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Conditions and challenges for increased biking as a climate change mitigation strategy. A case study of Östersund, Sweden

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Abstract

Transfer to non-motorized transportation to the greatest extent possible is an important climate change mitigation strategy. Biking is a sustainable mean of transportation and increased biking is desirable on global, national, regional, local, and individual level. This study use Östersund, located in the middle of Sweden, as a case to analyse the conditions and challenges for increased biking and what role the biking infrastructure system, weather-related factors, and policies and programmes may play. A literature study on weather-related factors and policies and programmes was performed. How biking has developed over time was analysed and a distance analysis, the bike path infrastructures length and continuity, and accessibility was analysed in a geographical information system (GIS) environment. Investments on increased biking in Denmark and the Netherlands has been successful when a lot of effort has been put into development of the bike path infrastructure. The same result has been reached in Malmö, Sweden. However, the time aspect should not be underestimated since reaching high number of bikers seem to take many years, even decades. In the case of Östersund, temperature, wind and precipitation cause a decrease in biking. Number of bikers follow seasonal changes in temperature, the latter two have a temporary influence. Biking in Östersund is increasing even though there are fluctuations every other year. An interesting observation is that during the increased trend of biking the bike path infrastructure has been expanded. The bike path infrastructure is inconsistent with sudden ends every 2,03 km which may create a threshold for the increase of biking. Accessibility of the bike path system is high since over half the population has no longer than 100 m to a bike path. Distance may be a constricting factor since over half of randomised journeys are longer than a considerable comfortable biking distance of 5 km. Urban planning that treats biking as any other mean of transportation, development of a biking culture and individual habits is crucial for biking to increase.

Keywords: *Climate change mitigation, biking, biking infrastructure, GIS, biking policies and programmes, Östersund.*

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1. Introduction

Anthropogenic drivers are likely the dominant cause of the observed changes in the atmospheric composition. These changes have led to a warmer climate with sea level rise, increased floods and droughts, diminished snow and ice, and other risks that have an impact on the human and natural systems (IPCC, 2014). Climate change mitigation is an ongoing strategy to limit the effects of climate change. Climate change mitigation is one of mankind's largest modern challenges and requires actions on all levels – global, national, regional, local and individual level. (Chen et al., 2017).

Globally, about a quarter of the total greenhouse gas emissions derives from the transportation sector (Creutzig et al., 2015). In Sweden, about a third of the total greenhouse gas emissions derives from the transportation sector, and a major part comprises from road traffic, especially short trips made with cars (Swedish Environmental Protection Agency, 2017). Transfer to non-motorised transport is an important climate change mitigation strategy and is also desirable from a health, economic and natural resource perspective (Lovelace et al., 2011).

Using a bike for transportation is considered to be a sustainable mean of transportation, which improves the personal health and leads to reduced greenhouse gas emissions (Spencer et al., 2013). In a life cycle assessment, Lacap & Barney (2015) show e.g. that a bicycle emits 90,1 gCO_{2e}/km compared to a car which emits 366,4 gCO_{2e}/km.

Selecting a *mean of transportation* is a quite complex process and contains a variety of decisions. Such a decision is often based on three factors – individual, external and travel-specific factors. *Individual factors* are the preferences, notions and skills that the traveller has. Attitude, habits, feeling of safety, socio-economy and knowledge is a few examples on individual factors. *External factors* refer to things that vary in time and space, which an individual cannot change. Climate and weather, time of day and road conditions are examples of external factors. *Travel specific factors*, which include physical attributes such as infrastructure and end destination, affects when the journey has started (Lindelöw, 2009).

Both the external environment and individual subjectivity influence the choice of mean of transportation. An external environment that provides activity opportunities may also encourage the choice of active transportation, such as biking (Kim & Ulfarsson, 2008). Spencer et al. (2013) state that increased biking can be reached by increased safety and comfort for the traveller. If biking is to become a viable transportation option bikers need to feel safer. Conditions and challenges for increased biking varies and each city has its own conditions and challenges.

Östersund, the focus of this thesis, has set a goal of being fossil fuel-free and energy efficient by 2030. One of the tools to achieve this goal is by an initiated biking program with the main purpose to increase the number of bikers within the city (Östersund municipality, 2014).

2. Purpose, objectives and scope

The purpose of this study is to analyse the conditions and challenges for increased biking and what role the biking infrastructure system, weather-related factors, and policies and programmes may play. Östersund will serve as a case study.

The objectives are to:

I. Understand the development of biking and the bicycle in a historical perspective.
II. Describe the purpose and main actions of biking policies and programmes in an international perspective and in what ways these have affected biking.
III. Analyse the development of biking in Östersund.
IV. Understand how the number of bikers is affected by weather-related factors.
V. Analyse in what way travel distance, and bike path infrastructure continuity and coverage affect biking.
VI. Perform a case study of Östersund.

The study focuses on the city of Östersund as a case for conditions and challenges for biking. Central to the analysis is where biking occurs, or more specifically on the bike-path infrastructure system and in different weather conditions. Biking distance, and the coverage and accessibility of the bike-path infrastructure system have received extra attention. The role of biking policies and programmes, both on international and local level is also investigated.

3. Background

This chapter briefly describes and discusses the history of biking and the development of the bicycle-technology. In addition, the current knowledge on how distance, weather-related factors, and the bike path infrastructure affects biking is presented.

3.1 Modern history of biking

The bicycle and biking had its breakthrough in the late 1800s and became a symbol for dreams of freedom, speed, modernity and change. The bicycle was important for transportation purposes as other means of transportations was sparse (Hagström et al., 2014). The breakthrough of biking is linked to a wave of nationalism that emerged in Europe. The bicycle became an important vehicle and gave access to leaving the city and discover the beauty of the countryside where it was believed that the remains of a genuine people's culture could still be discovered. With a bicycle, this journey could be done within a reasonable time frame (Nilsson, 2014).

During the 1920s and 1930s Europe was characterized by ideas of functionalism and urban planning was focused on the modern and functional city. Parallel to the wave of functionalism, cars started to gain interest by the public and owning a car became more common. Biking reached new records during the 1940s which can be explained by functional city planning. Urban areas were divided into different zones with residences in one zone, industries in another, shops in a third zone and so on. The industries were moved to the city outskirts and for a growing working class, who had to commute to work, the bicycle became the exclusive option.
During the 1950s and 1960s, personal cars had its breakthrough and outcompeted the bicycle. In the functional and modern city, cars were prioritized and the infrastructure was developed with motorized traffic primarily in mind. During the 1960s the bike was no longer considered a commercial mean of transportation but something that was performed by athletes as a sport or for recreation purposes during the weekends (Koglin, 2014).

During the 1970s, the bicycle had a renaissance. Anti-car movements, environmental awareness and biking organisations used the car´s harmful impact on the local and global environment, and traffic jams as arguments to promote biking. At the same time the support for biking increased among politicians and planners. In Europe, the increased interest in biking also coincides with the transition from an industrial society to a service society. A focus on production, function and the needs of the working class have been replaced by a focus on consumption and the needs of the middle class. The bike has today become a symbol for an environmental friendly, healthy and flexible mean of transportation which attracts the modern urbanite (Emanuel, 2014).

3.2 The development of the bicycle and biking

The modern bicycle, also known as a safety bicycle, is the model we see today with a steerable front wheel, equally sized wheels and a chain drive to the rear wheel. The development of the safety bike was the most important change in the history of the bicycle.

Another important innovation was the multiple-speed bicycle and derailleur gears which is the type of gear technology we see on bikes today. The possibility to shift gears without having to remove the wheel shortened traveling time, improved comfort and gave the biker the possibility to ride uphill with less input of work.
In the mid-1900s, the racing bicycle grew in popularity. These bikes are recognized by the dropped handlebar which resembles the horns of a goat. This much lighter bicycle with bigger and narrower wheels and often up to 15 gears made it possible to go faster and easier to climb hills.

The next important innovation is the mountain bike. This bicycle made it possible to bike in most terrain since it has a sturdier frame and wheels with large knobs for increased traction. By the year 2000, the mountain bike was by far the most popular bike in the world. The development of the bicycle is an ongoing process and today we see bicycles with carbon and aluminium frames instead of frames made of steel, gear shifting systems are becoming electronic, and a lot of effort is put to make bicycles lighter and more aerodynamic (Herlihy, 2006).

Today, the electric bicycle (e-bike) is gaining popularity. The e-bike is a traditional bicycle with an integrated electric motor powered by a rechargeable battery. The electrical motor assists the bikers pedal power (Turner, 2013). The e-bike has greater speed and acceleration, which makes it a potential challenger as a commuting mean of transportation (Du et al., 2013). Gojanovic et al. (2011) show that the e-bike is an alternative for the biker who want to commute to work and meet physical activity guidelines without having to make a lot of effort in hilly terrain and the need to shower when arriving at work.

The sales of e-bikes are booming. In Sweden sales went up with 50% between 2016 and 2017. Since 2014, the number of e-bikes sold has doubled (Svensk cykling, 2018). In China, 2,5 million e-bikes was sold between 2002 - 2012 (Wei et al., 2013). 2016 was a record year for most countries in western-Europe, Denmark, Germany, the Netherlands, and Austria all had record sales. In Germany one on five bikes that are sold is an e-bike. One out of ten bikes in Denmark is an e-bike, and the Netherlands, 950 000 e-bikes was sold in 2016, an increase with almost 300 000 bikes compared to 2015 (Bike Europe, 2018).

Not only the bicycle has changed but also the way the bicycle is used. The development has gone from an individual transporting himself or herself, to use the bike as a mean of transportation for several individuals simultaneously. For example, bicycle carriers and cargo bikes are now used to transport children and used by haulage firms and moving companies to transport goods (Bjørnarå et al., 2017).

3.3 Weather-related factors and its effect on biking

Not surprisingly, bikers seem to prefer dry, calm, sunny and warm conditions to biking in rainy, windy and cold weather (Böcker et al., 2016; Thomas et al, 2012). However, some bikers differ from this statement. Seasonal variations are also prone to influence the choice or mean of transportation. Karlsson (2000), and Bergström & Magnusson (2003) show a seasonal variation with a decrease of bikers in autumn and winter and increasing number of bikers during summer and spring. Air temperature, precipitation, and winds seem to be the strongest influential weather-related factors (Nankervis, 1999; Keay; 1992, Richardson, 2000; Tin Tin et al., 2012; Winters et al., 2007). The closer the air temperature reaches 0°C, or as the air temperature get lowered, the number of bikers decreases (Miranda-Moreno & Nosal, 2011). Yet, Amiri & Sadeghpour (2014) find that air temperatures down to -20°C do not stop biking. Phung & Rose (2008) show that winds with a velocity over 10 m/s is a barrier for biking. Nikolopoulo & Lykouidis (2007) show that winds during warm summer months have a cooling effect and biking increases with wind speed in this case.

Nosal & Miranda-Moreno (2014) find that the number of bikers decrease when it rained in the morning even if it stopped later in the day. Rietveld et al. (2004) however, do not find a relationship between precipitation and decrease of biking when interviewing bikers in the Netherlands.

3.4 Bike path infrastructure

Cities with a high density of bike paths, and city streets, where bikers have been given priority, tend ~~s~~ to have higher rates of biking (Marshall & Garrick, 2011; Schoner & Levinson, 2014). Further it is believed that a fragmented bike path infrastructure system with sudden ends, where bikers must integrate with motorized traffic, creates conflicts and possible dangerous situations (Buehler & Dill, 2015). Niska (2007) shows in his focus group interviews, that bikers ask for a direct and continuous cycle path network with high standard maintenance and accessibility.

Germany and the Netherlands have put a great effort to both tie together and expand the bike path infrastructure networks to reach important rural and urban nodes with increased biking as a result (Pucher & Dijkstra, 2000). Parker et al. (2011) studied the biking in New Orleans after the first on-street bike lane was painted and found an 57% increase of bikers over one year.
A well-functioning bicycle transportation network may have a biker increasing effect. However, it is important to note that bike paths act as magnets to attract people already on bikes rather than encourage non-bikers to change mode of transportation (Schoner et al., 2015).

3.5 Travel distance

Bergström & Magnusson (2003) investigated the possibility to transfer car trips to bicycle rides at four major Swedish companies in Luleå (*SSAB Tunnplåt* and *Scania Chassikomponenter*) and Linköping (*Saab AB* and *Ericsson Mobile Communication*). By handing out 200 questionnaires at each company, with a total response rate of 72% the study, they show ~~s~~ that car trips up to 5 km were transferable to bike. But a greater number of car trips would be transferred if the distance is shorter than 3 km. Forward (1999) shows a strong association with transportation mode choice and distance. There is a positive attitude toward biking or walking during trips shorter than 5 km. However, over half of the respondents in the study answered that they would use the car on a short trip if they were in a hurry, if it was in the evening or if they had a lot to carry. On the other hand, if the weather is fine or there is heavy traffic, biking or walking are the preferred choice for trips shorter than 4 km. When the respondents were asked about trips shorter than 2,5 km, more than 50% answered that even though they were in a hurry or that they have a lot to carry, biking or walking were preferred to the car.

Loukopoulos and Gärling (2005) identify that 4,1 km is a threshold for biking. 80% of the trips longer than 4 km were made by car. Other similar distance thresholds are identified by Nazelle et al (2010), Kim and Ulfarsson (2008) where 75% of the trips longer than 4,8 km and respectively 60% of the trips longer than 2,25 km are made with a car instead of active transportation, such as biking or walking.

4. A presentation of Östersund – the case-study

The case-study area covers, as mentioned before, the Östersund city, which has approximately 62 000 inhabitants of which 45 523 live within the very city (Östersund municipality, 2018). The city is situated on the shore of lake Storsjön. Fig 1 shows Östersund´s position in Scandinavia, land use in the area, and the boundaries of the study area.

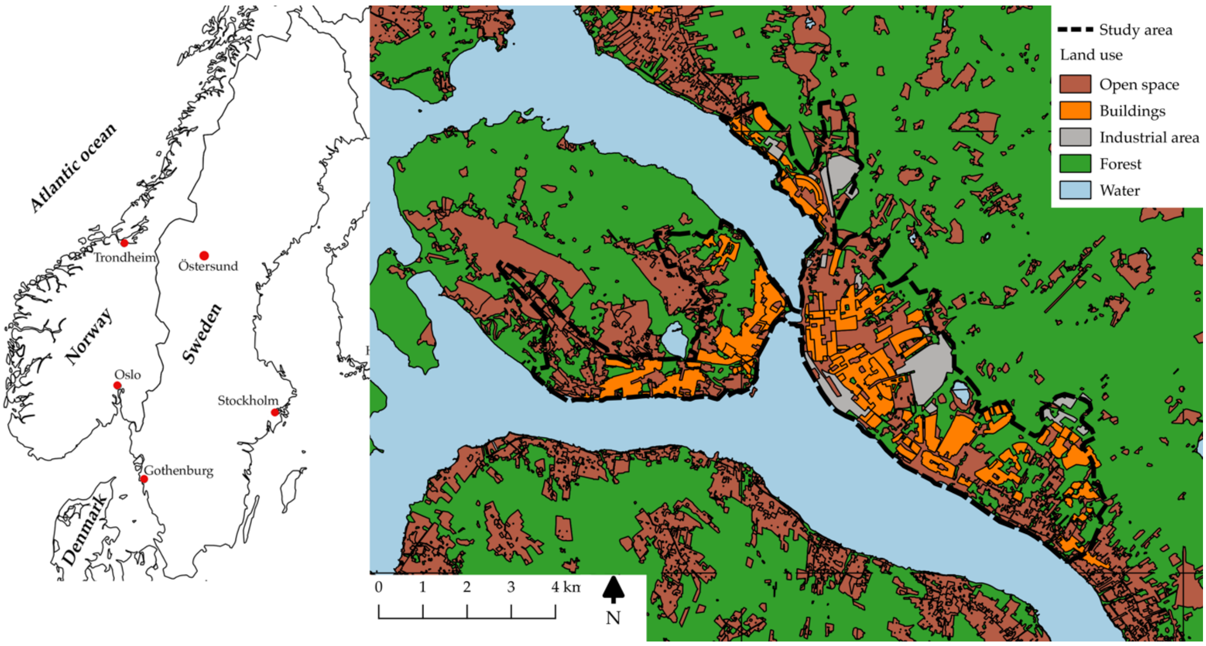

Figure 1. Östersund´s position in Scandinavia and an overview of the land use in the area around Östersund. The study area is marked with a dashed black line. (Map created by author).

Östersund has a maritime climate with cool summers and mild winters. Östersund´s position and proximity to the Atlantic, from which westerly winds affect the climate, is different from the otherwise predominant conditions in the Swedish inland. The total yearly precipitation amounts to 343,3 mm. The yearly mean temperature is 3,5°C and the period November – March has a mean temperature below 0°C (SMHI, 2016).

4.1 Östersund bike path infrastructure

Bike paths are classified into three classes, i.e. main biking routes, other biking routes, and recommended routes in mixed traffic. In this study, main biking routes will be referred to as *Class 1* bike paths. These paths are separated from motorized traffic and have the highest priority when it comes to removal of snow and leaves, and ground repairs. Furthermore, they have two lanes so that bikers use the left side and pedestrians the right side of the path. Other biking routes are referred to as *Class 2* bike path. These are also separated from motorized traffic, but do not have separate lanes for biking and pedestrians. Class 2 bike paths have a lower snow and obstacle removal priority, and are maintained second to Class 1. Recommended route in mixed traffic will be referred to as *Class 3* bike paths. These are, as class indicate, recommended but are in some cases separated from motorized traffic with road marking. Class 3 paths are maintained after Class 1 and Class 2 (Östersund municipality, 2014).

5. Theory

Transportation of any kind is performed within the built environment. Barton (2009) defines the built environment as "the human-made environment that may be subject to planning". Barton includes in the term not only buildings and hard infrastructure, but also greenspace. He further argues that good planning of the built environment can provide access and opportunities for active transportation. Critical determinants for active transportation includes the density, accessibility, connectivity and the quality of the route network.

In many places in the world, municipal planners have started to consider a future of less extensive reliance on automobiles and put a focus on enhanced possibilities for active transportation. Efforts to encourage walking and biking are now embedded in the public discourse (Zipori & Cohen, 2014). Policies and factors related to the urban morphology is of high relevance when choosing a mean of transportation (Bruhèze & Veraart, 1999). Urban planning may be an important tool to enhance levels of active transportation. But equally important is that policy makers must rely on planning professionals to translate policies into practice (Koohsari et al., 2013).

Nilsson (1998) developed a conceptual behaviour model that explains the mean of transportation choice at an individual level. She argues that society's resources, priorities, laws, norms and information set the framework for the actions of the market and public interests. At the same time, the market and public interests can affect the framework of society. The actions of market economy interests influence the location of activities, as well as the characteristics, consequences and image of the means of transport. Public interests affect the structure of buildings, the supply of services and the standard for transportation opportunities through the construction, operation and maintenance of road networks and bicycle paths. This in turn affects the individual's objective activity and travel opportunities as well as the individual perception of the activities and opportunities. The individual's choices also depend on the resources and restrictions, such as economic or time and access to the means of transport. This individual perception and individual circumstances also depend on objective characteristics of the individual. The mean of transportation choice also depends on habits, which in turn depends on previous choices, which seems to have an inertial effect on changes in the means of choice. Strategic choices of housing, work, leisure etc. also affects which trips are made and if they are objectively possible to carry out a bicycle in terms of distance.

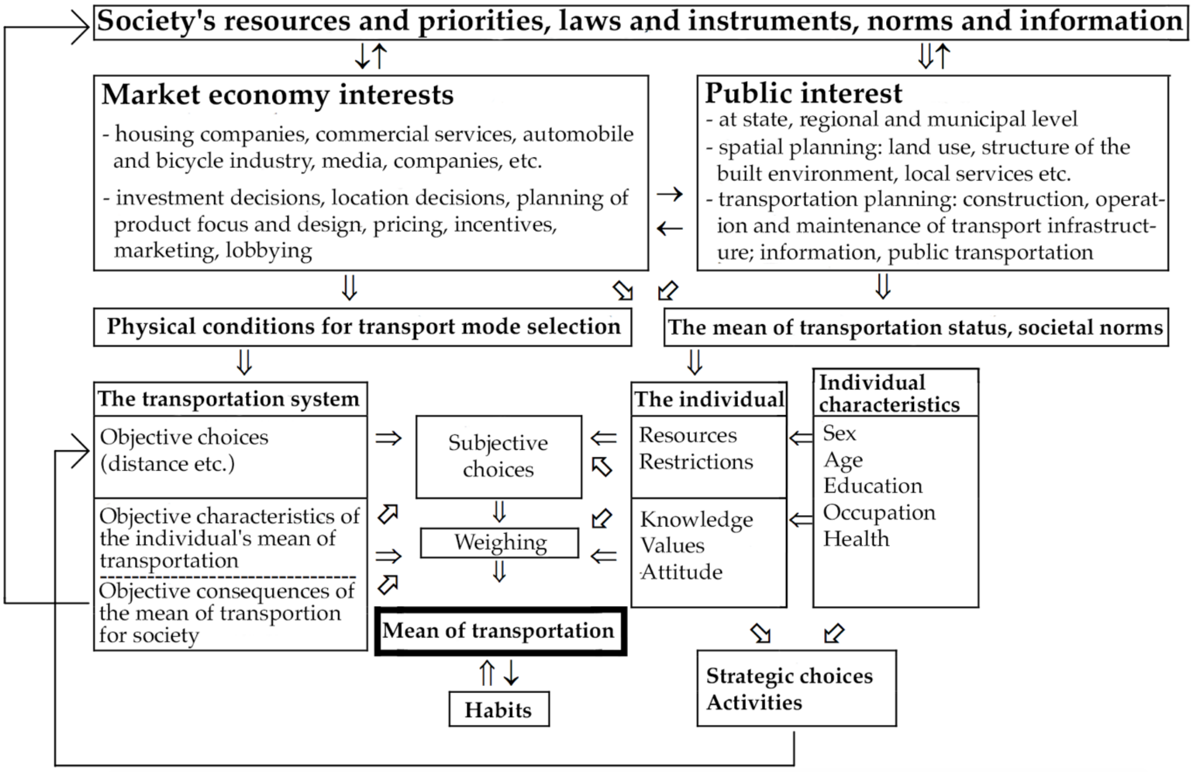

Figure 2. Nilsson (1998) conceptual behaviour model. (Authors interpretation of Nilsson 1998.)

The individual is the force behind the active transportation, but not only individual perceptions, habits, the society etc. determine the mean of transportation. There are several factors, barriers and motives for biking. Exercise, limited environmental impact, economy, are some motives while cold and rainy weather, steep topography, poor bicycle infrastructure are a few examples on barriers (Eriksson, 2009).
Figure 2 show Lindelöw´s (2009) conceptual decision-making model, which is developed from Nilsson (1998). He argues that the modal choice depends on three factors: *individual*, *external* and *travel specific* factors. *Individual factors* are factors that the traveller possesses such as, sex, socio-economy, attitude, and knowledge to name a few examples. *External factors* cannot be influenced by the traveller or by the specific trip. Weather and climate, time of day and topography are a few examples. But also, things like rebuilding of the infrastructure and taxes on gasoline are such external factors. *Travel specific factors* affect the travel experience, for example safety, available infrastructure and the sense of security. The decision-making is also based on the decision to travel or not. It is assumed that there is an objective for the trip.

External factors and the individual's perception of the purpose of the trip determine in what way and with which transport mean the trip is carried out. Route choice becomes interesting when a trip has begun. Individual, external and travel specific factors affect the decision to travel, mean of transportation and route choice. All trips including planned trips that are not carried out, give new input to future travel decision-making through impressions and revisions. The same feedback is made to the individual, external and travel specific factors. Lindelöw argues that the degree of feedback decreases with increased habit travelling. For example, commuters will not be affected in the decision-making process as much as a person who will carry out a recreational trip.

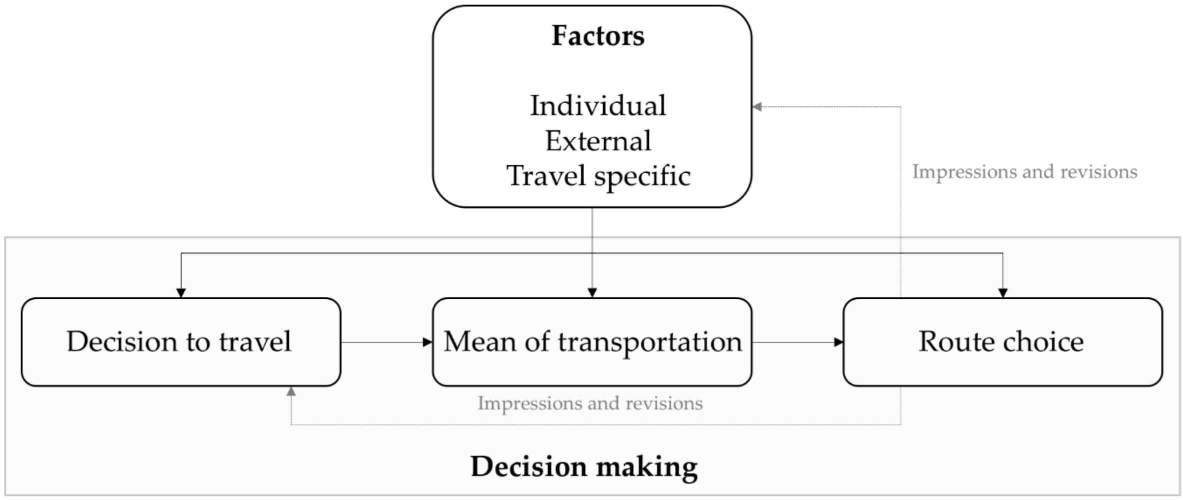

Figure 3. Lindelöw (2009) conceptual decision-making model which is developed from Nilsson (1998). (Authors interpretation of Lindelöw, 2009.)

6. Method

This chapter presents the methods used and the character of the studied literature and documents.

6.1 Biking policies and programmes in an international perspective

The EUs urban mobility policy, *The Green Paper: "Towards a new culture for urban mobility"* was studied, and the main purpose and objectives with a focus on biking were identified. EU-members national biking strategies were also studied and the main objectives were identified. Local policies and the brief history of biking in Copenhagen, Denmark and Groningen, the Netherlands were studied and the influence on biking from these policies is presented.

6.2 Biking policies and programmes in a national and local perspective

The Swedish national biking strategy was analysed and the main objectives was identified. Local policies from Malmö and were also studied, however, more in detail to identify the influence of the policy on biking. A special focus was on Östersund.

6.3 Östersund case-study

Östersund serves as a case where the local biking strategy is studied, development of biking, weather-related factors, and the bike path infrastructure is analysed to identify conditions and challenges for increased biking.

Östersund municipality's *biking strategy* was studied and the main objectives and measures for increased biking are presented and discussed in relation to international, and national strategies and programmes.

The *development of biking* in Östersund was analysed. Östersund municipality has set up a measuring station at the Frösö bridge in the central parts of Östersund. Data on number of passages per year was compiled and presented in a diagram and a table. The percentage change between following years and the percentage change in relation to the start of the measurements was calculated and compared.

A literature review Kröyer et al. (2017) performed a study on *weather-related factors* influence on biking in Östersund. The study is used as a result on how biking in the study area is influenced by weather.

Regarding bike path infrastructure continuity, a digital map covering the different classes of bike paths was imported into a geographical information system (GIS) environment. The digital map was georeferenced and aligned to an already existing map with proper coordinate system and projection covering the study area. The different classes of bike paths within the study area was manually digitized. The length of each class was calculated and summarized.

A *sudden end* is defined as a point in the bike path infrastructure where the path ends without the possibility of continuing on a path dedicated for biking. A sudden end is found where a Class 1 or a Class 2 bike path leads to a Class 3 path, or where a bike path of any class leads to a road dedicated to motorized traffic and ends. If any of the classes lead into an isolated residential area, with only one road leading into the block and ends on a road dedicated to motorized traffic, it is not considered as a sudden end. If any of the classes leads into an industrial area and ends on a road dedicated to motorized traffic it is considered a sudden end. If a bike path, of any class, leads to a recreational area and ends there, or leads to the edge of the study area it is not considered as sudden ends.

The number of sudden ends was summarized and divided with the length of each bike path class and the total length of the entire bike path infrastructure to get sudden end occurrence per km within the infrastructure system.
Endings in the bike path infrastructure was found by using spatial query and the expressions:

- WHERE "*class 1 bike path*" AND "*class 2 bike path*" TOUCH "*class 3 bike path*" OR "*motorized street*" AND "*industrial area*"
- WHERE "*class 1 bike path*" AND "*class 2 bike path*" TOUCH "*class 3 bike path*" OR "*motorized street*" AND "*residential area*"
- WHERE "*class 1 bike path*" AND "*class 2 bike path*" AND "*class 3 bike path*" TOUCH "*motorized street*" AND "*residential area*"
- WHERE "*class 1 bike path*" AND "*class 2 bike path*" AND "*class 3 bike path*" TOUCH "*motorized street*" AND "*industrial area*"

The sudden ends that are not considered as a sudden end were manually removed.

To measure *accessibility*, 100 m buffer zones were created for each class of bike path. A spatial data set showing different types of housing within the study area was used to calculate the number of households within each buffer zone through spatial query and the expressions:

- *"detached houses"* AND *"apartment buildings (rental)"* AND *"apartment buildings (tenant-owned)"* TOUCH *"bike path class 1 buffer"*
- *"detached houses"* AND *"apartment buildings (rental)"* AND *"apartment buildings (tenant-owned)"* TOUCH *"bike path class 2 buffer"*
- *"detached houses"* AND *"apartment buildings (rental)"* AND *"apartment buildings (tenant-owned)"* TOUCH *"bike path class 3 buffer"*
- *"detached houses"* AND *"apartment buildings (rental)"* AND *"apartment buildings (tenant-owned)"* TOUCH *"bike path all classes buffer"*

The number of people with no more than 100 m to the bike path was then calculated by using the number of different households within the buffer zones and number of residents in the different housing. The number of residents was calculated by using an adjusted residential mean value for the different housing types. The adjustment is based on statistics from SCB (2016) and represent a mean value of residents living in the different housing types. Detached houses are considered to have three residents each. Half of the rental apartment buildings is considered have twelve residents in each building, and the other half of the apartment buildings is considered to have 18 residents in building. Tenant-owned apartment buildings is considered to have 18 residents in each building.

For a *distance analysis*, the random points in layer bounds tool in the QGIS software was used to create 15 random points within the study area. The points represent a theoretical start respectively end destination points for a journey. A distance factor of 500 m was used to avoid points being too close to each other. Points that did not end up on a bike path were manually moved to the closest bike path. A distance matrix was created with the distance matrix tool in QGIS and the distance between each point was calculated by the software. The distance between the points is the shortest possible distance when travelling on a bike path. The distance between points is classified based on literature in three different classes: *"clearly possible biking distance"*, *"possible biking distance"* *"possible too far distance"*.

7. Results

7.1 Biking strategies

This chapter focuses on biking strategies on European level where EUs mobility strategy is presented. Biking strategies and their influence on biking in Copenhagen, Denmark and Groningen, the Netherlands, two cities that have high number of bikers and successful biking policies, is presented. In the end of this chapter biking in Sweden is in focus.

7.1.1 EU-level biking policy

To this day, the EU has not implemented a specific cycling strategy. However, the EU commission´s Green Paper *"Towards a new culture for urban mobility"* (European Commission, 2007) focuses on finding solutions for urban mobility that should make economic development possible, enhance the quality of life for inhabitants, and protect the environment in European urban areas. The green paper states that traffic congestion in towns is a major obstacle. A solution for this is promotion of sustainable means of transportation such as biking or walking. Sustainable transportation options should be made attractive. A way of promoting biking is development of high quality and fluid infrastructure systems, and implementing local policies with a focus on biking that make it possible for travellers to transport themselves in a safe and secure way. One important aspect is to create a new mobility culture through urban planning. The new culture should result in an optimization in the use of all the various modes of transport and densifying of cities. Short trips should be transferred from motorized vehicles to any kind of sustainable mean of transportation, preferable biking or walking since it also has health benefits. EUs green paper is a recommendation document, which EU member states and local governments can use as inspiration.

7.1.2 Copenhagen biking strategy and influence on biking

Copenhagen has a long history of biking. Already in 1892, the first bicycle path was established in the city and the bicycle network has since then only increased. Denmark has a strong and long-lived biking culture where a strong decline in biking never occurred. One important factor for this is Denmark's conditions after the second world war when the car had its breakthrough. After world war II Denmark was a relatively poor country with a poor population. This led to a low number in car ownership and lack of resources for big infrastructure projects, which focused on cars. This in turn led to a city planning which included biking even through the 1960s, where several other European countries excluded biking from infrastructure plans (Koglin, 2014).

The current bicycle strategy has the ambition to make Copenhagen the best cycling city in the world and there is a focus on developing the infrastructure in the form of unique three lane bicycle tracks, new bicycle and pedestrian only bridges over canals, redesign of intersections, and rebuilding school routes, just to name a few examples. Previous strategies have also focused on infrastructure development, especially expansion of bike paths (City of Copenhagen, 2011). Today, more trips are made with bike than by car in Copenhagen with its surrounding suburbs and the number of bikers involved in accidents are lower than ever (City of Copenhagen, 2017).

7.1.3 Groningen biking strategy and influence on biking

The bicycle and biking in the Netherlands has since the early 1900s been a symbol for the nation. The bicycle and biking symbolises one positive aspect of being Dutch and is a great part of the Dutch culture. Another important aspect is that, when the bicycle became more accessible among the public, the prosperous upper class did not abandon biking. This resulted in biking becoming a reconciliation technology instead of a technique that was used in the class conflict (Emanuel, 2014).

The city of Groningen, in northern Netherlands, promotes itself as the biking capital of the world. In the 1970s, the city of Groningen through the *Traffic-circulation Plan* made the choice to create more room for pedestrians and cyclists in the city centre. The plan made it impossible for cars to cross the inner city since they had to use a ring-road, which became a time-consuming process. For bikers moving around in the city became easier and safer. But the traffic-circulation plan did not come without protests, especially from businessmen and shop owners who were afraid to lose their business. 40 years later, 61% of all trips in Groningen is made by bicycle, there are 3,1 bikes per household, and a lot of innovative solutions for bikers can be found in the city. For example, rain sensitive traffic lights, which give quicker priority to bikers on wet days, heated bicycle paths and 10.000 parking spaces for bikes close to the train station. (City of Groningen, 2015).

7.1.4 Sweden's national biking strategy

Sweden's first national biking policy *A national cycling strategy for more and safer cycling* was implemented in late 2017. The main objectives are to reduce congestion and the environmental impact of travel in built-up areas, and contribute to improved public health. The strategy should contribute to a sustainable society with a high quality of life and stimulate sustainable transport solutions. An important starting point in the strategy is the biker. Bikers are not a unified group with similar habits but are rather a varied group. The strategy also focuses on strengthen positive trends in biking and getting more people to change their habits to start, and continue biking. Means of reaching these objectives are through higher priority in planning processes, demonstration projects, improvement and development of the bike path infrastructure (Regeringskansliet, 2017).

7.1.5 Biking in Malmö

In Malmö, Sweden, the city's first bicycle program was established in 1976. But not until 1999, when a revised plan was implemented, did the bicycle trend in Malmö sparked. Today, there are around 470 km of bicycle paths within the city, compared to 100 km in the 1980s. Malmö received prices for its investment in biking and is today sometimes called the biking capital of Sweden. On a regular basis, one out of four citizens use the bike as a transportation mode. The city of Malmö put a lot of effort in developing its bicycle transportation network, e.g. support rails were mounted at traffic lights so the biker does not have to lift the foot from the pedals, extended green light for bikers at traffic lights, windbreakers at exposed routes, and streets where bikers have priority (City of Malmö, 2012). Further, planners in Malmö always had the idea of trying to keep the city growth within the ring road that surrounds the city. This resulted in urban infill and a situation where it is easier and faster for cars to use the ring road (Emanuel, 2014).

7.1.6 Summary

A lot of focus in biking strategies seem to lie on the bike path infrastructure. Development of the bike path infrastructure, among other things has led to high number of bikers in both Copenhagen, Groningen, and Malmö. But looking closer at Copenhagen and Groningen, a successful investment in biking may take time since it is a lot about developing a culture for biking.

7.2 Östersund case study

This chapter will look closer at Östersund. The local biking strategy and the development of biking in Östersund will be presented. Conditions and challenges, with a focus on the weather and the bike path infrastructure, will be analysed.

7.2.1 Östersund biking strategy

In 1980, a bicycle path plan was adopted by Östersund municipality. The result of the plan was 83 km of bike paths. In 2002, the first biking program was implemented and the main result of this was an expansion of the bike path infrastructure with 43 km. Between 2002 and 2018 the bike path system was extended with 39 km. In 2014, Östersund municipality implemented a second biking strategy with the main goal to develop Östersund to a biking city with a well-functioning biking environment. Among other things, the strategy focuses on separating biking from motorized traffic, a well-connected bike path infrastructure system, promoting bicycle commuting, especially trips longer than 20 km, improved bike path maintenance, and an extended and safe bike path infrastructure. By 2020, 20% of all trips within the city shall be made with a bike and the infrastructure system will be extended. By 2030, all suggestions in the program should be executed (Östersund municipality, 2014).

7.2.2 Development of biking

Figure 4 shows the daily number of passages at the Frösö bridge biking measuring station between 2012 and 2018. There is a clearly visible seasonal variation in number of passages.

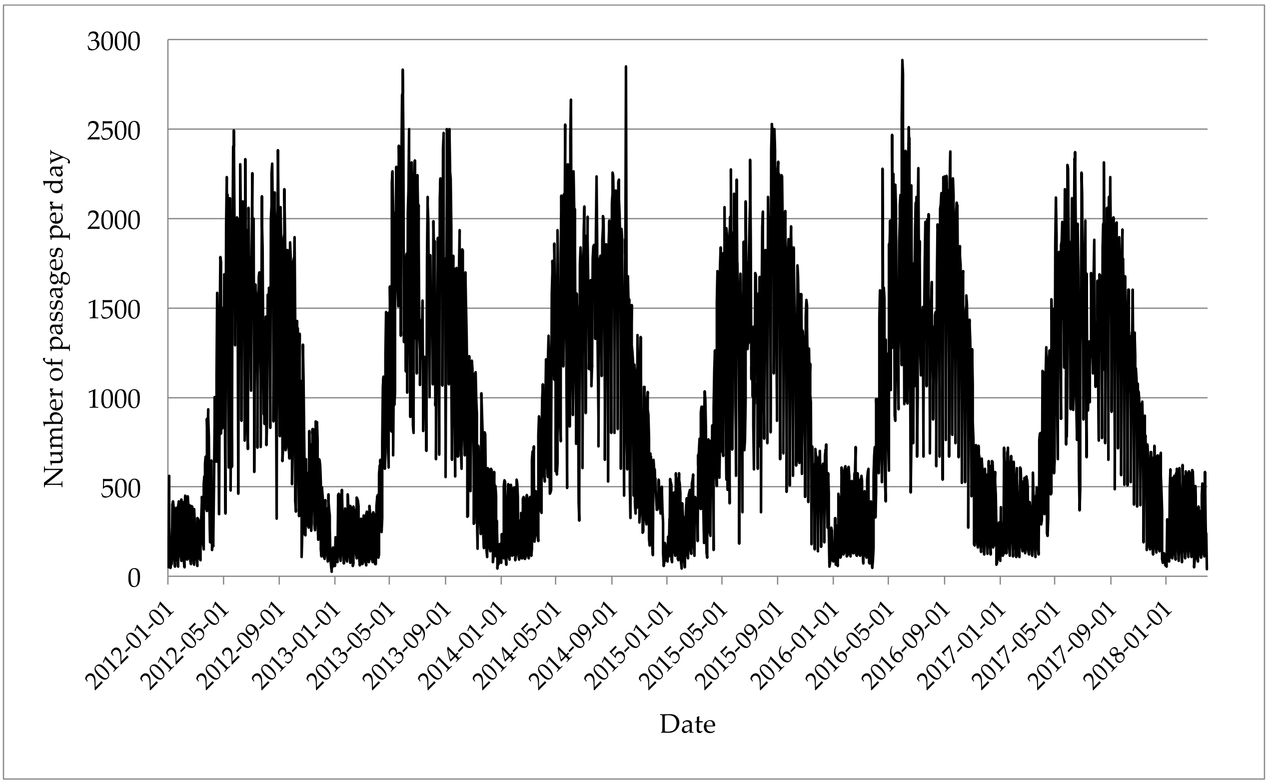

Figure 4. The seasonal variation in number of passages is clearly visible. Between May and September, the number of passages remain stable at a relatively high amount. A decrease starts in October to stabilize again in December. In March, *the number of passages starts to increase again. (Figure created by author.)*

Between May and September, the number of bikers is rather stable. Until December there is a gradual reduction and another stable period begins in March, when the number of bikers starts to increase again. During the days with the highest number of passages, about 2 800 passages are made. These days are typically found in May through September. During the days with the lowest number of passages, about 50 – 100 passages are made. So, the variation is quite large.

Table 1 shows the yearly development of total number of passages at the biking measuring station at the Frösöbridge between 2012 and 2017. Compared to 2012, when the measurements started, every year has had more passages. However, when looking at the change compared with previous years the number of passages fluctuates. Between 2012 and 2013, passages increased with almost 6% and the following years number of passages have varied between 350 000 and 370 000. A general increase can be noticed between 2013-2016 even though it fluctuates, but number of passages in 2017 is lower than in 2013.

Table 1. The yearly development of the total number of passages at the Frösö bridge measuring station. (Table created by author.)

Year	Number of passages	Percentage change compared with previous year	Percentage change compared to 2012
2012	*333 757*		
2013	*353 291*	5,85%	5,85%
2014	*361 756*	2,40%	8,39%
2015	*358 531*	-0,89%	7,42%
2016	*370 495*	3,34%	11,01%
2017	*353 118*	-4,69%	5,80%

7.2.3 Weather-related factors influencing biking

Kröyer et al. (2017) studied the biking in Östersund, and they found that the seasonal biking variation could be explained with seasonal temperature variations. Decreasing temperatures result in decreasing number of bikers. Precipitation and wind also seem to influence the number of bikers, where an increase in precipitation and wind strength result in decreasing number of bikers. The last two mentioned factors do not have as strong seasonal influence as temperature but have a temporary reducing effect. From November through February, neither of the investigated weather-related factors seem to have any larger effect on the otherwise stable number of passages.

7.2.4 Bike path infrastructure length and continuity

Figure 5 shows a map over the bike path infrastructure system and identifies sudden ends. 89 sudden ends were found with the spatial query, among these, eight were identified to not be considered as a sudden end since they ended at a recreational area or at the limit of the study area.

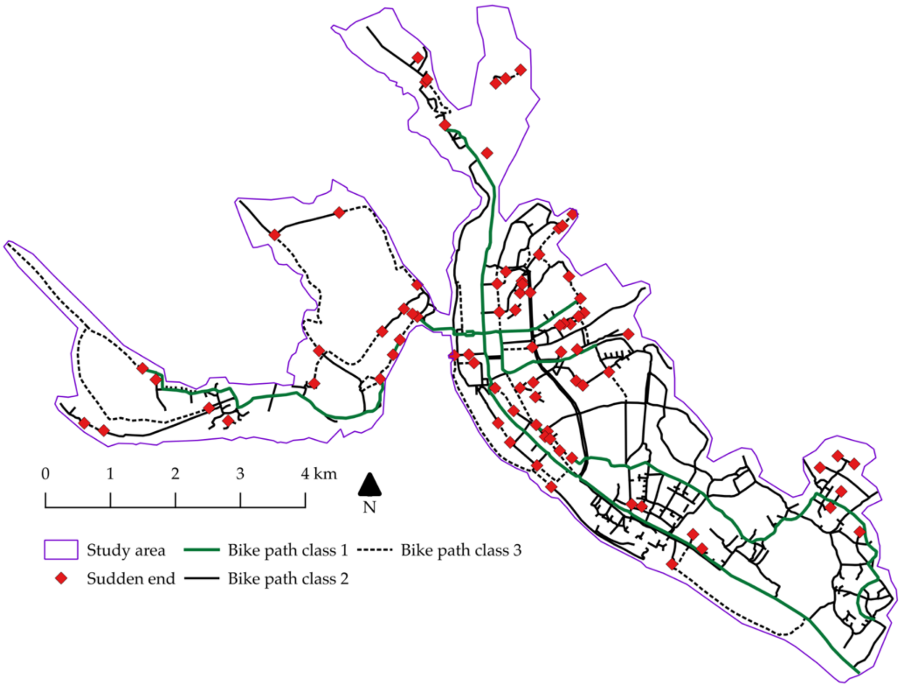

Figure 5 show a map of the bike path infrastructure system and the identified sudden ends.
A total of 81 sudden ends and a total bike path length of 165 km result in a sudden end every 2,03 km.
(Figure created by author.)

When only looking at class 1 bike paths, eight sudden ends are found. All but one sudden end is found where a class 1 path meets a class 3 bike path. The single end is found where the path meets a street, which is prioritized for motorized traffic.
The total length of class 1 bike paths is 29,5 km. With eight sudden ends, it results in a sudden end every 3,7 km.

Class 2 bike paths have a total length of 103 km and are prone to end in residential areas. 62 sudden ends are identified within the class 2 bike path infrastructure system. This result in a sudden end every 1,6 km. Most of the sudden ends occur where Class 2 paths meet ~~s~~ a class 3 path. But there are also ends found where the bike path meets a street prioritized for motorized traffic. There are particularly four isolated patches of class 2 bike path where the path runs through a park and leads into a street dedicated for motorized traffic.

Class 3 has a total length of 32,5 km with 11 sudden ends identified. This results in a sudden end every 2,9 km. In many cases, a Class 3 path ends in a street prioritized for motorized traffic, but there are cases where a path ends in an industrial area or ends with no apparent reason.

Most of the sudden ends are found where a Class 1 or 2 ends in a Class 3 path, and where a bike path of any class ends in a street for motorized traffic. Depending on where the biker is going, there is the possibility to make the entire journey on a bike path. The places where the sudden ends occur indicate an inconsistent infrastructure system. A total of 81 sudden ends are identified within the bike path infrastructure, with a total length of 165 km, which means that a sudden end occurs every 2,03 km. This indicates that the bike path infrastructure system can be considered as non-consecutive. But it also depends from where and to where the biker is going. Table 2 shows a summary of the identified sudden ends in the different classes and the total bike path infrastructure.

Table 2 show a summary of the identified sudden ends in each bike path class and a total of the entire bike path infrastructure system. (Table created by author.)

	No. Of sudden ends	**Length (km)**	**Sudden end occurrence (km)**
Class 1	8	29,5	3,7
Class 2	62	103	1,6
Class 3	11	32,5	2,9
Total	81	165	2,03

7.2.5 Bike path infrastructure accessibility

Within the study area there are 6 015 detached houses. Considering three residents in each house result in 18 045 people living in these houses. There are 1 588 rental apartment buildings where 794 buildings are considered to have twelve residents in each apartment building. Another 794 rental apartment buildings are considered to have 18 residents in each building. This result in a total of 23 820 people living in rental apartments within the study area. Tenant-owned apartment buildings are considered to have 18 residents in each building. There are 217 tenant-owned apartment buildings within the study area, which result in 3 906 residents living in tenant-owned apartment buildings. The estimation of residents living in the different housing types result in a total of 45 771 people living within the study area. The actual population within the study area is 45 523 (SCB, 2016) so the resident estimation can be used to calculate how many people that have access to the bike path infrastructure system.

Figure 6 shows the 100m buffer zone around all different bike paths. A total of 23 361 (51%) residents have access to the bike path infrastructure system.

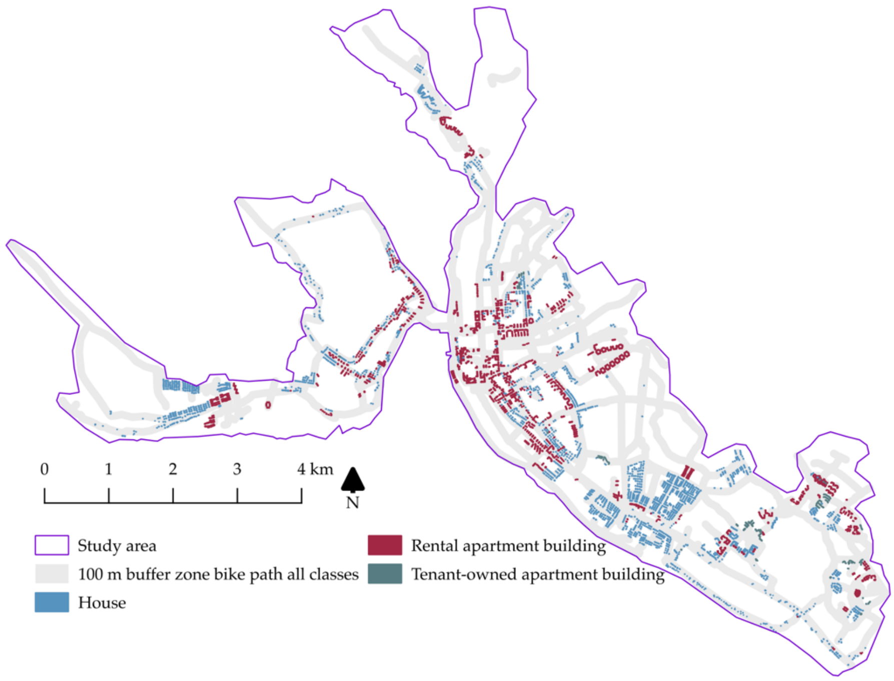

Figure 6 show all classes of bike path and the different type of house that the 100m buffer zone touches. 6 066 residents have direct access to Class 1 bike path. 15 685 residents have direct access to Class 2 bike path and 1 917 residents have direct access to Class 3 bike path. In total, 23 361 residents, which is 51% of the total population have direct access to the bike path infrastructure system. (Figure created by author.)

The 100m buffer zone around Class 1 bike paths and the different type of houses that touches the buffer zone include 422 detached houses, 278 rental apartment buildings and 35 tenant-owned apartment buildings within the buffer zone which result in 6 066 residents (13%) in the different housing types with direct access to Class 1 bike paths. The 100m buffer zone around Class 2 bike paths and the different type of houses that touches the buffer zone, i.e. 15 684 (34%) residents, have direct access to class 2 bike paths in 2 020 houses, 572 rental apartment buildings, and 58 tenant-owned apartment buildings.

The 100m buffer zone around Class 3 bike paths and the different housing types that touches the buffer zone include 170 detached houses, 93 respectively 3 rentals, and tenant-owned apartment buildings were identified. This results in a total of 1 917 (4%) residents having access to the Class 3 bike paths. If looking at the entire bike path infrastructure system, half of the estimated population have not longer than 100 m to a bike path. This indicates that the bike path covers most of residential areas and that lack of bike paths should not be an argument not to bike.

7.2.6 Biking distance analysis

Figure 10 shows the randomized points of possible starting respectively end destinations generated from the GIS software. Only point 3 and 14 had to be moved manually to be on a bike path. The spread of the points covers the entire study area from north to south and east to west and represent possible biking routes and distances.

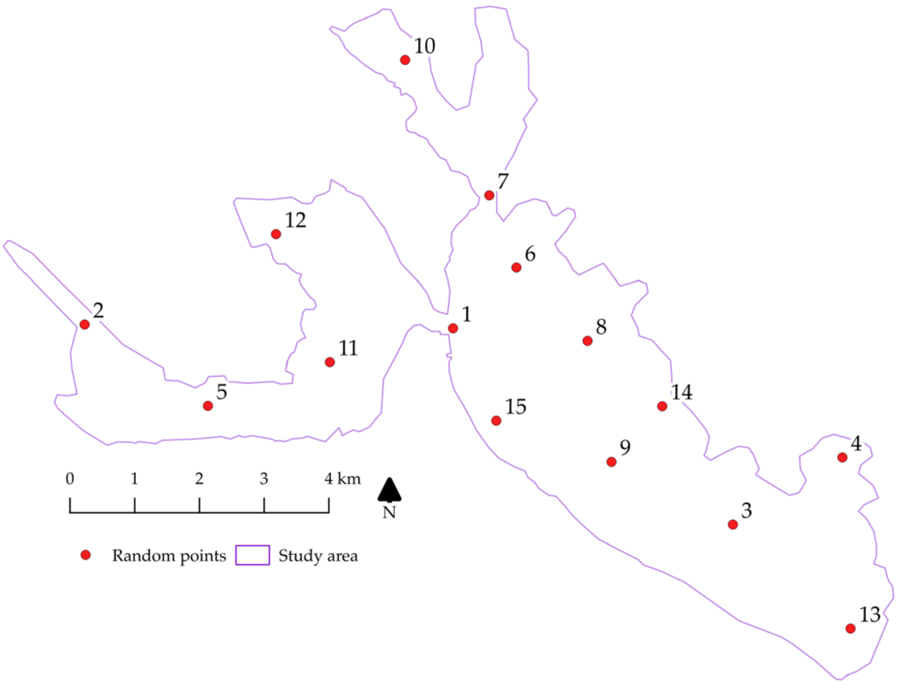

Figure 7 show the GIS software randomized points starting respectively end destinations which covers the entire study area and represent possible biking routes and distances. (Figure created by author.)

Table 3 shows a distance matrix that display the distances between the randomized points displayed in km in a matrix. Bergström & Magnusson (2003), Forward (1999), Loukopoulos and Gärling (2005), Nazelle et al. (2010) and, Kim and Ulfarsson (2008) argues that distances between 2.25 and 5 km are distances people are willing to bike. Distances from 0 – 3 km are classified as *"clearly possible biking distance"*, distances between 3,1 – 5 km are classified as *"possible biking distance"*. Distances over 5 km are classified as *"possible too far distance"*. The matrix use a colour scheme to display distances in different intervals based on the former mentioned literature. Green represent 0 – 3 km, yellow represent 3,1-5 km, and red represent distances over 5 km.

Table 3. A distance matrix display the distances between the randomized starting respectively end destinations in km. The shortest between two points is 1,14km and is found between point 9 and 14. The longest distance is 15,25km and is found between point 2 and 4. The distance between 27 points are under 3km, 21 points are between 3,1 – 5km, and 57 points have a distance over 5km. (Table created by author.)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	0														
2	7,26	0													
3	6,21	12,51	0												
4	6,36	15,25	1,62	0											
5	4,87	2,33	10,51	12,27	0										
6	1,41	8,12	5,84	5,64	6,15	0									
7	2,04	8,68	6,96	6,62	6,99	1,19	0								
8	2,29	8,69	4,26	4,13	7,53	1,57	2,71	0							
9	3,45	10,11	2,80	3,35	8,73	3,34	4,53	1,90	0						
10	4,03	11,20	9.41	8,97	9,76	3,64	2,46	5,17	6,98	0					
11	2,27	4,48	7,85	9.73	1,95	3,83	4,92	4,42	5,81	7,03	0				
12	3,09	6,55	9,00	10,98	2,99	5,12	5,79	5,70	6,85	8,28	1,53	0			
13	7,80	14,16	1,64	2,65	12,99	7,48	8,60	5,90	4,36	11,05	9,92	11,15	0		
14	4,10	10,22	2,25	2,32	9,46	3,59	4,70	2,01	1,14	7,15	5,89	7,41	3,90	0	
15	1,77	8,76	4,66	5,13	6,21	2,32	3,42	1,80	1,87	5,70	3,78	5,13	6,19	2,80	0

The shortest distance between two points is 1,14 km and is found between point 9 and 14. The longest distance between two points are between point 2 and 4 with 15,25 km. In total, there are distances between 27 points that are under 3 km, 21 points that are between 3,1 – 5 km, and 57 points where the distance is over 5 km. Only the distance between 10 points is longer than 10 km and no single distance is over 16. Depending on the route, there are several distances that are possible to make with a bike if the previously mentioned literature is taken into consideration. On the other hand, over half of the possible journeys is longer than 5 km which may create hesitation. So, distance is an issue in Östersund.

8. Discussion

The bicycle and biking, as a mean of transportation, has gone from being a symbol for dreams of freedom and modernity, to becoming outcompeted by the car, to becoming a status symbol for the modern urbanite (Nilsson, 2014; Koglin, 2014; Emanuel, 2014). Apart from being a status symbol, biking is now considered a sustainable mean of transportation (Spencer et al., 2013) and is an important vehicle to emphasize in a climate change mitigation strategy (Lovelace et al., 2011). To increase biking, a number of barriers need to be overcome and the factors that affect biking need to be understood. Since biking has had a renaissance and has received high status among the environmental aware people, the timing to invest in biking is beneficial. Focus should be on the bikers increased safety and comfort. However, a universal solution does not exist since each city has its own challenges and opportunities. Choosing the bike as a mean of transportation is however a more complex issue, as Nilsson (1998) and Lindelöw (2009) show with their conceptual decision-making models. Both the external environment and the subjective individual preferences affect ~~s~~ the choice. Habit is important and Lindelöw argues that bikers that are used to commute have an easier choice to make. At an individual level, developing a habit for biking is important. But a habit cannot be developed without good conditions for biking.

A specific EU-level biking policy does not exist. There is, however, an urban mobility strategy with the purpose of creating a new mobility culture through urban planning. Member states can use the mobility strategy as inspiration for national policies, which in turn can be translated into local and regional actions. Sweden has clearly been inspired by the EUs Green paper and the first national cycling strategy is focused on the biker and change of the individual habits. The strategy also focus on improvement and development of the bike path infrastructure.
In both Copenhagen, Denmark and Groningen, the Netherlands, over half of all trips are made with bike. These cities are for that reason successful in the investment on biking. A similarity between these cities is that a focus on increased biking has been going on for several decades. On a national level, for both Denmark and the Netherlands, the bicycle is symbolic and biking is a culture and a part of the Danish and Dutch identity. Biking was never excluded from the planning and a result of that, biking was never abandoned and a new culture did not have to be built from the ground, which is more or less the case for Sweden where biking was not

considered a commercial mean of transportation when the car had its breakthrough. In Sweden, Malmö is considered to be the biking capital and has like Copenhagen and Groningen focused on biking for over three decades. The investment on biking did not pay off the first 20 years, but the decision makers in Malmö did not give up and in the end, it had a positive impact on biking. Malmö is not on the same level as Copenhagen and Groningen, but bikers are part of the Malmö cityscape. The case of Malmö has in similar ways as Copenhagen and Groningen included biking in the planning process and have prioritized biking as an important mean of transportation which seem to be productive for increasing of biking. Another similarity between the three cities is that they all have made it more complicated for cars and easier for bikers to reach the inner cities.

Anyway, the matter can be twisted and turned, but weather is an important issue since biking occur at the same place where weather occurs. Several studies (e.g. Böcker et al., 2016; Bergström & Magnusson, 2003; Winters et al., 2007; Keay, 1992) show, not surprisingly, that biking in dry, calm, sunny and warm conditions is much more common than biking in rainy, windy and cold conditions. Yet, Amiri & Sadeghpour (2014) show that biking occurs in temperatures down to -20°C. The people who bike in these temperatures are probably habit commuters, who are familiar with these conditions, which makes the decision to bike easier. Biking in Östersund is no difference from the previously mentioned studies and is affected by temperature, winds and precipitation and number of passages varies with season (Kröyer et al., 2017). Between December and March the number of passages is the lowest with some days 50-100 passages. During this time, probably only habitual commuters bike in Östersund and the prevailing winter conditions. Biking in dry, warm and sunny conditions is not an issue since it is quite comfortable and it is easy to dress properly. However, biking in cold, rainy and windy conditions is completely different. To consider in what way these factors may affect the journey and then dress properly is a time-consuming process and for the non-habitual biker, the decision is likely to not bike. For the habitual biker that have experience of biking in different conditions, all it takes is a glance at the weather to know how to dress to have a comfortable journey.

The following years from 2012 and forward have all a higher number of passages at the biking measuring station which indicates that there is an increasing trend of biking in Östersund. There are, however, fluctuations every other year which needs further investigation. One interesting observation is that 2016, where the highest number of passages is recorded at the biking measuring station, is also the year when e-bikes hit new sales records. The record of e-bike sales is probably not the only reason for high number of passages but it may still be a part of the reason. To fully investigate the 2016 fluctuation, a closer investigation of the weather during that year and if conversion or expansion of the bike path infrastructure occurred would be needed to be able to draw any certain conclusions.

Barton (2009) argues that the density, accessibility, connectivity and the quality of the route network are critical determinants for active transportation. A theoretical statement that is confirmed by Niska (2007), and Buehler & Dill (2015) and others. Looking at successful biking investments as those in Copenhagen, Groningen and Malmö, the cities have in common that development of the bike path infrastructure has had high priority, which seems to be beneficial. Biking occurs on bike paths, and a well-connected, safe and accessible bike path infrastructure would encourage biking and be a prerequisite for biking. Schoner et al. (2015) state that bike paths attract people who already bike rather than inspires non-bikers. However, if there were no bike paths at all, would anyone bike? Probably yes, but an existing bike path infrastructure result in more bikers as Parker et al. (2011) show. To invest in a well-functioning bike path infrastructure system should be beneficial for bikers and non-bikers. At least it could provide conditions for biking and a starting point for developing a habit for biking.

In Östersund, the bike path infrastructure system was expanded with 43 km, between 1980 and 2002, until 2018, another 39 km was added. Unfortunately, there is no data on number of bikers between 1980 and 2012 so the infrastructures expansion on the number of bikers is unclear. However, from 2012 biking has slightly increased. Something has had a positive impact on biking in Östersund. Perhaps, parts of the increase of bikers might be a result of the expansion of the bike path infrastructure but the time series is a bit too short to draw any sure conclusions.

But the bike path infrastructure also has its limitations on biking. Sudden ends are found every 2,03 km within the system. Considering that a possible biking distance is 5 km, the system can be characterized as inconsistent. It of course depends on the journey´s start and end and some bikers can indeed make a trip without ever leaving the bike path. But if you travel from Frösön to the mainland, the traveller must meet a sudden end at some point, which may cause a hesitation in the choice of biking.

About half of the population within the study area has no longer than 100 m to a bike path. Because of this, the coverage of the bike path infrastructure can be considered good, but it can of course be expanded to reach more people. It is on the other hand unclear if the accessibility has an impact in biking, but since safety and comfort seems to have an impact, close access to a bike path should result in at least consideration of the choice of mean of transportation. At least for trips where biking is less complicated than driving a car, accessibility may have an impact on higher numbers of bikers.

A distance analysis with randomized possible trips show that out 105, 57 trips is over 5 km which is considered as a too far distance to bike (Bergström & Magnusson, 2003; Forward 1999; Loukopoulos and Gärling, 2005; Nazelle et al., 2010; Kim and Ulfarsson, 2008). This is of course subjective and some bikers may travel far longer than that. However, to increase biking, 5 km seem to be some sort of upper limit for the non-biker that still has not developed a habit of daily biking. The randomized points do not represent the actual journeys that people make but they represent possible journeys.

Depending on from where the journey takes place, the distance may clearly be an obstacle for developing a habit for biking. Overall, distance is an issue that may affect biking. Distance is, however, an obstacle like weather that cannot be addressed in a simple way. The individual attitude on what is too far to bike plays an important role. A possible solution for this is the E-bikes, which have gained popularity during the last 15 years (Svensk cykling, 2018; Wei et al., 2013, Biking Europe, 2018). Gojanovic et al. (2011) argue s that the e-bike is a perfect alternative for the person who wants to bike to work without having to shower at arrival. The biker puts in less effort for longer distances.

Östersund´s focus on increased biking lies on development of the bike path infrastructure. Which of course is very productive, since it has worked on other places. Even though one cannot be sure, investments in bike paths seem, at least, not to have created a further barrier for biking since the number of passages at the biking measuring station from 2012 has increased. But not only investments in the infrastructure is a winning concept, urban planning and a traffic situation that is more complicated for cars, at least for reaching the inner city should be considered. Östersund also strive to get people to bike quite long distances, over 20 km in this case. Which might be a bit counterproductive since 3-5 km is reasonable biking distances.

9. Conclusion

To increase the number of bikers, inclusion of bicycles and bikers in the urban planning process as an important mean of transportation is in general terms crucial. Underpinning the development of a biking culture is another central aspect. This is a slow process, which may take several decades. But looking at cities where bikers outnumber cars, the biking culture is important. At an individual level, developing a biking-habit is decisive and will simplify the decision-making process, when a mean of transportation is selected.

There are several push and pull factors for biking. Weather and the transportation system are two important ones. Dry, warm, and sunny weather conditions in combination with a dense, accessible, a well-connected and safe route network are favourable conditions for biking. In Östersund, temperature, winds and precipitation are the dominant weather-related factors that influence biking. Temperature has a seasonal effect and the number of bikers in winter and autumn is much lower than during summer and spring. Habitual bikers seem to bike during the winter. Even though there is fluctuation in number of bikers, there is an increasing trend of biking in Östersund. Record sales of e-bikes may have had an impact on a specific high number of yearly bikers. The bike path infrastructure system has been expanded from 1980 and forward in a slow pace. At the same time as the bike path infrastructure has been expanded, the number of bikers has increased so investments in the system seem to have had a positive effect on biking. The system is inconsistent and sudden ends are found on average every 2,03 km. However, it is possible not to meet a sudden end during a journey. This of course depends on the specific journey, but the average high density of sudden ends may be a threshold for biking. Over half of the population in Östersund has no longer than 100 m to a bike path so the bike path system is highly accessible and creates an opportunity for increased biking. Distance is an issue since over half of randomized journeys is over the limit that is considered comfortable to bike. The individual attitude and the specific journey of course matter, but long distances may create hesitation when considering biking.

Especially for non-bikers who have not developed a habit for biking yet. Östersund´s investments in increased biking focus on development of the bike path infrastructure and on trips longer than 20km. Investments on the infrastructure may result in an increase. For an investment in longer distances the individual biker´s habit need to change, sometimes in a fundamental way.

9.1 Recommendations and further studies

Östersund is on the right track and invests in biking with a focus on the bike path infrastructure system. Class 1 bike paths should be expanded since they receive higher levels of maintenance and bikers on these paths do not interact with motorized traffic and pedestrians have a dedicate area on the path. The sudden ends should be fixed and a goal should be to have no sudden ends at all. As a start focus should be on having a minimum of sudden ends at every 5 km.

The investment in journeys longer than 20 km might be futile since a comfortable biking distance is up to 5km. It would be better to invest in trips shorter than 5 km, especially in the inner city. A good idea might be to have parking spaces for cars where it is possible to either park your own bike or borrow a bike for further travel into the central city.

Development of a biking culture may help people to develop an individual habit for biking. How to develop a culture is a question that probably someone could spend an entire carrier on trying to answer. However, a start could be to make it easier for bikers and harder for cars to reach certain seemingly attractive points. What or where these points are remains unanswered in this thesis. Studies that focus on where people travel is of high interest in this case and could answer the previous question. Another interesting question that should be answered to solve the "bike increasing puzzle" is where people actually do bike and what bikers want. The development of a biking culture should emanate from bikers and not a non-biker that makes decisions in a warm office and comfortable chair.

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