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Gothenburg as a Bicycle Friendly City

Master's thesis in Infrastructure and Environmental Engineering

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Cover:
A pedestrian and cycle path within the inner city of Gothenburg, Vasagatan.

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Abstract

Cycling is an attractive transportation alternative with benefits including improved health and increased social interactions. Additionally, cycling is a transportation mode with low environmental impacts and occupies a limited space in traffic. A vision of the municipality of Gothenburg is that 75 % of the citizens should perceive the city as bicycle friendly. However, studies have shown that only 41 % have this opinion. To reach the goal of increasing the perception of Gothenburg as a bicycle friendly city, the aim of this study is to identify necessary factors for a city to be perceived as bicycle friendly. Further, critical factors for specific stretches within Gothenburg will be investigated.

This master thesis consists of several parts and methods. Firstly, a literature review and interviews are conducted to create an overview of important factors for a bicycle friendly city in general. These results are used to identify characteristics which in turn form a basis to create a structured interview in terms of a survey. The aim of the survey is to highlight lacking factors within the bicycle network of Gothenburg from a user perspective. The result of the questionnaire is analyzed to identify the most critical factors of the city, which are assigned to specific routes. In turn, the critical factors are simulated in a spatial analysis using assumptions including route choices from origins to destinations. Lastly, an observation is conducted to verify the results of the spatial analysis. Further, the aim of the observation is to study possible improvement measures for specific stretches of the routes.

The result of the literature review and interviews with experts, showed that high priority of cycle infrastructure and traffic safety, including orientability and passability, are important for a city to be perceived as bicycle friendly. The interview with the public sector verified that this also applies to Gothenburg. According to respondents of the survey, representing users, the bicycle network of Gothenburg is lacking in several aspects. Some examples of lacking factors are connectivity and continuity along the network, segregation from motor vehicles and pedestrians, proper lane width, and generally, the priority of cycle passability compared to other transportation modes. Further, the main critical factors associated with specific routes are connectivity and continuity, existence of cycle paths, and segregation from pedestrians. The spatial analysis shows that these factors are related to stretches gathered around the inner city of Gothenburg where various road users have to interact. Observation of selected routes verified that critical factors and associated stretches identified by users, coincide.

In summary, the main factors to achieving a bicycle friendly city are related to passability and traffic safety within the bicycle network. In Gothenburg, one of the main critical factors is connectivity and continuity along the network. The identified critical stretches, based on investigated factors, are mostly gathered around the central parts of the city. In conclusion, the analysis of this thesis has located and verified problems within the bicycle network of Gothenburg. Therefore, it is recommended to apply this method when investigating existing traffic situations and to further identify the potential for improvement.

Keywords: bicycling, bicycle friendly, bicycle infrastructure, critical, factor, route, stretch, traffic safety, Gothenburg.

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Linn Hermansson, Josefin Ngo, Gothenburg, May 2022

List of Concepts

Below is the list of concepts that have been used throughout this thesis listed in alphabetical order:

Cycle lane	Lane on a road only for cyclists/moped riders
Cycle path	Dedicated road only for cyclists/moped riders
Cycling facility	Space within the street that are designed for the movement of cyclists
Factor	A circumstance, fact, or influence that contributes to a result
Feature	A prominent part or characteristic
Green wave	Connected traffic lights to enable a consistent flow over multiple intersections
Orientability	The conditions of the environment and their impact on one's ability to orient oneself
Pedestrian and cycle path	A path dedicated for pedestrians and cyclists consisting of two separated lanes for cyclists and pedestrians respectively
Route	A way or course taken from an origin to a destination
Soft measure	Non-physical measure (e.g., promotion and marketing)
Streetscape	Visual elements that define the character of a street (e.g., road, adjacent buildings, and greenery)
Stretch	A part of a route or a network

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BP	Available and proper parking for bikes
CC	Connectivity and continuity along with the network
CL	Existence of cycle lanes
CP	Existence of cycle paths
DS	Clear directions and signs
IDK	I don't know
L	Extended lighting at cycle paths/lanes
LSZ	Low speed zones for motor vehicles
LW	Proper width of cycle lanes
MR	Maintenance of roads
OF	Other factor
PM	Appropriate paving material
SP	Segregation from pedestrians
SV	Segregation from motor vehicles

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1
Introduction

The introduction of the report consists of a background creating a context of the study, an aim clarifying the purpose, research questions that will be investigated to fulfill the aim, and limitations defining the scope.

1.1 Background

Prioritizing cycling in a city is a way of reaching both sustainability of the transportation system and from an environmental and health perspective. This is because of the bicycle's limited occupancy of space in the traffic room, its low emissions, and positive health effects in the form of daily exercise. A modal shift from driving cars to bicycling has a espacially high effect on sustainability, from both an environmental and health perspective. Further, since this would decrease the occupancy of space significant, congestion and delay in traffic would be reduced. According to Tight et al. (2011), the potential benefits of increasing cycling and walking within a city are extensive. The benefits include *"reduced local noise and air pollution, decrease in emissions of greenhouse gases, improved safety, better fitness levels of the population, as well as changes which are more difficult to quantify such as greater sociability of the urban environment, increased freedoms for children to use the environment and an overall improvement in urban quality of life."* (Tight et al., 2011, p. 1589).

The Municipality of Gothenburg has a goal that the city should have a bicycle friendly environment by the year 2025 (Göteborgs Stad, 2015). The goal includes that the majority of the citizens should consider Gothenburg as a cycling city. Along with this goal, the city is constantly expanding, the population growth is increasing and the urbanization entails that more targets are within walking and cycling distance. According to Göteborgs Stad (2022a), the number of inhabitants in the municipality will increase by around 20 % until the year 2040. This increase, and the changes that follow, require a more developed traffic network that prioritizes both walking and cycling as transportation modes to achieve sustainability.

The comprehensive document used for traffic planning in Gothenburg is the "Transport Strategy for a Close-knit City", which includes goals and directions aiming to make everyday life simpler in the city (Göteborgs Stad, 2014). This strategy is concretized when planning for action and investments and is the starting point for plans and projects related to different transportation modes. Cycling is included

in two out of three focus areas of the strategy consisting of "travel", where creating easily accessible regional centers is prioritized, and "urban space", where the goal is to create more attractive city environments. The importance of treating cycling as its own transportation mode, by giving it its own structure, is described as important to improve travel opportunities between major target points. This could be done by, for instance, separating cyclists from other road users or by prioritizing cycling compared to other transportation modes in situations where the space has to be shared. The strategy also stresses the importance of a commuting network with high standards, such as good passability and few conflicts with other modes. To create more comfortable areas, where people want to move around, the strategy stresses that the streetscape needs to be rearranged. One suggestion related to cyclists is to implement the concept of cycling speed areas, where motor traffic has to adjust to cyclists, in narrow streets. However, the strategy stresses that in some conflicts with pedestrians, the cyclists have to adjust to their speed. At specific locations where the cyclist's passability should be prioritized, separation from pedestrians could be done by redirecting cycle stretches or constructing multilevel junctions. Further, a gene and navigable network, without barriers is highlighted to create an attractive urban environment. For cyclists, this means a network that takes them close to their destination, which makes route efficiency, a dense network of cycle paths, and available parking in every block important.

As a concretization of the Transport Strategy, the traffic committee of Gothenburg, leading the Transport Administration, adopted a Cycle Programme year 2015 (Göteborgs Stad, 2015). In order to achieve the goal of the program, several measurements within the transport system are applied yearly. All measures are aiming to promote and facilitate cycling both through increasing the knowledge about cycling and through developed infrastructure planning. A plan of action for cycling is published every year, aiming to support the construction of a developed and coherent infrastructure for cycling, facilitate good standards of the cycling transport system around the year, offer services that increase the attractiveness of the transport mode, and to strengthen the image of Gothenburg as a cycle friendly city.

The plan of action includes both major changes to the infrastructure system, as well as minor implementations in order to facilitate cycling (Göteborgs Stad, 2022b). Focusing on the changes in infrastructure, the plan for 2022 includes measurements such as planning and constructing development of commuting stretches, where specified stretches are financed by Sverigeförhandlingen. Further, linking incoherent parts of the comprehensive cycling system, and planning for the construction of raised cycle passages to increase the passability and safety for the cyclist at selected locations, will be done. The plan includes both completing and further planning for increased parking including major development at the Central Station of Gothenburg. Lastly, one goal is to implement new pavements of around 15-20 km of cycle paths within the city in order to increase the standards of the transportation system.

Gothenburg was the municipality that received more funding for investment in commute biking compared to other municipalities in Sweden year 2021 (Rehnström,

2021). Despite this, and regardless the implementation of the Cycle Programme year 2015, the city still needs improvement in the cycle network in order for the environment to become bicycle friendly. According to Göteborgs Stad (2020), the yearly increase of bicycling needs to be 8.2 % to meet the goals of 2025. Today, the measured yearly increase of bicycling trips, between 2011 and 2020, is only 5.1 %. Further, the result of a survey investigation showed that only 41 % of the citizens think that Gothenburg is a bicycle friendly city. This can be compared to the goal of 75 % year 2025.

The popularity of cycling varies within Gothenburg. In the southeast part of the city, six out of ten citizens are cycling, and in the northeast, only three out of ten consider themselves cyclists (Göteborgs Stad, 2020). This can be compared to statistics for Copenhagen, where two out of three Copenhageners are cycling (Haustein et al., 2020). According to Haustein et al., the major factors why the cycling level is high in the city are the high safety, security, and the priority of planning for cycling. Cycling in Copenhagen has increased by 30 % since 1998 while injuries related to cycling have been reduced by 33 % (Andersen et al., 2018). The cycling strategy of Copenhagen is one example of an implementation that has entailed a positive cycling perception among the citizens, which has significantly increased the cycling generation. In other parts of the world, such as Copenhagen, strategies can be studied and potentially applied in order to improve the cycling conditions in Gothenburg.

1.2 Aim and Objectives

The aim of the master thesis is to identify necessary factors needed to achieve a bicycle friendly environment in a city. Further, the perception of the bicycle network in Gothenburg according to traffic network users is investigated. Additionally, the study aims to identify specific routes and stretches within Gothenburg which are considered critical. Further, possible improvement measures for critical stretches are studied. In order to fulfill the aim, the following research questions will be studied:

- Which factors are needed to achieve a bicycle friendly city?
- What is the perception of the bicycle network in Gothenburg based on identified factors, according to the users?
- Which bicycle routes or stretches within Gothenburg are critical based on identified factors, and how can they be improved?

1.3 Limitations

The study will investigate what is needed to achieve a bicycle friendly city including various perspectives. Although, results along the way will limit further analyses and discussions. When investigating possible improvement measures, the perception of a user of the bicycle network is prioritized. However, the interaction with other road users is taken into account. An additional boundary of the study is the geographical area. When identifying critical routes or stretches, associated with critical factors, the delimited area includes the bicycle network of Gothenburg municipality.

1.4 Outline of the Report

- Chapter 1, *Introduction*: Presents the background, aim, research questions, and limitations of the study.
- Chapter 2, *Literature Review*: Summarizes previously conducted studies related to factors necessary to achieve a bicycle friendly environment in a city.
- Chapter 3, *Methodology*: Presents the conduction of the study, including a qualitative research consisting of interviews and a questionnaire, and a spatial analysis including a physical observation.
- Chapter 4, *Analysis*: Contains results and analyses of the interviews and the spatial analysis.
- Chapter 5, *Discussion*: Discusses the result based on the research questions of the study. Further, potential uncertainties, biases, and related impacts are discussed.
- Chapter 6, *Conclusion*: Answers the research questions of the study, and contains recommendations for future research.

2
Literature Review

This section summarizes previously performed studies in cities around the world, related to the topic investigated in this study. The earlier conducted studies mainly analyze and present necessary factors in order to achieve a bicycle friendly environment in an urban area. However, various other aspects related to bicycling are introduced as well. Both the methodology and the results of the literature review are presented in this section.

2.1 Methodology

The literature review was conducted to create a framework for the thesis. The search was based on the keywords cycling, sustainable, city, and factor. The keywords formed search strings in different constellations, and were used in order to obtain relevant documents. However, when the search strings were applied, additional modifications of the keywords and their combinations were made to improve the research further. The search strings of the literature review are presented in Table 2.1.

Table 2.1: Search Strings

1	(cycling*) AND (sustainable* OR environment* OR emission*) AND (city OR urban)
2	(cycling*) AND (increase* OR develop*) AND (criteria* OR factor*) AND (city* OR urban OR society)
3	(cycling*) AND (increase* OR impact OR saving*) AND (city* OR urban OR society) AND (emission*)
4	(cycling*) AND (city* OR urban OR society) AND (safe*)

The research included both scientific papers and gray literature. Further, the articles with relevant titles were screened through, and the irrelevant documents were discarded. In turn, the screening led to the decision of either further reading of the paper, or not. Search engines such as Google, Google Scholar, and Scopus were used for the literature review. The software Mendeley Reference Manager preserves a clear overview of all documents, and was therefore used to obtain a structured

management of the found references. Furthermore, a systematic literature review was conducted, where strategies such as snowballing was applied as this provides more quality to the research.

2.2 A Definition of a Bicycle Friendly City

A fundamental development goal of contemporary cities is the conversion to a bicycle friendly city where cycling is considered as a primary transportation mode (Zayed, 2016). A study was conducted where the scope was the urban readiness of cities to be bicycle friendly. The study focused on the factors of socioeconomic and urban characteristics that have to be present in order for cycling to be considered a primary mode of transport. Zayed (2016) analyzed 20 bicycle friendly cities, resulting in identification of the main requirements for urban cycling. The definition of a bicycle friendly city was presented as a city with efficient infrastructure, transportation policies, and societal consensus to make cycling a primary means of transport. Further, a bicycle friendly city was described as a city that has authorities prioritizing a people and environment friendly city, rather than a car friendly city. The bicycle friendly city also has a dedication of creating bike lanes with suitable spacing. By fulfilling these conditions, the result would be that the bicycle is a realistic transportation mode, particularly for short trips. Furthermore, the study showed that cycling provides benefits including urban mobility, environment, health, and social aspects. The presented aspects are further explained in this literature review.

2.3 Identified Factors

The following section presents important factors needed to achieve a bicycle friendly environment, that has been identified in the investigated studies. The factors are related to bicycle infrastructure and traffic safety.

2.3.1 Bicycle Infrastructure

In a study made by Yang et al. (2019), 39 earlier studies focusing on the association between built environment and cycling, conducted between the years 2007-2017, were reviewed. The aim of the review was to identify factors of infrastructure that could potentially have an impact on cycling generation. The reviewed studies were performed in different countries, however, most of the investigations were conducted in the United States, Belgium, and Australia. The results showed that, throughout all 39 studies, there was a high correlation between street connectivity and cycling frequency, including commuting cycling, where an improved connection of bike lanes resulted in an increased amount of cycling. Furthermore, the existence of cycle paths and facilities within the environment were additional factors that were considered the most important in order to generate both general and commuting cycling.

The current cycling network in Shiraz, Iran, has been considered ineffective since it is rarely used by cyclists (Paydar et al., 2021). A study was made to identify and rank

features (criteria) and associated factors (sub-criteria) within infrastructure based on their relation to cycling behavior. The method consisted of a Delphi study, where panels and experts were surveyed to present a group opinion, in order to analyze and conclude the identified features and factors related to bicycling behavior. Furthermore, an Analytic Hierarchy Process, a tool that is based on the pairwise comparison by experts, was used to weight the features and their related factors. The findings of the study showed that the physical infrastructure of the cycling network and traffic volume was the feature most related to cycling behavior. This included the related factors, listed in ranking order:

Proper width of whole passageway including street and the walkways
Types of street and their relative traffic volumes
Standard path width for biking
Appropriate paving material for biking network
Connectivity and continuity along with the cycling network
Separation of street side parking and biking path
Available and proper parking spaces for bikes" (Paydar et al., 2021, p. 6).

Hull and O'Holleran (2014) investigated whether the good design of cycle infrastructure increased cycling in a city. Six European cities were compared in terms of bicycle infrastructure against an adapted Level of Service, where accompanied ride-along was used. The investigated cities were Edinburgh, Cambridge, Amsterdam, Rotterdam, The Hague, and Utrecht. Firstly, a literature review was made to identify factors that either encourage or dissuade cycling. The review showed that the deciding feature was the cyclist's perception of safety in the neighborhood. However, the literature review also showed that contextual factors of the infrastructure design can encourage more cycling. The research comparison included coherence, directness, attractiveness, safety, and comfort. The conducted literature review was used to derive a scoring system used by the researchers during the investigation. The cycling investigation was performed by the researcher, an experienced cyclist, together with an inexperienced cyclist. The ride-along showed that the urban environment was perceived differently by cyclists with different amounts of experience. However, the study was not performed by a sufficient number of persons, which was seen as a limitation. To conclude, the study showed that the strongest drivers for uptake of cycling is formed by safety, comfort, continuity, and speed. Upgrade and maintenance of the infrastructure were also found to be important, particularly surface maintenance since this affects the safety and comfort perception. Lastly, the following were recommended consider when designing cycle infrastructure:

- *"Wide cycle lanes.*
- *Direct routes connecting all land uses.*
- *Segregation where possible, especially on trunk roads and busy centre roads. Segregation does not have to be expensive. Bollards/vegetation can offer segregation through provision of a visual deterrent from driving and parking in cycle lanes. Adoption of the Dutch guidelines for cycle infrastructure.*
- *Clear signage. Include signage in order to join a cycle lane.*

- *No discontinuities of cycle lanes at hazardous locations (Junctions and roundabouts).*
- *For intersections implement either a system to bypass the danger or provide bicycle priority traffic lights.*
- *Use of high quality material for cycle lanes can offer comfort and reduce maintenance.*
- *Speed barriers that are visible (night) and do not make the cyclist dismount.*
- *High quality lighting on darker cycle lanes.*
- *Attractive settings, e.g. Greenery and place making.*
- *Frequent and high quality bicycle parking, not just at transport hubs.*
- *Design of end of route facilities to be discussed with business and employers. (showers, bike storage).*
- *Funding needs to be forthcoming, otherwise good quality infrastructure cannot be implemented.*
- *Don't implement cycle infrastructure as an add-on. Consider when designing all transport mode networks."* (Hull & O'Holleran, 2014, pp. 385–386).

2.3.2 Traffic Safety

An example where strategic planning of cycling infrastructure entails an increased cycling generation is Copenhagen (Andersen et al., 2018). The city has invested heavily in the cycling infrastructure where safety is the main priority in the built environment. This has according to Andersen et al. (2018, p. 222) *"contributed to cycling being socially desirable in all age groups, in women, children and elderly and all socio-economic strata"*. Factors for a safe and convenient cycling city were studied during 2006-2011 in Seville to understand the effect of the bicycle network on the city's mobility (Marqués et al., 2015). The study presented infrastructural factors including segregation from motorized traffic, connectivity, continuity, visibility, uniformity, bi-directional traffic, and comfort. It also showed that the design of the infrastructure had to accommodate everybody, not just present cyclists. In order to satisfy the needs of everybody, the mentioned factors had to be fulfilled. According to Paydar (2021), traffic safety along the network was the second most important feature to increase the cycling at desirable stretches. This included factors, listed in ranking order:

"No presence of motorcycles on the cycle path
Presence of horizontal and vertical safety signs and traffic light
Good separation of cycling pathways from motorized traffic
Presence of middle islands for crossing" (Paydar et al., 2021, p. 6).

Subjective safety perceived from infrastructure design is not well researched (von Stülpnagel & Binnig, 2022). Therefore, a study in Berlin was performed by von Stülpnagel and Binnig, addressing this question. The researchers analyzed data retrieved from a large-scale online survey. The survey was based on images illustrating different cycle infrastructure designs, where the participants rated the images based

on the perceived subjective safety when imagining cycling at the different locations. The survey included around 1,900 images where different combinations of infrastructure factors were illustrated. Since the survey took place during autumn, the images conveyed an autumnal look, where the weather conditions always were the same, dry with a light but slightly overcast sky. Demographic data of the participants were included, such as gender, age, and if the cyclist had children. Furthermore, each participant rated ten random pictures at the scale 0 = 'unsafe'; 1 = 'rather unsafe'; 2 = 'rather safe'; 3 = 'safe'. The included factors of the study are listed below.

- Speed limit
- Street type
- Cycling lane type
- Cycling lane width
- Cycling lane surface
- Left cycling lane buffer
- Right cycling lane buffer and parking

The results of the survey showed that cycling tracks were considered safer than cycling lanes, however, they require more financial resources (von Stülpnagel & Binnig, 2022). However, compared to the results of the locations without cycle lanes, both cycleway types, tracks, and lanes were perceived as very safe. The demographic factors showed that the perceived subjective safety increased with increasing age, male participants felt safer than females, and cyclists with children felt less safe than those without children. Furthermore, the conclusions of the study were that many factors of the cycle infrastructure affect subjective safety. The main factor was the importance of having enough space on the cycling lane. However, extensive indications of buffers were not appreciated, particularly if the cycle lane was already narrow.

2.4 Cycling Behavior

A study performed in Stockholm and Copenhagen compared the cycling culture in the two cities (Haustein et al., 2020). Firstly, characteristics of the capitals were studied in terms of e.g., inhabitants, population density, bicycle sharing services, and density of cycling infrastructure. The cycling behavior and its potential factors were identified based on surveys that were answered by citizens over 18 years old in both cities. The result showed that the cycling perceptions were significantly more positive in Copenhagen compared to Stockholm. Further, the cycling frequency was also higher in Copenhagen. The explanation of this result was that inhabitants in Copenhagen feel safer and prioritized in the transport system to a greater extent than the inhabitants of Stockholm. According to Trafikverket (2014, p. 6), generally, the cyclists in Sweden have *"been frequently forced to adapt themselves to a road transport system that is basically not adapted to their requirements"*. Further, the inhabitants of Copenhagen think of cycling as a more efficient way of reaching their

destination. The city is built so that the fastest transportation mode for all trips with a distance below 10 km, is cycling (Andersen et al., 2018). However, according to Haustein et al. (2020), the difference in cycling frequency is not only affected by cycling infrastructure. The difference is also related to the overall cycling culture in a city. The two cities have different cycling policies where Copenhagen has a higher priority on cycling, which appears to affect which mode the citizens choose.

To better understand the real behavior of cyclists and their perception of the environment, and thereby be able to identify factors that impact their route choice, Desjardins et al. (2021) performed a qualitatively study in Hamilton, Ontario. The bicycling levels of Hamilton are significantly low compared to other cities in Canada. However, the city has developed its cycling infrastructure, and around 15-20 km of cycling infrastructure is constructed yearly. Further, policy measures promoting and normalizing cycling have been implemented. The qualitative study was based on semi-structured interviews. 14 citizens participated, selected out of responses on a Twitter post, and post-its found in bike stores and coffee shops. The participants fulfilled two criteria which included age over 18 and bicycling for transport, not only for recreational purposes, at least once a week. In the interviews, the participants were asked to answer general questions about cycling behavior and their thoughts about the built environment in the city taking three themes into consideration, (1) exclusion of road space, (2) infrastructure, and (3) streetscape. The results of the interviews showed that the built environment of Hamilton today, does not meet the preferences of the cyclists. The cyclists highly valued separation from cars and chose routes that minimized this interaction. The majority of the interviewed cyclists reported experiencing unpleasant conflicts with motor vehicles, which decreased their willingness to cycle in the city. Another factor that some of the interviewees highlighted was the provision of parking at the destination. While some cyclists did not think of this as a crucial factor, they still valued this as important. Furthermore, the cyclists preferred more nature and human-orientated environments during their cycling routes.

2.4.1 Equity

Cycling as a transportation mode is increasingly prioritized in Canada (Doran et al., 2021). However, the distribution of the benefits associated with cycling is not equally divided throughout society. The infrastructure does not accommodate all members of society, e.g., low-income earners, immigrants and people of color, women, and seniors. The conducted study reviewed earlier academic literature, as well as the city-level transport, in order to investigate whether the transportation plans in Canada consider equity. Further, the review aimed to investigate if planning practice can more effectively provide equity. The study mentioned *"Findings from the review of Canadian transport plans revealed four key themes related to how plans can, and do currently address equity, including (1) socio-spatial network analysis (2) consideration of equity in projects and priorities, (3) equity-oriented funding mechanisms, (4) inclusive design and safety."* (Doran et al., 2021, p. 1). Findings of the review showed that most plans do not address equity sufficiently enough,

or at all. However, the studied academic literature showed that cycling equity could increase if measures are implemented. Examples of tools that could increase equity are effective analysis, as well as measurements adapted locally to address the concerns of the residents, especially the most disadvantaged.

2.5 Public Authorities Initiative

The following section presents different public authorities initiatives categorized as *Traffic Calming*, *Bike Sharing*, and *Promotion of Cycling*.

2.5.1 Traffic Calming

Between 2006 and 2011, Dublin implemented several policies and changes to infrastructure to promote cycling (Caulfield, 2014). Some of the implementations included traffic calming measures in order to create a more bicycle friendly environment in the inner city. Concrete examples of the implementations were lowering the speed limit in the city center to 30 km/h, and the city council constructed a freight tunnel that redirected heavy goods vehicles out of the inner city year 2006. A data analyzed-based investigation studied the potential cycling increase in Dublin after the implementations by analyzing work trip data during the 5 year period. The result of the study showed that the cycling rate increased during this period, which could be an outcome of the traffic measures implemented to promote cycling. The main increase was identified in the city center of Dublin, where most of the implementations were made. Furthermore, the study showed that two of the key target groups, females and citizens with high enough income to own a car, had increased their cycling between 2006 and 2011 by 5 %. However, since this study only included work trips and thereby excluded general cycling, the results may underestimate the increase of the key target groups and the total cycling increase in the city. Further, since more implementations beyond traffic calming were implemented in Dublin, the increase in cycling generation is probably an effect of the measures working together rather than traffic calming working alone.

2.5.2 Bike Sharing

One of the initiatives implemented in Dublin between 2006-2011 was bike sharing systems (Caulfield, 2014). This included bike rental and purchasing schemes placed throughout the city. In 2011, there were 550 shareable bicycles spread out over 44 stations within the city. The measure has been proved to be a successful implementation with over three million trips in the first three years, where the main area of use is commuting. However, the study mentions that the main transport mode that the bike sharing schemes in the city replaced was walking and public transit. This substitution did not include the key target groups since it does not entail improved sustainability. Although, the city is planning to develop its bike sharing system and increase the number of stations to 102 which entails 1500 rental bikes.

Marqués et al. (2015) studied cycling in Seville between 2006-2011. The bike sharing system of the city, Sevici, was implemented in 2007 with immediate success. The bike sharing became an important part of the city's cycling infrastructure. The sharing system *"is indeed a third generation system, conceived as an "individual public transport system""* (Marqués et al., 2015, p. 35). The bikes within the sharing system are described as a 24-hour almost door-to-door everyday service with a high density of stations. Further, the system was designed to favor the connections of the traditional public transportation system, where the locations of the bike sharing stations always would coincide with the stations of the public transportation.

Bike sharing was an aspect included in the study made in Cincinnati, where different stakeholder criteria regarding the implementation of protected bike lanes were identified and analyzed (Zuo & Wei, 2019). In order to increase the connectivity within the cycling network, one of the important criteria for cyclists was that bike share stations should be available regardless of the destination. For transit users, one of the criteria in order to improve the connection between bicycling and transit, was bike sharing access to the transit service.

2.5.3 Promotion of Cycling

Dublin has used the promotion of cycling to improve the cycling culture in the city (Caulfield, 2014). Together with other measures, this has entailed an increase in the bicycle frequency during a studied time period of 5 years. The promotion is proven to be one of the key implementations in order to encourage bicycling in the city. "Bike Week" is one of the largest initiatives including several events that are being organized nationally every year since 2009. During "Bike Week", planned family cycling is arranged, traffic is removed from the streets in order to facilitate cycling, clinics for bike repair open, and several talks and events are performed at schools around the country in order to inspire children to increase their bicycling.

2.6 Different Stakeholders

It can be challenging to obtain additional space to develop the bike network in already built urban areas. Different stakeholders have different perceptions of the construction in need of consideration. A study that included a specific case in Uptown Cincinnati, Ohio, conducted by Zuo and Wei (2019), identified stakeholders and their criteria related to the implementation of traditional and protected bike lanes. The investigation aimed to present a systematic planning analysis to increase the connectivity within the bicycle network and improve the connection between transit and bicycling, with minimum effect on the motor vehicle and cost. A Multi-Criteria Decision Analysis was used as a tool to justify which bike lane type, including the varying level of traffic stress (LTS), that should be implemented in the studied area based on the criteria related to the affected stakeholders. Different LTS were used to describe the stress level of cyclists and cycle compatibility. 1-4 LTS levels were included in the study, presented below:

"LTS 1: tolerated by most children
LTS 2: tolerated by mainstream adult population
LTS 3: tolerated by American cyclists who are "enthused and confident" but still prefer having their own dedicated space for riding, and
LTS 4: tolerated only by characterized as "strong and fearless"" (Zuo & Wei, 2019, p. 54).

In this study, protected bike lanes were defined by fulfilling the LTS 1 level, while traditional bike lanes could vary between levels 1-4. This definition of LTS related to bike lanes was complimented with designated spacing requirements presented below.

Traditional bike lane

- *"When adjacent to a parking lane, the desirable reach from the curb face to the edge of the bike lane is 14.5 feet, the absolute minimum is 12 feet.* (14.5 feet=4.4 m, 12 feet=3.7 m)
- *A bike lane next to a parking lane shall be at least 5 feet wide, unless there is a marked buffer between them. The desired minimum is 6 feet.* (5 feet=1.5 m, 6 feet=1.8 m)
- *The desirable ridable surface adjacent to a street edge is 4 feet, with a minimum width of 3 feet."* (4 feet=1.2 m, 3 feet=0.9 m) (Zuo & Wei, 2019, p. 59)

Protected bike lane

- *"The desirable width for a protected bike lane should be at least 5 feet and 7 feet for areas with high bike volumes or uphill* (7 feet=2.1 m)
- *Three feet is the desired width for a parking buffer*
- *Where adjacent to a parking lane, the desired combined width of parking lane and buffer is 11 feet"* (11 feet=3.4 m) (Zuo & Wei, 2019, p. 59)

The study included the following stakeholders; bicyclists, transit users, motor vehicle users, and investors. One criterion that was important for bicyclists was the connectivity of low-stress bike paths between origins and destinations (Zuo & Wei, 2019). Considering transit users, they prioritize cycling access to the transit service while the motor vehicle users want less delay in traffic. The criteria related to investors is the capital cost of the implementation of the bike lane. With respect to the criteria of each stakeholder, several implementations were proposed within the studied area. It is also concluded that the suitable development approach varies with conditions e.g., land use, level of traffic, and transit provision. As an example, on local streets, where there are few concerns of congestion, the criteria of traffic delay do not need to be prioritized. The final conclusion of the study is that protected bike lanes are significantly favorable for bicyclists and transit users. However, other aspects could be of more importance for other stakeholders.

2.7 Cost

A second conclusion of the analysis in Cincinnati was that, though the implementation of protected bike lanes is beneficial for bicyclists and transit users, higher

costs and traffic delays also need to be considered in order to meet the criteria of potential investors and motor vehicle users (Zuo & Wei, 2019). The implementation of a protected bike lane usually generates a higher cost than the implementation of a traditional bike lane. Further, in central areas where the construction cost tends to be higher, the cost aspect should also be prioritized in line with increasing the bicycle network connectivity and transit-bicycle connection.

The study conducted by Marqués et al. (2015) in Seville during 2006-2001 identified an additional factor that would improve the bicycle infrastructure. *"Our analysis also suggests that the fast building of this type of infrastructure provides solid grounds for the development of utilitarian cycling, with high cost effectiveness, even in a city without a previous tradition in this sense."* (Marqués et al., 2015, p. 1). The fast implementation of construction would avoid that unused space from being used for other unexpected purposes. This effect is even more critical for more compact cities where space is highly demanded. An example of an unexpected purpose could be motorbike parking which would make the space useless for cycling. Therefore, efficient use of the bicycle infrastructure is also cost-efficient and improves the cycle network in general.

The cost of certain transportation modes could be a decisive factor in mode choice. As an example, according to a study performed in Bogotá, Colombia, by Masskink et al. (2011), trips to schools and universities most likely happen by walking or cycling since this type of traveler has limited mode choice options because of economic boundaries. 85 % of the participants included in the study were from the lower socio-economic strata, and 97 % of the cycling trips made in the city were performed by this group. The cycling trips by higher socio-economic strata are fewer but significantly longer compared to the lowest class. These findings indicate that economic circumstances could be a distinctive factor for cycling.

2.8 Advantages of Bicycling

Various advantages of bicycling are presented in the following sections categorized as *Health*, *Environmental Impacts*, and *Comparison to Car Trips*.

2.8.1 Health

According to Oja et al. (1998), both walking and cycling when commuting to work can be seen as a health-enhancing physical activities (HEPA). The definition of HEPA is 30 minutes, or more, of moderate-intensity exercise on a daily basis. Commuting to work by walking or bicycling mainly improves the cardiorespiratory and metabolic fitness of adults that previously were more sedentary. Due to the higher intensity of cycling, this transportation mode has higher effectiveness on health improvement compared to walking. One of the main conclusions of the study is that promoting walking and cycling as the main commuting mode is an effective way of increasing people's HEPA. This can be done by informative strategies and by highlighting the health-related benefits of the transportation modes. The study

showed that the main reason for not choosing to walk or cycle when commuting is the perception of poor and unsafe conditions. Therefore, improved safety of walking and cycling routes are identified as major determinant factors to generate this type of commuting.

In a study, including the four largest cities in Denmark, the relationship between increased cycling and injury rate of cyclists was analyzed and compared with potentially prevented disease and mortality because of the health effect of cycling (Andersen et al., 2018). The studied diseases were type diabetes 2 (TV2), cardiovascular diseases (CVD), and cancer, however other diseases were excluded because of lack of data. The result of the study showed that 3328 cases of TV2, 5742 cases of CVD, 2076 cases of cancer, and 6190 deaths were prevented because of health benefits from cycling each year in Denmark. This was compared with 26 deaths of cycle-related traffic injuries, 835 reported injuries of 297 light injuries year 2015. Therefore, the health benefits from cycling were 21 times higher than the risk of injuries and, 238 times higher compared to mortality. However, the calculations of prevented disease and mortality came with a large uncertainty since it is difficult to make a conclusion about causality.

2.8.2 Environmental Impacts

Carbon dioxide, CO_2, emission is one of the largest climates challenges today (Massink et al., 2011). The contribution of the transportation sector is around 23 % of the global CO_2 emissions and is continuously growing as a result of developing economies and increasing vehicle ownership. Since bicycling has an intrinsic zero-emission value, substituting other transport modes with cycling can contribute to a reduction of emissions. A method developed in a study, based on a specific case in Bogotá, Colombia, enables the estimation of a climate value of cycling based on replacing cycling trips with other modes. The result of the climate values was presented as additional CO_2 emissions that were based on data related to the current mode share of cycling mobility, a comparison to other transportation modes, and CO_2 emissions factors used to estimate climate values. In the specific case of Bogotá, the motorized and emitting transportation modes accounted for around 97 % of all trips made within the city. The motorized modes contributed to around 6,500 tons of CO_2 emissions daily. However, the main transport mode was the public bus, accounting for 60 % of the total traffic movement. The modal share of bicycling was 3.3 % of the total amount of daily trips which was 10 million. The climate value of cycling was calculated to be 151 tons daily in total, and around 55,000 tons CO_2 yearly, which can be seen as avoided emissions if choosing this mode over other alternative modes. The distribution of the most dominating alternative modes up to 2 km was around 43 % walking, 29 % bus, and 16 % car. Further, the alternative mode differed due to several purposes. The bus was the most dominating alternative for business, personal, return home, shopping, education, and work-related trips, while walking and car were the second and third most important modes.

A study made in Cardiff, Wales, investigated the potential of mitigating the greenhouse gas emissions by substituting short car trips with walking and cycling in the city (Neves & Brand, 2019). The study identified all trips made by 50 participants during a 7-day period in the years 2011 and 2012. Both a quantitative method, including GPS data, and a qualitative method, based on semi-structured exit interviews, were combined creating a mixed-method approach. A total of 2662 trips were identified of which 59 % were less than 3 miles (which approximately corresponds to 4.8 km), which in this study was defined as a short trip. Further, nearly half of all the identified car trips were shorter than 3 miles. Out of these short car trips, 41 % were identified as replaceable with cycling and walking. The substitution would entail a 5 % saving of CO_2 emissions from all the studied car traveling. Also, eleven of the participants used cycling as their everyday transportation mode. If these eleven would have been using their car instead, the CO_2 emissions would increase by 4 %. Lastly, the study mentioned wider environmental impacts of using cycling and walking as for instance "co-benefits" of improved air quality, reduced noise, and mitigated use of fossil fuel.

2.8.3 Comparison to Car Trips

According to Schepers and Heinen (2013), a modal shift from car trips to bicycles could result in more traffic injuries. The study reported that the most increasing accident could be single accidents of cyclists, with no car present. The investigation also mentioned that the effect of such a modal shift can be influenced by improvement measures implemented in order to decrease the risk of injuries for cyclists. This highlights the importance of adjusting the infrastructure for cyclists to make the environment safer.

The findings of a study in Cardiff, where the potential of replacing short car trips with cycling and walking was investigated, showed that nearly half of all car trips made within the city were shorter than 3 miles (4.8 km) (Neves & Brand, 2019). In the study, the average distance for cycling is estimated to be 4.1 miles (approximately 6.6 km). This means that some of the identified short car trips could be replaced by cycling. However, the study excluded trips with purposes that require a car. Residents that were interviewed in the study highlighted *"time constrains, convenience, need to carry heavy goods, giving a lift to passengers, escorting children (to and from school, day care facilities or leisure activities) or due to lack of feasible transport alternatives"* (Neves & Brand, 2019, p. 136) as main reasons of why they chose the car for short trips. They also stated that using the car for shorter trips was preferable since it did not require physical effort or was perceived as a safer alternative than cycling or walking. Therefore, trips, despite being shorter than 3 miles, that involved escorting and shopping trips to large retail areas and, in the cases when the resident was a passenger, were not seen as replaceable with cycling or walking. However, short car trips to local shops were defined as potential replaceable trips. This was based on the assumption that local shopping with a higher frequency entails lighter goods weight, which is more manageable when cycling or walking.

2.9 Sweden

The following chapter presents studies conducted in Sweden. The sections are categorized as *Cycling Development 1995-2014*, *Compilation of Cycling Data 2019*, and *The National Cycling Strategy*.

2.9.1 Cycling Development 1995-2014

According to Trafikanalys (2015) the cycling development trend in Sweden has decreased from the time period of 1995-2014. Trafikanalys made an investigation of the cycling development between these years in general but also based on municipality, age, gender, trip purpose, distance, and season. The analysis showed that the total amount of daily cycled kilometers has decreased by 16 % in the studied period of 2011-2014 compared to the 1990s, from 6.3 million to 5.3 million. The total amount of cycling trips generated in the country decreased by 34 % over the studied period. It is worth noting that this decrease happened along with ongoing population growth in the country.

Considering age, the study showed that children and young adults decreased their cycling between 1995-2014 (Trafikanalys, 2015). Children in the ages of 6-14 years cycled 42 % less at the end of the studied time period and young adults in the ages of 15-24 years, 46 % less. Other age groups have either stayed at the same level or returned to the same generation level after a temporary decrease. The study also showed that men tend to bicycle more than women and that the difference grew from 20 % in 1995, to 40 % in 2014.

According to Trafikanalys (2015) 58 deaths related to cycling occurred on average, yearly between 1995-1998 and the average cycled kilometers was 2.3 billion, which entails a death rate of 25 per billion cycled kilometer. During the studied time period 2011-2014, there were 23 deaths and 1.9 billion cycled kilometers per year, which resulted in 12 deaths per billion cycled kilometers. Therefore, the risk of dying in a bike-related accident has more than halved.

2.9.2 Compilation of Cycling Data 2019

According to a compilation of cycling data, gathered during the year 2019 by Trafikverket (2019), the cycling trend in Sweden has changed and an increasing frequency has been established. The population cycled around 2.7 billion km during 2019, which corresponds to around 7.4 million km on an average day. This is only around 2 % of the total transportation distance including all other transportation modes except for flight. On an average day, around 11 % of the population is cycling on a daily basis. The cycling generation is to some extent related to season, where around 14 % are cycling daily during the summer and 9 % during winter. Further, men cycled around 25 % longer during 2019 compared to women. The study stated that the number of daily trips decreased in the time period 2005-2016, but the comparison of this data with data from 2019, showed a clear increase.

When including all trips in Sweden (walking, car, public transport, motorcycle, and flight), around 11 % of the trips are made by bike (Trafikverket, 2019). Considering shorter trips, up to 5 km, around 20 % of the trips are made by bike and around 17 % for trips up to 10 km. It is mainly the young generation that bicycle as a daily transportation mode. On an average day, 16 % of people between the age of 6-24 years are cycling while the share is less for people in their middle age and even less for elders.

According to Trafikverket (2019), cycling generated the more amount of injuries during 2019 compared to other transportation modes including walking, personal car, moped, motorcycle, and truck/bus. While the rate of severe injuries has decreased e.g., for car driving, the rate has slightly increased over the last years for cycling. The most common type of accident is the single accident which constitutes 80 % of the severe injuries. These cycle-related accidents constitute half of all severe accidents in the country including all transportation modes. Considering mortality, 17 cyclists died in a cycling-related accident during the year which results in a rate of around 6 deaths per billion cycled kilometer.

2.9.3 The National Cycling Strategy

The National Cycling Strategy of Sweden was published in 2017 with the main purpose of increasing cycling within the country and increasing its safety (Näringsdepartementet, 2017). In order to meet this goal, the strategy expresses the ambition of the government and aims to support the involved stakeholders to take responsibility. The strategy intends to function as a platform to continue the joint work and should be followed up and further developed. The content of the strategy is based on close and broad dialogues with municipalities, non-profit organizations, authorities, and other involved stakeholders. Five so-called "focus areas" in order to increase cycling and its safety are presented in the strategy:

- *Highlight the role of bicycle traffic in community planning.*
- *Increase focus on groups of cyclists.*
- *Promote a more functional and user-friendly infrastructure.*
- *Promote safe bicycle traffic.*
- *Develop statistics and research* (Näringsdepartementet, 2017, p. 16).

The goal of the strategy has been followed up through an investigation of the possibility of practical implementations in society. For example, a new law states that cyclists over 15 years can use general traffic lanes, with a speed limit of up to 50 km/h, even if there is a bike lane available (Balkmar, 2020). If the speed limit is higher, the cyclist can use the general traffic lane if it facilitates the cyclist to reach the destination. The government also examined the possibility to adopt specific cycling speed streets, where the cyclists are prioritized before other modes (Näringsdepartementet, 2017). Furthermore, the strategy highlights the importance of developing the existing infrastructure that forms the current bicycle network and creating new connections based on the needs of different cycling groups. The importance of giv-

ing cyclists a dedicated lane is also mentioned. However, the implementation of soft measures, such as communication and information, are also stated as important factors to reach the goals of the strategy.

Even though the overall goal is to increase the general cycling in the country, by reaching both already experienced cyclists and non-cyclists, the strategy has pointed out some key target groups (Näringsdepartementet, 2017). Children and young people together with asylum seekers and foreign-born residents, are pointed out as potential future cyclists and are considered extra important. The main goal of the strategy is, however, by improving the safety of cycling within the country, to increase the cycling rate independently of the group of people. In order to reduce the death rate of cyclists and reduce collisions with motor vehicles, the use of helmets, separation from motor traffic, and safe passages are stated as important.

2.10 Summary

This section summarizes the main findings of the literature review. One major finding is that the main important features of a bicycle friendly environment in a city are proper bicycle infrastructure and traffic safety. These features are interrelated and to enable them, various factors need to be fulfilled. Several identified factors are important from both perspectives, see Table 2.2.

Table 2.2: Summary of Identified Factors

Bicycle Infrastructure
Connectivity and continuity along with the cycling network
Existence of cycle paths
Proper width of cycle lanes
Available and proper parking space for bikes
Segregation from motor vehicles
Appropriate paving material
Traffic Safety
The presence of the identified factors defining proper bicycle infrastructure, also increases the perceived safety. Additional factors presented in the literature review that would increase traffic safety further, are maintenance of roads, presence of safety signs and traffic lights, and prioritization of cycle infrastructure in the built environment.

The bicycle infrastructure and the perceived traffic safety, affect the cycling behavior, and in turn, the cycling culture of a city. When city planning, prioritization of cycling results in positive cycling culture. Although, studies show that the preferences of cyclists are not always met. The benefits associated with cycling are neither equally divided, where infrastructure does not accommodate all members of society. However, the studied literature shows that equity could increase if measures are implemented. Furthermore, there are cities with various public authorities initiatives, such as traffic calming, bike sharing, and different promotion techniques. Some of the studied initiatives have been successful, others have not. The sharing bike schemes have mainly replaced walking and public transit users, which are not the main target groups, while traffic calming increases the safety for cyclists, and promotion is encouraging cycling. Comparisons of stakeholders have shown that different stakeholders have different priorities, where cost issues can become relevant. The cost aspect should be prioritized differently depending on the situation, where construction tends to be more expensive in central areas.

The main advantages of bicycling highlighted in the literature review are health, and environmental impacts, particularly when compared to car use. Several studies show positive health effects when cycling, which could become a part of one's daily routine by cycle commuting. Concerning the carbon dioxide emissions within the transportation sector, changes have to be made. Bicycling has an intrinsic zero-emission value, which does not contribute to emissions, unlike other transportation modes. "Co-benefits" of bicycling are improved air quality, reduced noise, and mitigated use of fossil fuel. However, when comparing cycling to driving a car, participants of studies state that they prefer the car since it does not require physical effort, it is perceived safer, and it is practical when shopping.

In Sweden, the cycling development decreased between 1995-2014. It is also worth noting that the total cycling decreased despite the ongoing population growth. However, a compilation of cycling data during 2019 showed that the trend in Sweden had changed during that year and that an increasing frequency was established. Though, cycling was the transportation mode entailing most injuries during 2019. Furthermore, The National Cycling Strategy of Sweden was published in 2017 with the main purpose of increasing cycling and its safety.

3
Methodology

The approach of the thesis were methods including a literature review, a qualitative research in terms of interviews, and a spatial analysis using the software QGIS, which identified critical routes chosen for a physical observation. The method of the literature review is described in section *2.1 Literature Review, Methodology*. The chosen methodology for the thesis provides various study approaches which give a nuanced result.

3.1 Qualitative Research

The data collection and analysis of qualitative research is commonly described as a strategy that rather emphasizes words than quantification. The method of it is often described as an approach where the collection and analysis of data lead to an emergence of theory and categorization. The main steps of a qualitative research are listed below.

"Step 1. General research questions
Step 2. Selecting relevant site(s) and subjects
Step 3. Collection of relevant data
Step 4. Interpretation of data
Step 5. Conceptual and theoretical work
Step 5a. Tighter specification of the research question(s)
Step 5b. Collection of further data
Step 6. Writing up findings/conclusions" (Bryman & Bell, 2015, pp. 395–397)

Qualitative research in terms of interviews was applied to this study. The purpose of the interviews was to obtain data to acknowledge the research questions of the study. Therefore, factors that define the city as bicycle friendly were identified. An additional aim of the interviews was to identify cycle routes or stretches within Gothenburg that are perceived critical based on the identified factors and clarify why measures are necessary to achieve a bicycle friendly city. Both infrastructural measures and soft measures were identified. The study aims to create a wide perspective of decisive factors to achieve a bicycle friendly environment in Gothenburg. Therefore, the interviews included different stakeholders presented in detail in the following section.

3.1.1 The Public Sector and Experts

The starting point of this study included the main ideas of planning for a bicycle friendly city. This aspect was important to grasp and comprehend the overview perspective of decisive factors to achieve a cycle friendly environment in Gothenburg. Therefore, this perspective became a clear guideline for the design of the interviews, and the purpose of the interviews became evident.

The structure of the interview questions was organized and predetermined. However, in order to receive adequate data, subsequent questions were formulated and modified as the interview took place, based on the development of it. These post-constructed questions were continuously added until it was considered that the data collected from the interview was sufficient. This type of interview is categorized as a qualitative interview described as both semi-structured and unstructured (Bryman & Bell, 2015). In a semi-structured interview, a series of questions are usually prepared in a general form, however, the number of subsequent questions and the formulation of them can vary based on the specific inquiry. This type of interview was considered appropriate to address all research questions of this study.

As the research questions of the study are specific and straightforward, see section *1.2 Aim and Objectives*, the sampling of the qualitative research was purposive. The purposive sampling involves the selection of units, which in turn refers to the research questions (Bryman & Bell, 2015). The studied research questions indicated which samples were considered relevant, and were therefore used as a guide for the sampling. However, since the research partly aims to investigate fixed factors within the city of Gothenburg, the sampling became obvious. Since the bicycle network of Gothenburg is mainly designed by the Municipality of Gothenburg, which also determines the factors of the design, they were selected for one of the qualitative interviews. Thus, the sample consisted of an organization, and the selected units within the organization were a cycling expert, Malin Månsson, and a city planner, Emma Josefsson. Månsson and Josefsson work at the Transport Administration of Gothenburg, which is a part of the Municipality of Gothenburg.

Furthermore, by using a snowball approach, further cycling experts could be collected for further research and interviews. Four identified experts were interviewed to understand their respective perspectives on what is considered important to achieve a bicycle friendly environment. The interviewed cycling experts of the study are presented below.

Axel Pihl is currently working as a traffic planner at Tyréns. At Tyréns, he is involved in the early stages of projects and he has experience in various types of investigations and working with design, with a focus on active transport and public transport. Pihl also has experience from Cykelfrämjandet, where his work mainly consisted of developing the concept for analyzes of the cycle network and testing it in Swedish municipalities.

Erik Stigell is working as a project manager at the Swedish Environmental Protection Agency, a public authority treating environmental issues, where the environmental goals of Sweden are guiding their work. Further, Stigell has a doctorate in cycling as a public health strategy, and a Ph.D. in sports. Previously, he worked at Trivector Traffic as a traffic consultant and researcher for several years.

Gustaf Frid is the vice-chairman of Cykelfrämjandet in Gothenburg. Generally, he would like cycling to be given higher priority when there is a conflict of goals in urban development issues. He is also passionate about children's cycling, and he wants improved infrastructure around target points where there are children.

Rolf Broberg has cycled in Gothenburg all his life and has for long been interested in good bicycle traffic in the city, which resulted in him starting his own blog about cycling. Additionally, Broberg is active in Cyklefrämjandet where he emphasizes issues about the passability of cycling within the central areas of Gothenburg. Recently, he has started to work for the Transport Administration of Gothenburg on projects concerning orientability and evaluation of improvements for bicycling.

All interviews were audio-recorded to enable support for the use of the collected data and to be able to quote the interviewees when needed. Further, the recordings were transcribed manually, where conversation outside the interviews was considered unnecessary and therefore excluded. Recurring themes of the interviews were gathered and categorized in different subsections in order to obtain relevant analyzes and comparisons within the specific theme. The categorization also created a clear overview of the collected data and in turn, the analysis.

Finally, after compiling the data collected from the interviews, the analysis was validated by the interviewees. The final version of the analysis was sent by email to the respective interviewee who approved the content. One of the representatives of the Transport Administration approved the compiled view of the public sector. Lastly, minor adjustments were made based on the inputs of the interviewees.

3.1.2 Network Users

The perception of a bicycle friendly environment in Gothenburg, by users of the cycle network themselves, was studied using data collected through structured interviews in terms of questionnaires. The questions of the questionnaire were formulated with the purpose of addressing the research questions of the study. The presented answer alternatives that the participants could choose from, were inspired by outcomes of the literature review and conducted interviews with the public sector and experts. The process of designing the survey took place in several steps. Initially, discussions based on the research questions resulted in a first draft. This version was pilot tested with a group consisting of ten respondents. The pilot test resulted in feedback that in turn resulted in further discussions of the structure. Since major changes to the first draft were made, the survey needed to be pilot tested once again. The second pilot test consisted of two respondents. Feedback from the second pilot test led

to minor changes, and the survey could therefore be completed quickly. The final questionnaire was published and accessible during two weeks i March.

The survey was designed to both include experienced cyclist, but also people who rarely, or never, cycle in the city. This in order to not exclude reasons why these participants do not consider cycling as a possible transportation mode. Some questions referred the respondent to a specific subsequent question depending on the previous answer. Firstly, the participants stated their age, choosing between 7-14 (children), 15-24 (adolescence, young adults), 25-45 (adults), 46-60 (older adults), or 60 (elders). Secondly, general information regarding the gender and cycling frequency within Gothenburg was collected. The cycling purpose was collected for all but those who had chosen the alternative "Never" when stating their cycling frequency. Further, questions about the bicycle network, in general, were asked. The questions covered the respondent's satisfaction with the current network, their perceived safety, and possible improvement measures to increase their cycling. The participants were asked to state why they were satisfied with the bicycle network or not, and why they felt safe or not. Lastly, the participants were asked to name specific routes (origin and destination) within Gothenburg, if they had any in mind, that they considered critical. If they named a specific, the earlier questions concerning the bicycle network were repeated but were instead dedicated to the current route.

3.1.2.1 Convenience Sampling

In this study, a non-probability convenience sampling method was applied to collect data from the citizens of Gothenburg. A non-probability convenience sampling is a method of collecting respondents to the survey, based on availability for the researchers (Bryman & Bell, 2015). The survey was published using the researcher's social media accounts including Facebook and LinkedIn. Various Facebook groups were targeted to reach out to relevant respondents. One group was aimed at cyclists in Gothenburg where the members of the group discuss the cycling climate in the city. Another group was aimed at people with an interest in urban development in Gothenburg, the other for master's students within the program Infrastructural and Environmental Engineering at Chalmers University of Technology, and the last included females with a technical education background. The questionnaire was also published on both researcher's LinkedIn profiles and on one of the researcher's Facebook page.

3.2 Spatial Analysis

A compilation of the collected data in the questionnaire was carried out with a systematic approach, involving a spatial analysis. The software QGIS was used to simulate the routes collected from the survey, in order to obtain a gathered, and graphical overview of the data. The purpose of the spatial analysis was to highlight the most mentioned critical factors and the respective associated route. A critical factor was, in this study, defined as a lacking circumstance, fact, or influence of the

bicycle network that contributed to an impaired perception of the bicycle friendly environment. The results of the survey were analyzed, and this analysis could further lead to decisions on which and how many critical factors and their respective route would be simulated and therefore investigated in more detail.

The method of the spatial analysis included a so-called all-or-nothing assignment. This assignment is a part of the route assignment method, which in turn is a part of the four-step travel model. An all-or-nothing assignment assumes that there are no congestion effects, and loads all trips to the shortest path between an origin and a destination (Assi et al., 2019). Practically, the shortest path between a given origin and destination was identified by combining information from Google Maps and Open Street Map. However, if Google Maps suggested more than one route with the same distance, the shortest time became the deciding factor instead. But if a participant of the survey stated a route where it does not exist any cycle path or lane, the route was simulated based on the given route choice of the participant. In other cases where Google Maps was not updated, and instead showed an ongoing construction site where the cycle lane or path could not be used properly, own interpretations were made based on local knowledge about Gothenburg.

The visualization of the identified routes, which in turn forms a network, was manually created using the software QGIS. When the network was created, the route was in the first place assumed to follow the direction of traffic, and if a cycle path was marked on Open Street Map, it became the starting point of the route. However, if the current route did not consist of cycle paths, car roads were used instead. Walkways for pedestrians were used if neither cycle paths nor lanes, nor car roads, existed. Furthermore, QGIS was used to create one layer for each of the analyzed critical factors. Firstly, all named routes were manually created with a line. Secondly, the lines were summed in order to adapt the visualization of the stretches. Accordingly, the routes or stretches which were repeated, the lines were made thicker depending on how many times the specific route or stretch had been repeated. Similarly, the same method was applied to visualize the problematic areas, where polygons were created. Each area that had been stated was made less transparent depending on how many times the respective area was mentioned.

3.3 Observation

The results of the spatial analysis were analyzed to establish the most critical stretches within the bicycle network of Gothenburg. The most critical stretches and areas were subsequently identified by the thickness of the lines, or the darkness of the marked areas, visualized in QGIS. This led to the decision of performing a physical observation of a certain route including certain areas.

The observation was conducted in order to obtain accurate and updated information about the cycling experience along the route, which discussions and measures could later be based on. A further aim of the observation was to verify the problems mentioned by the participants of the survey. Since the simulation in QGIS was

made with a certain direction of traffic, the same direction as the stated one in the questionnaire, the observation was also conducted in the same direction.

The observation of the route was performed by the two researchers of this study. Both of the participants are female, young adults, with different experiences of cycling. One of the participants has more experience with cycling and uses the transportation mode on a daily basis, while the other does not bicycle as regularly but rather occasionally. The study took place on two occasions, two separate weekdays in April after a sufficient amount of data had been collected for the researchers to be able to make a fair estimation and decision of route.

4
Analysis

The data collected from the qualitative research of the study, consisting of interviews with various actors, is presented in this chapter. The data is categorized into themes, and differences between the various aspects of the actors are identified and presented. Further, the results of the spatial analysis are presented and analyzed.

4.1 Interview with the Public Sector

The main outcome of the interview, with Malin Månsson, cycling expert, and Emma Josefsson, city planner, representing the Transport Administration of Gothenburg, was related to how the administration is planning for cycling. Further, relevant routes that are in focus today are identified and the current extent of implemented measures, not related to infrastructure, are discussed. The detailed structure of the interview and formulated questions are presented in *Appendix A*.

4.1.1 Cycle Planning

Malin Månsson clarifies that the Transport Strategy of Gothenburg is the basis for traffic planning in the city. This strategy presents goals and strategies concerning transportation development. As an example, the strategy describes the goal of connecting different parts of the city and neighborhood municipalities with a fast cycling network. It is also stated that cycling should be a prioritized transportation mode to achieve an attractive urban environment and that the cycling frequency should be increased to increase sustainable transportation. The Transport Administration has developed the Cycling Programme where the purpose is to contribute to the goals and strategies of the Transport Strategy. The Cycling Programme states that a coherent and well-designed cycling network is the most essential to achieve the goals.

Månsson states the cycling network in the city is divided into three classes including the commuting, the comprehensive, and the local network. The commuting network connects the different districts of the city with adjacent municipalities, including bridges and infrastructure, and should be designed to enable a speed of 30 km/h. The comprehensive network constitutes of routes within districts that lead to major target points within the city, while the local network leads all the way to possible origins and destinations.

Månsson explains that currently, the development of the already existing commuting network is the highest prioritized network in the city. Further, the central parts of the city are prioritized since their cycling flow has increased, and the current standard is not sufficiently developed to manage these flows. Lastly, the Transport Administration is investing in overcoming barriers including watersheds, highways, and railways. However, the actions are partly controlled by agreements with Sverigeförhandlingen, which distributes funding to enable the implementation of improvement measures to increase cycling. An example of a route in need of improvement, that is highlighted by Sverigeförhandlingen, as a part of the commuting network, is the route between Backaplan-Kärra.

Concerning target groups, Månsson clarifies that the Transport Administration plans for specific trips rather than focusing on different target groups. However, Emma Josefsson claims that the recommended widths for cycle lanes are adjusted to enable overtaking, which enables both fast and slow cycling in the network. Though a well functioning network is prioritized over a fast network and something extraordinary is needed to enable a speed of 30 km/h. The goal is to create a bicycle network that is taking everybody into account. However, Månsson stresses that functionality is prioritized where the recreational perspective is not a part of the planning process, which excludes planning for the experience of tourism.

According to Månsson, decisions of what and where within the network improvements are needed, are sometimes based on the long-term planning of the Transport Administration and in other cases, on information and input from citizens. Cases that point out dangerous and poor infrastructure are prioritized according to principles and scope. Minor measures can be a result of own investigations where the Transport Administration themselves identifies deficiencies within the network. If a new concept is implemented, a pilot study and an after study are conducted through e.g., interviews along the specific route or stretch.

4.1.2 Orientability

The focus of the cycle planning for the city shifts during different time periods. According to Josefsson, the focus has lately been on developing and improving the existing network, both by connecting missing links of the network and by constructing more cycle paths. Therefore, an important focus today is the improvement of orientability in order for cyclists to feel confident about how to travel within the network. Improved orientability would facilitate the ability of the cyclist to orientate within the network.

"The traffic safety has traditionally been highly prioritized in Gothenburg, but this has unfortunately occurred at the expense of clarity, orientability, and passability." (Månsson, 2022).

Månsson explains that earlier solutions implemented in order to achieve traffic safety have consisted of secondarily constructions of cycle paths within the existing net-

work, rather than creating a throughout clear and safe path. This have resulted in that the Transport Administration needs to find secondarily solutions, seen as quick-fixes, to increase orientability. Further, Månsson states that children and new cyclists are groups that can perceive extra difficulties if the directions within the network are not clear enough.

Furthermore, Månsson states that, in some areas, it can be favorable to place cycle paths or lanes along the main streets aimed for motor vehicles, even if this concept inhibits the comfort. This is because it makes the cycle infrastructure more visible for people who currently do not see cycling as an alternative transportation mode.

4.1.3 Routes of Interest

As previously mentioned, the development of the commuting network is prioritized. This is in line with the directed funding received from Sverigeförhandlingen. Månsson and Josefsson refer to Sverigeförhandlingen to identify the chosen routes, which are presented below:

- Backaplan-Kärra
- Backaplan-Bräckemotet
- Stigberget-Saltholmen
- Hisingsbron-Älvsbron
- Annedalsmotet-Götaplatsen
- Nya Allén
- Övre Husargatan-Sprängkullsgatan
- Sahlgrenska-Kommungränsen Mölndal (Sverigeförhandlingen, 2017).

Beside these eight routes, the routes between Kallebäck-Ica Maxi Mölndal, Svingeln-Skansen Lejonet, and Brunnsparken-Ringön will be investigated even if no decision has been made according to Månsson. Further, Månsson claims that the Transport Administration is currently developing stretches reaching out to recreational areas, for example, the last part to Delsjöbadet, Alfred Gärdes väg, and Hisingen-Sillvik. However, where there is already existing cycle infrastructure, for example, the stretch extending towards Saltholmen, the focus is instead to implement minor improvement measures since the current lanes are narrow. Major cycle parking facilities are in construction or planned to be constructed along with stations of the West Link, including e.g., Haga and Korsvägen which are in construction, and the Central Station which is in the planning stage.

4.1.4 Other Improvement Measures

According to Månsson, the bike sharing system "Styr & Ställ" is one example of an implementation aiming to facilitate and increase cycling in the city. There is also an app called "Cykelstaden" where the user can e.g., search for route based on origin and destination, or find the nearest cycle pump. However, the Transport Administration has worked with campaigns in the past, but their main focus now is

to push other actors to promote cycling. One example is the concept "Cycle friendly working place", with initiatives including cycle storage at work for instance, which is a project that still exists but the administration does not market the project in the same extent as before.

Månsson points out that the City Council has given the Transport Administration an extensive mission to create and analyze a pilot area to increase the enforcement of the Cycle Programme. One example of a selected area is Backa, more specifically Selma Lagerlöfs Torg, which is a more socioeconomically vulnerable area. In such areas, where the cycling frequency has been shown to be lower compared to other parts of the city, the Transport Administration discusses other identified challenges. The assessment is that the low cycling frequency is not only a result of more worn infrastructure and poor pavement but that the measures need to be more dialog-focused and that partnerships with local actors are therefore prioritized.

4.2 Interview with Experts

The interviewed experts of the study possess a broad set of knowledge considering bicycling. The participating experts are Axel Pihl, Erik Stigell, Gustaf Frid, and Rolf Broberg, where everyone contributes to data covering a certain perspective. However, Cykelfrämjandet is a recurring association of the interviewees. It is a non-profit association working towards better, safer, and more attractive cycling in Sweden. Several of the interviewed participants are or have previously been part of the association. The detailed structure of the interview and formulated questions are presented in *Appendix A*.

4.2.1 Cycle Planning

According to Axel Pihl the cycle planning differentiates for each city since the challenges of the cities vary. However, he mentions that one of the main challenges is continuous cycle paths with high quality. When there is a lack of space, the cycle is often not prioritized. Furthermore, Gustaf Frid stresses that the cycle infrastructure has to become a part of the planning process at an earlier stage, rather than be seen as a flexible transportation mode that can be completed secondarily. He means that this course of action results in mediocre solutions excluding a holistic perspective. Proceeding, Erik Stigell highlights the cyclist's safety and perceived security as important factors when planning for cycling. He also emphasizes that it is important to plan for cycle infrastructure that enables cyclists to, cognitively, be able to move forward in an easy and natural manner. Lastly, Stigell mentions the importance of creating an interesting and attractive environment in order for the cyclist to be able to appreciate the city when traveling in it.

Rolf Broberg highlights wide commuting stretches as one main factor when planning for cycling. The width should allow overtaking since people cycle at different speeds. However, Broberg mentions that a wide cycle path or lane may not be possible everywhere, but in situations where it is possible, *"the compromise must not always*

fall to the detriment of the cyclist" (Broberg, 2022). Further, he stresses that since a large share of cyclists in the city travel straight to the inner city, they should be prioritized there as well. However, all transportation modes need to cooperate within the city center and the infrastructure should be designed to make that obvious for all.

Besides emphasizing well-function planning, Broberg is concerned that future urban development could jeopardize the passability of existing commuting stretches. He claims that urbanization in areas between the outskirts and the inner city will result in a more divided commuting cycle network than today. More intersections with traffic lights will complicate the trips and extend the travel time. Even today, Broberg highlights the importance of planning for well-functioning traffic lights at intersections. He claims that they even could be turned off, during certain times of the day, when the traffic flows are reduced.

4.2.2 Factors

Specific factors that need to be fulfilled to achieve a bicycle friendly environment in a city are discussed with the interviewees. Pihl refers to a concept including five focus areas considering a general approach for cycle analysis, presented below.

- Cohesion within the cycle network.
- An attractive cycle environment with limited noise and disturbance.
- High comfort with even surfaces and no cracks.
- A direct network where no detours are needed.
- Traffic safety without risks to one's health.

According to Pihl, all the focus areas are equally important, but they can come in conflict with one another. An example of aspects that can be at odds with one another is traffic safety and passability. If traffic safety measures are taken with no regard for passability, it can negatively affect people's willingness to cycle. Stigell stresses that planning with a holistic perspective could enable achieving both features. According to Stigell, it is possible to create both traffic safety and passability if cycling is prioritized sufficiently in different conflicts of aims, especially since cycling has a small surface claim in the traffic room.

Stigell highlights several factors that he claims need to be fulfilled to consider a city such as Gothenburg, bicycle friendly. One factor is to enable the cyclist to keep desired speed and that the infrastructure should not force the cyclist to slow down when it is not needed. Further, he mentions stimulating, fresh, and attractive environments including greenery and reduced noise. According to Stigell, this would differ from the current cycling climate in Sweden in general, which he describes is motivated by safety, not as an enjoyable experience.

Similar to Stigell's motivation of good cycle planning, Frid claims that it is important for cyclists to be able to reach their destination intuitively where all route choices and

traffic situations are resolved in a natural manner. To reach this intuitiveness, Frid presents similar factors as listed, including connectivity, orientability, continuity, and routes without detours. Further, he claims that segregation between pedestrians and cyclists is important and that it increases the intuitive feeling in traffic.

Broberg mentions proper width of cycle paths and lanes during a long distance, prioritizing cyclists at traffic lights, and parking near destinations, as important factors to achieve a bicycle friendly environment. Further, he specifies that it is important to give proper conditions for pedestrians to avoid them taking up space in the infrastructure assigned for cycling.

4.2.3 Identification of Stretches

Identification of a specific stretch in need of improvement is based on its connection to target points in the city, according to Pihl. A municipality should have a designated main cycle network and a local network. The main network is formed by the routes leading to important target points within the city, such as schools, workplaces, and sports facilities. The requirements of the main network should be comprehensive, and the stretches forming the network should therefore in turn also maintain a high standard. If a stretch within the network is problematic, improvement measures should be considered. To identify problematic stretches, it is important to include the perspective of cyclists.

According to Stigell, the identification of problematic stretches should be based on the geometric design considering both height and width, and there should be no fixed obstacles in the way. Further, speed changes could be measured and used as a basis for identification, where stretches noted with many decelerations should be prioritized. Since the Transport Administration possesses knowledge about these types of traffic flows and city-building projects within Gothenburg, Broberg stresses that they should be the main actor in identifying stretches. However, he also thinks that the aspect of cyclists should be taken into consideration and that it is important that cyclists engage in the discussion. Because of Broberg's local knowledge of Gothenburg, he discussed several areas that he thinks are in need of improvement, as follows:

- Linnéplatsen: Problematic roundabout where the traffic lights turn red for cyclists for busses to pass even when the busses turn and deviate from the intersection.
- Stenpiren-Skeppsbron: Conflict of interest between trams, buses, ferries, pedestrians, and cyclists at Stenpiren. Further, the urban development plans of the adjacent Skeppsbron seems to design the commuting cycle stretch as a long area for pedestrians.
- Area around the Central Station: Many cycle commuting lanes extend towards the area but do not connect to each other. This creates a barrier for cyclists in central areas of the city.

4.2.4 Passability and Traffic Safety

The main cycle network includes the commuting network as well, where passability has a high priority according to Pihl. Since the commuting cycle paths are used to reach their respective destination quickly, it is important that these are designed to work efficiently. To increase the passability as much as possible, other aspects may need to be less prioritized, for example, the recreational experience. An additional important factor to increase the passability of the cycle network is continuity where bike stretches do not suddenly end. Both Pihl and Frid claim that the paths and lanes should also be sufficiently wide. According to Pihl, this enables overtaking, since cyclists do not form a homogeneous group, but rather include both fast and slow cyclists.

Furthermore, traffic safety is discussed where Pihl presents several aspects. He emphasizes the importance of intersections where serious accidents usually occur. Speed securing by for example raised bicycle crossings could be one solution to reduce the number of accidents. Pihl also stresses the importance of maintenance during autumn and winter to reduce single accidents due to slipperiness. Further, other measures to increase traffic safety are continuous and wide lanes without unexpected curves. Besides traffic safety, Frid stresses the perceived security which means that one wants to avoid cycling through unsafe environments, such as dark parks and tunnels.

According to Stigell, the design of intersections is not only related to safety but also passability. He claims that, in some intersections, planners can avoid that cyclists need to stop which currently contributes to an incoherent network. This can be achieved by e.g., implementing cycle crossings, constructing cycle bridges, or connecting traffic lights to create a green wave for the cyclists. Further, it is important to have a geometry that enables 25-30 km/h, meaning that the curves are designed so that the cyclists can keep their speed, i.e., no sharp curves. Lastly, Stigell mentions a flat topography, good paving including well-functioning drainage, a natural gradient in curves, and lighting as important factors to achieve passability. Further, Broberg highlights two important factors to increase passability, including well-functioning traffic lights and enabling overtaking on paths and lanes, which are also stated by the other experts. However, he claims that the perceived safety is allowed to vary between different parts of the city. For example, certain areas need to be designed for adults while the network connected to schools must be available and manageable for children as well.

4.2.5 Target Groups

When cycle planning takes place, Pihl claims that it is important to consider different types of cyclists. Cyclists are often seen as a homogeneous group, however, this is not the case. Cyclists consist of people between 8 and 80 years old and even among adults, there are people with different cycling experiences. Therefore, cycle planning should include the aspect of different target groups, and some groups should be higher prioritized than others for specific stretches.

According to Stigell, to cater to several target groups when planning for cycling in the city, it is important to design wide and separated cycle paths and lanes with soft curves. He also mentions that bicycle gates should be excluded from the network since this complicates the passability of some bicycles such as cargo bikes. Concerning children, Stigell claims that they should be able to use the same infrastructure as adults, but the speed of motor vehicles adjacent to the cycle network should be reduced where many children are cycling. He further highlights that traffic rules at intersections can be challenging for children to understand, and the fact that they should manage that type of interaction is not optimal. Lastly, he mentions orientability as an important factor to include various target groups, and that is important to plan for more intuitiveness of cyclists.

An important target group according to Frid is children, however, he claims that they are excluded today. He thinks that at least one cycle commuting stretch should be connected to each school. Further, Frid claims that norms of today's society along with social structures hinder children from cycling to and from school and that the behavior becomes a vicious spiral.

4.2.6 Other Improvement Measures

The experts are asked to state other available measures that would increase cycling. According to Pihl, speed review is one example, where the speed is reduced on local streets where there is not sufficient space for bike lanes. Furthermore, various information campaigns or events could be implemented. An important soft measure that Pihl discusses is the cycling link to public transportation, where the importance of secure bicycle parking is emphasized. Frid agrees with Pihl regarding measures including campaigns. Frid and the rest of Cykelfrämjandet believe that cycling should be integrated into the curriculum for schoolchildren.

Stigell presents measures including colored roadsides to clarify the size of the cycle path or lane. Further, he highlights the operation and maintenance of the existing network e.g., trash collection but also flower and art programs. However, these programs need to be adjusted to the cycle infrastructure to ensure that it does not complicate cycling. Lastly, Stigell mentions angle adjusted trash cans along with the network, noise boards, and ensuring shadow over the paths as other measures that could increase the cycling frequency in a city.

Broberg has a vision that the major commuting network, in the future, will be signed in a manner comparable to motorways. Specifically, paths will be named and directions clarify where the paths continue and connect with other paths or lanes. According to Broberg, this would enable a more fluent flow for cyclists. Considering campaigns, Broberg thinks that this is useful to increase the interest in cycling among children and young people. Also, he highlights that adults can discover alternative ways to transport their children e.g., by cargo bikes.

4.3 Interview with Network Users

The collected sample of the structured interviews includes a total of 295 participants of various ages, genders, and cycling habits. The analysis of the data set is based on two variables, age, and gender. Based on these variables, the analysis partly includes a comparison between the survey results and statistics collected from the Swedish Statistics Agency, SCB.

Initially, the target group of this study consisted of all the inhabitants of Gothenburg. However, assuming that the answers will be sufficiently spread, and therefore be representative of the entire population of the city, is not reasonable due to a lack of data. Therefore, the decision of investigating different groups of the inhabitants is made, including age and gender. The proportions of these categories are examined to enable a reasonable comparison between the shares of the actual statistics, and the collected sample.

Out of 295 respondents, only one participant claimed to be between the age of 7-14. Only one answer in this age category does not represent this group of people sufficiently. Therefore the answer was excluded from the data set. Further, the whole age interval is excluded from the target group to create a decent data set. Discussions of the decision are based on whether the possibility of the survey even reaching out to respondents between 7-14 years old, how many of the respondents would have their own opinion regarding the bicycle network of the city, and whether all these respondents would understand the survey since it was conducted in English. Lastly, since only one answer is received, the decision of excluding the target group became obvious.

Regarding the upper interval of ages, similar discussions are made, which results in a similar outcome i.e., exclusion of a certain interval from the data set. It is assumed that a large share of inhabitants of Gothenburg from 70 years and above, would not be able to answer the survey. Biases are involuntarily introduced already when the survey was published since it was published in partially closed groups on various social media. Many elders are not actively engaged in social media channels and some could be limited by the fact that the survey is written in English. Consequently, with the chosen sampling method, it could be challenging to collect a sufficient data set, with a spread corresponding to the statistics. However, the share of people who cycle is less among elders compared to other age groups. Therefore, when comparing the results from the survey and statistics from SCB, the upper interval of ages is limited to an arbitrary figure which is considered reasonable for this study, 70 years.

4.3.1 Age

The spread of ages among the participants of the survey is presented in Figure 4.1.

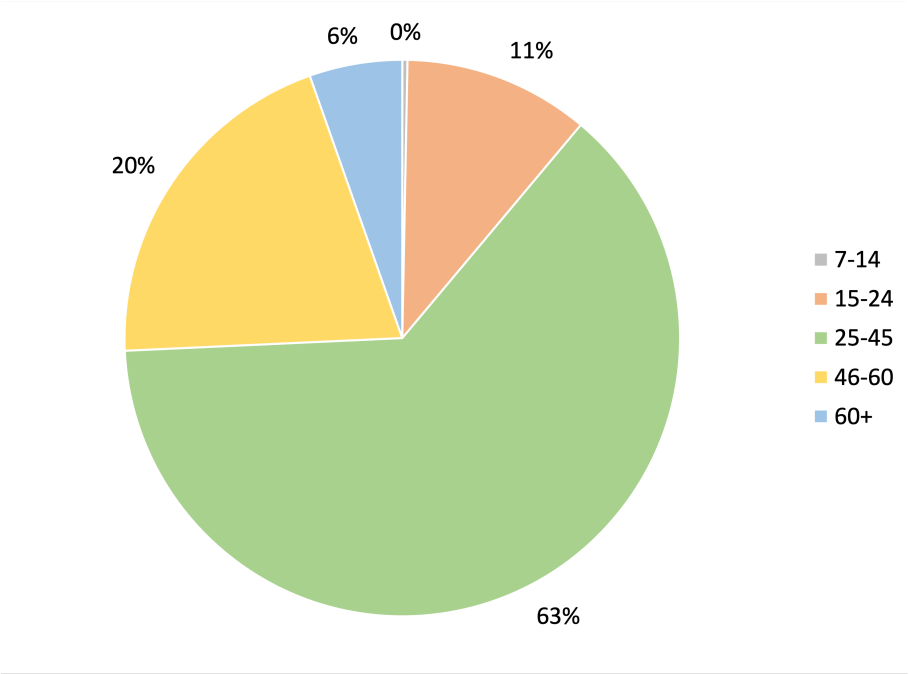

Figure 4.1: Ages of survey participants where the shares are rounded.

A comparison is made between the results of the questionnaire and statistics collected from SCB (SCB, 2022). The statistics include age data of the inhabitants within the Municipality of Gothenburg. The age spread according to the statistics is presented in Figure 4.2.

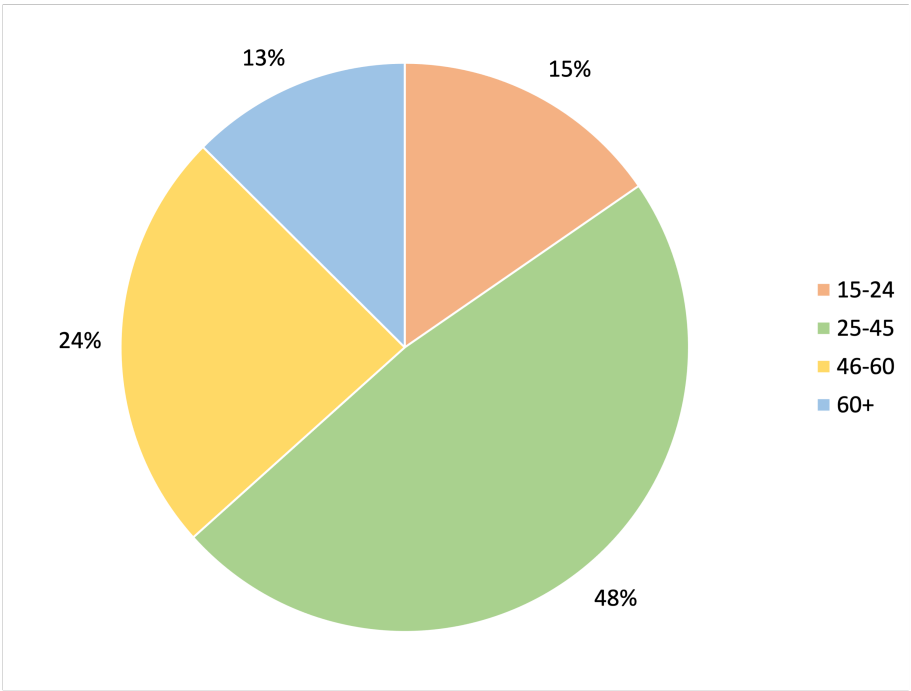

Figure 4.2: Statistics of age spread within the Municipality of Gothenburg where the shares are rounded.

As seen in Figure 4.1 and Figure 4.2, the age spread based on the participants of the survey, does not accurately correspond to the age spread of the statistics. However, the size distribution of the age ranges corresponds to the order of magnitude of the statistics. Further, the yellow part of the two diagrams corresponds to approximately the same number of participants, representing the age interval between 46-60, 20 %, and around 24 %. However, the vast majority participating in the questionnaire are between 25-45 years old, around 63 %, represented by the green color, while the corresponding age group of the statistics only constitutes 48 %. Since the survey was published on various social media, it probably mainly reached people in this age group. Further, this age group probably constitutes most cyclists and are the ones who generally understand English best. Therefore, this outcome seems reasonable. Further, a similar factor could probably explain the smaller blue part for the survey results, compared to the statistics, representing the age interval between 60-70 years, where the shares are around 6 % and 13 % respectively.

4.3.2 Gender

The shares of different genders among the participants of the survey are presented in Figure 4.3.

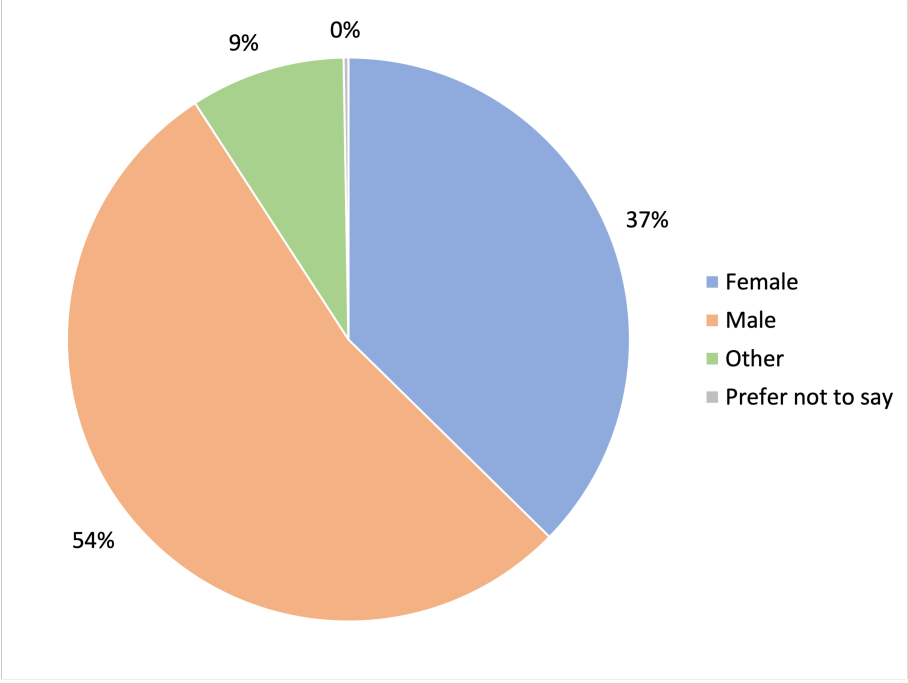

Figure 4.3: Genders of survey participants where the shares are rounded.

A comparison is made between the results of the questionnaire and statistics collected from SCB (SCB, 2022). The statistics include gender data of the inhabitants within the Municipality of Gothenburg. The gender spread according to the collected statistics is presented in Figure 4.4.

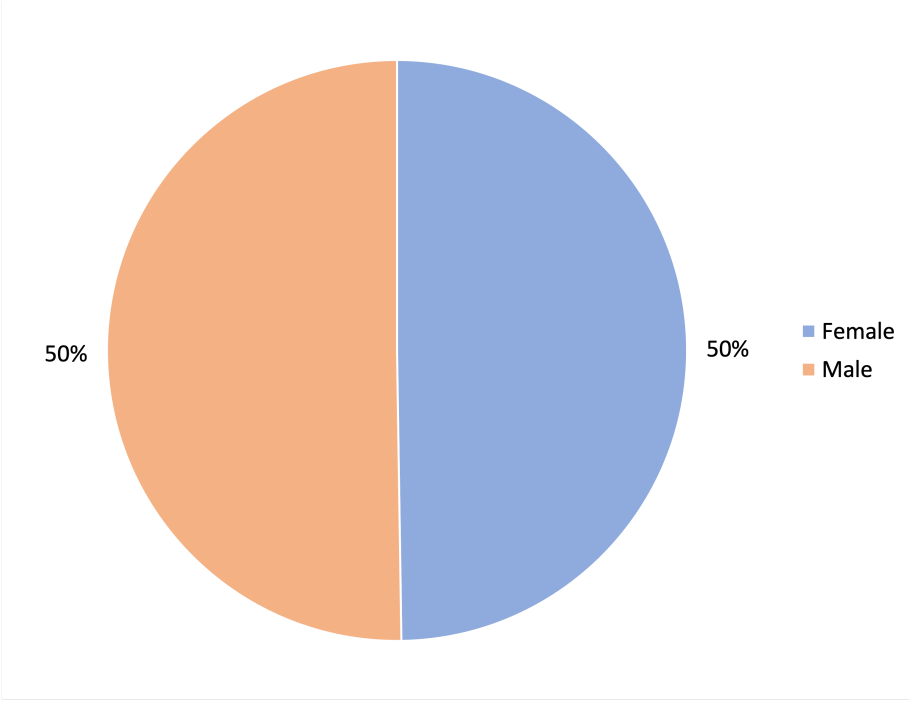

Figure 4.4: Statistics of gender spread within the Municipality of Gothenburg where the shares are rounded.

There are more men than women who participated in the survey, around 58 % and 41 % respectively, see Figure 4.3. According to the statistics, the distribution between the two genders should be equal. It could have been a coincidence that the distribution of answers between males and females resulted in this outcome. Further, the collected statistics do not consider the people not identifying themselves as either women or men, see Figure 4.4, which the survey of this study does. This could also have affected the differences. However, since the results of the survey are close to an equal spread, it is assumed to be representative of both men and women, and analyzes can still be made due to the high response rate.

4.3.3 Cycling Frequency

The participants are asked to state how often they are cycling within Gothenburg. The cycling frequency could also be chosen as "Season dependent" where the respondents, in that case, are asked to state their frequency during a specific time period. The results representing the answers to the question are presented in Figure 4.5.

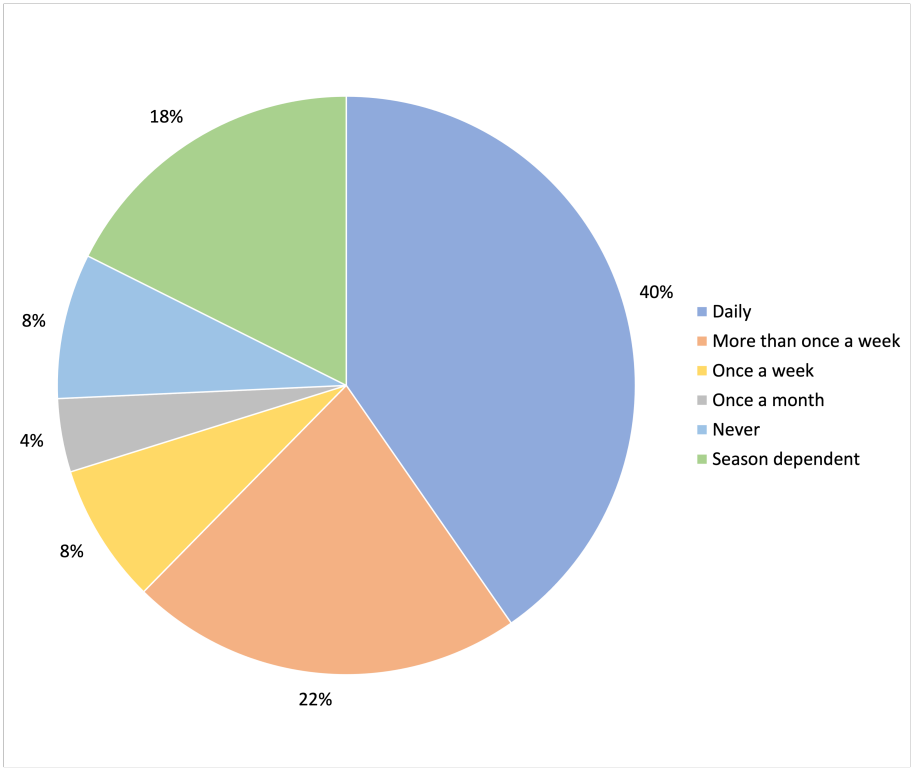

Figure 4.5: Cycling frequency of survey participants where the shares are rounded.

The largest share illustrated with the dark blue color, representing around 40 % of the participants, are cycling daily. However, this is probably a result of publishing the questionnaire in Facebook groups aimed for cyclists. Around 18 % of the participants are only cycling during specific seasons, illustrated in green. The majority of the cyclists that have a varying frequency over the year state that they cycle more during summer and warmer seasons. However, a large share highlight winter as the only season they are reducing their frequency compared to the rest of the year. Several participants state that they totally exclude cycling during winter. Among the answers, some highlight periods of snow, rain, or gravel on the road pavement as the only reasons why they would not cycle in the city, regardless of the season.

4.3.4 Cycling Purpose

The respondents of the study are asked to state which cycling purpose they have. The participant could choose several options, and write their own proposals. The results are presented in Figure 4.6. However, if the alternative "Never" is chosen when stating cycling frequency, the question about purpose is skipped. The detailed structure and formulated question are presented in *Appendix B*.

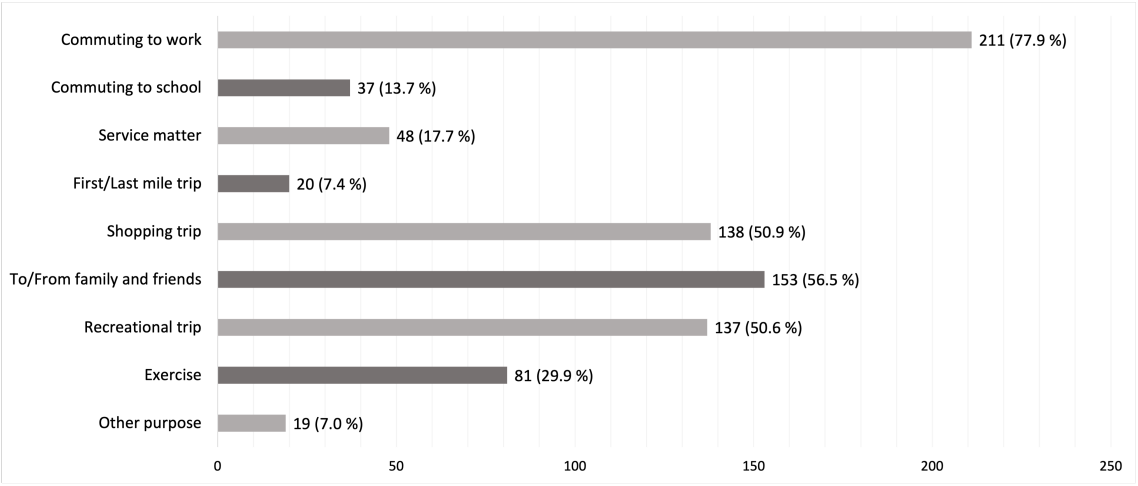

Figure 4.6: Cycling purpose of survey participants.

271 of 295 participants state a cycling purpose. The majority of the respondents, around 80 %, are commuting to work, see Figure 4.6. Further, many are using the bicycle for shopping trips, to and from family and friends, and going on recreational trips. 21 out of the 271 respondents, chose the alternative "Other purpose". The majority of the cyclists who have another cycling purpose than the proposed alternatives, state a purpose including transportation to and from the gym, or other types of leisure activities. A few participants of the survey state that they are cycling when transporting their children to and from kindergarten.

4.3.5 Bicycle Network in General

This section presents the results of the questionnaire covering the first part, questions of the bicycle network of Gothenburg in general.

4.3.5.1 Satisfaction

Regardless of cycling frequency, the respondents are asked to state their current satisfaction with the general bicycle network of Gothenburg. No further information is given with the purpose to obtain the intuitive answer from the participants. The satisfaction is stated on a scale of 1-5 where 1 represents "Do not agree" and 5 "Totally agree". The result shows that only around 3 % of the participants are fully satisfied with the bicycle network of the city, see Figure 4.7. Further, there is a large share, around 78 %, that states a satisfaction within the lower scale, between 1-3. The largest individual share, around 42 %, has chosen 3 which could be explained by the fact that some respondents have interpreted this alternative as neutral.

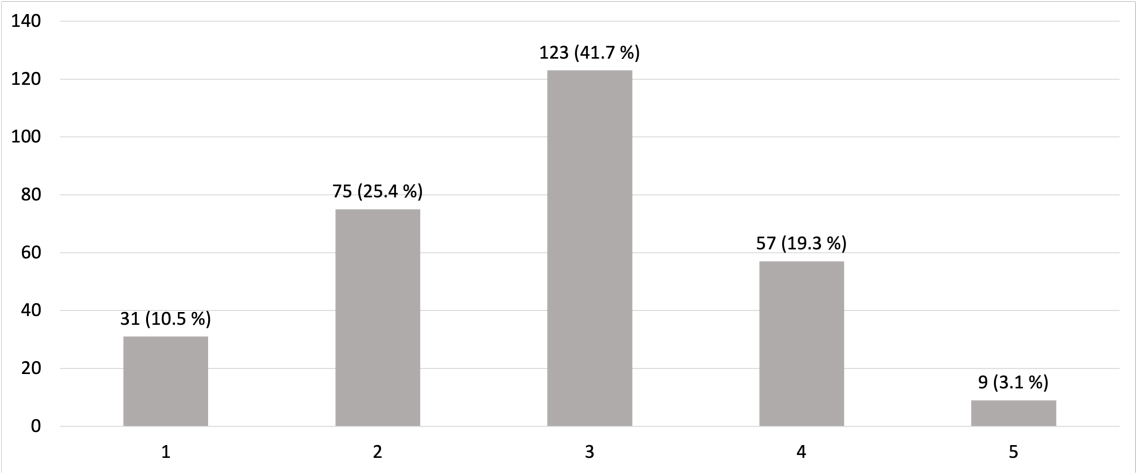

Figure 4.7: Scale of perceived satisfaction.

After the respondents stated their satisfaction with the current bicycle network in the city, they are asked to present specific factors affecting their choice. The question is formulated so that the respondents can highlight one or several infrastructural factors that, according to themselves, are lacking within the network. The result shows that the majority of the participants think that connectivity and continuity along with the network and segregation from pedestrians are reducing their satisfaction with Gothenburg's bicycle network, see Figure 4.8. Further, around half of the respondents think that more cycle paths are needed and that the current width of cycle lanes is not sufficient in order for them to be satisfied. The lack of clear directions and signs is also highlighted as a crucial factor reducing the satisfaction of the bicycle network for a large share of the respondents. The participants are also able to choose the option "Other factor" and state further factors that they perceive are lacking, which is done by around 16 %.

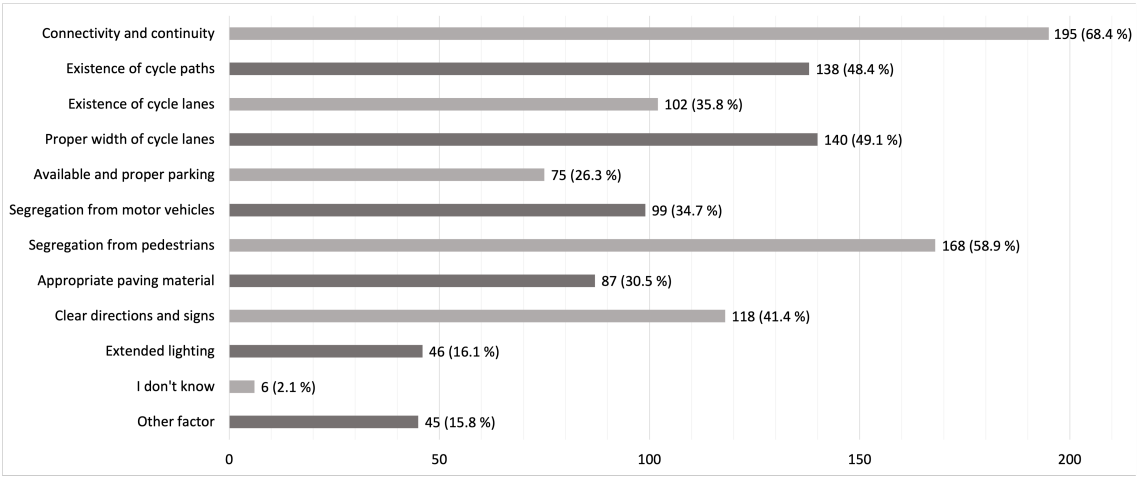

Figure 4.8: Lacking factors influencing perceived satisfaction of the bicycle network of Gothenburg.

A compilation of the data related to other satisfaction factors shows certain recurring factors. The factors are listed in ranking order based on how many times each factor is mentioned.

- Maintenance of the road including e.g. fixing cracks and cavities and shoveling of gravel and of snow during winter.
- Handling of cyclists during roadworks. e.g. changed routes, redirection to non cycle friendly streets, insufficient re-paving, and the increase of parked vehicles on the paths/lanes.
- Obstacles in the way include e.g., inconveniently placed signs, bars, speed bumps, and parked cars.
- Cyclists not feeling prioritized in both plannings of the network and in the physical network including crossings and the comparison to other modes.
- Other road users (including cyclists, pedestrians, and car drivers) who do not follow traffic rules
- Traffic lights not optimized and adjusted for cyclists.
- Cycle paths that lead to detours compared to reaching the destination in another way.
- Inappropriate road surface including sewage locks not on pavement level and cobblestone.

The listed factors are repeated among the answers of the respondents. Other factors that are mentioned are e.g., challenging topography, sharp curves, too many bars, lack of space that enables different speeds, and the fear of their bike being stolen. However, there are people that never bike due to other reasons than the surrounding environment. This would mean that despite implemented improvement measures, these people would still not choose bicycling as their transportation mode. Figure 4.5 shows that significantly more respondents are cycling compared to the respondents that never cycle, which could be a result of the survey being perceived as primarily aimed for people who consider themselves cyclists.

4.3.5.2 Perceived Safety

The respondents of the survey are asked to state their perceived safety when cycling in Gothenburg. The scale ranges from 1-5 where 1 represents "Do not agree" and 5 represents "Totally agree". The results show a spread perceived safety among the participants, see Figure 4.9. There are a few more who feel completely safe, more than 6 %, than not safe at all, less than 5 %, however, most respondents do not feel completely safe. Though, the majority chose the middle or the higher part of the scale, 3 and 4, around 36 % and 34 % respectively.

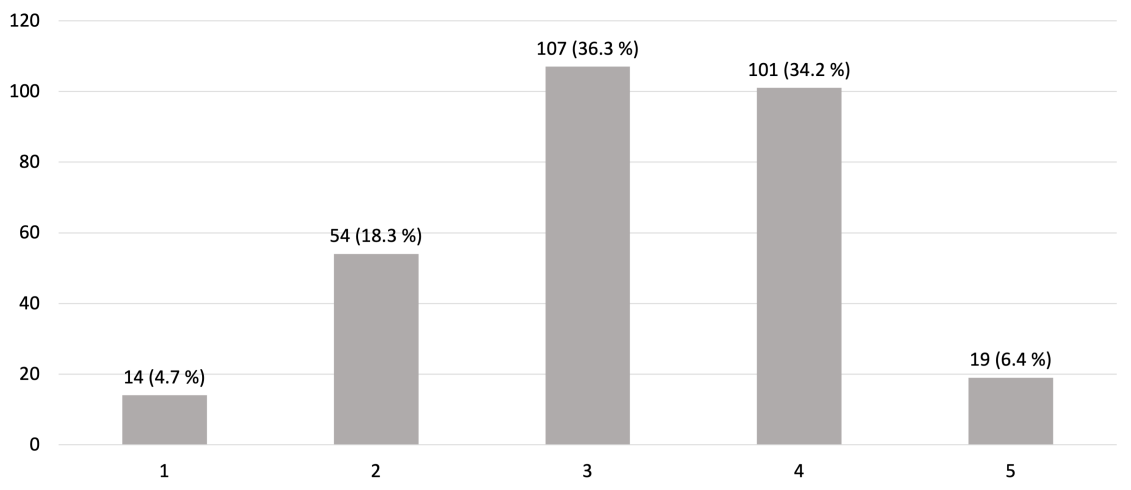

Figure 4.9: Scale of perceived safety.

Subsequently, the participants further expounded their answers on perceived safety. They were asked to choose one or more of the given alternatives of factors affecting their perceived safety, see Figure 4.10. The alternative which was stated by more than half of the group of respondents was "Segregation from motor vehicles", approximately 52 %. However, the other two factors that the participants highlight are "Segregation from pedestrians" and "Maintenance of roads", around 49 % and 45 % respectively. Further, more than 17 % highlight another factor than the given alternatives.

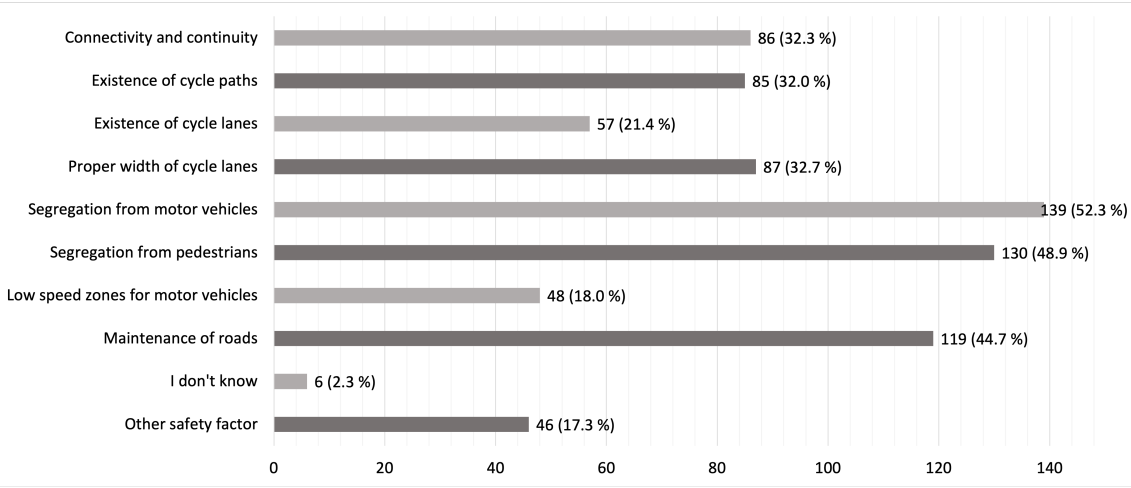

Figure 4.10: Lacking factors influencing perceived safety.

A compilation of the data related to other safety factors shows certain recurring factors. The factors are listed in ranking order based on how many times each factor is mentioned.

- Other road users (especially other cyclists and electric scooters riders) who do not follow traffic rules.
- Poor accessibility and guidance during road works.

- Various problems that arise around intersections, such as interaction with motor vehicles.
- Obstacles or objects on the road, such as incorrectly parked electric scooters or cars.

Further examples of other factors reducing the perceived safety are poor lightning and visibility, and theft. However, several stated factors could have been within the same categories as the above already proposed alternatives. Subsequently, this would affect the results.

4.3.5.3 Effect of Traffic Safety on Satisfaction

The data set, including the scale of network satisfaction and traffic safety, is analyzed by calculating the average, standard deviation, variance, coefficient of variation, and the covariation, see Table 4.1. The analysis is conducted to investigate the spread of the data collected in the survey concerning the network satisfaction and traffic safety in the city, see Figure 4.7 and Figure 4.9. The study aims to establish how homogeneous the perception of the respondents is.

Table 4.1: Average, Standard Deviation, Variance, Coefficient of Variation, and Covariation

	Network Satisfaction	**Traffic Safety**
Average	2.79	3.19
Standard Deviation	0.97	0.97
Variance	0.95	0.94
Coefficient of Variation	35 %	30 %
Covariation		**59 %**

The average of the network satisfaction shows that the user perception is within the lower scale, while the perception of traffic safety is slightly higher, see Table 4.1. Both values show that the overall attitude of the bicycle environment in Gothenburg has potential for improvement. The values for the standard deviation, variance, and coefficient of variation indicate that the average values are representative of the data set collected from the survey. Since the covariation is positive, the value implies that traffic safety relates to the overall perception of the bicycle network satisfaction and that the two variables behave similarly.

4.3.5.4 Other Improvement Measures

After establishing important factors related to cycle infrastructure and perceived safety, the participants are asked to state other improvement measures that would increase their cycling. The vast majority, around 77 %, believe that cycle passability

should be higher prioritized compared to other transportation modes, see Figure 4.11. Three other popular measures are "Traffic calming measures", "Bicycle friendly environment at work", and "Safe and weatherproof bike parking at home", however, these shares are still significantly lower than the first mentioned, approximately 29 %, 28 %, and 22 % respectively. The distribution of responses between the other alternatives is relatively even. Further, more than 14 % stated improvement measures in addition to the proposed alternatives.

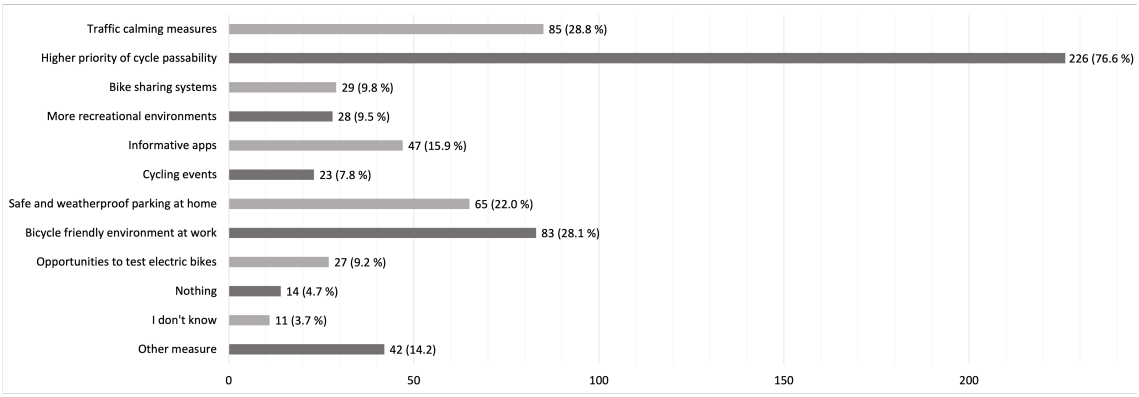

Figure 4.11: Other improvement measures to increase cycling.

A compilation of the data related to other improvement measures shows certain recurring measures. The measures are listed in ranking order based on how many times each factor is mentioned.

- Improvement measures connected to bike parking, such as increasing safety, more weatherproofed, and increasing the amount of parking.
- Other improvement measures that would reduce theft.
- More direct routes without unnecessary detours.
- General improvement of existing cycle paths and lanes.
- Clearer traffic rules for other road users, such as car drivers, e-scooter drivers, and pedestrians.

Further examples of improvement measures to increase cycling are avoiding cycle paths where there are cobblestones, enabling cycle wash, and establishing the possibility of combined trips, i.e., enabling the possibility to bring your bike on buses and trams.

Note that the most critical factor according to the survey result, "Higher priority of cycle passability compared to other transportation modes", is also related to infrastructural measures. Therefore, alternatives concerning soft measures, such as policies and marketing, will be excluded from further analysis and will not be a part of later discussions.

4.3.6 Specific Routes and Areas

The respondents are asked to name specific routes within the city that they perceive as critical. The routes are described by origin and destination. In total, around 65 % answered that they know one or more specific routes within the city that they perceive as problematic. The respondents have the possibility to list up to three routes in the questionnaire. When stating a problematic route, the participants are asked to list factors related to their perception of the route. Figure 4.12 shows how many times each factor has been stated as problems related to a specific route within the city.

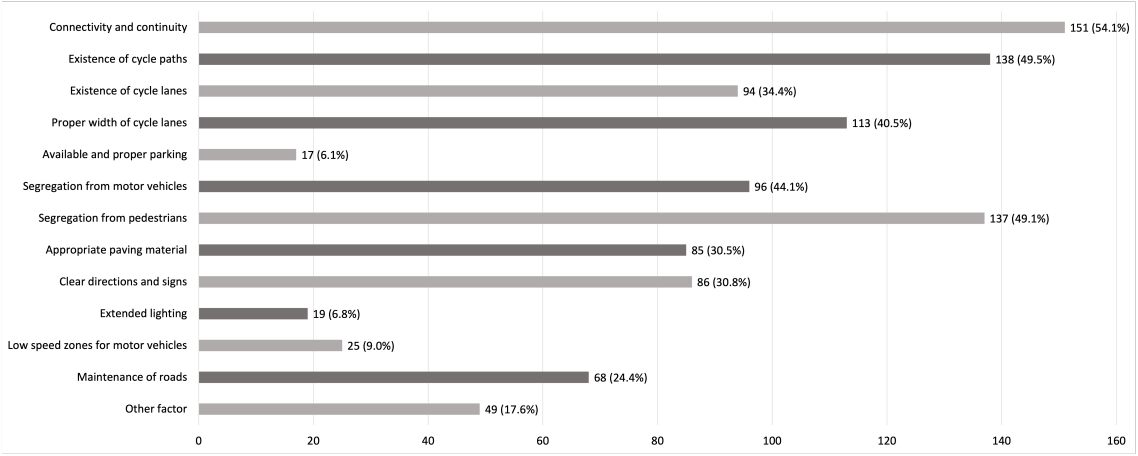

Figure 4.12: Compilation of lacking factors for specific routes and areas.

The three most critical factors representing specific routes or areas, are "Connectivity and continuity along with the network", "Existence of cycle path", and "Segregation from pedestrians", see Figure 4.12. All data collected from the questionnaire of identified routes and areas, and their assigned critical factors, is presented in a summarized table in *Appendix C*.

4.3.7 Comparison of Critical Factors

A comparison of the five most critical factors concerning the different perspectives, network satisfaction, perceived traffic safety, and specific routes is presented in Table 4.2. Explanations for respective factor is presented in *List of Acronyms*.

Table 4.2: Comparison of Critical Factors

Network Satisfaction	Perceived Safety	Specific Routes
CC (68.4 %)	SV (52.3 %)	CC (54.1 %)
SP (58.9 %)	SP (48.9 %)	CP (49.5 %)
LW (49.1 %)	MR (44.7 %)	SP (49.1 %)
CP (48.4 %)	LW (32.7 %)	LW (40.5 %)
DS (41.4 %)	CC (32.3 %)	SV (34.4 %)

The comparison of the most critical factors in Gothenburg, presented in Table 4.2, shows that connectivity and continuity is crucial considering network satisfaction. Considering perceived safety, the segregation from other road users is of higher importance. It could be assumed that the survey respondents are considering both network satisfaction and perceived traffic safety when describing specific routes within the city. However, the difference between the aspects could be a result of the inclusion and exclusion of various proposed alternatives in the questionnaire. Although, most of the critical factors are recurring for all aspects.

4.4 Spatial Analysis

The spatial analysis is conducted using QGIS, to enable a graphical visualization of the three most critical factors where each forms a network. As established, the three most critical factors related to specific stretches are, according to the participants of the survey, connectivity and continuity, existence of cycle path, and segregation from pedestrians, see Figure 4.12. This section presents the result of the spatial analysis of these three factors, see Figure 4.13-4.17.

Each network consists of red markings, representing a critical route or stretch, and a respective factor. Different thicknesses of routes or stretches illustrate how many times a route or a stretch is associated with the critical factor, where the thickness increases for each time a route or stretch is mentioned by the participants of the questionnaire. Further, some participants have named an area of the associated critical factor, which is also included in the spatial analysis. The critical areas are highlighted in red, using polygons, where the polygons are less or more transparent depending on how many times a specific area is specified. When analyzing the result of the spatial analysis, it is assumed that critical stretches within a critical area, are considered further problematic. Dashed, red lines, indicate parts when the cyclists travel by ferry.

4.4.1 Connectivity and Continuity Along with the Network

The parts of the cycling network associated with connectivity and continuity problems are presented in Figure 4.13. According to the respondents of the survey, the most critical stretches are gathered around the central parts of the city. However, the problem is also widely spread over the city of Gothenburg, see *Appendix D* where Figure D.1 presents an extensive perspective of the network.

Figure 4.13: Connectivity and continuity - the critical network.

One hot spot that is often recurring among the answers of the respondents, both in areas and within routes, are stretches included in the area around the Central Station, see Figure 4.14.

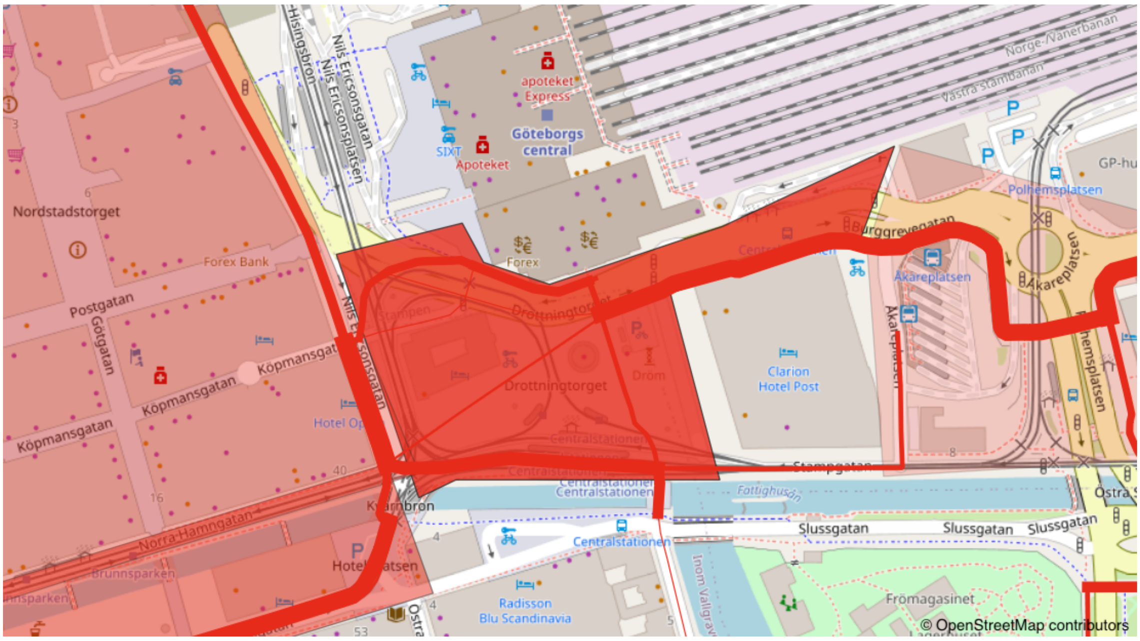

Figure 4.14: Connectivity and continuity - the critical area around the Central Station.

4.4.2 Existence of Cycle Paths

The parts of the cycling network associated with existence of cycle path problems are presented in Figure 4.15. The analysis of the cycle path availability shows that many

of the stretches associated as problematic correspond to the stretches associated with connectivity and continuity problems, see Figure 4.13. The perceived critical areas also coincide, however, the factors are perceived as more or less critical at some stretches. An extensive perspective of the network attributed with the critical factor is presented in *Appendix D*, Figure D.2.

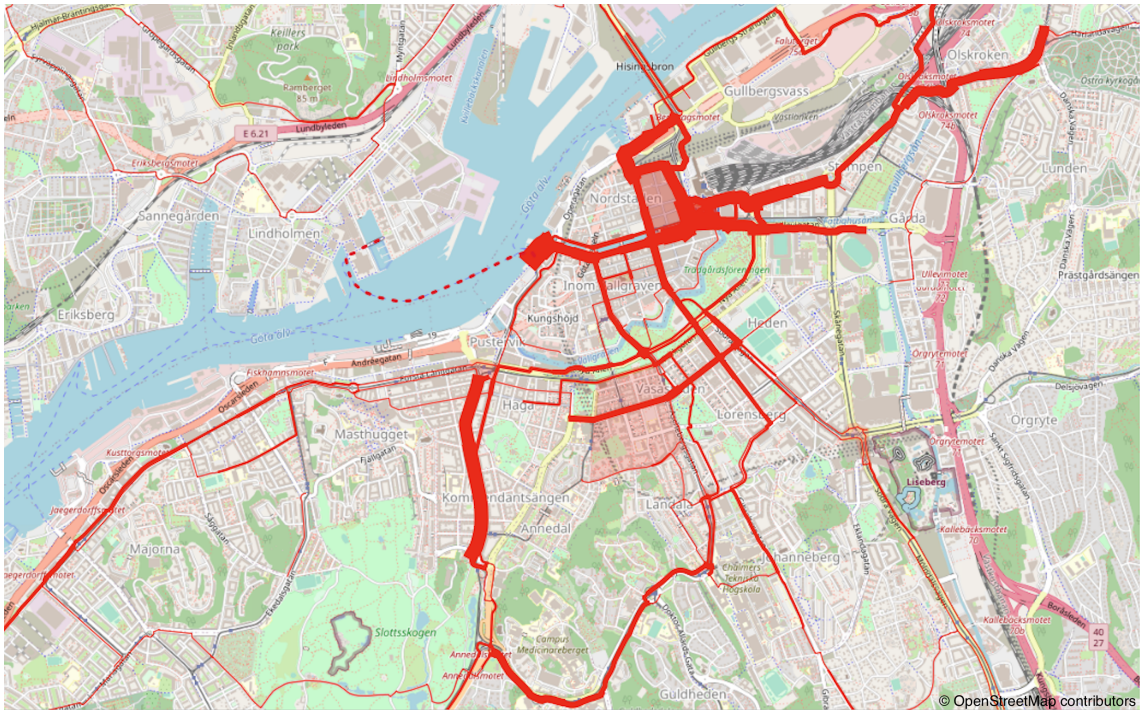

Figure 4.15: Existence of cycle paths - the critical network.

Three identified hot spot areas are identified including stretches within Stenpiren, Brunnsparken, and around the Central Station, see Figure 4.16.

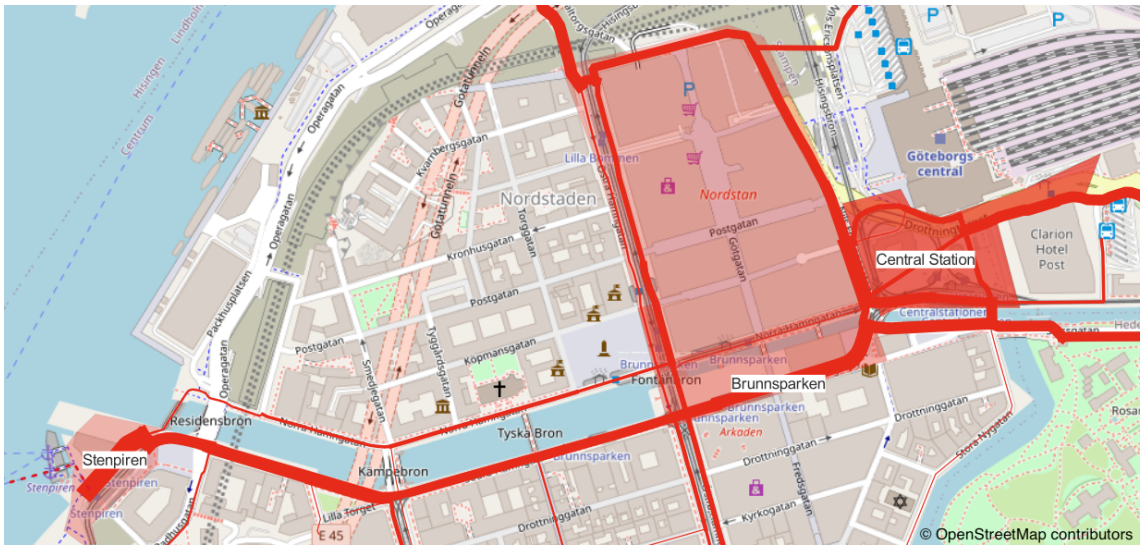

Figure 4.16: Existence of cycle paths - the critical areas at Stenpiren, Brunnsparken, and the Central Station.

4.4.3 Segregation from Pedestrians

The parts of the cycling network attributed with problems regarding segregation from pedestrians are presented in Figure 4.17. The spatial analysis of this critical factor shows higher intensity of the problem around the inner city, similarly to problems concerning connectivity and continuity, and cycle path availability, see Figure 4.13 and 4.15. The area around the Central Station is critical, however, the most critical stretches are located further south in the city. An extensive perspective of the network attributed to the critical factor is presented in *Appendix D*, Figure D.3.

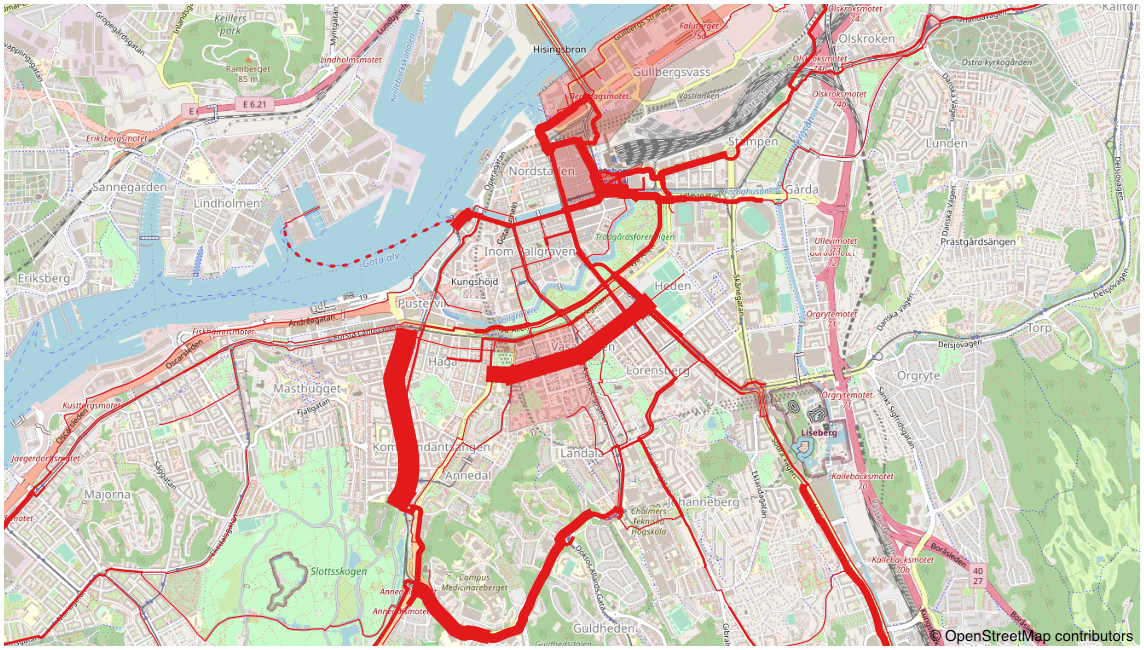

Figure 4.17: Segregation from pedestrians - the critical network.

Two identified hot spots of the critical factor are the streets Vasagatan and Linnégatan, see Figure 4.18 and Figure 4.19.

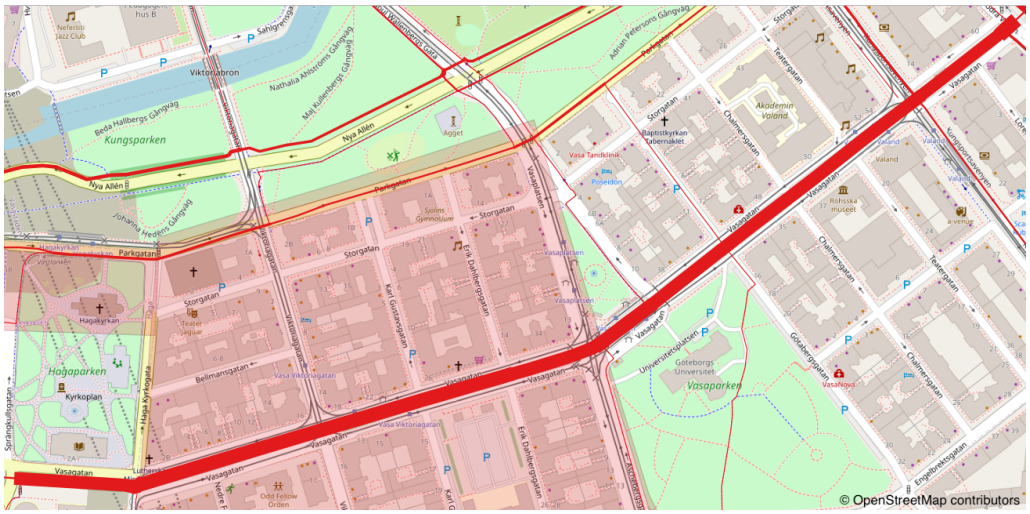

Figure 4.18: Segregation from pedestrians - main critical stretch, Vasagatan.

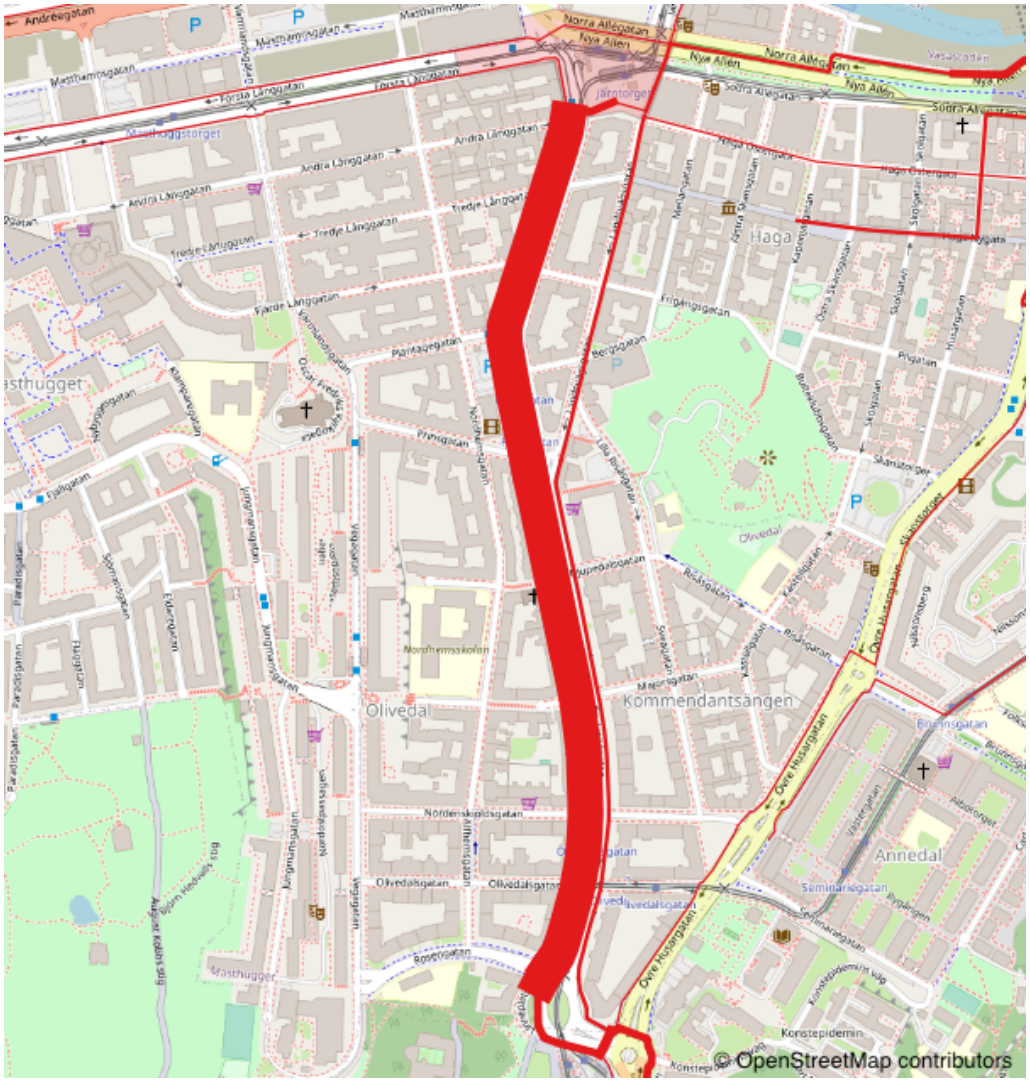

Figure 4.19: Segregation from pedestrians - main critical stretch, Linnégatan.

4.5 Observation

By analyzing the results of the spatial analysis, it is determined to physically observe three routes. The observation is conducted on two occasions where the first route is investigated during the first occasion, and the two other routes are observed during the second occasion. Both observations are conducted on a weekday after rush hour traffic in the morning but before lunchtime. The three observation routes are as follows:

- Redbergsplatsen-Stenpiren, consisting of several critical stretches
- Vasagatan
- Linnégatan

The observed routes are illustrated using QGIS, see Figure 4.20 and 4.21. The blue lines illustrate the routes, and the red pins highlight the locations of the below figures where more detailed investigations are conducted. The decision of observation routes is based on the outcome of the spatial analysis, where the investigated routes consist of several stretches and areas with alleged critical factors concerning connectivity and continuity, existence of cycle paths, and segregation from pedestrians. Detailed information of how critical the investigated factors are along the routes is presented in *Appendix E*, Figure E.1-E.7.

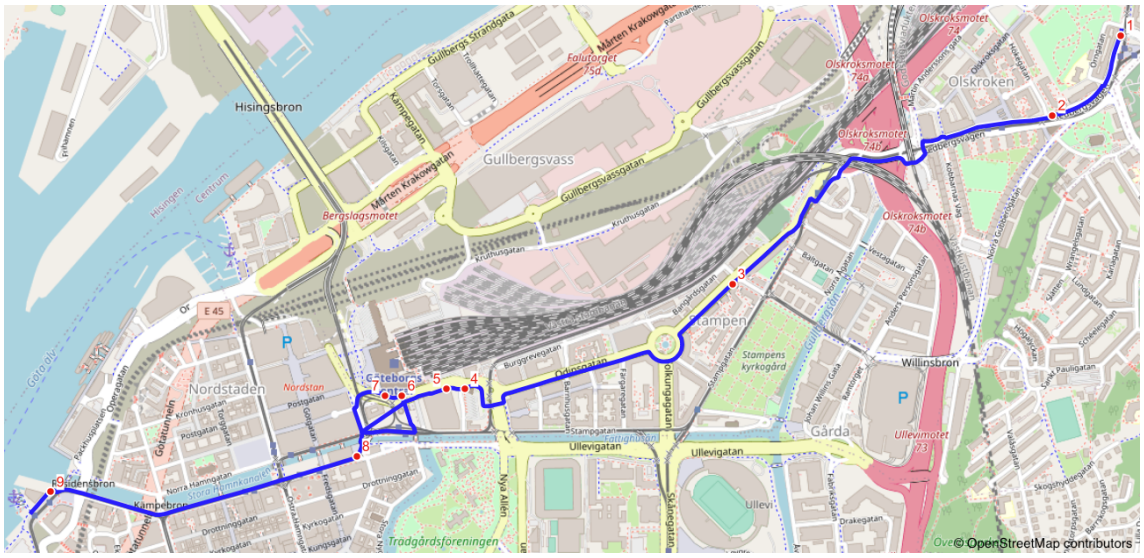

Figure 4.20: Visualization of the observation route between Redbergsplatsen and Stenpiren.

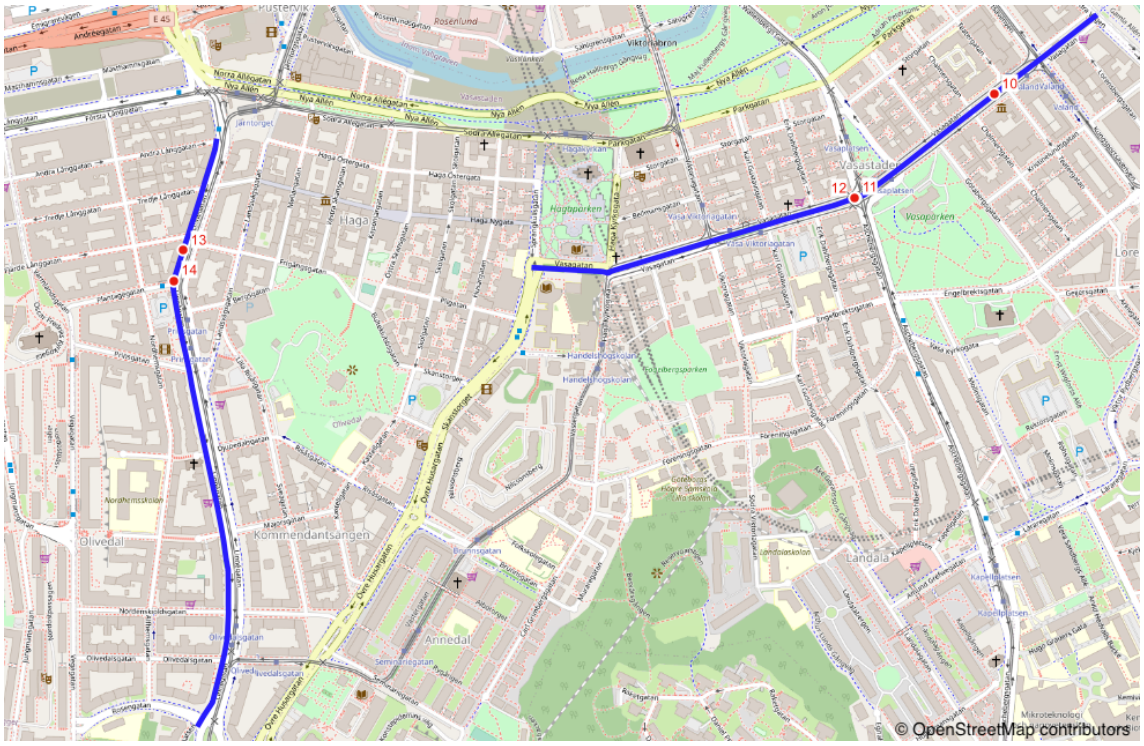

Figure 4.21: Visualization of the observation routes, Vasagatan and Linnégatan.

Note that since the traffic situation at Vasagatan and Linnégatan is similar throughout each route, the few pins represent the whole route, see Figure 4.21.

The main idea and attitude before the observation were to conduct an objective investigation and examine all possible critical situations for a cyclist. The route between Redbergsplatsen and Stenpiren was chosen for observation due to recurring problems along the way, starting at Redbergsplatsen, further along, the area around the Central Station, but also all the way to Stenpiren via Södra Hamngatan. The spatial analysis shows that the route mainly consists of critical factors including connectivity and continuity, and cycle path availability. Although, both the area around the Central Station and Stenpiren are perceived as critical concerning segregation from pedestrians as well, which is therefore investigated during the observation. Furthermore, the two most critical stretches associated with the factor segregation from pedestrians, are along the streets Vasagatan and Linnégatan, which is why these stretches are chosen for observation as well.

Figure 4.22 shows the start of the first observation route, Redbergsplatsen, pin 1. The cycle lane continues into the road aimed for motor vehicles. As shown in the figure there is a heavy flow of traffic in the area, which is a contributing factor to the lack of perceived safety while cycling on the road.

Figure 4.22: Pin 1 - Redbergsplatsen.

After passing Redbergsplatsen heading against Olskrokstorget, pin 2, the cyclists are demanded to interact with motor traffic through zipper merging, see Figure 4.23. However, motor vehicles are restricted to the speed of 30 km/h.

Figure 4.23: Pin 2 - Heading against Olskrokstorget.

Along Friggagatan, pin 3, the cyclists are segregated from pedestrians through lanes within a pedestrian and cyclist path, see Figure 4.24. However, at one part of the street the pavement marking, indicating the separation, disappears. This entails that pedestrians also use the cycle lane as can be seen in the figure.

Figure 4.24: Pin 3 - Friggagatan.

At Åkareplatsen, pin 4, before reaching the Central Station, the cycle path suddenly ends after passing the cycle passage, see Figure 4.25, and the cyclists have to interact with motor vehicles.

Figure 4.25: Pin 4 - Åkareplatsen.

As shown in Figure 4.26, pin 5, cyclists are forced to use the bus file to pass through the area towards the Central Station.

Figure 4.26: Pin 5 - Towards the Central Station.

The cycle path that ends at Åkareplatsen, pin 4, continues further along the stretch, after passing the Central Station, on the opposite side of the road, see Figure 4.27, pin 6. The distance between pin 4 and 6 is the stretch where cyclists have to use the bus file, presented as pin 5 above.

Figure 4.27: Pin 6 - The Central Station.

After reconnecting, the first part of the cycle path constitutes a pedestrian and cycle path, see Figure 4.27. However, further along the stretch, the pedestrian lane deviates while a cycle path continues. This leads to pedestrians, wanting to reach Nordstan, walking on the cycle path to avoid a detour, see Figure 4.28, pin 7.

Figure 4.28: Pin 7 - The Central Station heading towards Nordstan.

Södra Hamngatan, pin 8, has no existence of either a cycle path or a cycle lane, see Figure 4.29. The cycle path used when cycling from Nordstan deviates from the observation route. The cyclists need to use the road for trams and buses, or pedestrians. This is a central part of the city with heavy traffic, which increases the perception of feeling unsafe. This problem continues until Stenpiren.

Figure 4.29: Pin 8 - Södra Hamngatan.

The cycle stretch by Stenpiren, pin 9, is a part of the commuting cycle network. However, the marking of the path is not clear which results in it being used by pedestrians, see Figure 4.30.

Figure 4.30: Pin 9 - Stenpiren.

Vasagatan is an alley including surrounding greenery, with a dedicated pedestrian and cycle path, see Figure 4.31, pin 10. The figure shows the varying pavement material, causing a disturbance when cycling which slows down the speed when cycling. Thus, the cyclists follow their own lane, which is a relatively long stretch without any disturbing curves, but mostly a straight line. Theoretically, these conditions allow cyclists to bike unhindered without any major interruptions.

Figure 4.31: Pin 10 - Vasagatan.

Along Vasagatan, there is an intersection by every intersecting street, see Figure 4.32 showing an example. Each intersection is an interruption for cyclists. However, during the observation, at this time of day, this situation was not perceived as a major problem.

Figure 4.32: Pin 11 - Vasagatan.

Despite a dedicated cycle lane along Vasagatan, the space is still limited. As an example by pin 12, the lane for each direction is too narrow for a cargo bike, see Figure 4.33 where the cyclist is forced to use the lanes for both directions. Further, in cases of overtaking, the cyclists have to use the other lane, which is against the traffic. This was experienced more than once during the observation.

Figure 4.33: Pin 12 - Vasagatan.

Along Linnégatan, there is a dedicated pedestrian and cycle lane. However, pin 13 highlights the unclear markings of the cycle lane, see Figure 4.34. These markings blend into the surrounding pavement, which makes the separation unclear for both cyclists and pedestrians.

Figure 4.34: Pin 13 - Linnégatan.

An example of when the cycle lane is used by pedestrians is by pin 14, see Figure 4.35. Probably, this is the result of both indistinct markings and that the lane for pedestrians is narrow. The figure also shows outdoor furniture that is part of outdoor seating, which also contributes to an even more narrow walking lane, forcing larger groups of people to spread out further.

Figure 4.35: Pin 14 - Linnégatan.

4.5.1 Verification of Critical Stretches

The conducted physical observation enables verification of the results of the spatial analysis. The chosen routes of the observation are based on the fact that several stretches and areas within the routes are alleged with several critical factors. The routes consist of the most critical stretches and areas concerning the three analyzed factors, connectivity and continuity, existence of cycle paths, and segregation from pedestrians. Therefore, the chosen routes are the obvious choices for detailed observation. Subsequently, most of the highlighted critical factors for each stretch could be verified by the observation. Further, other critical factors experienced during the observation will be analyzed.

The routes of the first observation are visualized with blue lines in Figure 4.20. By the top of Redbergsplatsen, pin 1, the lack of connectivity and continuity, and existence of cycle path is experienced, which are problems indicated by the participants of the questionnaire. However, the most obvious perceived problem is related to segregation from motor vehicles, since the cyclists are demanded to use the roadway due to the sudden end of the cycle lane. Further along the street, heading towards Olskrokstorget where the cyclists have to interact with motor vehicles through zipper merging, pin 2, the same perceived problems regarding segregation from motor vehicles are verified. Motor vehicles are restricted to the speed limit of 30 km/h which means that the general speed limit of traffic in the area is relatively low. However, when there are heavy flows of traffic, the feeling of being safe for cyclists, could still be decreased. Additionally, there is neither a cycle path nor a cycle lane after the zipper merging. By Friggagatan, pin 3, the unclear marking resulting in insufficient segregation from pedestrians is perceived as a significant problem during the observation.

Moving towards the Central Station from Åkareplatsen, pin 4 and 5, both the critical factors connectivity and continuity and existence of cycle path are clearly perceived when conducting the observation. This is because there is no intuitive route choice for the cyclist when leaving Åkareplatsen. Further, problems concerning segregation from pedestrian and motor vehicles are also perceived since the cyclists have no dedicated space to move on. In the area around the Central Station and heading towards Nordstan, pin 6 and 7, there are perceived problems concerning segregation from pedestrians. This is especially perceived by pin 7, heading towards Nordstan, where the walking lane deviates. The spatial analysis also shows a lack of cycle paths by pin 7 despite that the observation verified the existence of a pedestrian and cycle path at the location. Since both lanes, the one for pedestrians, and the one for cyclists, are narrow, it is reasonable to claim that more developed segregation from pedestrians is needed. I.e., when there is a lack of lane width, the solution consisting of a pedestrian and cycle path, might not be the most suitable alternative.

Södra Hamngatan, pin 8, has been associated with several critical factors by the survey participants, which the observation verifies. The critical factors include the existence of cycle paths and cycle lanes and indirectly, segregation from both pedestrians and motor vehicles.

The end destination of the first observation route, Stenpiren, pin 9, is perceived as problematic concerning cycle path availability, despite the existence of a commuting cycle path. The observation of the area verifies the existence of a cycle path, however, the unclear pavement marking creates confusion for the various road users. The cycle path marking blends into the surrounding which is an open area for pedestrians, entailing the critical factor, segregation from pedestrians. This problem becomes even more critical due to the fact that the stretch is a part of the commuting network which should have a high standard where the cyclist should be able to maintain a high speed which is not possible by Stenpiren.

The observation route Vasagatan, pin 10-12, is located in the inner city of Gothenburg, in a busy area surrounded by schools, workplaces, shops, and restaurants. In the conducted survey, where participants could state their own experienced problems along critical routes, the alleged problems of Vasagatan are verified during the observation. At each intersecting street, there is also intersecting traffic, including pedestrians and motor vehicles, entailing problems with both segregation from pedestrians and motor vehicles. This will probably become even more apparent during rush hour traffic, causing many interruptions for cyclists along the street. However, due to the circumstances of Vasagatan, being a busy street, the importance of mutual respect in traffic becomes even more important. Despite the fact that the street consists of a straight line, it is important for a cyclist to understand the context, which is actually that the area is heavily trafficked by all possible types of traffic.

The observation at Linnégatan, pin 13-14, indicates that the unclear marking and the narrow walkway, partly due to open-air cafes, result in insufficient segregation from pedestrians. This verifies the result of the questionnaire that highlighted this as the, by far, most critical factor along the street. However, the spatial analysis shows that cycle path availability, also is repeatedly highlighted as critical for this route, see Figure 4.15. This could be explained by the fact that insufficient marking leads to the perception of a non-existing path. The combination of unclear markings and lack of lane width results in the need for an own cycle path is perceived as a more critical problem. In turn, the lanes within the pedestrian and cycle path are too narrow to separate the different road users sufficient.

By compiling the results and experiences of the observation, most of the results collected from the questionnaire are verified. A clear connection that became evident in many parts of the predetermined routes, is that several of the identified critical factors are interrelated. If one factor is lacking, another factor could be lacking as well. Further, an additional obvious critical factor identified during the observation was the lack of segregation from motor vehicles, at several investigated locations. By analyzing the results of the survey further, segregation from motor vehicles is also one of the most critical factors assigned to specific stretches in Gothenburg. Therefore, a spatial analysis is conducted for this critical factor as well.

4.5.1.1 Complementary Spatial Analysis

The parts of the cycling network attributed to problems regarding segregation from motor vehicles are presented in Figure 4.36.

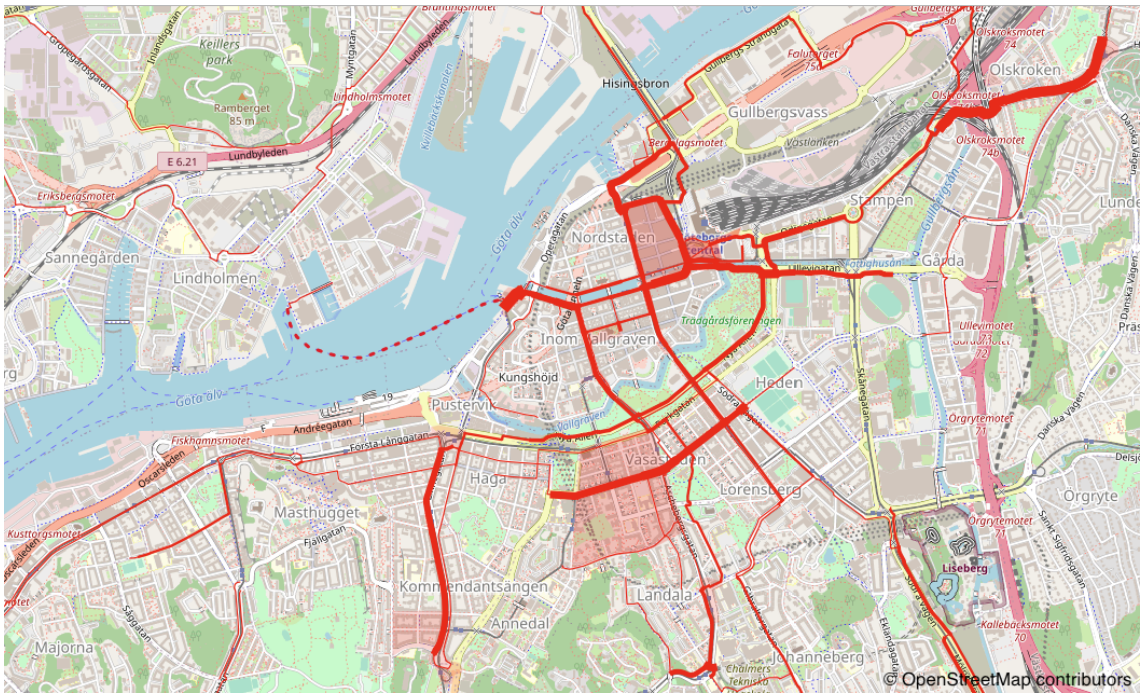

Figure 4.36: Segregation from motor vehicles - the critical network.

The spatial analysis shows that the problem is more concentrated in the inner parts of the city compared to the three most critical factors, previously analyzed. The degree of criticism concerning problems with segregation from motor vehicles, is fairly evenly spread over the inner city, see Figure 4.36. Many of the critical hot spots correspond to where, in the network, problems regarding segregation from motor vehicles are perceived during the observation. One example is at the beginning of the observed route between Redbergsplatsen-Stenpiren and in the area around the Central Station. An extensive network attributed with the critical factor is presented in *Appendix D*, Figure D.4.

4.5.2 Possible Improvement Measures

This section presents various possible improvement measures that can be implemented for different critical situations. The analyzed and discussed measures are based on the locations identified during the observation, see Figure 4.20 and Figure 4.21.

At the top of Redbergsplatsen, pin 1, the existing cycle lane ends and the cyclists have to continue into the road aimed for motor vehicles, see Figure 4.22. Since this increases the feeling of being unsafe in traffic, a suitable improvement to this critical situation would be to construct a cycle path. Considering that there already is space

for pedestrians by the right side of the trees, a proposal is to use parts of the space for pedestrians shown in the figure, and instead create a cycle path. By separating the cyclist from other road users more distinct would increase the traffic safety for the cyclist. Further, by continuing the cycle lane into the sidewalk would create a more coherent and gene network.

Further along the same street, heading towards Olskrokstorget, pin 2, the cyclists have to interact with motor traffic through zipper merging, see Figure 4.23. During the physical observation of this study, an assessment is made that there are possibilities to replace the zip merge solution, with a bicycle passage leading the cyclists across the road. By replacing the zipper merge solution with a cycle passage would avoid the interaction between cyclists and motor vehicles and therefore increase traffic safety. However, after crossing the road, a cycle path might be necessary in order for cyclists to avoid interaction with motor vehicles. Although, more detailed investigations are necessary to determine where and how the cycle path can extend.

Along Friggagatan, pin 3, there are parts of the pedestrian and cycle path which are missing clear markings, see Figure 4.24. A solution to this situation would be to mark the cycle lane along the whole street to separate the different road users more efficiently. Since this would improve the separation from pedestrians, which was one of the most perceived critical factors concerning traffic safety, this would be an appropriate improvement measure to increase safety. This would be a simple and quick measure but would have a big positive impact on cyclists.

The area around the Central Station, pin 4-6, consists of complex problems where major infrastructural measures are necessary to find solutions to improve the environment for cyclists. The main problem of the area is the interaction with motor vehicles in combination with the missing instinctive direction for cyclists. At least, the area is in need of clear directions that inform cyclists along the way through the area, to create a more intuitive route after leaving Åkareplatsen, see Figure 4.25. Furthermore, the re-connection of the cycle path by the Central Station, see Figure 4.27, also needs to be announced earlier to increase the intuitiveness of the cyclists. An alternative solution is to more efficiently redirect cyclists to other parts of the bicycle network. However, this is not desirable as this alternative requires detours.

When passing the Central Station heading towards Nordstan, pin 7, a cycle lane, within the existing pedestrian and cycle path, continues. However, the lane for pedestrians deviates resulting in the subsequent cycle path being used by pedestrians as well, see Figure 4.28. Since the area for the existing cycle path is sufficiently wide and could be shared with pedestrians, a suggestion is to continue the lane for pedestrians. This would create a more gene direction for pedestrians heading towards Nordstan. If this measure would have been implemented with clear markings that sufficiently separate the two transportation modes within the path, the situation could improve the traffic flow and safety for both modes.

The traffic situation for cyclists at Södra Hamngatan, pin 8, is significantly insufficient, see Figure 4.29. However, the area requires complex solutions with major infrastructural changes to create a safe and efficient road for cyclists since there is a lack of space. A solution could instead be a redirection for cyclists which would most probably not require a detour. The cyclists could be redirected between the two black dots and instead reconnect to the bicycle network via Norra Hamngatan, see Figure 4.37. Norra Hamgatan is located next to Södra Hamngatan and is sufficiently wide to implement a cycle lane that would connect to the cycle path by Residensbron. However, there is still a lack of space in the area around Brunnsparken since the space is highly loaded with various transportation modes.

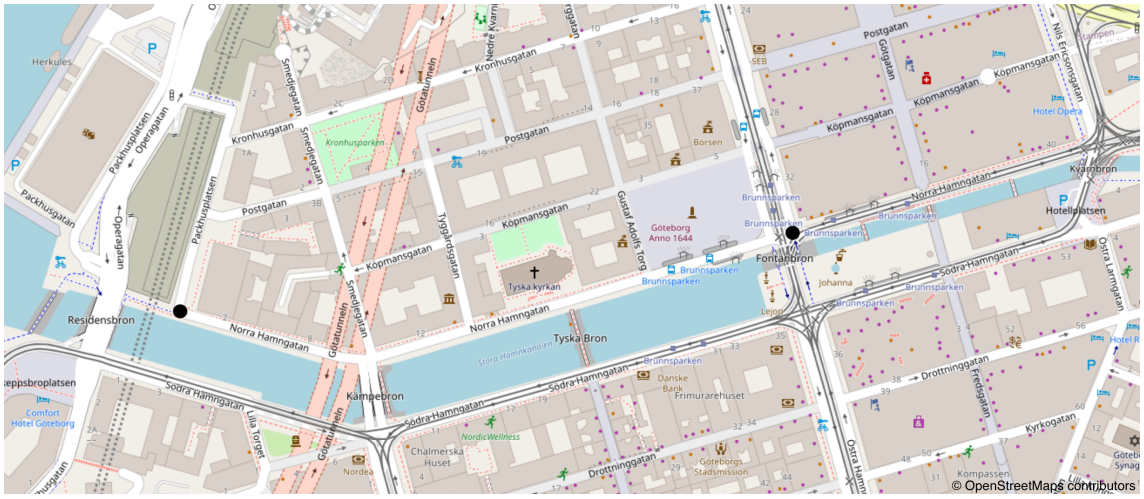

Figure 4.37: Södra Hamngatan and Norra Hamngatan, where a cycle lane could be implemented between the two black dots.

The stretch by Stenpiren, pin 9, being a part of the commuting cycle network, is in need of improvement due to the confusion in the area resulting in pedestrians using the cycle lane, see Figure 4.30. The situation would be highly improved for cyclists with small adjustments including more efficient marking that would separate the two transportation modes. A clarified marking would enable a consistent flow through the commuting network and the separation from pedestrians, that this solution would provide, increases traffic safety as well.

Along Vasagatan, pin 10-12, the problem with narrow cycle lanes, which complicates overtaking, is a complex situation. There is a lack of space and both cyclists and pedestrians are already given a large share of the traffic room. They are separated with greenery which is important for a sufficient separation from motor vehicles and contributes to the recreational environment. However, in order to enable overtaking and to avoid pedestrians walking on the cycle lane, some space could be taken from the greenery and instead be used to broaden the cycle lane. Further, to facilitate the cyclist, but also pedestrians and motor vehicles, the rules of priority at intersections along the street could be clarified by, for instance, more distinct markings or signs. One example could be to place "Warning for cyclist" signs at critical intersections to increase the passability for cyclists by avoiding other transportation modes crossing

the cycle lane inappropriately.

Along Linnégatan, pin 13-14, the current markings blend into the pavement of the street, and could instead be marked with another color to avoid pedestrians using the cycle lane, thinking it is a walkway, see Figure 4.34. The same applies to the one-way rule, where arrows indicating the direction could be marked more clearly. The problem with narrow lanes is complex since the space is insufficient for both pedestrians and cyclists, especially during seasons of outdoor seating. However, analyzing the result of the survey, some respondents that highlighted Linnégatan as critical, when asked about other factors, stated that they wished for a cycle lane placed along the roadway instead, see *Appendix C*, Table C.2. This could increase the passability for cyclists, but whether there is enough space for a cycle lane along the road or not, and how the safety of the cyclists is affected, needs to be further investigated.

5
Discussion

The discussion of the study consists of analyses of the results based on the research questions. Further discussions include potential uncertainties, biases, and related impacts of the study.

5.1 Bicycle Friendly City

The necessary factors to achieve a bicycle friendly city vary depending on the circumstances of the specific city. This section discusses important factors of an arbitrary city, comparing the priorities of Gothenburg. The analyzed results include the conducted literature review, as well as the interviews of the study. Further, the findings from the different interviews including different actors are compared and discussed.

Findings of the literature review consist of two main features considered crucial to achieving a bicycle friendly city, bicycle infrastructure and traffic safety. Bicycle infrastructure and traffic safety affect the cycling behavior of cyclists and even the cycling culture of a city. In turn, the features consist of various factors. Important factors related to the infrastructure of a bicycle friendly city are connectivity and continuity, the existence of cycle paths, proper width of cycle lanes, proper parking space for bikes, segregation from motor vehicles, and appropriate paving material. By prioritizing these factors, the perceived traffic safety of cyclists could also be increased. These findings also coincide with the results collected from the conducted questionnaire where the participants consist of network users in Gothenburg. The survey results show that connectivity and continuity along with the network is an important factor considering bicycle infrastructure, while separation from other road users is of more importance concerning traffic safety. Additionally, a higher priority of cycle passability compared to other transportation modes is also affecting the perception of the bicycle environment. The average value of the network satisfaction and the perceived traffic safety, based on the data set collected from the survey, show that the user perception of the two variables is within the lower scale. This indicates that the overall attitude of the bicycle environment in Gothenburg has potential for improvement. In turn, this again coincides with the findings of the literature review, showing that necessary factors are not always prioritized, despite being crucial to achieving a cycle friendly city. Furthermore, various advantages of cycling, including improved health and decreased environmental impacts, should be considered well-argued reasons to strive for achieving a bicycle friendly environment.

The interviews with the Transport Administration of Gothenburg, Gustaf Frid, and Rolf Broberg focus on Gothenburg, while the interviews with Axel Pihl and Erik Stigell discuss an arbitrary cycle city. In the interview with the Transport Administration of Gothenburg, they explain that they prioritize a coherent network when planning for cycling. Similarly, the experts highlight this as an important factor to achieve a well-functioning bicycle network. This is, in one perspective, in line with connectivity and continuity along with the network being the most mentioned factor when the respondents of the conducted survey, are asked to list factors that they think are lacking within the current network of Gothenburg. The fact that this is a prioritization of the administration is consistent with the perception of the participants of the survey, that connectivity and continuity is an important factor to achieve an improved bicycle network. However, it is worth noting that respondents highlight this as the most critical factor, while the Transport Administration highlights this as a factor they are striving to improve.

Further, the Transport Administration stresses that they want to prioritize orientability within the existing network since they have traditionally focused on constructing, developing, and improving cycle paths. Broberg, Phil, and Frid highlight orientability as a critical factor to enable intuitive bicycling in a city. This is in line with the respondents of the survey, where clear direction and signs are stated as one of the top five most critical factors when asked about general network satisfaction. However, according to the respondents, the lack of existing cycle paths is even more critical in the general view of the city's network and this factor is pointed out as the second most critical factor regarding specific routes. According to the Transport

Administration of Gothenburg, investment planning has resulted in higher priority of commuting cycle stretches. They want to bridge the existing barriers to create a more integrated city. However, Broberg stresses that future urbanization could have a negative effect on the commuting bicycle network. An example that he highlights is the development of the boulevard at Dag Hammarkjöldsleden. According to Broberg, this could impair the continuity of the cycle network, and the fast commuting will be forced to slow down.

Both the public sector and the experts are asked about how different target groups are approached and if there is any prioritization among different groups. According to the Transport Administration of Gothenburg, everybody should be taken into account when planning. Despite this, both Pihl and Broberg stress that the network is accommodated for different target groups depending on the specific areas. Further, Frid perceives that children are completely excluded from the bicycle network today.

The interviewees agree that passability is of high importance when planning for a bicycle friendly city. However, some of the interviewees mention that when traffic safety is prioritized, other features such as passability could be less prioritized. However, Stigell claims that a holistic perspective when planning enables management of both features. Further, several interviewees stress the importance of adapting the passability to different areas and situations. As an example, passability needs to be

prioritized for the commuting lanes. But in inner-city areas where there are many different traffic users who must interact, higher traffic safety is needed. In order to increase safety and enable the interaction between traffic users, traffic lights are used. However, both Stigell and Broberg emphasize the importance of not stopping the cyclist when it is not needed, which is also mentioned as a problem by the participants of the survey. The importance of creating green waves is mentioned.

The Transport Administration of Gothenburg claims that they do not prioritize routes for touristic trips with a recreational environment. However, Stigell claims that the recreational aspect should be higher prioritized and that an attractive environment is important to increase cycling. The result of the survey shows that around 50 % of the respondents are using bicycles for recreational trips. However, only 9.5 % state that more recreational environments would increase their cycling.

5.1.1 Critical Factors of Gothenburg

Critical factors within the current bicycle network of Gothenburg are identified through different perspectives in this study. From the questionnaire, including the perception of the bicycle network users in Gothenburg, identified factors are related to the general satisfaction with the current bicycle network, perceived safety, and problems with specific routes or stretches. The most critical factors in the different perspectives are presented in Table 4.2.

The comparison shows that connectivity and continuity along with the network is, according to the respondents of the questionnaire, a critical factor that needs improvement to increase their total satisfaction with the bicycle network. However, the result from the survey shows that concerning safety, sufficient segregation from other transportation modes is of higher importance compared to continuity. In addition to continuity, proper lane width and segregation from motor vehicles and pedestrians are recurring factors in all perspectives. However, the different perspectives do not fully correspond to each other. It is worth noting that the different perspectives do not totally include the same alternatives, see *Appendix B*, where the questionnaire is presented. The number of alternative factors, and which factors that are included, are related to the question that is asked to the respondent. When the respondents are asked to list factors that influence their perceived safety, some alternatives are excluded compared to selectable factors considering satisfaction of the network, and vice versa. Clear directions and signs, which is one of the most critical factors related to network satisfaction, is one of the factors that are excluded when investigating perceived safety. Similarly, maintenance of roads is not an alternative factor regarding network satisfaction. When the respondents are asked to list factors that are lacking on the stated specific route, all alternative factors are selectable.

The difference between the perspectives could also be explained by the fact that 35 % of the respondents did not answer questions related to specific routes. However, since the respondents were able to include more than one route in the survey, more answers in total, compared to the general view, are retrieved. It is assumed that,

in many cases, the general view of the bicycle network corresponds to which routes and related factors are highlighted. However, for some respondents, the general view and named route could differ.

Further, the results of the survey, spatial analysis, and observation show that many factors are interrelated. The critical factors are often highlighted together and are therefore often problematic in the same routes, see *Appendix C*, Table C.2. One clear example of a situation, where many factors could be described as lacking, is at Redbergsplatsen, see Figure 4.22. Here, the cycle lane suddenly disappears which entails interrupted connectivity and continuity. After the interruption, there is no existing cycle path or lane, and cyclists are not separated from motor vehicles. This means that one traffic situation could be described with different factors. It also highlights the importance of analyzing every specific highlighted situation in the bicycle network to be able to find the most suitable solution.

5.2 Focus Area in Gothenburg

The literature review and the interviews with the Transport Administration, and experts, resulted in identified factors necessary to achieve a bicycle friendly environment in a city. Since these factors were used in the questionnaire aimed for the citizens of Gothenburg, to highlight what they think is currently lacking within the city, potential critical factors in the cycle network could be determined. The spatial analysis of three identified critical factors, connectivity and continuity, cycle path availability, and segregation from pedestrians shows that critical stretches are to be found mainly in the central parts of the city. Further, around 80 % of the survey participants stated that they would increase their cycling if the cycle passability is higher prioritized compared to other transportation modes. The perception of this low prioritization can be related to the inner-city environment since the traffic flows are high and many transportation modes interact with each other in these areas. Therefore, the study shows that many of the lacking factors are, according to users of the traffic network of Gothenburg, located in the inner bicycle network constituting a part of the comprehensive network. The current top priority of the Transport Administration of Gothenburg is the development of commuting stretches connecting different districts of the city with adjacent municipalities. Further, they state that the network in central parts of the city is not sufficient and that it is not equipped for increased traffic flows. Because of this, the central network is also prioritized when the Transport Administration is planning for cycling in the city.

The result of the spatial analysis confirms the statement that the central network is perceived as critical. Considering the outcome of the analysis, it is important that the cycling network in the inner city is prioritized and developed. However, it is important to highlight that the high flows in the inner city probably have influenced the result of the survey. The intensity of the central parts could be a result of many cyclists using this part of the network more compared to stretches in the outskirt of the city. Further, many stretches within the inner city connect and are parts of several longer routes reaching the outskirts of the city. This leads to them being

marked out frequently and thereby highlighted as critical in the spatial analysis. One clear example of this is Odinsgatan, which is a part of the observation route between Rebergsplatsen-Stenpiren, see Figure 4.20. In the spatial analysis, the street is pointed out as critical concerning problems with connectivity and continuity, see Figure 4.13. However, the observation did not show any connectivity and continuity problems on this part of the route. The highlighting of the street could be a result of the fact that many different routes include this stretch and that this is a stretch linking many origins, located east in the city, with the inner city. Another example of when the results of the survey and observation do not fully correspond is at Friggagatan, see 4.20. Despite this street not being pointed out as critical, lacking segregation from pedestrians was identified during the observation. This indicates that the spatial analysis, based on the survey, did not cover all critical stretches within the city. Although, the observation proved that in most cases, where critical areas or stretches are pointed out in the spatial analysis, based on the survey respondents' perception, lacking factors are identified in reality. The fact that the method of this study resulted in an observation that verified many of the alleged problems in the network, in turn, shows the importance of including the perception of the network users when determining focus areas.

5.3 Subsequent Improvement Measures

Continuously during analyses of this thesis, is the fact that historical urban planning in Sweden has not been prioritizing cycling sufficiently in the traffic room compared to other transportation modes. Several of the interviewed experts, especially Phil and Frid, highlight that the cycle often is less prioritized where there is a lack of space and that it is seen as a flexible transportation mode that can be completed secondarily. At many locations, the space is already occupied by other transportation modes, and if the space should be dedicated for cyclists, another mode would have to be excluded from the traffic room instead. With other transportation modes in mind, it is, in some traffic rooms, challenging to plan for implementations with the goal of achieving a bicycle friendly environment. The fact that cycle infrastructure often consists of secondary constructions, is a recurring major factor that results in an unsustainable environment for cyclists. However, despite the need for the higher priority of bicycle infrastructure, all transportation modes should be able to use the same traffic room simultaneously and conveniently. Broberg emphasizes that the infrastructure should be designed to make the cooperation with other transportation modes obvious.

The low prioritization of the bicycle in urban environments is clearly distinguished during the observation of the critical route, that runs through central parts of Gothenburg. Especially around the Central Station and along Södra Hamngatan where no space is left to implement dedicated bicycle infrastructure, leading to cyclists having to use either space for motor vehicles or pedestrians, which jeopardizes their traffic safety. To be able to bicycle separation from other transportation modes, the cyclists would have to reconsider their route and take detours to reach certain destinations. With Broberg's well local knowledge of the bicycle network,

he highlights the problem around the Central Station as well. He perceives the area as critical since many commuting stretches extend toward the station without connecting to each other. This, by Broberg, pointed out barrier was distinct during the observation of the area. Additionally, Broberg stresses the conflict of interest by Stenpiren-Skeppsbron where the unclear marking of the cycle path, in combination with the area being used by trams, buses, ferries, and pedestrians as well, negatively impacts the environment for cyclists. The stretch is a part of the commuting cycle network requiring high standards for cyclists. This conflict was obvious when observing the area. However, the situation could, to some extent, easily be improved by marking the cycle path more clearly in order to separate cyclists from other road users.

This study shows that to achieve a bicycle friendly environment, and benefit from the many advantages of bicycling, upcoming future city projects have to include and prioritize planning for cycling in an early stage and compared to other transportation modes. This could avoid the infrastructure design limiting the possibility to, on a daily basis, travel by bike in a safe and comfortable way.

5.4 Uncertainties

This chapter discusses potential limitations considering the method and results related to the research question of the thesis.

5.4.1 Target Groups

To be able to define a city as cycle friendly, all citizens need to be taken into account. The goal of this study was to identify factors that could entail that people, despite cycle experience and different conditions, felt satisfied and safe when using the cycle infrastructure of Gothenburg. However, the study did not reach all target groups. Examples of this involuntary exclusion are discussed in this section.

The fact that some age groups are excluded from the study, because of a lack of data and assumptions, entails that not all citizens are included. For example, since only one answer is received within the age gap of 7-14 in the questionnaire, the perception of children is not taken into account when analyzing the survey data.

When the respondents are asked to specify their cycling frequency, the largest share, 40 %, states that they are cycling daily. Together, the alternatives including some amount of cycling constitute a vast majority of the answers. Only 8 % state that they are never bicycling in the network of Gothenburg. The large share of experienced cycling respondents is beneficial in the perspective that this constitutes network users that, based on their experience, can review the situation. This is advantaging when identifying specific routes within the network, but also to describe the general view of the city. However, the smaller proportion of respondents that do not bicycle, entails that the data collection does not fully represent those who may retrain from

cycling because of lacking factors in the environment, even though the goal of the study was to include this group as well.

Furthermore, since the data collected from the questionnaire is not fully reflecting the statistics of inhabitants in Gothenburg, considering age and gender, the results probably do not fully represent the overall perception of the citizens. Also, the used method when gathering data in the questionnaire, consisting of non-probability convenience sampling, has probably led to a targeted group limited by the members of the chosen Facebook groups. However, a probability sampling of such a large group, consisting of all inhabitants of Gothenburg, would require a large number of answers using formulas sent out by letters. This would be costly and was therefore not a possible option for this master thesis.

5.4.2 Various Critical Factors

The comparison of the results from the questionnaire, regarding critical factors, showed a difference when the respondent are asked to name lacking factors related to the general perception of the city and when considering specific routes. This may be a result of the fact that the question regarding specific routes, to some extent, contained more alternatives. However, the result indicates that the respondents have included both satisfaction with the network itself and the perceived safety when describing specific routes, which was the intention of the survey.

Furthermore, the general perception of the network of Gothenburg and related lacking factors have probably, to an uncertain extent, included the commuting network as well. This means that the spatial analysis, showing that the critical area mainly consists of the central parts of the city, could have been excluding other critical parts of Gothenburg. However, the observation of the chosen route showed that other factors, despite the factors included in the spatial analysis, were lacking as well. As an example, segregation from pedestrians which was critical, considering both the general satisfaction of the network and the traffic safety, was perceived as lacking at some parts of the route. This shows that if a larger number of factors had been included in the spatial analysis, a more extensive view of the cycling environment could have been conducted and more critical factors could have been related to a specific stretch or area.

5.4.3 Spatial Analysis Assumptions

When creating the network in the software QGIS, consisting of critical factors of the bicycle infrastructure, the highest priority was to follow cycle paths and lanes. Secondly, roads aimed for motor vehicles were followed. However, walkways for pedestrians were used when the cycle path sometimes transitioned into a walkway during a short stretch, and then transitioned back into a cycle path or a roadway. In some cases, the suggestion of Google Maps was a route that included cycling on walkways for pedestrians. Since those routes were suggested and therefore assumed as the shortest route, those routes were used. In other cases, Google Maps suggested

roads aimed for motor vehicles instead. In most of those cases, the cycle path in connection to the road could be followed with the same route alternative. However, sometimes the cycle path could not be followed during the whole route, which lead to using the motor vehicle road instead. As a result of the various assumptions made depending on each situation, the created network of the spatial analysis may differ from reality. Practically, the cyclists might choose a certain route that follows more cycle paths and is, therefore, more natural for them to choose. Although, the conducted physical observation showed that some routes included stretches where the roads for motor vehicles were the only alternative for cyclists. Altogether, a trade-off has been made for the respective situation during the creation of the network where certain approaches have been prioritized in a certain order.

When using Google Maps to identify the shortest path between origins and destinations, it was clear that the map was not fully updated. In some cases, when searching for directions between destinations, the route passed a construction site where the construction is complete today. One clear example was the area around Hisingsbron, which was completed in spring 2021. In those situations, local knowledge about the area was used and the route was adjusted to the current situation. However, smaller constructions or reconstructions that are not well-known might have not been discovered, which could have had an impact on the route choice and misrepresented the current situation.

The fact that only three of the most critical factors were investigated, entailed that some stretches presented as related to one problem could in fact be more critical considering another perspective. This could be discovered if more identified critical factors had been included in the spatial analysis. Further, one factor that was mentioned fewer times than the most critical ones, could be specified to a certain area or stretch, which would make that factor critical at that location.

The assumption that only already identified critical stretches within a critical area adds the level of criticism, excludes other stretches within the same area. In some cases, the respondents of the survey may have included several stretches when highlighting a critical area, which this study has excluded due to the assumption of only interpreting a few stretches as critical within an area. Unclear answers, when asking for specific routes in the survey, have also been excluded from further study, which could have impacted the statistics of critical factors. Further, in some of the answers, the respondent stated another factor without choosing this as an alternative when listing factors. In those cases, *Appendix C* was adapted secondarily and the "Other factor" was listed as a chosen alternative anyways. This probably entails that "Other factor" is more critical than the diagram, showing the statistics, indicated. In a few cases, the respondent would describe one of the already listed factors in the free answer for "Other factors". In those cases, the alternative factor was added instead and excluded from the "Other factors" description in *Appendix C*, which also has slightly affected the statistics.

6
Conclusion

In conclusion, the main necessary factors to achieve a bicycle friendly city, identified in this thesis, are related to bicycle infrastructure and traffic safety. Proper bicycle infrastructure includes different types of solutions adapted and prioritized for cyclists. Important factors are connectivity and continuity along with the cycling network, the existence of cycle paths, proper width of cycle lanes, and segregation from motor vehicles. Depending on how these factors are managed, the perceived safety of cyclists is also affected. Additionally, orientability and passability are important for a well-functioning bicycle network. The route choice should be gene and obvious, all decisions along the way should be intuitive and detours should not be needed.

According to users of the bicycle network of Gothenburg, the general satisfaction of the network could increase with the improvement of factors such as connectivity and continuity, segregation from pedestrians, and proper lane width. To increase the perceived traffic safety in general, factors such as segregation from motor vehicles and from pedestrians, as well as maintenance of roads, need to be improved. The majority of the users participating in the study, also state the importance of higher priority of cycle passability compared to other transportation modes. However, the three most critical factors specified for specific routes, within the city, are connectivity and continuity along with the network, the existence of cycle paths, and segregation from pedestrians. An explanation of why these specified factors differ from the general perception of the network could be the fact that the users include both an infrastructural and safety perspective when describing specific stretches.

The study shows that the most critical stretches, based on the most critical factors, are gathered around the inner city of Gothenburg. However, the fact that the inner city is critical could be a result of the high flows within these areas. Although, many of the central parts of the city consist of several stated problems related to each other, which have been verified through observations. Subsequently, this research shows the importance of including the perspective of users when identifying critical stretches. Since investigated factors have been identified and verified within the bicycle network of Gothenburg, this shows that the method of the thesis could be useful when analyzing an existing bicycle network, and when identifying potential for improvement. In the case of Gothenburg, both minor and major infrastructural changes are necessary to achieve bicycle friendly environments around the city. However, where minor changes are needed, the impact on cyclists would still be significant.

6.1 Recommendations for Future Research

The scope of this study covers the identification of various critical factors necessary for a city to be perceived as bicycle friendly. More specifically, the study identifies specific routes and stretches within Gothenburg, and their respective critical problems. However, analyses of the study only focus on a selected number of identified critical factors where several other factors could be further researched. Therefore, recommendations for future research include more detailed analyses of more of the identified critical factors. Similarly, the observation of the study can be conducted in a more extensive manner where more routes and their attributed problems can be investigated. This would further enable more detailed studies of different types of possible improvement measures adapted for more specific scenarios. An alternative is to delimit the study either by a smaller area or by a specific critical situation where a limited number of critical factors are investigated. In turn, such a delimitation would have a more detailed focus area and could therefore enable possibilities of investigating the implementation of major infrastructural measures for specific situations, which were not investigated in this study.

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A

Appendix A

Appendix A presents the templates consisting of interview questions.

Interview with the Public Sector

- How does the Municipality of Gothenburg plan for cycling?
- Do you cater for all target groups in all parts of the city or are there certain priority groups?
- Are you planning for different purposes?
- What factors do you think need to be fulfilled to consider Gothenburg bicycle friendly?
- Is there any difference in how it works in practice compared to the vision?
- Which cycle paths within the city are prioritized today and why? Are users or planners pointing out these stretches?
- Which problems have been identified with these stretches considering bicycle infrastructure?
- What possible improvement measures can be implemented to increase safety and passability of the cycle paths?
- What other tools are available to increase bicycling within the city?

Interview with Experts

- What is important when it comes to cycling planning?
- What do you think might be missing in the planning of cycling today?
- What criteria do you think need to be fulfilled to consider Gothenburg as bicycle friendly?
- How do you assess which cycle paths within a city that need to be improved? Is this based on the user's feeling?
- Are you aware of any stretches within the city that need to be prioritized?
- What possible improvement measures can be implemented to increase safety and passability of the cycle paths?
- How are all target groups being catered for? Is this being done?
- What other tools are available to increase bicycling within the city?

B

Appendix B

Appendix B presents the layout of the questionnaire, including questions and answer options. * presents a compulsory question, ■ means that more than one option can be chosen.

Whether a section is shown for the respondent or not is sometimes related to the answers in the previous section. If the answer is "Never" when asking about cycling frequency, the respondent is not sent to the "Cycling purpose" section. If the answer is "No" regarding specific stretches in Gothenburg, the respondent is not asked to state a stretch and describe it. It is possible to name up to three stretches.

Cycling in Gothenburg

Age*

- 7-14
- 15-24
- 25-45
- 46-60
- 60+

Gender*

- Female
- Male
- Other
- Prefer not to say

Cycling frequency (in Gothenburg)*

- Daily
- More than once a week
- Once a week
- Once a month
- Never
- Seasonally

If seasonally, please state when and how often during this time period.

Text answer

Cycling purpose

Please state you cycling purpose.

- ■ Commuting to work
- ■ Commuting to school
- ■ Service matter
- ■ First/last mile trip (i.e. to and from public transit, car use, walking)
- ■ Shopping trip (including groceries)
- ■ To/from family and friends
- ■ Recreational trips
- ■ Exercise
- ■ Other purpose

If other cycling purpose, please state what.

Text answer

The bicycle network in general

I am satisfied with the current bicycle network of Gothenburg.*
Do not agree

- 1
- 2
- 3
- 4
- 5

Totally agree

If you're not fully satisfied with the current bicycle network, please state why. Lack of...

- ■ Connectivity and continuity along the network
- ■ Existence of cycle paths (dedicated road only for cyclists/moped riders)
- ■ Existence of cycle lanes (lane on a road only for cyclists/moped riders)
- ■ Proper width of cycle lanes
- ■ Available and proper parking for bikes
- ■ Segregation from motor vehicles
- ■ Segregation from pedestrians
- ■ Appropriate paving material
- ■ Clear directions and signs
- ■ Extended lighting at cycle paths/lanes
- ■ I don't know
- ■ Other factor

If other factor, please state what.

Text answer

I feel safe when bicycling in Gothenburg.*
Do not agree

- 1
- 2
- 3
- 4
- 5

Totally agree

If you don't feel completely safe when bicycling, please state why. Lack of...

- ■ Connectivity and continuity along the network
- ■ Existence of cycle paths (dedicated road only for cyclists/moped riders)
- ■ Existence of cycle lanes (lane on a road only for cyclists/moped riders)
- ■ Proper width of cycle lanes
- ■ Segregation from motor vehicles
- ■ Segregation from pedestrians
- ■ Low speed zones for motor vehicles
- ■ Maintenance of roads
- ■ I don't know
- ■ Other safety factor

If other safety factor, please state what.

Text answer

Which other improvement measures can be implemented to increase your cycling (regardless you current cycling frequency)?*

- ■ Traffic calming measures (lowering of speed for motor vehicles)
- ■ Higher priority of of cycle passability compared to other transportation modes
- ■ Bike sharing systems
- ■ More recreational environments
- ■ Informative apps (with e.g., directions, locations of cycle pumps)
- ■ Cycle events (e.g., removing motor traffic from streets, arranged cycling trips)
- ■ Safe and weatherproof bike parking at home
- ■ Bicycle friendly environment at work (e.g., cycle storage)
- ■ Opportunities to test electric bikes
- ■ Nothing
- ■ I don't know
- ■ Other measure

If other measure, please state what.

Text answer

Specific stretch (1, 2, and 3)

Are there any specific bike stretch/es within Gothenburg that you think is in need of improvement?

- Yes
- No

- I don't know

Please state the specific stretch (start area-end area, e.g., Backaplan-Centralstationen).
Text answer

Please state why you think the stretch is in need of improvement. Lack of...
- ■ Connectivity and continuity along the network
- ■ Existence of cycle paths (dedicated road only for cyclists/moped riders)
- ■ Existence of cycle lanes (lane on a road only for cyclists/moped riders)
- ■ Proper width of cycle lanes
- ■ Available and proper parking for bikes
- ■ Segregation from motor vehicles
- ■ Segregation from pedestrians
- ■ Appropriate paving material
- ■ Clear directions and signs
- ■ Extended lighting at cycle paths/lanes
- ■ Low speed zones for motor vehicles
- ■ Maintenance of roads
- ■ Other factor

If other factor, please state what.
Text answer

Is there any other stretch you have in mind?
- Yes
- No

Approve

I approve that my answers are used as data in this master's thesis.*
- Yes

C

Appendix C

Appendix C presents the routes identified from the questionnaire with listed critical factors, where (X) represents the number of times the route is mentioned.

Table C.1: Specific Routes and Listed Factors

Description (X)	**Listed factors**
Almedal-Chalmers	CC, CP, CL, SV, SP, PM
Almedal-Korsvägen (2)	CC^2, CL^2, SV, OF
Angered-Gårdsten	CC, CP
Aröd-Skogome	CC
Aschebergsgatan	CC, SV
Avenyn (4)	CC^2, CP^2, CL^3, SV
Backaplan	SP
Backaplan (tunnel below Lundbyleden)	OF
Backaplan-Domkyrkan	SV, SP, DS
Backaplan-Hisingsbron	CC, LW
Blixtgatan	CC, CP, CL, PM, DS, MR
Botaniska-Annedalskyrkan	LW, SP, DS, MR, OF
Brunnsparken (7)	CC^7, CP^5, CL^5, SV^2, SP^2, PM^2, DS^4, LSZ, LW^2, BP
Brunnsparken-Gamlestaden	CC, CP, LW, SP, PM, DS, L, MR
Brunnsparken-Hisingsbron	CC
Centralstationen-Drottningtorget	CC, CP, CL, BP, SP, DS
Centralstationen-Gamlestaden	CC, LW, SP, PM, DS, L
Centralstationen-Linnéplatsen	CC, CP, CL
Centralstationen-Saltholmen	LW, SP, DS, MR

Centralstationen area (14)	CC[13], CP[11], CL[9], SV[6], SP[6], DS[3], MR, LW[3], BP, PM
Chalmersplatsen (2)	CC, LW, SP[2], DS[2], LSZ
Dag Hammarskjöldsleden-Sahlgrenska-Chalmers-Götaplatsen	CC, CP, CL, SP, PM, DS
Dag Hammarskjöldsleden-Sahlgrenska-Chalmers-Vasaplatsen	CC, CP, CL, SP, PM, DS
Djurgårdsplatsen-Såggatan (Ekdalsgatan)	CC, CP, CL, SV, LSZ
Domkyrkan-Chalmers	CC, CP, SV, DS
Domkyrkan-Frihamnsporten	CC, CP, SV, DS
Domkyrkan area	CC, CP, SV, DS
Drottningtorget-Brunnsparken	CC, CP, CL
Eriksberg-Sannegården	CC, CL, SV, MR, OF
Exportgatan	SV, SP, PM, MR
Fridkullagatan-Krokslätts parkgata	CC, CP, CL, SP, DS
Friggagatan-Hisingsbron	CC, CP, CL, SV
Frölunda-Mölndal	CC, CP, LW, MR
Föreningsgatan	CP, CL, SV
Gamla Allén	CP, SP, PM
Gamla Ullevi-Drottningtorget	SP, LSZ
Gamlestaden-Lövgärdet	CP, CL, LW, SP, PM, L
Gamlestaden-Redbergsplatsen-Järntorget	CC, BP, SV, DS
Gamlestadstorget	LW, SP, DS, L, OF
Gamlestadens Fabriker-Marieholmsbron	LW, SV, DS, LSZ, OF
Grönsakstorget (2)	CC, CP, CL, SV, OF
Grönsakstorget-Vasaplatsen	CC, CP, LW
Guldmyntsgatan/Högsboleden	CC, CP, CL, LW, BP, SV, SP
Götaplatsen-Lilla Bommen	CC, CP, LW, SV, SP
Götaplatsen area	CC
Göteborgsoperan area	CC, LW, PM, MR
Haga-Avenyn	CP, LW, SP
Haga-Heden	CC, CP, CL, LW, SV, SP, PM
Hagakyrkan area	CC, CL, LW, SP, DS

Handelshögskolan-Valand	OF
Hisingsbron	CC, CP, LW
Hisingsbron (south side)	CC, SP^2, OF^2
Hisingsbron-Avenyn	CC, CP, LW, DS, LSZ
Hisingsbron-Gamla Ullevi (2)	CC^2, CP^2, SV, SP^2, MR^2, CL, LW, PM, DS
Hisingsbron-Gibraltargatan	CC, CP, CL, LW, BP, SV, SP, PM, OF
Hisingsbron-Nordstan (2)	CC, SV, DS OF
Hisingsbron-Odinsplatsen	CP, CL, LW, SV, SP, OF
Hisingsbron-Olskroken	CC, CP, CL, LW, SV, SP, PM, DS
Hisingsbron-Stampen	CC, CP, LW, DS, LSZ
Hjalmar Brantingsplatsen-Herkulesgatan	CC, CP, CL, SV
Hjällbo-Gamlestaden (via Marieholmsgatan)	CC, CP, CL
Högsbo industriområde	CC, CP, CL
Högsbo-Älvsborgsbron	PM, OF
Importgatan	SV, SP, PM, MR
Inner city-Hisingen	CC, CP, CL, LW, BP, SP, PM, L, MR
Inner city-Saltholmen	CP, CL, SP, MR
Johanneberg-Brunnsparken	CC, CP, SV, SP, PM, DS
Järntorget (3)	CC, CP^2, CL, SV, SP, PM, MR, OF
Järntorget-Linnéplatsen (8)	CC^3, CP^3, CL^4, LW^6, PM^7, DS^2, MR^3, SV^2, SP^3, LSZ
Järntorget-Mariaplan	CP, SV, LSZ
Järntorget-Odinsplatsen	CC, CP, CL, PM, DS
Kapellplatsen	CP, SV, DS
Karl Johansgatan (west end)	SP, OF
Karl Johansgatan-Mariagatan (via Älvsborgsgatan)	CC, CP, CL, SV
Klippan-Marklandsgatan	LW, PM, DS, OF
Korsvägen-Gårda	CC
Korsvägen area (2)	CC, CP, LW^2, BP, SP^2, OF
Krokslätts parkgata	L, OF
Kungsportsplatsen	CC^2, CP, SV, SP

Kungsportsplatsen-Brunnsparken	CP, CL, SV
Kunsportsplatsen-Hisingsbron	CP, CL, SP, DS, MR
Kungsportsplatsen-Korsvägen (2)	CC, CP, LW^{2}, SP^{2}, PM
Kungssten-Slottsskogsvallen	CC, LW, SP, PM, DS, MR, OF
Kungsstensmotet-Sandarna/ Karl Johansgatan-Stigbergstorget	CC, CP, CL, SV, SP, DS
Kungsörn-Saltholmen	LW
Kvillestråket	CC, CP, LW, SP
Kålltorp-Centralstationen	CC
Landala-Sahlgrenska	CC, CP
Landalagatan	L, MR, OF
Lilla Bommen-Kungsportsplatsen	CC, CP, CL
Lilla Torget-Nya Allén	CP, CL
Lindholmen-Hisingsbron (north side)	LW, PM
Lindholmen-Lundby	CP, CL, SV, L
Linnégatan (17)	CC^{2}, CP^{7}, CL, LW^{12}, SV^{3}, SP^{15}, MR^{7}, PM^{9}, DS^{4}, BP, OF^{3}, LSZ
Linnégatan/Prinsgatan	CC
Linnéplatsen-Hamnstråket	BP, LSZ, MR
Linnéplatsen-Järntorget-Valand-Brunnsparken	CC, CP, LW, SV, SP, PM, DS, MR
Linnéplatsen-Stenpiren	CC, CP, CL, SP
Linnéplatsen-Wavrinskys plats (via Sahlgrenska) (3)	CP, CL^{2}, SP^{3}, PM^{2}, MR^{2}, LW^{2}
Linnéstaden	SV
Långedrag	CC, CP, CL, LW, PM, MR
Långedrag-Sahlgrenska	CC, CP, CL, LW, BP, SP, PM, L, MR
Läraregatan	CC, DS
Magasingatan (north end)-Göteborgs stadsmuseum	CC, CP, CL, SV
Majorna-Järntorget (2)	CC, CP, SV, SP, PM^{2}, DS, LW, MR
Majorna-Lilla Varholmen	CC, CP, CL, PM, L
Mariaplan-Ekedalsgatan-Djurgårdsplatsen	CL, LW, SV, SP, LSZ, OF

Marieholmsbron	MR, OF
Munkebäckstorget-Björkekärr	CC
Munkebäckstorget-Olskrokstorget	CP, SP, DS
Mölndal Centrum-Korsvägen (2)	CP, CL, SV, SP, MR, OF
Mölndalsvägen (6)	CC^2, CL^3, SV^2, SP^5, MR^3, DS, LW, OF
Nordstan-Svingeln-Gullbergs Strandgata (Hamnstråket)	CC, LW, PM, DS, MR
Nordstan-Odinsgatan	CC, CP, CL
Nordstan area (4)	CC^4, CP^3, CL^2, LW, SV^2, SP^2, DS, PM, MR
Norra Hamngatan	CP, CL, SV
Nya Allén (3)	CC, CP, CL, LW, SV, SP^2, PM, DS, L, MR, OF^2
Nya Allén-Centralstationen	CC, CP, CL, SP, DS
Nya Hovås-Radiomotet	CC, CP, LW, SV, SP, PM, L, MR
Nya Varvsallén-Tranered	LW, SP, PM, L, MR, OF
Näset-Tynnered-Frölunda-Påvelund-Långedrag	CC, SP, DS, MR, OF
Odinsplatsen-Nordstan	CC
Odinsplatsen-Stenpiren (2)	CC^2, CP, SV, SP^2, CL, DS
Olskroken (gas station)	CC, SV, LSZ
Olskroken-Centralstationen-Brunnsparken	CC, CP, CL
Per Dubbsgatan (3)	CP, LW^3, SP^3, PM, DS, LSZ, MR^2, OF
Pilbågsgatan (bus stop)	CC
Redbergsplatsen (5)	CC^3, CP^2, CL, LW^2, SV^2, SP, DS^2, CL, OF^2
Redbergsplatsen-Brunnsparken	CP, CL, SV
Redbergsplatsen-Gårda Bron	CP, CL, LW, SV, PM, DS
Redbergsplatsen-Redbergsvägen	CC, CP, SV
Redbergsplatsen-Svingeln (5)	CC^2, CP^5, SV^5, SP, PM^2, DS, CL, LW, LSZ
Ringögatan (3)	CC, CL^2, LW, SP, L, PM, MR
Rosenlund-Lundbystrand	CC, CP, LW, SV, SP, DS, MR
Sahlgrenska-Linnéplatsen	CC, CP, SP

Saltholmen-Inner city	CC, LW, PM, MR
Sankt Sigfrids plan (3)	CC, DS, LSZ, OF^3
Selma Lagerlöfs torg-Ringön	CC, LW, DS
Skogome-Backaplan	LW, SP, DS, OF
Skånegatan	CC
Stampen-Centralstationen	CC, LW
Stigberget	BP, DS, MR
Stenpiren (3)	CC, CP^3, CL, SV, SP^3, PM^2, DS, LSZ
Stenpiren-Centralstationen (3)	CC^2, CP^3, CL^2, SP^2, PM, DS^2
Stenpiren-Chalmers	CC, CP, CL, LW, BP, SV, SP, PM, MR
Stenpiren-Inner city	CP, CL, SV
Stenpiren-Järntorget	LW, PM
Stenpiren-Mölndal	CC, CP, CL, LW, SV, SP, PM
Stenpiren-Nordstan (2)	CP^2, CL^2, SV, PM, DS
Stenpiren-Odinsgatan	CC, CP, SV
Storås-Angered	CC, CP
Svingeln-Centralstationen	LW, PM
Svingeln-Centralstationen-Brunnsparken	CC, CP, CL
Svingeln-Polhemsplatsen	LW, SP
Säröbanan-Linnéplatsen (via Dag Hammarskjöldsleden)	CC, OF
Säröbanan-Sahlgrenska	LW, SP, PM, MR
Sävedalen-Ullevi Norra	CC, SP, MR, OF
Södra Biskopsgården-Höstvädersgatan-Sommarvädersgatan-Länsmansgården	CC, SP, DS
Södra Hamngatan	CP, CL, SV
Södra Viktoriagatan-Chalmers	CC, LW, SV
Södra Vägen	LW, SP, OF
Södra Vägen/Engelbrektsgatan-Södra Vägen/Nya Allén (Gamla Allén)	LW, SP, DS, OF
Södra Vägen-Redbergsplatsen (via Centralstationen)	CC, PM, MR

Trädgårdföreningen-Hisingsbron	CC, CP, CL, LW, SP
Ullevi Norra-Centralstationen	CC, CP, CL, SP, DS
Ullevi Norra-Domkyrkan (via Brunnsparken)	CC, CP, CL, LW, SV, SP, DS
Ullevi Norra-Järntorget	SV, SP
Ullevi Norra-Stenpiren (3)	CC^{2}, CP^{3}, CL, SV, DS^{2}
Ullevi Norra-Vikingsgatan (via Centralstationen)	CC, CP, LW, BP, SV, SP, DS
Vasastaden (2)	CC^{2}, CP, CL, SV^{2}, SP, DS
Vasagatan (15)	CC, CP^{4}, CL^{2} LW^{3}, SV^{5}, SP^{13}, PM^{10}, MR^{5}, DS^{2}, LSZ, OF^{3}
Vasagatan-Chalmers	CC, CL
Vasagatan-Övre Husargatan-Sahlgrenska	LW, SP
Vasaplatsen-Kapellplatsen	CC, CL, SV
Vasaplatsen-Stenpiren (via Domkyrkan)	CC, CP, CL, SV, SP, DS, LSZ, OF
Vasastaden-Johanneberg	CC, CP, LW, SP, DS, L
Viktor Rydbergsgatan	CC
Volvo Lunby-Karlatornet	CP, CL, SV, OF
Vågmästareplatsen-Brunnsparken	CP, PM, DS, MR
Västra Hamngatan	CL, SV
Wavrinskys plats-Chalmers (2)	CP, LW^{2}, SP^{2}, PM^{2}, MR^{2}, DS, LSZ
Wieselgrensplatsen-Eketrägatan	MR
Åkareplatsen	CC, DS
Åkareplatsen-Brunnsparken	CC, CL, SV
Åkareplatsen-Hisingsbron (2)	CC^{2}, CP^{2}, CL, LW, SV, SP, PM, DS, OF
Åkareplatsen-Stenpiren	CC, CP, LW, PM, DS, MR, OF
Övre Husargatan-Nya Allén	CC, SP, PM, DS

The following part of Appendix C presents other factors stated by participants of the questionnaire. Some factors are a combination of answers from several participants. Further, if more than one participant stated the same factor for the same route, this is indicated with a subsequent figure representing the number of times a specific factor is mentioned.

Table C.2: Other Factors

Description	**Other factors**
Almedal-Korsvägen	Needs to prioritize cyclists at traffic lights.
Backaplan (tunnel below Lundbyleden)	Sharp curve when leaving the tunnel, downhill for oncoming traffic.
Botaniska-Annedalskyrkan	Insufficient winter maintenance.
Dag Hammarskjöldsleden	Development of boulevard could impair the continuity.
Eriksberg-Sannegården	Dangerous intersections where cars come out blind.
Gamla Allén	Unclear traffic rules at intersection with Vasagatan.
Gamlestadens Fabriker-Marieholmsbron	Bridge pillars impair sight, insufficient painted cycle passages. Heavy traffic combined with many turns.
Gamlestadstorget	Too many sharp curves.
Grönsakstorget	Too crowded and the cycle infrastructure is used by other transportation modes.
Handelshögskolan-Valand	Uncomfortable speed bumps even when the speed is reduced.
Hisingsbron (south side)	Not enough space at red light, no green wave.
Hisingsbron-Gibraltargatan	Too many traffic lights, especially at Läraregatan/Gibraltargatan.
Hisingsbron-Nordstan	Too many traffic lights at the passage from Hisingsbron to Centralstationen/Nordstan.
Hisingbron-Odinsplatsen (via Centralstationen)	Construction work in combination with insufficient signage and heavy traffic complicates the cycling.
Högsbo-Älvsborgsbron	Insufficient snow shoveling.
Järntorget	Too crowded and the cycle infrastructure is used by other transportation modes.
Karl Johansgatan (west end)	Dangerous when crossing downhill.

Klippan-Marklandsgatan	The most suitable route is not clarified.
Korsvägen area	Insufficient traffic lights and unclear rules of priority at intersections.
Krokslätts parkgata	Bad insight.
Kungssten-Slottskogsvallen	Insufficient snow clearance.
Landalagatan	Insufficient drainage system.
Linnégatan	Place cycle lane within the street (2) and clarify one-way rules.
Mariaplan-Slottsskogsgatan/ Ekedalsgatan-Djurgårdsplatsen	Car parking next to the cycle lane resulting in loading zones for prams and luggage.
Marieholmsbron	Not comfortable street bumps.
Mölndal Centrum-Korsvägen	Insufficient snow shoveling.
Mölndalsvägen	Bad winter maintenance, too many traffic lights with low priority for cyclists.
Nya Allén	Many stops due to traffic lights at crossings (2).
Nya Varvsallén-Tranered	Insufficient snow clearance.
Per Dubbsgatan	Bus stop placed in the middle of cycle lane.
Redbergsplatsen	Pot holes, cyclists not prioritized at intersection too crowded, and the cycle infrastructure is used by other transportation modes.
Sankt Sigfrids plan	Much waiting and lack of space at traffic lights (3).
Skogome-Backaplan	Many crossings with bad sight.
Sävedalen-Ullevi Norra	Cycle road is much longer compared to going by e.g., car.
Södra Vägen	Too many red lights.
Vasagatan	Many crowded and unclear intersections including pedestrians and motor vehicles and no clear rules of priority.
Vasaplatsen-Stenpiren (via Domkyrkan)	An interruption at Vasaplatsen/Storgatan, the cyclists need to cross roads dedicated for cars and public transport.

Volvo Lunby-Karlatornet	Dangerous slope due to the surface material.
Åkareplatsen-Hisingsbron	A tunnel/railway viaduct is missing.
Åkareplatsen-Stenpiren	Higher priority of cyclists at Norra Hamngatan.

D

Appendix D

Appendix D presents parts of the spatial analysis where each critical network is illustrated from an extensive perspective.

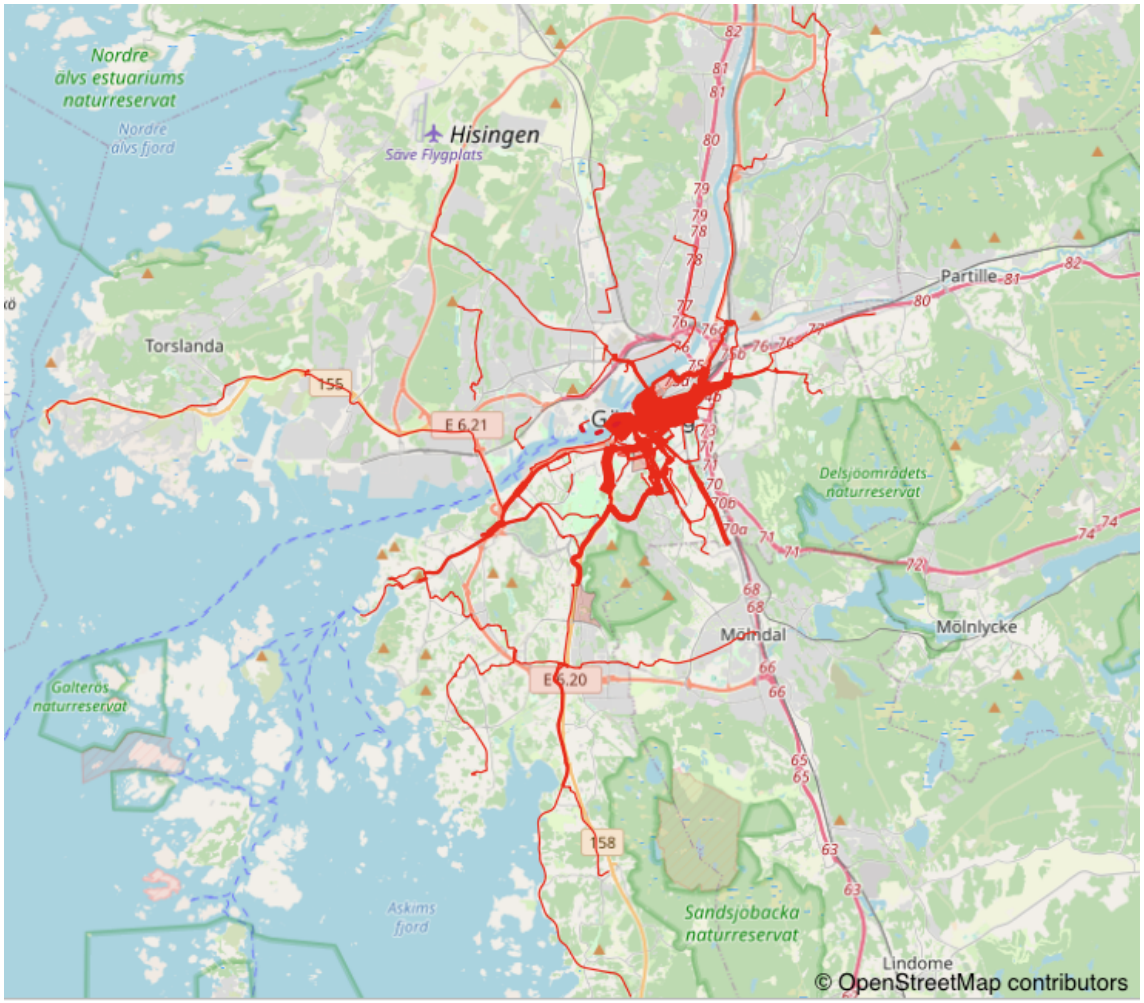

Figure D.1: Connectivity and continuity - the extensive critical network.

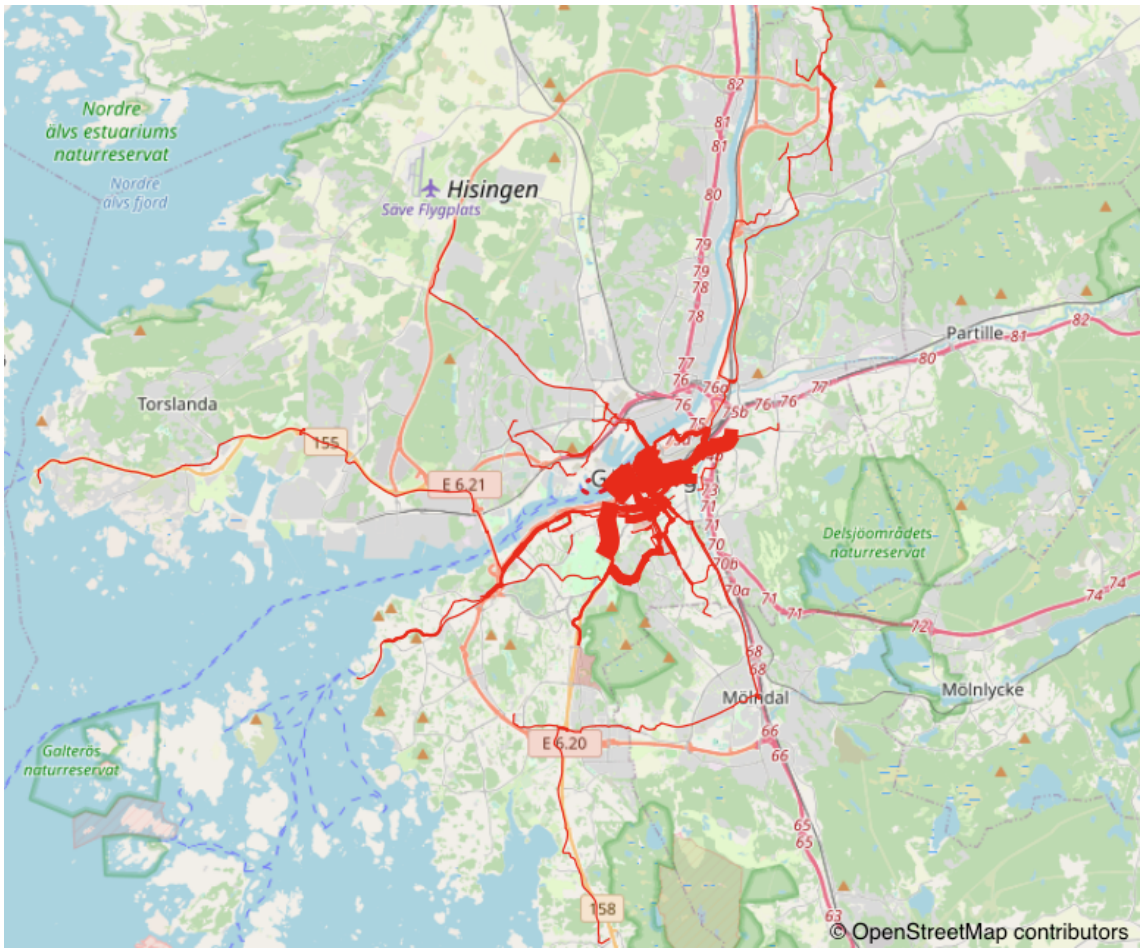

Figure D.2: Existence of cycle paths - the extensive critical network.

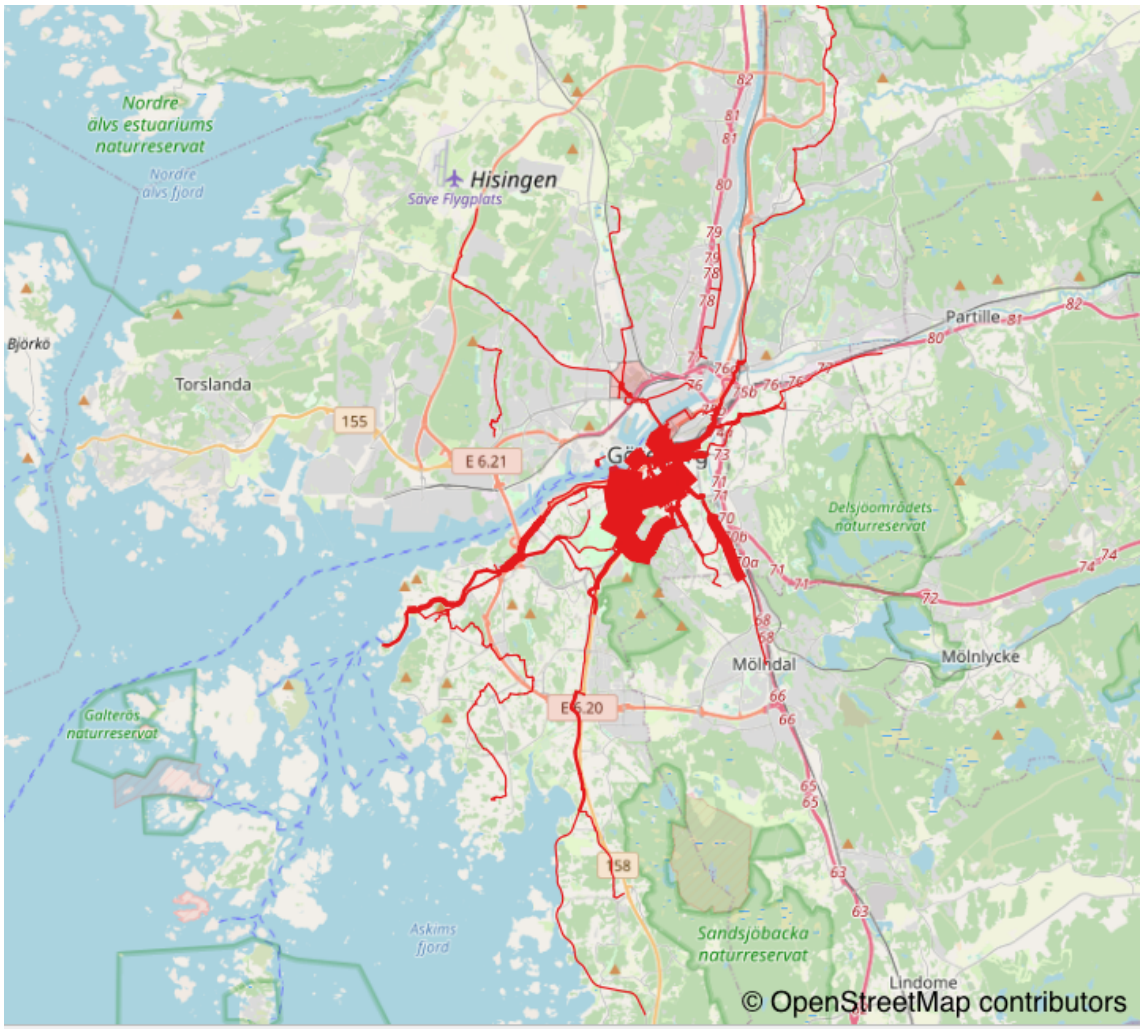

Figure D.3: Segregation from pedestrians - the extensive critical network.

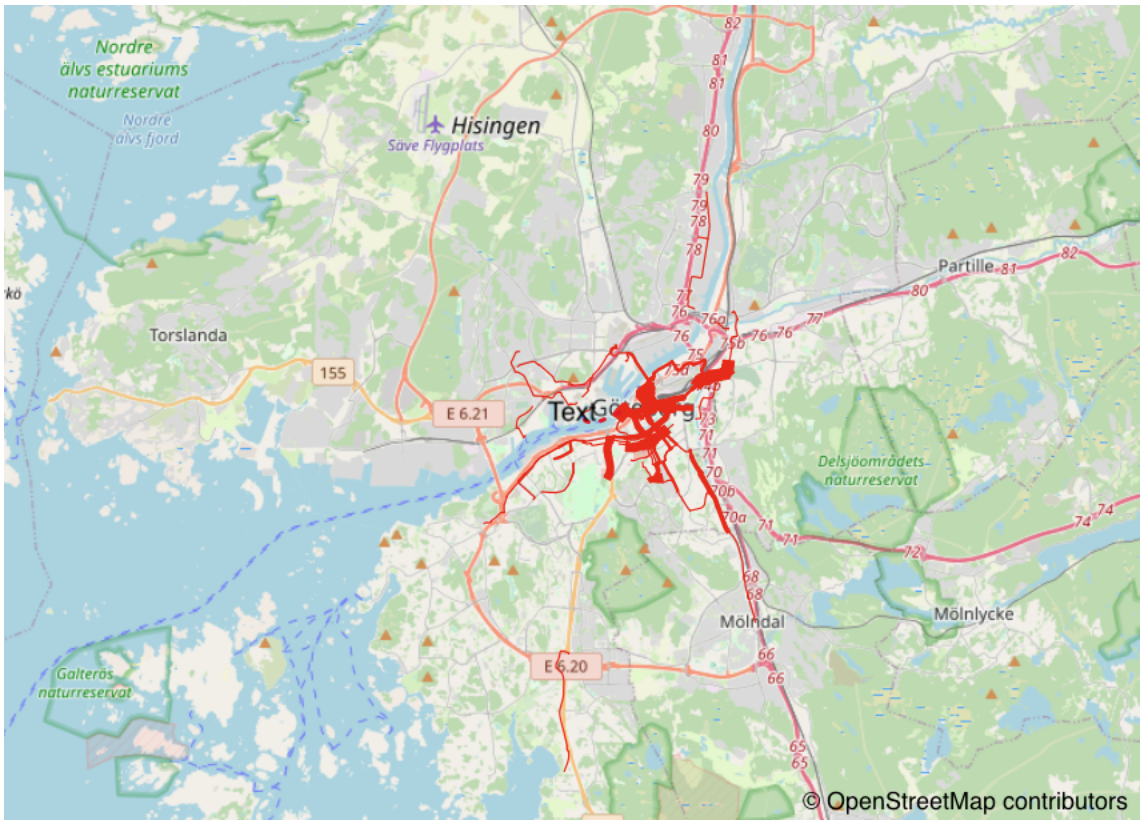

Figure D.4: Segregation from motor vehicles - the extensive critical network.

E

Appendix E

Appendix E presents detailed information from the spatial analysis of the observed routes. Figure E.1-E.7 shows how critical each investigated factor is along the routes. The factors include connectivity and continuity, existence of cycle paths, and segregation from pedestrians. The black labels represent how many times the stretches are mentioned as critical in the survey and the blue represents the areas.

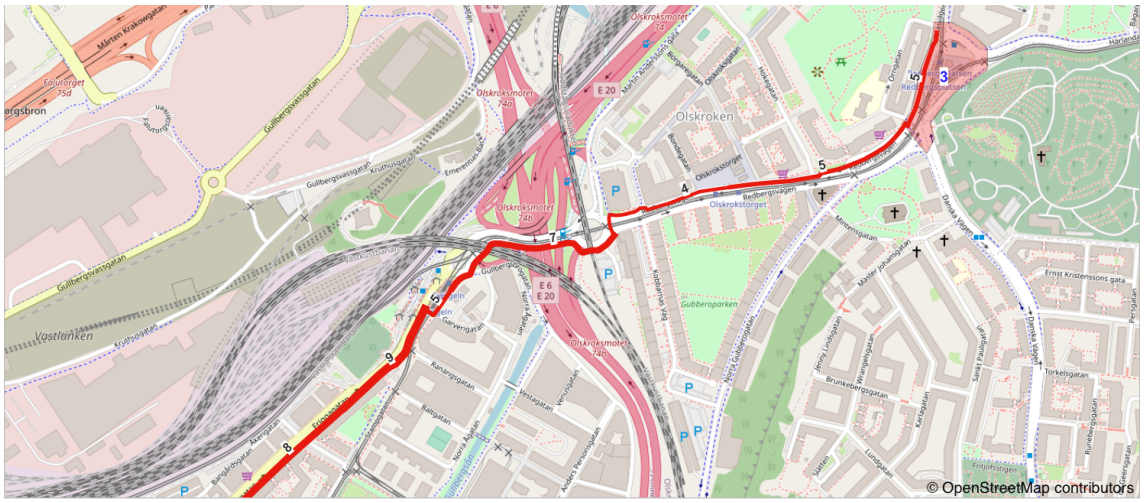

Figure E.1: Connectivity and continuity - The first part of the route from Redbergsplatsen to Stenpiren.

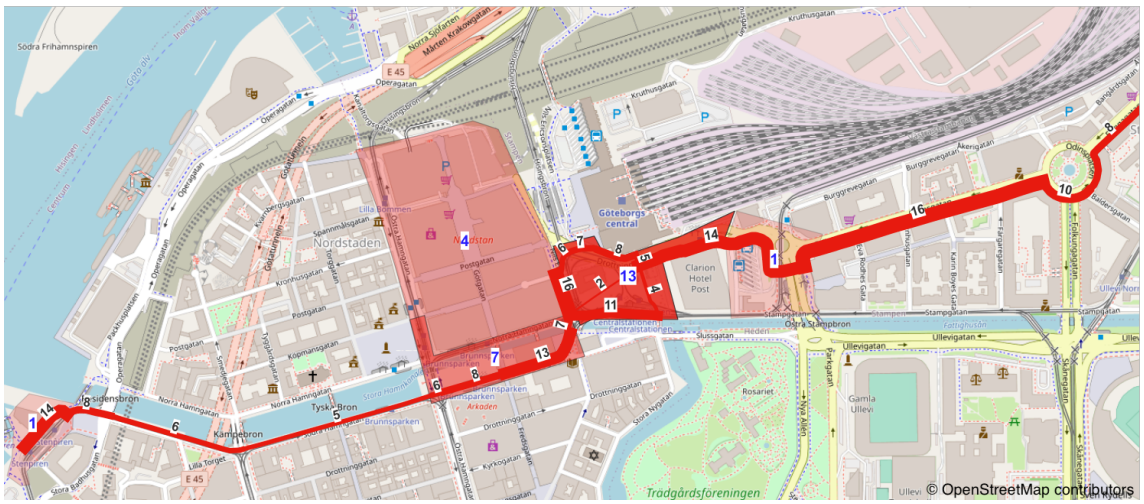

Figure E.2: Connectivity and continuity - The second part of the route from Redbergsplatsen to Stenpiren.

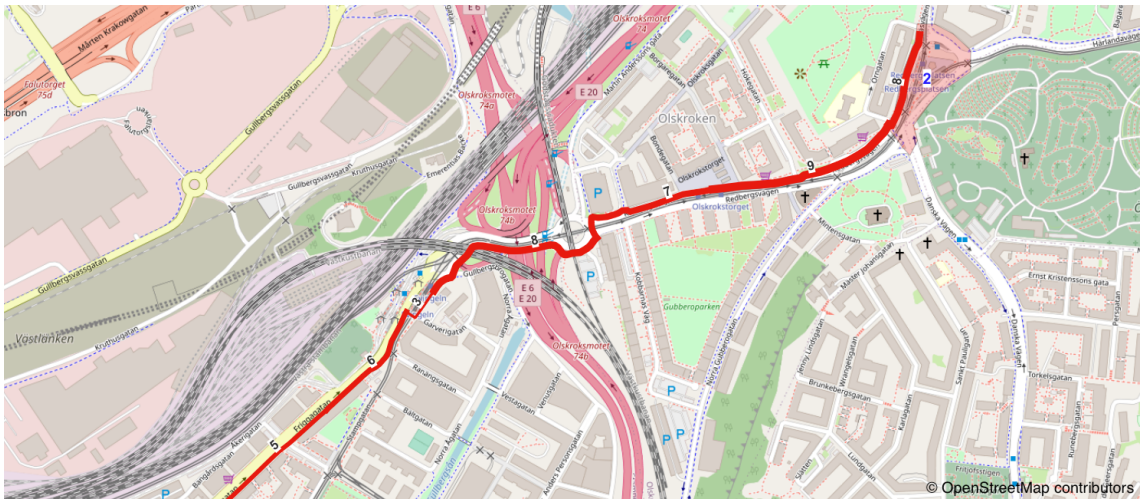

Figure E.3: Existence of cycle paths - The first part of the route from Redbergsplatsen to Stenpiren.

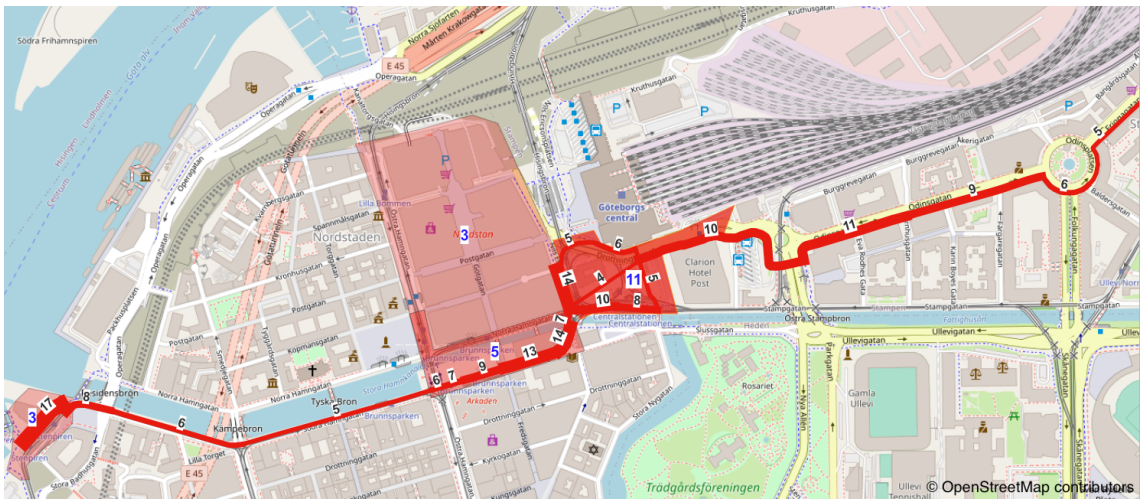

Figure E.4: Existence of cycle paths - The second part of the route from Redbergsplatsen to Stenpiren.

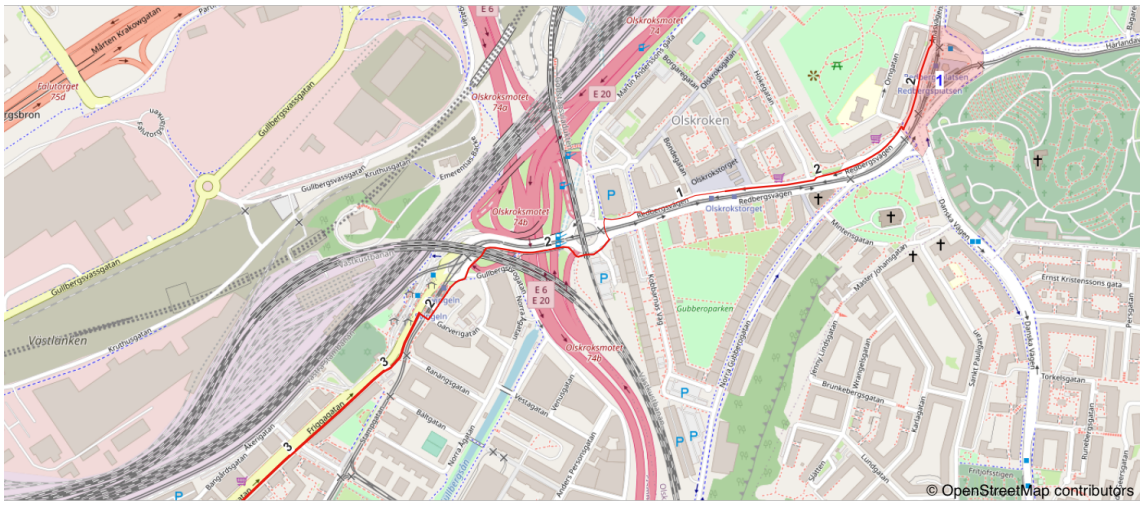

Figure E.5: Segregation from pedestrians - The first part of the route from Redbergsplatsen to Stenpiren.

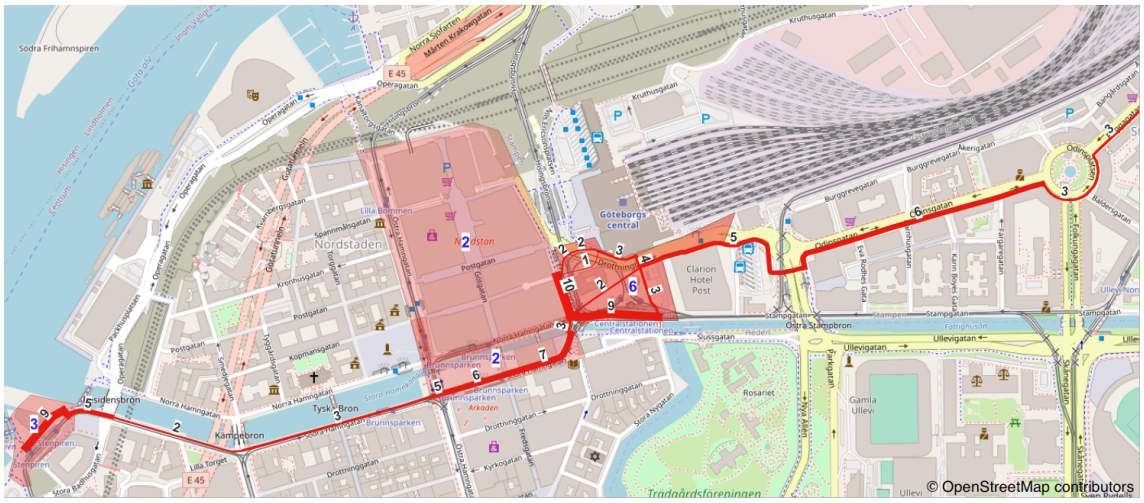

Figure E.6: Segregation from pedestrians - The second part of the route from Redbergsplatsen to Stenpiren.

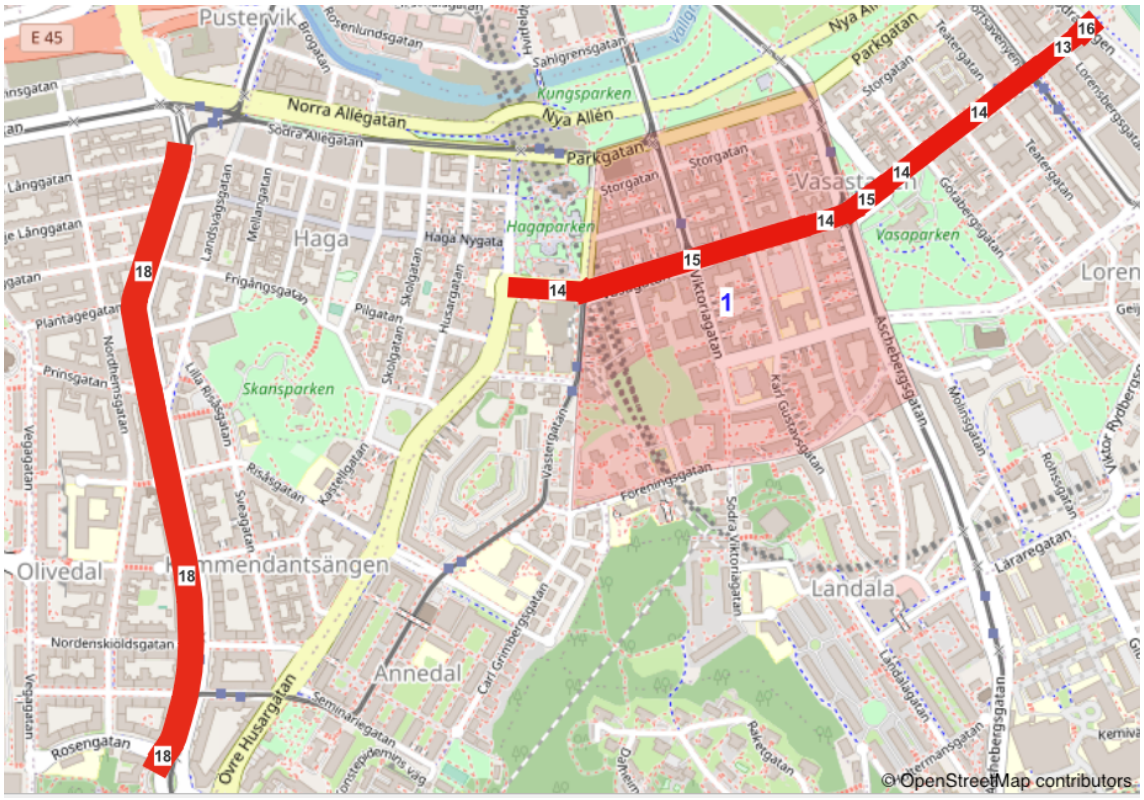

Figure E.7: Segregation from pedestrians - Vasagatan (to the right) and Linnégatan (to the left).

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