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SCHOOL OF BUSINESS, ECONOMICS AND LAW

Recycling Barge in Gothenburg – a sustainability analysis

Master's degree Project in Logistics and Transport Management

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Abstract

Previous innovations and services that have been developed in the area of sustainable urban mobility have sometimes had consequences that lead to unsustainability. This creates the need for investigating the potential outcomes of a service to identify the degree of sustainability. Based on the estimated growth in population and consumption an increase of waste and need for recycling can be expected. The purpose of this study is, therefore, to investigate under what conditions a recycling barge operating on inland waterways in the city of Gothenburg could be a sustainable option for urban waste logistics. The theoretical framework gives the reader the needed knowledge base for understanding how sustainable development is defined. Moreover, it gives insights on how sustainability interferes with urban logistics and make urban logistics a rather complex topic, which also interfere with waste projects conducted in urban areas. The strategy and design of this research is a qualitative case study. The major findings of this research are that the barge has significantly higher emission costs than the trucks currently going between the recycling centers and the sorting facility. The result also shows that the cost of operating the barge is high compared to the amount of waste collected. On a more positive note, the result indicates that the recycling barge has the potential of promoting people to recycle their waste more correctly and in this way create social value. The result also shows that the recycling barge creates a social value that the existing recycling centers have not been able to create. It can be concluded that the barge will mainly add on cost and environmental impact rather than replace parts of it created by the already existing recycling centers. Some of the important characteristics identified for making the recycling barge a sustainable option are; having an engine that emits low amounts of emissions, an infrastructure that enables the barge to be emptied without the need of being towed for a long-distance and having a high loading capacity so the barge gets fully utilized when moved.

Keywords: recycling, barge, sustainability, Gothenburg, urban logistics, waste logistics

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Agneta Andersson   Alicia Björkman

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Abbreviations

US	United States of America
GDP	Gross Domestic Product
Mile	Accounts for a Swedish mile (mil) of 10 kilometers
Km	Kilometer, distance of 1 000 meters
North side	North side of the river Göta Älv, including Eriksberg and Sannegården
South side	South side of the river Göta Älv, including Stenpiren, Rosenlund and Stigbergskajen
Södra Älvstranden	Stenpiren, Rosenlund and Stigbergskajen
CO_2	Carbon dioxide
NMVOC	Non methane volatile organic compound
CO	Carbon monoxide
NOx	Nitrogen Oxides
SOx	Sulfur Oxides
CH_4	Methane

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1. Introduction

The introduction chapter gives an understanding of the background of the researched topic. Followed by, the topic being problematized, and then the purpose of the research is introduced including the research questions. The research is conducted as a collaboration with actors and these will be introduced. The chapter ends by introducing the delimitations of the research.

1.1. Background

The phenomenon of people leaving rural areas and moving to urban areas has increased rapidly in the last decades. More than half (55 percent) of the world's population lived in urban areas in 2018 which is an extensive increase from 30 percent in 1950 (United Nations, 2018a). An increase that especially has occurred in already highly dense cities (Ritchie & Roser, 2020).

United Nations (2018b) observed that businesses in urban areas are more concentrated with a more diverse and well-educated labor force, leading to entrepreneurship and technical innovation flourishing compared to rural areas. Urbanization can, therefore, enable economic growth, poverty reduction and human development.

It has also been revealed that because of higher incomes, urban residents, in general, consume more per capita than residents in rural areas (United Nations, 2018b). In Sweden, the increase in urbanization and population, in general, has also led to an increase in consumption (Holmberg & Hansson, 2009). The annual household consumption has had an extensive increase over the last 20 years, and in 2018 it was 2 101 billion SEK (Roos, 2019). Figure 1 below, shows how the consumption per capita has steadily increased over the past 20 years (Statistics Sweden, 2019). The urbanization has slightly stagnated since 1975 but there has still been an increase while the rural areas have declined. The growth of urbanization since 1950 can be seen below in Figure 2, it also contains the forecast of increased urbanization until 2050 (United Nations, 2018c).

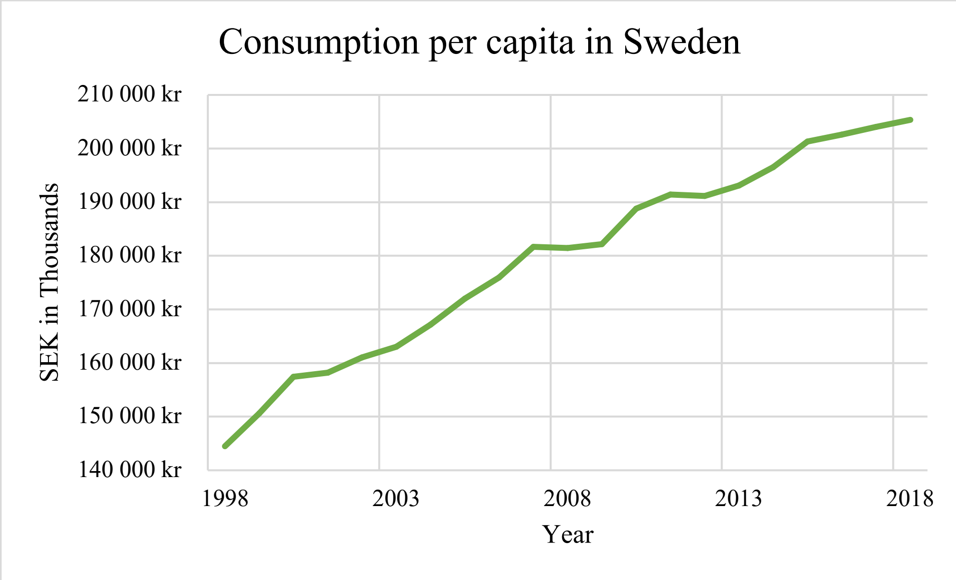

Figure 1. Consumption per capita in Sweden. Source: Statistics Sweden, 2019

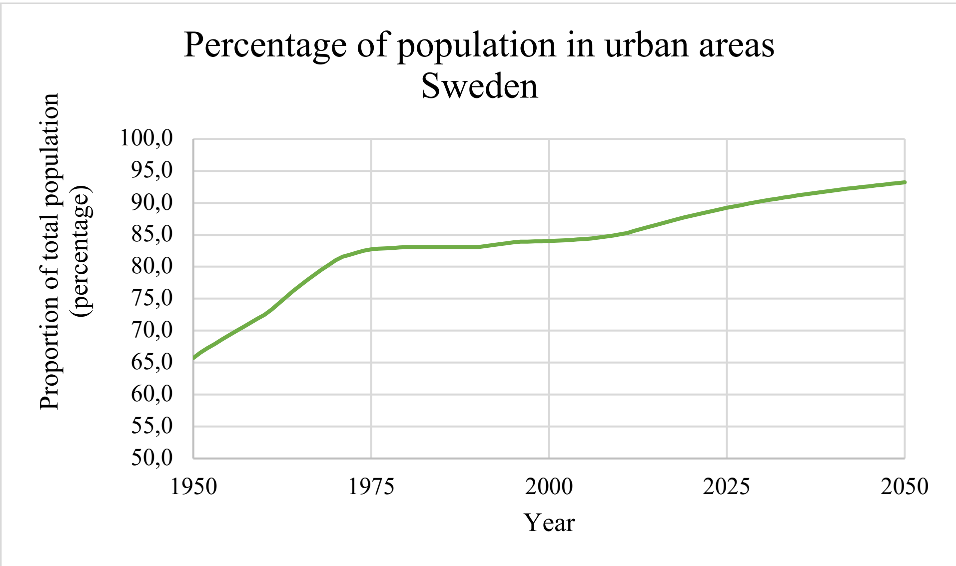

Figure 2. Percentage of population in urban areas Sweden. Source: United Nations, 2018c

While overconsumption and all of its consequences are widely debated topics today it is not a new phenomenon. Already in 1997, Mark Sagoff wrote the paper *Do we consume too much?* detailing how the expanding economy in the United States leads to an increase in consumption and how that was unsustainable. In many cases examples are often based on the issues in the US. However, Lee, Pant & Ali (2010) argues that the same trend exists in all developed countries to a certain extent. Especially, the Western countries have issues with overconsumption.

The combination of increasing population density and growing consumption lead to larger volumes of uncollected waste. A development with multiple health hazards. Urbanization has also shown to increase local emissions as a result of more concentrated energy use and congestion. In fact, social, environmental and financial sustainability are all expressed to be closely related to urbanization (United Nations, 2018b). National Geographic (n.d.) express that because of this there is a need for strong city planning with a close partnership between the private and public sector to develop new services.

1.2. Problematization

Gothenburg is expected to grow by close to a third of its current population[1] by 2035 which the municipality expresses demands sustainable planning. Several projects have started with the purpose of managing the expected increase of population. Projects such as an extension of the public transport system, development of the infrastructure, new housing, and offices (Gothenburg City, 2020a). There are also projects running by both the public and private sectors to develop the needed services for a sustainable living in urban areas. One of these initiatives is DenCity, consisting of several projects developed to create innovative solutions for sustainable urban mobility (Lindholmen Science Park, 2020).

There are, however, past examples that show how innovations and services that have been developed in the area of sustainable urban mobility have had consequences that led to unsustainability. For example, crowd shipping is one of those innovations, the service led to a change in behavior and as a consequence creating more environmental issues than before. The idea was to have people already traveling on the road for various reasons (such as work and groceries) to handle the last-mile delivery of smaller packages in the city, often via an app. In some cities such as Brussels, this has had some unexpected negative consequences where individuals used this service to make extra money. Even if they did not already have an errand or reason to be out driving, thus creating more congestion on the road. This creates the exact opposite effect of the whole idea of the project[2].

[1] City of Gothenburg current population is 579 281 as of December 31st, 2019. Retrieved from Statistics Sweden, Sunday April 19th, 2020.
[2] Cathy Macharis, Mobility, Logistics & Automotive Technology Research Center at Vrjie Universiteit Brussel, Lecture: Urban Freight Transport, University of Gothenburg School of Business, Economics and Law, Tuesday January 22nd, 2019.

Due to the above-mentioned issues, there is a necessity for investigating the potential outcomes to identify the degree of sustainability and not only observing the feasibility and need for the service. Based on the estimated growth in population and consumption, an increase in waste and the need for recycling can be expected. In parallel with this, the city of Gothenburg has established a long-term goal of decreasing the amount of traveling by car and instead promote walking, cycling, and public transport (Gothenburg City, 2020b). A development that most likely would mean that fewer people will have access to a car. Urban waste logistics projects are currently ongoing and contain attributes that talk towards being sustainable solutions but the question of how sustainable they really are still stands (Huchon, 2018; Stadt Zurich, 2020; Stockholm vatten och avfall, 2019)

1.3. Purpose of Study & Research Questions

The purpose of this study is to investigate under what conditions a recycling barge operating on inland waterways in the city of Gothenburg could be a sustainable option for urban waste logistics. A relevant topic due to increased urbanization which creates current and future sustainability issues demanding strong city planning. One of these issues is the increased amount of bulky waste and how to handle the logistics of it in a sustainable way.

Research question 1. How did the trial of the recycling barge acting on the inland waterways of Gothenburg contribute to a more sustainable city?

Research question 2. Based on this, what characteristics are most important in making such an initiative a sustainable option?

1.4. Collaborative Partners

The research is conducted in collaboration with two of the actors involved in the recycling barge project occurring in Gothenburg. Below these two actors will be described.

CLOSER

CLOSER is an organization that works towards establishing collaboration and projects between actors from the business community, industry, university and institutes, cities, regions, and government agencies. The organization work as a neutral platform with the goal of enhancing transport efficiency. This means using resources, energy, environment, and economy as efficiently as possible to achieve increased sustainability, growth, and competitiveness. CLOSER enables new, innovative products and solutions by gathering different actors and together with these identify needs and ideas that in the long run can help the transport industry (CLOSER, 2020a).

SSPA

SSPA is a consulting company and provide solutions within the maritime field. The company acts in the global market and describe themselves as bringing value through sustainable, innovative, and world-leading maritime solutions. SSPA got its foothold in the Swedish market in 1940 and since then SSPA has tested more than 8 000 ship hull forms (SSPA, 2020).

1.5. Delimitations

To maintain the scope of the research several delimitations have been made. Firstly, the research only focuses on the City of Gothenburg. The result can only be representative of the infrastructure and recycling behavior of Gothenburg and its inhabitants. If other cities possess a similar contexture as Gothenburg the result may be applicable. However, this is believed to be out of the scope of the research and has not been investigated.

The research is delimited by only researching the barge from the aspect of waste management. Inland waterways have the potential of being used for a wide range of operations but all operations have their infrastructure and challenges. The scope was, therefore, set on waste management.

This study is focused on the sustainability of the service of the barge from a financial, environmental, and social perspective. For this project the research disregards the technicalities of the barge and tugboat, such as engine and fuel types. Even though, it can have an impact on environmental sustainability the scope has been narrowed to exclude this part. This has been done as neither of the authors have the technical knowledge to properly include these aspects to make a fair analysis.

The aspect of why to recycle and the impact of doing so is neither treated. The authors have decided to limit the research by assuming that recycling waste has a positive impact on the environment. Therefore, no discussion will be held related to why people should recycle.

2. Theoretical Framework

The theoretical framework consists of three parts. First, the subject of sustainable development will be introduced together with the method of analysis. Then, a short section on the complexity of urban logistics is presented before moving to waste management projects. The below Figure 3 visualizes how sustainable development acts as an overhead and is a part of the complexity of urban logistics, and how this then interlinks with waste projects. The discussed topics are selected because they give the needed knowledge base for understanding how sustainable development is defined. Furthermore, it gives insights on how sustainability interferes with urban logistics and make urban logistics a rather complex topic which also interfere with waste projects conducted in urban areas. These are valuable insights since the project researched is operated in an urban area and have to deal with the complexity of urban logistics.

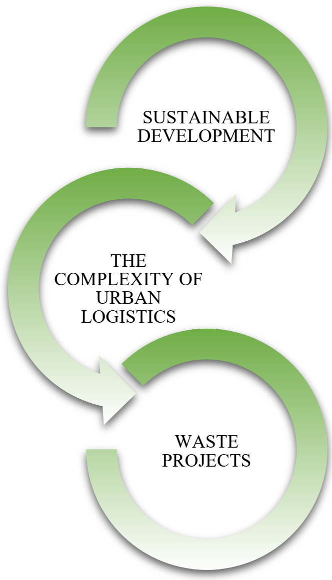

Figure 3. How the theoretical framework is interlinked. Source: Created by the authors

2.1. Sustainable Development

When the word sustainability first came around in the late 1970's early 1980's the meaning of it was heavily dependent on the context it was used in. Even though, there was a consensus of sustainability being the desired goal of environmental management it had different meanings in different contexts and situations (Brown, Hanson, Liverman & Merideth Jr., 1987). It was not until the 1987 General Assembly when the United Nations released the report *Our Common Future*, or Brundtland report, that a general definition was created. This meant that it received a wider spread and more ground to stand on as it was now also considered politically as an international policy (Chalmers, 2019). Rather than using the word sustainability the Brundtland Report called it sustainable development and defined it as:

''Development that meets the needs of the present without compromising the ability of future generations to meet their own needs''

(UNESCO, 2020).

Today, sustainable development consists of four segments; society, environment, culture, and economy, segments that can be used on their own or together, but they are always interlinked (UNESCO, 2020). The measurement of sustainability can vary a lot depending on the industry and context. Because of this, companies at times have issues with both how and why they should measure sustainability (Elkington, 1998). There are many different ways on how to measure and analyze sustainability.

The most common is to use the 'sustainability triangle' or 'three pillars of sustainability' in some form. This method looks at three aspects; financial, environmental (also sometimes referred to as ecological), and social (Kleine & von Hauff, 2009). While there is no defined person or group behind the concept it is widely considered to have been developed after being mentioned in the reports; Agenda 21, the 2002 World Summit on Sustainable Development, and the Brundtland report. Even if neither publication presents a clear framework or background it is still considered a good and viable method to use (Purvis, Mao & Robinson, 2019).

The different aspects measure the impact they have, good or bad as well as any potential improvements. Meaning, financial considers all financial aspects of a company or project, is it profitable and are the costs worth it. Environmental looks at the impact it has on the environment, does it generate emissions, are the effects positive or negative. Finally, social is about the impact a project has on society as a whole, does it make the society better or worse (Baumgartner & Ebner, 2010).

2.1.1. Social

Social sustainability is not as developed as the concepts of financial and environmental as social have often been accounted for in the other two. Fortunately, more and more organizations are trying to integrate social aspects into their work on sustainability, both in theoretical and practical terms. While there is no official definition, social sustainability is often considered to be policies that work to integrate and include diverse groups and cultures in an equal way (Dillard, Dujon & King, 2009).

One of the reasons social sustainability is often overlooked is due to the fact that social sustainability deals with changing people's behavior. Something which is often very hard and requires companies to get an understanding of why people would refuse the change before it can properly be implemented. This is something that needs to be developed further in order to make it easier for companies to promote social sustainability, not only internally but also externally by having a positive impact on the local communities (Vallance, Perkins & Dixon, 2011).

2.1.2. Environmental

Environmental sustainability is something that is increasingly becoming more and more important in today's society. Largely due to the increased conversations about climate change and the overuse of natural resources throughout society on a global scale. This has created a larger awareness amongst the general public allowing consumers to put pressure on both local and national authorities as well as businesses to be mindful when it comes to environmental issues (Fulton, Clarke & Amparo Albán, 2017).

Environmental issues are a big part of the United Nations Sustainable Development Goals for 2030 (United Nations, 2020). The Sustainable Development Goals together with an increased public awareness has led to many businesses, both private and public, striving to be more environmentally sustainable and to be open with how and what they do. This does not only lead to high customer satisfaction but is also financially advantageous for the business as investments are increasing most in companies that do something for the environment (Fulton, Clarke & Amparo Albán, 2017).

2.1.3. Financial

Financial sustainability differs from its social and environmental counterparts as financial structures are fully manmade and not developed by nature. Financial sustainability is often defined as one of two scenarios. The first one is when economic development has no negative impact on social and environmental development. Meaning, an increase in capital should not come at the expanse of social or environmental capital.

The other scenario is when financial sustainability is equal to economic growth, where an increase in the capital can be at the expanse of the others (KTH, 2018). In a more practical sense, Solow (1991) talks about financial sustainability being a sort of obligation to preserve present-day economic opportunities. By making sure that, rather than increasing them for future generations, especially in terms of production capacity, they are left as they are. As this view is often interpreted as no changes should occur to the economic structure Anand & Sen (2000) try to make it clearer. They developed the concept further by explaining that economic opportunities should be left for future generations to live a worthwhile and fulfilling life by preserving the good and change the bad economic behaviors. To conclude, financial sustainability is to preserve economic opportunities for future generations to live a good life.

2.2. The Complexity of Urban Logistics

There is an increase of attention towards urban transport amongst researchers and policymakers. The amount of published papers has increased yearly between 2000 and 2015 as well as the available funding at both local and European levels. The increased attention is among others a result of rapid urbanization, concerns for pollution and retention of a safe city, and the opportunities that are created from new available technology (Lagorio, Pinto & Golini, 2016). Even if urban logistics have negative impacts it is a vital component as it supplies goods to stores and acts as a link between supplier and customers. Urban logistics is also a big source of employment for cities (Crainic, Ricciardi & Storchi, 2004).

The demand for urban logistics increases with economic growth and urbanization. Meaning, that the demand for urban logistics can be expected to increase (European Commission, 2019a). An outcome of that is congested roads which lead to longer private and commercial journeys. Resulting in economic losses, for example the European economy lost approximately one percent of the GDP yearly due to congestion (Schliwa, Armitage, Aziz, Evans & Rhoades, 2015). Executing urban logistics operations with high quality and efficiency has become difficult because of congested roads, space constraints, and limitations of infrastructure, leading to negative economic outcomes (Behrends, 2016a). Traditionally, transportation of goods has not been addressed by the public authorities to any high extent except by actions such as regulation on parking, street access, and hours of operation. Freight transport has mainly been a private industry, and authorities have felt that they do not want to get involved in private firms' operations. This has, however, changed considering that the conditions are getting worse (Crainic, Ricciardi & Storchi, 2004).

Janhäll & Carlson (2017) argue that congestion increase emissions per kilometer as it creates a different driving behavior leading to an increase in fuel consumption and, thus, higher emissions. While both CO_2 emissions and local emissions are considered air pollutants and are potential health hazards in large doses (Nunez, 2019). It is the local emissions that are more dangerous as it includes NOx, SOx, and particles, all more of a health hazard than CO_2 even in small doses (World Health Organization, 2020). Decreasing congestion is, therefore, an important goal.

However, by decreasing congestion for a specific transport mode, the travel time becomes improved which leads to more passengers choosing to transport themselves with this mode of transport. An effect called travel time elasticity and describes the relation between traffic increases and travel time. A travel time elasticity of 0,5 means that a decrease of ten percent of travel time gives an increase of five percent in traffic. The emission effects of decreased congestion do, therefore, not become as high as it would have without the travel time elasticity. Well managed traffic will decrease congestion accordingly and improve travel time but increase the traveling by car. The authors do, however, present that the driving behavior that occurs in a queue involves a lot of starts and stops, creating two to three times higher CO_2 emissions compared to a smooth traffic flow (Janhäll & Carlson, 2017).

Behrends (2016a) expresses that the growing urban logistic problems lead to increased awareness of urban logistics. Resulting in cities around the world engaging in projects to manage urban logistics with the goal of improving logistic performances while reducing the negative environmental and socio-economic impacts. Unfortunately, the results from many of these experiments have shown unwanted side effects and a problem of projects being dependent on subsidies from governments. An outcome partly because of the complexity and diversity of urban logistics. A complexity that derives from cities consisting of several economic sectors and has a large pool of various supply chains and beyond that cities differ in conditions such as size, geography, climate, and economy. Cui, Dodson & Hall (2015) exemplify this by writing that the positioning of a major port in a historical city center will create one type of planning, regulatory, and infrastructure. While the positioning of a major port located in an urban periphery will create another type of planning, regulatory, and infrastructure. Meaning, that the development of freight networks needs to be crafted to account for the specificity of that city (Behrends, 2016a; Cui, Dodson & Hall, 2015).

2.3. Waste Projects

Waste logistics is one of the sub-categories within urban logistic and emphasizes on the waste that occurs from urban activities. Waste that needs to be collected and transported to recycling facilities and disposal sites. This demands dedicated pick up tours and specialized vehicles (Behrends, 2016a). With increased urbanization and consumption comes an increased pressure on waste logistics and a need to develop waste collection and waste logistics to meet the demands of today and tomorrow. Otherwise, there is a risk that urban areas will be overflown with uncollected waste. To do this technological developments and sustainable solutions will be the answer (den Boer, Kok, Ploos van Amstel, Quak & Wagter, 2017).

As mentioned above all cities have their infrastructure and because of this have different opportunities and potentials to use it within waste logistics. There have been quite a few projects over the last 20 years where existing city infrastructure has been used for waste management. Unfortunately, many of them no longer exist due to various reasons, most commonly lack of investment and interest from politicians (Janasz, 2016). However, there are still some successful ones that are still active and three of them will be showcased below. These three projects were chosen not only due to them still being active, but they have an impact on the scope of this research. The French example was chosen as it also deals with a barge. The Swiss was selected due to the usage of trams which could also be incorporated into existing infrastructure in Gothenburg. Last, the Swedish was chosen as an example because it is in Sweden and could have an impact on Gothenburg as well.

2.3.1. Recycling Barge River'tri in Lyon

Lyon is a city located in southeast France and together with the suburbs Lyon has a population of 1,6 million. Lyon is also located on the confluence of the two rivers, Rhônes and Saônes (Nationalencyklopedin, 2020a). Because of this an investigation was made to see if the river could be used for waste logistics as most of the existing recycling centers are located outside the city and require a car to reach them. With a growing population, Lyon felt the need for additional recycling centers. However, due to lack of available land it would have been impossible to build one in the city.

The recycling barge was developed in 2016 and is a collaboration between Suez France, Campagnie Fluviale de Transport (CFT), Campagnie Nationale du Rhônes (CNR) and Voies navigables de France (VNF) with funding from both the city and region (Suez, 2020). The idea they developed is River'tri, a waterborne recycling center that is open to the public every Saturday between 9 – 17 at the Fulchiron quay in the fifth arrondissement. The barge accepts the same type of bulky waste a regular recycling center does (Huchon, 2018). Both customers with cars, bikes, and by foot are welcome to use the River'tri. In the evening it returns to its designated parking spot in the Port of Lyon where it is emptied and the waste join the regular recycling chain (Initiatives for the Future of Great Rivers, 2020).

2.3.2. Cargo Tram & E-Tram in Zurich

Zurich is the largest city in Switzerland and has a population of almost 385 000 (Nationalencyklopedin, 2020b). Despite its small size, Zurich has a total line length of 165 km in its tram network but not all are used in the current public transport system (Eltis, 2015). With this in mind the CEO of the municipal waste company Entsorgung und Recycling Zürich (ERZ) initiated and developed the project in 2003 together with the local tram company VBZ. Converting old trams and wagons into a functional waste collection unit and using the existing tram tracks. In the beginning the service served only four stops before going into its designated depot where the containers were emptied.

The Cargo Tram operates on those tracks that are rarely used by public transport as to not interfere with the regular tram service. An additional unit only for electronic waste, the E-Tram was introduced in 2005 (Arvidsson & Browne, 2013). Today, the Cargo Tram and E-Tram serves eleven stations on a set schedule where they stop at each stop ten to twelve times a year. As most of the stops are located at or near the tram lines end stations the idea is that if people cannot walk to a stop, they can take the bus and/or tram there. The Trams accept any bulky or electronic/industrial waste as long as it is not longer than 2,5 meters or weight more than 40 kilos. The service is available to private persons only, no company can use it, and to encourage people to use the service it is free for all Zurich residents (Stadt Zurich, 2020).

2.3.3. Popup Återbruk Stockholm

Stockholm is the capital of Sweden and has a population of 960 000 with many people living in very dense and congested areas with limited access to cars (Stockholms Stad, 2020). Because of this Stockholm Water and Waste has created the popup Återbruk project together with KTH, the Royal Institute of Technology in 2017 that encourages locals to not only recycle but to reuse as well by making the process easy and location accessible (Mohammadi, 2019).

Popup Återbruk consists of two containers that are easily moved and are available at different places in the city during weekends April to October. The places it pops up at is made for pedestrian and bicycle access to make it easy to recycle without having to use a car in the city. If needed Återbruk also has a cargo bike available for free rental. Besides acting as a recycling station that accepts the usual bulky waste such as plastics and cardboard Återbruk also accepts hazardous waste such as chemicals and batteries. The only requirement is that you should be able to bring it with you without using a car. In addition, it also has a reuse corner where people can drop off furniture, clothes and other household items. Those items with lower value are available for people to pick up for free at Återbruk whereas the more valuable items go to second-hand stores Stadsmissionen and Myrorna (Stockholm vatten och avfall, 2019).

The theoretical framework has created a good foundation for understanding how sustainable development is defined and how organizations tend to work with sustainable development. It has also given insight into how urban logistics has become a rather complex topic. The conditions for urban logistics are getting worse with increased congestion and emissions. Where projects brought forward to manage urban logistics to increase logistics performance have shown unwanted side effects and dependence on subsidies from governments. An outcome that partly has to do with cities being different and projects, therefore, needs to be adapted to the specific city. Within waste management a few projects acting in urban areas have succeeded and been active at least a few years. What can be concluded from the ones presented above, is that they all have been adapted to the infrastructure of the specific city. The knowledge retrieved from the theoretical framework will be of value throughout the result and analysis. Especially, when it comes to the usage of the quays and distances traveled by the barge. Since, these are impacted by the existing infrastructure of Gothenburg.

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3. Methodology

In the methodology section the research strategy and design will be presented. There is also a short introduction to the barge project. This is followed by an introduction to the method of data collection and content analysis. The section ends with a short discussion on the research quality and the ethics surrounding it.

3.1. Research Strategy

The goal of this study was to understand under what conditions a recycling barge could be a sustainable solution for urban waste logistics which lead to the decision of conducting a qualitative study. A research strategy that tends to emphasize words and the interpretation of them (Bryman, 2012). However, a qualitative strategy does not interfere with the ability of using quantified data. Quantified data can be used but depending on how the data is analyzed determines if it becomes qualitative or quantitative. Meaning, that a qualitative study does not only limit the research to the interpretation of words (Collis & Hussey, 2014). The selection of a qualitative strategy was decided because of its ability to create a deeper understanding of a phenomenon and context (Justesen & Mik-Meyer, 2011). And its focus on interpretation of data (Bryman, 2012) which was seen as needed for answering the research questions and fulfilling the purpose of the study.

In Gothenburg all the recycling centers are owned by the municipality and, thus, funded by local taxes. However, the daily operations are outsourced to waste management company Renova. Additionally, the environmental and social aspects are interlinked with societal impacts. Leading to the study taking a societal perspective. To make a comprehensive analysis of the recycling barge as it is a new recycling system was put in comparison to the old one, which is the regular recycling centers.

3.2. Research Design

The research has been conducted as a case study. A research design that implies a detailed and intensive investigation of a certain case in its natural setting (Bryman, 2012; Collis & Hussey, 2014). The term "case" is usually associated with a location such as a community or an organization (Bryman, 2012). In this study "case" refers to a floating recycling project taking place in the city of Gothenburg's inner waterways. The decision of only investigating one project occurring in Gothenburg was built upon the arguments of cities having different infrastructures and are govern differently which means disparity in conditions (Cui, Dodson & Hall, 2015; Behrends, 2016a). A case study enables a more in-depth investigation and it is common that several methods are used to make the study more profound (Collis & Hussey, 2014). Selecting a case design empowered the authors of this thesis to get an in-depth understanding to, later on, generalize these into theories.

3.2.1. Case Description: Surface-efficient Transport Solutions – The Recycling Barge

DenCity is a collaboration project between industry, society, and the educational sector, it is currently ongoing and lead by CLOSER (CLOSER, 2018). DenCity as a project started with a pre-study in 2015. The goal of the study was to investigate how the changing urban centers can make it possible to create innovative transport solutions that are also sustainable in the long run. The project concerns both freight and public transport. The project has now reached stage three, which is the implementation stage (CLOSER, 2020b). The recycling barge is one of those project ideas that was tested in real life. It was designed to function as a floating recycling center on the river Göta Älv and accepts most of the same bulky waste a normal recycling center does. A short introduction to the recycling barge itself can be found below in Figure 4. There is also a picture showing how the barge is towed by the tugboat.

Barge: Melina
25,12 x 10,18 meters, and a deadweight of 279 tons

Tugboat: B/B Hector
11,65 x 4,45 meters, engine Scania DS 14 314 hp from 1989

Containers:
4 recycling center containers divided into three sections each
2x20 ft containers for hazardous waste and reuse

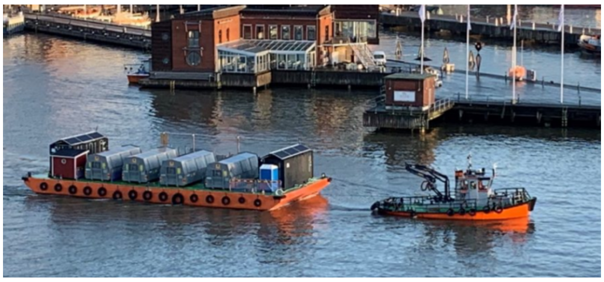

Figure 4. Information about the barge and tugboat. Source: Respondent 4

Photo credit: Fredrik Wilkensson

Bulky waste can be divided into various categories such as combustible (furniture and books), non-combustible (glass and porcelain), hazardous waste (spray cans and paint cans), and electronics (cables, lightbulbs and batteries). Due to limited space the barge does not accept garden waste and appliances such as a fridge or stove (Gothenburg City, 2020c). Furthermore, there is a collaboration with Björkåfrihet, a chain of second-hand stores, to collect clothes and furniture for reuse. One objective was to reduce the pressure on regular recycling centers and to offer a service where there is no need to swipe a recycling card. A recycling card gives the cardholder access to a recycling center six times a year for free and then a fee is paid (Gothenburg City, 2020c). Another objective of this trial phase was to see if the river could be used for waste logistics. It would also be more accessible for the people living by the river and those that do not have access to a car (CLOSER, 2020c).

3.3. Research Method

As expressed above, case studies tend to use several methods to make the study more profound (Collis & Hussey, 2014). An approach used in this study, in total three different methods were used to collect data which were, secondary sources, interviews, and observations.

3.3.1. Data Collection from Secondary Sources

Bryman (2012) express that the search and use of secondary data can be a frustrating and protracted process. By phrasing that even if documents are available it does not mean that it is less time consuming or easier to deal with than primary data. Collis & Hussey (2014) defines secondary sources as data collected from existing sources such as publications and databases.

Previous studies have been conducted on the recycling barge project and the authors believed it to be vital to get an overview of the already existing data. Furthermore, as this research was conducted with collaboration from involved stakeholders it created access to data that could be of value. Enabling the authors to get a good foundation to understand which empirical data was missing and was needed to be supplemented to be able to answer the research questions. Data that was seen to have the potential to be valuable was found in the following:

Articles

The authors have been searching for chronicles, submissions to papers, and blogs discussing things such as the recycling centers in general, the recycling behavior of inhabitants, issues, or strengths with the existing system. This was done by using the search engine Google, Google Scholar, and the University of Gothenburg's online library. The goal was to get an understanding of the current situation with recycling centers and people's attitude towards this. Furthermore, the mileage cost for private cars was retrieved from an article published by Teknikens Värld (2018). In 2018 the car magazine performed a large driving test with 116 car models where the cost per mile was one of the parameters tested

Survey

Following the six-week trial run in the Autumn of 2019, SSPA administrated a phone survey to 100 random selected visitors with ⅓ from each area (Eriksberg, Sannegården & Södra Älvstranden). The authors got access to this survey because of the collaboration with SSPA and it was a valuable set of data for the sustainability analysis.

Statistical Data

During this process the authors were given access to the statistical data from the trial run of the barge. The data included the number of visitors of each quay and the amount of waste that was collected at each quay. In addition, the city of Gothenburg provided data on the number of visitors and waste collected from regular recycling centers as well. Data over wrongly sorted waste was also provided to the authors.

Furthermore, the population amount as well as car ownership of Gothenburg was collected via Statistics Sweden online database. Also, Google Maps and Ratsit were used to collect the number of inhabitants within the postcodes that were found in the catchment area of the quays. Additionally, data regarding the traffic intensity in Gothenburg were collected from the city's official website where they publish statistics regarding the traffic intensity.

3.3.2. Data Collection from Primary Sources

Unstructured and Semi-structured Interviews

The authors conducted unstructured interviews through phone and face to face while semi-structured interviews were conducted via email. Unstructured interviews are described as allowing the respondent to answer freely, with just a single question being asked and then interfere with following up question when believed to be worthy. An unstructured interview tends to give an impression of it being more of a conversation than an interview (Bryman, 2012). The respondents were the experts within their specific topic, and it was believed to be valuable not to limit the interview to the authors' pre-knowledge. An unstructured interview was, therefore, selected for the face to face and phone interviews. The respondents were informed of why the authors contacted them and had time to prepare for this before the interview and then speak freely about it when the interview took place.

When it comes to semi-structured interviews a few questions were prepared in advance, questions that encourage the respondent to talk about the main topics of the research. If needed follow-up questions can be asked (Collis & Hussey, 2014). A semi-structured approach was used when executing the interview through email, this was selected based on the authors having specific questions that were seen to be valuable to ask but did not want to limit the interview by not being able to ask follow-up questions.

To protect the privacy of the respondents and the organizations they work for, they have been anonymized and categorized based on their expertise. In total, interviews were held with five respondents, the full list is shown below in Table 1.

Respondent 1	Waste and Water Expert
Respondent 2	Environmental expert and developer of CUTS MODEL
Respondent 3	Maritime Expert
Respondent 4	Barge Expert
Respondent 5	Emission Expert

Table 1. Respondents that were interviewed. Source: Created by the authors

All interviews were executed through email but for respondent 2, two additional interviews were held, one face to face and one through phone. An additional phone interview was held with respondent 5 as well.

Using email as a platform for conducting the interviews was selected because of its ability to send a small set of questions and then give the respondents time to reply in their own pace. Bampton & Cowton (2002) express that this takes pressure from the respondent and provide the opportunity to reply with well thought out answers. Furthermore, it gives the interviewers the same opportunity of following up with well thought out supplementary questions.

The authors turned to experts within the areas of waste management, environmental issues, maritime transport, and emissions. This meant that the discussed topics at certain points become rather complex. Using emails as an interview platform allowed the authors to work with the received answers and understand these, before replying with supplementary questions which was seen as valuable.

There was one interview that occurred face to face, this was when the authors met with respondent 2. The goal of the interview was to get an understanding of how the CUTS model was constructed and how to work with it. The CUTS model was used to interpret parts of the collected data and is further explained in chapter 3.4.2. The authors saw it as vital to have a physical meeting since it enabled demonstrations and explanations along with the visualization of the model. It also created the ability to ask follow-up questions in real-time which was seen as necessary. The authors later held a follow-up interview through phone with the respondent. This was done to create some further clarification concerning the model.

One phone interview was also conducted with respondent 5 and could be seen as a complementary interview after having had a previous email conversation with the respondent. The interview was held to get some further explanation of what had been replied through emails and the goal with the interview as a whole was to identify the emission factors for the barge.

Participatory Observations

Marshall & Rossman (1989) defines observation as a systematic description of events and behaviors in the social setting of the study. There are different types of observations that are used in different settings and fields of studies. For this study, the authors choose to use participating observations. DeWalt & DeWalt (2002) argues that participatory observation is a process that allows researchers to learn about the different behavior and activities of the people in the study in a natural setting by participating and observing the process.

The authors have been participating in meetings concerning the barge which created further insights to the project and the thoughts behind it. Getting a wide understanding of the project created a better foundation to recognize the barge's different impacts on the already existing system. The authors have mainly been listening and taking notes of what has been said, however, the attendance knew the authors role in the meeting. Kawulich (2005) argues that taking field notes is an important part of participated observation as it allows researchers to keep track of the activity as well as helping when it is time to write down and explain the observation in the research report. By attending the meetings, the authors were also given access to the material presented during the meetings. A list of the meetings the authors attended is shown below in Table 2.

Date	Where/How	Who
23rd of January 2020	Skype	CLOSER and a French equivalent
3rd of March 2020	Skype	SSPA, Gothenburg City and a Swedish consultancy agency within sustainable solutions
31st of March 2020	Skype	Gothenburg City and a Swedish consultancy agency within sustainable solutions

Table 2. Meetings the authors attended. Source: Created by the authors

3.4. Analysis and Interpretation of Data

To interpret the collected data three different tools were used. The first one was Microsoft Excel, a tool that helped the authors to structure the statistical and numerical data. The second one is the CUTS model, and this was used to interpret the emission and congestion factors and what these meant for the operations made by trucks, private cars, and the barge. The third one was conducting a content analysis and that was used to manage the collected data from the survey[3]. The mentioned tools will be described in the below sub-sections.

3.4.1. Analytical Data Tool

All the statistical and numerical data collected was managed by Microsoft Excel. The tool was selected due to the visualization and analytical possibilities (Microsoft, 2020). Which meant that also the data collected for the CUTS model was as a first step managed and structured in

[3] Survey conducted following the six-week trial run, Autumn of 2019.

Microsoft Excel and then transferred to the CUTS model for further analysis. The result from the content analysis conducted on the survey was also managed in Microsoft Excel.

3.4.2. The CUTS Model

In the process of analyzing the collected data related to emissions and congestion the CUTS model was used. Behrends (2016b) explains that the goal of the model is to create a holistic understanding of the implications of different measures. The purpose is to take relevant stakeholders into account and evaluate the appropriateness of urban freight transport measures. The model was selected because of its ability to evaluate if successful measures, applied elsewhere, can be successfully implemented in the local context. In this study three measures were entered:

1. Trucks going between recycling center and sorting facility.
2. Private cars driving between the catchment areas and recycling centers.
3. The movement of the barge.

The model was developed in the program Filemaker which is a database tool. The user of the model input emissions factors, traffic conditions and routes. The model then aggregates the data into the emission and congestion costs. The equations behind the model can be found in Behrends (2016b).

In Figure 5 the structure of the model is visualized, the model is broken down into three branches. Logistic and transport efficiency was, however, disregarded and the model has mainly been used to evaluate the parameters within impact efficiency since it represents the local authorities' goals. This decision was built upon the societal perspective of the research and the scope. The value was found in the costs for CO_2, local emission and congestion for the different measures. Local emissions include NMVOC, CO, NOx, SOx, and CH_4 (Behrends, 2016b).

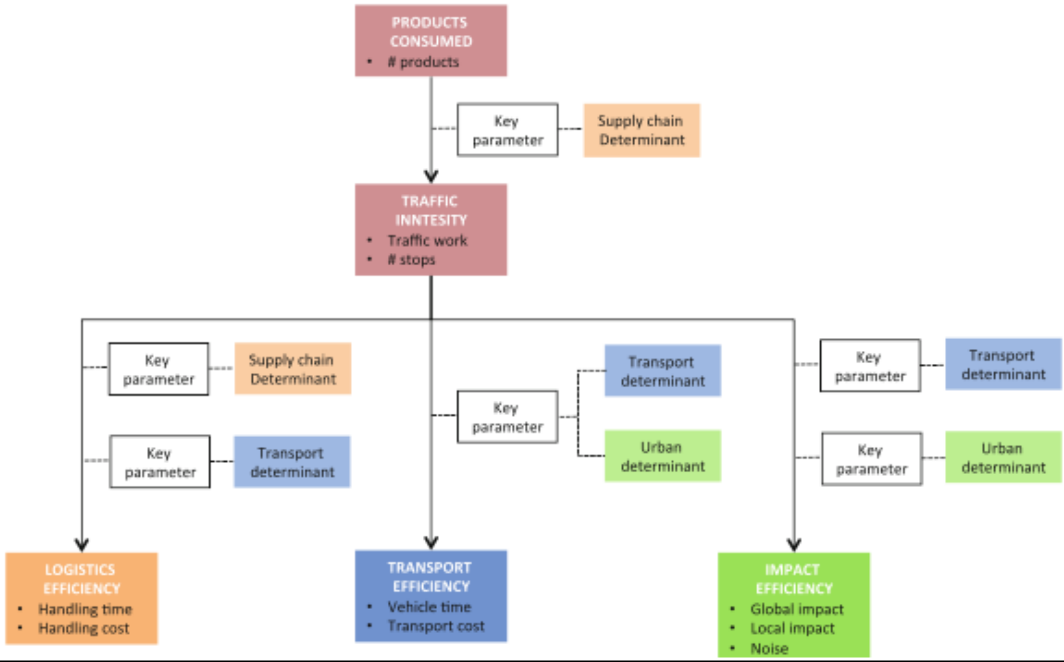

Figure 5. CUTS Model Structure. Source: Behrends, 2016b

The data needed for the model have been gathered from a wide range of sources. Consisting of discussion with experts within the topics of waste management, maritime transport, and emissions as well as the use of published papers and handbooks. Information on the entered data and the assumptions that were made can be found in Appendix 1. However, as the results from the model were presented in Euros the authors converted it into SEK to match the financial data.

3.4.3. Content Analysis

In a qualitative study content analysis means to systematically gain an understanding of the data collected. This is especially a good tool to use if the research has generated an extensive amount of data. Content analysis forces researchers to focus on selective aspects of data that relate to the overall topic as well as the research question (Schreier, 2014). One approach of doing this is by coding the data, and in this way making it easier to analyze it (Hsieh & Shannon, 2005). This approach was selected when working with the data collected from the survey[4].

[4] Survey conducted following the six-week trial run, Autumn of 2019.

Coding

Coding is when the themes of the text are put into coding units in order to be categorized. In the survey the participants were asked questions about their thoughts on the idea as well as their experience visiting the barge. The authors were given access to the transcribed data from the interviews. Out of the 19 questions asked in the survey the authors selected the four that were seen to contribute the most to the sustainability analysis. With an extensive number of respondents and the fact most of the four questions consisted of longer sentences with a lot of text the data was hard to interpret.

Emergent coding was used, this means that the authors first went through the data and based on this created the coding units (Stemler, 2000). Each coding unit was presented with a color to match and this was how the text was sorted into the themes of the coding units. Following this it was easy to turn the coding units into pie charts to get a better understanding of the answers given by the visitors as well as providing a visualization of the data. In addition, the coding was separated into which quay the answers came from to be able to analyze any potential differences in experiences depending if visitors were from the North or South side.

3.4.4. Assumptions

Some assumptions have been made during the analysis and interpretation of data, a summary of them is listed here. The full explanation of the assumptions and the sources they are built upon can be found in Appendix 2. The assumptions that were seen as more valuable for the reader to remember, have been repeated in the chapter where the result is presented. The assumptions made for the CUTS model have also been repeated in the chapter explaining the sources of the data used in the model which can be found in Appendix 1.

Private Cars

- A petrol Car Euro 6 is used by the residents of Gothenburg.
- The private passenger takes the fastest route to the recycling center.
- The private passenger car has one person in the car when going to recycling center weighing 75 kilos.
- It is assumed that a private person brings 130 kilos when going to a recycling center by car.

Trucks

- Mapping out which roads the trucks travels on between the recycling center and sorting facility the assumption has been made that the trucks avoid city traffic and local roads.
- It has been assumed that the trucks going between the recycling centers and sorting facilities carries ten tons of waste and a 2,3-ton container.

Residents and Barge

- Every time the trial schedule had a gap of two or more days the barge went to Skräppekärr to be emptied which created seven different routes.
- The towing cost is assumed to be steady at 20 000 SEK, an average of the actual cost.
- It has been assumed that the staff working on the barge is on site one hour before and after opening and closing time.
- Residents visit the quays that are on the same side as their housing.
- It is assumed that visitors of Stenpiren otherwise visit Sävenäs recycling center. Högsbo recycling center is matched with Rosenlund and Stigbergskajen. While Bulycke recycling center is matched with Eriksberg and Sannegården.
- Barge visitors walks or rides a bike to access the quays.

3.5. Quality of Research

The sustainability analysis that has been conducted was executed with a qualitative strategy and, therefore, the evaluation of the study has used the criteria more suitable for qualitative research. These criteria are: *Credibility, Transferability*, *Dependability,* and *Confirmability*. Questioning how believable the findings are? Do the findings apply to other contexts? Are the findings likely to be applied at other times? Has the investigator allowed his or her values to intrude to a high degree? The goal was to visualize the range of trustworthiness (Bryman, 2012).

Credibility

For this research project the authors have had an open dialogue with various experts within the fields of the research. These experts have been able to validate the results from the research to make sure no misinterpretation has occurred, leading to increased credibility.

Transferability

For this project the level of transferability is slightly unclear. As have been explained in the theoretical framework urban logistics project is very much dependent on existing infrastructure in the cities. However, the transferability exists in terms of how the results have been analyzed, using the sustainability triangle of financial, environmental, and social.

Dependability

The authors have had a high level of dependability in this research process. Every meeting and correspondence with experts have been documented and field notes have been taken.

Confirmability

The authors have tried to describe the research process as clear as possible and making sure the data and results are interlinked with each other. The complexity of this study has created the need for making assumptions. By doing this the trustworthiness of the study may be harmed. However, all the assumptions that have been made are clearly stated and explained.

3.6. Ethics

In the process of conducting social research there is a chance of ethical issues arising. To manage the ethical issues that could appear the authors of this report conducted the study with the four main ethical issues in mind. Bryman (2012) expressed that these are; harm to participants, lack of informed consent, invasion of privacy, and deception.

Harm to Participants

To avoid this the authors have had an open dialogue with not only each other but all involved parties to confirm everything is alright.

Lack of informed consent

Again, the authors have worked against this by having an open dialogue with the respondents.

Invasion of Privacy

To make sure no one's privacy is compromised all respondents and meeting participants have been anonymized. The exception being the collaborative partners of CLOSER and SSPA as well as the city of Gothenburg.

Deception

The authors have been open from the first point of contact with all respondents that the questions asked are concerning a Master thesis project.

Next, the result will be presented. The assumptions that were seen as more valuable for the reader to remember when reading the result will be repeated in this chapter. All to simplify for the reader.

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4. Results

In this section the results will be presented. The chapter is structured by first presenting the results from investigating the people that act within the systems. Followed by presenting the social result. The reason for these being presented first is because the following results are built upon data from findings regarding the scope and perception. Then, the environmental result will be presented, ending with the financial data. Each category has several sub-categories.

4.1. Scope of the Recycling Barge

As mentioned in the methodology the new system of the barge will be compared to the old one of regular recycling centers. The old system refers to the process of residents traveling to the recycling center by car followed by a Renova truck going from the recycling center to a sorting facility with the collected waste. To make the comparing applicable three recycling centers were identified to be the ones the inhabitants in the catchment areas would otherwise travel to. These are shown in Table 3 below.

The corresponding recycling centers and quays		
Sävenäs Recycling center	↔	Stenpiren
Högsbo Recycling center	↔	Rosenlund and Stigbergskajen
Bulycke Recycling center	↔	Eriksberg and Sannegården

Table 3. Showing the corresponding recycling centers and quays. Source: Created by the authors

Both the waste collected by the barge and regular recycling centers are taken to a sorting facility. The waste from regular recycling centers goes to sorting facility Marieholm, while the barge went to Skräppekärr. The reason the barge is being emptied at Skräppekärr is that the quay at Marieholm did not work with the barge, while the quay at Skräppekärr did[5]. Both are located in the eastern part of the city on the riverbank.

To start the process of understanding the impact the barge can have on society it was vital to first identify the potential visitor range the barge has at the different quays. Figure 6 was created, showing the catchment area of each quay, the area within the bubble. It was created by

[5] Respondent 1. Meeting 27th of January 2020.

calculating the median of how far visitors traveled to use the recycling barge at the different quays.

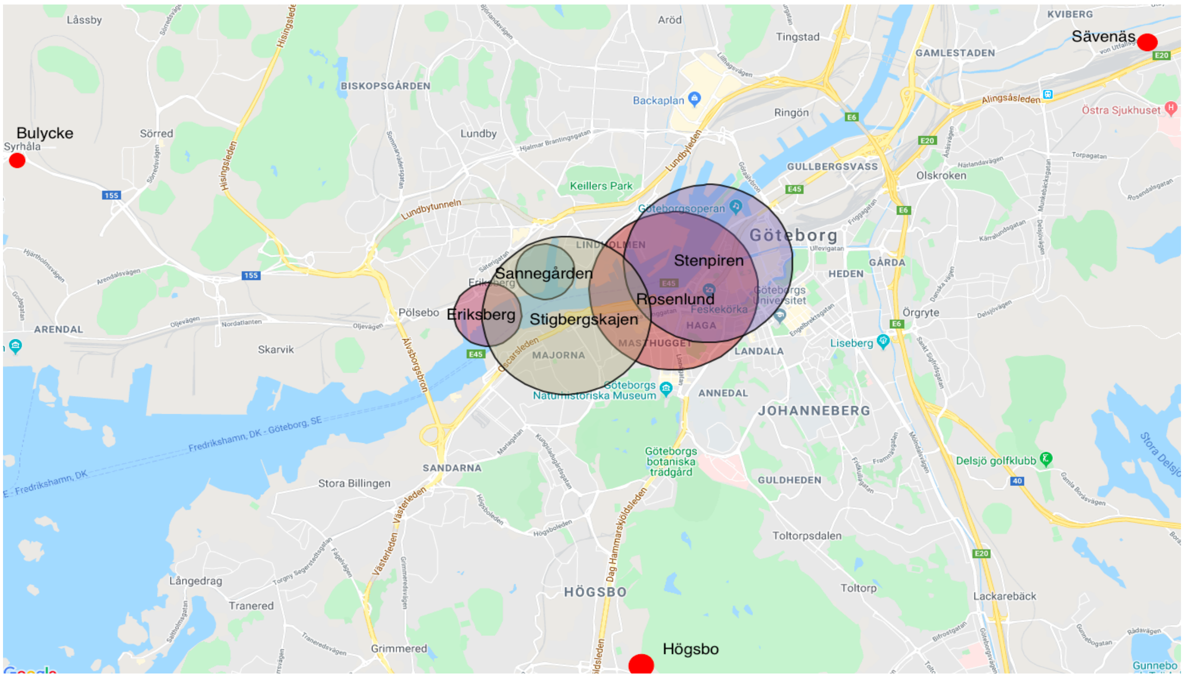

Figure 6. Map showing the catchment area of the quays based on the survey. Note: It has been assumed that people visit quays that are positioned on the same side as their housing. Source: Survey conducted following the six-week trial run, Autumn of 2019.

Extracting and creating the map enabled the authors to get an understanding of the number of people the barge can reach out to. As well as how this is divided between the different quays. In addition, a second figure was created based on where the visitors lived in relation to the quay they visited. This figure was also considered useful as it showed a more detailed visualization of the distance the visitors were willing to travel and can be found in Appendix 3.

Postcodes within each range were brought forward and in this way data of how many people registered as living in each catchment area could be visualized. There are, however, areas that are overlapping which means that the inhabitants can go to several quays, as can be seen below in Figure 7. The figure demonstrates the number of people living in the area that is not overlapped, as well as the amount living in the overlapping areas. The figure is limited by showing people between the ages of 21 to 100. A decision that was built upon 21 being the average age of when young people leave their parents' home in Sweden 2017 (Eurostat, 2020). This is also an age when it is possible to have a driver's license.

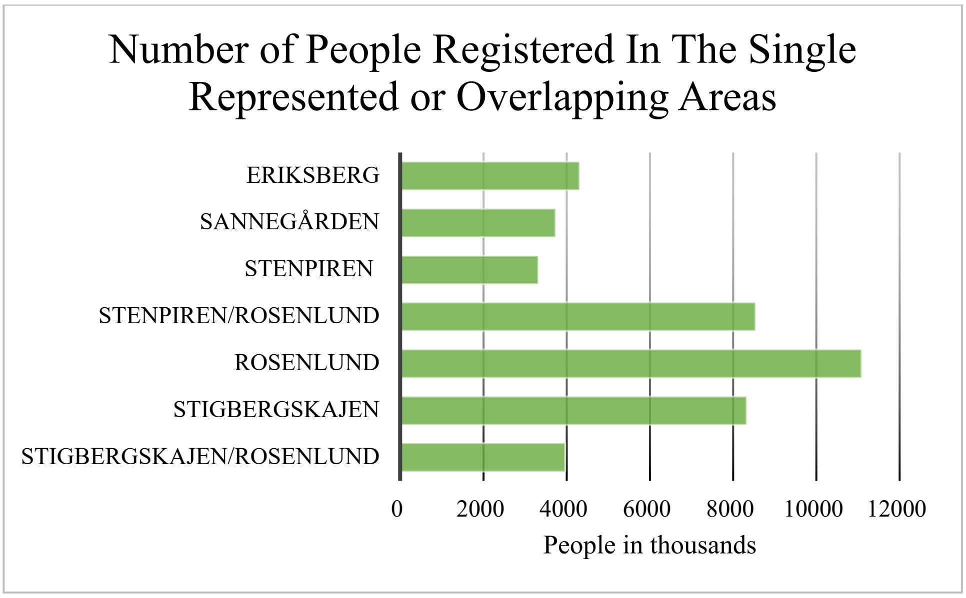

Figure 7. Number of people registered in the single represented or overlapping areas. Source: Ratsit, 2020

The extraction of postcodes visualizes that Stenpiren on its own reaches out to quite a low amount of people compared to the other quays. Roughly 3 300 individuals are registered within this area, but Stenpiren and Rosenlund together have on the other hand the second-highest amount of people registered. Meaning, that the resident can choose either of the two to visit.

Rosenlund on its own covers a small landmass which talks toward the quay being otiose considering that the other quays covered the most of Rosenlund's range. However, cities usually are clustered, meaning that specific areas are more for housing while others are for shopping and offices. The area that Stenpiren covers single-handedly is mainly an area for shopping and there are few people registered on postcodes there. On the other hand, the area that Rosenlund on its own cover is an area of housing which becomes clear when observing Figure 7. Rosenlund has the highest amount of people registered even if the space in itself is quite small.

The table in Appendix 4 visualize that the majority of the visitors came from the north side of the river, Eriksberg represented 55 percent of the total visits while Sannegården stood for 38 percent. Approximately three percent of the total visits occurred at Rosenlund followed by Stenpiren with two percent. An interesting discovery is that Stigbergskajen only stood for one percent which is surprising considering that the quay has the potential to attract a large pool of people.

Summarizing up all catchment areas there is approximately a range of 43 260 people. In the investigation of the accessibility of a car the authors found that Statistics Sweden (2017) presented that in Gothenburg municipality the total amount of cars per 1 000 inhabitants was 338. This means that approximately 30 percent of the inhabitants in the catchment area of the barge would have a car. The result from the survey also indicates that it is more common to have a car in the household on the north side than the south as can be seen in Figure 8 below. Over 60 percent of the respondents using the Eriksberg quay had a car in their household and at Sannegården the number was even higher with over 70 percent. While at Södra Älvstranden only 36 percent had a car in their household.

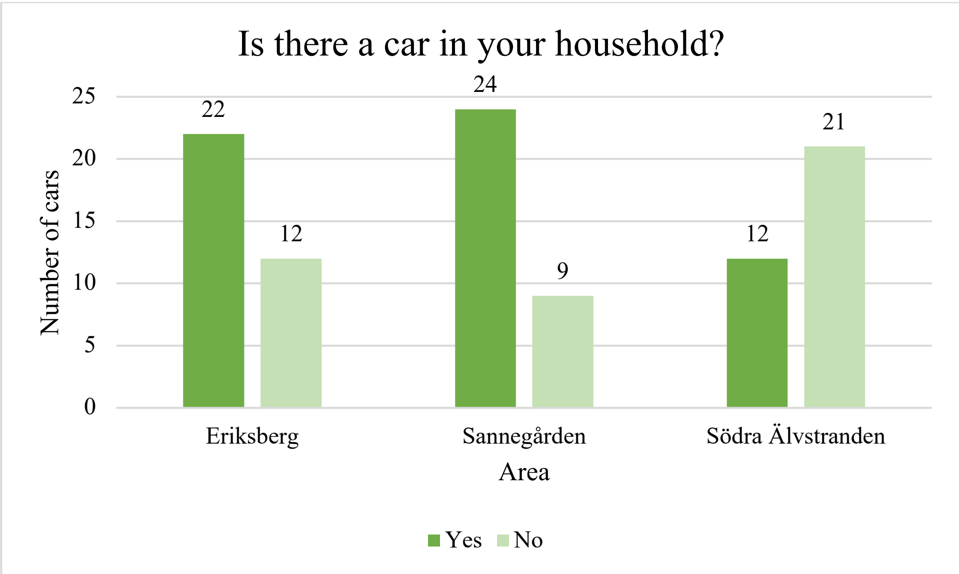

Figure 8. Is there a car in your household? Source: Survey conducted following the six-week trial run, Autumn of 2019

4.1.1. The Residents of Gothenburg's Recycling Behavior

Every two years Gothenburg Waste and Water department performs organized spot checks in certain areas about how people dispose of their waste. The data collected from these spot checks show that waste that should have gone to a recycling center are sorted incorrectly. The most incorrectly sorted type of waste that should have gone to a recycling center from the last spot check in 2018 can be seen below in Figure 9.

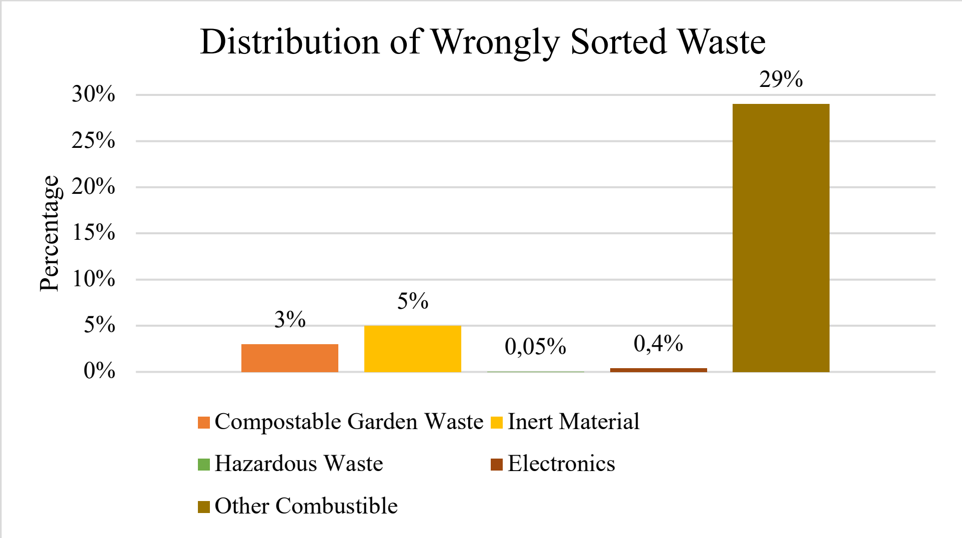

Figure 9. Distribution of wrongly sorted waste. Source: Respondent 1

Fch (2015) a nonprofit organization that works towards cooperating and pushing the development for central Hisingen, a district in Gothenburg, made this statement:

"Many property managers need to spend a lot of time collecting furniture, gadgets, and other bulky waste that have been incorrectly left in environment houses or other public areas such as outside wind storage, cellar corridors, and others."

The article visualizes a scenario of residents throwing their bulky waste incorrectly. It is phrased that a lot of time is spent on going to locations collecting bulky waste that has been placed at incorrect locations. A problem that is not only occurring for the property owners in Hisingen but is supported by others.

Löwendahl (2019) published an article in Hem & Hyra saying that housing companies in western Sweden pays millions of SEK annually to handle the wrongly sorted and dumped gadgets. It is further expressed that the problem is increasing. Their investigation visualized that many of the property owners in Gothenburg testify about the same despair. In the article, gadgets such as engine oil, washstands, couches, car parts, and washing machines are pointed out as things that are left in the environment houses. It is expressed by a janitor dealing with these problems that the way people act is at some points understandable. This is elaborated by mention that the small environmental centers in a lot of areas do not exist anymore and a lot of people do not own a car or have access to one. Meaning, that these people dump their gadgets in the environmental houses rather than taking them to a recycling center.

When analyzing the data collected from the survey conducted Autumn of 2019 an answer that appeared quite often was that visitors did not know where their closest recycling center was located. The data also painted a picture of the barge making it possible for residents to recycle not only more often but more correctly as well.

4.2. Social

4.2.1. Residents Perception of the Recycling Barge

The majority liked the barge due to the simplicity of it and accessibility of the barge on the quays as can be seen in Figure 10. This is further demonstrated as the second-largest response was due to visitors not needing a car, making it easy for those who do not own or have access to a car to reach a recycling center. Otherwise, it can be difficult for those who have no access to a car to reach a regular recycling center. These are often located outside of the city center and not close to any residential areas.

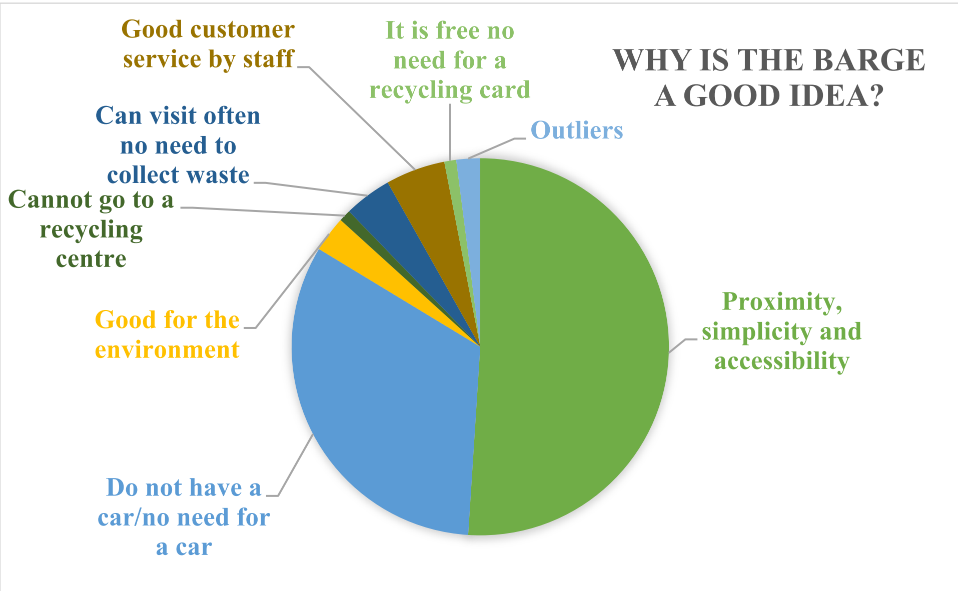

Figure 10. Why is the barge a good idea? Source: Survey conducted following the six-week trial run, Autumn of 2019.

When observing why visitors would use the barge again, why they choose the barge rather than the recycling center, and the main advantages of the barge the responses given were similar. The charts are all shown in Appendix 5.

The result shows that visitors seem to have been appreciating the simplicity and accessibility of the barge, including the opening hours a mix of weeknights, and weekends. In addition, visitors appreciated the fact that due to the accessibility they could throw waste more often and no longer needed to accumulate waste over time. Visitors seem to appreciate the closeness of the barge and the quays it stops at to their work and home, making it easy for them to recycle their waste. The visitors also seemed to consider the fact there is no need for a recycling card and thus, free to use. A sub context that was picked up amongst the answers was that many people felt encouraged to clean out their closets and storage units due to the simplicity and accessibility of the barge. The fact that the barge is accessible to people without any access to a car proves to be a strong motive for the barge. Most of the ones without access to cars appreciate the fact they no longer would need to rely on friends and family with cars to help them recycle. They can now do it on their own as it does not require a recycling card and is free for the general public. As well as, encouraging and making it easier for people to recycle correctly.

Another important factor is that in terms of the staff the overall response was overwhelmingly positive. Nobody had anything negative to say about any of the staff and most experienced them being nicer than the ones working at the regular recycling centers. Also, over five percent of the visitors did not know where 'their' regular recycling center is located making the barge optimal in their opinion. A few also liked the idea of using inland waterways rather than increasing the congestion on the road, especially as Gothenburg is a coastal city.

Based on the data gathered from the survey[6] almost all visitors were overwhelmingly positive to the barge itself as well as the services offered. The authors, however, discovered that there is a slight variation between the North and the South-side.

4.2.2. The Disparity Between the North and South Side of the River

In the question of why the barge was a good idea there was not much difference in the perception between the north and the south sides. However, when observing why using the barge and not a recycling center, it was an interesting question to break down in the three areas as they all presented a different chart. Meaning, all three areas preferred the barge over the

[6] Survey conducted following the six-week trial run, Autumn of 2019.

regular recycling center for different reasons, and neither presented a chart similar to the overall response. The charts are shown in Appendix 5.

Eriksberg mentioned the proximity to the house as the largest reason why they would use the barge over a recycling center. But also, because it does not require a car as well as the accessibility and the opening hours. The people also appreciated that they were able to go there by themselves, and the barge provides the opportunity to throw out waste more often, no need to collect it at home. A few also preferred the barge as they did not know where the closest recycling center was located. In Sannegården over half of the respondents used the barge over the recycling center due to its proximity to where they live, followed by no need for using a car. Some people also used the barge as they were not aware of where the closest recycling center was located or could not get there themselves.

The respondents at Södra Älvstranden gave slightly different reasons as 60 percent used the barge as they did not have access to a car. Again, the proximity to one's house was mentioned but not by too many as they also appreciated the opening hours and accessibility. Something all respondents seem to agree over was that most would use the barge for the high level of customer service by the staff onboard compared to the ones working at the recycling centers. A few even mentioned they had had bad customer service experiences at a regular recycling center and did not go there anymore unless they had to.

4.3. Environmental

4.3.1. Travel Pattern of the Barge

The distance the barge travels has a low variation between the routes while the collected waste for each route has a higher fluctuation (Appendix 6). Comparing the route that collected the most waste, with the one collected the least there is a difference of 7 262,25 kilos. On the other hand, the CO_2 and local emission cost from the two routes does not differ to any extreme degree. This indicates that the biggest impact on the emissions between the aspect of distance or weight is shown to be distance. This is further strengthened by respondent 3 expressing that the barge had an even fuel consumption whether the barge was loaded or not[7].

[7] Respondent 3. Email conversation 9th of March 2020.

The barge is not self-driven, meaning, that the tug that tow the barge needs to tow 279 tons constantly while the waste only adds on average roughly four tons. The waste, therefore, stands for a quite small share of the total weight and does not impact the emissions to any high degree. This demands that the barge use its full capacity considering that the emissions mainly increase by distance and not weight.

The barge is, however, limited due to spatial problems and it is the volume that is the limitation of how much that can be loaded on the barge rather than weight. Meaning, that the barge can carry more weight but because of volume problems it is estimated that approximately 6,5 tons can be filled before it needs to travel to Skräppekärr to be emptied[8].

Since the longest distances occur when the barge is moved between Skräppekärr and any of the quays the conclusion can be drawn that the biggest emissions can be found when the barge is going to be emptied. The movement of the barge between the quays themselves and the quays and Skräppekärr can be seen in percentage below in Figure 11.

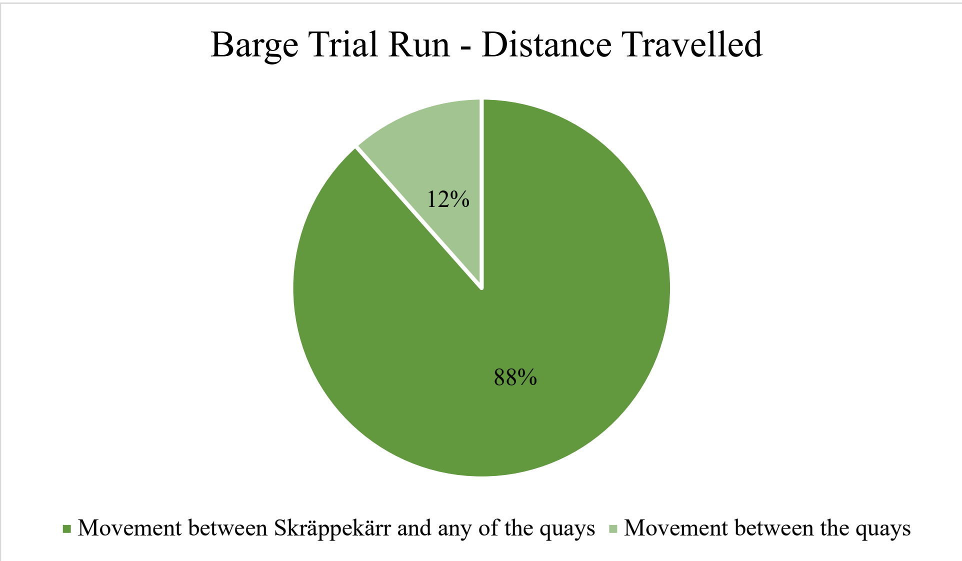

Figure 11. Distance travelled by the barge. Source: Respondent 1.

4.3.2. Emissions Created by Trucks, Private Cars and Recycling Barge

The result visualizes that the CO_2 and local emissions costs are extensively higher for the barge than for the Renova trucks as can be seen in the below figures. Figure 12 presents the emissions going back and forth between Marieholm and each recycling center by truck. While Figure 13

8 Respondent 1. Email conversation 2nd of March 2020.

shows the emissions for the different barge routes. Because each route has its starting point from Skräppekärr where the barge leaves with no waste and the route ends with going back to Skräppekärr to be emptied it can be argued to be a fair comparison with a truck. Creating a good foundation to answer the complex question of how environmentally sustainable the barge is.

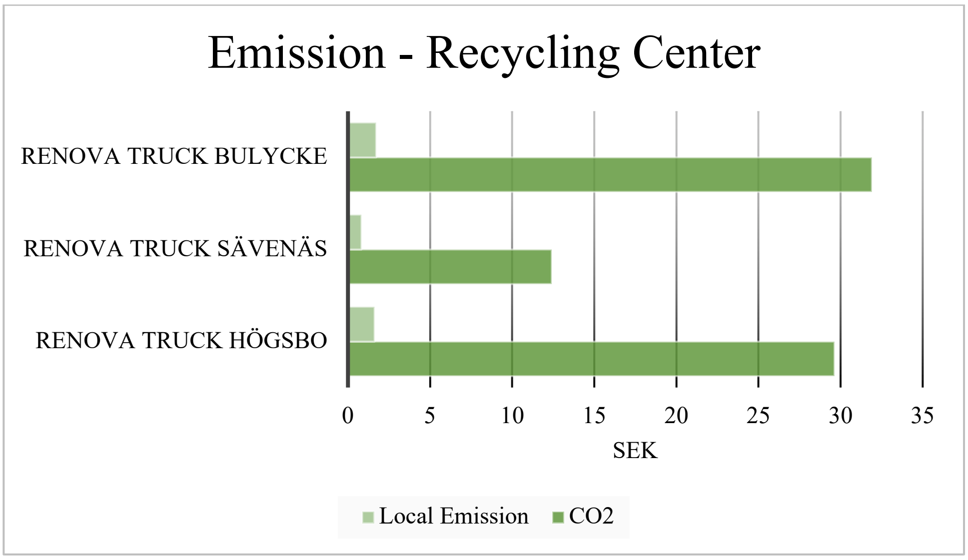

Figure 12. Emissions in SEK – recycling center. Source: CUTS model

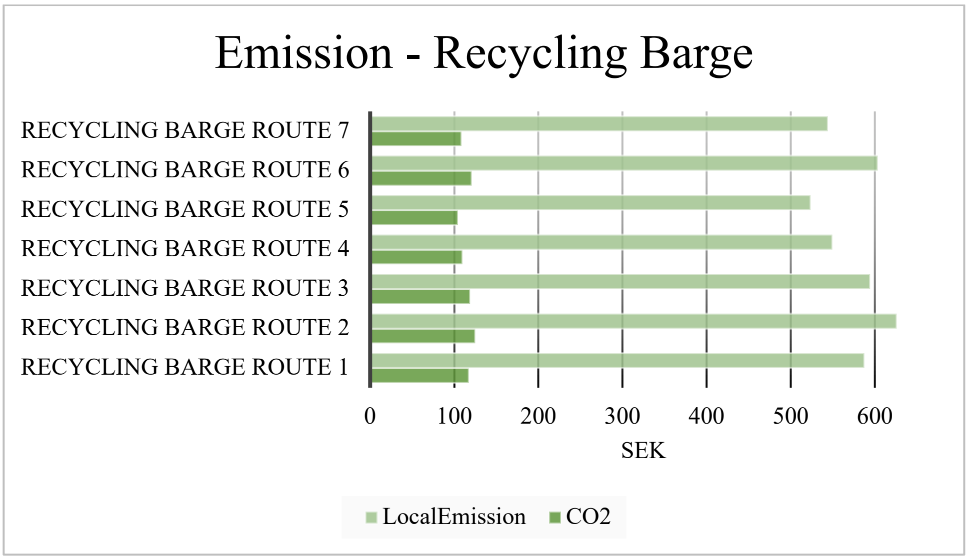

Figure 13. Emissions SEK – recycling barge. Source: CUTS model

It can be observed that the CO_2 cost is approximately four times higher for executing one route compared to using a truck. While the local emission cost is approximately 415 times higher for one route with the barge compared to a truck.

Since the old system also consist of emissions from private cars these need to be accounted for. When observing Figure 14 the CO_2 is significantly lower for a private car than for the barge and trucks. The local emission cost is almost non-existent when it comes to private cars, this is due to the newer engines today do not emit that much as before[9].

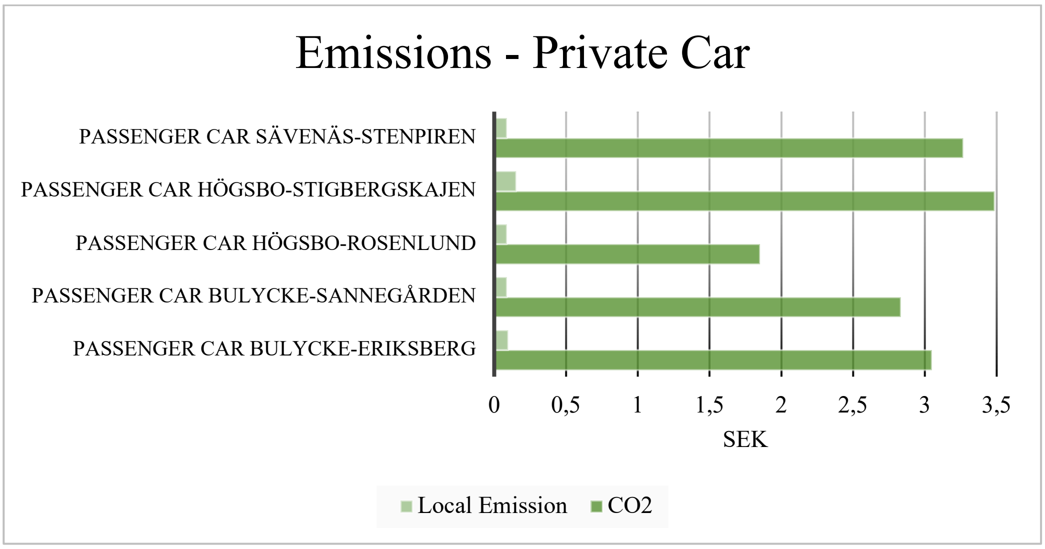

Figure 14. Emissions SEK – private car. Source. CUTS model

To create a better understanding of how the old system as a whole stand against the barge the authors created a scenario of 20 tons being collected for both the recycling center and the barge. The amount of 20 tons was selected as the barge can carry approximately 6,5 tons and with three routes it gives a total of 19,5 tons waste[10]. While the truck is assumed to be at full utilization and can, therefore, be loaded with ten tons waste, meaning, two trips to the sorting facility. For private cars it would mean 154 trips to the recycling center to create a total of 20 tons with the assumption of every car carrying 130 kilos of waste.

To simplify the scenario only one recycling center was observed and one quay. Eriksberg's quay was selected due to having the highest number of visitors during the trial and Bulycke recycling center was used as these are linked. The result from the created scenario is shown in Table 4 and visualizes that the total CO_2 cost for the old system is higher than for the barge. On the contrary the local emissions are significantly lower for the old system than the ones created by the barge.

[9] Respondent 2. Phone conversation 20th of April 2020.
[10] Respondent 1. Email conversation 2nd of March 2020.

Result 20 tons collected by both recycling centers and the barge - SEK		
	CO_2	Local emission
Trucks	64	3
Private cars	470	15
Old system total:	533	19
Barge Eriksberg	361	1 808

Table 4. Result 20 tons collected by both the recycling center and barge - SEK. Source: CUTS model

It is also of value to mention that the result shows that 30 percent of Gothenburg's residents own a car. Meaning, that it would account for 728 car trips back and forth to the recycling centers based on the numbers of visitors from the trial. These 728 car trips would give a CO_2 cost of roughly 2 100 SEK and a local emission cost of 70 SEK which is still lower local emission than for the barge in above scenario.

4.3.3. Congestion Created by Trucks, Private Cars and Recycling Barge

Trucks and private cars bring with extensive congestion costs as can be seen in Figure 15. If again assuming that 30 percent of the visitors from the trial would have taken a car to their recycling center it would have given a congestion cost of roughly 85 000 SEK. The barge avoids congestion costs considering that it operates in the city's inland waterways and has a constant free flow.

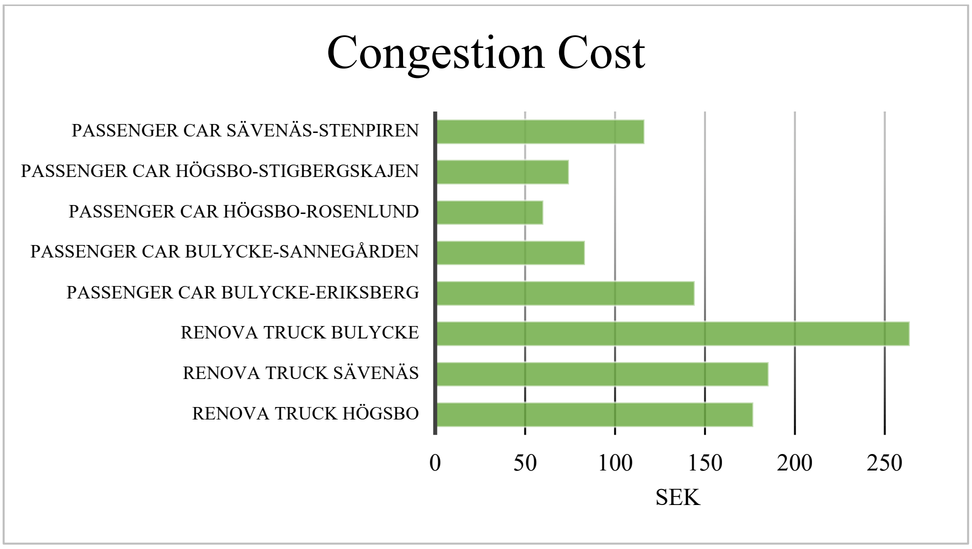

Figure 15. Congestion cost SEK. Source: CUTS model

When researching the private cars and the possible impact they have on congestion the result indicates that the roads that connect the recycling centers and catchment areas are not only utilized for recycling. Rather the traffic that occurs on these roads due to going to recycling centers can be seen as minor. This can be argued after analyzing the traffic flow (Gothenburg City, 2020d).

A road that most would take if going to Bulycke recycling center is Torslandavägen, for example if you travel from Eriksberg or Sannegården. A part of this road was in 2017 daily trafficked by approximately 33 400 cars (Gothenburg City, 2020d). The data represent weekdays and the amount will most likely decrease in the weekends but should still have a high traffic flow considering that it links among others the suburbs and the city center together. Bulycke had in 2019, 35 664 visitors and if assuming that all of these visitors took a car it is slightly more than the traffic that occurs daily on Torslandavägen.

Observing the roads connected to Högsbo recycling center a similar situation was visualized. At Odhners Gata, a street visitors are made to drive on if wanting to go to Högsbo recycling center. The first section of the street had in 2014 a daily traffic flow of 10 500 and the second section that was last measured in 2007 had a traffic flow of 5 700 (Göteborg Stad, 2020d). Högsbo recycling center on the other hand had in 2019 a total of 113 581 visitors. The amount fluctuates some between the months but approximately it would mean 311 visitors a day if assuming the recycling center is open every day of the year. Meaning, that the street should be used to a high extent for other purposes than going to the recycling center. The area around Högsbo recycling center also hosts a wide range of shops, training facilities and the street acts as a passage.

4.4. Financial

4.4.1. Cost of the Barge and Recycling Centers

The revenue from recycling is limited due to few sources of income. Meaning, that cost from a recycling center and barge extensively overshadow the potential incomes. Because of this the authors have chosen to disregard the inflow of cash. The total cost for the six-week trial run of the recycling barge was 735 064 SEK giving a weekly cost of 122 511 SEK. A full breakdown of the costs for the barge is shown below in Table 5.

Cost Items		Unit price	SEK
Rent			
	Barge		280 000
	Containers		10 000
Transport			
	Tow barge including tug driver	20 000	280 000
	Fuel SEK/Liter	16,74	18 414
Hired Staff			
	Staff SEK/Hour		
		300	38 700
		300	38 700
		300	21 600
	Maintenance SEK/Hour	500	15 000
Operational			
	Emptying of waste		30 000
	Extra emptying of electronic waste		750
Materials			1 900
		Total	735 064
		Weekly	122 511

Table 5. Breakdown of costs from the barge trial run. Source: Respondent 1 and Respondent 4

As can be seen some costs such as the rent for the barge and containers were fixed one-time costs. The towing of the barge, fuel, and labor cost were variable costs that changed depending on use.

Some of these calculations have been made with certain assumptions in mind. For example, the towing cost varies slightly but 20 000 SEK was used as a mean to make for easier calculations. Also, the fuel price stated is from February 2020, rather than for the Autumn of 2019 when the trial took place. Furthermore, when calculating the labor cost for the barge it was assumed the staff worked opening hours plus one hour before and one after. Due to the trial being six weeks long a weekly cost was calculated to make a cost comparison with a regular recycling center. Moreover, the costs for the three recycling centers representing the catchment area have been calculated into a weekly cost as seen below in Table 6.

Cost (SEK)	Bulycke	Högsbo	Sävenäs
Yearly	7 244 887	8 025 861	5 535 813
Monthly	603 741	668 822	461 318
Weekly	139 325	154 343	106 458

Table 6. Operating costs of recycling centers. Source: Respondent 1

Even though, all three recycling centers have the same function and more or less the same type of costs, the amount varies quite a lot between them. This is evident in Table 6 where it is easy to see that Bulycke and Högsbo have higher costs than Sävenäs. Additionally, the full breakdown of the costs can be found in Appendix 7. However, as with the barge, rent is a large cost for the recycling centers as well. Labor costs are also very high for the centers as they are staffed more or less every day. Depending on the condition of the facility the maintenance costs vary between the center

4.4.2. Traveling Cost for the Individual

Based on the average distance from the map in Figure 6 above the cost for a one-way car trip to the recycling centers from each quay's catchment area were calculated. The car cost is explained in the methodology. The result is shown below in Table 7.

Quay used	Recycling center	Average distance (km)	Petrol car cost (SEK)
Stenpiren	Sävenäs	9,00	105,65
Rosenlund	Högsbo	5,41	63,48
Stigbergskajen	Högsbo	8,45	99,20
Eriksberg	Bulycke	7,49	87,93
Sannegården	Bulycke	8,14	95,56
Average		7,70	90,37

Table 7. Cost of private cars going to recycling centers. Source: Google Maps & Teknikens Värld, 2018.

The main difference in cost comes from the distance traveled, even if none of the distances are very far the cost is between 60 and 106 SEK. Additionally, the actual cost would be higher as the person would need to drive back home, and congestion is not accounted for. On the other hand, the recycling barge is a free service that cannot be accessed by car. Meaning, that the individual would need to either walk or use a bike. Neither of which has a variable cost when in use.

The chapter has presented the result from the research in words, graphs, and tables. Initially, results concerning the number of people and the area the barge has the potential to reach out was presented, also how ownership of cars may be divided between the inhabitants of Gothenburg. Followed by the result regarding inhabitants of Gothenburg's recycling behavior. The result showed that wrong disposal of waste is occurring and is a problem. Then, the result from the social data collection was presented, containing residents of Gothenburg's perception of the barge. The environmental part presented results showing that the emissions from the barge is mainly a result of traveled distance and not weight carried. The emission cost for trucks, the recycling barge, and private cars was presented and the same goes for congestion. Lastly, the financial result was presented, divided by first presenting the result for the barge and recycling centers and, secondly the traveling cost for the individual was presented. Next up, the sustainability analysis, containing discussion concerning the presented result.

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5. Sustainability Analysis

The goal of the sustainability analysis is to understand how sustainable the trial was and which the most important characteristics are for making the initiative a sustainable option. As sustainability largely is about finding the balance between social, environmental, and financial sustainability, this section is not divided in the same manner as the results. Rather, the sustainability triangle is used as a tool, and all three aspects are taken into account throughout the analysis to be able to answer the research questions.

5.1. The Scale of the Barge in Relation to the Recycling Centers

One of KTH (2018) definitions of financial sustainability is economic growth which means with that definition in mind neither the old nor new system can be considered financially sustainable. The reason being that both systems generate much higher costs than any potential revenue. However, recycling centers have to exist because of their important role in a functional society and, therefore, a cost that needs to be handled.

The weekly cost of operating the recycling barge is lower than the weekly cost for operating two of the three recycling centers. In the findings the calculated cost for operating the barge weekly is shown to be 122 511 SEK. While the recycling centers had the following costs weekly; Bulycke: 139 325 SEK, Högsbo: 154 343 SEK and Sävenäs: 106 458 SEK. This means that if only the financial aspects are taken into consideration it can be argued that the barge is more financially sustainable than two of three recycling centers. However, Bulycke and Högsbo collect in total roughly 470 tons in a week. While the barge in one week collected roughly five tons.

A discovery that indicates that the recycling barge will most likely not impact the operations occurring at the recycling centers at the current stage. The recycling centers collect such a high amount of waste that the demand for trucks that goes between the recycling center and Marieholm will most likely not decrease. Meaning, that the barge will mainly add on cost and environmental impact rather than replace parts of it from the old system.

Financial sustainability is furthermore defined as an increase in capital should not come at the expanse of social or environmental capital (KTH, 2018). Where financial sustainability is to preserve economic opportunities for the future generations (Anand & Sen, 2000). Leading to the topic perhaps instead needs to be discussed from the perspective of if the barge is financially justifiable based on its environmental and social impacts.

The barge has the potential of increasing the collected waste from the trial run considering that it can reach out to extensively more people than done during the trial. For example, if all people within the catchment areas visit the barge and bringing with them 11,5 kilos, which was the average per visit (Appendix 4), the waste collection would roughly be 497,5 tons. However, that would be an extensive increase and it is unlikely to happen in that degree, but an increase can still be expected if the recycling barge gets further established. This does not on the contrary necessarily mean that it would impact the recycling centers truck operations. The reason being that the result visualized that Gothenburg has had problems with people disposing of their waste incorrectly.

5.2. Incorrect Disposal of Waste and its Implications for the Recycling Barge

Waste that should have gone to the recycling center is left in various places, creating a cost for society. To reach the recycling centers it is necessary to have access to a car. The centers are located outside the city center and not near any housing complex. And as the research indicate only about 30 percent of the people in the catchment area own a car. Making it very hard for the remaining 70 percent to go to a recycling center for their bulky waste. The lack of accessibility possibly forces people without access to a car to either having to take their waste with them on public transport or take a taxi, as out of the three only Sävenäs is within walking distance to a bus stop. This makes it very hard for the inhabitants from other areas to visit a recycling center regularly. Forcing them to collect their waste at home, or to dispose of it incorrectly with the regular household waste. This was one of the reasons why many visitors liked the idea of the barge. Simple and accessible means it is much easier for people living in the area to dispose of their bulky waste correctly. Moreover, many people living in the city do not know where their closest recycling center is located or how to get there which also shows that they are not users of the old system.

The result indicates that the recycling barge has the potential of promoting people to recycle their waste differently than before, creating a change in behavior. Meaning, that the project could bring social value to the resident of Gothenburg. As it gives residents that previously could not dispose of their waste correctly the possibility of now doing that by visiting the barge.

A discovery that also could mean that even if the barge manages to attract more people and in this way be equal to the existing recycling centers waste wise it may not mean that the two systems are competitors. The decision for the visitors may not have been either go to a recycling center or the recycling barge. But rather dispose of their waste incorrectly or correctly by visiting the recycling barge. An alternative that did not exist before and the residents were potentially made to throw their waste incorrect or store at home due to not be able to go to a recycling center. This would, however, also mean that the waste collected at the recycling centers would not have any significant decrease due to the barge getting more established and collecting more waste. It would rather mean that the waste collected at the barge would add on to the waste collected at the recycling centers and, therefore, not impact the trucks going to Marieholm. Meaning, that as mentioned above the barge would only add on cost and environmental impact rather than replace parts of it from the old system.

Interestingly, the results from comparing the inhabitant's perception between the north and south side show that the north side appreciated the barge being close to their work or home, making it simple and accessible to dispose their waste. The south side thought the best thing about the barge was that it does not require a car to get there. This result is in line with the car-ownership on the south side, as the result shows that there were fewer car owners on the southside compared to the north side. Eriksberg's visitors appreciated the fact that with the barge they could throw away their waste by themselves and not rely on others to do it. This was not something that was mentioned by either Sannegården or the south side.

However, one thing the north and south side had in common was that in their minds the barge made it much easier for the inhabitants to throw away their waste correctly. Dillard, Dujon & King (2009) expressed that social sustainability is among others the involvement of including diverse groups. Which the barge does considering that it gives people that previously could not recycle their bulky waste correctly, now the ability of doing so. Creating a change that also avoid negative social impacts such as it might make neighbors angry seeing waste disposed incorrectly. It also brings positive environmental and financial impacts. If the waste is put into the ''circle of life'' it can potentially avoid more polluted air as well as destroy landmass. While the indirect cost of managing the wrongly disposed waste could potentially decrease as Löwendahl (2019) expressed millions of SEK is spent on handling this currently.

Another factor to take into consideration is the level of service from the staff working on the barge or at the recycling centers. As many people may be unsure about where to throw different kinds of waste when visiting the barge or centers. Meaning, they would need to be assisted by the staff working there. When looking at the response from the visitors at the barge it was clear that they preferred the staff at the barge rather than the recycling centers. Quite a few mentioned the high service level of the staff as one of the reasons the barge was a good idea. As well as giving it as a reason as to why they would visit the barge again. Adding social value that several visitors believed the recycling centers are lacking.

5.3. Gothenburg's Infrastructure and the Selection of Quays

The analysis shows that the barge has the potential of adding social value for the residents of Gothenburg. Furthermore, the barge possibly also decreases indirect environmental and financial cost from lowering incorrect disposed waste. The next step will be to analyze the actual financial and environmental cost of operating the two systems.

The result indicates that it is important to consider if a quay brings value based on the number of visitors it can attract or the volume of waste that is collected. The environmental cost for towing the barge between the quays are arguably small compared to emptying the barge. Meaning, that from an environmental point of view it could be argued that the barge should visit as many quays a possible before going to Skräppekärr to be emptied. With the condition of no long distance between the quays. As this may enable a higher collection of waste before going to Skräppekärr. On the other hand, for the barge to be able to collect more waste the spatial limitations of the barge need to be managed so the capacity increases. Otherwise, higher collection of waste will only lead to more trips to Skräppekärr which would add to the environmental costs.

Furthermore, it is not only the number of visitors a quay can attract that impacts on whether the barge should stop or not. It also has to do with the existing infrastructure of the city and its quays. As have been mentioned for the trial run these five quays were selected due to them already having the necessary infrastructure to handle the barge and its service. Additionally, with the barge being emptied at Skräppekärr instead of Marieholm further proves that this service is dependent on existing infrastructure in the city. A founding that interlinks with the discovery from the theoretical framework. In that chapter waste projects in other cities were presented and visualized how urban projects are adapted to the infrastructure of the specific city and the founding in this research proofs this further. There is no standardized way on how to design, implement or the potential outcome of an urban project, instead this depends on the specific city. Furthermore, this means that some improvements and/or changes to the new system may not happen unless there are major changes when it comes to the infrastructure. This is both in terms of the quays the barge stops at as well as the sorting facility it empties its waste at.

However, towing the barge brings a financial cost and the result showed this to be approximately 20 000 SEK per towing which is quite a lot. Meaning, that the quays that are selected need to collect enough waste to make it justifiable of towing the barge to that quay. From the trial, Stenpiren is a quay that could be questioned if it brings value or only adds on the emission and cost for the project. The quay did not collect any high levels of waste (Appendix 6). However, the barge only visited the location three times, meaning, that if the presence had been higher more waste could have been collected. On the other hand, this waste would most likely have been originated from the area covered by both Rosenlund and Stenpiren considering that is where people live. Meaning, that the waste could still have been collected but instead by Rosenlund's quay. This is further visualized on the map in Appendix 3 where it can be seen that few of Stenpiren's visitors came from the area that Stenpiren on its own covered. Stigbergskajen similar to Stenpiren also had low attendance and only attracted one percent of the total visits from the trial. Different from Stenpiren, Stigbergskajen has the potential to reach out to a large scale of people.

Even if the south side quays have the largest population it was the north side that attracted most visitors. One of the reasons for this could be the distance between the quay and where people live. This is evident in the map in Appendix 3 showing where people lived in relation to the quay they visited. Based on this map it is easy to see that the people visiting the north side lived much closer to the quay than on the south side. This can be further explained as around the area of Stenpiren is mostly commercial buildings, not many people live there. While Rosenlund and Stigbergskajen has many residential buildings in their catchment area, one of the main roads goes between the housing and the quay.

This is something that many people might see as an obstacle as they would have to cross the road to get to the quay. Even though, there are tunnels or bridges where this can be done safely, it is most likely a major reason why the inhabitants on the south side choose not to visit the barge. Furthermore, it was most likely easier for the people on the north side as well as many of them would have seen the barge on the quay from their homes. Making it easier for them to take some time out of their day and visit the barge. Summarizing up all this it is evident that the barge needs to attract more visitors on the south side. This is needed to make it more sustainable to account for the high financial costs of towing the barge.

5.4. Operating Trucks, Barge and Private Cars and its Impact on the Sustainability

As the result shows the barge creates high levels of CO_2 and local emission costs and these are mainly an outcome of the traveled distance by the barge. This leads to the utilization of the barge is of high importance considering that the majority of movement occurs when going back and forth to Skräppekärr to be emptied. That does, however, not mean that the different quay does not impact the sustainability of the barge as discussed above.

If observing the emissions from the barge the result visualizes that according to respondent 1 the barge can approximately collect 6,5 tons waste when taking volume limitations in consideration. The barge is limited by spatial issues were the volume of the waste hinders more waste to be collected even if the barge could potentially carry more weight. However, the 6,5 tons is only an estimation built upon the data from the trial and can differ extensively between routes considering that it depends on the volume of the waste. For example, if a visitor brings an item that is large in terms of volume but light in terms of weight it will have an impact on how much waste that will be transported when going to Skräppekärr to be emptied. Making it hard to get knowledge about when the barge needs to be emptied.

As a result of the above-mentioned points should the barge get established and increase the amount of collected waste it would also mean an increase in emptying. How many emptying to account for based on the increase is hard to know. From the result, it can on the other hand be established that operating the barge for one route gives significantly higher emissions than for operating a truck. On average a barge route creates CO_2 cost of 115 SEK and local emission cost of 576 SEK. While a truck creates an average CO_2 cost of 25 SEK and local emission cost of 1,50 SEK. The trucks also transport more waste than the barge as the trucks can transport ten tons of waste each time. There are some reasons for the emission differing so significantly. One being that Renova, the company that handles the daily operations at the recycling centers, has a very updated fleet of trucks. Thus, also having a low environmental cost. The tugboat towing the barge has an engine that is significantly much older and a higher level of emission. Making the environmental cost for the barge that much higher, especially in relation to the distance traveled.

Even if it seems more tediously to have inhabitants take their car, drive to a recycling center and then have a truck take the full containers of waste to the sorting facility. The trucks operating within the old system does not have that big of an impact on the environment as the recycling barge does. A discovery that harms the perception of the barge being environmentally sustainable. The private car is, however, not accounted for here which may change the perception.

5.4.1. The Importance of Residents Walking to Dispose of their Waste Instead of Driving

The result shows that some people may not dispose of their waste correctly as discussed above but it also shows that others do. Some people choose between going to the recycling centers or the recycling barge and saw the barge as valuable because they did not need to slide their recycling cards. Meaning, that a share of people would go to the recycling center if not the barge existed. However, the result shows that the traffic created by visitors going to the recycling center plays a minor role in the traffic flow. What is visualized is that the potential of decreasing the number of cars going to a recycling center by providing inhabitants with the barge may not impact the traffic flow in Gothenburg to any significant degree. Meaning, that the congestion impact of these car trips declining would be minor.

If adding the travel time elasticity that Janhäll & Carlson (2017) discuss it could instead promote additional car drivers to use the roads for other purposes because of improved travel time. The potential congestion improvement of reducing traveling to recycling centers may, therefore, be quite small. On the other hand, the decreasing of cars going to the recycling center may not improve the travel time to any significant level, because it stands for such a small share of the traffic. Meaning, that the travel time elasticity may not occur but rather just remove one car from the road without improving the travel time.

Even if the congestion may not be improved, the emissions from these cars can at least be avoided. The result from the created scenario of 20 tons collected waste by both the old system and barge, showed that the avoidance of cars played a vital part. Since the CO_2 cost was lower for the recycling barge when weighing in the CO_2 cost created by both the trucks and private cars.

The result also showed that a potential outcome of the trial run was the avoidance of 728 car trips. Movement that otherwise would have created a CO_2 cost of roughly 2 100 SEK and a local emission cost of 70 SEK. The total CO_2 cost for these cars is significantly higher compared to operating the barge for one route as the barge had an average CO_2 cost of 115 SEK. Meaning, that potentially the high CO_2 cost from the barge may be justifiable considering that it could decrease private car trips. On the other hand, the assumption has been made that in one car trip to a recycling center 130 kilos of waste are collected. Giving a collection of roughly 95 tons of waste with 728 car trips. If transferring that waste to the barge and weighing the spatial limitation it would mean the need of 15 routes, giving a CO_2 cost of approximately 1 725 SEK.

A cost that still is lower than for the car trips but then it is also important to consider that these car trips only stands for 30 percent of the visitors. Meaning, that 70 percent of the visitors would not take a car to a recycling center. Therefore, not weighing up the emissions the barge creates by avoiding a car trip but as discussed previously it may get people to recycle waste more correctly.

Furthermore, the local emissions stay low even when accounting for 728 car trips. Respondent 2 discussed this during one meeting saying that due to the newer engines in private cars local emission is almost non-existing and does not emit local emission as much as before[11]. World Health Organization (2020) also expressed that local emissions are more dangerous than CO_2 in urban areas. If then observing the barge the local emissions are extensively higher with a cost of 576 SEK which interferes with the environmental sustainability of the barge even if the CO_2 cost may be justified by the avoidance of car trips. However, if imagining that the local emission would be zero the barge could be argued to be more environmentally sustainable than the old system. Meaning, that if the barge managed to be developed to a stage of emitting significantly

[11] Respondent 2. Phone conversation 20th of April 2020.

less local emissions than it did during the trial, it could have less environmental impact than the old system.

The result also indicates that the project to an extent moves the traveling cost from the inhabitants to the municipality. Meaning, the recycling centers do not account for the traveling cost for those inhabitants who visit the centers. The operational cost is higher for the barge than for the recycling centers, but the barge may visualize hidden costs from the recycling center. Cost that the resident before stood for but now is moved to the municipality which increases the cost for the solution. For the case of the arguments if assuming that all visitors of the barge during the trial of 2019 would instead have gone to the recycling center by car. It would have created approximately a total cost of 445 689 SEK for the inhabitants using the distance traveled and mileage cost. An extensive number considering that this only accounts for 2 427 inhabitants. A cost that previously was taken from the resident but with the barge it can be observed as the municipality takes responsibility for a share of this cost by offering a mobile recycling solution. From a societal perspective this could be seen as positive considering that it then is a solution available for everyone without demanding the inhabitants to spend any capital going there.

Table 8 below, highlights the aspect that has been discussed in the sustainability analysis. The aspects are presented in two columns, where the aspects that are seen as promoting sustainability are presented in one, and in the second column the aspects that are observed as diminishing the sustainability.

Promoting	Diminish
+ Promoting resident to recycle more correct.	- Does not impact the existing recycling center, only add on emissions and financial costs.
+ Decreasing car trips which balance up the CO_2 emission from barge.	- High CO_2 costs from the barge.
+ Caters to residents without cars or no access to cars.	- High local emission cost from the barge.
+ Moving cost from the inhabitant to municipality.	- High cost of towing the barge.
+ No congestion costs created by the barge.	- Dependent on existing infrastructure.
	- Spatial limitation hindering volume increases.

Table 8. Aspects that promote or diminish the sustainability of the barge. Source: Created by the authors

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The sustainability analysis has discussed the barge possible impact on the existing recycling centers. The chapter has discussed if the volume collected at the recycling center will decrease due to the barge and if the trucks going between recycling centers and Marieholm will be affected. The chapter has further discussed how the barge can promote the residents of Gothenburg to dispose of their waste more correctly and the outcomes of this change in behavior. The importance of selecting the right quays has also been discussed and created insight in how a city infrastructure impact the shaping of an urban freight project. Lastly, the sustainability analysis has discussed how the movement of trucks, barge, and private cars create both environmental and financial costs. These three measures, trucks, barge, and private cars have been discussed in relation to each other. Creating an understanding over what it means if one measure is replaced by the other one.

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6. Conclusions & Recommendations

In this section the authors will present their concluding thought about the research. Followed by the research questions being answered. Finally, the chapter ends with some future recommendations for improvements and additional research needed.

6.1. Conclusion

The barge brings social value that the recycling centers have not been able to offer. Meaning, that the barge can be argued to be a socially sustainable option from a societal perspective. However, it is the environmental and financial that mainly interfere with the sustainability of the barge.

The sustainability analysis showcases that the barge will mainly add to environmental and financial costs when placed in relation to the recycling center. Since the local emission cost is significantly higher than operating a recycling center it diminishes the idea of the barge being a sustainable mobile solution for waste logistics.

The barge might help decrease car trips that have previously been taken to visit the recycling centers. However, these car trips stand for a small share of the traffic, as the roads are to a high extent being used for other reasons than recycling. Therefore, congestion will most likely not be improved. The emissions from these cars can, however, be avoided and the analysis shows that the CO_2 emission from the barge may be balanced up by the avoiding of car trips to the recycling center. Especially, if the access to a car is higher in reality than what have been shown in this research. This in turn promotes the sustainability of the barge.

On the other hand, the old systems local emissions are extensively lower than for the barge and local emissions are more dangerous than CO_2. Which diminish the sustainability of the barge.

Nonetheless, the barge encourages people to recycle their waste, meaning that it may slightly even out the CO_2 and local emissions cost created. The dilemma of that, is that if the barge manages to increase its visitors and encourage more people to recycle it will most likely also mean more turns to empty the barge. This leads to additional high environmental and financial costs are created. This will most likely overshadow the positive outcomes from recycling waste that previously was disposed of incorrectly and the decreased car trips.

Because of the environmental impact it complicates justifying the financial aspect. The barge collects less waste than the recycling center but has similar costs. The barge is limited due to both capacity and spatial problems. Meaning, that even if the barge attracts more people, the towing of the barge involves high transport and emissions costs. Making it difficult for the barge to expand its visitor base without increasing cost and emissions considering that it then needs to be emptied more times. Since many of the visitors do not have access to cars and would not have gone to a recycling center previously. Therefore, the extra emissions from the barge will not be offset by visitors avoiding a car trip to the recycling center.

Research Questions

Research question 1. How did the trial of the recycling barge acting on the inland waterways of Gothenburg contribute to a more sustainable city?

The conclusion that can be drawn is that the trial of the recycling barge contributed to sustainability by promoting residents to recycle their bulky waste more correctly. A development that is positive both from a social and environmental perspective but also from a financial perspective.

Research question 2. Based on this, what characteristics are most important in making such an initiative a sustainable option in the longer term?

It can be concluded from the research that the most important characteristics for making the recycling barge a sustainable option in the long term are firstly, an engine type that emit less emissions, especially local emissions. Secondly, an infrastructure that enables the barge to be emptied without the need of being towed for a long distance. Thirdly, high loading capacity so the barge gets fully utilized when moved. Last, visiting quays that have the potential of collecting much waste.

6.2. Recommendations

Based on the response from the survey[12] one future recommendation would be that the barge is equipped with a container that can take garden waste. Even if people can throw away smaller flowers with food waste visitors during the trial run had the wish of being able to take all garden waste to the barge as well. Garden waste is also something that is often disposed of incorrectly according to the test the city has performed.

If the barge is being considered to become a permanent solution it would be a good idea to investigate the possibility of making the barge itself mobile. Currently, it is being towed by a tugboat, emitting high amount of emissions. If a fuel efficient and low emissions engine could be placed on the barge it could improve the environmental sustainability of the barge.

Future Research

When it comes to additional research one recommendation would be to look into the issue of incorrect disposal of waste. The city is already doing spot checks every two years, but as have been established in this paper it is a growing problem. Thus, research into this issue as well as the financial consequences it might have. This would not only benefit the city of Gothenburg but also the project around the recycling barge.

However, the recommendations mentioned above would all need further research before implementation. As the recycling barge itself is in the trial stage still, additional research would be needed before making it a permanent fixture on the river.

[12] Survey conducted following the six-week trial run, Autumn of 2019.

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8. Appendices

Appendix 1 – CUTS model; explanation of data and assumptions

- A petrol car is used in the research as it is still the most commonly used in Sweden (Körkortonline, 2019). Göteborgs Stad (2020e) also express that most of the households in 2018 consisted of one person which lead to the assumption that each car would travel with one passenger. A rigid truck 20-26t diesel was used when researching the trucks going between the recycling centers and sorting facilities. A decision built upon information from respondent 1 with insight into these operations. Euro VI have been used for both the private car and rigid truck.
- The energy consumption and emission factors were extracted from Infras (2014) for both private cars and the rigid trucks. Except CO and CH_4 that was lacking for the private car. This was instead taken from an air pollutant emission inventory guidebook (Ntziachristos & Samaras 2019). Furthermore, for the private car the energy consumption was only given on average, however, the rigid truck contained data of energy consumption driving, empty, full, and an average. Therefore, the change value between the average and full/empty was calculated for the truck and this was then used to calculate the full and empty energy consumption for private cars.
- The external cost for the area rural, suburban, and urban was gathered from the handbook on the external costs of transport version 2019 (European Commission, 2019b). The congestion cost for the different road types acting in a metropolitan area (local, main, and motorway) was retrieved from Ricardo (2014).
- The emission factors for the barge was generated from the interview held with respondent 5.
- The model demand detailed data as well as an extensive amount of data which have meant that assumptions have been needed to be made. The assumptions made by the authors are the following:

1. The 2019 schedule for the barge pilot was by the authors structured into seven different routes. This was done to break done the project and, in this way, simplify the collection and analysis of the result. The decision was built upon the barge being emptied seven times. The assumption was therefore made that every time the schedule had a gap of

two or more days the barge went to Skräppekärr to be emptied which created seven different routes.

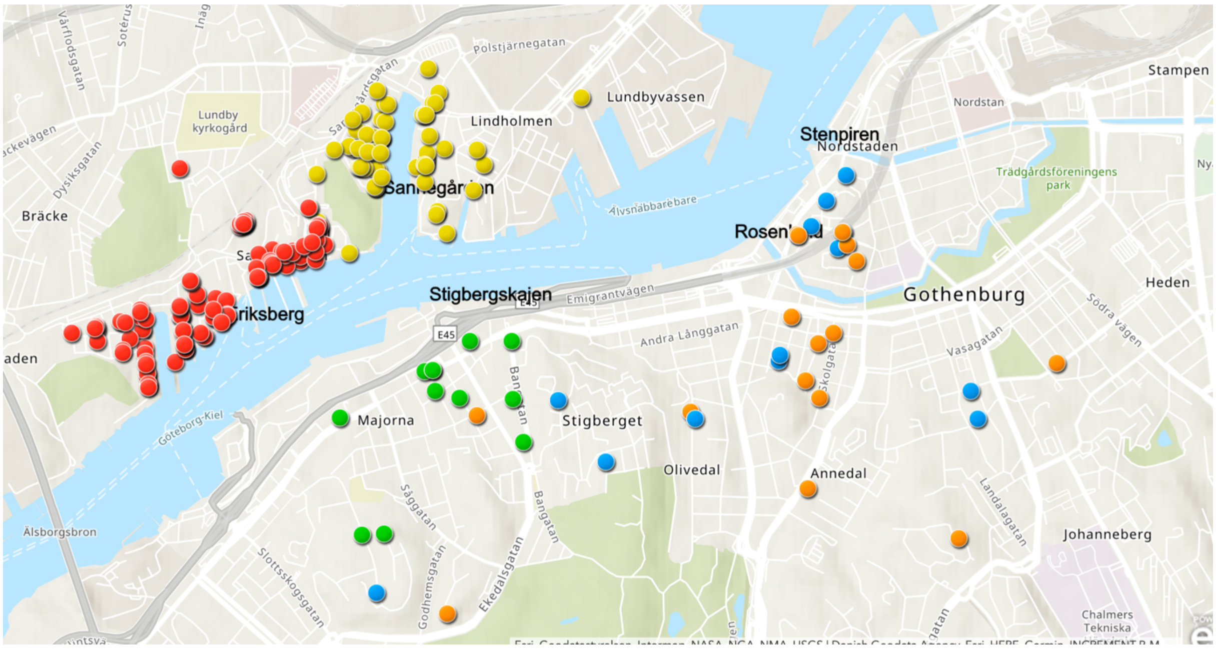
2. To simplify the sorting and analysis of data the recycling centers have been matched with the quays. It is assumed that visitors of Stenpiren or within the catchment area of Stenpiren otherwise visit Sävenäs. Högsbo is matched with Rosenlund and Stigbergskajen. While Bulycke is matched with Eriksberg and Sannegården.
3. It has been assumed that the trucks going between the recycling centers and sorting facilities carry ten tons of waste and a 2,3-ton container. An assumption based on the information of the vehicle operating these distances which enabled the authors to get information on the max load of the vehicle. It was then assumed that the vehicle always was filled to the max, therefore, giving ten tons of waste.
4. It has been assumed that the passenger cars are operated single-handedly with a driver of 75 kilos and carries 130 kilos waste when going to the recycling center. 130 kilos were selected due to the average waste brought by a visitor was 170 kilos. However, the authors believed the weight most likely differs extensively between visitors and, therefore, the weight selected for the model was a bit lower than the average.
5. As petrol is the most common fuel amongst private cars in Sweden (Körkortonline, 2019) it is assumed the inhabitants of Gothenburg drive a petrol car.
6. Mapping out which roads the trucks travel on between the recycling center and sorting facility the assumption that has been made that the trucks avoid city traffic and local roads. Therefore, the assumed route has been brought forward by using Google Maps and then selecting the route that goes around the city using mainly main roads and highways. It has also been assumed that these operations occurred during working hours and avoid peak hours in traffic (Before 08:00 and after 16:00).
7. Mapping out the distance traveled by inhabitants of Gothenburg when going to the recycling center a location consisting of housing near to each quay was selected. Using google maps the tool gave several different route options for each location, in this scenario the distance was selected based on convenience. Meaning that an individual will most likely choose the route option that is believed to be the most

Appendix 2 – Assumptions

	Assumptions	Founded in
Private Cars		
	A petrol Car Euro 6 is used by the residents of Gothenburg	A petrol car is used in the research as it is still the most commonly used in Sweden (Körkortonline, 2019).
	The private passenger car has one person in the car when going to recycling center weighing 75 kilos	Göteborgs Stad (2020e) express that most of the households in 2018 consisted of one person.
	It is assumed that a private person brings 130 kilos when going to a recycling center by car.	The average waste brought by a visitor was 170 kilos in 2019. The authors believed the weight most likely differs extensively between visitors and, therefore, the weight selected for the model was a bit lower than the average. Calculated based on email conversation with respondent 1 on 28th of February 2020.
	The private passenger takes the fastest route to the recycling center	Based on the logic of wanting to get to the recycling center as fast as possible.
Trucks		
	It has been assumed that the trucks going between the recycling centers and sorting facilities carries ten tons waste and a 2,3 tons container. That the trucks are 20-26t rigid trucks and Euro class 6.	An assumption based on the information of the vehicles operating these distances, received from respondent 1 via email on 9th of March 2020. It was then assumed that the vehicle always was filled to the max, therefore, giving ten tons of waste.
	The assumption that have been made that the trucks avoid city traffic and local roads.	Based on the importance of efficient logistic performance considering the economic losses in not operating efficiently (Behrends, 2016a).
Residents and Barge		
	Every time the trial schedule had a gap of two or more days the barge went to Skräppekärr to be emptied which created seven different routes.	The decision was built upon the barge being emptied seven times as per email conversation with respondent 1 on 6th of February 2020.

	The towing cost is assumed to be steady at 20 000 SEK, an average of the actual cost.	An average of the actual cost. The breakdown of the actual cost can be found in Appendix 7.
	It has been assumed that the staff working on the barge is on site one hour before and after opening and closing time.	Based on email conversation with respondent 1 on 11th of March 2020.
	It is assumed that visitors of Stenpiren otherwise visit Sävenäs recycling center. Högsbo recycling center is matched with Rosenlund and Stigbergskajen. While Bulycke recycling center is matched with Eriksberg and Sannegården.	Built upon the location of the recycling centers in regard to the quays used. They have been matched with the recycling center closest to the quay in terms of driving distance.
	Residents visit the quays that are on the same side as their housing	Founded in the results from mapping out where the visitors lived in relation to the quay they visited. Visualized in the map in Appendix 3.
	Barge visitors walks or rides a bike to access the quays	Founded in the retrieved information that the selected visiting quays cannot be accessed by car since there is no parking close by. Mentioned on the meetings authors attended.

Appendix 3 – Map where visitors lived



Color and which quay they visited:

Red – Eriksberg

Yellow – Sannegården

Green – Stigbergskajen

Orange – Rosenlund

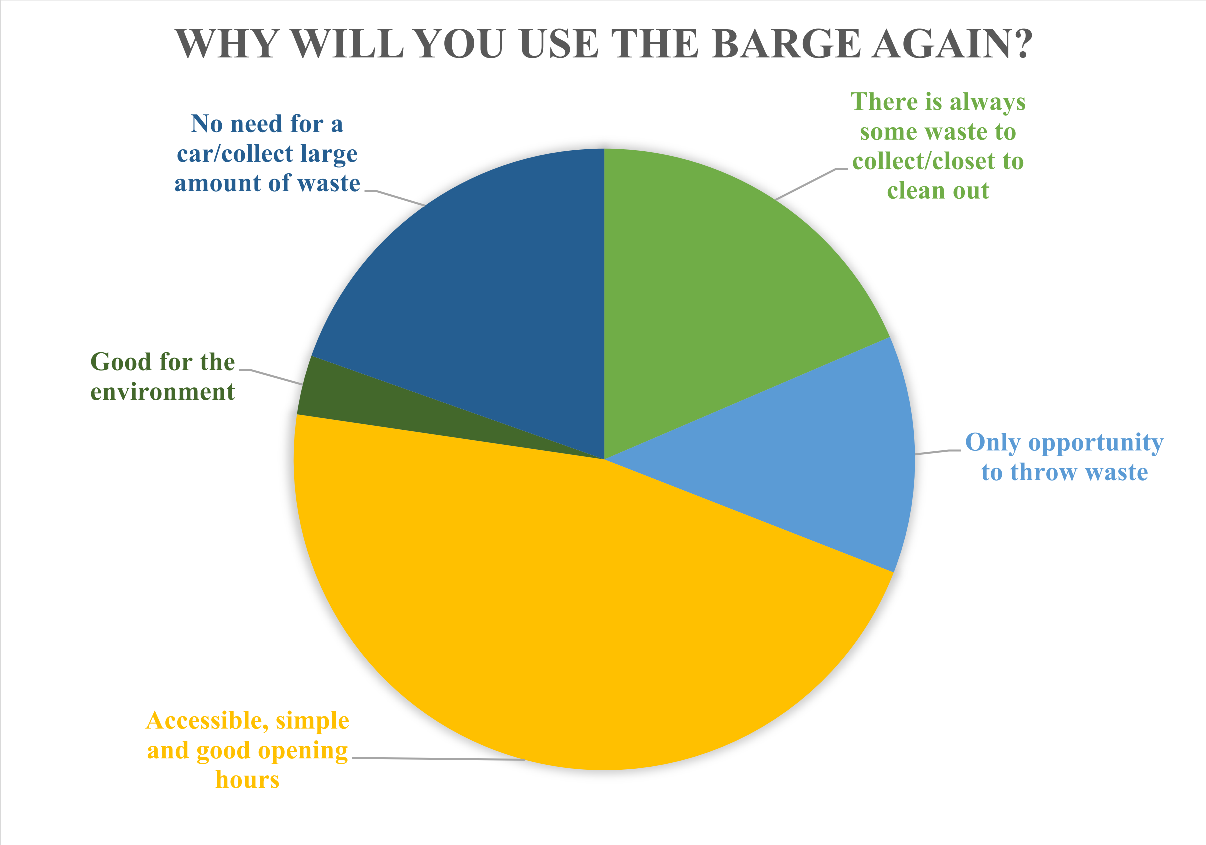
Blue – Stenpiren

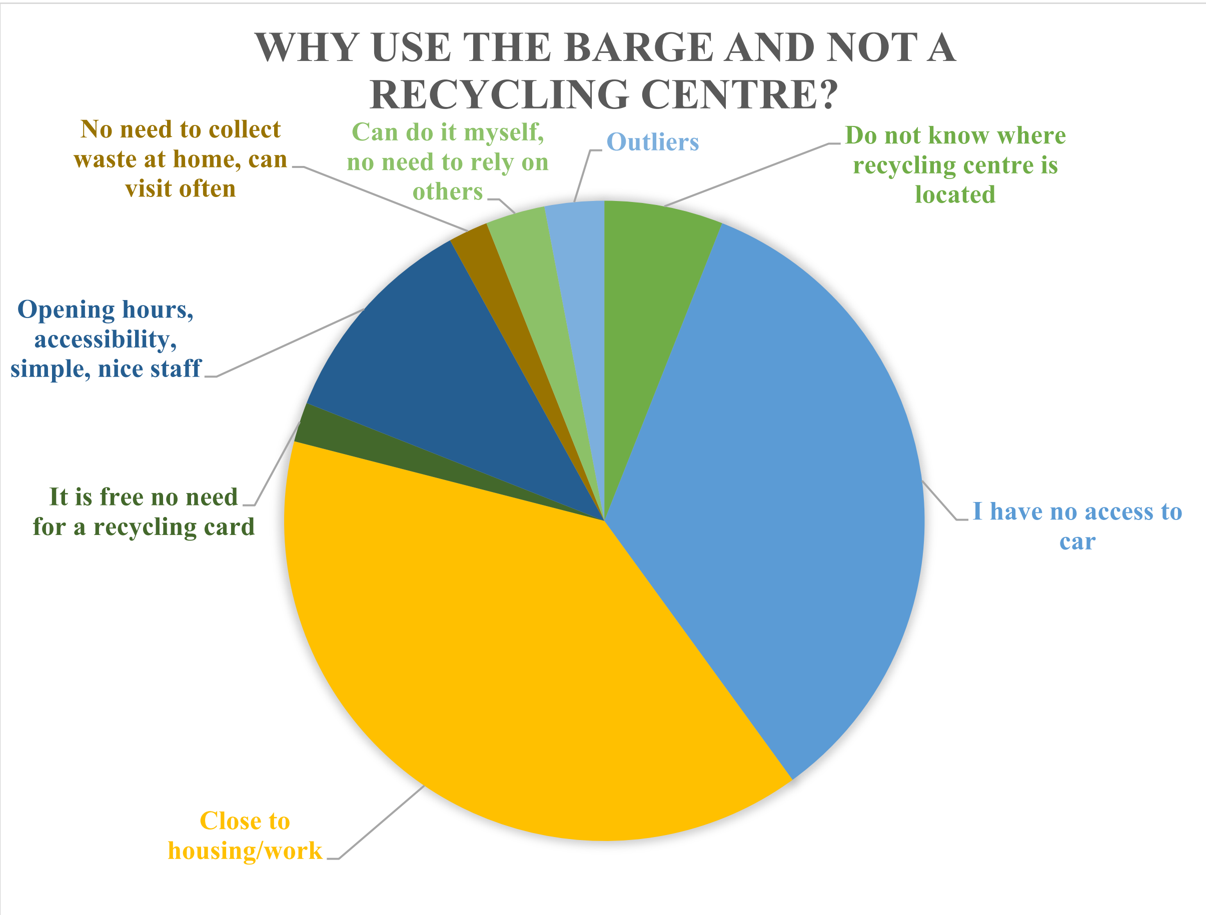
Appendix 4 – Table over number of visitors from each quay and how much waste was collected

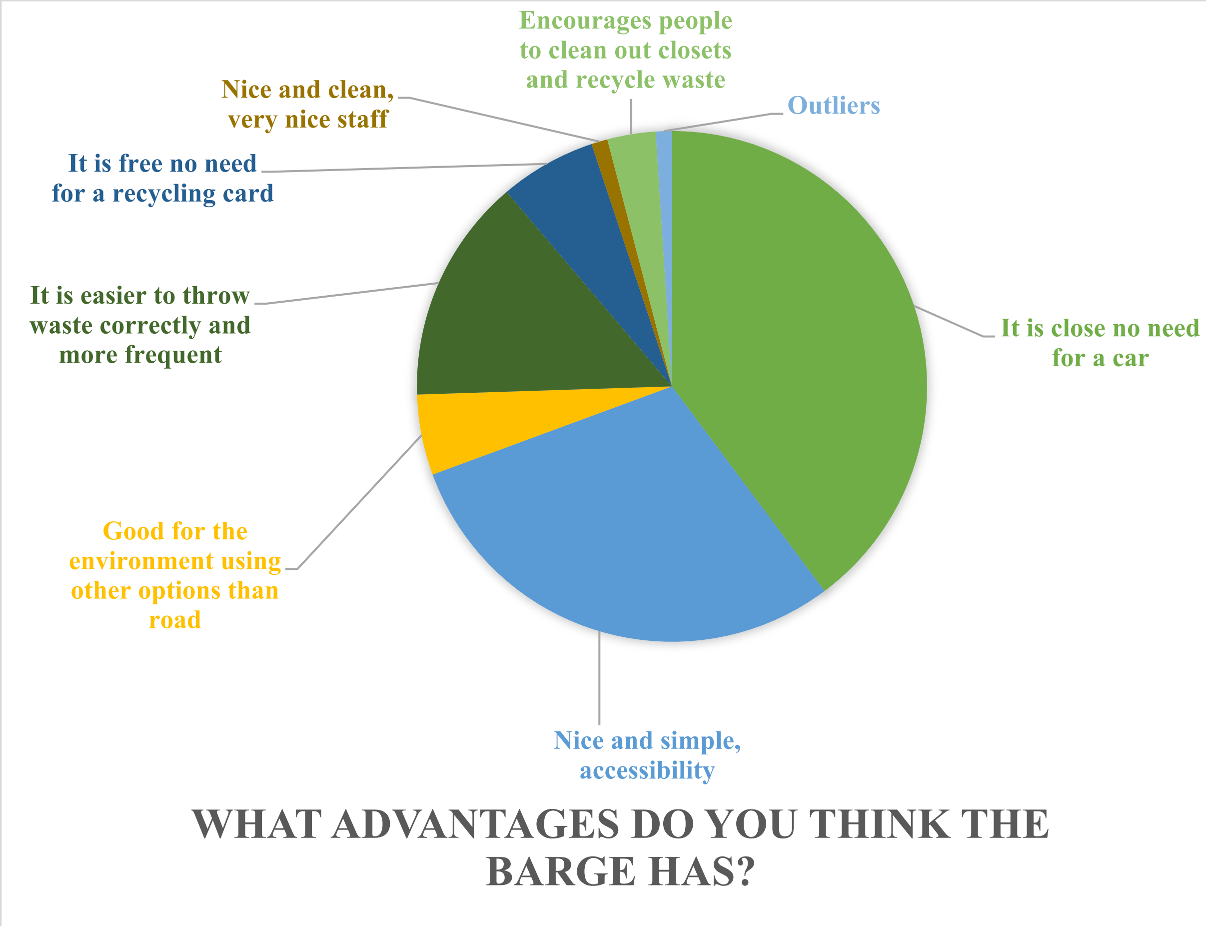
Quays	Number of visitors	Percentage of visitors	Number of days	Total waste collected (kilos)	Waste collected daily (kilos)
Eriksberg	1340	55%	6	15 410	2 568,33333
Sannegården	928	38%	8	10 672	1 334
Rosenlund	81	3%	5	931,5	186,3
Stigbergskajen	29	1%	2	333,5	166,75
Stenpiren	49	2%	3	563,5	187,833333
Total	2427	100%		2 791 0,5	

Average amount of waste brought per visitor: 11,5 kilos

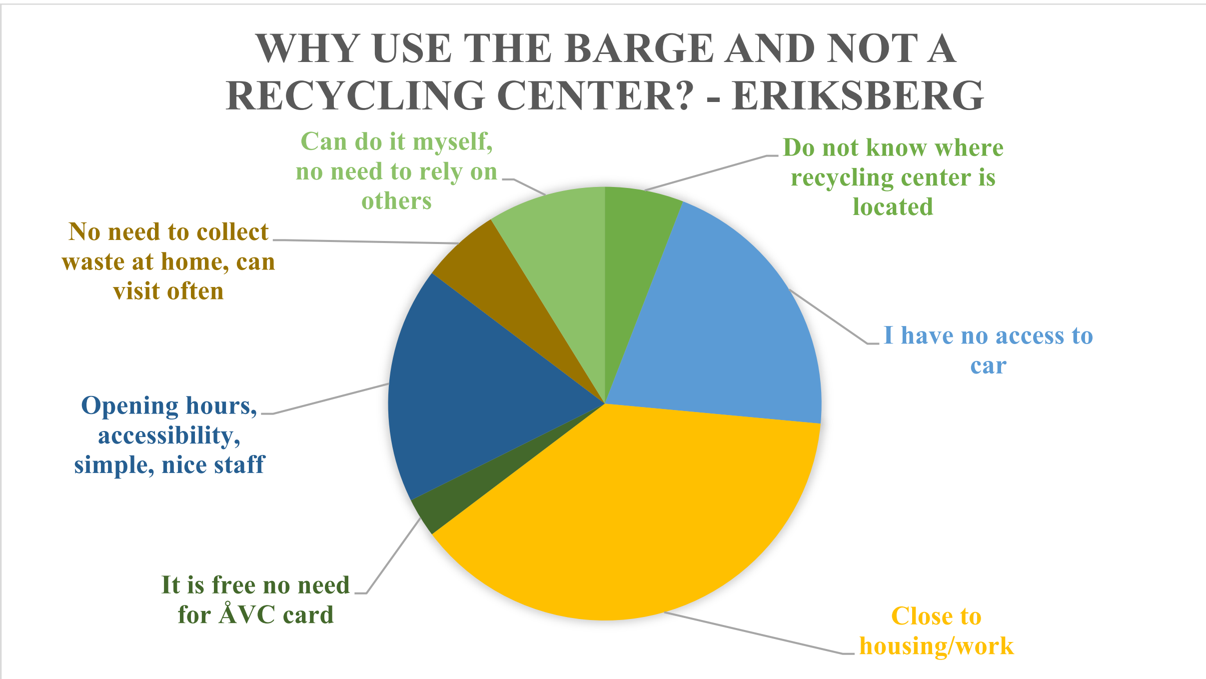
Appendix 5 – Pie charts from the survey conducted following the trial run

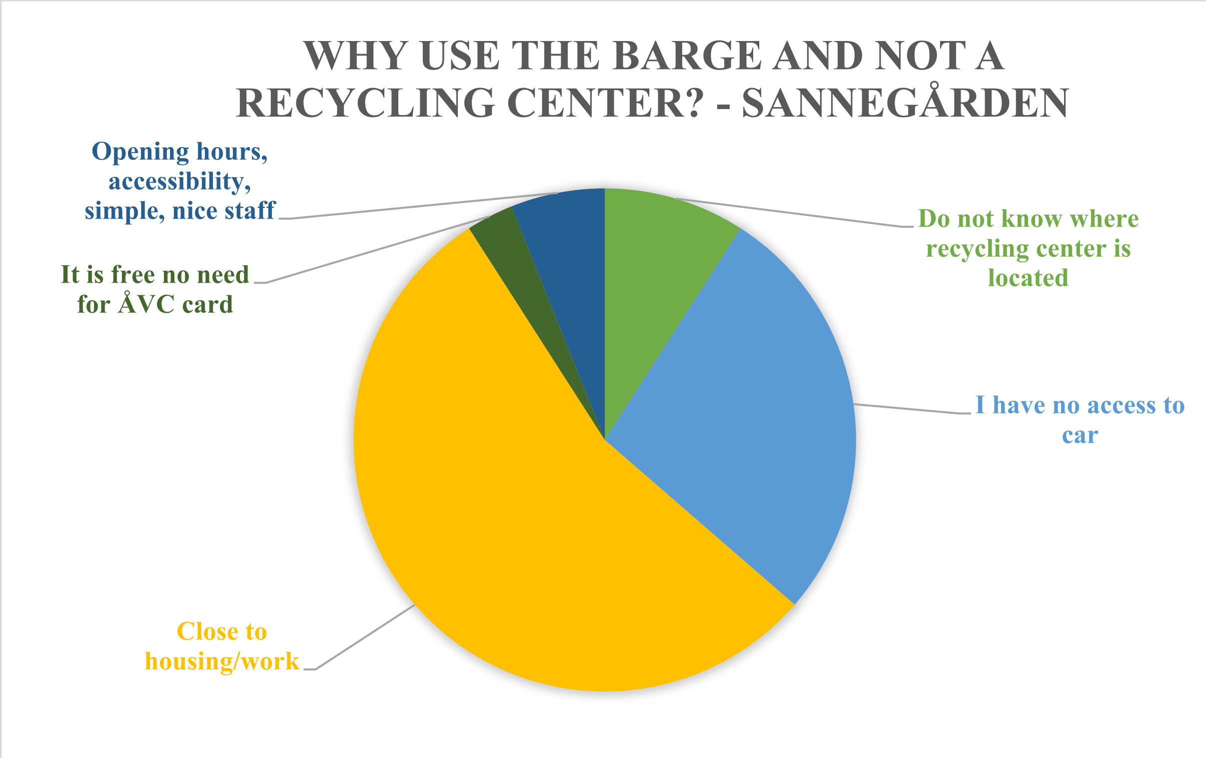


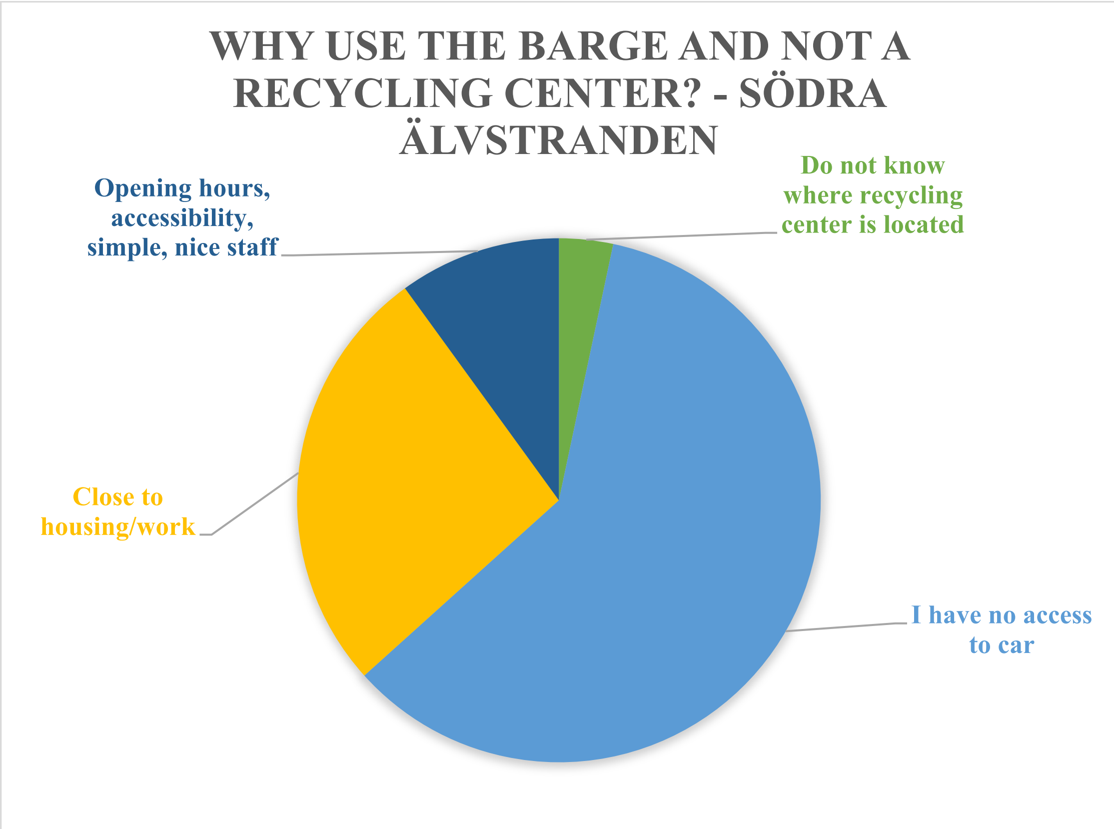




North side vs. south side




WHY USE THE BARGE AND NOT A RECYCLING CENTER? - SANNEGÅRDEN
Opening hours, accessibility, simple, nice staff
It is free no need for ÅVC card
Do not know where recycling center is located
I have no access to car
Close to housing/work


WHY USE THE BARGE AND NOT A RECYCLING CENTER? - SÖDRA ÄLVSTRANDEN
Opening hours, accessibility, simple, nice staff
Do not know where recycling center is located
Close to housing/work
I have no access to car

Appendix 6 – The schedule and routes of the barge (distance and waste collected at each stop)

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
38			Rigging	Rigging	Rigging	Sannegården	Sannegården
39		Stenpiren	Rosenlund			Eriksberg	Eriksberg
40		Sannegården	Sannegården				Stigbergskajen
41		Eriksberg	Eriksberg			Rosenlund	Rosenlund
42		Sannegården	Sannegården				Stigbergskajen
43		Stenpiren	Stenpiren			Eriksberg	Eriksberg
44		Rosenlund	Rosenlund			Sannegården	Sannegården
45	De-rigging	De-rigging					

	Route 1 (Days)	Waste (KG)	Next Stop(Km)
Stop 1	Skräppekärr	0	6,61
Stop 2	Sannegården (2)	2668	2,19
Stop 3	Stenpiren (1)	2855,833333	0,56
Stop 4	Rosenlund (1)	3042,133333	4,91
Stop 5	Skräppekärr	3042,133333	
Total	Total		14,27
	Route 2 (Days)	Waste (KG)	Next Stop(Km)
Stop 1	Skräppekärr	0	7,32
Stop 2	Eriksberg (2)	5136,666667	1,28
Stop 3	Sannegården (2)	7804,666667	6,61
Stop 4	Skräppekärr	7804,666667	
Total			15,21
	Route 3 (Days)	Waste (KG)	Next Stop(Km)
Stop 1	Skräppekärr	0	6,09
Stop 2	Stigbergskajen (1)	166,75	1,03
Stop 3	Eriksberg (2)	5303,416667	7,32

Stop 4	Skräppekärr	5303,416667	
Total			14,44
	Route 4 (Days)	Waste (KG)	Next Stop(Km)
Stop 1	Skräppekärr	0	4,91
Stop 2	Rosenlund (2)	372,6	1,83
Stop 3	Sannegården (2)	3040,6	6,61
Stop 4	Skräppekärr	3040,6	
Total			13,35
	Route 5 (Days)	Waste (KG)	Next stop (Km)
Stop 1	Skräppekärr	0	6,09
Stop 2	Stigbergskajen (1)	166,75	1,98
Stop 3	Stenpiren (2)	542,4166667	4,65
Stop 4	Skräppekärr	542,4166667	
Total	Total		12,72
	Route 6 (Days)	Waste (KG)	Next Stop(Km)
Stop 1	Skräppekärr	0	7,32
Stop 2	Eriksberg (2)	5136,666667	2,43
Stop 3	Rosenlund (2)	5509,266667	4,91
Stop 4	Skräppekärr	5509,266667	
Total			14,66
	Route 7 (Days)	Waste (KG)	Next stop(Km)
Stop 1	Skräppekärr	0	6,61
Stop 2	Sannegården (2)	2668	6,61
Stop 3	Skräppekärr	2668	
Total	Total		13,22

Whole trial	Waste (KG)	Distance
Route 1	3042,133333	14,27
Route 2	7804,666667	15,21
Route 3	5303,416667	14,44
Route 4	3040,6	13,35
Route 5	542,4166667	12,72
Route 6	5509,266667	14,66
Route 7	2668	13,22
Total	27910,5	97,87

Appendix 7 – Full cost breakdown of recycling center

All numbers presented in SEK.

Category	Cost Items	Bulycke	Högsbo	Sävenäs
Rent				
	Rent of facilities and leases	257 445 kr	365 551 kr	312 303 kr
	Purchase of services from operator	3 295 359 kr	6 076 245 kr	3 297 248 kr
Transport				
	Rent and lease of trucks	96 697 kr	87 208 kr	- kr
Labour				
	Worked hours of consultants	671 051 kr	34 272 kr	40 738 kr
	Hired staff (outside)	84 396 kr	38 951 kr	72 635 kr
Operational				
	Electricity	63 292 kr	60 842 kr	46 974 kr
	Water and sewage	5 351 kr	36 718 kr	10 513 kr
	IT services	61 860 kr	89 844 kr	66 669 kr
	IT programs and license fee	3 575 kr	7 610 kr	3 575 kr
Maintenance				
	Purchase of maintenance material	4 600 kr	77 104 kr	- kr
	Produced maintenance material	35 091 kr	13 975 kr	- kr
	Indoor cleaning services	27 278 kr	27 277 kr	42 927 kr
	Gardening	21 984 kr	1 063 kr	8 640 kr
	Snow shoveling and salting of roads	11 252 kr	65 221 kr	- kr
	Small reperations and building maintenance	5 497 kr	29 061 kr	26 880 kr
	Reperation and maintenace of machines	17 978 kr	63 317 kr	- kr
	Plant construction (entreprenad)	879 267 kr	276 783 kr	115 843 kr
	Repair construction (entreprenad)	46 399 kr	63 619 kr	230 127 kr
	Inspection of construction work (entreprenad)	7 400 kr	- kr	- kr

Security				
	Security of facilities (alarm, guards etc.)	- 26 113 kr	32 769 kr	15 442 kr
Consultancy				
	IT consultancy services	133 881 kr	34 648 kr	7 148 kr
	Additional services	- kr	97 753 kr	- kr
Others				
	General fees	19 684 kr	37 463 kr	5 999 kr
	Depreciation of properties for operations	1 155 431 kr	357 490 kr	975 586 kr
	Interest on loan from affiliates	366 234 kr	51 078 kr	256 566 kr
	Total	**7 244 887 kr**	**8 025 861 kr**	**5 535 813 kr**

Appendix 8 – List over interviews with respondents

Respondent 1	**Waste and water expert**
4th of February, email	Sent the summary of amounts of waste and visitors at each recycling center.
5th of February, email	Clarifying the data in file" Hur mycket folk slänger fel"
6th of February, email	Informed that the barge was emptied seven times
14th of February, email	Sent the simplified summary of the economy The transport cost is related to emptying
14th of February, email	Sent over the file of what respondent 4 invoiced for the barge and tugboat. As well as information of the tug consuming 1 000-1 100-liter diesel. Cannot recall if the cost is specified in the file. If not, the cost is in this case included in the cost for towing the barge.
28th of February, email	Sent financial data for recycling centers and amount of waste.
2nd of March, email	Clarifying that the electronic waste is accounted for in another way, so they don't have this in their system. Attached "Ersättningsunderlag"
2nd of March, email	Capacity of barge in kilos. More a question of space limitation rather than weight
4th of March, email	The most trucks going between recycling center and sorting facility is Euro VI and some Euro V
6th of March, email	All trucks are Euro VI demountable trucks.
9th of March, email	Received registration number for one of the trucks going between recycling centers and sorting facility.
11th of March, email	Informed about the staff on the barge, two employees on the weekdays and three during the weekends.
11th of March, email	Received information concerning the cost of unloading of the waste at Skräppekärr.

16th of March, email	Received a map over housing plan for next trial run, Autumn 2020
Respondent 2	**Environmental expert and developer of CUTS model**
26th of February, email	Sent articles; Factors influencing the performance of urban consolidation schemes; GrönBostad, Glue final
28th of February, email	The CUTS model was sent to the authors.
2nd of March, face-to-face	Meeting explaining the CUTS model and how to use it and what data is needed.
9th of March, email	Refers to a paper that could help to identify the emission for the barge
10th of March, email	Advised the authors to use the truck that is already in the model considering that it is equal to the one we got inform by respondent 1 was used.
11th of March, email	Attach the emission factor for this truck as well as for private cars. Guidance to observe Gothenburg as a metropolitan area and using this attribute in the model.
20th of April over the phone	Help with some issues with the model. Also, assist in validating the results from the model and how to interpret them.
Respondent 3	**Maritime expert**
4th of March, email	The barge fuel consumption and average speed.
9th of March, email	Expressing an even fuel consumption even if the barge was loaded or not.
10th of March, email	Inform that the fuel consumption may be even higher than predicted earlier.
Respondent 4	**Barge expert**
18th of March, email	Information of the barge and tugboat
20th of March, email	Discussion concerning Euro classes, does not believe this existed when the engine came but instead this appeared later on.
Respondent 5	**Emission expert**

19th of March, email	Helping will calculating emission for barge, express that it may need to be calculated on the age rather than euro class since this did not exist when engine was released in 1989
30th of March, email	Sent over some emissions calculations for the barge
2nd of April, over the phone	Further explained the emissions of the barge from the document he sent over.

Appendix 9 – people registered by postcodes

Quays	Postcodes	Registered
Stigbergskajen/Rosenlund	41464	926
Stigbergskajen/Rosenlund	41463	981
Stigbergskajen/Rosenlund	41318	2054
Stenpiren/Rosenlund	41328	758
Stenpiren/Rosenlund	41327	1346
Stenpiren/Rosenlund	41304	1348
Stenpiren/Rosenlund	41303	401
Stenpiren/Rosenlund	41302	917
Stenpiren/Rosenlund	41301	958
Stenpiren/Rosenlund	41123	524
Stenpiren/Rosenlund	41121	25
Stenpiren/Rosenlund	41120	833
Stenpiren/Rosenlund	41119	601
Stenpiren/Rosenlund	41118	589
Stenpiren/Rosenlund	41117	74
Stenpiren/Rosenlund	41114	161
Stigbergskajen	41465	1063
Stigbergskajen	41462	1027
Stigbergskajen	41461	955
Stigbergskajen	41460	755
Stigbergskajen	41459	1191
Stigbergskajen	41458	1135
Stigbergskajen	41456	909
Stigbergskajen	41455	1292
Stenpiren	41138	208
Stenpiren	41126	542
Stenpiren	41125	1159
Stenpiren	41116	54
Stenpiren	41115	59
Stenpiren	41113	272

Stenpiren	41110	30
Stenpiren	41108	123
Stenpiren	41107	57
Stenpiren	41106	73
Stenpiren	41105	693
Stenpiren	41104	46
Sannegården	41760	1471
Sannegården	41758	1080
Sannegården	41757	1181
Rosenlund	41317	1030
Rosenlund	41316	1128
Rosenlund	41315	1257
Rosenlund	41309	1454
Rosenlund	41308	1435
Rosenlund	41307	757
Rosenlund	41306	470
Rosenlund	41305	776
Rosenlund	41143	1040
Rosenlund	41128	737
Rosenlund	41122	996
Eriksberg	41766	1370
Eriksberg	41765	1137
Eriksberg	41764	941
Eriksberg	41762	861
Totalt	54	43260

Appendix 10 – Number of visitors and waste from recycling centers

Number of visitors

2019	Sävenäs	Högsbo	Bulycke
Jan	2798	7740	2029
Feb	2585	7178	1942
Mar	3689	9528	2976
Apr	4194	10476	3573
Maj	4116	10294	3486
Jun	3868	9808	3511
Jul	4084	11482	3738
Aug	4331	11172	3627
Sep	4177	10161	3274
Okt	4263	10740	3239
Nov	3925	9312	2784
Dec	3604	5690	1485
Total	45634	113581	35664

Waste collected

2019	Waste (Tons)
Bulycke	5956
Högsbo	18969
Sävenäs	8290

Appendix 11 – Results from CUTS model

Emissions private car in SEK

	CO_2	Local Emission
Passenger Car Bulycke-Eriksberg	3,05	0,10
Passenger Car Bulycke-Sannegården	2,83	0,09
Passenger Car Högsbo-Rosenlund	1,85	0,09
Passenger Car Högsbo-Stigbergskajen	3,48	0,15
Passenger Car Sävenäs-Stenpiren	3,27	0,09

Emissions trucks in SEK

	CO_2	Local Emission
Renova Truck Högsbo	29,62	1,62
Renova Truck Sävenäs	12,41	0,83
Renova Truck Bulycke	31,91	1,71

Emissions barge in SEK

	CO_2	Local Emission
Recycling Barge Route 1	117,29	587,41
Recycling Barge Route 2	125,02	626,10
Recycling Barge Route 3	118,70	594,41
Recycling Barge Route 4	109,77	549,54
Recycling Barge Route 5	104,54	523,60
Recycling Barge Route 6	120,55	603,46
Recycling Barge Route 7	108,68	544,18
Recycling Barge Total Pilot	804,44	4028,29

Congestion cost in SEK

	Congestion costs
Renova Truck Högsbo	176,89
Renova Truck Sävenäs	185,36
Renova Truck Bulycke	263,85
Passenger Car Bulycke-Eriksberg	144,26
Passenger Car Bulycke-Sannegården	83,35
Passenger Car Högsbo-Rosenlund	60,19
Passenger Car Högsbo-Stigbergskajen	74,37
Passenger Car Sävenäs-Stenpiren	116,32

Appendix 12 – Roads travelled by truck and private car

Trucks																	
Högsbo- Marieholm					A Ohnersgatan		Söderleden		Västerleden		Oscarsleden		E45		Marieholmsgatan		Total
					Local Road		Main Road		Main Road		Main Raad		Highways		Local Road		
					Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (Km)	Capacity	
					0,989	Free Flow/N	1,25	Free Flow	6,9	Free Flow	2,1	Free flow	5,57	Free Flow/N	3,26	Free flow / Ne	20,069
Marieholm Högsbo					Marieholmsgatan		E45		Oscarsleden		Västerleden		Söderleden		A Ohnersgatan		
					Local Road		Highways		Main Raad		Main Road		Main Road		Local Road		
					Distance (Km)	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	
					3,26	Free flow /N	5,57	Free Flow/N	2,1	Free flow	6,9	Free Flow	1,25	Free Flow	0,989	Free Flow/Nea	20,069
Sävenäs - Marieholm					Von Utfallsgatan		Sävenäsleden		E20		Partihalls Förbindelsen		E45		Marieholmsgatan		
					Local Road		Main Road		Highway		Main Road		Highway		Local Road		
					Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	ce (Km)	Capacity	
					1,87	Free Flow /N	0,4	Free Flow/N	0,59	Free Flow	0,66	Free Flow	0,37	Free Flow/N	3,26	Free flow / Ne	7,15
Marieholm-Sävenäs					Marieholmsgatan		E45		Partihalls Förbindelsen		E20		Sävenäsleden		Von Utfallsgatan		
					Local Road		Highway		Main Road		Highway		Main Road		Local Road		
					Distance (Km)	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	
					3,26	Free flow / N	0,37	Free Flow	0,66	Free Flow	0,59	Free Flow	0,4	Free Flow/ N	1,87	Free Flow/ Ne	7,15
Bulycke - M	ulyckevägen		Hamneviksvägen		Torslanda Vägen		Hisingsleden		Älvsborgsbron		Oscarsleden		E45		Marieholmsgatan		
	Local Road		Local Road		Main Road		Main Road		Main Road		Main Road		Highway		Local Road		
	Distance	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (Km)	Capacity	Distance (Km)	Capacity	
	0,21	Free Flow	0,43	Free Flow	4,1	Free Flow /C	1,25	Free Flow	2,9	Free Flow	2,10	Free flow	5,57	Free Flow/N	3,26	Free flow / Ne	19,82
Marieholm -	arieholmsgatan		E45		Oscarsleden		Älvsborgsbron		Hisingsleden		Torslanda Vägen		Hamneviksvägen		Bulyckevägen		
	Local Road		Highway		Main Road		Main Road		Main Road		Main Road		Local Road		Local Road		
	Distance (Km)	Capacity	Distance (Km)	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	Distance (K	Capacity	
	3,26	Free flow / N	5,57	Free Flow/N	2,10	Free flow	2,9	Free Flow	1,25	Free Flow	4,1	Free Flow /N	0,43	Free Flow	0,21	Free Flow	19,82

Cars																					
Eriksberg -Bulycke									Västra Eriksbergsgatan		Lundbyleden		Ovädersgatan		Hisingleden		Torslandavägen		Bulyckevägen		
									Local Street		Main Road		Main Road		Main Road		Main Road		Local Road		
									Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
									1,55	Near Capacit	0,42	Free Flow	0,41	Over Capacit	0,65	Free Flow	4	Free Flow/N	0,46	Free Capacity	7,49
Bulycke - Eriksberg									Bulyckevägen		Torslandavägen		Hisingleden		Ovädersgatan		Lundbyleden		Västra Eriksbergsgatan		
									Local Street		Main Road		Main Road		Main Road		Main Road		Local Road		
									Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
									1,55	Free Flow/ N	0,42	Free Flow /C	0,41	Free Flow	0,65	Free Flow	4	Free Flow	0,46	Near Capacity	
Sannegården - Bulycke											Kolhamnsgatan		Lundbyleden		Hisingleden		Torslandavägen		Bulyckevägen		
											Local Road		Main Road		Main Road		Main Road		Local Road		
											Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
											0,3	Free flow/Ne	2,73	Free Flow	0,65	Free Flow	4	Free Flow/N	0,46	Free Capacity	8,14
Bulycke - Sannegården											Bulyckevägen		Torslandavägen		Hisingleden		Lundbyleden		Kolhamnsgatan		
											Local Road		Main Road		Main Road		Main Road		Local Road		
											Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
											0,46	Free Capacity	4	Free Flow/O	0,65	Free Flow	2,73	Free Flow	0,3	Near Capacit	8,14
Stigbergskajen-Högsbo											Karl Johansgatan /Djurgårdsgatan		Oscarsleden		Högsboleden		Dag Hammarsskjöldsleden		A Ohners gatan		
											Local Road		Main Road		Main Road		Main Road		Local Street		
											Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
											0,33	/Free Flow N	3,32	Free Flow	3	Free Flow /Ne	0,9	Free Flow	0,9	Free Flow/N	8,45
Högsbo - Stigbergskajen											A Ohners gatan		Dag Hammarsskjöldsleden		Högsboleden		Oscarsleden		Karl Johansgatan /Djurgårdsgatan		
											Local Street		Main Road		Main Road		Main Road		Local Road		
											Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
											0,9	Free Flow/N	0,9	Free Flow	3	Free Flow / N	3,32	Free Flow	0,33	Over Capacit	8,45
Rosenlund - Högsbo											Nordhemsgatan		Prinsgatan		Linnegatan		Dag Hammarsskjöldsleden		A Ohners gatan		
											Local Street		Local Street		Local Street		Main Road		Main Road		
											Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
											0,067	Near Capacit	0,12	Over Capacit	0,68	Over Capacity	3,7	Free Flow	0,84	Free Flow/N	5,41
Högsbo -Rosenlund											A Ohners gatan		Dag Hammarsskjöldsleden		Linnegatan		Prinsgatan		Nordhemsgatan		
											Local Street		Main Road		Local Street		Local Street		Local Street		
											Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
											0,84	Near Capacit	3,7	Free Flow	0,68	Near Capacity	0,12	Near Ca	0,067	Near Capacit	5,41
Stenpiren - Sävenäs	Stora Badhusgatan		Surbrunnsgatan		Masthamnsbron		Emigrantvägen		Järnvågs gatan		E45		Partihallarna		E20		Sävenäs leden		Von Utfallsgatan		
	Local Street		Local Street		Local Street		Main Road		Local Street		Highway		Main Road		Highway		Main Road		Local Street		
	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
	0,4	Free Flow	0,069	Free Flow	0,15	Free Flow	0,15	Free Flow	0,1	Over Capacit	3,7	Free Flow/N	1,6	Free Flow	0,58	Free Flow	0,55	Near Capcity	1,7	Near Capacit	9,00
Sävenäs - Stenpi	Von Utfallsgatan		Sävenäs leden		E20		Partihallarna		E45		Järnvågs gatan		Emigrantvägen		Masthamnsbron		Surbrunnsgatan		Stora Badhusgatan		
	Local Street		Main Road		Highway		Main Road		Highway		Local Street		Main Road		Local Street		Local Street		Local Street		
	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	Distance	Capacity	
	1,7	Over Capacit	0,55	Near Capcity	0,58	Free Flow	1,6	Free Flow	3,7	Free Flow/O	0,1	Over Capacit	0,15	Free Flow	0,15	Free Flow	0,069	Near Capacit	0,4	Free Flow	9,00