an alternative's performance might yield slightly different scores. This variability underscores the dynamic nature of the evaluation process and the nuanced interplay between the criteria and the stakeholders' viewpoints.

8.4.1. Economic impact

In this context, the economic impact of waterborne freight transport will be examined first, focusing on the affordability criterion. To evaluate the costs of the different alternatives, various factors must be taken into account, including initial investment costs, transhipment costs, and personnel costs. Since all alternatives require personnel, this cost is consistent across all cases. Initial investment costs refer to the capital required to purchase or upgrade infrastructure, equipment, and vessels. Alternatives one to six require the acquisition of vessels with a crane or a movable platform. For the first two alternatives, loading and unloading facilities are already available at Oosterdok, eliminating the need to purchase them. However, storage space is limited, so these costs will be minimal. In the third and fourth alternatives, loading and unloading facilities need to be installed at the quay near the Central Logistics Point, which requires construction. Additionally, the CLP needs to be set up for storage and consolidation, as well as waste management, resulting in additional costs. For the fifth and sixth alternatives, specific loading and unloading locations are required, but current infrastructure can be used. In the seventh alternative, no new infrastructure is required, and the current fleet can be utilized, resulting in minimal costs.

Affordability is identified as a criterion that holds importance for multiple stakeholders, including the shipper, logistics service provider, receiver, and local government. The shipper and receiver primarily emphasize cost-effective delivery, as depicted in table 5-1. However, considering the considerable investments required, these costs could potentially be transferred to the shipper and, subsequently, the receiver if the vessels aren't optimally utilized. This ripple effect can negatively impact cost efficiency. Minimizing investment costs becomes crucial in achieving the lowest possible expenses for the receiver. Consequently, alternative seven attains the highest score since it doesn't involve any investment. Conversely, alternatives three and four receive lower scores due to their requirement for investments in vessels and a central logistic point.

On the other hand, the logistics service provider focuses on investment viability and profitable operations, as indicated in table 5-1. They seek transport solutions that minimize costs and maximize profitability. Additionally, they are the party responsible for investing in the means of transport. Their ability to operate effectively relies on investments from various sources, including the local government. In the case of alternative seven, the logistics service provider makes the least substantial investments. Although this aspect is consistent across all alternatives, alternative seven offers the most advantageous investment scenario for them.

The local government can play a significant role in subsidizing substantial investments for waterborne transportation initiatives. It's important to note, however, that substantial investments are regarded as a negative factor in the morphological chart. Among the presented alternatives (1 through 6), all of them necessitate an investment in vessels, which can potentially be aided by the local government. Notably, alternatives one and two benefit from existing loading and unloading facilities, thereby eliminating the need for additional investments. Consequently, this configuration yields a more favourable affordability score for the local government. Similarly, the fifth and sixth alternatives also exhibit this advantage. Alternatives three and four, however, present a slightly different scenario. These alternatives require the establishment of dedicated loading and unloading sites, in addition to a central logistics hub, which might require substantial financial commitment from the local government. Remarkably, the seventh alternative receives the highest score. This is attributed to the fact that no new investments are required at all in this scenario. The resulting scores are illustrated in Figure X, encapsulating the comparative affordability assessment for each alternative. The government's perspective on investing in boats is distinct, as they place significance on sustainable investments. Consequently, this perspective reframes the notion of investment as a positive endeavor. As a result, the criteria associated with affordability are assigned scores ranging from neutral to positive. The extent of priority given to such investments can vary depending on the prevailing approach of the local government. If sustainability is a high priority, the positive impact of investments could be even more pronounced, leading to a more positive score for these criteria. In essence, the government's approach to investment underscores their commitment to sustainability, reshaping conventional views and influencing the scoring of related criteria in a positive direction. The scoring flexibility also acknowledges that different local government perspectives can contribute to a nuanced evaluation of investment-related factors.

8.4.2. Environmental impact

The environmental impact encompasses the vital sustainability criterion, which holds significance for all stakeholders participating in the process. The assessment of sustainability is based on the measurement of greenhouse gas emissions, primarily CO_2, ad air pollutants like SO_2, NO_x and PM10. All the alternatives employ electric vessels, which result in almost zero emission of these substances. Moreover, even in cases where post-transportation involves electric vehicles, there are no emissions of CO_2, SO_2, NO_x and PM10. This thesis does not evaluate the actual environmental impact of these vehicles. As a result, the alternatives receive a highly positive rating in terms of sustainability.

However, for the seventh alternative, where goods are transported to a consolidation centre via diesel-powered trucks and then delivered into the city using electric vehicles, there are emissions. The trucks used in transportation emit pollutants, thus reducing the sustainability rating of this alternative. Although it is possible to transport goods to the consolidation centre using non-electric cars, regardless of the environmental zone regulations, the alternative still generates greenhouse gas emissions and air pollutants. Therefore, the sustainability rating for this alternative can be considered neutral. This assessment applies uniformly to all stakeholders engaged in the process.

8.4.3. Transport impact

The transport impact pertains to the system's efficiency, reliability, and flexibility. These aspects hold significance for the shipper, logistics service provider, and receiver. In contrast, the importance of these criteria is relatively diminished for the local government and local residents (see table 5-1).

The utilization rate determines efficiency, but it can only be calculated retrospectively. To make a qualitative assessment of the transport system's performance, observations of resource utilization and waste minimization are crucial. Factors such as fuel efficiency, load capacity utilization, and route optimization can be considered. The first and second alternatives involve transporting goods from the UCC at the Papierweg to the Oosterdok hub by water. After bundling, the goods are transported to the receiver via the most optimal route. Efficiency is high if the vessel sails with a full load, but limited storage and consolidation space results in a neutral efficiency score. Additionally, waste collection must be well-timed to avoid any waste remaining at Oosterdok for long. In the third and fourth alternatives, goods are transported to the CLP by water and can be stored for longer periods. Since there is space for storage, the vessel can be used efficiently, and additional goods can be brought if needed. Also, there is space for waste storage, making the system efficient, resulting in a positive efficiency score. The fifth and sixth alternatives involve delivering goods directly to the receiver's quay, increasing transport efficiency. By stopping at several locations along the quay, only a short distance needs to be covered to the receiver. Using a moveable platform has additional advantages in this regard. The movable platform can carry several roll containers simultaneously, reducing handling time. The platform is unaffected by bank or quay heights and can adjust the degree angle to reach any height. The platform can extend far enough not to be bothered by greenery at the edge of the quays, making it easy to stop at multiple locations. Both options score well in terms of efficiency. Alternative six scores even better because of the efficiency of the movable platform. For this reason, this alternative has a very positive score. The seventh and last alternative is to transport goods by trucks to a consolidation centre outside the city and then deliver them by electric vehicles into the city. With space for consolidation and storage, goods can be delivered with a high utilization rate, making the system highly efficient. The seventh alternative scores positively in terms of efficiency.

The reliability of a transport system depends on its ability to perform its intended function with an acceptable level of performance, which can be affected by disruptions and delays. Disruptions and delays can occur due to various reasons including traffic congestion, accidents, roadworks and weather conditions. Traffic congestions is one of the most common issues that affect road transport, particularly in urban areas with heavy traffic. Congestion can result in significant delays, leading to late deliveries and decreased reliability of the transportation system. When it comes to transportation by vessel, reliability is higher. Waterborne transport is not subject to the same delays that road transport can face due to traffic congestion. Unlike roads, waterways do not experience heavy traffic, and there are usually no bottlenecks that cause delays in the delivery of goods. This means that waterborne transport can offer a more reliable and predictable transportation system, without being impacted by unpredictable factors such as traffic jams, roadworks or accidents. However, waterborne transport can still face other challenges, such as adverse weather conditions like storms or ice on the canals, which can affect navigation and cause delays or interruptions in the transport of goods. These challenges apply to all six transportation alternatives. The disruptions and delays that affect road transport also impact alternative seven where electric vehicles are used for on-carriage. As a result, this alternatives receives a slightly lower score compared to other waterborne options. Consequently, road transport receives a negative reliability score, while alternatives three, four, five, and six, which involve waterborne transportation and short on-carriage distances, receive positive scores. Alternatives one and two, which involve a combination of waterborne transport and on-carriage with electric vehicles, receive neutral scores in terms of reliability.

The flexibility of a transportation system is measured by its ability to adjust to external changes while meeting customer demands and maintaining an acceptable level of system performance. Indicators such as frequency of service and adaptability to demand can be used to evaluate this aspect. A higher frequency of service indicates a more flexible transport system that can handle increased demand and respond more quickly to changes in demand. When it comes to flexibility, transport by vessel is more challenging in terms of adapting to changes in demand compared to truck transport. Trucks have a much higher frequency of movement, making them more flexible than vessels. Therefore, options one to six are evaluated negatively in terms of flexibility, whereas option seven is given a positive score. This assessment applies uniformly to all stakeholders engaged in the process.

8.4.4. Social impact

In terms of social impact, the criteria of noise pollution and road safety are employed, primarily holding importance for the local government and citizens (see table 5-1). To assess noise pollution, factors such as vehicle type, speed, location, infrastructure, payload, time of day, existing noise level, and population density are taken into account. In the first two alternatives, the Oosterdok hub is used, which is located outside het Wallengebied, resulting in lower population density and less inconvenience for residents. Although electric vehicles are used to transport goods into the city, they produce minimal noise pollution. Therefore, both alternatives have low noise pollution and can be evaluated very positively. In the third and fourth options, the CLP is used, which is located in the heart of het Wallengebied, resulting in higher population density and noise nuisance during the transhipment of goods from the vessel. The time of day of the delivery is critical in minimizing noise emissions. However, the use of electric boats ensures quiet transport of goods over water. Both alternatives result in some noise pollution, but it is minimal and can be assessed as neutral. In the fifth and sixth options, goods are transhipped at multiple locations in the city centre, resulting in short-term noise nuisance for local residents. However, due to the brief duration of transhipment, the noise pollution is minimal and can be evaluated as neutral. In the seventh option, goods are unloaded directly from electric vehicles, resulting in minimal noise pollution similar to the first two options. Therefore, this option can also be evaluated positively in terms of noise pollution for both the local government and the citizens.

The transportation of goods can lead to an increase in accidents, and road safety is affected by the number of vehicles on the road and the type of area. Compared to road transport, the use of vessels can improve road safety. Hence, in terms of road safety, road transport will be the main focus of evaluation. In the first two alternatives, the electric vehicles need to cover a relatively long distance for on-carriage, and multiple vehicles are required to deliver the goods to the receiver. As the number of vehicles increases towards the city centre, where there is a lot of traffic, the likelihood of unsafe traffic situations also increases. Nonetheless, since the number of accidents is still relatively low, these alternatives are assigned a neutral score in regards to road safety. In the third and fourth alternatives, the distance from the quay to the CLP is short, but it is in a densely populated part of the city with a lot of other traffic and multiple transitions from road to pavement. This increases the chances of unsafe traffic situations, but the short distance minimizes the probability of accidents. Hence, both alternatives are assessed positively in terms of road safety. The fifth and sixth alternatives are similar to the third and fourth alternatives and are also assessed positively in terms of road safety. In the seventh alternative, like the first two alternatives, several transport movements are required into the city, resulting in a neutral assessment in terms of road safety.

8.4.5. Overview of morphological chart for the stakeholders

The outlined criteria, along with their respective scores, collectively generate a morphological chart encompassing all stakeholders in the process. This chart offers a comprehensive view of how each alternative fares across the criteria deemed significant to each specific stakeholder. Additionally, it has the potential to highlight both the advantageous aspects and potential challenges associated with each alternative. These aspects are succinctly examined for each stakeholder involved.

The morphological chart for the shipper is illustrated in Table 8-1, and remarkably, the same chart applies to the receiver, as seen in Table 8-3. Similarly, the Logistic Service Provider (LSP) showcases an almost identical chart, as displayed in Table 8-2. Notably, the only variance across these three tables pertains to the affordability score. The LSP features a marginally less positive outlook for alternatives one, two, five, and six, largely due to the transfer of investment costs to the shipper and receiver. Enhancing these scores for the concerned stakeholders could potentially involve leveraging local government investments. Further examination reveals a shared challenge among these three stakeholders: the negative impact on flexibility for the alternatives over water. Currently, these alternatives lack the desired level of flexibility compared to waterborne options. However, it's noteworthy that this situation might evolve with factors like increased customer demand, expanded vessel usage, and extended lead times. In such instances, the flexibility criteria may transition toward more positive scores. Moreover, focusing on utilization rates offers a pathway to improving efficiency for these stakeholders in relation to these alternatives. Enhancing utilization directly amplifies system efficiency, providing a potential avenue for enhancement.

Tabel 8-1. Morphological chart Shipper

Shipper					
Impact area	*Economic*	*Environmental*	*Transport*		
Criteria	*Affordability*	*Sustainability*	*Efficiently*	*Reliability*	*Flexibility*
Alternative 1	Positive	Very positive	Neutral	Neutral	Negative
Alternative 2	Positive	Very positive	Neutral	Neutral	Negative
Alternative 3	Neutral	Very positive	Positive	Positive	Negative
Alternative 4	Neutral	Very positive	Positive	Positive	Negative
Alternative 5	Positive	Very positive	Positive	Positive	Negative
Alternative 6	Positive	Very positive	Very positive	Positive	Negative
Alternative 7	Very positive	Neutral	Positive	Negative	Positive

Tabel 8-2. Morphological chart LSP

Logistic service provider					
Impact area	*Economic*	*Environmental*	*Transport*		
Criteria	*Affordability*	*Sustainability*	*Efficiently*	*Reliability*	*Flexibility*
Alternative 1	Neutral	Very positive	Neutral	Neutral	Negative
Alternative 2	Neutral	Very positive	Neutral	Neutral	Negative
Alternative 3	Neutral	Very positive	Positive	Positive	Negative
Alternative 4	Neutral	Very positive	Positive	Positive	Negative
Alternative 5	Neutral	Very positive	Positive	Positive	Negative
Alternative 6	Neutral	Very positive	Very positive	Positive	Negative
Alternative 7	Very positive	Neutral	Positive	Negative	Positive

Tabel 8-3. Morphological chart Receiver

Receiver					
Impact area	*Economic*	*Environmental*	*Transport*		
Criteria	*Affordability*	*Sustainability*	*Efficiently*	*Reliability*	*Flexibility*
Alternative 1	Positive	Very positive	Neutral	Neutral	Negative
Alternative 2	Positive	Very positive	Neutral	Neutral	Negative
Alternative 3	Neutral	Very positive	Positive	Positive	Negative
Alternative 4	Neutral	Very positive	Positive	Positive	Negative
Alternative 5	Positive	Very positive	Positive	Positive	Negative
Alternative 6	Positive	Very positive	Very positive	Positive	Negative
Alternative 7	Very positive	Neutral	Positive	Negative	Positive

In the context of citizens' concerns, the existing situation (alternative seven) emerges as the least favorable choice (see table 8-4). However, this perspective varies for other alternatives when it comes to the noise pollution and road safety criteria. For alternatives one and two, noise pollution scores better due to unloading activities taking place outside het Wallengebied. Conversely, these alternatives receive lower scores for road safety due to the utilization of electric small vehicles for on-carriage. Alternatives three to six follow the opposite pattern, with lower scores for noise pollution and higher scores for road safety. The prioritization between these criteria hinges on the prevailing circumstances and the potential to enhance either aspect. For instance, introducing additional safety measures for small electric vehicles could elevate the road safety score for alternatives one and two. Simultaneously, adopting new technology for boats and unloading equipment could lower noise pollution for alternatives three to six. Ultimately, the decision between noise pollution and road safety trade-offs depends on the contextual priorities and the feasible strategies to boost either criterion.

Tabel 8-4. Morphological chart Citizens

Citizens			
Impact area	*Environmental*	*Social*	
Criteria	*Sustainability*	*Noise pollution*	*Road safety*
Alternative 1	Very positive	Very positive	Neutral
Alternative 2	Very positive	Very positive	Neutral
Alternative 3	Very positive	Neutral	Positive
Alternative 4	Very positive	Neutral	Positive
Alternative 5	Very positive	Neutral	Positive
Alternative 6	Very positive	Neutral	Positive
Alternative 7	Neutral	Positive	Neutral

The local government faces similar considerations concerning the environmental and social impact criteria as the citizens, as outlined in table 8-5. In addition to these factors, the local government also evaluates the affordability criterion, categorized under economic impact. Alternative seven emerges as particularly favourable in terms of affordability. On the contrary, the other alternatives necessitate greater investments by the local government, which might appear unfavourable at first glance. However, the extent of investment in urban waterborne freight distribution is contingent on the prevailing local government's stance. The potential multitude of positive impacts associated with this endeavour could lead to a more favourable perspective. This indicates that these criteria might receive more positive ratings, depending on the priorities and decisions of the current local government.

Tabel 8-5. Morphological chart local government

Local government				
Impact area	*Economic*	*Environmental*	*Social*	
Criteria	*Affordability*	*Sustainability*	*Noise pollution*	*Road safety*
Alternative 1	Positive	Very positive	Very positive	Neutral
Alternative 2	Positive	Very positive	Very positive	Neutral
Alternative 3	Neutral	Very positive	Neutral	Positive
Alternative 4	Neutral	Very positive	Neutral	Positive
Alternative 5	Positive	Very positive	Neutral	Positive
Alternative 6	Positive	Very positive	Neutral	Positive
Alternative 7	Very positive	Neutral	Positive	Neutral

8.5. Phase 4: Implementation guidance

The implementation guidance for urban waterborne freight transport in het Wallengebied involves a collaborative session with stakeholders. While this thesis may not conduct these sessions due to time constraints, it is possible to explain the topics that can be discussed during these sessions. The set-up of the sessions would focus on the 16 steps outlined in Chapter 7, which provide detailed guidance for the implementation process. These steps serve as a roadmap for addressing the challenges and opportunities associated with urban waterborne freight transport in het Wallengebied. Considering the criteria scores, the sessions would identify trade-offs, showstoppers, and enablers. The goal would be to understand how areas with low scores or potential obstacles can be turned around to become feasible and green solutions.

One key trade-off that emerges is the balance between environmental impact and economic viability. While waterborne solutions score positively in terms of sustainability, they often face challenges in terms of affordability. This is primarily due to higher initial investments or longer transit times compared to other transportation modes. Addressing these economic challenges becomes crucial, and one success factor identified is providing financial support through subsidies, grants, or incentives. By offering financial assistance, the economic feasibility of waterborne freight transport can be improved, making it a more viable option.

Active involvement and engagement of the local government is also highlighted as a crucial success factor. The local government can play a pivotal role in providing regulatory support, infrastructure planning, and coordination. Their involvement helps integrate waterborne freight transport into the existing legal framework and ensures the necessary support for its successful implementation. During the collaborative sessions, stakeholders would discuss strategies to overcome these challenges and find solutions that balance environmental sustainability with economic feasibility. By considering the identified trade-offs and leveraging success factors, it becomes possible to develop a comprehensive plan for implementing urban waterborne freight transport in het Wallengebied, promoting a more sustainable and efficient transportation system.

Flexibility is a critical consideration in urban waterborne freight transport, as it determines the system's ability to adapt to external changes while meeting customer demands and maintaining satisfactory performance. However, striking the right balance between flexibility, cost-effectiveness, and sustainability poses a challenge. High flexibility often comes with increased costs and resource requirements, highlighting the need for careful decision-making. To address the flexibility trade-off, a comprehensive approach is necessary. This involves leveraging advanced technology and data-driven solutions to optimize routes and operations, fostering collaboration among stakeholders to address changing demands, and incorporating adaptable design elements into the waterborne freight transport infrastructure. By prioritizing flexibility during the planning and implementation stages, stakeholders can create a resilient and efficient urban waterborne freight transport system that can effectively respond to the dynamic nature of urban environments and evolving customer needs. This approach ensures that the system remains adaptable, competitive, and aligned with environmental and economic goals.

These examples of trade-offs serve as valuable topics for discussion during collaborative sessions. However, due to time constraints, their implementation goes beyond the scope of this thesis. Nonetheless, exploring and addressing these trade-offs can contribute to a deeper understanding of the complexities involved in urban waterborne freight transport and facilitate the development of more effective and sustainable solutions.

9. Validation of the design methodology

In this chapter, the focus is on the validation of the design methodology that has been developed as part of this thesis. The main objective of the validation process is to evaluate the acceptance of the design methodology by determining its usability and functionality. Section 9.1 will provide a comprehensive examination of various validation approaches available for the design methodology. Subsequently, a specific validation method will be selected for implementation in this thesis, and the rationale behind this choice will be discussed. In Section 9.2, the focus will shift towards the implementation of the chosen validation method. This section will outline the execution of the validation process. Lastly, Section 9.3 will present the concluding remarks of this chapter. It will summarize the key findings derived from the validation process, emphasizing the implications for the practical use and further refinement of the design methodology.

9.1. Different ways of validating the design methodology

Validating a design methodology for urban waterborne freight transport is crucial to ensure its effectiveness and usefulness. The validation process involves gathering feedback from stakeholders and experts who will be utilizing the design methodology. In the following sections, we will discuss different approaches to validate the methodology.

9.1.1. Stakeholder consultation session

An ideal approach to validate the proposed design methodology would involve organizing a stakeholder consultation session with representatives from each stakeholder group identified in Chapter 5. However, considering the constraints of limited time and resources, it may not be possible to invite every stakeholder individually. Instead, one organization from each stakeholder group can be invited to represent the interests and perspectives of that particular group.

The session can be conducted either online or in-person, with a preference for an offline session to facilitate better interaction among participants. The session would commence with an introduction, providing background information on the thesis project, the identified problem, the objective of the design methodology, and a brief overview of the requirements derived from the analysis. Following that, the development of the design methodology and its elaboration through het Wallengebied in Amsterdam can be presented. After the information has been shared, stakeholders would be encouraged to express their thoughts, provide feedback, and pose any questions they may have regarding the proposed design methodology. It would be important to document these questions, feedback, and criticisms to inform the final version of the design methodology and its elaboration for the case study. The session would continue until each stakeholder has had the opportunity to share their concerns, ask questions, and make remarks.

However, organizing such a stakeholder consultation session would require substantial time and resources. It would involve assembling a dedicated team to facilitate the session, designing the stakeholder consultation process, creating new data management plans and consent forms, documenting the entire process, analysing the outcomes, and incorporating the feedback into the final version of the design methodology. Given the limited time and resources available for the thesis project, this comprehensive approach may not be feasible.

9.1.2. Targeted interviews with experts

To conduct effective interviews for validating the design methodology for sustainable urban waterborne freight transport, it is important to ask questions that gather comprehensive feedback on different aspects of the methodology. During the interview, it is important to foster an environment of open and honest discussion, allowing the interviewees to freely share their perspectives, insights, and feedback on the design methodology. Follow-up questions should be utilized when necessary to explore specific areas of interest or concern in greater depth.

The questions can serve as a foundation for getting feedback and insights from stakeholders regarding the effectiveness, usability, and relevance of the design methodology for sustainable urban waterborne freight transport. It is essential to tailor the questions to the specific features and functionalities of the methodology being validated, taking into account the expertise and perspectives of the interviewees. Here are some examples of questions that can be asked:

1. What are your initial thoughts on the design methodology?
2. Do you believe the design methodology adequately addresses the challenges and objectives of sustainable urban waterborne freight transport?
3. Are there any key elements or considerations that you feel should be emphasized or included in the design methodology?

Upon completion of the interviews, the gathered insights should be carefully analysed and integrated into the ongoing development and refinement process of the design methodology. The feedback provided by the experts and stakeholders should be utilized to address identified limitations, enhance functionalities, and improve the overall usability and effectiveness of the design methodology. However, considering the limitations of time and resources, conducting interviews may not be a viable option for validation in this thesis project. As a result, an alternative approach should be considered for effective validation of the design methodology.

9.1.3. Self-validation

In addition to involving experts for validation, there is another approach to evaluate and validate the generic process through self-reflection. This self-validation can be conducted using the previously prepared requirements. During this process, the design methodology is carefully assessed to determine if the established requirements have been met and how they were addressed. Questions such as whether it was easy or challenging to meet the requirements, difficulties faced in obtaining the right data, and potential areas for improvement are considered. Valuable insights and observations from the design process are carefully noted, ensuring that the design process serves as a solid foundation for this evaluation. Furthermore, through reflection, it may become apparent that certain aspects have not been fully explored, warranting attention in a follow-up study. This reflective process also highlights areas where adjustments may be necessary to refine the design methodology.

9.2. Validation and limitations of the design methodology

The self-validation approach has been chosen to assess and validate the design process. The requirements outlined in Chapter 6 are used for this purpose and will be briefly explained below. The mandatory requirements serve as the baseline criteria that the design must meet. The initial requirement is that the design effectively transports freight. This condition was easily met in the process, as it solely concentrates on transporting freight from the urban consolidation centre to the final destination outside the city. The second requirement stipulates that the design must possess the intended capacity. In this context, the waterborne freight transport system should be equipped to manage the projected freight quantities within the urban area. Although progress has been made in outlining the involved quantities and sectors, much of the data, due to shifts caused by factors like the pandemic, is no longer fully representative. Consequently, further research is needed to establish accurate numbers. Requirement three concerns the scalability of the design. This implies that the transport system must be flexible enough to accommodate variations in demand, such as during peak periods or shifts in freight volume. The chosen alternatives align well with this requirement.

Requirement four emphasizes the interoperability of the design. This necessitates that the transport system can seamlessly integrate with other transportation systems, including pre-transportation. This condition is satisfied as the alternatives account for a location where pre-transportation is already in place. The fifth to ninth requirements encompass compliance with physical waterway characteristics, surrounding infrastructure, applicable laws and regulations, as well as technology availability and capabilities. These criteria are all addressed at the inception of the design process through the comprehensive problem description. This foundation shapes the preparation of alternatives. Likewise, requirements eight and nine, focusing on technology and cost-effectiveness, respectively, were proactively factored in during the initial stages with accurate situational mapping.

Subsequently, the trade-off requirements, including affordability, sustainability, road safety, compliance with noise regulations, efficiency, reliability, and flexibility, constitute the morphological chart's criteria. The selection of the optimal alternative considers the score attributed to these criteria. However, as highlighted in previous sections, these criteria are not uniformly scored by all stakeholders, introducing the potential for variation across alternatives and stakeholders.

The design methodology for designing sustainable urban waterborne freight distribution is a valuable resource. However, it is important to recognize that the methodology also has certain limitations that should be considered. One significant limitation is the methodology's reliance on the availability and quality of data. The accuracy and effectiveness of the methodology depend heavily on having relevant and up-to-date data. Insufficient or outdated data can compromise the reliability of the methodology's outputs, potentially leading to suboptimal design decisions. To address this limitation, efforts should be made to improve data collection methods and ensure data quality to enhance the methodology's performance.

Another limitation is related to the scoring of alternatives within the methodology. The alternatives discussed in the thesis are scored using colours based on their expected impact. However, it would be beneficial to test these alternatives before implementing them. By conducting testing and validation, valuable insights can be gained regarding potential bottlenecks and areas for improvement. This prior knowledge can greatly inform decision-making and contribute to the development of more effective alternatives. The evaluation and scoring process of the methodology may also be influenced by subjective judgments and preferences of stakeholders. This subjectivity introduces the possibility of biases and can lead to different outcomes depending on the evaluators involved. To mitigate this limitation, it is important to explore and develop objective evaluation criteria and methods that reduce subjectivity and enhance the reliability of the methodology's evaluations.

Lastly, in order to maintain usability and user-friendliness, the methodology may employ simplifications and assumptions that do not fully capture the complexities of real-world scenarios. While this approach facilitates usability, it can result in less accurate results or outcomes that may not perfectly align with practical implementations. To address this, future research should focus on refining the design methodology by incorporating a more comprehensive representation of real-world complexities while still ensuring usability. By acknowledging and addressing these limitations through further research and development, the design methodology can be improved to provide more robust and reliable assistance in the design, evaluation, and implementation of urban waterborne freight transport systems.

9.3. Conclusion

This chapter focuses on addressing the last sub-question, SQ4: What are the various methods to validate the design, and which one is selected? This chapter explores three distinct validation approaches. The preferred method entails engaging stakeholders through consultations or focused interviews with experts to gather input and feedback from pertinent parties. However, given constraints in terms of both time and resources, these validation methods are not feasible within the scope of this study. Therefore, the chosen avenue for validating the design is self-validation.

10. Conclusion

This chapter encompasses several key components. Section 9.1 focuses on the main research question and sub-questions, presenting the principal research findings. Additionally, Section 9.2 offers recommendations for future research and the expansion of the designed model.

10.1. Main thesis findings

At the outset of this thesis, a series of sub-questions were formulated to progressively address the main research objective: Design of a methodology for sustainable urban freight distribution via waterways. The following sections provide answers to both the sub-questions and the main research objective of this thesis.

SQ1: What is the current status of the system in which urban waterborne freight distribution will be implemented?

To answer this sub-question, a layered approach was adopted, leading to the formulation of four additional sub-sub questions, each addressing specific aspects of the system. These sub-sub questions were thoroughly explored and answered, resulting in valuable insights into the existing conditions and challenges surrounding urban waterborne freight transport. The findings and analysis from this sub-question formed the foundation for identifying and defining the requirements that the design of the design methodology should fulfil.

SQ1.1 What is the current status of urban freight transport and what are the key challenges in implementing sustainable transportation solutions?

A sustainable approach to goods distribution seeks to meet present needs without compromising the ability of future generations to meet their own needs. This thesis recognizes three fundamental components: economic growth, social justice, and environmental protection. Sustainable goods distribution must address the needs of the present generation by contributing to social justice and economic growth while also safeguarding the environment for both present and future generations. Several solutions can contribute to sustainable distribution, but it is crucial to understand the potential implementation challenges to avoid obstacles when introducing new concepts. One key barrier is the high capital expenditure involved in implementing sustainable transportation solutions. Additionally, conservative attitudes and a reluctance to share information pose challenges to adopting innovative practices. Another obstacle is persuading receivers to change their behaviour, as they may not fully grasp how their ordering patterns impact transport flows. The involvement of multiple stakeholders is also a significant challenge in achieving sustainable urban freight transport solutions. Effective collaboration and coordination among stakeholders with diverse interests and objectives are essential. It is important to acknowledge that there is no one-size-fits-all solution to enhance transport efficiency and address environmental, social, and economic impacts simultaneously. Solutions for urban freight transport should be based on a robust business case that takes into account the objectives and priorities of all stakeholders involved. By considering the various challenges and opportunities inherent in sustainable transportation solutions, this thesis aims to develop a comprehensive understanding and propose strategies that support the successful implementation of sustainable urban freight transport systems.

SQ1.2 What are the main functions of urban waterborne freight transport?

The essence of waterborne distribution comprises five main steps that are integral to the smooth movement of goods. These steps are pre-transport, transhipment from pre-transport to the vessel, waterborne transport, transhipment from the vessel to on-carriage, and on-carriage. The first step, pre-transport, involves activities and processes conducted prior to loading the goods onto the vessel. This includes tasks such as packaging, labelling, documentation, and consolidation of cargo to ensure proper handling and identification. Once the goods are prepared, the next step is the transhipment from the pre-transport mode to the vessel. This transfer typically takes place at a transhipment hub or terminal, where efficient loading and unloading operations are carried out to facilitate the transition from the initial mode of transport to the vessel. Waterborne transport forms the core phase of the distribution process. Here, the goods are transported through waterways using specialized vessels designed for cargo transportation. Upon reaching the destination, the transhipment process from the vessel to on-carriage takes place. This involves transferring the goods from the waterborne transport to another mode of transport for further distribution. Efficient transhipment operations ensure a seamless transition of goods between different modes of transport. Finally, the on-carriage step completes the waterborne distribution process. It involves transporting the goods from the quay to their final destination, which can be a distribution centre or directly to the end customer. This last leg of the journey ensures that the goods reach their intended recipients and concludes the waterborne distribution process. These five steps are essential components of waterborne distribution, highlighting the sequential stages involved in efficiently moving goods through waterways. Effective coordination, infrastructure support, and operational efficiency are crucial to ensure the smooth and reliable flow of goods throughout the distribution process.

SQ1.3 What urban waterborne freight transport initiatives have been implemented and what are the critical success and failure factors for large-scale implementation in urban areas?.
Drawing on the experience of inland waterway transport for urban distribution, a comprehensive analysis has identified critical success and failure factors that can be categorized into technical, social, political, economic, and legal aspects. The viability of waterborne transport as a competitive alternative to road transport largely depends on the presence of significant accessibility problems. In such cases, the success of waterborne transport initiatives hinges on several key factors. Firstly, the existence of a dense and navigable waterway network is vital for efficient and successful operations. Additionally, the strategic positioning of goods receivers, urban hubs for shippers, and suitable transhipment locations are critical considerations. The utilization of specialized vessels, equipment, and specific loading units also plays a positive role in the effective implementation of waterborne transport and enables seamless intermodal logistics. Urban waterborne freight transport initiatives have demonstrated feasibility across various segments, ranging from parcel delivery to waste transport for return flows. Moreover, combining waterborne transport with road vehicles for last-mile delivery facilitates its application in cities with less dense waterway networks. This hybrid approach allows for flexible and efficient distribution. Waterborne transport initiatives are often motivated by the desire to address growing accessibility problems, environmental pollution, infrastructure damage, noise pollution, and visual intrusion caused by road-based alternatives. The adoption of waterborne transport has shown a positive impact in mitigating these issues. However, it is essential to consider the various costs associated with waterborne transport, as they can present significant challenges to its widespread implementation.

One of the major failure factors lies in the additional costs incurred during waterborne transport, including initial investments and transhipment expenses. These costs need careful consideration during the analysis and planning stages to ensure the economic viability of the transport system. Successful implementation of urban waterborne freight transport concepts relies on the active involvement of both private and public stakeholders. Local authorities play a crucial role in managing and supporting innovative transport concepts. Collaboration between these stakeholders is instrumental in addressing failure factors and overcoming obstacles related to funding, infrastructure capacity, and the creation of suitable loading and unloading facilities in urban areas. Overall, an in-depth understanding of these critical success and failure factors is essential for formulating effective strategies and policies that promote the large-scale implementation of sustainable and efficient urban waterborne freight transport systems.

SQ1.4 What are the interests of the main stakeholders in urban waterborne freight distribution?
The stakeholders involved in urban freight distribution were categorized into five relevant groups: shippers, receivers, logistics service providers, local governments, and the citizens living and consuming within the considered urban area. Each stakeholder group has its own specific objectives related to urban freight distribution. In order to evaluate a given initiative, these objectives were translated into criteria, which can be further classified into impact areas: environmental, economic, social, and transport.

The waterborne freight transport evaluation framework selected a set of criteria based on comprehensive information. The most important criteria were then classified according to the defined impact areas. In the economic impact area, the focus is on the affordability of waterborne transport, which refers to the production costs associated with establishing and maintaining the transport system at the desired performance level. These costs are relevant to all stakeholders involved. The environmental impact area examines the sustainability performance of waterborne transport, including the emissions of greenhouse gases and air pollutants. Greenhouse gas emissions, such as CO2, and air pollutant emissions like NOx, SO2, and PM10, have negative impacts on the Earth's climate, human health, and the natural environment. The societal impact area encompasses noise pollution and road safety. Noise pollution refers to the noise caused by goods transport that is perceived as a nuisance by people. Road safety relates to traffic safety, including accidents and material damage. These impacts primarily concern citizens and local governments. Lastly, the transport impact area involves the shipper, logistics service provider, and receiver, and focuses on efficient, reliable, and flexible transport. Efficient transport relates to operational utilization and measures the capacity utilization of the transport system. Transport system reliability assesses the probability that the system can perform its intended function at an acceptable level, taking into account on-time performance and the quality of goods. Flexibility refers to the system's ability to adapt to external changes while maintaining performance that meets customer requirements.

By considering these impact areas and their corresponding criteria, stakeholders can evaluate and address the various aspects of urban waterborne freight transport, ensuring a comprehensive and balanced approach to sustainable, efficient, and customer-centric transport systems.

SQ2 What are the requirements for the design of urban waterborne freight distribution?
The analysis conducted in the previous questions serves as the foundation for formulating the requirements of the design. These requirements encompass both mandatory and trade-off requirements, which are further categorized into functional and non-functional requirements, along with any associated constraints. There are 16 requirements for the design of the urban waterborne freight transport system. These requirements encompass various aspects such as infrastructure planning, operational efficiency, environmental sustainability, and regulatory compliance. They are aimed at creating a comprehensive and optimized transport system that effectively utilizes waterborne freight transport within the urban context.

SQ3. *What methods can be used to design sustainable urban waterborne freight transport?*
The design methodology incorporates a comprehensive problem description that maps the existing urban logistics situation and establishes clear goals to be achieved through the implementation of urban waterborne freight transport. To develop such a problem description and define goals and objectives, the following steps can be followed: defining the current urban situation, setting objectives, and analysing the logistics context and processes.

The design functionality of the design methodology enables users to create and modify various aspects of urban waterborne freight transport. This functionality encompasses the components and factors discussed in previous chapters. Users can explore different design scenarios, make adjustments, and evaluate the impacts on freight transport efficiency and effectiveness. To facilitate this process, a morphological chart is utilized. Morphological analysis aids decision-makers in exploring the design space, identifying key design criteria and parameters, and evaluating trade-offs between different solutions based on multiple criteria. By breaking down the complex system into smaller components, morphological analysis simplifies the identification of potential solutions.

Once the alternatives are prepared, they are assessed and evaluated against the criteria established by the various stakeholders involved in urban waterborne freight transport. Evaluating the performance of measures and the methods chosen for evaluation are complex tasks. Morphological analysis scoring is a technique employed to evaluate the potential solutions generated during the morphological analysis process. While various scoring methods can be utilized, the fundamental concept is assigning scores to potential solutions based on predefined criteria. In the case of the design methodology, a scorecard is utilized, where criteria values are scored using smart colouring techniques.

In order to provide effective implementation guidance for urban waterborne freight transport, it is crucial to identify and address trade-offs, as well as critical success and failure factors associated with the implementation process. Implementing urban waterborne freight transport involves navigating various complexities and considering the diverse perspectives and interests of stakeholders. To ensure successful implementation, it is important to delve deeper into the concept of trade-offs and critical success and failure factors, understanding their implications and addressing them proactively.

10.2. Recommendations for further research

To address the limitations of the design methodology for sustainable urban waterborne freight distribution, several recommendations for further research can be made. Firstly, it is important to focus on improving data collection methods and data integration processes. Further research should explore ways to collect accurate and timely data on different aspects of urban waterborne freight transport, including infrastructure, vessel performance, logistics processes, and stakeholder preferences. Developing mechanisms to ensure data quality and reliability, such as data validation and verification techniques, will be crucial in enhancing the accuracy and effectiveness of the design methodology.

Secondly, conducting sensitivity analysis and further validation of the design methodology is recommended. This involves assessing the robustness and reliability of the methodology’s results by conducting sensitivity analysis and validation studies. By examining the impact of different data inputs and scoring methods on the results, researchers can identify potential uncertainties and areas for improvement. Validating the methodology’s predictions and recommendations through multiple case studies will also enhance its credibility and demonstrate its applicability in real-world scenarios.

Thirdly, it is recommended to organize collaborative sessions specifically for the case study of het Wallengebied. These sessions should involve key stakeholders, including shippers, receivers, logistics service providers, local authorities, and citizens. By facilitating joint discussions and encouraging active participation, valuable insights can be gained. This collaborative approach allows for the exploration of diverse perspectives and the identification of specific challenges and opportunities related to urban waterborne freight transport in het Wallengebied. Engaging stakeholders in this process can foster a deeper understanding of their needs and concerns, leading to more informed decision-making and the development of effective strategies tailored to the unique context of het Wallengebied.

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Appendix

Appendix 1 - Trends and statistics in urban freight transport

This section highlights the most far-reaching trends, which are expected to have a major impact on how urban freight transport is shaped in the future (MDS Transmodal Limited, 2012; Ploos Van Amstel, 2015). Trends in urban logistics vary worldwide and therefore this research focuses on European cities and specifically Dutch cities. European cities are similar in the sense that they are gradually built around medieval city centres where commercial and residential buildings are strongly intertwined (Ambrosini & Routhier, 2004). The layout creates synergy between a pleasant residential environment and economic activity. Striving to preserve this layout also has adverse consequences, as many European cities face spatial scarcity.

The increase in the number of people living in urban areas will increase the demand for goods in these areas. Furthermore, the rise of e-commerce has brought about many changes in urban goods transport. The role of retailers has changed as consumers can now buy many products online, whereas they used to buy most of their goods from retailers in the city centres. They now have to compete with highly efficient online shops. In 2021, online orders from Dutch consumers amounted to €30.6 billion. This shows an increase of 16 per cent compared to 2020. A total of 373 million online purchases were made, a growth of 13 per cent compared to 2020. Especially since the outbreak of the corona crisis, this spending has risen sharply. Towards the end of 2021, this number dropped and in the last quarter of 2021 there was even a small contraction of 1 per cent (Emerce, 2022). With the increase in online sales, retailers' profit margins are under pressure and they need to change their approach. Retailers are minimising their stock by applying just-in-time principles (Dablanc, 2011). In this way, expensive space for storage can be reduced and used for selling products. As a result, retailers order more frequently and in smaller quantities. This development has led to an increase in high-frequency shops that stock very small quantities of each good and replenish these goods ad hoc. In addition, interest in smaller shop formats is believed to be increasing again for number of very practical reasons. In smaller shop formats, the experience becomes more attractive from the consumer's point of view because personalised service becomes possible as retailers get to know their customers better, monitor their shopping behaviour and expectations, and consequently change the product offering, the presentation of goods and the layout of the shop, and offer new services (MDS Transmodal Limited, 2012). These changing ordering patterns have major implications for the activities of shippers and carriers.

Another trend relates to service levels. Customers nowadays expect delivery within a certain time frame. In most cases, this involves delivery within 24 hours of placing an order, but there are even companies, such as Instabox, that have started offering same-day delivery services. Instabox Group's clients include companies such as H&M, Ikea, Amazon and bol.com (Instabox, 2022). Receivers or end users have more freedom in choosing times and delivery locations. The combination of this extra service combined with increased transmission frequencies and decreased volumes make it difficult to use vehicle capacity efficiently (Boerkamps and van Binsbergen, 1999; Savelsbergh and Van Woensel, 2016).

There is also a trend in the diversification of goods flows. Besides the traditional flows from manufacturers to retailers, there are alternative goods flows that continue to grow due to increasing popularity. The largest alternative goods flow is caused by online sales platforms that allow customers to sell goods directly to each other. Retailers feel the need to participate in e-commerce because products can be delivered directly from suppliers or they can sell goods from their shop inventory over the internet (Hayashi et al., 2014). Return flows occupy an increasing share of the total flow of goods and include returning goods bought online and services such as waste collection.

Finally, the economy is in a transition from linear to circular. A circular economy should transform discarded goods into resources for others, closing cycles in industrial ecosystems and minimising waste. It changes economic logic by replacing production with sufficiency. This means reusing what can be reused, recycling what cannot be reused, repairing what is broken and remanufacturing what cannot be repaired (Stahel, 2016). The circular principle can be applied to the needs system of production and consumption, as companies focus on continually making the supply chain more sustainable by taking back discarded goods for repair, reuse, reassembly and recycling. Companies work together to use flows efficiently, share infrastructure and make transport as efficient as possible (Bal et al., 2018).

The above trends show a growth in transport movements in urban areas. This trend was already visible in recent years and will only increase further (MDS Transmodal Limited, 2012). The combination of this growth with the fragmentation of goods flows creates a challenge for carriers in the field of last-mile distribution. Last-mile distribution is already recognised as the least efficient segment of the supply chain (Gevaers et al., 2011). The fact that 85% of the transport market is made up of small freight carriers (Dablanc, 2011), which often operate only one freight truck, will only make it more difficult to carry out last-mile distribution efficiently. Major challenges therefore await the future of urban freight transport.

Appendix 2 - Components of urban waterborne freight transport

Besides the five main steps of urban waterborne freight distribution, there are a number of other very important components that need to be explored, i.a. the characteristics of the vessel, the equipment for transhipment, the load carrier and the loading units. The components are discussed in the appendix 2.

Pre-transport

There are several important components to consider in pre-transport for urban waterborne freight, specifically the vehicle type and propulsion type. For urban waterborne freight transport, a common example of a vehicle type for pre-transport could be a truck or a van. These vehicles are typically used to transport goods from the origin point (such as a warehouse or a production facility) to the waterway terminal (UCC) where the goods will be loaded onto waterborne vessels for further transport within the urban area. The propulsion type for vehicles involved in pre-transport for urban waterborne freight can vary based on factors such as vehicle size, distance travelled, and environmental objectives. Diesel-powered vehicles are still commonly used, but there is a growing emphasis on adopting more environmental-friendly options to reduce emissions and enhance air quality in urban areas. There are different types of vehicles using alternative fuels such as natural gas, petroleum gas, hydrogen, biofuels, electric vehicles with a battery or fuel cell, and hybrid vehicles (Departement Mobiliteit en Openbare Werken, 2013). The choice of propulsion type depends on infrastructure availability, vehicle range requirements, operational costs, and environmental considerations, as well as local policies and technological advancements.

Transhipment from pre-transport to the vessel

For transhipment from pre-transport to the vessel in urban waterborne freight transport, several key components are involved, including the location of the transhipment facility, the transhipment equipment, and the storage and consolidation of goods.

In terms of the transhipment facility's location, it is optimal to position it on the outskirts of the urban area. This allows the facility to serve as a centralized hub for consolidating goods before their transfer to the waterfront for water-based transportation into the city. The location of the facility plays a critical role in the feasibility and effectiveness of waterborne transport. It should be easily accessible for trucks delivering goods, ensuring smooth logistics operations. However, it is also important to strike a balance by placing the facility at a sufficient distance from the city center to mitigate the negative impacts associated with truck traffic, such as congestion, noise, and pollution. By finding this balance, the facility can maintain accessibility while minimizing disruptions within the urban environment. Additionally, the transhipment facility should be strategically positioned near a waterway that provides a strong connection to relevant waterways within the urban area. This integration with the wider waterborne transport network facilitates efficient movement of goods between the facility and the urban centre.

Loading and unloading goods from pre-transport onto the vessel in urban waterborne freight transport require appropriate equipment, with the crane being a key component. The crane's primary responsibility is transferring goods from the quay onto the deck of the vessel. The specific method employed for this operation depends on the type of crane utilized. Cranes can vary in size, accommodating different capacities and handling requirements. They are designed to handle various weights and sizes of freight, ensuring efficient and safe loading and unloading operations. The capabilities of the crane play a crucial role in facilitating the transfer of goods between the pre-transport stage and the vessel, optimizing the overall efficiency of the waterborne freight transport system.

Waterborne transport

In urban waterborne freight transport, several components play a significant role in ensuring efficient and effective operations. These components include vessel type, vessel size, vessel equipment, propulsion type, operating method, and route. Different vessel types are utilized in urban waterborne freight transport, designed specifically for navigating urban waterways and meeting the logistics needs of urban areas. Common examples include barges and tug/push boats, which are specialized vessels capable of pulling or pushing other vessels. The size of the vessel employed in urban waterborne freight transport is influenced by factors such as passage profiles, clearance heights of bridges and locks, and nautical requirements within the city (van Doorn & Zwart, 2016). These considerations dictate the maximum width, length, depth, and clearance height that vessels can have, ensuring safe navigation in urban waterways. Vessels used in urban waterborne freight transport can be equipped with various types of transhipment equipment to facilitate the efficient transfer of goods between the vessel and the quay. This equipment includes cranes, which can be mounted on the vessel or the quay itself. The choice of transhipment equipment depends on factors such as cargo volume, vessel size, and available infrastructure, aiming to optimize cargo handling operations.

The propulsion type chosen for urban waterborne freight transport vessels depends on vessel size, speed requirements, noise and emission considerations, and regulatory factors. Common propulsion types include electric, hybrid, and diesel propulsion, with each option offering different benefits and trade-offs. The operating method in urban waterborne freight transport can be categorized as manual, automated, or semi-automated. Manual operations involve human operators controlling vessel movements and cargo handling. Automated operations rely on advanced technologies for automating these processes, while semi-automated approaches combine human operators with automated systems. The selection of the operating method depends on technological capabilities, regulations, costs, and specific system requirements. The route planning for urban waterborne freight transport involves determining the optimal path for vessels to navigate within the urban area. Factors considered when planning the route include the location of waterways, accessibility of terminals, clearance heights of bridges and locks, and the desired destinations within the urban area. The goal is to establish efficient and cost-effective routes while considering environmental impacts, cargo handling optimization, and compliance with regulations and infrastructure limitations.

Transhipment from the vessel to on-carriage

During the transhipment process from the vessel to on-carriage in urban waterborne freight transport, three key components come into play: the location of the transhipment facility, the transhipment equipment, and the storage and consolidation of goods.

When selecting the location for a transhipment facility in an urban area, several principles are taken into account. These include choosing a hotspot with proximity to a significant number of logistics deliveries, strategically enhancing the existing network, and ensuring a standardized layout for safety on the water and road. Minimizing negative impacts and allowing for flexible use of the quay are also important considerations. These principles guide the decision-making process to find an ideal location that supports urban waterborne freight transport operations while minimizing adverse effects on the surrounding environment and maximizing functionality within the urban infrastructure.

In urban waterborne freight transport, the limited space and high traffic volume in the city centre can pose challenges for installing cranes on the quay. Efficient coordination and scheduling of loading and unloading operations are essential to minimize disruptions to surrounding traffic and ensure smooth freight transfer. Balancing logistical requirements with urban constraints is crucial to maintaining an efficient and sustainable waterborne freight transport system in the city.

During the transhipment process from the vessel to the quay in the city centre, temporary storage and consolidation of goods may be necessary. The choice of storage and consolidation method depends on factors such as the nature of the goods, available space on the quay, and required safety measures. Effective communication among stakeholders involved in the transhipment process is vital to ensure a seamless and efficient operation. Options for storage and consolidation include utilizing warehouses with specific storage conditions for different types of goods, such as perishable items, or arranging temporary storage within the means of transport located at the quay for on-carriage. By carefully considering the nature of the goods, available space, and establishing effective communication channels, the storage and consolidation process during transhipment can be optimized, ensuring efficient and secure handling of goods in the urban waterborne freight transport system.

On-carriage

In the on-carriage phase of urban waterborne freight transport, three key components are involved: vehicle type, vehicle size, and propulsion type. The choice of on-carriage vehicle type for urban waterborne freight transport depends on several factors, including the nature of the goods, distance to be covered, and local regulations. Common vehicle types used for on-carriage in urban waterborne freight transport include trucks, vans, electric vehicles, and cargo bikes. Selecting the appropriate vehicle type should consider factors such as the volume of goods, delivery distance, infrastructure availability, and local regulations promoting sustainable transport options. Assessing the specific requirements of the transport operation is crucial in choosing the most suitable vehicle type that optimizes efficiency, minimizes environmental impact, and ensures operational feasibility.

The size of the on-carriage vehicle for urban waterborne freight transport can vary depending on the specific requirements of the transport operation. The vehicle's size should be suitable for accommodating the volume and dimensions of the goods being transported. For smaller loads or last-mile deliveries, vehicles such as vans or cargo bikes can be used due to their compact sizes, allowing them to navigate through narrow urban streets and access areas with limited space. For larger loads or longer distances, trucks with varying sizes and capacities may be utilized. Careful consideration should be given to the size of the on-carriage vehicle to ensure efficient and safe transportation while taking into account any size restrictions imposed by local regulations or infrastructure limitations.

The propulsion type for on-carriage vehicles in urban waterborne freight transport can vary, with common options being diesel, electric, or hybrid propulsion. The choice of propulsion type depends on various factors such as the specific requirements of the transport operation, availability of infrastructure (such as charging stations for electric vehicles), cost considerations, and the sustainability objectives of the urban waterborne freight transport system. Evaluating the advantages and disadvantages of each propulsion type and considering the overall environmental impact is important in selecting the most appropriate propulsion type for on-carriage vehicles.

General

The final component in urban waterborne freight transport is the loading unit. A loading unit for urban waterborne freight transport is a standardized device or container used to transport goods. It is specifically designed to be loaded onto and unloaded from different types of load carriers, such as vessels and trucks. The loading unit provides a standardized and secure way to transport goods, ensuring their safety and efficient handling during the transportation process. Loading units come in various forms, including containers, pallets, or specialized cargo units. They are designed to accommodate different types of goods and can be easily transferred between different modes of transportation, allowing for seamless intermodal transport operations. Developing a standard loading unit is not very difficult in itself, but it is difficult to create a standard that is accepted and used by many actors. The standard loading unit facilitates transhipment, which means that large-scale use can have many positive effects, e.g. improved urban accessibility, reduced pollutant emissions, increased transport efficiency and reduced logistics costs. Implementation is the biggest problem because many actors need to make initial investments to reap the benefits (Quak. 2011).

The various components of urban waterborne freight transport have a significant impact on the outcomes of initiatives. The following section explains the significant influence of these components on the success or failure of such initiatives.

Appendix 3 – Initiatives in Europe

Several concepts have been set up in Europe and show that inland navigation can be used for urban freight distribution in several transport segments, ranging from parcel delivery to deliveries to local shops and restaurants and waste transport. Concepts in Paris, London and Lille will be discussed in this section.

Paris

Several initiatives using waterways for urban freight distributions have been set up in Paris. French service provider Vert Chez Vous has been operating a multimodal delivery service using two alternative modes of urban distribution since 2012. On the Seine, a "warehouse barge" called Vokoli operates with a fleet of electrically assisted cargo bikes to deliver small and medium-sized parcels of 10 kg. From the port of Tolbiarc, the vessel sails along the Seine past ten specially equipped stops for loading and unloading. At each stop, the electric bikes are unloaded and then serve recipients across Paris from business to business. Around 4,000 parcels are delivered daily to customers such as Raja (office supplies), Wala (cosmetics), Sanofi Aventis (pharmaceuticals), Muji and, recently, Okaidi, a children's clothing brand (Taniguchi & Dablanc, 2014). The city of Paris also uses the waterways to transport containers of food products to the city centre every day. French supermarket Franprix, supplies 80 shops in Paris in this way. From the port of Bonneuil-sur-Marne, 450 pallets of goods in 26 containers are transported daily by barge to the port of La Bourdonnais, near the Eiffel Tower. In the process, a distance of 20 kilometres is covered. From here, transport company Norbert Dentressangle transports the containers by ordinary diesel trucks to the final location. The reduction in CO2 emissions is estimated at 37% (Taniguchi & Dablanc, 2014). Not only urban distribution can be organised via water. Return flows or reserve logistics can also be done by water. Since 2005, there has been an initiative in Paris that combines product delivery and waste collection. This is run by household waste processor Syctom and paper company UPM Kymmene. Collected old newspapers and magazines are shipped by motor vessel with a crane on board to Grand-Couronne for recycling and the newly produced paper rolls are sent back to Paris by ship. Here, they are used by the paper company to print newspapers and magazines (Janjevic & Ndiaye, 2014).

Lille

In Lille, waterborne transport has been widely used to transport household waste since 1999. The idea arose when the city had to close its household waste incinerators, which processed up to 1,300 tonnes of waste per day. The port organised a barge system with open containers to transport household waste to a nearby waste treatment plant. Since 2007, the region's two main processing centres have been accessible by barge and 30 to 40 containers are sent by barge daily, resulting in an annual volume of about 220,000 tonnes of household waste (INE/EFIP, 2008).

London

In London, a similar initiative to the one in Paris was launched in February 2007 by the UK's largest supermarket chain, Sainsbury's. Daily deliveries of supermarket products were shipped from its distribution centre in south-east London via the River Thames to a location relatively close to the shop in west London. This concept tested the potential of transporting time-sensitive goods (INE/EFIP, 2008).

Appendix 4 - Initiatives in the Netherlands

In a number of cities in the Netherlands, various logistics flows have shifted from the road to the water. In Utrecht, the concept of supplying catering establishments in the city centre by means of the beer boat was the first to appear. This gave other parties ideas and so a private party, Mokum Mariteam, developed a similar concept for various goods flows in Amsterdam. Express Delivery Company DHL also developed a floating service center to deliver the postal and package flows in Amsterdam via the water. A pilot is currently being conducted where the catering industry around the Nieuwmarkt is supplied by water. In this subsection, consecutively, the Utrecht Beer Boat, the Amsterdam City Supplier, the DHL Floating Service Center and the Nieuwmarkt are treated.

Beer boat Utrecht

Utrecht is characterized by narrow streets, historical buildings, bridges and an abundance of water. Utrecht's policies, such as length and weight restrictions, time windows, city compartmenting, low-traffic zones and low-emission zones, combined with the city's characteristics, caused problems for urban freight distribution. This is how, in 1996, the concept of the Utrecht Beer Boat was born, an alternative to traditional road transport. The Beer Boat is (since 2010) an electrically powered barge that supplies the center of Utrecht with drinks and other catering equipment. The boat is owned by the municipality, which leases the boat to companies that provide the distribution services (Bertens, 2011). The boat has a hydraulic crane, so that the various roll containers can be deposited on the quay without damage. The ship has a loading capacity of 40 to 48 roll containers, which corresponds to a total loading capacity of six delivery vans or two trucks (Bestfact, 2013). In 2010, 65 customers were supplied with various goods; fresh, chilled an frozen products, beer, soft drinks and spirits. The ship can also be hired for occasional transports and deliveries and, in order to make optimal use of the ship, return cargo was also provided (Maes et al., 2015).

Mokum Mariteam Amsterdam

As in Utrecht, Amsterdam's policy restrictions are causing problems for urban freight distribution. This gave rise to the initiative "Vracht door de gracht" by Mokum mariteam. It is a joint venture between three shipping companies, a waste disposal company and a logistics service provider. Unlike the Utrecht Beer Boat, the City Supplier is an initiative that grew entirely out of the business community. The City Supplier takes care of the last few kilometres into the city via the waterway. The boat is driven by electric motors, has a length of 20 metres and a width of 4.25 metres, and has a loading capacity of 85m3 or 56 tonnes. Post-transport is provided by a manually operated, electric pallet truck and return flows are included for optimal capacity utilization. Since 2010, Mokum Mariteam and the United Companies of the Food Center Amsterdam (FCA) have been working together to focus on goods flows that can be transported in high volumes (Maes et al., 2015).

DHL floating service Amsterdam

The floating DHL service was originally a tourist canal boat that was converted into the DHL floating service center in 1997 by removing the seats, adding postal sorting tables and installing walking bridges on the vessel. The boat departs from the Westerdokskade, where it is loaded with mail supplied by DHL trucks. From there, the vessel follows a fixed route through the inner city, stopping at various locations in the city. The boat then returns to the Westerdokskade where the DHL delivery vans are ready to collect the return mail. From the vessel, the mail and packages are delivered by bicycle and for larger package by van. The ship has a length of 17 meters and net volume for transport of 30m2 (Maes et al., 2015).

Nieuwmarkt

A pilot on the Nieuwmarkt is investigating whether supplies for the catering industry around the Nieuwmarkt can be moved from the road to the water. The pilot is carried out by a collaboration of electric carrier ZOEV City together with Sligro, Bidfood and the municipality of Amsterdam. Every morning at 8:30 am, an electric boat will sail from a distribution centre of the two wholesalers to the docking point near the Nieuwmarkt, the Geldersekade. Here, rolling containers including beer, frozen bitterballen and fresh produce, are lifted onto the quay from a large container lying on a boat. From there, with the cargo is delivered by several light electric freight vehicles (LEFV) to the participating catering establishments (about 20 catering establishments around the Nieuwmarkt). Stocking takes until the afternoon. In the initial phase, about 30 containers are transported a day. These are rolling containers that are also used in supermarket supplies (Gemeente Amsterdam, 2022c). The aim is to replace the seventeen Sligro and Bidfood trucks that currently supply the catering establishments around the Nieuwmarkt with electric boats and electric vehicles. Both the crane, sailing and charging of the cars will be electric. The batteries also provide cooling on the boat and in the trolleys. These have to remain constantly below a certain temperature. The pilot has been temporarily paused. Battery capacity is a challenge as everything is electric. The pause will be used to make improvements in the power supply of the electric boat and the manoeuvrability of the electric vehicles. Cost and volume also proved an issue as transport became about 50% more expensive than by road. Capacity utilisation needs to be increased to solve this problem.