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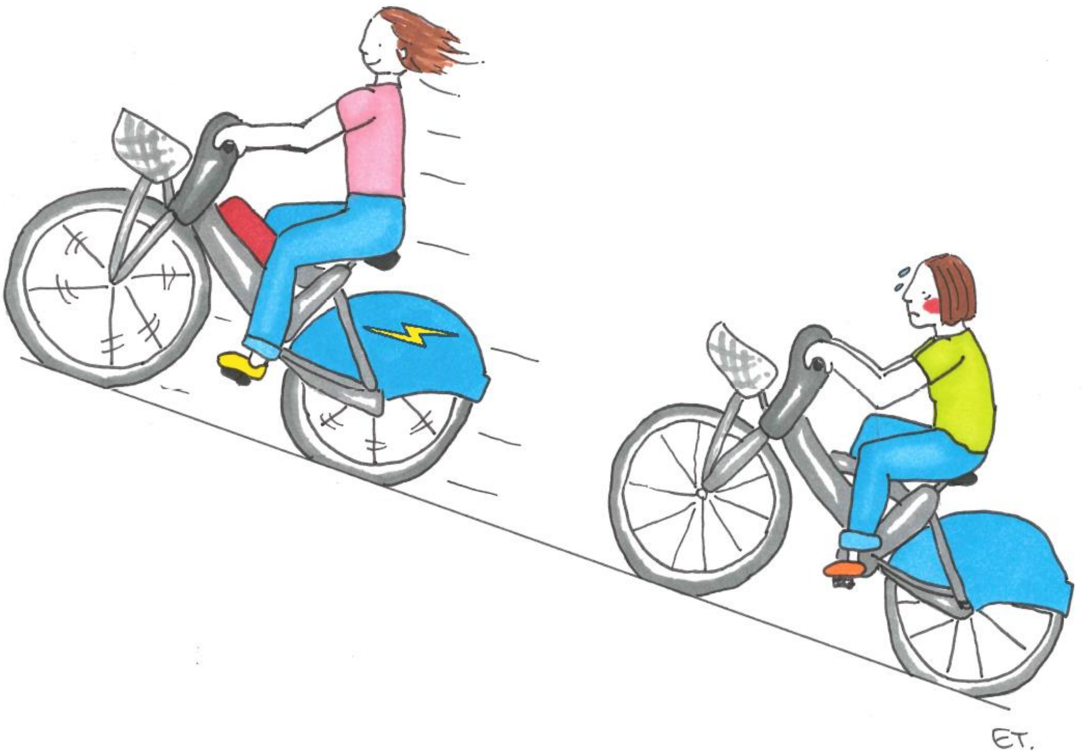

Electric Bicycles in Bike-Share Systems

An Investigation of the Potential for Electric Bicycles in Gothenburg's Bike-Share System Styr & Ställ

Master's Thesis in the Master's Programme Infrastructure and Environmental Engineering

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Cover:
Illustration of the simplicity to cycle uphill with an electric Styr & Ställ bicycle compared to a conventional Styr & Ställ bicycle. Illustrated by Elin Tjäder (2016).

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ABSTRACT

Gothenburg is growing geographically as well as population-wise and experiences a densification. Solutions for sustainable transportation are needed, and a way to promote this is by having a bike-share system (BSS). Today Gothenburg has a BSS with conventional bicycles, Styr & Ställ, located in the city centre. Due to the growing city the system might need to develop and expand. This thesis investigates the potential of e-bikes in Styr & Ställ and the possibilities to expand the system due to e-bikes. This both include an extensive literature review on BSS, interviews and case studies with European cities with electric BSS, and analysis of where to develop the system geographically.

It is found that there are some topographic limitations in the current system in Gothenburg, which can be approached by e-bikes. It is also possible to go further with an e-bike and therefore include more areas in the system. With e-bikes more and other groups of users can be reached, for instance older people, physically limited people, or people in context that do not want to arrive sweaty.

Analyses were done in order to find suitable areas for an expanded BSS. The expansion areas that were found for the system are mainly the sub-districts Majorna, Masthugget, Frölunda Torg, Krokslätt, Lunden Olskroken, Gamlestaden, Lindholmen and Rambergsstaden. This is an overall radial expansion except from a corridor towards Frölunda Torg and Gamlestaden. Furthermore, stations based on destinations of interests such as public transport nodes, parks, squares, universities, and working places were suggested and located.

The conclusion is that there is a potential for electric bicycles in Styr & Ställ and that the system should be combined with both conventional and electric bicycles, in order to approach a broader user group. The system is also recommended to expand to the areas mentioned above. People that already use the BSS will be able to continue to use it in the same way, and people that prefer an e-bike in order to cycle, will them too have a socially, economic, and environmentally sustainable transport alternative that also improves the public health.

Key words: electric bike-share system, combined bike-share system, bike-share system, electric bicycle, Styr & Ställ, bicycling, sustainable transport

Elcyklar i lånecykelsystem

En utredning av potentialen för elcyklar i Göteborgs lånecykelsystem Styr & Ställ

Examensarbete inom masterprogrammet Infrastructure and Environmental Engineering

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SAMMANFATTNING

Göteborg håller på att växa, både geografisk och invånarmässigt och blir en allt tätare bebyggd stad. Därför behövs det transportlösningar som är hållbara, och en sådan lösning kan vara lånecykelsystem. Göteborg har idag ett lånecykelsystem, Styr & Ställ, som har sin utbredning i de centrala delarna av staden. Eftersom staden växer kan det finnas ett behov att Styr & Ställ också gör det. I det här examensarbetet utreds potentialen för elcyklar i Göteborgs lånecykelsystem Styr & Ställ. Detta görs genom en litteraturstudie av lånecykelsystem, samt intervju- och fallstudier av europeiska städer som har lånecykelsystem med elcyklar.

Det framkom att i dagens Styr & Ställ finns topografiska begräsningar, men dessa kan lösas med hjälp av elcyklar. Elcyklar möjliggör även längre resor vilket innebär att fler områden kan inkluderas i systemet. Vidare visade det sig att elcyklar kan öppna upp systemet för nya grupper i samhället, till exempel personer som inte vill bli svettiga, personer med fysiska begräsningar eller äldre personer.

Det gjordes analyser för att ta fram lämpliga områden för en utvidgning av Styr & Ställ. Av dessa analyser framkom det att primärområdena Majorna, Masthugget, Frölunda Torg, Krokslätt, Lunden Olskroken, Gamlestaden, Lindholmen och Rambergsstaden är lämpliga. Detta medför att en utvidgning skulle ske huvudsakligen radiellt, med undantag för utvidgningar längs stråk till Gamlestaden och Frölunda Torg. Dessutom placerades föreslagna stationer ut vid målpunkter som kollektivhållplatser, universitet, parker, torg och arbetsplatser.

Slutsatsen som dras är att det finns en potential för elcyklar i Styr & Ställ, men då som ett komplement till de vanliga cyklarna samt att systemet bör utvidgas till områdena nämnda ovan. Ett kombinerat system gör att personer som redan använder systemet kan fortsätta att göra det på samma sätt och personer som föredrar att cykla med elcykel har också de ett socialt, ekonomiskt och ekologiskt hållbart transportalternativ som även förbättrar folkhälsan.

Nyckelord: el-lånecykelsystem, kombinerat lånecykelsystem, lånecykelsystem, elcykel, Styr & Ställ, cykling, hållbara transporter

Contents

Preface

In this Master's thesis, electric bike-share systems has been studied and the potential of implementing electric bicycles in the bike-share system in Gothenburg Styr & Ställ has been investigated. The project was carried out during the spring of 2016 at the department of Civil and Environmental Engineering at Chalmers University of Technology. The thesis was performed at Trivector Traffic in Gothenburg.

The authors of this report are Sofie Erlandsson and Olivia Hägglöf, with supervision from Caroline Mattsson at Trivector Traffic and Gunnar Lannér at Chalmers University of Technology.

We would like to thank the employees at Trivector for help and support, and the providing of office space. Especially thanks to our supervisor Caroline Mattsson, and Axel Persson at Trivector Traffic for help with GIS. We also thank Gunnar Lannér at University of Technology for supervision, Emma Sjögren at Trafikkontoret for answering questions and help with finding contacts in other cities, Anna Clark at Trivector Traffic for help with translation of technical terms, and all who participated in the interviews and gave input to our thesis.

Gothenburg, June 2016

Sofie Erlandsson and Olivia Hägglöf

Notations

Vocabulary used in the thesis	Explanation
Bike-share system **BSS**	Bike-share system, also known as bike-share programme or bike sharing scheme, is an advanced technical system of specially designed bicycles meant for short-time rental. It is aiming to be available for the general public, which differs from a bicycle pool where there often are a few bikes that can be used by a small group of people, for example at companies.
Electrically assisted bicycle **Electric bicycle** **E-bike**	Electrically assisted bicycle, also known as pedelec. Electric bicycles referees to electric bicycles approved according to EU standards. Other types of electric bicycles are not concerned in this report.
Electric bike-share system **E-bike share system** **EBSS**	Electric bike-share system is a bike-share system with only electrically assisted bicycles, also known as e-bike scheme.
Combined bike-share system **Combined BSS**	Bike-share system with the combination of conventional and electric bicycles.
OBIS	Optimising Bike Sharing in European Cities is an EU project and a handbook for BSS
ITDP	Bike-share Planning Guide from the Institute for Transportation & Development Policy
The Bicycle Programme	Reference to the current valid bicycle programme in Gothenburg called *Cykelprogram för en nära storstad 2015-2025*
The Traffic Strategy	Reference to the current valid traffic strategy for Gothenburg called *Trafikstrategi för en nära sorstad - Göteborg 2035*
The Development Planning Strategy	Reference to the current valid development planning strategy for Gothenburg called *Strategi för Utbyggnadsplanering - Göteborg 2035*

Translation of Names:

Names used in Swedish	English translation
Göteborgs Stad	The City of Gothenburg, i.e. the municipality of Gothenburg
Trafikverket	Swedish Transport Administration
Trafikkontoret	Urban Transport Administration in the City of Gothenburg
Västtrafik	The public transport company in Gothenburg
Stadsbyggnadskontoret	Urban Planning Administration in the City of Gothenburg

Fastighetskontoret	Real Estate Administration in the City of Gothenburg
Vision Älvstaden	Rivercity Gothenburg vision

Glossary:

English	Swedish
District	Stadsdelsområde, t.ex. Centrum, Lundby, Angered
Sub-district	Pimärområde t.ex. Johanneberg, Guldheden, Lindholmen
Comprehensive planning	Översiktsplan
Local plan	Detaljplan
Proximity	Genhet
Procurement	Upphandling
Function density	Funktionstäthet
Key figure analysis	Nyckeltalsanalys, nykoanalys
Isochronal analysis	Analys av isokronkartor
Destination analysis	Målpunktsanalys

1 Introduction

This chapter contains a short background to the thesis, the aim and objectives as well as the delimitations. The method presented in this chapter is general for the report and more detailed described methods for the analyses are presented in Chapter 6. The outline for the report is presented in the end of this chapter.

With the on-going urbanisation and densification of cities, solutions for sustainable transport are needed. One way to solve the urban transport sustainably is by having a bike-share system. In the last twenty years bike-share systems has been implemented in numerous cities around the globe, in different sizes and configurations. Today it could be seen as almost a norm that a city with a size of Gothenburg has a bike-share system. Bike-share systems with electric bicycles have been more of a recent trend, since electric bicycles can increase the modal share of bicycling. New electric bike-share systems are implemented each year. In Europe these systems can especially be found in the alpine regions, where the topography is challenging.

1.1 Background

Gothenburg is the second largest city in Sweden with about 550,000 inhabitants (Göteborgs Stad, 2016) and is located on the west coast. The city centre is situated by the river Göta Älv and has generally flat topography, while some sub-districts are located on higher levels, such as Johanneberg, Lunden, and Masthugget. Gothenburg has the largest harbour in the Nordic Countries and the Gothenburg region has been the centre for car industry in Sweden for many years. Almost half of all trips made in Gothenburg with car (Trafikkontoret, 2015:c), which results in congestion and poor air quality in the city. In order to prevent this from increasing even more, the present and future planning for Gothenburg are in favour for sustainable transport, such as public transport, walking and bicycling (Trafikkontoret, 2014). There are over 100,000 bicycle trips made in Gothenburg every day, which corresponds to about 7 % of all the trips done in the city (Göteborgs Stad, n.d.:a).

In an urban area like Gothenburg it is important to promote sustainable transport modes, such as bicycle. To improve the cycling rate in the city a good way is to have a public bike-share system. This is in line with Gothenburg's profiling as being a bicycle-friendly city. There have been two smaller bike-share projects before, one system primarily addressing companies in a small-defined area and one private with a small number of bicycles across the city in 2005 (Robèrt & Peterson, 2009). In 2010 Gothenburg's first large-scale public bike-share system Styr & Ställ was launched, covering the flat, central parts of the city. Overall the system has been successful, more memberships have been registered than expected as well as more trips have been made.[1]

The contract for the current system is about to expire and there is a possibility for a new system to take place. At the same time, the City of Gothenburg has received some wishes from the inhabitants concerning larger coverage area of Styr & Ställ (Göteborgs Stad, 2015:a), which would include barriers like challenging topography and high bridges over the river Göta Älv. A relatively new concept is to use bicycles with

[1] Emma Sjögren, project manager for Styr & Ställ at Trafikkontoret, the City of Gothenburg, interviewed 2016-02-18 and e-mail correspondence during the spring of 2016

electrical assistance in a bike-share system. However, very few, if any, studies or investigations have been done in this area of study in Sweden. Furthermore, there are only a few studies carried out for bike-share systems in Gothenburg and none of these have evaluated the possibilities of using electric bicycles.

1.2 Aim and objectives

The overall aim of the thesis is to investigate the potential for electric bicycles in the bike-share system Styr & Ställ in Gothenburg. The aim is also to analyse how the coverage area for Styr & Ställ can be developed geographically with e-bikes in the system.

The objectives with this thesis are to identify differences between conventional and electric bicycles in bike-share systems, in terms of target groups, performance and network design. It is also to find out what benefits and possible challenges there are with bike share system with the conventional bicycles and e-bikes respectively.

1.3 Delimitations

The thesis focuses on the design of the network and the possibility for geographical expansion that electric bicycles can provide. Even though the study is made before a potential change of system or operator due to the expiring contract, there is no specific timeframe for potential establishments or expansion considered, more than the analyses are based on current conditions. The selection of subjects that are studied for the potential for electric bicycles in Styr & Ställ will not cover operation related issues of bike-share, with the exception of unevenly distributed bicycles. Procurement, contract and ownership, and financial resources are not handle in this thesis. Even so, cost difference and pricing rates for e-bikes and conventional bicycles are mentioned, since it is a result from the interview study.

The physical boundary is set to the municipality of Gothenburg, due to major differences in how statistical data are categorised in the City of Gothenburg and surrounding municipalities, for example the City of Mölndal. Furthermore, the assumption of having the same station type as today is made, which is a fix station type, and therefore the station types hybrid or free-floating will not be evaluated in this thesis.

Bike-share systems with electric bicycles exist in North America, Asia and Europe. The interview and case studies for this thesis are based on European cities with this type of system. Reasons for this are that the EU has its own regulation for electric bicycles, which differs from other places in the world, and it is assumed that it is easier to adapt solutions from European cities than from other continents.

1.4 Method

To investigate the potential of e-bikes in Styr & Ställ in Gothenburg was it necessary to do a literature review on bike-share systems and the bicycle planning in Gothenburg. Literature especially studied for the bike-share part of the thesis are the Bike-share Planning Guide from the Institute for Transportation & Development Policy (ITDP, 2013) and the handbook Optimising Bike Sharing in European Cities (OBIS, 2011). The Bike-share Planning Guide from ITDP (2013) is an evaluation of best practice in bike-share in the world and provides guidelines for implementing a successful bike-share system. The handbook from OBIS (2011) is from an EU financed project and is an evaluation of more than 50 bike-share systems in Europe, which resulted in a handbook. The aim of the handbook is to help other cities to establish and optimise their bike-share system. Furthermore, literature related bicycling and development planning in Gothenburg were studied, for example the Bicycling Programme (Trafikkontoret, 2015:a), Traffic Strategy (Trafikkontoret, 2014) and the Development Planning Strategy (Stadsbyggnadskontoret & Fastighetskontoret, 2014), as well as reports and memos about Styr & Ställ.

The next step was to find information that the literature was lacking and as mentioned in the background, there are little literature on bike-share systems in Gothenburg and bike-share systems with electric bicycles. Therefore, interviews were made with experienced people in the field and case studies on some European cities were conducted.

The following people were interviewed for study of the purpose, development and operation of Styr & Ställ:

- Emma Sjögren, project manager for Styr & Ställ at Trafikkontoret, the City of Gothenburg, interview and e-mail correspondence
- Rickard Wendel, Senior Advisor and Establisher at JCDecaux Sverige AB, telephone interview and e-mail correspondence

The following people were interviewed for evaluation of experiences from electric bicycles in bicycles pools in Gothenburg and the region of Västra Götaland:

- Ulf Jakobsson, marketing manager at Move About, telephone interview about the bicycle pool with electric bicycles at Science Park Lindholmen
- Johan Wedlin, Business Developer and Anne Yu, Researcher at Victoria Swedish ICT, answers on a qualitative questionnaire about bicycle pools with electric bicycles in the region of Västra Götaland

For the mapping of different bike-share systems with electric bicycles in European cities questions were sent out to experts in five cities. The questionnaires were adapted for each city, but had some general topics about implementation, design and function of the bike-share systems. The following people were interviewed:

- Pia Preibisch Behrens, project manager at the Technical and Environmental department in the Municipality of Copenhagen, answers on a qualitative questionnaire about Bycyklen
- Maria Berrini and Valentino Sevino, CEO resp. Director of Mobility Planning at Agency of Mobility, Environment, Territory in the City of Milan and Sergio Verrecchia, director of Contracts, Development & Bike Sharing at Clear Channel Italia, answers on a qualitative questionnaire about BikeMi

- Sergio Fernández Balaguer, Department of Communication and Consulting at the Municipal Transport Company of Madrid, answers on a qualitative questionnaire about BiciMAD
- Wolfgang Forderer, Head of the Mobility department in the Mayor's Policy Office, City of Stuttgart, answers on qualitative questionnaire about e-Call a Bike
- Fermín Echarte Peña, Mobility Department in the city of San Sebastian, answers on a qualitative questionnaire about dBizi

With the interviews and literature study as a background the potential of electric bicycles in Styr & Ställ was analysed. The analysis is divided into four analyses, which are listed below.

- The first analysis is based on the literature review, interview and case studies
- The second analysis is a key figure based on statistical data about population density, workplaces and services on a sub-district level and was conducted to evaluate which areas that are suitable for Styr & Ställ.
- The third analysis is an isochronal analysis, which were done to estimate the difference between conventional and electric bicycles in a BSS in Gothenburg, in terms of time and distance.
- The fourth sub-analysis is an analysis of destination points of interest in the areas found in the second and third sub-analysis, and was carried through in order to find potential locations for additional stations.

The results from the analysis were then consolidated in a concluding result of the potential for electric bicycles in Styr & Ställ. The main tool for the analyses was the computer software ArcGIS, which is a Geographical Information System (GIS) that enables processing, presentation and distribution of geographic data (ESRI, n.d.). Methods for the analyses are presented more in detail in Chapter 6.

1.5 Outline of the thesis

The thesis can be divided into eight chapters, which are described in the following text.

Chapter 1 – INTRODUCTION, is this chapter were a short background to the thesis is presented, the aim and objectives as well as delimitations. The method presented in this chapter is general for the report and the methods for the analyses are presented in Chapter 6.

Chapter 2 – INTRODUCTION TO BICYCLING AND BICYCLE PLANNING IN GOTHENBURG, contains a short review on sustainable transport and general background information regarding bicycling and electrically assisted bicycles. This chapter also contains a part on bicycle planning and conditions in Gothenburg.

Chapter 3 – BIKE-SHARE SYSTEMS, is a general chapter about bike-share systems and present benefits, planning guidelines and challenges with bike-share systems.

Chapter 4 – ELECTRIC BICYCLES IN BIKE-SHARE SYSTEMS, presents the benefits and challenges with bike-share systems with e-bikes. The users and target groups are also presented as well as experiences from European cities with this type of bike-share system. This chapter is mainly based on the result from the interview study since there is very little literature on the subject.

Chapter 5 – THE BIKE-SHARE SYSTEM STYR & STÄLL, main chapter for describing how Styr & Ställ is configured today, user groups and the public acceptance. Here is also the expansion potential of Styr & Ställ described in terms of urban development plans, parameters to consider and principles for geographical expansion.

Chapter 6 – ANALYSIS OF THE POTENTIAL FOR ELECTRIC BICYCLES IN STYR & STÄLL, is a chapter where four analyses are presented with their methods and results. The results end up in concluding result and proposed solution for electric bicycles in Styr & Ställ.

Chapter 7 – DISCUSSION, is where the literature review, analyses and the report in general are discussed.

Chapter 8 – CONCLUSIONS AND FURTHER STUDIES, holds the main conclusions of the thesis and recommendations for further studies on e-bikes in Styr & Ställ.

2 Introduction to Bicycle and Bicycle Planning in Gothenburg

This chapter is an introduction to bicycling in general and can be seen as a background chapter for this study. A short review on the subject of sustainable transport as well as the characteristics bicycling in general and e-bikes are presented. One part of this chapter is focusing on bicycle planning and conditions in Gothenburg.

In the past personal mobility has only been a privilege for the rich who could afford a private car (Low, 2003). This has changed over the past fifty years when the broader mass in the industrialised countries have this personal freedom of mobility due to technical development among other things. A big part of the urban social life today includes and requires personal mobility: getting to and from work, leaving and picking up the kids from school, visiting friends, and shopping at the supermarket. According to Dekoster and Schollaert (1999) in Europe more than 30 % of all trips of all trips are made with car in urban areas under three kilometres, and 50 % less than five kilometres. For these sorts of trips bicycle could easily replace car for a large part of the population and it would have effects like less congestion traffic (Dekoster & Schollaert, 1999) and less emission of greenhouse gasses. Moreover, the on-going urbanisation results in more people living and working in cities, i.e. the population density is increasing (Low, 2003). This increasing transport put higher demand on sustainable transport solutions. Walking, bicycling, and public transport are what today is seen as the most obvious sustainable transport modes, even though the car industry is promoting hybrid and electric cars as sustainable options. Therefore, it is important to promote and facilitate the use of transport modes as bicycle in order to start a positive trend toward sustainability.

2.1 Urban transport today and sustainability

The effects of increased transport with car and freight are well known as emissions of greenhouse gases and particles, which can have several effects on human health, at worst long-term and even life threatening (Trafikverket, 2012). It is also known that traffic noise and vibrations affect people negatively and may even have fatal long-term consequences (Öhrström, 2004). Increased traffic contributes also to increased traffic congestion, which has effects such as big time loss for individuals and the society. Other effects with increased motorised traffic are that unprotected road users, such as bicyclists and pedestrians, are pushed away by motorists (Svensson, 2008). There are also health related problems caused by traffic accidents and poor safety in traffic in traffic environments.

Planning for environmentally friendly and sustainable transport alternatives has come increasingly under discussion at EU, national, and local level. Many cities work to become more sustainable and environmentally friendly in all sectors, especially in the transport sector (Miljödepartementet, 2004). One reason for this may be that they want to market themselves in this way to attract investors and new inhabitants to the city. Another reason may be that there is an acute problem in the city with such congestion and air pollution that makes it vital to make a change. To define sustainable transport, it is important to first define sustainable development. One of the most commonly used definitions of sustainable development is from the Brundtland report of 1987:

”Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future.” (Brundtland, 1987). There are three dimensions of sustainability, environmental, social, and economic, and all must cooperate in order to achieve comprehensive sustainability (The Center of Sustainable Transportation, 2002). Characteristics of sustainable transport systems can be defined by the following, based on The Center of Sustainable Transportation (2002) and Miljödepartementet (2004):

- Transport systems should in terms of *social sustainability* provide all humans and businesses in the society with their basic need for mobility and communication. The development of transport systems should be in a safe practise for both humans and the environment.
- Having reasonable pricing, being effective and fair as well as providing different transport alternatives accomplishes *economic sustainability* of transport systems. It should also be supporting in a competiveness economy and contribute to a sustainable regional development.
- *Environmental sustainability* in transport systems is when waste, emissions, noise and land use are put to a minimum the planet can manage. The resources that are used in the transport systems are renewable or to that degree it is possible.

Bike-share systems is claimed to be a sustainable transport mode (Béland, 2014) and studies have shown that BSS has several benefits, for example that the health benefits are greater than the risks and that is reduces CO_2 emissions (Rojas-Rueda, et al., 2011). More about BSS and its benefits are described later in this report.

2.2 Bicycling today

There are several benefits with bicycling, for example improving the public health. The mortality can decrease with 30 % for people that are physically active by walking or cycling 30 minutes per day (Trafikverket, 2015:b). Naturvårdsverket (2005) writes that increased cycling gives less inactive people and decreased obesity, which leads to decreased medical costs and mortality and thereby increased gain for the society. Naturvårdsverket (2005) further states that to increase bicycling and achieve the above described, it is important to develop bicycle measures. The priorities for a sustainable bicycle environment are to give the cyclists their own space in the traffic environment and to lower the speed where cyclists and motorists interact (SKL & Trafikverket, 2010). The increase of people in motion coming from increased cycling gives a higher sense of security among the citizens, which is a factor of influence to what extent bicycle is use.

Bicycles represent 10 % of the trips made with personal transport used today in Sweden (SKL & Trafikverket, 2010) and the majority of these trips are shorter than five kilometres. However, in larger cities bicycle is used for longer distances, around eight to nine kilometres. There are different types of cyclists, for example children, adolescents, fast adult commuters, and casual cyclists (SKL & Trafikverket, 2010). Bicycle is a flexible transport mode, which increases mobility to some groups of the society, i.e. adolescents and people with no or limited access to car or with limited access to public transport (Queensland Government, 2016). This is likewise a common reason to use bicycle also among adults, where the most frequent cyclists are between 25 and 44 years old (SKL & Trafikverket, 2010). Furthermore, there are many other benefits with bicycling, both direct and indirect. Other than the flexibility and sustainability of cycling without emission of noise or pollutants (Göteborgs Stad, n.d.:a), it is also relatively cheap. This makes the user group non-limited economically. Approximately 80 % of the world's population can afford a bicycle, while only 10 % can afford a car (Queensland Government, 2016).

The previously mentioned heterogeneous group of bicycle users creates a conflicting demand within the group, due to different interests in speed and safety. There are several conditions for bicyclists that are important to consider when planning for bicycling (SKL & Trafikverket, 2010). Conventional bicycles are run by muscle power and therefore bicyclists are sensitive to detours, elevation differences, and unjustified stops. Bicycle traffic also puts demands on short distances and proximity. The difference in speed between cyclists and pedestrians creates different demands on availability, where for example bicyclists have a much higher need for continuity of road signs and frequent route guidance (Trafikverket, Boverket, SKL, 2015:b). It also creates an issue with accidents between the two transport modes (Svensson, 2008). The bicycle is instable, since it is a two-wheeler. Thus, there is a need for an even surface, good operation and maintenance infrastructure, and space for swaying (SKL & Trafikverket, 2010). Like pedestrians, bicyclists are unprotected road users and therefore more exposed in a collision situation with other vehicles (SKL & Trafikverket, 2010). In terms of traffic safety, it is important to separate the cyclists from the fast and heavy motorised traffic. The closeness to the environment also puts a higher demand on an attractive traffic environment than for other modes of transport (Svensson, 2008).

There are several things that affect if and how a bike is used. Rietveld and Daniel (2004) published a paper on determinants of bicycle use and have made four classifications of these factors: individual and socio-cultural factors, generalised costs of bicycling, generalised costs of other transport modes and local authority, initiatives, and policy variables. Individual and socio-cultural factors that influence bicycling can be several things like income, age, gender and upbringing conditions (Rietveld & Daniel, 2004). A country's cycle modal share or culture can affect the use depending on the view of cycling (Trafikverket, 2015:a). The purpose of the travel is also important to whether it is going to be conducted by bicycle or not. Commuting to school or work is one of the most common trips with bicycle. The second categorisation of bicycling dependences presented by Rietveld and Daniel (2004) is generalised costs of bicycling, which are monetary costs, travel time, physical need and comfort, traffic safety and security. Costs for other transport modes also influence the use of bicycles, either encouraging or discouraging. Trafikverket (2015:a) says that car ownership has a negative effect on bicycling but public transport instead has a positive effect. Another factor is local and national authorities, which can influence the use of other transport modes through polices like fuel taxation, parking policies, and road pricing tools (Rietveld & Daniel, 2004). Authorities can also influence bicycling by organising and building bicycle infrastructure.

2.3 Electric bicycles

An electric bicycle, or e-bike, is a bicycle supplied with an electric motor that gives assistance when pedalling. For e-bikes allowed in Sweden the power is turned off when the bicycle reaches 25 km/h (Clark & Nilsson, 2014). This makes it possible to be as free as with a conventional bicycle but not having to use as much physical effort, and at the same time use a sustainable transport mode since there is no tailpipe emissions.

An advantage with an e-bike compared to a conventional bicycle, is that it is easier to carry heavy load and usually is faster than a conventional bicycle. However, the reasons for choosing an e-bike instead of a regular bike is primarily because it is easier to cycle uphill and then the possibility to cycle further than with a conventional bicycle (Yu, et al., 2014). The possibility to go further together with the fact that less physical effort is needed makes the e-bike, unlike conventional bicycles, a possible replacement of cars too. In a study from an electric bicycle pool it turned out that 11 % would have taken car for the same trip, if the electric bicycle were not provided (Langford, et al., 2013). Among the users of privately owned e-bikes in Sweden the replacement for cars is even higher, 20-50 % of the trips would otherwise have been with car (Clark & Nilsson, 2014). However, e-bikes can also replace travels with conventional bicycle and public transport to some extent. Furthermore, Yu et al. (2014) say the average distance of journeys made with electric bicycle was found to be a few times longer than for conventional bicycle.

Even if much of the physical strain is removed by the assistance from the electric motor, continuous pedalling is still needed. Studies, like for example Gojanovic et al. (2011), have shown that electric bicycles have health benefits like conventional bicycling does. According to Simons et al. (2009) help commuting to work with an e-bike helps inactive or deskbound people to reach the daily physical activity guidelines.

Looking at privately owned electric bicycles, the primarily user groups are middle age, 45-60 years old, and people older than 60 years (Clark & Nilsson, 2014). They are either commuters or cyclists at leisure. Clark and Nilsson further states that e-bikes also enable utilisation for people with lower physical capacity and/or disabled people, and with an ageing population, this group will grow. The reason in general for not using an e-bike found from an interview made by Yu et al. (2014), is mainly that they are too expensive, answered by 45 %, and then the risk of theft, 23 %. At the same time only four percent answered that they do not like to cycle in general.

The retail of private e-bikes has had a mixed result, but there has been a clear growing trend seen over the past five years (Trafikverket, 2015:a). E-bikes sold in 2015 correspond to about five percent of the total amount of sold bicycles (Svensk Cykling, 2015:b). Lars Strömgren from the interest organisation for bicyclists in Sweden, Cykelfrämjandet, says in an article that e-bikes now are sold to new groups in the society, where many replace their second car with an e-bike (Åhgren, 2016).

2.4 Bicycle planning in Gothenburg

Gothenburg has started to work towards becoming a so-called bicycle-city and is a municipal member of the association Svenska Cykelstäder [eng. Swedish Bicycle-Cities] (Svenska Cykelstäder, 2014). Trafikkontoret (2015:a) has gathered experience from other European countries and underlined six factors of success when it comes to bicycle-cities:

- A fine and highly developed bicycle network
- Extensive separation from pedestrians and cars
- Bicycle-parking facilities of high standard
- High integration with the public transport system
- Restrictions for car traffic
- Communication with the cyclists

The Traffic Strategy for the City of Gothenburg until 2035 is based on the concept of creating a city where the quality of life is high, there is competiveness for business and the development is done sustainably (Trafikkontoret, 2014). This is made through the three focus areas *Travels*, *Urban space*, and *Freight transport*. Bicycle planning is integrated in the first two focus areas, *Travels* and *Urban space*. The main goal for travels is to "[…] create a region centre that is easily accessible [authors' translation]." (Trafikkontoret, 2015:a, p. 20). It is emphasised in the Traffic Strategy that the bicycle should be seen more as a transport mode of its own and therefore should have its own infrastructure. Much of the planning involves separation of bicyclist from pedestrians and car traffic. It is also important that it is easy, quick and safe to commute with bicycle in Gothenburg. The main goal for the second focus area, urban space, is to have an "[…] attractive urban environment and a rich urban life [authors' translation]." (Trafikkontoret, 2015:a, p. 20). Furthermore, it says in the Traffic Strategy that Gothenburg should be a city where there is a priority for pedestrians and bicyclists and there is a balance in conflict areas between these two. Human pace for bicyclist and pedestrians is essential for an attractive urban space. Bicyclists should have a proximate and fine-mesh bicycle network.

2.4.1 The Bicycle Program

The Traffic Board in Gothenburg adopted the Bicycle Programme for the years 2015 to 2025 in mars 2015, which is a strategic document and an elaboration of the Traffic Strategy. The vision for the Bicycle Programme is as follows: "Gothenburg is an attractive bicycle city. The bicycle is a competitive vehicle - it is fast, easy and safe to cycle to destinations both close and far away [authors' translation]." (Trafikkontoret, 2015:a, p. 9). The core of the Bicycle Programme is that when increasing the quality of the bicycle infrastructure, also the competiveness of bicycle will increase. The main focuses in the programme are accessibility for bicycle and how to make it easier for the bicyclists (Trafikkontoret, 2015:a). Styr & Ställ is seen as part of investments in bicycling, within the bike-share program[2].

The programme has two goals. The first is that by 2025 to have the numbers of bicycles tripled from the year 2011. The other goal is to have three out of four of inhabitants in Gothenburg think Gothenburg is a bicycle-friendly city (Trafikkontoret, 2015:a), which around 48 % of the inhabitants thought between 2010 and 2015 (Trafikkontoret, 2016). In order to reach this goal Trafikkontoret (2015:a) has decided on four areas of measure to create an attractive bicycle-city: infrastructure, operation and maintenance, support and services, and communication. For instance, should the bicycle network be designed in a way to enable fast commuting with low interaction with other transport modes, in combination with proximate trips up to the destination (Trafikkontoret, 2015:a).

2.4.2 Bicycling in Gothenburg

The percentage of travels with bicycle in Gothenburg has increased from six to seven percent since 2011 (Trafikkontoret, 2015:a). However, as Trafikkontoret (2015:a)

[2] Emma Sjögren, project manager for Styr & Ställ at Trafikkontoret, the City of Gothenburg, interviewed 2016-02-18 and e-mail correspondence during the spring of 2016.

compares Gothenburg with Malmö, which has about 25 % bicycle trips, Gothenburg is far behind. Figure 1 shows the percentage of different transport modes made by the people living in Gothenburg and all the travels in Gothenburg. Travels made with bicycle by the residents in Gothenburg represent eight percent of the travels, compared with all travels made in Gothenburg where the bicycle percentage is seven percent (Trafikkontoret, 2016).

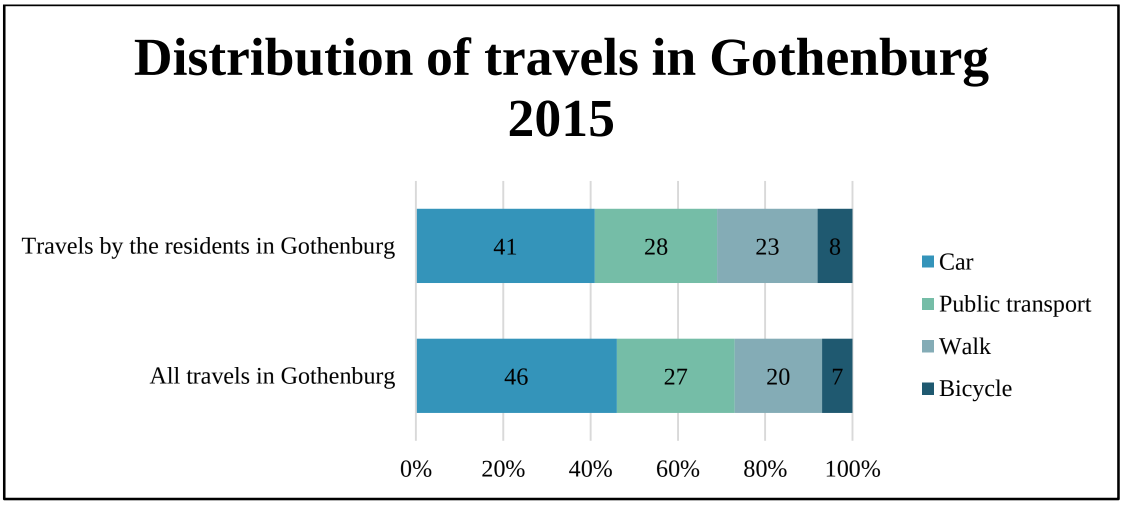

Figure 1: Distribution of travels by residents Gothenburg and for all travels in Gothenburg in 2015, based on Trafikkontoret (2016).

Of all the bicycling trips done in Gothenburg about 90 % of them are shorter than 10 km (Trafikkontoret, 2015:a). It is also these that have the largest potential to achieve the goal of three-doubling of the bicycling is by targeting the shorter trips made with car, from a few kilometres up to 10 km. Trafikkontoret (2015:a) gives the example that if 10 % of the short trips, 0-10 km, made with car, instead are made by bicycle, it results in an increasing percentage of bicycling with 50 %.

2.4.3 Traffic safety and security

Trafikkontoret (2015:a) states in the Bicycle Programme that traffic safety is crucial for the attractiveness of bicycling. They also write in the programme on page 18 that "[…] the challenge is to continue to develop traffic safety but it should be in the frame of the cyclists' demands on good accessibility [authors' translation]". The amount of killed and severe injured bicyclists in Gothenburg has decreased with 75 % since the 90's (Trafikkontoret, 2015:b). A trend break happened around year 2011 when the total amount of traffic injuries begun to level off, and the same applies for the total amount of injured bicyclists. During 2014 the amount of severe injuries did not increase, however the moderate injuries increased in comparison to the year before. One bicyclist died in traffic in 2014 (Trafikkontoret, 2015:b). Moreover, singe bicycle accidents are the largest accident group and stands for about 80 % of the total bicycle accidents (Trafikkontoret, 2015:b). Around half of these accidents are due to poor road conditions, e.g. design, operation or maintenance. Other reasons are the bicyclist's behaviour and problems with the bicycle.

The use of helmets has a steady increment; from about 10 % in the early 90's to 65 % in 2014 see Figure 2. Although, the increment from 2013 to 2014 was marginal, from 64 % to 65 %. (Trafikkontoret, 2015:c).

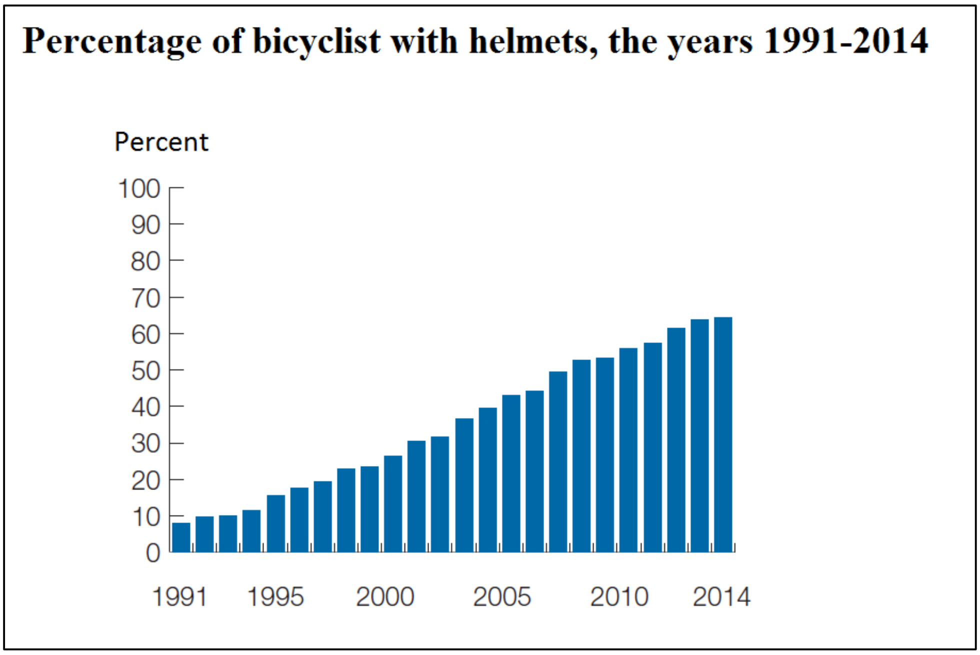

Figure 2: The percentage of bicyclists with helmet in Gothenburg from 1991 to 2014, percentage on the y-axis and years on the x-axis, based on Trafikkontoret (2015:c).

The bicycle theft has increased with the growing rate of bicycles in the city. Although, in 2015 the bicycle thefts decreased with 10 % compared to the previous year. Trafikkontoret (2015:b) writes that there could be two different reasons to this, either that more bicycle racks were built or that there were less reported thefts due to higher deducible at the insurance companies.

3 Bike-Share Systems

In this chapter the concept of bike-share will be introduced, including its benefits and challenges as well as how to plan a bike-share system in terms of physical development and target groups. This is a general chapter about bike-share systems with some examples from Gothenburg. For more specifics of Styr & Ställ can be found in Chapter 5 and bike-share systems with electric bicycles are presented in Chapter 4.

A bike-share system has no common definition, but OBIS (2011, p. 10) describes bike-share systems as a "[…] self-service, short-term, one-way-capable bike rental offer in public spaces, for several target groups, with different network characteristics". This can be compared to a bicycle pool, where the users are a delimited group and there are a small number of bicycles that should be pre-booked before use (Göteborgs Stad, n.d.). The purpose with a bike-share system is to reduce congestion, act as a good complement to other transport mode (Béland, 2014) and show the advantages with bicycle as a flexible transport mode (Göteborgs Stad, n.d.).

3.1 Origin and development of bike-share systems

In 1965, Amsterdam had what can be seen as the first bike-share system, where bicycles were collected, painted white, and placed unlocked in the city for free public usage (Home, 1991). After that, a few similar bike-share systems appeared in different cities. However, it was not until Copenhagen introduced their bike-share system 30 years later, with chained bikes that could be borrowed in exchange for a returnable coin, that bike-share system became more common in cities in different parts of the world. Copenhagen's system was the first organised large-scale urban bike-share system and was launched in 1995 (Shaheen & Guzman, 2011). Bike-share systems are divided into four generations. The kind from Amsterdam is seen as the first generation: free of use and without stations, locks or deposit. The second generation is the kind of system implemented in Copenhagen, also called coin-deposit systems (Shaheen & Guzman, 2011). This generation has fixed stations for borrowing and return, but the theft was still high due to the users' anonymity and low deposit cost. Typical for the third generation is integration of technology for registration, user identification, payment and tracking of the bikes. This generation is the most common today and Styr & Ställ in Gothenburg is of this type of BSS (Mattsson, et al., 2014). The fourth generation has the features from the third generation but is closer linked to public transport with combined travel planners (Shaheen & Guzman, 2011). The new technology also makes it possible to implement the technology directly in the bicycles, which makes a terminal for pick up not necessary (Mattsson, et al., 2015).

There are different kinds of systems used today and the most common are systems that are station based (Mattsson, et al., 2014), which is what is used in the current system of Styr & Ställ today. This means that the available bicycles are docked at stations located across the coverage area of the system. The BSS-users pick up and return the bicycles at a station, but it can be at different stations. Systems that do not have stations, but instead a certain area to find and return the bicycles are called free-floating systems (Mattsson, et al., 2014). In order to make this possible the bicycles need to be equipped with technology for information, such as GPS and pickup possibility, i.e. fourth generation of BSS. It is also possible to combine a station based and a free-floating system, which then forms a hybrid system. In a hybrid system it is allowed to place the bicycle anywhere within the operating area, but this area can also contain stations (Mattsson, et al., 2014). These kinds of systems can use incentives for returning a bicycle at a station, such as discount for future travels or as in Munich, free cycling time (UITP, n.d.).

3.2 Benefits with bike-share systems

Bike-share systems have many benefits, which are similar to those for bicycling in general. BSS has two major advantages; low implementing costs and short timeline for implementing, about two to four years, compared with other transport and infrastructural projects (ITDP, 2013). Some of the benefits with bike-share systems are listed and described in Table 1. The benefits can be categorised as transport benefits, economic benefits, health benefits, and benefits for city image. Studies have shown that BSS not only attract new cyclists, but also existing cyclists, because of its convenience and practicality (ITDP, 2013). The improved image of cycling in the city and increased cycling modal split can contribute to more investments in bicycling infrastructure. ITDP (2013) writes that there are also cities that experience benefits across generations, classes, ethnicity and gender.

Table 1: Benefits with bike-share systems, based on (ITDP, 2013). The benefits are elaborated further in the next three sub-chapters, together with some new angels on environmental, social and economic benefits.

Benefit with BSS	Description
Reduced congestion and improved air quality	BSS is a sustainable transport mode and can replace other transport modes for shorter trips.
Increased accessibility	It gives the users greater access to areas where public transport (PT) does not cover or where there is a gap between PT stop and final destination. Another benefit is that it is easier to go further with bicycle than by foot.
Improved image of cycling	With BSS cycling becomes more visual in the city and this new modern project can contribute to increase the cycling culture in the city.
Provide complementary service to public transport	BSS can be seen as a complement to PT and can replace shorter trips otherwise done with PT, taxi or car.
Improved health of inhabitants	Cycling contributes to both better physical and mental health.
Attract new cyclists	BSS makes cycling possible to persons who do not own a private bicycle or have access to bicycle parking or storage.
Improve a city's image and branding	BSS is in line with sustainable transport and is therefore good practise for cities that want to brand themselves as sustainable and modern, or as a bicycle-city.
Generated investment in local industry	Demand for BSS services, hardware and software can possible simulate the local industry and create new job opportunities.

3.2.1 Environmental benefits

Since bicycles are seen as sustainable transport modes bike-share system can also be seen as a sustainable transport mode. Beroud and Anaya (2012, p. 27) state that BSS are "[…] frequently justified on the basis of their CO_2 emission reducing potential and air pollution reducing potential." Beroud and Anaya (2012) further write that the savings in CO_2 is only when the BSS is replacing trips that would have been done with motorised transport modes. Moreover, Dekoster and Schollaert (1999) write that bicycles are faster than cars in urban areas on short distances, i.e. under five kilometres, and especially in traffic jam conditions. These sort of trips with car could be replaced by BSS if the system is dense enough and provides with a high level of service (Beroud & Anaya, 2012). A bike-share system dose not only contribute to less emissions, but also decreased need of infrastructure, which take up a lot of space (Eriksson & Mattsson, 2016). Although, important to notice is that BSS itself is not sustainable on all levels, where redistribution of bicycle between BSS stations, operation and maintenance are related with motorised transports CO_2 emissions (Beroud & Anaya, 2012).

Bike-share systems is claimed to be sustainable transport modes (Béland, 2014) and studies have shown that BSS has several benefits, for example that the health benefits are greater than the risks and that it reduces CO_2 emissions (Rojas-Rueda, et al., 2011).

<u>The environmental benefits with bike-share systems can be summarised as:</u>

- Reduce CO_2 emissions and other air pollutants
- BSS can replace car on shorter distances, i.e. five kilometres, in urban areas
- Decreased congestion

3.2.2 Social benefits

A bike-share system, if well designed and adapted to the local conditions, it can generate many benefits for the society. Beroud and Anaya (2012) states in theirs study that the easy access to bicycles that BSS brings is most socially beneficial in low-income areas or areas there are cultural barriers to bicycling. Moreover, when having access to a BSS it is possible for people to cycle without the need of buying or maintaining a bicycle. Beroud and Anaya (2012) also write that the cost of BSS varies from city to city, but are relatively low compared with for example public transport. Many BSS targets several different user groups, e.g. tourists, commuters, casual cyclists (OBIS, 2011), see Section 3.3.1. Therefore, the BSS is more beneficial for the society the more people have access to the system. For example, Eriksson and Mattsson (2016) (2016) write in their study of social values in BSS that Styr & Ställ has been beneficial for the City of Gothenburg and businesses, as well as the residents and people visiting Gothenburg. Moreover, Eriksson and Mattsson (2016) write that the City of Gothenburg gets a more effective and flexible traffic system, especially since its purpose is to decrease the pressure on the public transport system. Another positive effect BSS have is that cycling becomes more visual in the city. This can result in, as mentioned earlier, an improved image of the city (OBIS, 2011), but this also can lead to reduced speed by motorised traffic, which benefit other cyclists as well as pedestrians (Beroud & Anaya, 2012). Furthermore, Beroud and Anaya (2012) write that the low cost, easy access and near universal access of BSS can open up for new potential user groups, i.e. get more people to cycle, which in turn has positive effects on the public health.

The health effects from a bike-share system are basically the same as for ordinary bicycling, but the degree of the effect depends on which transport mode the shared bicycle replaces (Eriksson & Mattsson, 2016). The health effects are the largest when changing from private car, since the car often is close to the home and is parked close to the final destination. Eriksson and Mattsson (2016) further say that a change from public transport also have large effects, but since it is often required to walk to the nearest public transport stop the effects are not as extended as for changing from car. If the shift of transport mode instead is made from walking the health effects are close to zero (Eriksson & Mattsson, 2016). Madrid has the major goal to move trips that are normally done by car to use the bike-share system BiciMAD instead (Larsen, 2014). In order to target car users rather than pedestrians, Madrid has decided to not have the first 30 min free of charge (Larsen, 2014). Having the first 30 min free of charge is a common practice for BSS, but it should be noticed that Madrid has a bike-share system with electric bicycles. Electric bicycles are reviewed further in Chapter 5.

Eriksson and Mattsson (2016) write that a bike-share system that are both well developed and maintained can contribute to better security. This is because it creates more life and movement in public spaces and the station itself becomes meeting points, this makes the city feel more secure. Security is a subjective concept (Holmberg, et al., 2008) and can be described as the synonym to subjective and experienced risk. Holmberg et al. (2008) writes that it is important for both the society and individual since if a space is unsecure it affects travel opportunities and travel quality. Moreover, Holmberg et al. (2008) writes that the fear of accidents or crime changes peoples travel patterns, for instance stays away from places or causes restrictions in people’s mobility in the city. Eriksson and Mattsson (2016) write also that investments in the public space, like BSS, create a social presence from the municipality and consequently increases the security.

The social benefits with bike-share systems can be summarised as:

- Access to bicycles of all groups in the society
- Public health benefits, similar to private bicycling
- Developed and maintained BSS can contribute to better security in the city
- The municipality gets a more flexible transport system in the city and improved image of bicycling in the city

3.2.3 Economic benefits

Many of the benefits with bike-share systems mentioned in previous sections have also socio-economic benefits and effects. Beroud and Anaya (2012) write that the reduction of emissions can be a result of modal shift from CO_2 intensive transport modes to shared bicycles. Less motorised vehicles further contribute to lower accident costs. Bike-share system also contributes in a reduction in overcrowding public transport and in motorised traffic congestion, which have transport economic values. Moreover, the public health benefits result in a healthier and more productive workforce in the society. Bike-share systems also contributes to increased accessibility since it creates new trips would else never been done (Beroud & Anaya, 2012).

Economic benefits can also be viewed from the users' perspective. New bicycles, electric or conventional, are for instance cheaper than new cars in many ways, such as purchase cost, maintenance, and power or fuel. This is for a privately owned bicycle, which still costs a couple of thousand SEK. For the alternative with a public bike-share system, the user does not purchase a bicycle, but the service to use one. This makes it possible for many people to pay less since there are many people sharing one bicycle. This is a so-called service and flow system (Hawken, et al., 1999). The fact that many people share same bicycles decreases the amount of required bicycles compared to if people were to own their own. This means more effective usage of material and natural resources as well. The operator is also interested in having good quality bicycle that last long (Hawken, et al., 1999).

<u>The economic benefits with bike-share systems can be summarised as:</u>

- Reduction in overcrowding public transport and in motorised traffic congestion
- Socio-economic benefits from improved public health and reduced emissions
- Accident cost benefits
- Increased accessibility
- Cheaper for the users and less material intensive

3.3 Planning and designing a bike-share system

When planning and designing a bike-share system it is important to know what aspects that are important in order to create a popular and functional system. In Table 2 several success factors for a bike-share system that are of high or moderate importance are listed and described. The success of a BSS is also dependent on the different stakeholder perspective and OBIS (2011) has identified these to be politicians and planners in the municipality, citizens and other users, operation companies and private companies that provides with hardware and software for BSS.

Table 2: Success factors for bike-share systems and its importance, based on Curran (2008), ITDP (2013) and OBIS (2011).

Factor	Description	Importance
Bicycling infrastructure	The quantity and quality of designated bicycling space, e.g. dedicated bicycle lanes, intersection facilities, low speed streets.	High
Bicycle re-distribution	Mechanism to address asymmetrical demands for bicycles by location. This affects the reliability of the BSS from a user's perspective.	High
System accessibility	Costs of use including monetary and convenience costs. Pricing structures that incentivise short trips helping to maximise the number of trips per bicycle per day.	High
Density and trip demand	Demand of one-way trips in multiple directions and at all hours during the day. The network of stations is dense with average spacing of 300 m.	High
Network configuration	Location specific network design based on system objectives and travel demands.	High
Maintenance	Bicycles and access terminals in good operating condition.	High

Stations	Fully automated locking system that allow users easily to check bicycles in or out of bike-share stations.	High
Integration with other transport modes	Integration with public transport, car sharing, ferries etc. in terms of registration, payment, and access card in order to make it easier for the users to combine the different transport modes.	High
Financing model	Crucial for the sustainability of the BSS. Important aspects for the financial model are the size of the system related to the city size, and the ambitions.	High
Quantity of public transport	Capacity to motivate residents to forgo car trips into the city centre.	Moderate
Technology platform	Speed of access, real time information, privacy and security of data.	Moderate
Bicycles	Bicycle specifications respond to user demographics and operating conditions, and has specially designed parts and sizes that discourage theft and resale.	Moderate
System availability	Hours of service	Moderate
Public attitudes towards bicycling	Penetration of mode, willingness to *share the road* and willingness to utilise mode.	Moderate
Safety and security	Terminals and bicycling facilities are well lit and patrolled if necessary.	Moderate

Each factor has several indicators and some of these are explained in detail in the OBIS (2011) handbook. Those that are relevant to the scope of this thesis will be examined in the following sub-chapters.

3.3.1 Target groups

When planning a bike-share system it is important to define who the target group is, to be able to create a successful system. Bike-share systems have often more than one target group. One way to find target groups is to classify users based on trip purpose. One common classification is the following (OBIS, 2011):

- Tourists
- Commuters
- Businesses
- Leisure users

The target groups can differ depending on what scale the system is. Bike-share system in an urban area are often focusing on daily users, e.g. commuters and leisure users; compared to larger scale BSS on a regional level that often has tourists as focus group (OBIS, 2011). Table 3 shows different requirements and problems for different target groups.

Table 3: Requirements and issues for different target groups (OBIS, 2011).

	Target groups			
	Commuters	**Leisure users**	**Businesses**	**Tourists**
Requirements	- Dense station network - Stations near PT stations and living quarters - Bicycles and docking spaces available	- 24/7 service - Safety during the night	- Dense station network - Lock on bicycle	- Stations near PT - Stations near points of interest
Problems	- Lack of rush hour availability	- High prices for longer rental	- Lack of options to carry goods from errands	- High prices of longer rentals

3.3.2 Planning guidelines

ITDP (2013) has set up general planning guidelines for bike-share systems concerning coverage area, station density, amount of bicycles, and docking spaces, and system performance, see Table 4. These guidelines will be more described in the following text. Apart from these there are also guidelines from ITDP (2013) for bicycles in a bike-share system: they should be robust, practical and attractive. The guidelines for the stations say that it should be easy to pick up and return bicycles and the instructions should be clear, the stations should also be well visible and have security systems.

Table 4: Planning guidelines for BSS (ITDP, 2013).

Criteria	Guidelines
System efficiency	4 - 8 trips per day and bicycle
Market penetration	20 - 40 trips per day and resident
Minimum system coverage area	10 km^2
Station density	10 - 16 stations per km^2
Number of bicycles	10 - 30 bicycles for every 1,000 residents
Docking spaces per bicycle	2 - 2.5 docks per bicycle

Performance metrics

The system efficiency can be measured in average number of daily uses per bicycle. ITDP (2013) has a guideline for designing for four to eight uses per day. If the daily uses are less than four, the system might not be cost-efficient. Over eight uses per day is an indication that the system has too few bicycles to meet the demand. This also means that the BSS has a low market penetration and therefore might not meet the aim of the project, e.g. increased cycling modal share. The market penetration can also be analysed by the average daily uses per inhabitants and the recommendation for this is one daily trip per 20 to 40 inhabitants (ITDP, 2013). Table 5 illustrates the performance metrics.

Table 5: BSS performance in terms of trips per bicycle and trips per 1,000 residents, based on ITDP (2013).

	Trips per bicycle - measuring infrastructure usage	
Trips per 1,000 inhabitants measuring market penetration	Low performance	Moderate performance
	Moderate performance	High performance

System's coverage area and size

ITDP (2013) identifies choosing and setting the boundaries for the system coverage area as the most critical point in planning a popular and successful bike-share system. Determine the number of stations is also included in this part of the planning. The boundary for the coverage area is dependent on the purpose and aim of the BSS and should include large set of users' origin and destination points (Mattsson, et al., 2014). Finding which areas that are suitable for a BSS can be done by looking at density of workplaces, public transport, and population (ITDP, 2013). The coverage area should be dense and have a mix between residence, workplaces and other points of interest in order to achieve high trip generation capacity. City centres often fulfil these criteria. If the area is too small there is a risk that the performance of the BSS is low due to low connection to points of interests and therefore not an attractive choice of transport mode. To summarise, the coverage area should be large enough and dense, to meet the goal of high ridership due to its convenience, reliability and accessibility (ITDP, 2013).

Station location and density

The station density of a bike-share system is recommended by ITDP (2013) to be 10 to 16 stations per square kilometre, which can be expressed as about 300 m spacing between the stations. OBIS (2011) write that 300 m is seen as a short enough walking distance if the proposed station would be full. If the spacing is over 300 m there is a risk of losing BSS-users due to its inconvenience (OBIS, 2011). ITDP (2013) shows that there is a relationship between trips per bicycle and station density, where the system efficiency grows with increasing station density.

As mentioned in Section 3.3.1 different target groups have different requirements for how the network should be designed. For commuters stations near public transport are desirable, for tourists it is important to have stations near tourist attractions, and for residents and leisure users it is instead important to have connections with stations between residential areas and city centre (OBIS, 2011). ITDP (2013) have set up the following principles for station location:

- Adjacent to public transport nodes
- Along existing bike lane
- Near corners
- In mixed areas, i.e. areas with high function density
- Not next to physical barriers
- Station-density of 10-16 stations/km^2

ITDP (2013) have set the guideline of 10 to 30 bicycles for 1,000 inhabitants as an optimal amount of bicycles. If the number of bicycles is too high, more than 30 bicycles for 1,000 residents, it can lead to too few uses per day and bicycle, and therefore an oversized BSS. ITDP (2013) has also identified a relationship between station density and performance: the higher station density the higher market penetration for the system, i.e. more generated trips per inhabitants.

3.4 Challenges with bike-share systems

Implementation and operation of a bike-share system come with some challenges that have to be handled. Finding the right type of system, designed for the city's needs and conditions is key to achieve a successful bike-share system, see for example ITDP (2013) and OBIS (2011). Challenges that are reviewed in this thesis are unevenly distributed bicycles, climate, security, theft and vandalism, and safety risks. Challenges that are specific to BSS with electric bicycles are presented in Section 4.4.

3.4.1 Unevenly distributed bicycles

One of the major challenges in bike-share systems is uneven flows and distribution of bicycles, which can be the result of commuting flows or hilly conditions. Beroud and Anaya (2012) write that many cities have problems with uneven flows due to commuting from home to work, which results in full stations at the destination point and empty station at starting point. This problem Gothenburg also has, in for instance the area Gårda (Karlgren, 2014), where a lot of workplaces are compared with residence and the area are not well serviced by public transport. How Styr & Ställ is used today are described further in Section 5.2.

Bicyclists often tend to dislike inclines from four to eight percent and slopes over eight percent are often avoided since the effort needed is too great (Midgley, 2011). Experiences from bike-share systems, for example Barcelona and Paris, are that bike-share stations that are on a higher altitude in the city tend to be empty of bicycles since the users only use them to go downhill and use other transport modes to go uphill, see for example Beroud and Anaya (2012) and Midgley (2011). This results in obvious operational and logistical problems for the operator of the BSS and as mentioned previous increased emissions of CO_2. Some cities have tried to address this, for example Paris and Barcelona, by giving the BSS-users a small discount if they either use a bicycle from a crowded station or return a bicycle at station with few bicycles (Beroud & Anaya, 2012), however, this has in general not worked out very well and the problem with unevenly distributed bicycles still remains.[3] Another way to address this problem in cities with hilly conditions is by implementing bicycles with electrical assistance in the BSS, see for example Bührmann (2007) and Midgley (2011). Bike-share systems with e-bikes are described further in Chapter 4.

3.4.2 Climate

Today there are bike-share systems in cities spread over the world and in different climate zones (Midgley, 2011). Figure 3 shows usage curves for eight European cities with bike share systems and how it corresponds to the average temperature (OBIS, 2011).

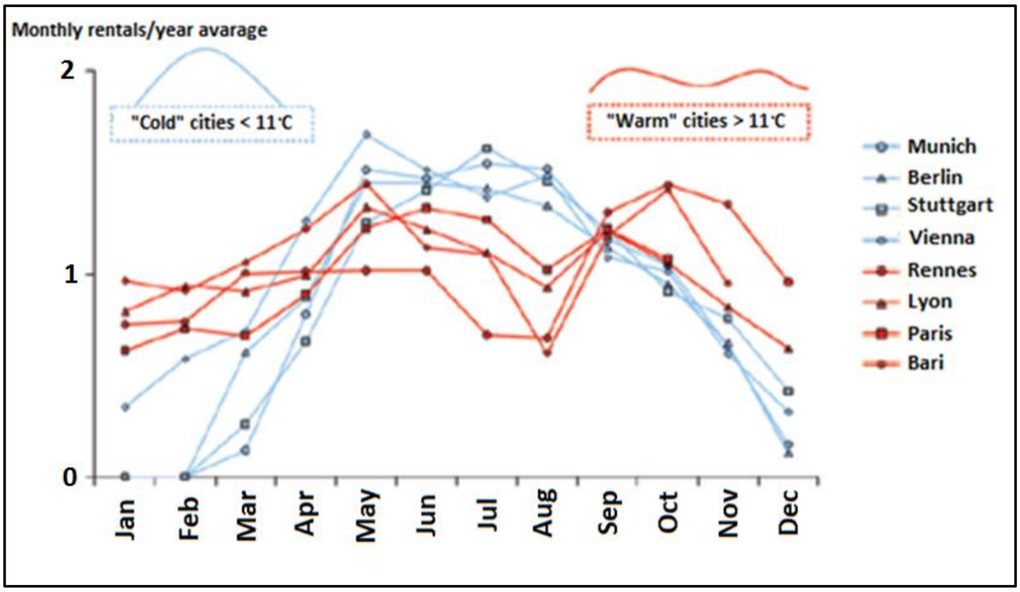

Figure 3: Relation between monthly rentals divided by average monthly rentals for the whole year in eight European cities. The blue lines represent cities with cold climate, average temperature below 11 degrees Celsius, and red represent cities with warm climate, average temperature above 11 degrees Celsius (OBIS, 2011, p. 31).

It is possible to generalise that cities in colder climates have their peak of usage in the summer and cities in warmer climate peaks in spring and autumn. It is important to notice that the demand of BSS during winter conditions is not only affected by the weather itself, but also the condition of the bicycling infrastructure (OBIS, 2011). With this as a background it is easy to understand why cities in the northern countries in Europe shut down their BSS during the winter months and most countries in the south of Europe have open during the whole year (Midgley, 2011).

3.4.3 Security, theft and vandalism

As mentioned in earlier there are some security benefits with bike-share systems. However, since many BSS are open 24/7 there are some security issue during night-

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[3] Emma Sjögren, project manager for Styr & Ställ at Trafikkontoret, the City of Gothenburg, interviewed 2016-02-18 and e-mail correspondence during the spring of 2016

time. Curran (2008) has done a feasibility study of public bike system done in Vancouver identifies security issues with bike-sharing that are similar to public parking lots, when using the system during evening- and night-time and in areas with high crime rate. Moreover, Curran (2008) also mentions that the threat of physical violence is similar for bicyclist and pedestrians, but much higher than for people using public transport, since the flow of people is larger. Curran (2008) suggests that the lighting should be good around the BSS stations and an emergency call button at the stations to increase the personal safety and security.

Bührmann (2007) writes that vandalism of bike-share systems often are higher than the average of vandalism in the city when it is introduced, but this is very dependent on location of the stations. Furthermore, Bührmann (2007) writes that the vandalism of BSS often declines after a while when it has become a part of the urban landscape. Many of the BSS today have user identification technologies and tracking systems, but theft and vandalism are still a big problem for several cities, for example Paris and Barcelona (Midgley, 2011). Paris suffered from much more vandalism and theft than expected and has the highest rate compared to all other bike-share systems. Almost the whole system of 20,600 bicycles has been replaced during the first two years of operation (Midgley, 2009). Their bicycles cost 400 Euros each and this has resulted in high operation and maintenance costs.

According to Rickard Wendel[4] at JCDecaux, the current company that operates Styr & Ställ, vandalism of Styr & Ställ has been very low, much lower than expected. One specific station was during a nearby reconstruction site a more frequent subject to this in 2015. However, it was later moved a bit to a more open area and the vandalism ended. Furthermore, Wendel says also that all the Styr & Ställ stations are today located so that they are visual to avoid these kind of issues.

3.4.4 Safety risks

One of the main boundaries for implementing a bike-share system is law on helmet use. Only a few cities in the world have a law for bicycle helmet use combined with a BSS (Midgley, 2011), examples are Bogotá in Colombia and Melbourne in Australia (ITDP, 2013). For example, Mexico removed their helmet law on the grounds on social equality. The argument was that not all people could afford a helmet (ITDP, 2013). In Australia there is a helmet law and the BSS in Melbourne has come up with the solution to give out free helmets to their users (Melbourne bike share, n.d.). Sweden has a helmet law for children under 15 years old, but there is a debate today about helmet law for adults as well (Kronqvist, 2015).

Arguments for not providing helmets to bike-share users is mainly hygiene related issues. The operator SmartBike in Washington says that hygiene and risk of not fulfilling the local health regulations is the reason for not providing helmets (ITDP, 2013). Another concern with providing helmets to BSS users is how to manage the helmets. When leaving a helmet at the station for the next user to use, the helmet is exposed to weather and there is always the issue of vandalism and theft (ITDP, 2013). Midgley (2011) writes that since bike-share systems are based on self-service it is difficult to provide the users with helmets. Instead the users must bring their own helmet

[4] Rickard Wendel, Senior Advisor and Establisher at JCDecaux Sverige AB, telephone interview 2016-03-15 and e-mail correspondence during the spring of 2016

in many cases, but this goes against the flexibility of the system, for example combining travels with public transport and spontaneous trips. Midgley (2011) states that there is not much research done on helmet usage and helmet solutions for BSS. However, the helmet issues in BSS may not be that big of an issue since there are several studies (OBIS, 2011) showing that the health benefits with bicycling are overruling the risk of riding a bicycle without helmet (Martin, et al., 2016).

When Styr & Ställ were implemented in Gothenburg in 2010 had the City of Gothenburg requirements that the operator would provide the users with helmets, Rickard Wendel[5] says. JCDecaux bought 1,000 helmets for the start of Styr & Ställ, which the subscribers could come and pick up at the JCDecaux office in Gothenburg. Wendel says that this were not popular, only 10 subscribers used the helmet service and therefore was this service not continued. The reason for this Wendel says that it could be that those who want to use helmet bring their own helmet.

Midgley (2011) writes that motorists complain over BSS users not following the traffic rules and propose the solution of introducing training programs for inexperienced bicyclists. However, Martin et al. (2016) have done a study about bike sharing and bicycle safety, which shows that it is safer to cycle bicycles from a bike-share system than an own bicycle. Martin et al. (2016) write that the reason for this is that BSS-users are more careful, since they often are inexperienced cyclists. Other reasons they also present are the design of the BSS-bicycle is heavier and has fewer gears than ordinary bicycles and that the BSS-users do not trusts the bicycles as much as an own bicycle. Some say that more cyclists make it safer to cycle. Though, it can also create a so-called herd mentality, where people in the back just follow those in front and the individuals' sense of responsibility is compromised (Martin et al., 2016). In OBIS (2011) it is stated that general experiences from cities with BSS, for example Stockholm and Berlin, are that large increment of bicycling has not resulted in increased bicycle accident rates.

The bicycle police officer of Gothenburg, Thomas Åsenlöf, says to the local newspaper Göteborgs-Posten that the amount of cyclists has increased in the last couple of years (Möller, 2016). Åsenlöf says that congestion taxes, increased retail of e-bikes and the bike-share system Styr & Ställ can be reasons for this increasing popularity of bicycling in Gothenburg. Åsenlöf further says that the backside of this is that these new bicyclists often are inexperienced which results in more bicycle incidents. Though, according to Wendel[5] it is very rare that Styr & Ställ bicycles are involved in accidents. An indication for this is that during 2010-2015 three accidents were reported in the statistical database Strada (Swedish Traffic Accident Data Acquisition) (Transportstyrelsen, 2016).

[5] Rickard Wendel, Senior Advisor and Establisher at JCDecaux Sverige AB, telephone interview 2016-03-15 and e-mail correspondence during the spring of 2016

4 Electric Bicycles in Bike-Share Systems

This chapter will present general information about electric bicycles in bike-share systems and is mainly based on the interview and case studies on European cities with this type of systems. Both benefits and challenges with electric bike-share systems are presented, as well as users and target groups. For more information about electric bicycles in Styr & Ställ specifically, see Chapter 6.

Electric bike-share systems have started to appear in cities worldwide over the last couple of years, and more are appearing every year. Today there are 9,400 public e-bikes by estimation in the world allocated among 70 cities, such as Copenhagen, Madrid, San Sebastian, and also in cities in USA, Japan and China (DeMaio, 2016). Of the larger electric bike-share systems is Europe the most common is fully electric BSS, which means that all bicycles are electric (DeMaio & Meddin, 2016). There are some combined BSS, which have both conventional and electric bicycles, but they are generally small and located in alpine cities (DeMaio & Meddin, 2016).

4.1 Bike-share systems with electric bicycles

As mentioned earlier, there are some already existing electric bike-share systems, some bigger and some smaller. Most systems are commissioned by the municipality and operated by an outside company. Today there are several companies providing electric bike-share systems, like the outdoor advertisement companies Clear Channel and JCDecaux, or passenger and logistic company like Deutsche Bahn AG. Some companies are specialised in just electric bike-share systems, like the Canadian company Bewegen and GoBike from Denmark. Following systems are from some of the interviewed cities and are presented as example of how electric bike-share systems can be designed.

4.1.1 Copenhagen, Denmark

Copenhagen has a fully electric bike-share system, Bycyklen, with 1,860 e-bikes and 100 stations operated by Gobike (Gobike, 2014). The bicycles are equipped with tablets for login for pickup, information, and navigation with GPS (Bycyklen, 2014:a). Since all this is operated via the tablet there are no terminals at the stations. When docking a bicycle to the station it is recharged until next use, but if the battery level is too low the bicycle is locked until it has reached a proper battery level. The bicycles are available to hire hourly, or with a monthly subscription to get a lower hour price. For the monthly subscribers are the first 30 minutes for free (Bycykeln, 2014:b). After usage, it is possible to return the bicycle at an already full station as long as the bicycle is placed within a 25 metres radius (Bycyklen, 2014:a).

As mentioned earlier, Copenhagen first had a bike-share system of second generation from 1995. It was taken away in 2012 and the new electric system was launched in 2014. To include electric bicycles in the system was not demanded from the city, but was suggested from the winning bidder.[6] However, it was not considered needed sine

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[6] Pia Preibisch Behrens, project manager at the Technical and Environmental department at the Municipality of Copenhagen, answers on questionnaire about Bycyklen on 2016-03-10

Copenhagen is a relative fat city. According to Pia Preibisch Behrens[7] at the Municipality of Copenhagen was the original idea suggested 20 % of the bicycles to be electric, but after winning the operator preferred all bicycles being electric due to logistical issues.

4.1.2 Milan, Italy

The bike-share system in Milan, BikeMi, is a combined BSS and consists of 3,800 conventional bicycles and 1,000 e-bikes divided among 300 stations around the city. BikeMi is operated by Clear Channel (Clear Channel Italia, n.d.). The bike-share system is open all-year around, from 7 am to 1 pm (BikeMi, n.d.:a). The first half hour is free of charge for the conventional bicycles, and then charge with 50 cents per half hour. The e-bikes are instead charged from start and increased for every half hour, beginning at 25 cents (BikeMi, n.d.:b). The electric bicycles are not recharged in the docking station and thereby both types of bicycles go in every docking point.[8] The electric bicycles with low battery are instead picked up by operator and transported to a warehouse to recharge and returned the bicycles when fully recharged.[8]

BikeMi was launched in December 2008 with only conventional bicycles. The e-bikes were introduced in May 2015 at the opening of World Expo 2015 (Fahrradportal, n.d.). The main reason for adding electric bicycles was to increase the number of users and to better connect the outskirts areas to the city centre. A bike-share system with only e-bikes was neglected due to high costs.[8]

4.1.3 Stuttgart, Germany

The bike-share system e-Call a Bike in Stuttgart was launched in 2011 and is operated by the passenger and logistic company Deutsche Bahn AG, which have bike-share systems in several cities in Germany. E-Call a Bike is a combined BSS with 100 electric bicycles and 450 conventional bicycles, divided among 44 stations throughout the city (Daude & Forderer, 2012). The docking spaces are designed so the locking mechanism also recharges the electric bicycles, thereby both types of bicycles can be placed in all docking spaces.

Stuttgart has a bicycle share of six to seven percent and electric bicycles were implemented as a measure to increase this.[9] E-bikes were also seen as a good solution regarding the large difference in altitude in Stuttgart. To enhance bicycling even more two additional charging plugs for private e-bikes were installed at every station (Daude & Forderer, 2012). The first 30 minutes with the conventional bicycles are for free and is after that charged with one euro per every half hour. Wolfgang Forderer[9] says that the City of Stuttgart subsidies this for the users. The electric bicycles are charged with 12 cents from the minute (DB AG, n.d.). The system is open all year around, however

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[7] Pia Preibisch Behrens, project manager at the Technical and Environmental department at the Municipality of Copenhagen, answers on questionnaire about Bycyklen on 2016-03-10

[8] Maria Berrini and Valentino Sevino, CEO resp. Director of Mobility Planning at Agency of Mobility, Environment, Territory in the City of Milan and Sergio Verrecchia, director of Contracts, Development & Bike Sharing at Clear Channel Italia, answers on questionnaire about BikeMi on 2016-03-18

[9] Wolfgang Forderer, Head of the Mobility department in the Mayor's Policy Office, City of Stuttgart, answers on questionnaire about e-Call a Bike on 2016-03-22

the electric bicycles are taken away when it is very cold because they are losing a lot of performance in terms of capacity.[10]

According to Wolfgang Froderer[10], there is an on-going procurement in Stuttgart for a new and regional bike-share system to be implemented in 2017 and this system will also have both electric and conventional bicycles. Users will be allowed to take a bicycle at a metro station located outside Stuttgart and keep it until the next morning for one euro. This is in order to solve last mile problem for commuters that live outside Stuttgart.[10]

4.1.4 Electric bicycles by JCDecaux

In 2015 JCDecaux presented a bicycle for bike-share systems that could be used both as a conventional and electric bicycle. The bicycle has an electric motor in the front that gives assistance when a battery is connected, which can last up to 10 kilometres (JCDecaux, 2015). For this solution, the user owns or rent their own battery and recharges it at home, and plugs it in the bicycle if they want electric assistance[11], see Figure 4. This makes every bicycle in the bike-share system a potential e-bike and since they are not recharged at the stations, same stations and docking points as for their conventional bicycles can be used. According to Richard Wendel[11] these bicycles are not much heavier than the conventional bicycles JCDecaux currently supply. At the writing of this thesis, there are no cities that have implemented this solution.

Figure 4: The battery solution for the electric bicycles from JCDecaux (DeMaio, 2016).

4.2 Benefits with bike-share systems with electric bicycles

The benefits with an electric bike-share system come from the electric bicycles and thereby many of the advantages are the same as with a privately owned e-bike.

[10] Wolfgang Forderer, Head of the Mobility department in the Mayor's Policy Office, City of Stuttgart, answers on questionnaire about e-Call a Bike on 2016-03-22

[11] Rickard Wendel, Senior Advisor and Establisher at JCDecaux Sverige AB, telephone interview 2016-03-15 and e-mail correspondence during the spring of 2016

However, these advantages are in this case combined with the advantages from a bike-share system, and thereby to a larger extent (DeMaio, 2016).

DeMaio (2016) states that e-bikes are "[…] one more reason now to take bike-share and one less reason to not take a car." In Section 2.3 it is said that electric bicycles can replace cars to a higher degree than conventional bicycles can. There is also a chance for a chain reaction, if people that formerly used public transport will start using the e-bike share, then it would ease of the public transport and make it more attractive for car users to switch transport mode.

The average distance cycled with e-bike is found to be 9.8 km, which is more than three kilometres longer than for conventional bicycles (PTV Group, 2013). Therefore, it is possible to go further in the system with electric bicycles and save travel time or run quicker errands. Bike-share systems with electric bicycles can also be bigger than a conventional bike-share system, both larger geographically but also extended to hillier areas, and still feasible to cycle through the whole system. This makes it possible to connect areas crossly against public transport as well as areas with poor public transport. It is also possible to make destinations available to more people, where public transport or a conventional BSS are not feasible. This could for instance be highly located tourist attractions, distant recreation areas, bathing places or nature areas. Further, a geographically larger area means that more people will be included in the coverage area, but also gives opportunity for new routes to be made, as the locations of the stations do not have to fulfil all the same criteria (DeMaio, 2016). With an electric bike-share system distance and topography will not be the physical barrier it is today, hence the user group can enlarge.

According to Fermín Echarte Peña[12] at the city of San Sebastian, they have seen a reduction in redistribution to hilly areas after implementing electric bicycles in their bike-share system. Reduced redistribution leads to decreased costs as well as lower environmental impact from the vehicles used for the movement.

<u>Benefits with bike-share systems with electric bicycles can be summarised as:</u>

- Longer and faster travels
- Overcome barriers like challenging topography and high bridges
- Reduction on need of redistribution of bicycles, i.e. lower operational costs and emissions
- Complement and cover areas where public transport is low
- Greater possibilities to attract car users than conventional BSS
- New demographics of people into bike-sharing

[12] Fermín Echarte Peña, Mobility Department in the city of San Sebastian, answers on questionnaire about dBizi on 2016-03-23

4.3 Users and target group for bike-share systems with electric bicycles

With a bike-share system with e-bikes it is possible to reach a wider user group than a conventional bike-share system. For instance, as stated in Section 2.3 and earlier in this chapter, there is a greater possibility to attract car users as well as public transport users. According to a survey of travel habits 51 % of the commuting trips were performed by car (Trafikkontoret, 2012). It is also more likely that people who live in hillier areas or people who have some distance to work or school are more attracted by e-bikes than the conventional bicycles (PTV Group, 2013).

The target group for Gothenburg's bike-share system is primarily daily commuters and secondly tourists. This is in line with other cities' target groups, which were found out in interview study. Madrid[13] and Copenhagen[14] both have commuters as their primarily target group. However, they both experience a more frequent use from tourists than expected. Milano also have commuters living in the city as their main target group, as well as commuters from outside of Milano who change transport mode from car or public transport to BikeMi when they reach the city.[15] Furthermore, in the city of Stuttgart as well as San Sebastian the target group is people that do not usually cycle, such as car and motorcycle users[16]. Wolfgang Forderer[17], head of the mobility department in the city of Stuttgart, also states that more important than getting the right target group was to present a visible offer and to show that cycling in Stuttgart is possible.

Since electric bicycles do not require as much physical effort as a conventional bicycle new user groups are possible and enables people to carry heavy load with them. This could be older people that are more physically restrained. As mentioned previously, San Sebastian first had a regular bike-share system, which later was replaced by a system with electric bicycles[16]. It was then noticeable that older people in San Sebastian used the electric BSS in a greater extent than before. Electric bicycles are also suitable for companies that depend on mobility in their organisation[18]. It is easy to take an e-bike to a business meeting as well as the working place without concern of arriving exhausted or sweaty, which have been a valid reason for usage in Milan[15]. Their target groups otherwise are commuters, public transport users, and those who change transport mode. However, the e-bikes in Milan especially attract those who live in the outskirts of the system zone and have longer journey to the centre[15].

Wolfgang Forderer[17] believes that the target groups for the conventional and the electric bicycles are similar, however the errand determines the choice of bicycle. If the trip that

[13] Sergio Fernández Balaguer, Department of Communication and Consulting at the Municipal Transport Company of Madrid, answers on questionnaire about BiciMAD on 2016-03-21

[14] Pia Preibisch Behrens, project manager at the Technical and Environmental department at the Municipality of Copenhagen, answers on questionnaire about Bycyklen on 2016-03-10

[15] Maria Berrini and Valentino Sevino, CEO resp. Director of Mobility Planning at Agency of Mobility, Environment, Territory in the City of Milan and Sergio Verrecchia, director of Contracts, Development & Bike Sharing at Clear Channel Italia, answers on questionnaire about BikeMi on 2016-03-18

[16] Fermín Echarte Peña, Mobility Department in the city of San Sebastian, answers on questionnaire about dBizi on 2016-03-23

[17] Wolfgang Forderer, Head of the Mobility department in the Mayor's Policy Office, City of Stuttgart, answers on questionnaire about e-Call a Bike on 2016-03-22

[18] Ulf Jakobsson, marketing manager at Move About, telephone interview on the bicycle pool with electric bicycles at Science Park Lindholmen 2016-02-25

is to be made is uphill or the cyclist does not want to arrive sweaty, then an electric bicycle will be chosen.

<u>Users and target groups in bike-share systems with electric bicycles can be summarised as:</u>

- Commuters in the outskirts of cities and commuters in general
- People who normally do not use bicycle due to physical conditions or preferences
- Car commuters
- People living or working in hilly areas
- People who carry heavy load or do not want to arrive sweaty, for example to work

4.4 Challenges with bike-share systems with electric bicycles

As with everything, new implementations come with challenges, also e-bike share systems. In general, the challenges that arise are the same as for a regular bike share system, but the focus for this sub-chapter will be on the additional challenges that come with an implementation of electric bicycles in the system.

With a bike-share system with e-bikes it is desirable to attract new users, preferably car users. This means that people who might not be very used to cycle in an urban area and are less experienced with how to interact with traffic as a cyclist (Goldmann, 2015). There is also this additional factor of using an electric bicycle, which can be a new thing to many users.

There is also a challenge that lies within actually attracting car users. People that already cycle or walk is not aimed for, since they already have the capability and behaviour that is sustainable. In order to compete with driving, car users need to be introduced to e-bikes and their benefits as a convenient transport mode. According to Trafikkontoret (Trafikkontoret, 2016) 8 out of 10 are not willing to change their primarily transport mode, where car users corresponds to 28 % of these.

E-bikes have higher average speed than conventional bicycle (Clark & Nilsson, 2014). Clark and Nilsson (2014) state that the high speed together with the fact that they have faster acceleration and are heavier could increase the accident risk, but especially worsen the degree of injuries compared to conventional bicycles. It is possible to set an own maximum speed for the e-bikes in a BSS. For instance, Madrid has their limit at 18 km/h for their electric BSS (González, 2014) and Copenhagen at 22 km/h (Bycyklen, 2014:c).

Electric bicycles are more expensive than conventional bicycles, which also make an electric bike-share system more expensive. For example, the electric bicycles in Madrid and Milano are estimated to cost two to three times as much as a conventional bicycle. Apart from the higher cost of the bicycles, there will be additional costs concerning a reliable electricity connection to every station in order to charge the bicycles as well as costs for the actual electricity used. The electric part of Milan's BSS is approximately

25% higher than the traditional one.[19] With the solution by JCDecaux where the users own and recharge the batteries it means, according to Rickard Wendel[20] at JCDecaux, that the bicycles will only be 25-30 % more expensive to the operator than the regular bicycles. However, users' fee will increase with the additional cost of payment for battery.

Because of the higher value of e-bikes, it also makes them more vulnerable to vandalism and more theft-attractive. This has become a serious problem in Madrid. The plan was to expand the system from around 1,500 bicycles from start in 2014 to just over 2,000 bicycles in 2015 (Gallo, 2015). However, over 1,000 bicycles have been stolen or vandalised beyond use, making the company loose great amount of money every month (Gallo, 2015).

It is important to be prepared for theft and vandalism with for example proper insurances. Some operators integrate the cost for a loss of 10 % of the bicycles per year in the financial models (ITDP, 2013). It is however important to understand the situation in each specific city, since this can differ a lot. Pia Preibisch Behrens[21], project manager at Copenhagen municipality, says that since the bicycles are heavy and unpleasant to ride without charged battery, they are unattractive to steal as they only can be charged in the docking station. With GPS integrated in the bicycles it is possible to track a bicycle that is stolen or taken outside the system.

Other cities, such a Madrid and also San Sebastian have had significantly more problems with this and thereby also need to take more measures. The bike-share system in San Sebastian had poor solution for locks in the beginning, which was later improved.[22] Madrid will develop a closer collaboration with the local police and have a campaign in media to reduce and prevent the issue.[23]

Challenges with bike-share systems with electric bicycles can be summarised as:

- Difficulties to get people to change transport mode and attract car users
- Inexperienced electric bicycle users
- Speed issues
- Higher costs of both bicycles and system
- More vulnerable to vandalism and theft

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[19] Maria Berrini and Valentino Sevino, CEO resp. Director of Mobility Planning at Agency of Mobility, Environment, Territory in the City of Milan and Sergio Verrecchia, director of Contracts, Development & Bike Sharing at Clear Channel Italia, answers on questionnaire about BikeMi on 2016-03-18

[20] Rickard Wendel, Senior Advisor and Establisher at JCDecaux Sverige AB, telephone interview 2016-03-15 and e-mail correspondence during the spring of 2016

[21] Pia Preibisch Behrens, project manager at the Technical and Environmental department at the Municipality of Copenhagen, answers on questionnaire about Bycyklen on 2016-03-10

[22] Fermín Echarte Peña, Mobility Department in the city of San Sebastian, answers on questionnaire about dBizi on 2016-03-23

[23] Sergio Fernández Balaguer, Department of Communication and Consulting at the Municipal Transport Company of Madrid, answers on questionnaire about BiciMAD on 2016-03-21

5 The Bike-Share System Styr & Ställ

In this chapter the bike-share system in Gothenburg will be described in terms of design, function, users, and the inhabitants' attitude towards it. Development plans and other factors that can affect if and how an expansion could occur is investigated.

The city of Gothenburg implemented its bike-share system Styr & Ställ in August 2010, which has since the start been operated by the advertisement company JCDecaux. The system is growing each year and today it consists of 1,000 bicycles and 2,000 docking spaces divided among and 66 stations (JCDecaux Sverige AB, n.d.:c). The bicycles can be seen in Figure 5.

Figure 5: Bicycles in Styr & Ställ at Gustav Adolfs torg in central Gothenburg (Gothenburg Tourist Centre, n.d.)

5.1 Description of Styr & Ställ

The stations are located in the city centre with a distance of 300-500 meters apart (Mattsson & Emqvist, 2013). Stations have primarily been located adjacent to bicycle roads, but topography and destinations have also been considered. In order to be an extension of the public transport system, there are also stations located close to the larger transport nodes (Mattsson & Emqvist, 2013). The coverage area is the central parts of Gothenburg, on the southeast side of the river Göta Älv, see Figure 6 on the next page. It can be seen in the figure that the stations are located at low altitude and hillier areas are avoided.

With the present system it is possible to use the bicycles at all hours and all days of the week from March to the end of December. The aim of the bike-share system is to be a complement and an alternative to the public transport systems. Styr & Ställ is mainly to be used for shorter trips, where a bicycle can be picked up at one station and returned at another (Göteborgs Stad, n.d.:b). This agrees with the utilisation of daily commuters, which is the main target group. Since the implementation of Styr & Ställ the utilisation has increased and the system has expanded gradually. The number of uses in 2015 were 727,000 (Trafikkontoret, 2016). However, it is important to note that a usage is when a bicycle is moved, either by a cyclist or redistribution.

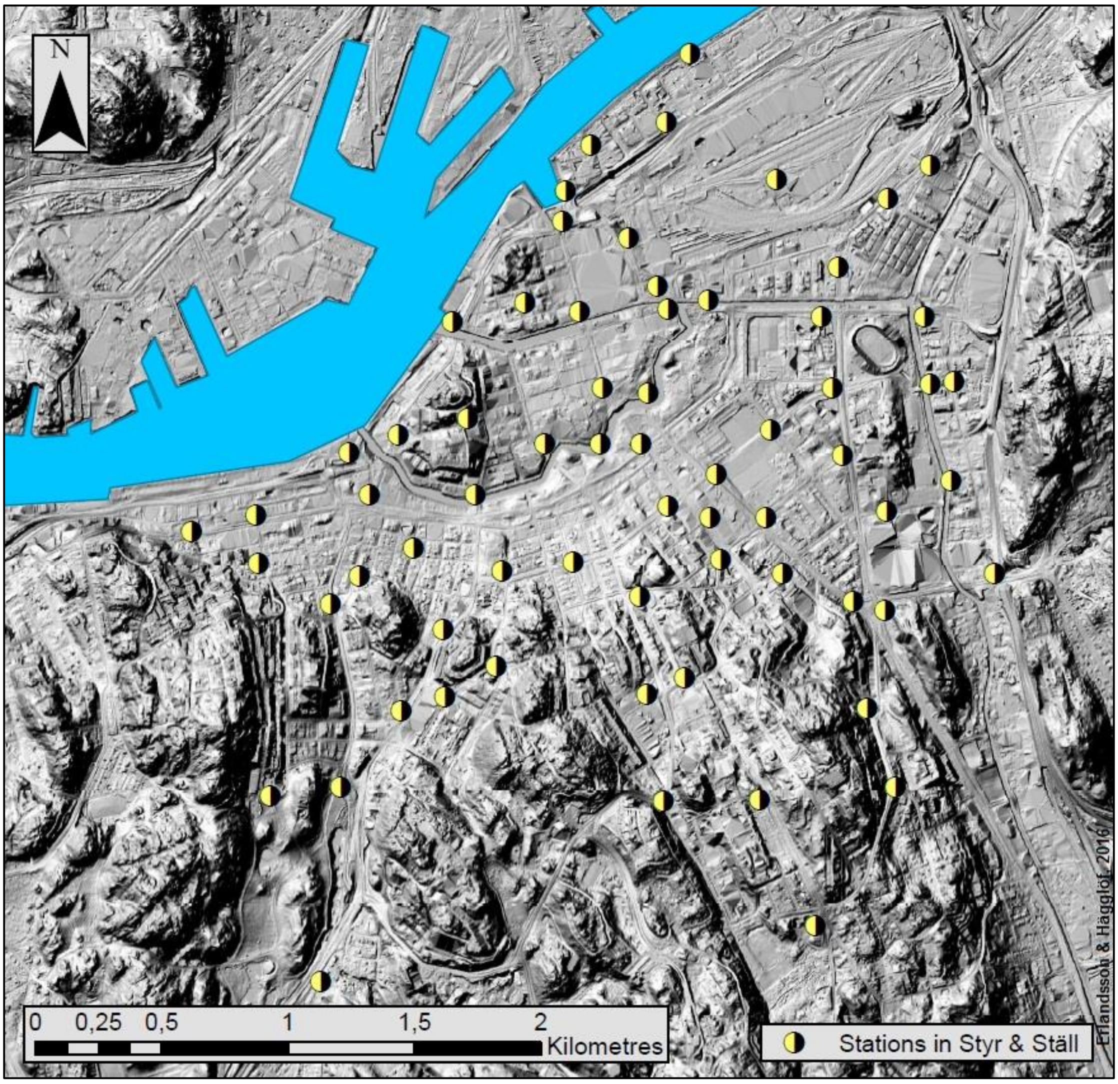

Figure 6: Topography map over current stations in Styr & Ställ. Map conducted by the authors in GIS with elevation data from Lantmäteriet and station data from Trafikkontoret 2016.

In order to use a bicycle a membership subscription is needed. This can either be for three days at a cost of 25 SEK or for the whole season for 75 SEK (JCDecaux Sverige AB, n.d.:a). The bicycles are then free to use the first 30 minutes of a ride and after that the pricing increases for every following 30 minutes (JCDecaux Sverige AB, n.d.:b). The three days' membership is primarily meant to be a service for visitors and tourists.

Styr & Ställ has today redistribution related issues. Stations with uniform commuting get full quickly in the morning and emptied in the afternoon (Karlgren, 2014). The main problems for this are for example in the area of Gårda and the station at Kruthusgatan, see Appendix I. Overall there is a somewhat skewed distribution in Gothenburg. Figure 7 shows the balance between travels to and from the stations from 2014 during weekdays. The green dots indicate the stations which have a surplus of bicycles that thereby need to be redistributed to the stations with a blue mark, which are stations with a shortage of bicycles. The size of the green and blue spots shows how uneven the distribution is. There is one of the stations that has perfect balance, Valand, and is located almost in the middle of the system zone.

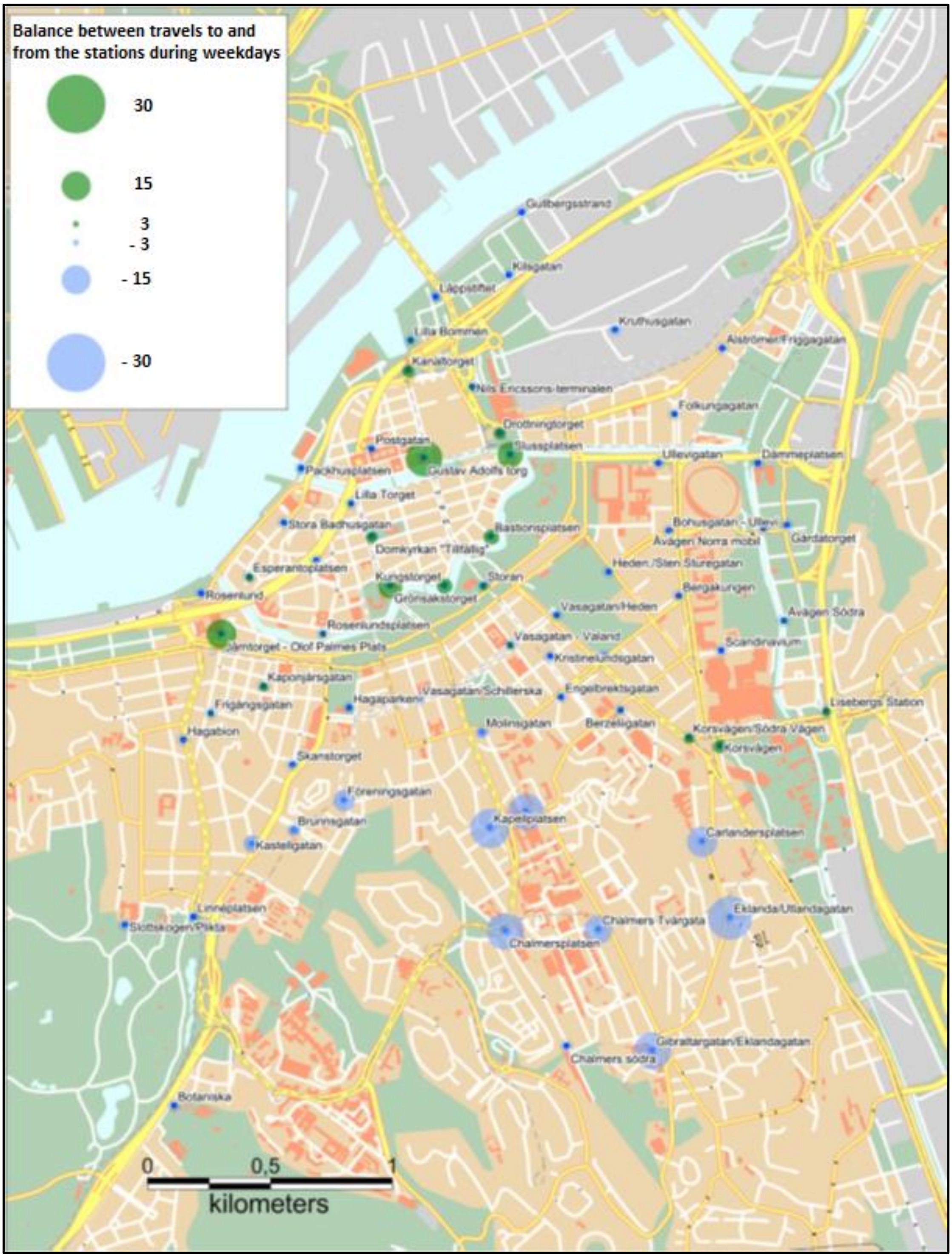

Figure 7: The balance between travels to and from the stations from 2014 during weekdays. It is important to notice that the system has expanded with more stations since 2014, for example Masthuggstorget in the west. The figure does also include the station at Chalmers Södra that was planned but never built (Karlgren, 2014).

It is clear that more trips are made from south to north than in the other direction. This can be explained by the large altitudinal differences, where the blue dots are located higher than the green ones.

5.2 Styr & Ställ users today

The majority of Styr & Ställ's users are people who use it to go to and from their daily activity, which corresponds to the main target group of daily commuters (TNS Sifo, 2014). However, most people use it a couple of times per week, 41 %, and 10 % use it every day. In the survey from TNS Sifo (2014), people were asked what transport mode they would use if not bicycle from the bike-share system and it turned out that the transport mode primarily replaced was public transport, see Figure 8.

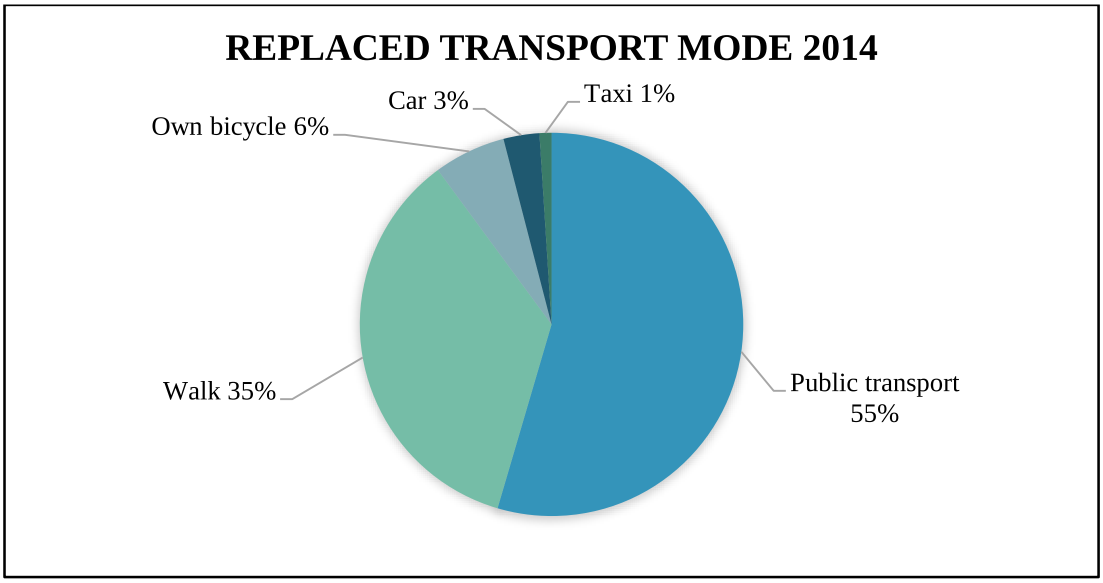

Figure 8: Transport mode that were replaced by Styr & Ställ in 2014, based on TNS Sifo (2014)

From a study by Nikitas, Wallgren and Rexfelt (2015) it was found that there is a small steady annual increase of the number of subscribers for Styr & Ställ. People that uses the bike-share system as their secondary travel mode is seen as the most important increase. This group doubled between 2010 and 2014 and represented 20 % of the users (Nikitas et al. 2015).

Figure 9 shows the different age groups that have a seasonal subscription for Styr & Ställ in 2015 (JCDecaux Sverige AB, 2016). Subscribers older than 75 as well as remaining subscribers can be found in Appendix II. The age group 26-35 years old was the largest user group for Styr & Ställ in 2015, followed by the group of 18-25 years old. In 2015 there was a total of 13,512 seasonal subscribers for Styr & Ställ. There were more men using Styr & Ställ in 2015 than women, and the biggest difference is seen in the two age groups previously mentioned.

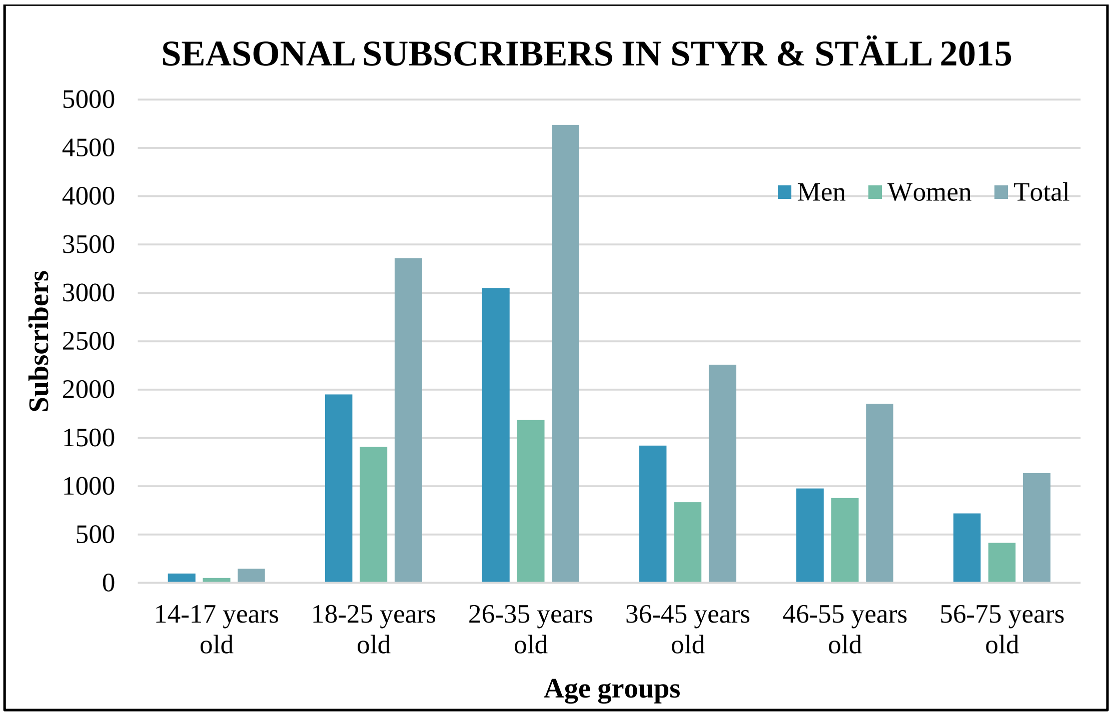

Figure 9: Age and gender of the main groups for seasonal subscription of Styr & Ställ in 2015, based on data from JCDecaux Sverige AB (2016). Subscribers older than 75 and remaining subscribers can be found in Appendix II.

5.3 Public acceptance of Styr & Ställ

Styr & Ställ is a popular bike-share system. According to a survey from TNS Sifo (2014), 97 % of the users are pleased with the system. Nikitas, Wallgren and Rexfelt (2015) studied the public acceptance of the public bike-share system in Gothenburg. From their interview survey was it found that "[…] the respondents generally believed that Styr & Ställ is a pro-environmental, inexpensive and healthy transport mode, which complements the city's public transport services and promotes a more human-friendly identity for Gothenburg." (Nikitas et al. 2015, p.1). To the statement that Styr & Ställ is good for Gothenburg, 92.4 % of the respondents agreed, and this also includes respondents that does not currently use the system.

The usage of bike-share systems differs for different age groups, people in the age between 18 and 34 are more likely to subscribe than other (Fishman, et al., 2015). People over the age of 60 generally are more physically limited and do not cycle to the same extent neither bicycles in a bike-share system nor regular bikes. Other reasons for not using Styr & Ställ appeared in the survey from Nikitas et al. (2015). The most common reason was that the respondents had an own bicycle and after that that they just did not want to. Some people did not use Styr & Ställ since they did not have a station in their neighbourhood and some people emphasised things as limited road safety and hilly topography. Furthermore, did the study conclude that since most of the respondents had a positive attitude towards Styr & Ställ. Nikitas et al. (2015) conclude further that Styr & Ställ need to expand to more destinations and that the public are in favour of further investments in the system.

Nikitas et al. (2015) had also statements on electric bicycles in Styr & Ställ in their study. One statement was "[…] if some electric bicycles will be introduced to the programme I might be more likely to use Styr & Ställ" (Nikitas et al., 2015, p.8). The result shows that the respondents did not seem too positive with the idea. However, in general people were more positive than negative to the statement that Styr & Ställ would be better if electric bicycles were introduced in addition to the conventional bicycles (Nikitas et al. 2015).

5.4 Expansion potential for Styr & Ställ

Gothenburg is in the process of going from being a small town to a big city. In the nearest 20 years a lot is going to happen in Gothenburg in terms of urban development (Göteborgs Stad, 2009). This can influence the development of Styr & Ställ when new dense and mixed areas are developed in the city[24]. Hence, new possibilities are created concerning users and expansion.

5.4.1 Development plans in Gothenburg

The Development Planning Strategy for Gothenburg 2035 and Vision Älvstaden two of the main policy documents for future urban planning in Gothenburg. The prognosis for Gothenburg is that the population will increase with 150,000 inhabitants from 2014 to 2035 (Stadsbyggnadskontoret & Fastighetskontoret, 2014). This means an increasing of about 10,000 inhabitants each year.

The purpose with Vision Älvstaden is to strengthen the core in the Gothenburg Region and Vision Älvstaden intends the central districts along with the river Göta Älv; Centrum, Majorna-Linné and Lundby (Göteborgs Stad, 2012). The aim is to connect these districts with each other and reduce the physical barrier that the river Göta Älv is. One part of this vision is to create an attractive public transport and continuous walking- and bicycling paths in this area (Göteborgs Stad, 2012). There is a plan for new connections over the river Göta Älv in Vision Älvstaden. The old bridge Götaälvbron is going to be replaced by the bridge Hisingsbron, which is lower than the old one and could therefore among other things facilitate more pedestrian and bicycle trips over the river. There is also going to be two new public transport connections over the river; one between Stigberget and Lindolmen in the West and one between Ringön and Gullbergsvass in the East.

The goal is to build many new residences and workplaces in this central part of the city; 30,000 residences and 40,000 workplaces until 2020 and after 2020 another 30,000 residences and 30,000-40,000 workplaces (Göteborgs Stad, 2012). Figure 10 shows the different steps in the development plans. The development is going to be in line with the Master Plan for Gothenburg from 2009, i.e. new buildings are going to be complementary to the already established settlements (Göteborgs Stad, 2012). The new main development areas in Vision Älvstaden are:

[24] Caroline Mattsson and Axel Persson, consultants and civil engineers at Trivector Traffic, 2016

- Lindholmen
- Södra Älvsstranden
- Backaplan
- Centralenområdet
- Frihamnen
- Ringön
- Gullbergsvass

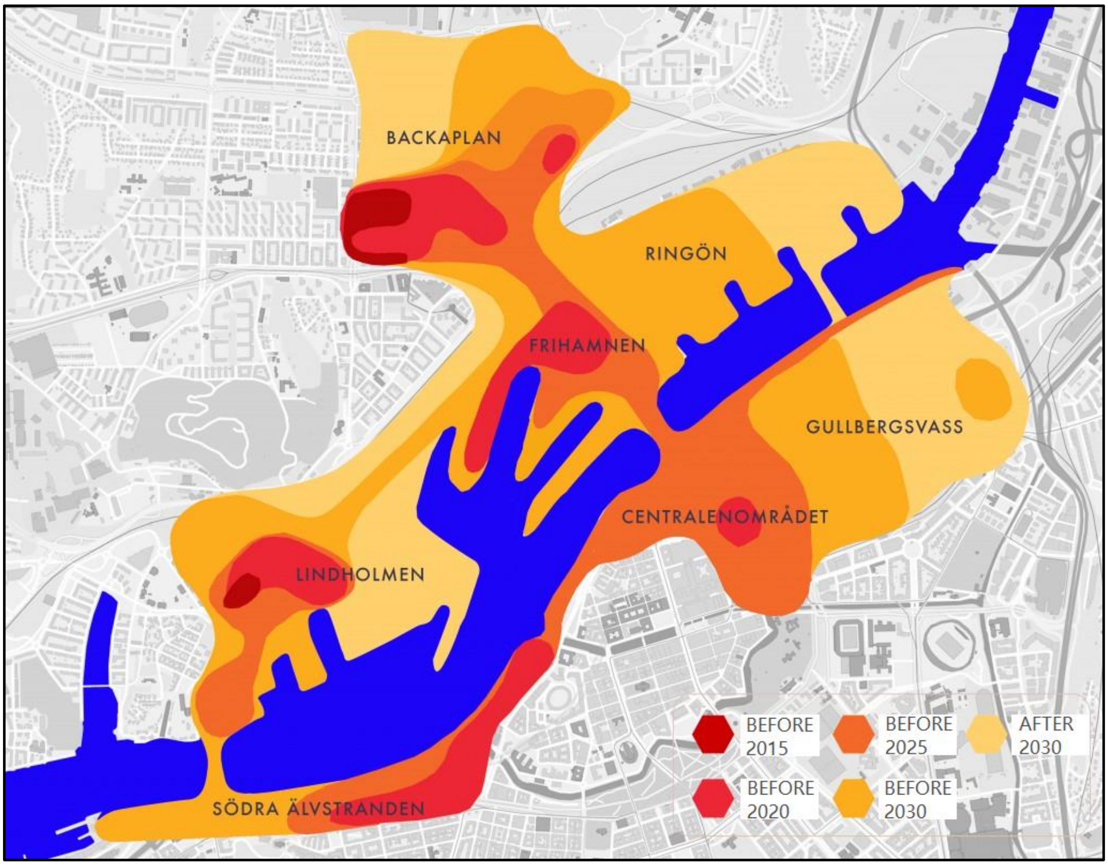

Figure 10: Developing plans for Gothenburg (Älvstaden, n.d.)

The Development Planning Strategy for Gothenburg 2035 (Stadsbyggnadskontoret & Fastighetskontoret, 2014) focuses on the part of the city called *mellanstaden* – the continuous urban area which is just outside the inner city. This is an area where a large part of the population lives and works in, and it is well served by public transport and has good availability of services. The strategy has the basis that Gothenburg should grow and develop in a sustainable way. This should be done by densification of the already built urban areas and around important and strategic public transport nodes, see Figure 11. Strategic nodes that were identified in the Master Plan of 2009 should be the centre of gravity for urban development and these are Angered centrum, Gamlestads torg, Frölunda Torg, Backaplan and the inner city (Stadsbyggnadskontoret & Fastighetskontoret, 2014). The Development Planning Strategy also points out smaller nodes and local squares that can be developed to strategic nodes.

The inner city is going to expand into areas in direct contact with the inner city, i.e. parts of mellanstaden (Stadsbyggnadskontoret & Fastighetskontoret, 2014). Districts that are mentioned in The Development Planning Strategy to be possible for this expansion can be seen in Figure 11 and are the following:

- Majorna and Kungsladugård in the West

- Olskroken, Bagaregården and Lunden in the East
- Guldheden, Medicinareberget, Krokslätt and Mölndals dalgång in the South

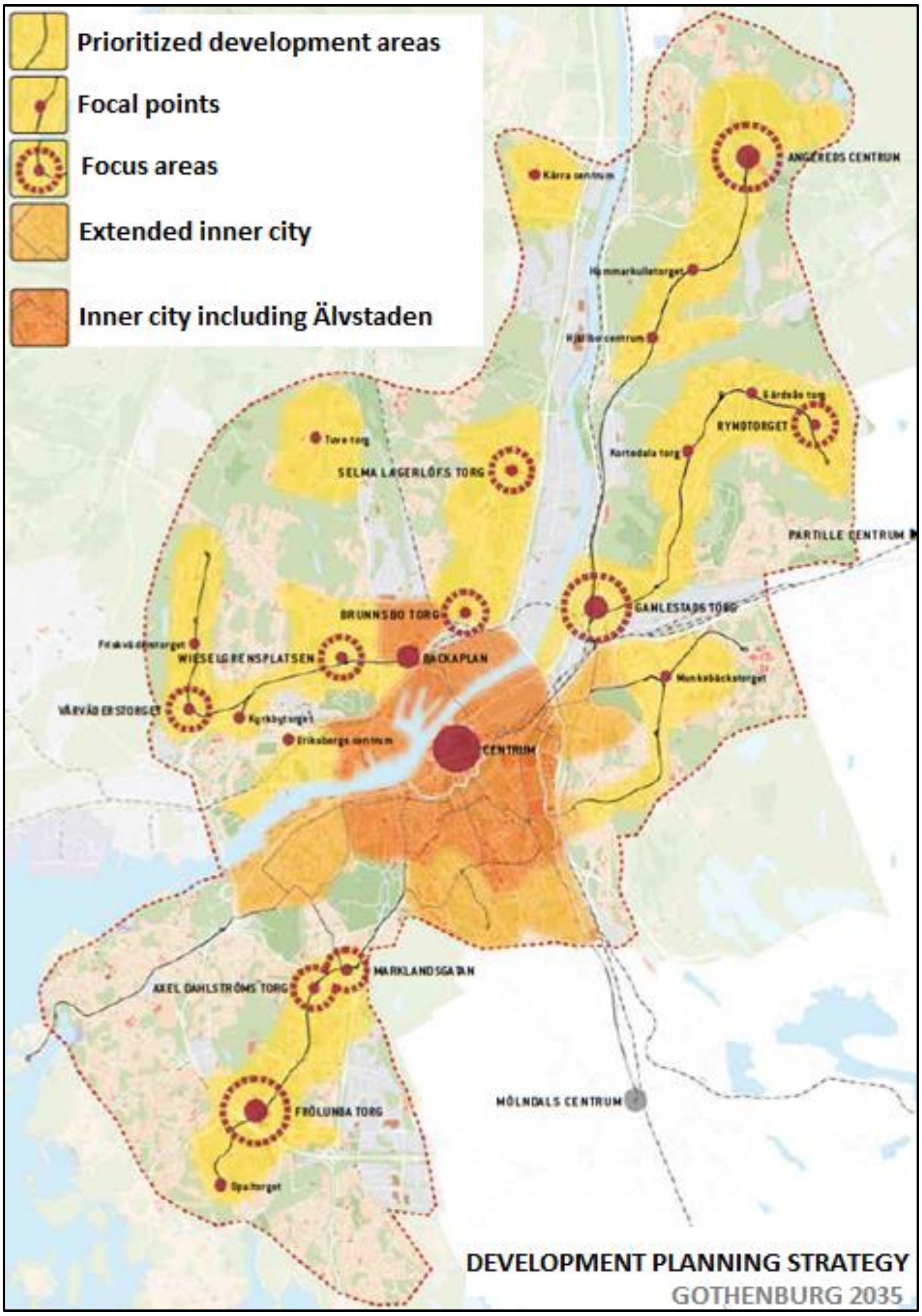

Figure 11: The Development Planning Strategy for Gothenburg 2035 (Stadsbyggnadskontoret & Fastighetskontoret, 2014)

5.4.2 Parameters that affect decisions concerning an expansion of Styr & Ställ

Mattsson and Emqvist (2013) did an investigation on a future expansion of Styr & Ställ to the island Hisingen, where they defined parameters that affect decisions when concerning an expansion of Styr & Ställ, see Table 6. The parameters are based on the goals of The Master Plan of Gothenburg and Vision Älvstaden as well as experiences from other cities with bike-share systems. Moreover, the focus for these parameters are on conventional bicycles and therefore is topography not a parameter that effects an extension with e-bikes.

Table 6: Parameters that affect decisions concerning an expansion of Styr & Ställ based on Mattsson & Emqvist (2013)

Parameter	Description
Link parts of the city together	The master plan of Gothenburg and Vision Älvstaden have the overall goal to link the different parts of Gothenburg together, and their main focus is to connect the central parts, i.e. the north and south Älvstranden.
Increased reach of public transport	One of the main goals of Styr & Ställ is to complement the public transport both in terms of unloading and to cover areas with important points of interest which have few public transport (PT) connections.
Important destination points	The stations should be placed adjacent to important destination points such as PT nodes, workplaces, shopping malls, service points and schools.
Spacing of stations	Dense spacing of the stations is important for the success of the system.
Redistribution of bicycles	To minimize the need of redistribution of bicycles is the travel patterns needed to be analysed for the extension of the coverage area. This is done to locate which areas where the demand is large and therefore a need of large station or denser spacing of stations.
Settlement density	Areas with high settlement density generates often a bigger demand of short travels which can be done with Styr & Ställ.
Topography	The topography is an important parameter when considering an extension of Styr & Ställ with conventional bicycles since it affects both the travel flow and location of stations.

5.4.3 Principles for extension of Styr & Ställ

Mattsson and Emqvist (2013) presents in their investigation three principles for expansion of Styr & Ställ and these are listed below and showed in Figure 12.

1. Gradual extension from the centre, i.e. the current system zone
2. Satellites
3. Courses to or from the centre

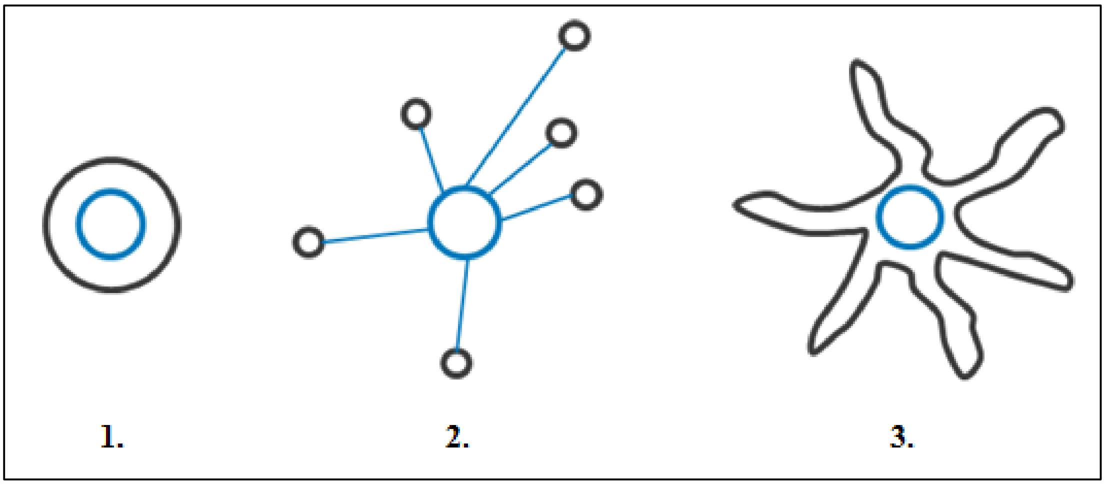

Figure 12: Illustration of the principles for extension of Styr & Ställ (Mattsson & Emqvist, 2013)

With gradual extension means even radial development of the system zone from the centre. The spacing of the stations will be the same as before, i.e. 300 to 500 meters apart. Mattsson and Emqvist (2013) writes that it is necessary to analyse to what extent the gradual development should be and it should be based on the settlement density and destination points.

The second principle is to expand the system with satellites, i.e. establish smaller sub-systems outside the centre. Mattsson and Emqvist (2013) suggests that this can be done in the strategic nodes highlighted in the Traffic Strategy: Angered centrum, Backaplan, Gamlestaden and Frölunda Torg. These are also part of the focus areas in the Development Planning Strategy (Stadsbyggnadskontoret & Fastighetskontoret, 2014).

The last principle of expansion is to expand the system zone along courses from the centre to the strategic nodes mentioned before. Mattsson and Emqvist (2013) writes that it could also be done by first creating the satellites and then expand from these along course to the centre.

6 Analysis of the Potential for Electric Bike-Share System in Gothenburg

This chapter is where the potential of electric bike-share systems in Styr & Ställ is analysed. Four analyses are presented and concluded in a final result and suggestion.

The potential of electric bicycles in Styr & Ställ analysed in four different analyses and are concluded in a final result. The analyses are:

- Analysis of key findings found in literature and interviews
- Key figure analysis based on population density, workplaces and services on a sub-district level
- Isochronal analysis where the difference between conventional bicycles and e-bikes in Styr & Ställ, in terms of time and distance, is analysed
- Analysis of destination points of interest in the areas found in the second and third analysis

6.1 Analysis and key findings from literature and interview study

In this sub-chapter key findings from literature and the interview study are presented and analysed. In Section 6.1.2 the potential of electric bicycles in Styr & Ställ is evaluated according to the literature and interviews. Each section ends with a summary of key findings within each topic.

6.1.1 General findings of bike-share systems

The literature review showed that there are several benefits with bike-share systems, for example increased accessibility in the city, improved health of the inhabitants, and new cyclists generated. Bike-share systems are a good complement to public transport and can replace car trips on distances at least under five kilometres in urban areas. To what extent bike-share systems are beneficial depends on what transport mode that is replaced.

Challenges with BSS were also found in the literature, and that they are important to overcome to be able to create a successful BSS. One common challenge is unevenly distributed bicycles, which can be a result of commuting flows or hilly condition. The study showed that Gothenburg experiences both these issues. Studies suggest implementing electric bicycles in cities where uniform flows are an issue due to topography. One example is Stuttgart where electric bicycles has been introduced in their BSS to increase the bicycling share and as a solution to tackle the topography related issues. With electric bicycles, location of stations is not as limited.

It was seen that most of the users of Styr & Ställ are in the age group between 18 and 35 years old while the most frequent users of e-bikes are from 40 years old and up. This means that the groups complete each other and with a BSS that has both conventional and electric bicycles these user groups can be combined to an even larger group of BSS-users.

Summarised key findings for bike-share systems:

- Benefits with BSS
  - Increased accessibility
  - Improved public health
  - Modal shift from motorised transport to bicycle
  - Reduced congestion and air pollution
  - Attraction of new cyclists and improved image of cycling in the city
- Challenges with BSS
  - Unevenly distributed bicycles
  - Low helmet use
  - Theft

6.1.2 Potential of electric bicycles in Styr & Ställ

The conclusion drawn from the study of Styr & Ställ is that it is a successful bike-share system and there is no need to implement electric bicycles in the current system. The system zone today is in the city centre and the stations are generally located in flat areas. However, if the system were to expand as desired both by the users and inhabitants as well as the City of Gothenburg, the topography will be a major barrier to the expansion. Moreover, the different strategic documents show that Gothenburg will grow a lot in the next 20 years, especially the central parts, and therefore it is natural that Styr & Ställ should grow as well. Gothenburg will have more inhabitants and the core will become denser and with a higher mix of housing and workplaces. The demand on the traffic system in the city will be higher and sustainable transport alternatives are necessary.

Today the main purpose of Styr & Ställ is to be a complement to the public transport system, and electric bicycles can do this to an even greater extent compared to conventional ones. With electric bicycles in the system new groups in the society can be introduced to bicycling, for example older people, people who cannot afford an e-bike and people who do not want to be sweaty when doing errands. Another benefit with an expansion of Styr & Ställ with electric bicycles is that longer distances can be covered within the system zone, which means that the public transport can be unloaded even more. Furthermore, destination points in Gothenburg become more connected and enable longer travels with Styr & Ställ and thereby decrease the need of changing transport mode.

Summarised key findings for the potential of electric bicycles in Styr & Ställ:

- The system zone of Styr & Ställ should expand
- There is a potential of electric bicycles in Styr & Ställ due to topographical barriers
- New user groups can be attracted by e-bikes
- Faster and longer travels can be made

6.1.3 Proposed solution

Following is a description of the proposed solution for Gothenburg, both technically and geographically.

Type of system

The best solution for Gothenburg seems to be a bike-share system with both conventional and electric bicycles, i.e. a combined bike-share system, like the two studied cities Milan and Stuttgart. However, Stuttgart's technical solution appears to be the best since both types of bicycles can be docked in the same docking space and the electric bicycles are recharged automatically in the docking station. In Milan there is also one type of docking station, but personnel at the operation company recharge the batteries for the electric bicycles manually. Therefore, Milan's system is seen as much more ineffective and results in unnecessary operation costs. The system provided by JCDecaux is believed to impede spontaneous e-bike-trips due to the user's responsibility of bringing the battery. There is also uncertainties is using a completely new and untried system kind.

With both conventional bicycles and e-bikes Styr & Ställ does not lose any users that prefer conventional bicycles. It was found that are some users that agree with that e-bikes are not needed in Styr & Ställ. This implies that there are users that still would choose a conventional bicycle even if e-bikes were offered.

Safety measures

There are some concerns about the higher pace that comes with the e-bikes. A solution for this is to regulate the maximum speed of the e-bikes. What is recommended for Gothenburg is to do as Copenhagen, where the cycle mode is set to a standard assistance from the beginning but if wanted it is possible for the user to adjust in order to increase or decrease the assistance. By having this solution, it is possible to satisfy more types of users with the same bicycle.

Although the accident risk is not possible to eliminate and very few BSS users use helmet, studies have shown that the socio-economic benefits are far greater with BSS that it is not seen as a reason to avoid cycling, conventionally or electrically. Still it is highly encouraged to use helmet when cycling. Therefore, it is suggested that the user is provided with a helmet. Styr & Ställ's earlier solution with getting a helmet at an office is believed to be too inconvenient to function. A helmet should instead be connected to each bicycle. The helmet should be adjustable in size and of a design that people want to use. To use a design that is unattractive to steal is not recommended since it also will make it unattractive to wear. It is therefore suggested to have some kind of lock for the helmet in order to make sure the helmet is retuned with the bicycle and to obstruct theft. For sanitary reasons antiseptic should be placed at each station and users can have their personal cap underneath the helmet if wanted.

Cost and theft

The literature study shows that electric bicycles for bike-share systems are more expensive than conventional. This would therefore result in higher costs for Styr & Ställ if electric bicycles are implemented. In order to keep the usage between the two types of bicycles proportional it is suggested that the cost of using an e-bike is higher than the conventional bicycle. The conventional bicycles should be free of charge the first 30 minutes as it is today, but the use of an e-bike should be charged from the first minute. This is also believed to attract car users rather than pedestrians and conventional cyclists.

A challenge for electric bike-share systems is the risk of theft. As Pia Preibisch Behrens[25] reasoned about low theft rate in Copenhagen due to unattractiveness to cycle e-bikes without battery is not applicable on the electric system that JCDecaux offer. In JCDecaux system the users have their own battery and charger and therefore not need the station in order to get the bicycle to work. Nevertheless, shared e-bikes have been stolen from systems that recharge in the stations. When looking to the interviews this problem seems to be more extensive in southern Europe, where for instance Madrid has suffered from much theft and vandalism. The little theft and vandalism of Styr & Ställ could indicate that there will be little also in the future. However, it is important to have well-working GPS installed in all the bicycles in order to know where they are.

Expansion areas

The expansion of Styr & Ställ should be in line with the different policy documents for spatial and traffic planning in Gothenburg. Most natural is that the system first expands to the parts that are called extended inner city in the Development Planning Strategy, i.e. Majorna, Kungsladugård, Olskroken, Bagaregården, Lunden, Guldheden, Medicinareberget, Krokslätt and Mölndals dalgång. The Master Plan and Vision Älvstaden has a goal of linking the city together, and especially connecting the city centre with Hisingen. The most likely areas for Styr & Ställ to expand on Hisingen are those closest to Göta Älv, i.e. Lindholmen and Backaplan, and this would make a radial expansion. In the future Frihamnen, Ringön and Gullbergsvass would also be areas of interest for Styr & Ställ due to their central locations and the fact that they will be developed to dense urban areas.

The two strategic nodes pointed out in the Traffic Strategy, Backaplan and Gamlestaden, seem also as reasonable expansion areas for Styr & Ställ, since they are located close to the current system zone. The two other strategic nodes, Frölunda Torg and Angered centrum appears to be too far away from the centre, but they could instead be suitable as two satellite systems of Styr & Ställ. Frölunda Torg is closer to the city centre than Angered centrum, and Styr & Ställ could therefore be extended gradually to Frölunda Torg. Analyses have to be done in order to establish whether Frölunda Torg and Angered centrum are feasible areas for Styr & Ställ or not.

The location of stations and the system design for the new expansion of Styr & Ställ should be analysed and evaluated according to the planning guidelines from ITDP (2013) and experiences from OBIS (2011).

[25] Pia Preibisch Behrens, project manager at the Technical and Environmental department at the Municipality of Copenhagen, answers on questionnaire about Bycyklen on 2016-03-10

Summarised key findings for the solution:

- Styr & Ställ should have e-bikes as a complement to the conventional bicycles
- The e-bikes should be recharged automatically in the docking stations
- Limited maximum speed with e-bike
- Adjustable electric assistances
- Helmets as well as antiseptic should be provided at the stations
- Higher cost rates for e-bikes than conventional bicycles
- GPS in all bicycles
- The expansion should be in line with development and traffic planning strategies in Gothenburg
- Important to include Hisingen in Styr & Ställ
- First expand to the extended inner city
- Future development areas can be included
- Possible satellite systems in Angered centrum and Frölunda Torg should be analysed
- Station location and density should be analysed and evaluated according to planning guidelines

6.2 Key figure analysis

This analysis is based on four key figures concerning population and function in order to find suitable areas for a bike-share system. The analysis was conducted in Excel and ArcGIS, to be able to visualise the result in maps.

6.2.1 Description and method for key figure analysis

This method is developed from a method created by Caroline Mattsson and Axel Persson[26] at Trivector Traffic, who also had some input from Trafikkontoret during the process. In the analysis in this thesis all 94 sub-districts in Gothenburg were included. The sub-districts are studied in terms of different types of populations, which are registered population, daytime population, and night-time population. These, together with the area of the sub-districts, were combined to form four different key figures. The statistics in this analysis are from Göteborgsbladet by Stadsledningskontoret (2015:b) and the data varies from the years of 2012 to 2014. The concept “daytime population” is where working people have their workplace and “night-time population” is where working people have their residence. The key figures and their explanations can be found in Table 7.

[26] Caroline Mattsson and Axel Persson, consultants and civil engineers at Trivector Traffic, 2016

Table 7: Key figures used in the analysis and their units, based on the method by Mattsson and Persson[27] and Spacescape (2013)

Key figure	Unit
Population density	Registered population / km^2
Density of daytime population	Daytime population / km^2
Function density	Daytime population * Night-time population / km^2
Degree of self-sufficiency	Daytime population / Night-time population

Population density was analysed to get the full picture of the population base in the area. This key figure represents especially potential users during weekends and evenings. *Density of daytime population* is instead a measure of the working population in the area and is therefore an indication of how many people moving in the area during daytime[27]. *Function density* is a measure of how close it is between housing and workplaces. It shows the need for people to stay/go in or leave the sub-district due to work. The higher *function density* the sub-district has, the livelier it is during both daytime and night (Spacescape, 2013). It also shows that the area is dense and therefore creates a satisfactory user potential and utilisation of a bike-share system[27]. *Degree of self-sufficiency* is a measure of how mixed an area is between housing and workplaces. If there is an equal mix of residence and workplaces the degree of self-sufficiency is one. If the result instead is higher than one, this means that there are more people working in the area than living there. Conversely there are more people living in the area if the degree of self-sufficiency is lower than one.

The method created by Mattsson and Persson[27] does not have any exact numbers on what the key figures should be. Instead it includes a quantitative assessment of the key figures and the Development Strategy[27], as well as a comparison with other bike-share systems. However, approximate values for the key figures were made based on the conditions in Gothenburg, but they are seen as a part of the overall assessment. In Table 8 the figures used in this thesis are presented. The limits for passing are based on the Mattsson and Persson[27] method. An extra range for those that are close to passing is added, which is a deviation of 25 % from the passing limit. This was done since the limits are approximate and in order to find areas that are close to these limits. With extensive developing plans in Gothenburg such areas could fulfil the guidelines within a few years. Even if they do not, there are likely to be areas within the sub-districts that fulfil them today.

[27] Caroline Mattsson and Axel Persson, consultants and civil engineers at Trivector Traffic, 2016

Table 8: Approximate limits for key figures that pass, are close to pass, and that fail the guidelines, based on the method by Mattsson and Persson[28].

Key figure	Fail	Close	Pass
Population density [reg. pop./km²]	> 3,000	3,000 - 3,999	≥ 4,000
Density of daytime population [day pop./km²]	> 3,000	3,000 - 3,999	≥ 4,000
Function density [day pop.*night pop./km²]	> 7.5 million	7.5 – 9.99 million	≥ 10 million
Degree of self-sufficiency [day pop./night pop]	< 0.75 > 6.25	0.75 - 0.79 5.01 - 6.25	0.80 – 5.00

Maps for each key figure are presented in Figures 21 to 24 in Appendix III. These are combined in order to find sub-districts suitable for Styr & Ställ.

A difficulty with doing this analysis on a sub-district level is that the key figure value is applied as an average for the whole area. If the sub-district has very divided land use, e.g. it contains both a dense urban area and a large green area, the key figure value might be misguiding according to Mattsson and Persson[28]. This was compensated in two cases where the land use differentiation was extra clear. In Änggården and Gamlestaden 3/4 and 2/3 of the total area, respectively, were deducted due to low habitation.

6.2.2 Results from key figure analysis

The result shows that all sub-districts inside the current coverage area of Styr & Ställ are within the range of *close* or *pass* in three out of four key figures, see Table 11 in Appendix III. Landala is an exception since it was only in the range of pass or close in two out of four key figures. However, Landala has only one station at a square in the outskirt of the area (JCDecaux Sverige AB, n.d.:c).

When looking at new possible areas for a bike-share system, the conclusion drawn from the current system is that if the sub-district is in the range of *close* or *pass* in three out of four key figures it is seen as a suitable area for a bike-share system, according to this analysis. This could be argued to be a reasonable approach since the current bike-share system is functioning successfully. The additional sub-districts that were found by this approach to be suitable for a bike-share system are presented in Figure 13.

[28] Caroline Mattsson and Axel Persson, consultants and civil engineers at Trivector Traffic, 2016

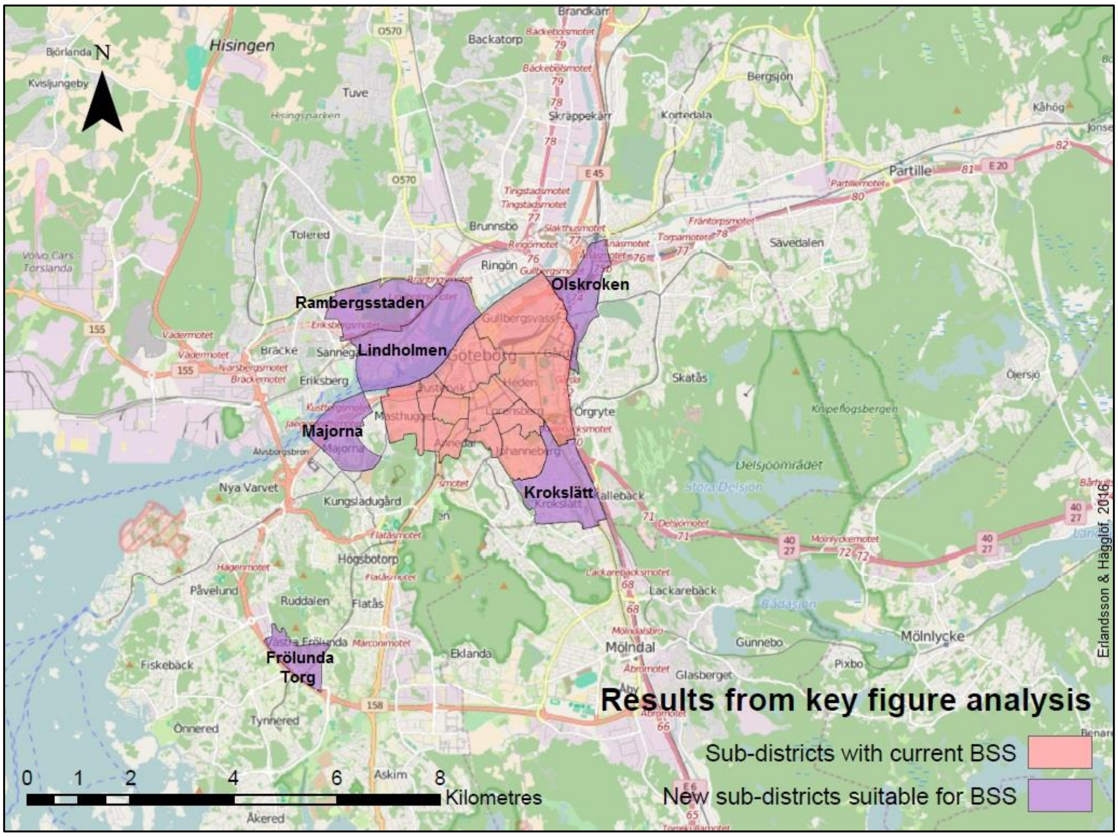

Figure 13: Map over the sub-districts that have bike-share system [pink] and additional sub-districts that are suitable for bike-share system [purple].

The sub-districts that was found to be suitable for a bike-share system are Majorna, Krokslätt, Olskroken, Rambergsstaden, Lindholmen and Frölunda Torg. These sub-district are close to sub-districts with existing bike-share system with the exception of Frölunda Torg which is approximately six kilometres from the city centre.

6.3 Isochronal analysis

The purpose with doing an isochronal analysis was to see the difference between conventional bicycles and e-bikes in a BSS in Gothenburg, in terms of time and distance.

6.3.1 Description and method for isochronal analysis

For the isochronal analysis the bicycle trip planner from Trafiken.nu was used, which is organised by Trafikverket, Trafikkontoret and Västtrafik (Trafiken.nu, 2016:a). The bicycle trip planner is a computer tool and an app with the purpose to help when planning a bicycle trip. The tool is available for trip planning for the region of Västra Götaland, parts of Halland, and Skåne (Trafiken.nu, 2016:b). It is used by entering a starting point *A* and a destination point *B*, to which the program automatically gives a suggested bicycle route. The length and duration of the suggested route are given, as well as an elevation profile. With the bicycle trip planner, it is possible to choose between two travel ways, the fastest way or a trip on as many bicycle roads as possible. The cycling manner is divided into three levels to choose from; *casual*, *normal* and *powerful*. These are based on the power generated in order to get a realistic algorithm, where *casual* is 75 Watt, *normal* is 100 Watt and *powerful* is 125 Watt.[29] A complete table of speed for different inclinations is found in Appendix IV.

The analysis was done to see how far it is possible to go with a conventional bicycle versus an e-bike in a BSS, in the time frame of five, fifteen and thirty minutes. The five-minute-period was chosen as a representation of the shorter trips made in Styr & Ställ. A five-minute-trip with a bicycle from a BSS is estimated to take around 10 minutes to walk (Trafikverket, Boverket, SKL, 2015:a). This is the walking distance that is reasonable for a daily activity (Trafikverket, Boverket, SKL, 2015:b). Longer than that is assumed to be preferred to be done by bicycle. The average usage time of Styr & Ställ is around 15 minutes (JCDecaux Sverige AB, 2015) and the first 30 minutes are today free of charge and therefore most trips are made in this timespan. Furthermore, in the current system the longest travel time between two stations are 28 minutes according to the bicycle trip planner. The current Styr & Ställ station at Gustav Adolfs torg, located close to Brunnsparken, were chosen as the starting point for all trips. Gustav Adolfs torg is located in the city centre and is one of the most frequently used stations (Karlgren, 2014).

The travel way was set to *as many bicycle roads as possible* due to the assumption that Styr & Ställ-users generally are inexperienced bicyclists and therefore may not feel safe cycling in traffic. Another reason is that not many use helmets in the system and therefore do not want to ride along with motorised traffic.

The cycling manner were set as *casual* for conventional bicycle since the bicycles in Styr & Ställ are quite robust and not as easy to cycle fast as a private bicycle. For the e-bike the cycling manner was put as *powerful* to get a representation of what an e-bike can replace, i.e. the extra power comes from the motor instead of the cyclist.

There are three connections from central Gothenburg to the island Hisingen; the two the bridges Götaälvbron and Älvsborgsbron, and the free of charge ferry Älvsnabben between Stenpiren and Lindholmen. There are other ferries as well, but they are part of the public transport system and were therefore not included. The bicycle trip planner does not include Älvsnabben in the bicycle route, though it is possible to take a bicycle on the ferry. Due to this, travel time for routes going with Älvsnabben was investigated separately. The average time for using the connection was calculated to nine minutes, see Table 12 in Appendix IV. Another source of error in the bicycle trip planner is that the elevation of the high bridges Götaälvbron and Älvsborgsbron are not included. To adjust this, one minute was added for each travel with conventional bicycle over these bridges. This was however not done for trips with e-bike, since the elevation was not seen as a factor of influence for this type of bicycle.

The data collected from the bicycle trip planner were compiled in ArcGIS for geographic visualisation and to enable combination with the other analyses.

6.3.2 Results from isochronal analysis

When starting from Gustav Adolfs torg and moving outwards radially for a certain time, the area possible to cover during this time is found. This is done for both conventional

[29] Noel Alldritt, head of division for IT/GIS, Trafikkontoret, City of Gothenburg, telephone conversation, 2016-05-18

bicycle as well as electric bicycle and the results are presented in Figure 14 for five-minutes-trip and in Figure 15 for fifteen-minutes-trip. The area possible to cover with conventional bicycle is presented in blue and the area for electric bicycles in orange. Both figures have the same scale.

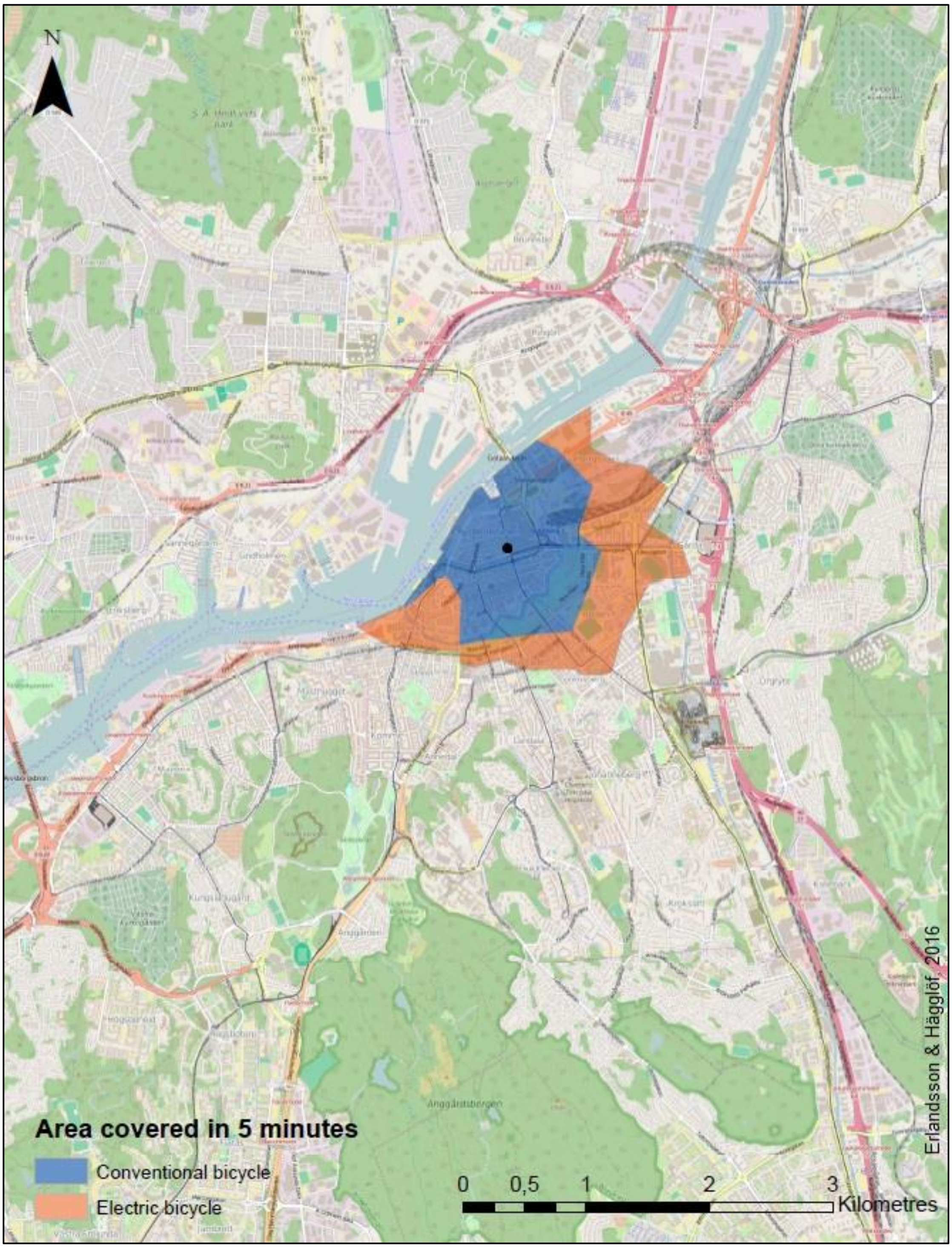

Figure 14: Areas possible to cover by conventional bicycle [blue] and by e-bike [orange] in five minutes.

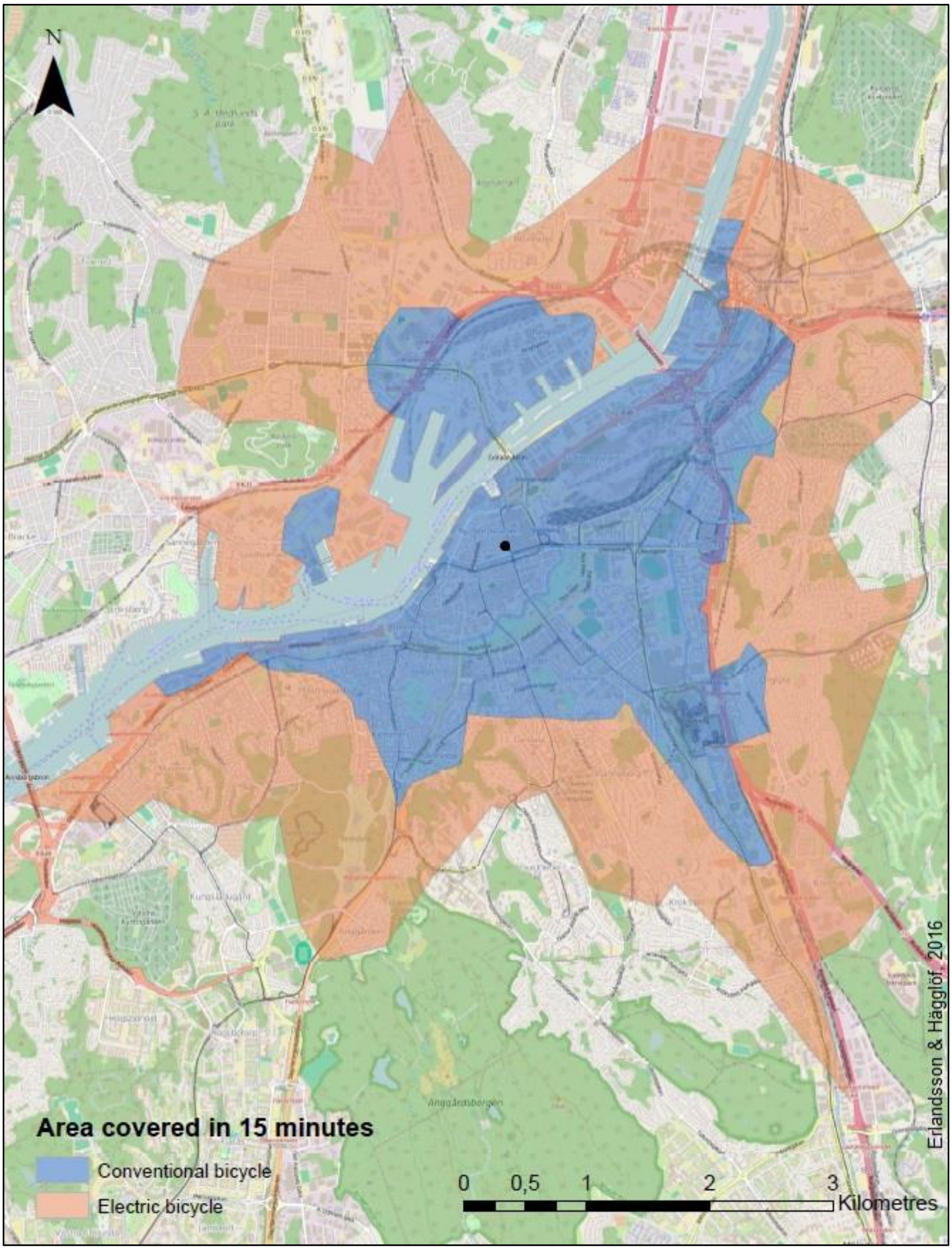

Figure 15: Areas possible to cover by conventional bicycle [blue] and by e-bike [orange] in 15 min.

For five-minutes-trips the difference between conventional and electric bicycles is small, but still distinct. The reach with e-bike is from a couple hundred meters to almost one kilometre in some areas. It is not possible to reach Hisingen with either conventional or electric bicycle in five minutes. For the fifteen-minutes-trips the difference is bigger. With e-bike it is possible to cover larger areas than with conventional bicycle especially the hilly areas, for example Masthugget including large parts of Slottskogen, Medicinareberget, the south parts of Guldheden and large part of

Johanneberg and Lunden. Hisingen can be reached with both conventional and electric bicycle, but a much larger area is covered with the electric ones.

The possible areas to cover in the thirty-minutes-trips for the two types of bicycles are presented separately. For easier comparison the areas covered in 5, 15 and 30 minutes are presented together. The area for conventional bicycle is presented in Figure 16 and electric bicycle is presented in Figure 17, where the scale is the same for both figures.

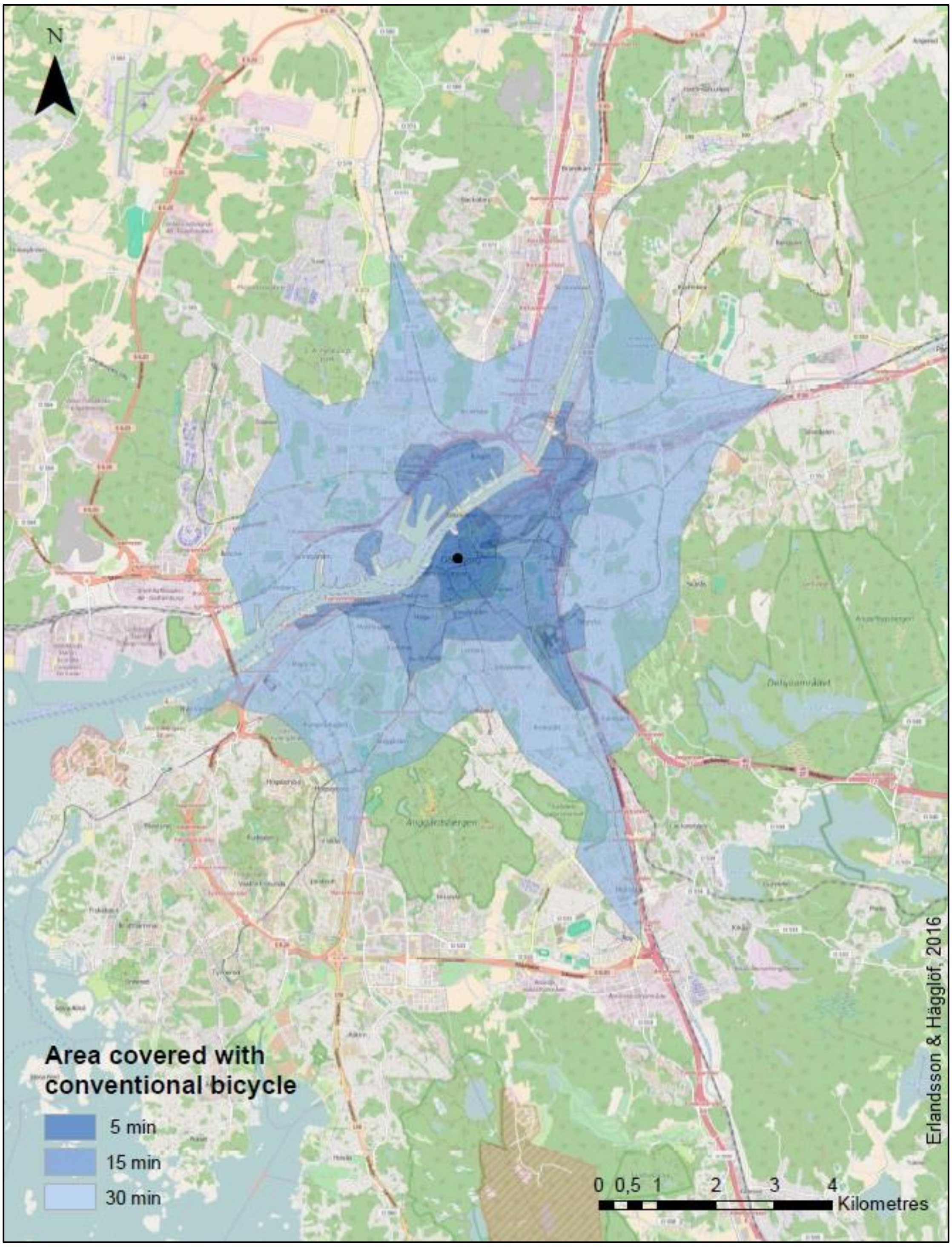

Figure 16: Area covered by conventional bicycle in 5, 15, and 30 min.

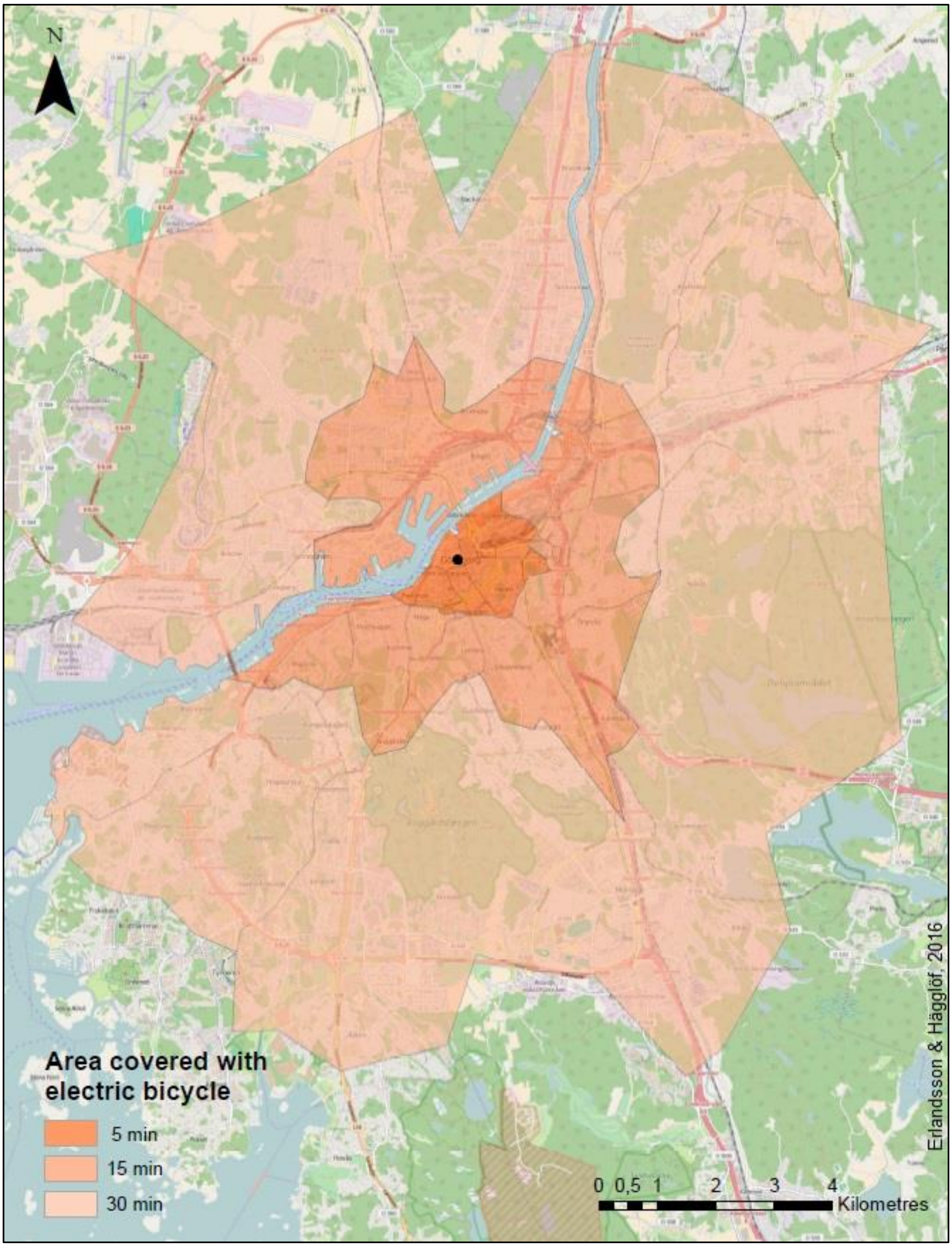

Figure 17: Area covered by e-bike in 5, 15, and 30 min.

When comparing the shape for the covered areas in the two figures, is it possible to see that the shape for the electric bicycles is rounder than for conventional. The area for the conventional has more of a star-shape, with peaks in the areas around large roads and valleys. Both bicycle modes cover smaller areas on the Hisingen side of Göta Älv than on the south side.

6.4 Destination analysis

A destination analysis was carried through in order to find potential locations for additional stations. An important purpose of Styr & Ställ is to complement public transport. Therefore, stations should be placed adjacent to public transport stops and also areas with poor public transport (Mattsson & Emqvist, 2013). The stations should be paced in mixed areas (ITDP, 2013), located close to destinations such as workplaces, car pools, and malls (Mattsson & Emqvist, 2013). Moreover, in order to attract daily users and commuters, stations need to be close to residence as well as schools and other daily activities. Styr & Ställ in Gothenburg has an age limit at 15 years old for usage (JCDecaux Sverige AB, n.d.:d). This means that schools for smaller children are not interesting as station location in Gothenburg, however high schools and universities are.

6.4.1 Description and method for destination analysis

In order to find areas of interest, information from the key figure analysis and the isochronal analysis as well as the studied literature were combined and studied. The Development Planning Strategy was especially taken into consideration for this analysis. Some areas adjacent to the current system that did not pass the criteria in the key figure analysis, were still evaluated in this analysis, since they can have some destinations to consider and within a reasonable travel time. Stations were proposed at destinations located adjacent to such as public transport stops, health care centres, squares, malls, universities, office complexes, recreation areas, parks, tourist attractions and sports fields. Moreover, some residential areas close to local squares or stores were included. Since the stations are meant for a system with both conventional and electric bicycles, topography was not a boundary when locating places for stations. If anything, it was a motive to locate a station at high elevation because transport modes as conventional bicycle and walking are more physically demanding than using an electric bicycle.

Some stations are going to be further apart than others since there is a possibility that there are no clear destination points between them. If that is the case some complementary stations are needed to fulfil the criteria of a station distance being 300-500 metres. However, locating complementary stations is not part of this analysis.

6.4.2 Result from destination analysis

The stations are presented together with the area covered in a fifteen-minute-trip in Figure 18. The specific station locations can be seen in Appendix V. The area reachable within 15 minutes with conventional bicycle is blue and the additional area with electric bicycle is orange. The dark yellow dots are the already existing stations in the current system and the bright yellow dots are the suggested additional stations.

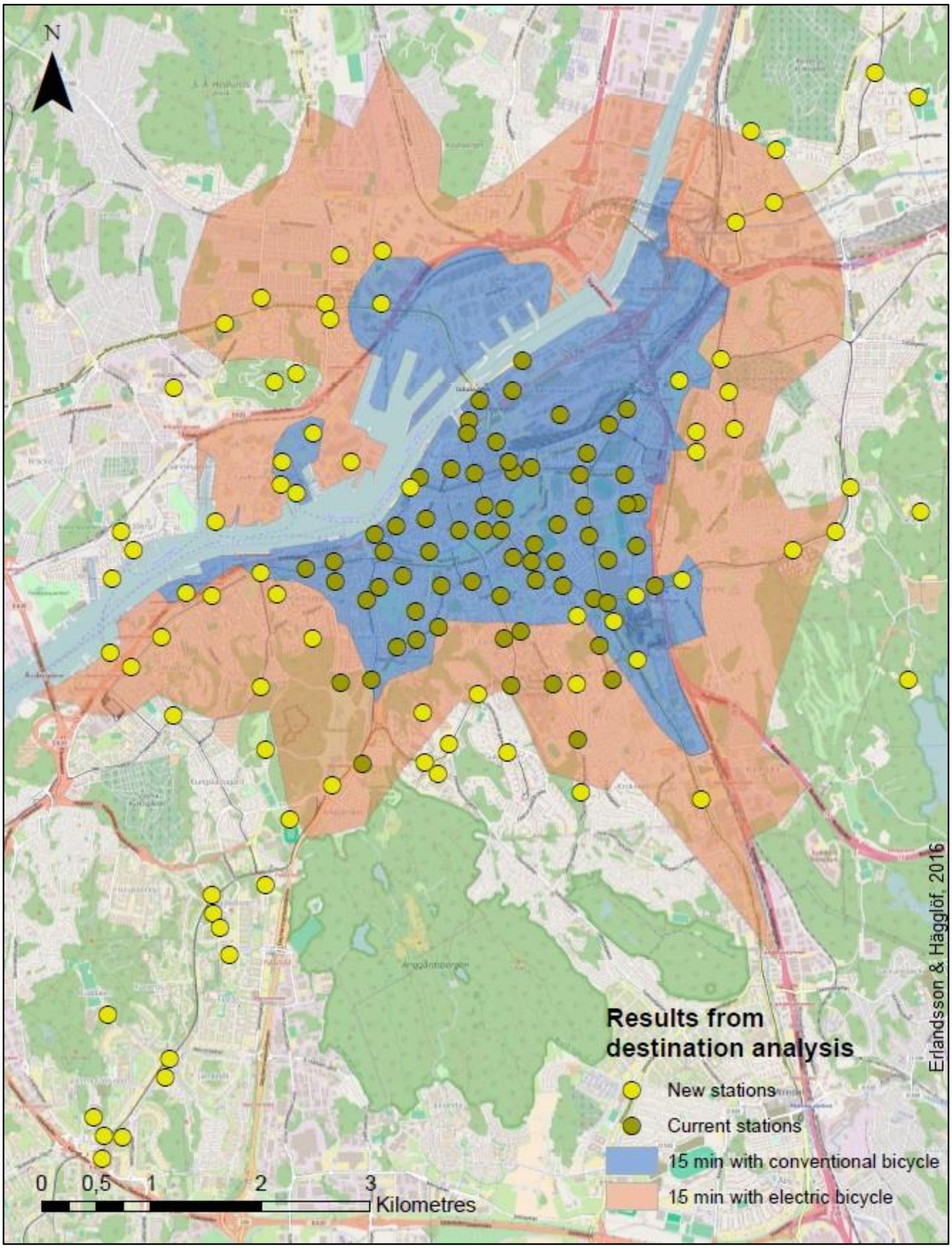

Figure 18: Current and suggested additional stations with the area of 15 min travel time from the isochronal analysis.

In the west of Gothenburg seen in Figure 18 above, stations are proposed in several locations in the district of Majona-Linné, for instance Majorna, the hilly areas Stigberget and Masthugget and some in Kungsladugård in connection with the park Slottskogen. Moreover, stations are suggested to be located at destination points in Medicinareberget, area of the hospital Sahlgrengska and Guldheden, which connect Linnéplatsen and Johanneberg.

More stations are added at destination points in the current system zone of Styr & Ställ, for example one at the new ferry stop and public transport node at Skeppsholmen. Two more stations are suggested at destination points in the hilly parts of Johanneberg. Furthermore, three stations are proposed in the area surrounding Korsvägen at the attractions Liseberg, Universeum and Världskulturmuseet. It is also seen that there is an extension of the coverage area to Krokslätt where a station should be located.

In the east of Gothenburg stations are proposed in Örgryte at tram stops and at the destination points Delsjöbadet and Skatås. Furthermore, the coverage area is extended to Lunden, where stations are suggested for example at the destination points Olskrokstorget and Redbergsplatsen. Also parts of the areas Gamlestaden and Kviberg should be included.

Several stations are suggested at destination points at the south side of Hisingen, at Lindholmen and Eriksberg along the water and then also parts of Rambergsstaden, Kvillebäcken and Backaplan. The popular destination point Ramberget has got a station as well.

It is seen that most current stations are in or close to the area covered in a fifteen-minute-trip with conventional bicycle. Likewise, many of the new stations are inside or close the area covered in a fifteen-minute-trip with electric bicycle and would thereby be easily accessible from the centre. From the key figure analysis, it was found that Frölunda Torg, located southwest of the centre also had qualities for a bike-share system. Therefore, a corridor of stations was added ending at Frölunda Torg. Even though Frölunda Torg is located outside the area covered in a fifteen-minute-trip, it is still possible to reach within 30 minutes by electric bicycle, seen in Figure 17 from the isochronal analysis.

6.5 Concluding result

Gothenburg is growing and will need more extensive sustainable transport solutions, and a developed bike-share system is recommended. It is also found that there are several areas outside the current system zone that would be suitable for a bike-share system and therefore an expanded system zone is suggested as presented later in this section. However, these include several berries as challenging topography and high bridges. In order to make it possible to travel to the centre in a reasonable travel time in the larger system zone and to deal with topographic challenges electric bicycles are recommended to implement in Styr & Ställ. Electric bicycles are also believed to increase the bicycle modal share as they approach other users than the conventional bicycles do, both by a larger geographical area but also older people and people that are physically limited. E-bikes are also suitable on more occasions, when the user does not want to arrive sweaty or when carrying heavy loads. The system should still have conventional bicycles in order to keep satisfied users and to promote conventional bicycling when possible. More technical suggestions are presented in the end of this section.

The key figure analysis in combination with the isochronal analysis gave suitable areas to study more closely in order to find proper destination points for stations, which was done in the destination analysis. When knowing the location of the stations the actual system zone is also found. The system zone is the area that is covered by stations and the outer stations form the outline of the zone. It is important to note that these stations are based on the destination analysis and complementary stations are needed. In some areas the system zone is adjusted in order to make the system zone more continuous. This can be for instance where a major road affects the actual possibility to cycle or where there are opportunities to take a shortcut between two stations. The stations in the current system is in the blue area, seen in Figure 19, and the additional stations form the yellow areas. The hatched areas represent areas with major development plans that will be suitable for a future bike-share system.

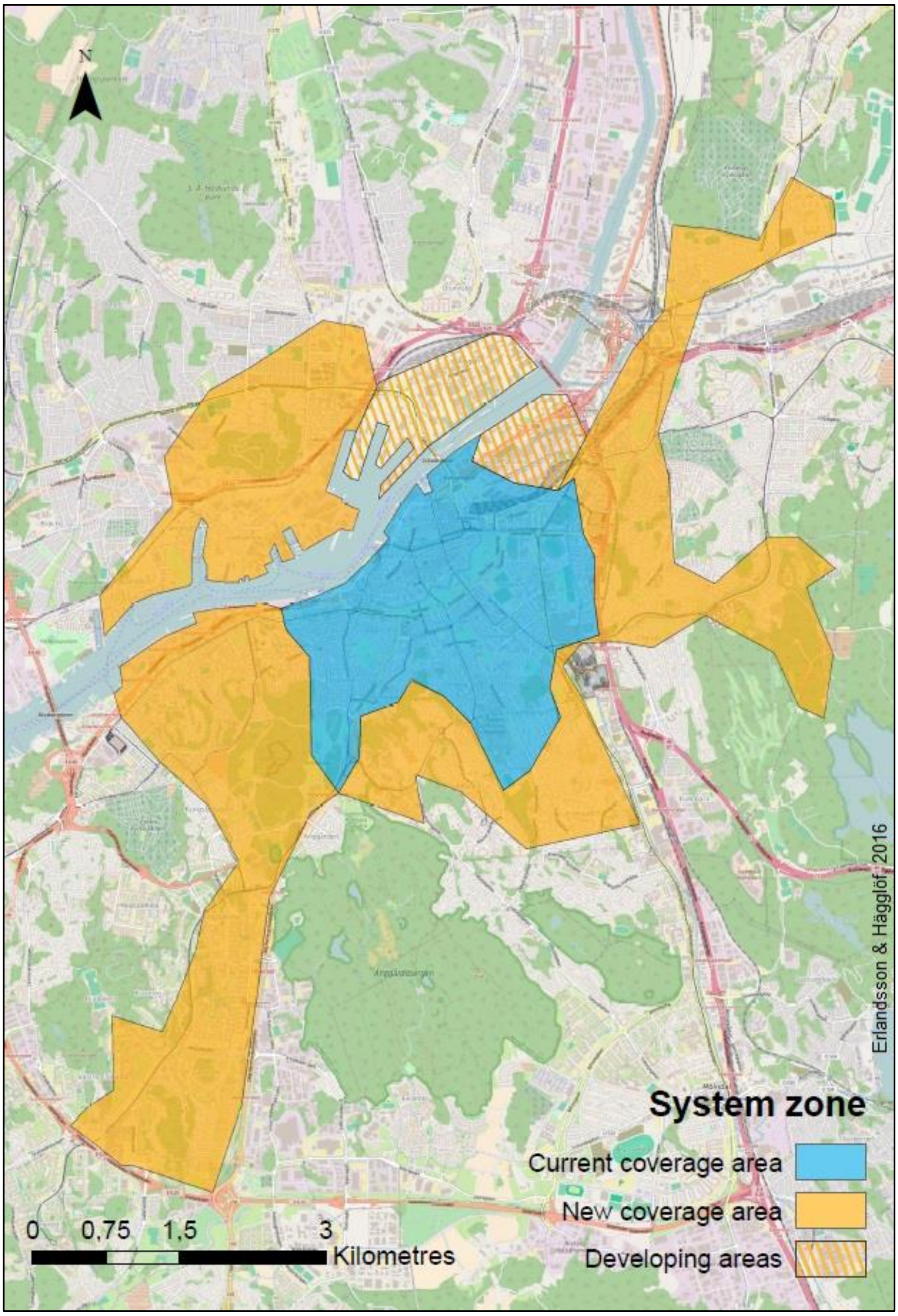

Figure 19: Suggestion of new system zone for Styr & Ställ.

The suggested system zone will reach over to Hisingen where it includes Lindholmen and Eriksberg along the water and then also parts of Rambergsstaden, Kvillebäcken and Backaplan. Around the current zone it is also suggested to expand towards Majorna, Guldheden and Krokslätt as well as Frölunda Torg and thereby include parts of Högsbo. To the east areas as Lunden, Skatås, Olskroken and partly Gamlestaden and Kviberg are included. According to the Development Plan areas as Frihamnen, Ringön and Gullbergsvass are going to develop in the future and are therefore included here as potential expansion areas. The current and suggested areas were calculated from ArcGIS and are presented in Table 9.

Table 9: Approximate areas of the system zones

Zone	Approximate area
Current system zone	7 km^2
Suggested system zone (current + new)	26 km^2
Developing areas	2 km^2

It is important to keep in mind that a system zone is indefinable, since it is technically possible to cycle any path between two stations or as far as wanted. The areas and numbers presented above should therefore be seen as indications of system size. Nevertheless, the suggested system zone is much larger than the current and it is therefore also suggested that the expansion should be gradual.

The different analyses have been consolidated into one suggested system, technically and geographically. The following solutions are suggested for a new bike-share system in Gothenburg:

- The BSS should have both conventional bicycles and e-bikes.
- It should be possible to dock both types of bicycles in all docking stations and the e-bikes should start recharging at docking.
- Limited maximum speed with e-bike.
- Adjustable electric assistances.
- Helmet should be provided at each bicycle as well as antiseptic gel at the stations.
- Higher rates for the e-bikes than the conventional bicycles.
- All bicycles should have GPS.
- The system zone should be expanded in relation to the easier accessibility of e-bikes, radially and with Frölunda corridor additionally.
- The expansion should start from areas close to the current system zone.
- Development areas can be included in the future.

7 Discussion

In this chapter the thesis is discussed. First the general method, delimitations, and limitations are discussed and followed by discussion of the analyses' methods and results. The chapter is finished in a general discussion about the thesis and the proposed solution.

7.1 Discussion of general method, delimitations and limitations

In this thesis a geographical boundary is chosen to the municipality of Gothenburg. However, the municipality of Mölndal is located adjacent to the district Centrum in Gothenburg and could thereby be seen as suitable since the district of Centrum is the main area for Styr & Ställ. The Development Planning Strategy stated that the inner city will grow towards Mölndal, which can mean that Mölndal eventually will become suitable for Styr & Ställ as well. When planning for a future bike-share system Mölndal should be considered and analysed to see if a collaboration between the two municipalities is appropriate.

Another delimitation made is to not include financial factors or other operational agreements. This is however of great importance and is essential for the procurement. Styr & Ställ was launched in 2010, and much has happened within this field since then, for example there are more actors and companies offering bike-share systems and especially electric bike-share systems have become more established.

This thesis does not consider the current contract time nor timespans for possible development. It is based on current conditions and the longer it takes before this possible development is considered the less up-to-date it will become. More areas are expected to be suitable as the city develops and grows.

A major limitation for this thesis is the lack of available literature on fully electric bike-share systems and bike-share systems with combination of conventional and electric bicycles, as well as scientific studies in bike-share systems in Sweden and Gothenburg. Therefore, it has been necessary to do interviews and case studies on other cities with bike-share systems with electric bicycles. Five cites were studied, whereof two had the combination of electric and conventional bicycles. The case study could be bigger and include more cities so that more perspective could be reviewed and the result be more balanced. There was also a limitation of how many questions that could be included in the questionnaires and interviews for this study. The delimitation to only look at cities in Europe seems reasonable since these cities' conditions are more likely to be similar to Gothenburg than for instance Chinese or American cities.

7.2 Discussion of the key-figure analysis

The key figure analysis is based on the working population and thereby does not include students, unemployed, or older people. Unemployed and older people might not have a major effect on the result since they generally are more even spread over the city, but students are often living in a few areas in the cities. There are large student quarters in some parts of Gothenburg, which affects the night-time population. Daytime population is also misleading since the large universities accommodate many students during the day. Examples of areas where this might occur are Johanneberg, Krokslätt, Lindholmen, Medicinareberget and Kviberg. Furthermore, the key figure analysis only considers day and night population and does not take into account people that visit a specific sub-district, for example for shopping, cinemas, restaurants, museum, and cafés. The guideline values that should be fulfilled in this analysis are based on values of the current system's sub-districts. However, since the current system is located in the city centre where these kinds of activities are densely located, only day- and night time population might be misleading for how many people that actually have access and uses the system. Areas located outside the city centre might therefore pass the guidelines without actually being suitable for a BSS. Although, people that visits the city centre without either working or living there might not be a target group for Styr & Ställ since they might be more of casual users.

Further, this analysis is based on the sub-districts in Gothenburg. A sub-district is in this context a quite large area and can have very different character in different parts. Some sub-districts that had very distinguished areas were adjusted, but there are likely other sub-districts that would give another outcome if the studied area were to be smaller. In order to get a more extensive analysis, other key-figures should be included which could consider for instance distance to service and work, as well as infrastructure and bicycle network in different areas. The sub-district areas should also be smaller, but not too small to avoid every area being homogeneous. A destination analysis would still be a good complement though.

It is important to notice that the statistical data for population are from different years and the relation between them might deviate from the actual. The data is also from a couple of years ago and might have changed since then.

In the analysis the key figure limits were taken from the method by Mattson and Persson[30]. Even though there an extra limit for close values was added it still has their values as starting point. For instance, the limit for *degree of self-sufficiency* could be questioned. In the city centre this number amounted to 14 but it is known that the bicycles in this area are very frequently used. Perhaps the limit should be increased in order to include areas with large daytime population because nevertheless it is during the day the bicycles primarily are used. It is important though, to consider what kind of area it is and what business there are. An industrial area would probably not have the same movement and activity during the day as an area with mixed businesses.

The analysis also showed that six sub-districts fulfil only two of the key figures where Kvillebäcken was one of them, see Table 11 in Appendix III. In the last couple of years there has been a big development project in Kvillebäcken, which includes new offices, shops and residence. Since the data for this analysis is from 2012-2014 it is possible that Kvillebäcken today would be suitable for a BSS, if more updated date would be used.

7.3 Discussion of the isochronal analysis

For the isochronal analysis a bicycle trip planner is used to compare cycling with conventional and electric bicycles. This bicycle trip planner is not adapted for electric bicycles or Styr & Ställ bicycles. However, it has different cycling manners and was

[30] Caroline Mattsson and Axel Persson, consultants and civil engineers at Trivector Traffic, 2016

therefore seen as reasonable tool. It is an estimation what manner correspond to an e-bike and a Styr & Ställ bicycle, respectively. The fact that *powerful* corresponds to 125 Watt is considered reasonable to use since it has a maximum speed at 25 km/h, just as most e-bikes do. It is important to keep in mind that the areas presented are for visualisation and do not necessarily show the exact travel-time for a certain area since there are multiple factors affecting actual travel-time. For instance, stopping-time at intersections and traffic lights is not taken into account in the bicycle trip planner, nor in this analysis.

Gustav Adolfs torg is chosen as the starting point for all measures, since it is a central and very frequently used station. However, if another station were to be chosen the results could have been very different. For example, the station at Valand is the most centrally located station in the system today and this might have been a better point to base the analysis if no expansion was in question. For this analysis Gustav Adolfs torg represent a centrally located place for inhabitants and visitors and are therefore more accurate.

The first 30 minutes is for free in Styr & Ställ, which is the same as for many other bike-share systems with conventional bicycles. Today it is theoretically possible to cycle through the whole system under 30 min. If the system is to expand it would not be possible anymore. However, not many people are using the system for that long, since the average using time is 15 minutes. The 30-minute-trip comparison is more an indication on how far it is possible to go during the free period and not a deciding system zone. As mentioned before 15 minutes is the average using time and it is therefore the 15-minute-trip comparison is made. Even so, the 15 minute’s use is the average of today. If a longer average travel-time is desired it might be better to design the system based on a longer usage time and thereby use a higher number than 15 for this kind of analysis.

The area covered on Hisingen when going with the ferry Älvsnabben is dependent on the waiting time and for this analysis the average waiting time is used. This means that the covered area could both be smaller and bigger than what the results show. The greatest difference would be for the conventional bicycles for the 15 minutes’ trip, since if the waiting time is longer than average it might not be possible to even make it over to Hisingen.

As described earlier more connections over Göta Älv are planned. These are believed to contribute to increased movement over the river for all transport modes. Thereby the coverage area on Hisingen is expected to increase or at least have reduces travel time.

In summary, the resulted area is dependent on the choice of starting point, and the area of 15 minutes can be questioned. It is therefore more relevant to view the results as an indication of difference in travel-time between the two types of bicycles as well as an indication of how much of Hisingen that is easily accessible with bicycle.

The cuspidal behaviour of the area covered with conventional bicycle is likely to be due to that conventional cyclists are more dependent on flat and coherent bicycle roads than e-bike users. The points which form the areas have been selected radially from Gustav Adolfs torg. The analysis has been made by hand and if a software were to be used it is possible that the result would have turned out differently.

7.4 Discussion of the destination analysis

The destination analysis is an overview analysis, where a schematic suggestion of how stations could be placed are presented. The locations of the stations are based on the current conditions in the areas that were found suitable in the key figure and isochronal analysis. It is planned for extensional establishments in the future and along with this also new areas and destinations will come. Therefore, it is likely that destinations more relevant than some of the suggested will appear. Moreover, sources of errors in the earlier analysis will affect the result for the destination analysis as well.

The destination points are chosen according to the studied literature. However, it is still possible that the destination points are chosen in a subjective manner and perhaps inconsequently in the different areas. Therefore, it is essential to combine this kind of analysis with other analyses in order to evaluate the result. For instance, an investigation of how many people frequent a certain station area.

From the results it is seen that complementary stations are needed in order to fulfil the criteria of 300-500 metres. It could be argued that an even smaller distance is preferable, at least in the more central parts. Additional stations within the current system zone are not considered in this thesis and an investigation for a possible densification of stations are suggested. If the stations are located outside the centre, it can be more accepted to have longer distance between stations as long as there are more stations clustered, for instance as it is in the Frölunda corridor. It is also possible to deviate from the recommended distance if there are no proper stops between two stations and only one way to choose. This is why the station at the lake Delsjön in east is quite far from the closest station. However, there is a possibility that stations in the periphery of the coverage area is going to be under high demand on certain times of the day and cause a high need of redistribution of bicycles. For example, there is a possibility that the stations at Skatås and Ramberget would be full during weekends and evenings, but empty during weekdays.

7.5 General discussion of literature review and proposal

The proposal is to expand Styr & Ställ geographically and implement electric bicycles as a complement to the conventional bicycles in order to tackle the issue with topography barriers. However, it might not solve the issues with unevenly distributed bicycles completely. People will probably be more willing to cycle uphill with an electric bicycle, but still use the conventional for going downhill. This could result in an uneven distribution between the two bicycles types in the system and could especially be an issue if there is different pricing for the two bicycle types. One solution to solve this could be by not charging trips with e-bike from stations that are located on a hill. Another solution, which could be in combination with the previous one, is that the operator do not, to any great extent, redistribute e-bikes to the stations on higher altitude. Moreover, stations in the outskirt of the system zone will always have issues with uneven distribution of bicycles since they are either cycled to or from, but rarely are passed. Thereby it might not be possible to have the same criteria fulfilled for availability of bicycles and spacing of stations in the outskirts of the system zone.

More cyclists are what is strived for with an expanded Styr & Ställ. This is good from several perspectives, although there might be some effects that are not as positive as well. It is important that the bicycle network is safe, suitable for different types of cyclists and meet their different needs of speed and space. More cyclists require more infrastructure and it can be questioned whether the infrastructure today in Gothenburg is suitable for the great amount of cyclists that is strived for. It could be seen as essential that the bicycle infrastructure should develop together with the expansion of Styr & Ställ, by separation from other transport modes and create double lanes. Furthermore, it is necessary to expand Styr & Ställ successive along with the development of the city and it is central to implement the system from the beginning of new establishments, before the citizens set their travel habits.

A modal change to bicycle is beneficial when the former transport mode is motorised. Since it is not possible to prohibit anybody from using the Styr & Ställ, there might be a risk that people who otherwise would walk or use a conventional bicycle choose an e-bike because it is easier. Therefore, higher pricing for electric bicycle could be one way to have people staying with conventional bicycle. However, there might still be people who prioritise indolence over cost.

More car users are expected to be attracted by an electric bike-share system than to the current system, but it will still be difficult to get them to change travel mode and travel habits. There might be a need for other incentives or policies for a change, for example congestion charges, cost for parking or availability of parking spaces could be regulated. Parts of parking lots in the city could instead be used for Styr & Ställ stations and/or bicycle parking to promote cycling even more. There should also be campaigns when the new expanded system with electric bicycles are introduced in order to target new users, for example car users, people in the new expansion areas, or people that generally do not use bicycles.

One risk of targeting people that generally do not use bicycles is that it can result in more inexperienced cyclists in the traffic system. These people might cycle more slowly than others, which will slow down faster cyclists. There could be a risk of making the cycle network less attractive for some users. Moreover, there will probably be many people using an electric bicycle for the first time and might cycle in a higher speed than they can manage, which could put themselves and other road users at risk. Even if conflicts and issues can be seen as a concern it is important to keep in mind that Gothenburg has already implemented a bike-share system before, that also entailed new cyclists, with good outcome. However, events where people can try and learn how to handle the electric bicycles would be preferable.

In the proposed solution it is suggested to take up the service of providing helmets for the users of Styr & Ställ, with the difference of having the helmets locked to the bicycles instead of distribution at offices. It is possible that there will be a law on helmets for adult bicyclist in the future. Encouragement of using helmets seems to be important, but nothing says that people will start using them. Especially when the helmets have not been provided before. But this could also attract new users who did not want to use the system before due to the lack of helmets.

In order for bike-share systems to be seen as a completely sustainable transport mode it is important that the electricity for recharging the bicycles is green and the materials for the systems are sustainably produced. People today are more aware of this and expect the system to be sustainable throughout.

8 Conclusion and Further Studies

The thesis shows that electric bicycles in the bike-share system Styr & Ställ in Gothenburg would be beneficial even though the current system design does not require them. E-bikes are recommended if the system were to expand, due to the topography barriers outside the current system zone. Electric bicycles enable cycling in hilly conditions and longer trips. Electric bicycles can also open up Styr & Ställ to new groups in the society, for example older people, people who cannot afford an own e-bike and people who do not want to be sweaty when doing errands. Everything point to the fact that Gothenburg will grow a lot in the next 20 years, the centre is going to expand and become denser with a higher mix of housing and workplaces. Therefore, it is natural that Styr & Ställ should grow as well. This is also in-line with requests from the public and the increased need for sustainable transport modes in the city. The analyses show that there are several areas close to the current system that are suitable for a bike-share system today already. There are also developing areas that probably will be suitable for the system in the future. However, it is recommended that Styr & Ställ expands gradually, due to the large size of the suggested expansion.

For this thesis some delimitations have been made that should be considered in further studies in order to get a more thorough analysis and result. Cost for the system as well as benefits that is convertible to monetary value need to be evaluated in order to perform a cost-benefit analysis. This is needed in order to find a suitable solution and design for a new bike-share system.

The municipality of Gothenburg is set as the geographic boundary of this thesis. However, Mölndal should also be included in the analysis of a potential expansion of the system due to its proximity to Gothenburg.

Even though there have been some technical suggestions for the system, different providers and their specific designs should be evaluated in order to find a suitable solution. Demands that are needed or desired should be considered for a procurement.

This study is more of a strategic study. Therefore, more detailed analyses are needed for the location of stations and the feasibility of these locations, for example electricity connection, closeness to bicycle roads, ownership of the land and local plans. The amount of bicycles as well as the proportion of each bicycle type is not considered here but also need to be investigated. Furthermore, complementary stations are needed in order to meet the guidelines for station density. The specifics for the technical and infrastructural solutions need to be studied as well.

The analysis performed in this thesis could benefit from a more extensive demographic investigation to find what people there are in certain areas regarding age, travel habits, who the daily commuters are, and people that actually would use an expanded electric bike-share system.

The expansion of Styr & Ställ is suggested to be developed gradually, and therefore it is necessary to analyse and prioritise how this should be done in detail.

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Appendix I

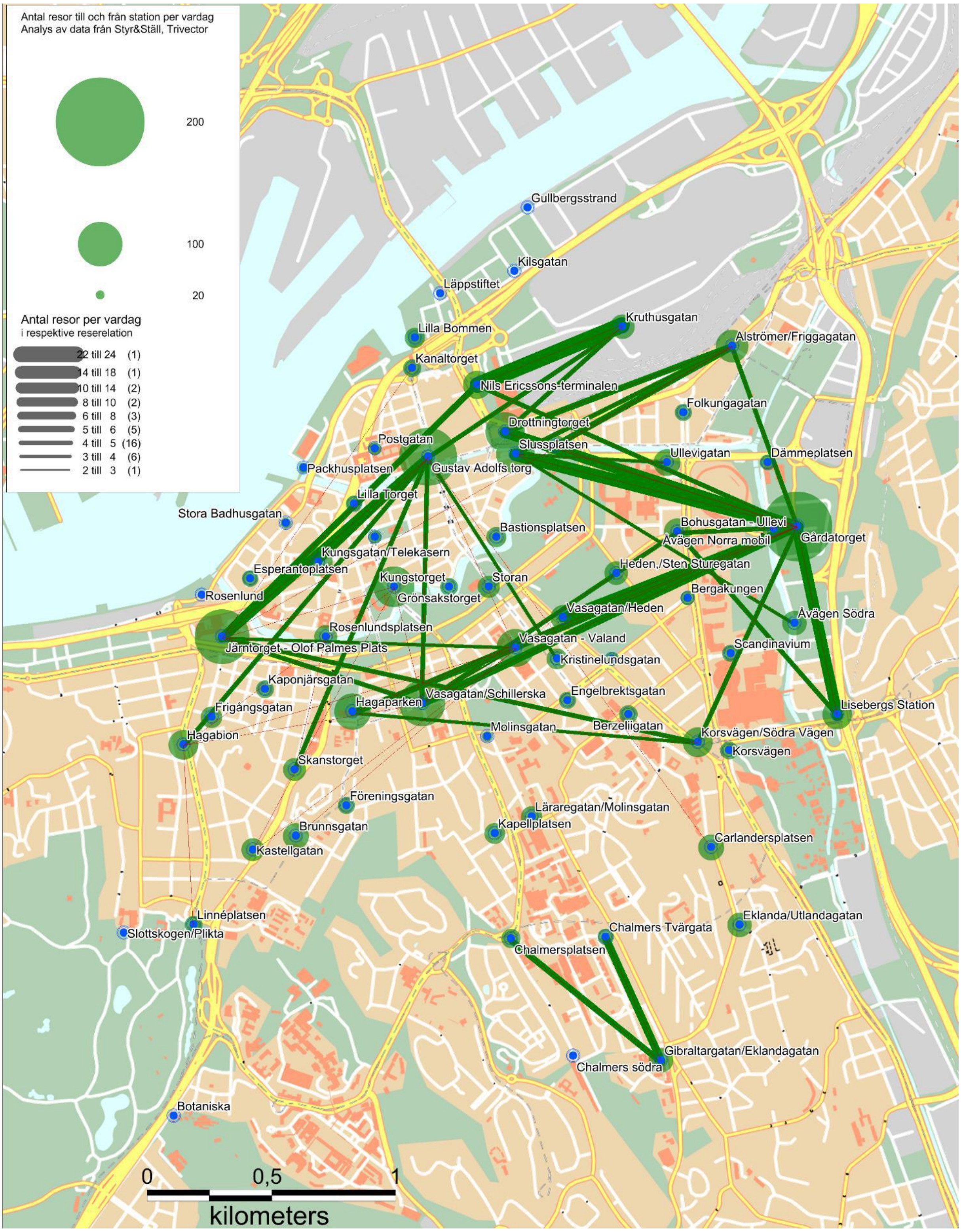

Figure 20: Frequent travels with bicycles from Styr & Ställ (Karlgren, 2014).

Appendix II

Table 10: Subscribers in Styr & Ställ 2015

Age bracket	Men	Women	Total sum
14 - 17 years old	96	50	146
18 - 25 years old	1951	1408	3359
26 - 35 years old	3052	1686	4738
36 - 45 years old	1421	836	2257
46 - 55 years old	977	877	1854
56 - 75 years old	719	416	1135
More than 75 years old	9	5	14
NA	6	3	9
Total sum	8231	5281	13512

Appendix III – Key Figure Analysis

Table 11: Sub-districts that are in the range of close and pass in two, three, or four key figures out of four. The first value represents pass and the second close.

	Number of fulfilled key figures		
Sub-district	**4**	**3**	**2**
Kungsladugård			1+1
Majorna	4+0		
Stigberget			2+0
Masthugget	4+0		
Haga	4+0		
Annedal	4+0		
Olivedal	3+1		
Krokslätt	3+1		
Johanneberg	4+0		
Landala			1+1
Lorensberg		3+0	
Vasastaden	4+0		
Inom Vallgraven		1+2	
Stampen	3+1		
Heden	3+1		
Olskroken	3+1		
Överås			0+2
Lunden			2+0
Kvillebäcken			1+1
Rambergsstaden	3+1		
Lindholmen		2+1	
Tofta			1+1
Frölunda Torg	3+1		

Sub-districts in current system zone	(orange)
Additional sub-districts	(purple)

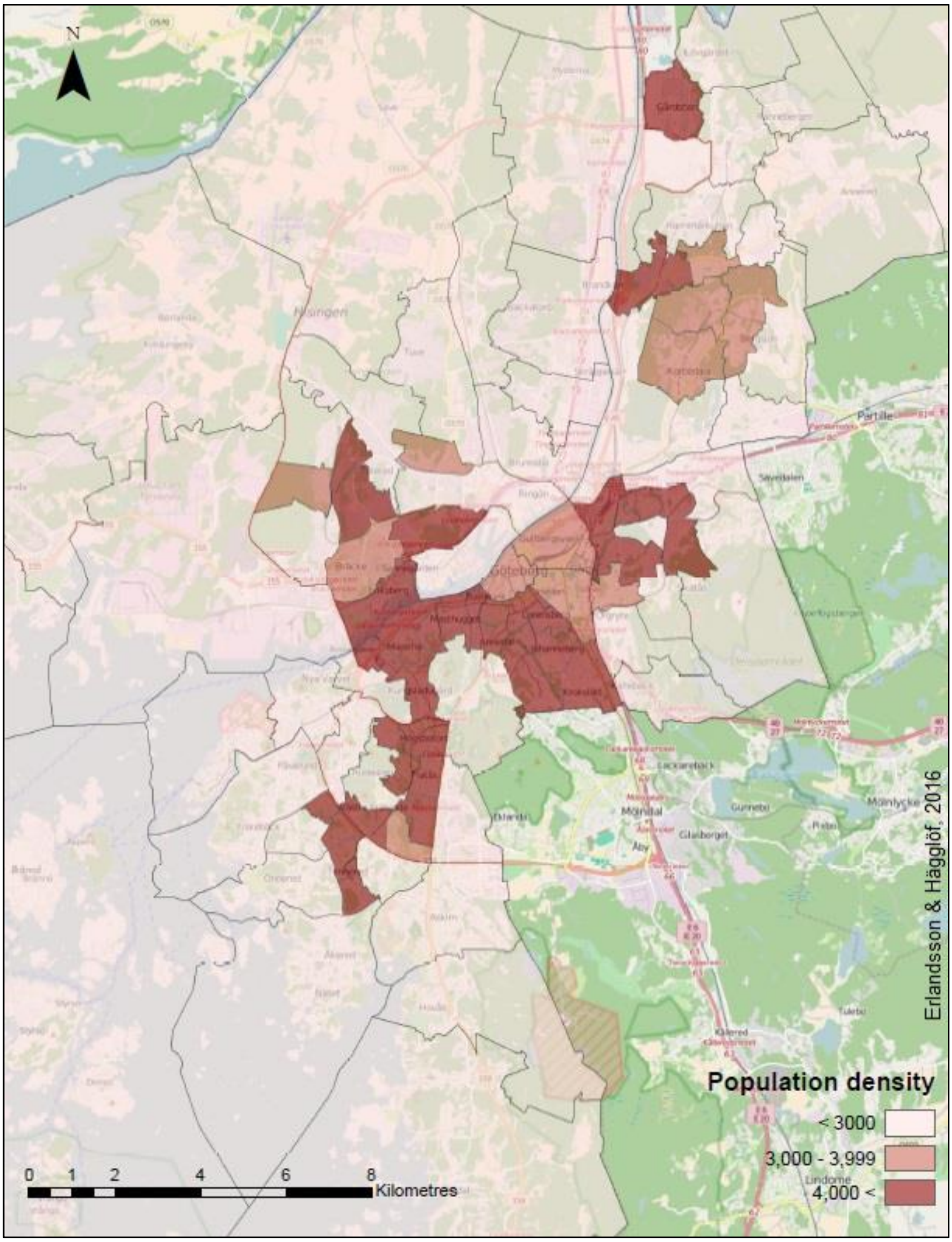

Figure 21: Population density, Registered population / km^2

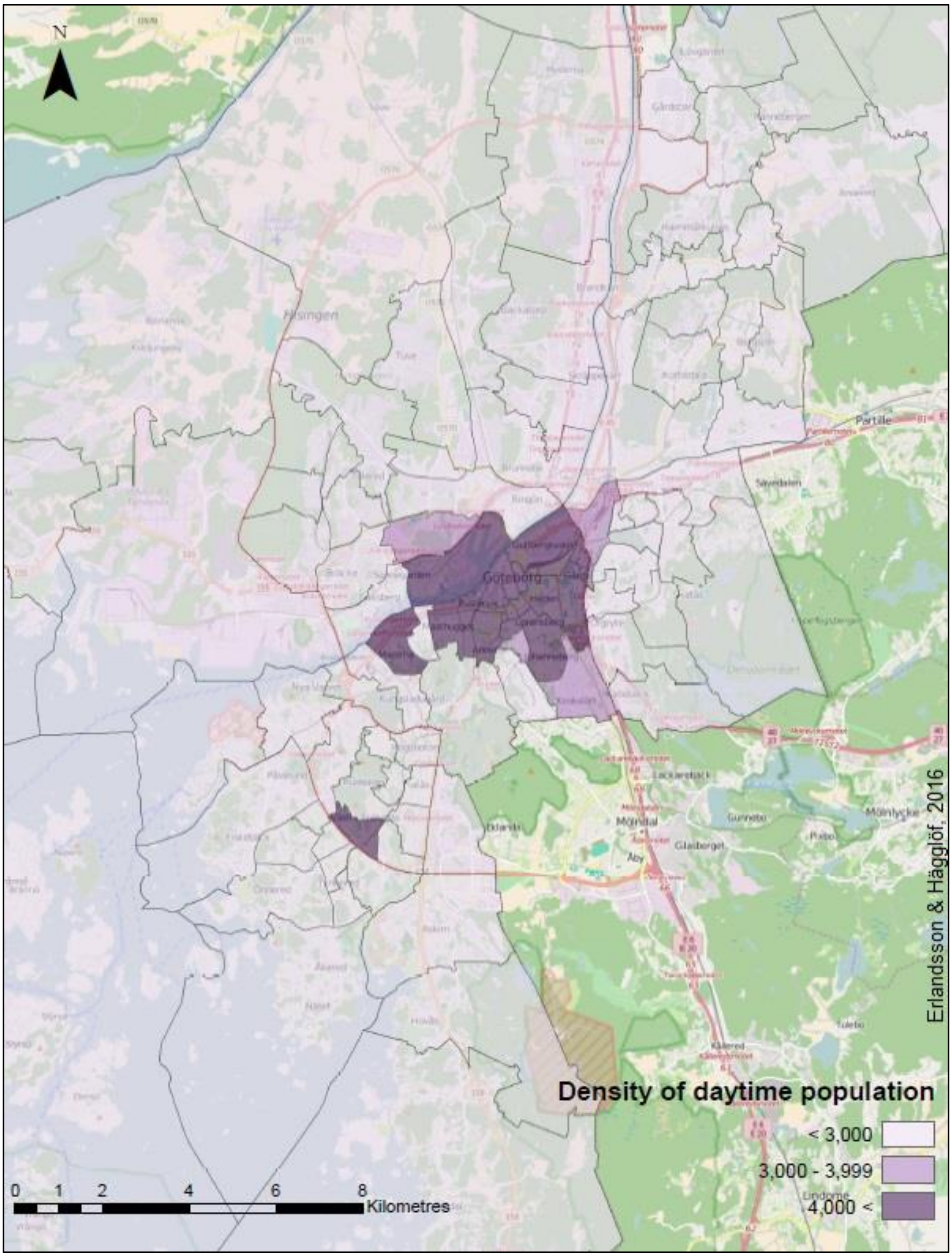

Figure 22: Density of daytime population, Daytime population / km²

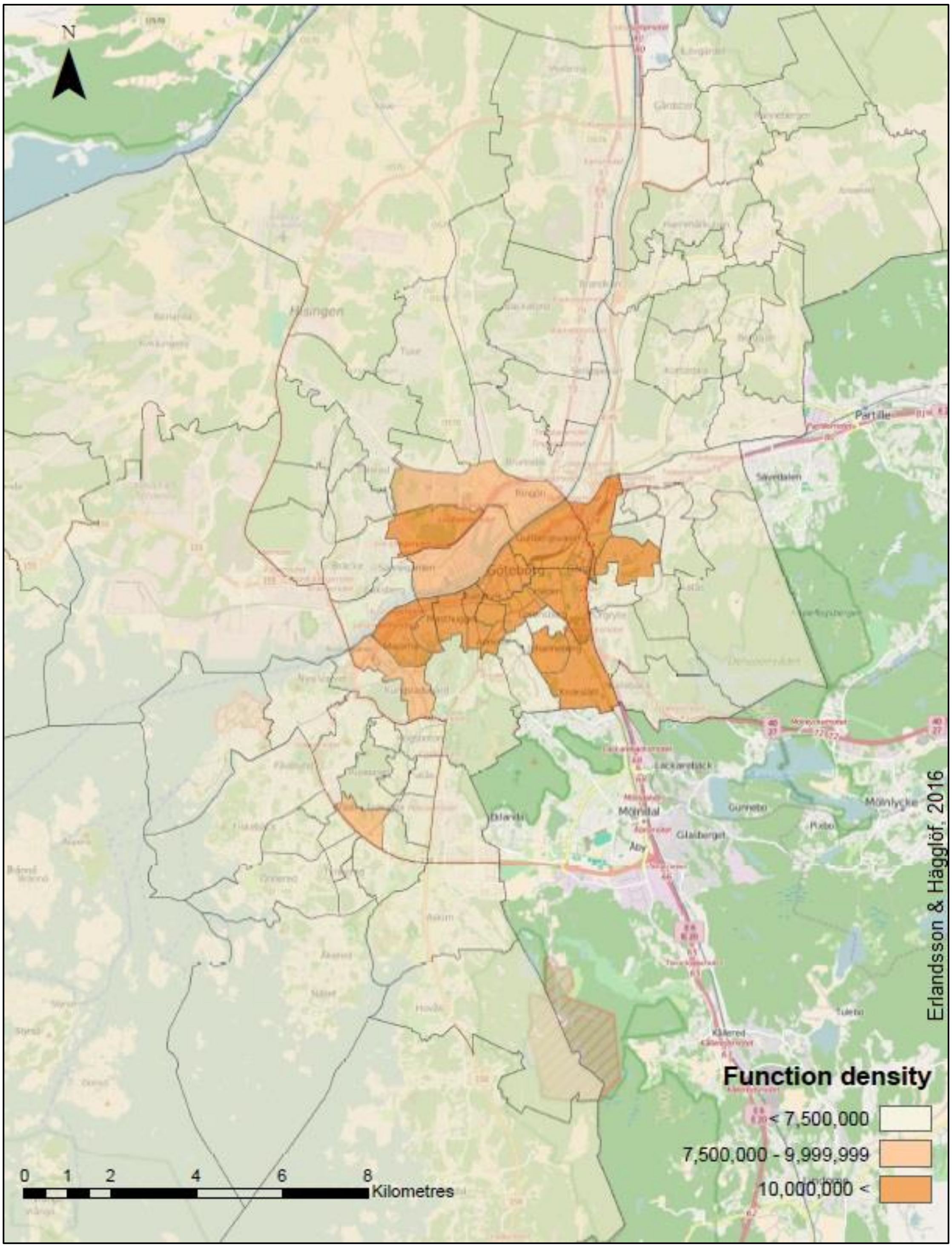

*Figure 23: Function density, Daytime population * Night-time population / km^2*

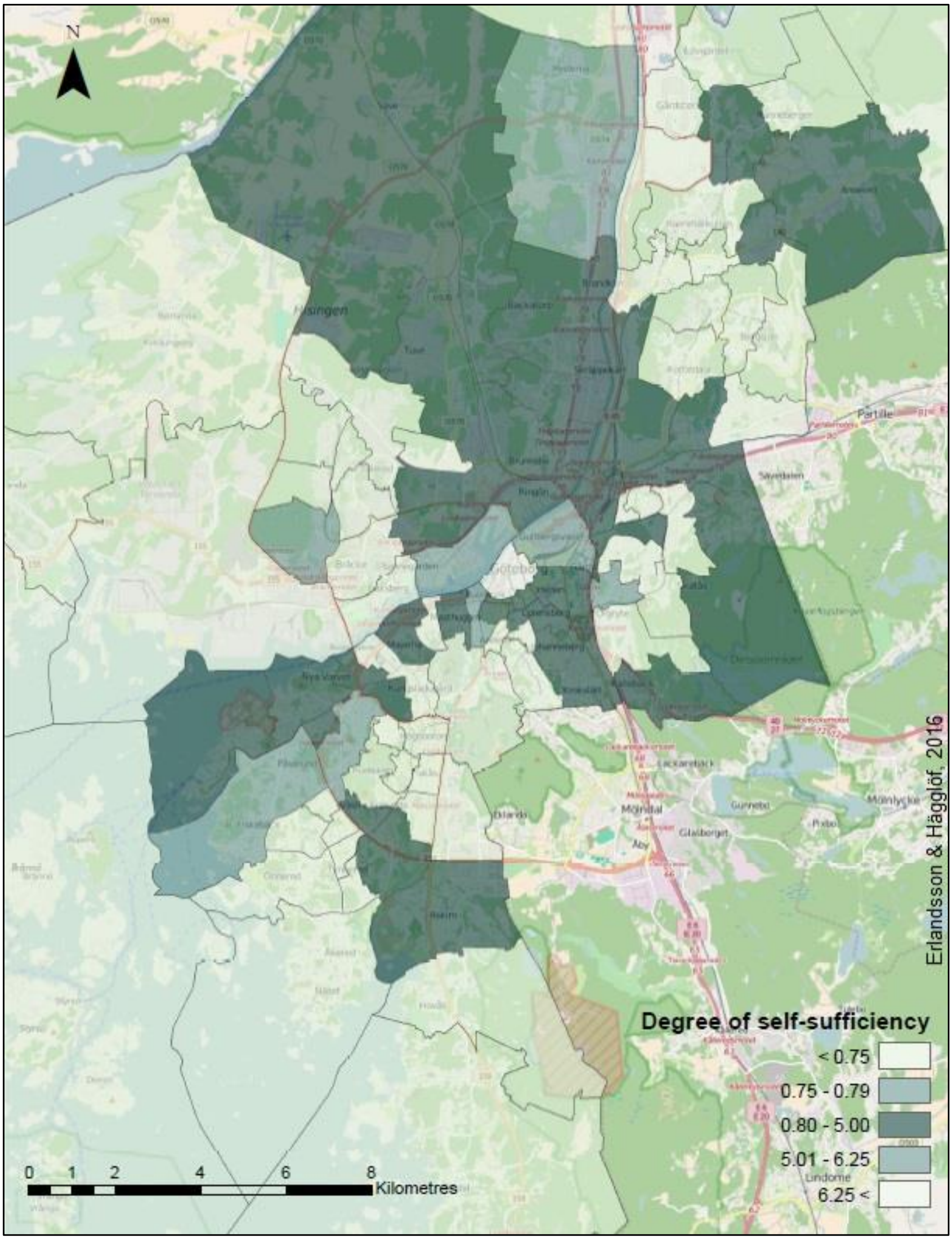

Figure 24: Degree of self-sufficiency, Daytime population / Night-time population

Appendix IV – Isochronal Analysis

Table 12: Travel time for the Älvsnabben connection. Based on travel time from (Västtrafik, 2016).

Time	Minutes
Travel time	5 min
Departure frequency	Every 7 or 8 min
Average waiting time	4 min (≈ 3.75 min)
Average total time	9 min

Table 13: Speed [km/h] for different inclinations [%] and power [W] based on data from Triona.

Watt	0%	1%	2%	3%	4%	5%	6%
20	9.1	4.7	3.0	2.2	1.7	1.4	1.2
30	12.0	6.8	4.5	3.3	2.6	2.2	1.8
40	14.3	8.7	5.9	4.4	3.5	2.9	2.5
50	16.1	10.5	7.3	5.4	4.3	3.6	3.1
75	19.9	14.3	10.5	8.0	6.4	5.4	4.6
100	22.7	17.4	13.3	10.4	8.5	7.1	6.1
150	27.1	22.3	18.1	14.8	12.3	10.4	9.0
200	30.6	26.1	22.0	18.5	15.7	13.5	11.8
250	33.5	29.2	25.3	21.8	18.9	16.4	14.4
350	38.1	34.3	30.7	27.3	24.2	21.6	19.3
400	40.0	36.5	32.9	29.6	26.6	23.9	21.5
450	40.0	38.4	35.0	31.8	28.7	26.0	23.6

Watt	7%	8%	9%	10%	12%	15%	20%
20	1.1	0.9	0.9	0.8	0.7	0.5	0.4
30	1.6	1.4	1.3	1.2	1.0	0.8	0.6
40	2.1	1.9	1.7	1.5	1.3	1.1	0.8
50	2.7	2.4	2.1	1.9	1.6	1.3	1.0
75	4.0	3.5	3.2	2.9	2.4	2.0	1.5
100	5.3	4.7	4.2	3.9	3.3	2.7	2.0
150	7.9	7.0	6.3	5.8	4.9	4.0	3.0
200	10.4	9.3	8.4	7.6	6.5	5.3	4.1
250	12.8	11.5	10.4	9.5	8.1	6.6	5.1
350	17.3	15.7	14.3	13.1	11.2	9.2	7.1
400	19.4	17.6	16.1	14.8	12.7	10.5	8.1
450	21.4	19.5	17.9	16.5	14.2	11.7	9.1

Table 14: Speed for 125 Watt from interpolation between 100 Watt and 150 Watt.

Inclination [%]:	0	1	2	3	4	5	6	7	8	9	10	12	15	20
Speed [km/h]:	24.9	19.9	15.7	12.6	10.4	8.8	7.6	6.6	5.9	5.3	4.9	4.1	3.4	2.5

Appendix V – Destination Analysis

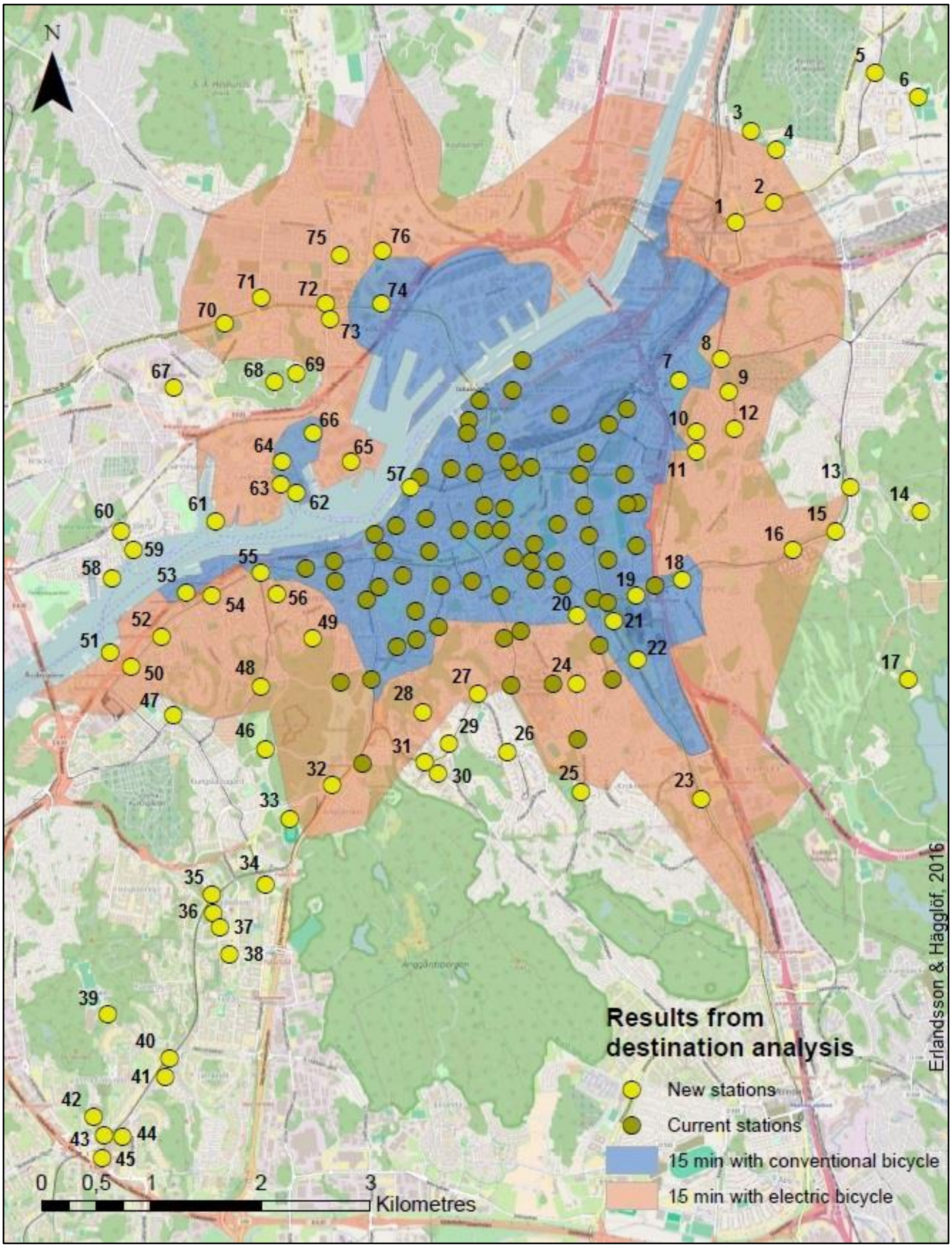

Figure 25: Map from the destination analysis with station numbers. See Tables 15 and 16 for station location and comments.

Table 15: Explanations of abbreviations used in Table 16.

Abbreviations	Explanation
PT	Public transport
SC	Sport centre/area
RA	Recreation area/tourist attraction/culture
SQ	Square
S	Shopping area/store
U	University
H	Hospital
W	Workplaces

Table 16: Station numbers and their locations and comments.

Station no.	Station location	Comment
1	Gamlestadstorget	PT
2	SKF	PT
3	Gamlestadshallen	SC
4	Gamlestadsvallen	SC
5	Beväringsgatan	PT
6	Krutvägen	SC
7	Olskrokstorget	PT/SQ
8	Redbergsplatsen	PT
9	Danska vägen	PT/S
10	Snikens Kulle	RA
11	Överåsvallen	SC/PT/S
12	Pärlstickaregatan	PT
13	Welandergatan	PT
14	Skatås	RC
15	Töpelsgatan	PT
16	Bögatan	PT
17	Delsjöbadet	RC
18	S:t Sigfridsplan	PT
19	Liseberg main entrance	RA
20	Näckrosdammen	U/RA
21	Universeum/Världskulturmuseet	RA
22	Liseberg South entrance	RA
23	Mölndalsvägen/Varbergsgatan	S
24	Spaldingsgatan	PT
25	Mossen	PT/SC
26	Dr Fries Torg	S/PT
27	Wavrinskys plats	PT
28	Medicinareberget	U/H
29	Medicinaregatan	PT/U/H

Station no.	Station location	Comment
30	Sahlgrenska main entrance	H
31	Sahlgrenska huvudentré	PT
32	Slottsskogen South	PT
33	Slottskogsvallen	SC
34	Marklandsgatan	PT
35	Axel Dahlströms torg	PT
36	Axel Dahlströms torg	SQ
37	Högsbo vårdcentral	H
38	Högsbo sjukhus	H
39	Ruddalen	SC
40	Frölunda Musikvägen	PT
41	Marconi/Heidhallen	SC
42	Valthornsgatan	RE/SC
43	Frölunda Torg	PT/S
44	Frölunda Torg North entrance	S
45	Frölunda Torg South entrance	PT/S
46	Azaleadalen	RE
47	Mariaplan	PT
48	Majvallen	SC/PT
49	Mastugget/Slottskogen	RE
50	Jaegerdorffsplatsen	PT
51	Klippan Färjeläge	PT
52	Chapmans Torg	SQ
53	Skärgårdsgatan	H/W
54	Kaptensgatan	PT
55	Stigbergstorget	PT
56	Masthuggskrykan	RE
57	Skeppsbron	PT
58	Styrfarten	RE
59	Eriksbergs Färjeläge	PT
60	Eriksbergstorget	PT
61	Slottsberget	PT
62	Lindholmspiren	PT
63	Campus Lindholmen	U
64	Lindholmsallén	PT
65	Lundbystrandhallen	SC
66	Regnbågsgatan	PT
67	Volvo	W
68	Ramberget	ER
69	Keillers Park	RE
70	Lundbybadet/Bravida Arena	SC
71	Wieselgrensplatsen	PT/SQ
72	Kville Saluhall	S/PT
73	Vågmästareplatsen	PT
74	Hjalmar Brantingplatsen	PT/S

Station no.	Station location	Comment
75	Gamla Tuvevägen	S
76	Deltavägen/Backaplan	S