CHALMERS
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Capacity and availability for bicyclists

An analysis of the situation during the construction period of Station Korsvägen including proposals for measures

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

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Cover:
Congestion and limited availability on a waiting area at Korsvägen

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ABSTRACT

The transport sector is an essential part in developing a sustainable society. Many cities aim to reduce their environmental impact by increasing the bicycle use although the capacity limits are already about to be reached at several bicycle paths in Sweden. Gothenburg is no exception, where the vision is to triple the number of bicycle trips between 2011 and 2025. Several large infrastructure project will be implemented in Gothenburg during the same period. One of the largest is Västlänken, a railway tunnel with three stations, including Station Korsvägen. The aim of this thesis is to study capacity and availability for bicyclists. A case study will be conducted at Korsvägen to investigate the present situation regarding capacity and availability for bicyclists and estimate if these parameters are possible to maintain during the construction of Station Korsvägen. Furthermore, proposals for measures to develop the tender documents in order to improve the capacity and availability for bicyclists will be made. This study shows that the definition of capacity and availability for bicyclists is unclear and few studies has been conducted. It can be defined in numbers, in terms of bicyclists/hour, as well as in words. The case study of Korsvägen shows no lack of capacity based on the numerical definition. However, conducted observations indicates that there are lack of capacity and availability at several locations, mainly at intersections and waiting areas in terms of queues and conflicts. Thus, the availability and perceived capacity may be limited even though there is no measured lack of capacity. The conclusion is that it is important to identify the locations with limited availability to assess the quality of the bicycle network. None of bicycle paths around Korsvägen fulfils the recommended widths for good and safe availability based on the flow. Several bicyclists will have increased travel time and decreased traffic safety through Korsvägen during the first construction stage. Both factors are important for bicycling to be seen as a competitive mode of transport. In order to improve the capacity and availability for bicyclists during the construction it is proposed that the bicycle crossings are converted into bicycle priority crossings and that the zebra crossings are made accessible for disabled in terms of physical measures and information as a soft measure. In-depth analyses and cost estimations are needed before the proposed measures can be implemented. This report can hopefully be used to improve the situation regarding capacity and availability for bicyclists during the construction of Station Korsvägen in particular and serve as guidance and inspiration in general.

Key words: bicycling, availability, capacity, delay, travel time, Korsvägen

Kapacitet och framkomlighet för cyklister

En analys av situationen under byggtiden av Station Korsvägen med åtgärdsförslag

Examensarbete inom masterprogrammet Infrastructure and Envrionmental Engineering

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SAMMANFATTNING

För att utveckla ett hållbart samhälle är transportsektorn en essentiell del. Många städer har som mål att minska miljöpåverkan genom att öka cyklandet samtidigt som kapacitetstaket snart är nått på flera cykelvägar i Sverige. Göteborg är inget undantag och har som vision att cyklandet i staden ska tredubblas mellan 2011 och 2025. Flera stora infrastrukturprojekt ska genomföras i Göteborg under samma tidsperiod. Ett av de största är Västlänken som är en järnväg i tunnel med tre stationer, däribland Station Korsvägen. Syftet med denna rapport är att studera kapacitet och framkomlighet för cyklister. En fallstudie kommer att utföras på Korsvägen för att utreda den nuvarande situationen för cyklister sett till kapacitet och framkomlighet för att analysera möjligheten att bibehålla dessa parametrar under byggskedet av Station Korsvägen. Åtgärdsförslag till förfrågningsunderlaget kommer tas fram för att förbättra kapaciteten och framkomligheten för cyklisterna. Studien visar att definitionen av kapacitet och framkomlighet för cyklister är otydlig. Få studier har genomförts inom området och definitioner förekommer såväl i siffror som i ord. Studien av Korsvägen visar att kapacitetsbrist inte råder sett till antalet cyklister per timme. Observationerna tyder däremot på att det finns kapacitets- och framkomlighetsproblem på ett flertal platser, främst i korsningar samt väntytor i form av köer och konflikter. Framkomligheten och den upplevda kapaciteten kan därmed vara begränsad utan att den uppmätta kapaciteten visar på kapacitetsbrist. Slutsatsen är att det är viktigt att lokalisera områden med begränsad framkomlighet för att bedöma statusen på cykelnätet. Ingen av cykelvägarna runt Korsvägen uppfyller de rekommenderade bredderna för god och säker framkomlighet baserat på flödet. Säkerheten samt restiden genom Korsvägen kommer påverkas negativt för många cyklister under det första byggskedet. Båda dessa faktorer är viktiga för att cykel ska ses som ett konkurrenskraftigt färdmedel. För att förbättra framkomligheten och kapaciteten under byggtiden föreslås att cykelpassagerna görs om åtill cykelöverfarter samt att övergångställen tillgänglighetsanpassas. I kombination med de fysiska åtgärderna föreslås mjuka åtgärder i from av information. Innan de föreslagna åtgärderna implementeras krävs vidare analyser och kostnadsberäkningar. Förhoppningen är att denna rapport kan användas för att förbättra situationen för cyklister under byggnationen av Station Korsvägen i synnerhet samt fungera som inspiration och vägledning i allmänhet.

Nyckelord: cykling, framkomlighet, kapacitet, försening, restid, Korsvägen

Contents

Preface

In this study, the capacity and availability of the bicycle network around Korsvägen has been investigated. The work has been performed on the behalf of ÅF and the work has been carried out at their office in Gothenburg from January 2016 to June 2016.

This Master's thesis was carried out on the department of Civil and Environmental Engineering, at the division of GeoEngineering within the Road and Traffic Research Group at Chalmers University of Technology. The work has been supervised by Johan Hallberg at the section of Traffic Analysis at ÅF, Henrik Rönnqvist at the section of Traffic Management at ÅF and Gunnar Lannér, Senior Lecturer at Chalmers University of Technology. The examiner has been Professor of the Practice Anders Markstedt. The authors are thankful for their invaluable support and encouragement throughout the work. The authors would also like to send thanks to: Styrbjörn Bergdahl and Ebbe Borg at ÅF, Ingela Lundgren-Sandberg at Trafikkontoret, Thomas Andersson at SWARCO and Claes Johansson. Finally, thanks are given to the opponents, Miriam Brill and Hanna Persson Brink, for valuable feedback.

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Johanna Edoff

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Notations

DICTIONARY

Accessibility	Tillgänglighet
Availability	Framkomlighet
Bicycle commuting network	Pendelcykelnät
Bicycle crossing	Cykelpassage
Bicycle priority crossing	Cykelöverfart
Bidirectional	Dubbelriktad
Case study	Fallstudie
Conflict point	Konfliktpunkt
General bicycle network	Övergripande cykelvägnät
Delay	Fördröjning
Destination	Målpunkt
Field study	Fältstudie
Implementation plan	Genomförandeplan
Local bicycle network	Lokalt cykelvägnät
One-way	Enkelriktad
Tender documents	Förfrågningsunderlag
The West Swedish Agreement	Västsvenskapaketet
Traffic and Public Transport Authority in Gothenburg	Trafikkontoret, Göteborgs Stad
Waiting area	Väntyta

ABBREVIATIONS

ITS	Intelligent Transportation System
MM	Mobility management
SALAR	Swedish Association of Local Authorities and Regions
STRADA	Swedish Traffic Accident Data Acquisition
Södra Vägen N	The part of Södra Vägen located north of Korsvägen
Södra Vägen S	The part of Södra Vägen located south of Korsvägen
TH	Teknisk Handbok
TRAST	Trafik för en Attraktiv Stad
VGU	Vägar och gators utformning

1 Introduction

Traffic is the cause of many of the environmental problems that several cities are struggling with today. Approximately 40 percent of the carbon dioxide emission and 70 percent of the air pollution in Swedish cities is caused by the traffic (Trivector, 2010). In addition to carbon dioxide emissions and air pollution traffic is also causing noise and intrusion of the physical environment as well as having negative health effects (Ericsson and Ahlström, 2008).

A sustainable development of the transport system with reduced environmental impact is of great importance when developing a sustainable urban environment. The overall transport goal set by the Government of Sweden is to have a socio-economical efficient and long term sustainable transport system for all citizens (Regeringskansliet, 2015b). Out of a sustainability perspective, bicycling has several advantages as a means of transport. Some of the advantages are that bicycling does not emit emissions, is more space-efficient compared to cars, brings good health and promotes social meetings.

In order to deal with the environmental problems and other negative effects brought by motoring many cities are working and aiming to increase the bicycling. Increased bicycling is good for the city and the city life (Göteborgs Stad, 2015). Bicycling creates life and movement in the city room and contributes to an attractive urban environment. As more people choose bicycling as their means of transport the load on the road network and public transport will be reduced, which is beneficial for all road users.

1.1 Background

The City of Gothenburg is evolving from a large small-town to a near city (Göteborgs Stad, 2015) and the population in the whole West Swedish region is expected to grow with 203 000 inhabitants until the year of 2025 (Trafikverket, 2013b). A growing population will lead to an increased need of travel and this increased amount of trips should mainly be done with commuter train, bus, tram or bicycle according to Trafikverket (2013b). The evolvement of the city structure will lead that to the city is getting denser and this in turn will mean that there will be more destinations within walking and bicycling distance (Göteborgs stad, 2015). In a dense city bicycling is a quick way to move around. Making improvements for the bicyclist will hopefully increase the bicycle usage. This goes in line with City of Gothenburg's vision presented in *Cykelprogram för en nära storstad 2015-2025*. The vision involves the goal to triple the number of trips done by bicycle from 2011 to 2025 and that three out of four citizens of Gothenburg should regard Gothenburg as a bicycle friendly city until the year 2025. The overall goal is to make bicycling in Gothenburg fast, easy and secure.

This goal is aimed to be achieved even though several large infrastructural investment shall be constructed during the same time frame. The three largest investments are Hisingsbron, Marieholmstunneln and Västlänken, but it also includes initiatives to improve travels by train, bus, tram, car as well as bicycle (Göteborgs Stad, 2016). The investments are all a part of the West Swedish Agreement which aims to develop the region in a sustainable way by making it easier to travel, develop attractive public transport and reliable transports to industries and businesses, better environment and enlarged commuting possibilities for anybody who would like to live, work or study in the West Swedish region (Trafikverket, 2013b).

One part of Västlänken, which is a railway tunnel under centre of Gothenburg, is the underground Station Korsvägen. The consultant company ÅF is responsible for producing the tender documents, which includes how the traffic should be arranged at Korsvägen during construction. The construction site will in the first stage consist of an excavation to the east and close to Liseberg and in the second stage a significantly larger excavation more to the west. This will of course affect the surrounding traffic and various bicycle paths will be unavailable due to the large open excavations, in both the first and second construction stage. This will force the bicyclists to take other routes through Korsvägen, which might lead to an increased load on the new paths.

However, according to Vectura (2010) the capacity limit is already about to be reached at several bicycle paths in Sweden. The capacity problems occur first and foremost at crossings but also along narrow bicycle paths where there is limited amount of space. If the capacity limit is reached, there is a higher risk that bicyclists will relocate into areas constructed for other transport modes. If relocated into the road there will be an increased risk of collision, which might lead to injuries. Furthermore, there is a risk that people might choose other transport modes instead of bicycling due to the fear of being in an accident (Envall and Koucky, 2013).

Thus, in order to fulfil the goal to triple the number of bicycle trips in Gothenburg it is essential to deepen the knowledge and find ways to define and measure capacity limits and availability problems on bicycle paths. The construction of Station Korsvägen will last between 2018 and 2023, hence it is important to examine the extent of the impact that it might have on the bicycle traffic that goes through the area during this period.

1.2 Aim

The aim of this thesis is to study capacity and availability for bicyclists. A case study will be conducted at Korsvägen to investigate the present situation regarding capacity and availability for bicyclists and estimate if these parameters are possible to maintain during the construction of Station Korsvägen. Furthermore, proposals for measures to develop the tender documents in order to improve the capacity and availability for bicyclists will be made.

1.3 Delimitations

The geographical boundary of the case study is the bicycle network in the area of Korsvägen and it is only the construction of Station Korsvägen and its effects on the bicycle traffic that will be studied. The impact on other transport modes due to the construction will not be investigated.

All investigations were performed in the maximum hour to get the worst case scenario. This applies both to the bicycle traffic, public transport and car traffic.

The thesis only intend to study the capacity and accessibility during the construction of Station Korsvägen in comparison with the current capacity and accessibility available at Korsvägen. The final design of the traffic around Korsvägen, after the construction, is still being processed.

The analysis of the capacity and availability during construction is based on the review version of the tender documents. Changes may be done after the review but due to restrictions in time it was not possible to wait until after the review was finished.

During the same time period as Station Korsvägen is constructed other projects are about to be constructed in the City of Gothenburg. The construction of the other projects may affect how bicyclists choose to travel through Korsvägen. However, this was not taken into consideration in this study.

The data extracted from STRADA was limited to the years between 2003 and 2015 since that was all the information that was available. Only accidents that involved a bicyclist, both single-accident and collision with other transport modes, were included in this study.

The study is based on data between 2013 and 2015 from the bicycle barometer, since this was the data that could be provided. Regarding the car traffic data from 2015 was used.

1.4 Methodology

The methods used in this thesis has been divided into four different parts; literature study, field study, analysis of tender documents and suggestions and recommendations. The different parts are described in depth below.

1.4.1 Literature study

In order to create a foundation of knowledge about the subject an initial literature study was performed. Information about bicycling was gathered from articles, scientific reports and studies, books and reliable internet sources. The literature study intends to explain the advantages with bicycling, bicycle planning and capacity and availability for bicyclists.

Furthermore, studies on different types of documents on public authorities' advice and guidance regarding design of bicycle paths the definition of capacity on bicycle paths was performed. Some of the studied documents are: VGU, TRAST, the GCM-handbook, the bicycle program in Gothenburg *Cykelprogram för en nära storstad 2015-2025* and TH (Teknisk Handbok).

Information has also been gathered about Korsvägen and the traffic situation around Korsvägen. Statistics and data on bicycle accidents at Korsvägen between the years 2003 and 2015 has been provided from the STRADA database by The Swedish Transport Agency. To get even more information about where accidents or problematic areas around Korsvägen occur an article in the local newspaper Göteborgs-Posten, where the inhabitants could pinpoint areas in the bicycle network that they perceived to be unsafe etc., was studied.

1.4.2 Field study

A field study has been conducted and used as a research design in order to examine the bicycle conditions around Korsvägen. The field study consists of four parts; traffic count, measurements of travel time; measurements of delay and observations of capacity and availability. The methodology for the separate parts is presented below.

1.4.2.1 Traffic count

In order to get the distribution of the bicycle flow at Korsvägen a traffic count was performed during the hour of maximum flow. The bicyclists was counted for eight stretches individually, i.e. a bicyclist passing two or several stretches was counted separately for the different stretches. Furthermore, the direction of the bicyclists was registered and a distinction between clockwise and counter-clockwise was made.

Data containing the maximum hour for all weekdays between the years 2013 and 2015, collected by a bicycle barometer managed by the City of Gothenburg, was used to interpret the hour of maximum flow. The bicycle barometer is located just south of Korsvägen and it is assumed that the condition at this location can be used to represent the conditions at Korsvägen.

Since seasonal variation for bicycling occurs it would be desirable to do the traffic count during the time with the highest monthly flow. However, due to time restrictions the count was performed in March. Thus, in order to investigate the variation in flow over the year data from a bicycle barometer was used. From the year 2015 additional data exist, including information on the number of bicycle passages every 15 minutes through the whole year. Therefore, data on the maximum hour and data for all hours was used for 2015. The data was used to create a graph showing the distribution of bicyclist at Korsvägen over the year. This was done, according to a method presented in Björketun and Carlssons report *Trafikvariation över året* from 2005, by summarising the total bicycle flow for each month. The values for each month were then divided by the total flow of the year. Finally, the quota for each month was multiplied by 12, so that an index of 100 represents the annual average daily traffic (AADT).

To be able to retrieve the distribution of bicyclist at Korsvägen over the year some alterations with the data had to be done. First of all, data from the first 13 days in January was missing in 2015. The daily average of January was calculated and then added for the missing days. In cases when just one day was missing the average of the day before and the day after was used. All weekends was removed since this data differed from the weekdays. Furthermore, all holidays were removed since a huge drop in number of bicyclists was observed. For example the number of bicyclists dropped with about 50 percent on the 1st of May compared to the surrounding weekdays. The following holidays was removed after similar observations: Easter, Holy Thursday, Midsummer, Christmas and New Year’s Eve.

The maximum flow during the year can be obtained by adjusting the results from the traffic count with the index for the month in which the count was performed and the index for the month with the highest index. The maximum flow is calculated as shown in Equation 1. No adjustment needs to be done regarding the hour of the day since the average maximum hour is the same in March and September (see Appendix I).

$$maximum\ flow = measured\ flow \times \frac{mean\ index\ September}{mean\ index\ March} \qquad (1)$$

1.4.2.2 Measurements of travel time

In order to estimate the travel time multiple bicycle runs was made in both directions on eight stretches. On stretches where conflict points with public transport or signalised intersections occurred the travel time was measured for situations where these did not cause any stops or delays, since these situations are studied separately.

The type of method, where a certain stretch is driven several times, is also used when analysing the travel time for cars and is then referred to as floating car (VTI, 2005). The floating car principle also includes that the speed of the vehicle preforming the measurement should be the same as the traffic ahead of oneself (Trafikverket, 2015b). In other words, during an on-going measurement, the number of cars that are overtaking the measurement car should be the same as the number of cars that the measurement car itself overtakes. The results from the multiple drives can be used to calculate an average travel time on the stretch.

Since the amount of car traffic will affect the speed and travel time of the bicyclists, as bicyclists are obeyed to adjust their speed at bicycle crossings and give way to cars, it is assumed that the car traffic is affecting the bicyclists, at crossings etc. the most during peak hours. Thus, the car peak hour represents the hour when the disturbance from car traffic is the most. This hour was chosen since the availability of bicyclists is of interest and this hour would represent the hour when the car traffic is influencing the availability the most.

In order to evaluate which hour it might be data on car traffic from 2015 for every 15 minutes at five stations around Korsvägen was used. The data from each station includes traffic flows on each road leading into Korsvägen (Södra Vägen N, Skånegatan, Örgrytevägen, Södra Vägen S and Eklandagatan). The total traffic flow for every hour was calculated for each station and the sum of the five stations was assumed to be the total traffic into/from Korsvägen.

To obtain the travel time for all runs a GoPro camera was mounted on a bicycle to record the bicycling for each stretch. The start and finish of each stretch was marked out with two cones attached with a string. These were passed in the same speed as was held within the stretch, where the floating car principle was adopted. After the bicycling the movies were analysed and the travel time on each stretch was compiled with an accuracy of one second. Measurements of the travel time was continued to be done until a pattern was found, where only small variations occurred.

1.4.2.3 Measurements of delay at intersections

To get the total travel time the effect of the intersections where public transport is operating was taken into consideration. This was done by measuring an average delay due to the public transport at the different stretches. To get the worst case scenario the maximum hour of the public transport had to be identified. First, all public transport modes passing Korsvägen had to be recognised. Six tram lines and 18 busses including the bus to the airport were found to pass through Korsvägen. It could clearly be seen that the maximum hours were between 7.00-8.00 and 16.00-17.00. Between 7.00 and 8.00 a total number of 219 busses and trams passed and between 16.00 and 17.00 a total of 224 busses and trams passed. This was estimated to give similar delay, which motivated measurements during both mornings and afternoons. This also made the measurements more efficient since they could be performed twice a day.

The time a bicyclist stood still at an intersection was noted with a stopwatch. All stops below two seconds were taken out of the calculations and not seen as a stop since such short stops were hard to measure in a correct way. Furthermore, the number of bicyclists that did not need to stop were counted.

1.4.2.4 Observations of capacity and availability

As a complement to the measurement an observation was performed. Previous to the observation a protocol was created using experiences from the earlier visits at the site. The main focus was to find conflict points, complicated situation and areas where congestion occurred, everything that could lower the availability for bicyclists. The observation was performed both during the morning and the afternoon at each stretch.

During the mornings the observations was performed at the peak bicycle hour (7.00-8.00) and in the afternoon an hour assumed to been more frequently used by pedestrians (16.00-17.00). This was done to see if other situations occurred due to the different circumstances. It should be noted that all assessments are subjective and based on the experience and knowledge of the observers.

During a period of one week in April (6^{th}-13^{th}) construction was going on at the tram tracks towards Örgryte. The bicycle path running along the east side of Korsvägen, in this thesis called Stretch A, was due to this closed and bicyclists was redirected to use the other paths to travel through Korsvägen. Since this created a situation similar to construction stage 1 of Station Korsvägen, observations of critical areas were conducted.

1.4.3 Analysis of tender documents

The tender documents of Station Korsvägen was retrieved from ÅF and analyses have been carried out with respect to the capacity and availability for bicyclists passing Korsvägen during the construction period. The analysis was performed by using the information gathered in the literature study. The data from the field study was used to compare the two stages of construction and the design of today.

1.4.4 Proposals for measures

Based on the analysis of the tender documents proposals for measures in order to improve the design of the two construction stages was developed.

2 Bicycling in theory

Bicycling can be described as a system consisting of three components: the bicyclist, the bicycle and the infrastructure (see Figure 1). The three components are affecting each other mutually within the system and a change in one component has an impact on the other components (Trivector, 2014). The system can also be affected by transport policy measures directed towards one or more components within the system. By applying policy measures it is possible to target and manage goals and visions.

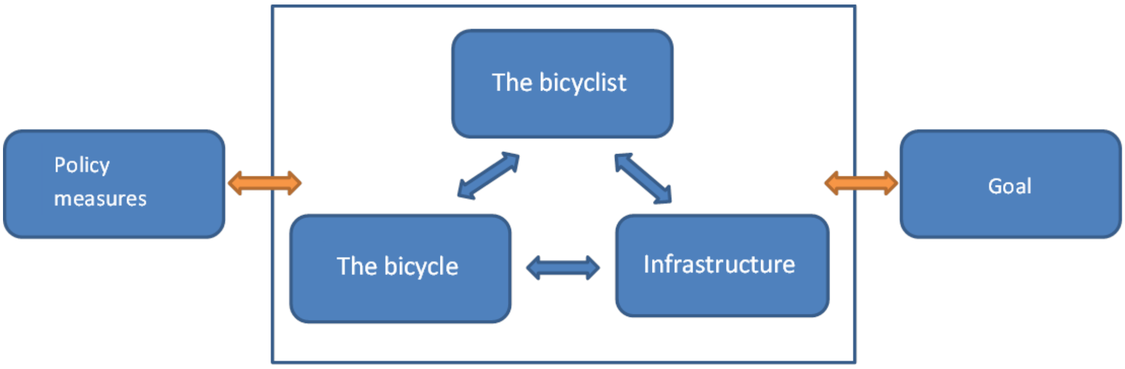

Figure 1 The bicycling system (Trivector, 2014).

The characteristics of the bicycle such as price, size and speed are included in the bicycle component. Whereas the infrastructure component incorporates the bicycle network, parking ability at different destinations, ability to change from bike to other transport modes at junctions as well as operation and maintenance. The bicyclist component includes why, where and when somebody is choosing to bike. On a more detailed level the bicyclists' ability, behaviour as well as interest and requirements can be taken into account.

The first modern bicycle was fabricated in the 1880s and it spread fast around the world. The bike made it possible to travel longer distances when going to work, school and other social meetings. During the Second World War bicycling was the most common transport mode and 7 out of 10 trips were made by bike in Stockholm (Sveriges Radio, 2013). This could partly be explained by the prohibition to drive private cars for a period of time after the beginning of the war and furthermore by that gasoline was rationed.

Since the breakthrough of the car in the middle of the 20th century motor vehicles started to take over as the most dominant transport mode (Trafikverket, 2014c). As people started to get better financials the car ownership increased rapidly and in 1950 Sweden had the highest car density in Europe (Lundin, 2008). The rapid increase caused problems with accidents and congestion, since the cities were not planned for cars. Thus, the urban planners had to decide whether the cars should be designed to fit the society or if the society should be designed to fit the car.

The latest was chosen and Lundin (2008) refers to Sweden as the 'car society' between the years of 1950 and 1970, when construction of houses, social relations and urban planning were shaped by the interests of the car. Furthermore, big traffic routes and parking facilities were constructed in order to create a car-friendly society. The same development could be seen in most western European countries where the use of the car was favoured. This contributed to declined bicycling since the bicyclists needs were ignored (Pucher and Buehler, 2012). This way of planning can be referred to as mobility-based planning, where the physical movement and the efficiency of the transport system is in focus (Zachariadis, 2012). If using mobility-based planning the solution to congestion would be to build new roads or add more lanes. Thus, a cycle of automobile dependency tends to be created. Another type of planning is the accessibility-based, which focuses on peoples and businesses ability to reach the goods, services and activities that they aim for. With this mind set solutions to congestion problems includes improvements of and incitements to use other transport modes as well as policies to reduce the need of travel.

2.1 The advantages of bicycling for sustainable transportation

Today's car usage cannot be seen as sustainable since the emissions from car traffic are causing climate change, air pollution and eutrophication as wells as acidification of waters and land (Naturvårdsverket, 2015). Moreover, traffic is affecting our health with traffic noise, which can cause problems with sleeping and reduced concentration, and particles that can cause cardiovascular disease. In order to reduce the climate change and the negative consequences of the transport sector sustainable development is needed.

The term sustainable development is well known and frequently used today. It was coined in the 1980s and the most used definition is the following from the Brundtland report in 1987 (United Nations, 2010):

> *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

In recent years there are indications showing that the car traffic in many Western countries is no longer increasing (Trivector, 2016a). The previously apparent increase of private car use has stagnated and even decreased in some cases, this phenomenon is often referred to as peak car use. Studies made by Trafikanalys in 2013 show that this is a trend in the centre of big cities in Sweden (Trafikverket, 2014c). There is not one single reason to this development. According to researchers some contributing factors are the urbanization, change in valuations and increased density of cities (Trivector, 2016a). The negative effects from car traffic on human health and the environment has also been getting more and more attention in recent years, which can be a contributing factor to a more sustainable development.

Lunds kommun (2005) states that planning which aims to reduce the vehicle use is a tool, which increases the possibilities to create attractive and sustainable cities. Planning for the people instead of the car is a way to achieve goals and directives, with the ambition to decrease the transports. To do this cars has to become less dominant and sustainable transport modes must be given more space in the cities.

Bicycling, walking and public transport are all considered as sustainable transport modes. These transport modes has a high potential to replace the car traffic, especially in cities. Naturvårdverket (2005) states that cycling and walking is favoured by a dense city structure, with short distances, a wide selection of destinations and a well-developed network for bicycle and pedestrian traffic.

Pucher and Buehler (2012) states that there are many reasons to promote increased bicycling. Bicycling is consuming significantly less amounts of non-renewable resources, compared to all motorized modes of transportation. This is beneficial not only for the environment but for human health as well, because of improved air quality, reduced noise pollution and reduced greenhouse gas emissions. Epidemiological studies also show that human health benefits can be gained from at least thirty minutes of every day moderate-intensity activity. Thus, the daily physical activity from bicycling can as an example prevent or reduce the risk of getting chronic diseases, high blood pressure, diabetes and obesity.

Another advantage is the fact that bicycling takes up less space than car traffic in terms of required space for infrastructure and parking facilities (Pucher and Buehler, 2012). The infrastructural space requirement is dependent on the speed of the vehicle, since higher speed demands wider lanes and lager radius (Göteborgs Stad, 2013). Thus, motorised vehicles occupy rather big areas per passenger. Stangeby and Norheim (1995) refer to a Norwegian study that showed the least space (0.8 m^2 per passenger) is occupied by pedestrians while cars demand the most with 22.1 m^2 per passenger (see Figure 2). Bicycling is occupying 9.7 m^2 per passenger which is less than half of the area needed for car traffic.

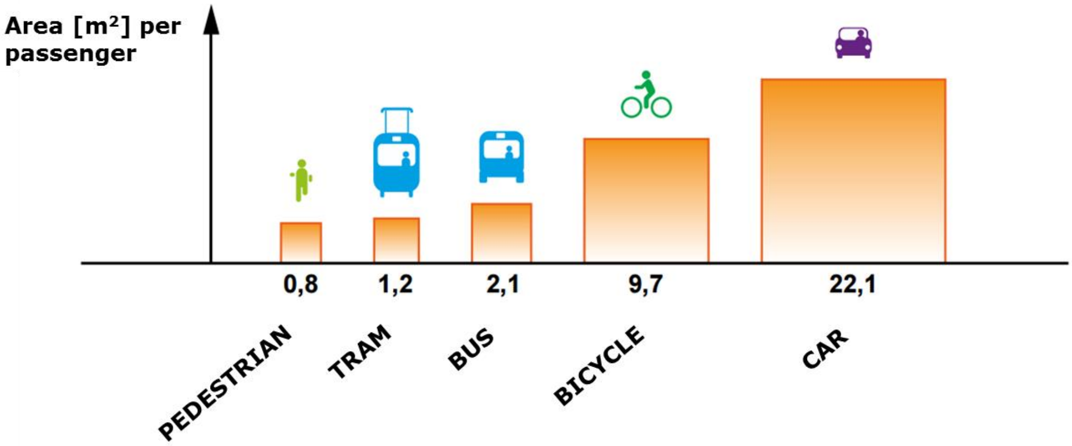

Figure 2 Amount of space required for different transport modes per passenger (Stangeby and Norheim, 1995).

Another way to illustrate the amount of space required by different traffic modes is to compare the space needed to transport a certain amount of passengers by different transport modes (see Figure 3). The same amount of space needed for 60 cars can be used to accommodate about 16 buses or over 600 bikes (Cobcroft, 2012). Some cities are struggling with lack of space in the city centres and high levels of congestion. The cities are growing and people are moving into the cities from the rural areas, referred to as urbanization (Svanström, 2015). Thus, bicycling has the ability to decrease traffic jam on roads.

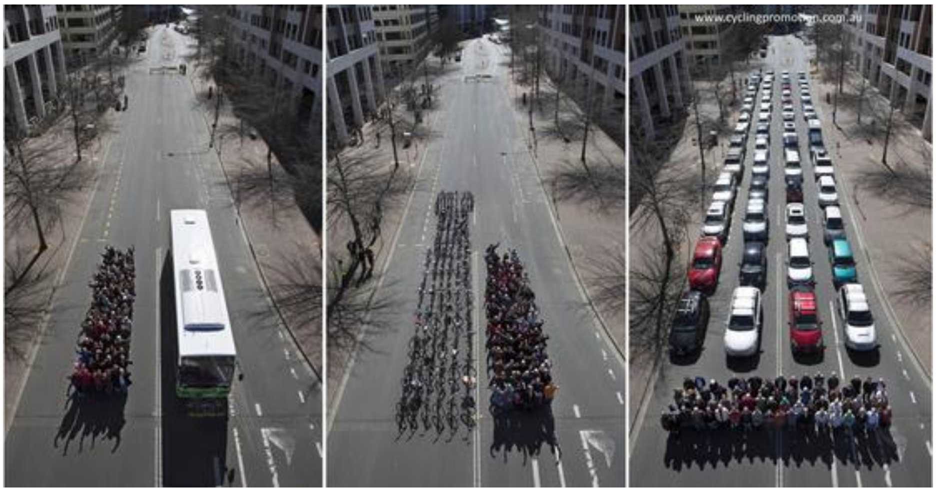

Figure 3 Required space to transport the same number of passengers by public transport, bicycle and car (Cobcroft, 2012).

Moreover, bicycling has an economical benefit on both an individual and societal level. It is far less expensive in user expenses as well as in infrastructural investments for municipalities and the government, compared to private car and public transport (Pucher and Bueler, 2012). A study made by Gössling and Choi (2015) shows that the cost to the society is more than six times higher for every driven kilometre by car compared to bicycling. The study compared the two transport modes with regard to accidents, climate change, health and travel time.

Furthermore, bicycling is a socially fair transport mode since it can increase the mobility for all groups, it can be afforded by as good as everyone and is physically feasible for most people (Pucher and Bueler, 2012). Overall, the environmental, economic and social sustainability of bicycling is hard to beat.

2.2 Factors which are influencing bicycling

Bicyclists, together with pedestrians and moped riders, belong to the group of vulnerable road users. These traffic modes do not have any protective shell and are therefore more exposed and vulnerable in case of collision with a motorized vehicle (Svensson, 2008). Unlike in car traffic muscle power is required for bicycling, which means that bicycling has high demands on short distances with as little detours as possible. However, the convenience with bicycling is the freedom to plan the trip without having to adapt to any timetable. Bicycling is in this regard very similar to the benefits usually considered to car traffic. Another similarity between car traffic and bicycling is that the bicyclist is considered as a vehicle road-user and is therefore obligated to follow the road traffic regulations.

Furthermore, bicycling has, like car traffic, high requirements on continuity and good guidance in the traffic network since it is possible to reach rather high speeds (Svensson, 2008). The average speed of a bicyclist is 16 km/h; those who use the bicycle to commute or exercise can reach significantly higher velocities. The rather high speed of the bicyclist sets a demand on sufficient availability. To stop and push the button to announce ones presence at a signalised intersection is for example inconvenient for a bicyclist, it takes muscle power to get going again and results in a noticeable delay (Svensson, 2008).

Bicycling is one out of many possible transport modes in urban areas. It is therefore important to understand how bicycling is perceived in comparison to other transport modes such as car, public transport and walking. Even if bicycling has many positive effect on both health and environment many people does not even consider it as a possible transportation alternative. Some of the most common motives not to bicycle are bad weather, too long distances, difference in altitude, low perceived traffic safety, fear of getting the bicycle stolen, lack of facilities at work, lack of time, poor bicycle infrastructure, high inconvenience and the car users' negative attitude and behavior (Eriksson, 2009). It is not possible to say which of these motives that are the most important since different studies reach different conclusions. Eriksson (2009) claims that it is reasonable to think that the motives not to bicycle are highly dependent on the specific context. Hence, a lot of different reason can easily be identified.

2.2.1 Travel distance and travel time

The tendency to bicycle decreases with increased travel distance (Sveriges Kommuner och Landsting, 2007). A convenient bicycle distance is often considered to be up to five km and at longer distances the share of bicycling is decreasing (see Figure 4). Too long distance is also one of the most common motives to why people does not choose to bicycle more according to Gatersleben and Appleton (2007). However, Bergström and Magnusson (2003) indicate that the accepted travel distance is varying with the season. During the winter months a distance of about three kilometres is acceptable, while five kilometres is tolerable in summer. There is also a small difference in accepted travel distance between the genders. Men tend to bicycle slightly longer distances compared to women, four respectively three kilometres in general (Trafikverket, 2011).

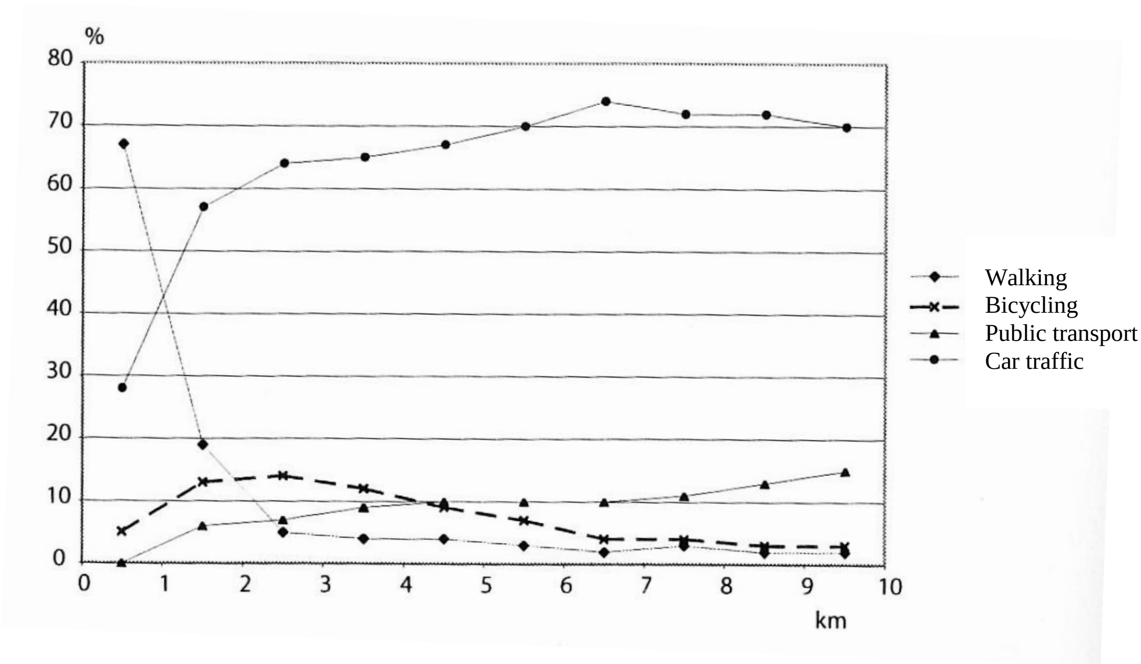

Figure 4 How travel distance is influencing the choice of transport mode (Svensson, 2008).

The travel distance is not only affecting the travel time but also the effort needed to bicycle. Dense cities with short distances between the starting point and point of destination is preferable to encourage bicycling (Svensson, 2008). How much of a detour that is needed to reach a destination compared to the shortest possible distance, as the crow flies, is also influencing the choice of transport mode. The actual travel distance should not be more than 25 % longer than as the crow flies (Sveriges Kommuner och Landsting, 2007).

Travel time is another important aspect in order for bicycling to be a competitive alternative to car traffic. By dividing the travel time for bicycling with the travel time by car the travel time ratio can be calculated, which can be used to estimate the efficiency of a travel mode. The travel time ratio between bicycling and car should be below 2 in urban areas, meaning that the bicycle travel should not take more than twice the time that it takes to go by car (Sveriges Kommuner och Landsting, 2007).

According to Zahavi's law or Hupke's constant humans spend 70-80 minutes per day to transport themselves. This value is constant, but the speed of the travel modes has increased and we have therefore been able to increase the travel distance. If this was to be adapted on bicycling distances of 9-13 kilometres would be acceptable commuting distances.

2.2.2 Weather and climate

Bicycling is weather dependent and the amount of bicycle trips decreases during the winter months. The weather is one of the most common reasons to why people choose not to go by bicycle. When the bicycle traffic was investigated in two Swedish cities it showed that the bicycle traffic was reduced with 47 % in the winter months (Bergström and Magnusson, 2003). Svensson (2008) also states that big weather changes can decrease bicycling by 20-50 %. In Van Hout's (2008) investigation on the bicycle habits of students, rain appears to have low impact on the bicycle share, while low temperatures around the freezing-point decreased the number of bicycle trips.

Ljungberg (1987) has developed correction factors that makes it possible to correct the measurements from bicycle traffic counts and take the actual weather of the day of measurement into account. The correction factors describe how the weather is affecting the choice to select bicycle as transportation mode for one particular day (see Table 1).

Table 1 Correction factors to account for weather variations when doing bicycle traffic counts (Ljungberg, 1987).

WEATHER	Clear	Light rain	Heavy rain	Windy (0-10 m/s)	Misty
Correction factor	1.0	0.85	0.70	0.75	0.80

2.2.3 Traffic safety

Bicycling is the transport mode that is exposed to the most severe injuries out of all transport modes (Trafikverket, 2014d). In 2012 a total of 4500 accidents with a severely injuring outcome occurred, 2000 (40 %) of them was including bicyclists. Furthermore, each year 20-30 bicyclists out of 300 are involved in fatal accidents. The majority, about 80 %, of the total number of all pedestrian, bicycling and moped accidents happen in urban areas, while only 20 % happen on the countryside (Svensson, 2008). Most of the reported accidents in urban areas happen at intersections.

Two-thirds of all bicycle accidents are single-vehicle accidents, where only one road user is involved (Svensson, 2008). The remaining accidents are collision-accidents where about half of them are between cyclists and the other half is motor vehicle collisions.

The fear of getting injured deters risk averse and vulnerable groups form riding bicycles. Pucher and Buehler (2012) state that people would bicycle more if the risks introduced by motorised traffic were diminished. Thus, to improve the safety of bicycling is not only important to reduce the number of injuries but it would also encourage people to bicycle more.

Studies show that there will be a decreased risk to an individual bicyclist of being seriously injured when the level of bicycling increases within an area, referred to as *safety in numbers* (Jacobsen, 2003). The number of fatal accidents per kilometer is for example less in the Netherlands and Denmark where bicycling is well spread (Pucher and Buehler, 2012). One reason could be that with an increased number of bicyclists they become more prominent, which makes the cars adjust their speed and the severity of the accidents decreases.

2.3 Bicycling in Sweden

Approximately 90 % of all adults in Sweden have access to a bicycle (Svensson, 2008). Smaller towns have the biggest number of bicycles per resident while Stockholm and Gothenburg has the least. The bicycle traffic decreases with increased city size and well-developed public transport. An increase in car density is also leading to a decrease in bicycling.

According to the latest national travel survey, where all Swedish residents between the ages of 6-84 are included, the bicycling in Sweden has decreased in the past 20 years. In the middle of the 90s the total number of bicycle trips per day was 2.8 million, the same number in 2014 was 1.9 million (Trafikanalys, 2015). During the same time period the population has grown with 8 %, which leads to a total decrease of bicycle trips with 38 % per person and day. The decrease is present in all ages, for all travel purposes and for both men and women.

On the contrary, the average length of a bicycle trips has increased with 31 % in recent years (Trafikanalys, 2015). It is mostly the travel distance to work that has increased, which is not typical for bicycling in general but applies for all travel modes.

Around 7-10 % of the total number of person trips and 2 % of the amount of travels per person-kilometre in Sweden are made by bike (Trafikverket, 2011). The number of bicycle trips is relatively evenly distributed across the country. However, cities with high levels of bicycling can often be characterized by high density and relatively short-range distances.

The majority of all bicycle trips has a duration of 30 minutes or less and a distance of five kilometres or less, also called short distance trips (Trafikverket, 2011). Only 10 % of all short distance trips are made by bike. At the same time the maximum distance of almost half of all travels with car is 5 kilometres. Thus, Sveriges Kommuner och Landsting (2007) states that to increase bicycling for short distance trips has a high potential and is moreover particularly important since the car has a big modal share for such distances. Nearly two thirds of the short distance bicycle trips are related to work, school or leisure travels and the most bicycle trips are made on weekdays between 7 and 8 in the morning and 16 and 17 in the afternoon (Sveriges Kommuner och Landsting, 2007).

In the middle and south part of Sweden the amount of bicycle trips are three times more during summer in June-August, compared to winter. Further north the difference is even larger, where 10 times more bicycle trips are made in summer compared to winter.

According to measurements done at a bicycle path used mostly by bike commuters the most common speed is around 20 km/h (Amnell, 2012). Some reaches speeds of about 30 km/h. According to Trafikverket (2011) a bicyclist in a metropolitan city bikes four kilometres in 26 minutes while the same distance takes 15 minutes in rural areas. Factors that are affecting the mean speed are the infrastructure, congestion and stops at intersections.

The number of fatal road accidents involving bicycles has decreased and an average of 26 bicyclists has been fatally injured during the past 10 years (Trafikanalys, 2015). Most of these accidents are collisions between motor vehicles and bicyclists. While single-bicycle accidents is the main reason why bicyclist are injured, mostly due to slippery roads. The number of injured bicyclists is containing hidden statistics since all accidents are not reported to the police. According to the police about 300 bicyclists get seriously injured every year. On the other hand, 3000 bicyclist are hospitalized for at least 24 hours due to traffic accidents according to patient records.

The Government of Sweden wants to increase the share of bicycling in Sweden and make bicycling safer. In September 2015 the Ministry of the Environment and Energy revealed that there is an intention to, in dialog with responsible actors, develop a national bicycle strategy (Miljö- och energidepartementet, 2015). As a part in the strategy the Government suggest a two year long (2016-2017) investment, a total of 100 million Swedish krona, in measures to encourage bicycling.

The strategy should be a platform for the upcoming work and support the governments decisions (Regeringskansliet, 2015a). Moreover, it should be a support to regions, municipalities and organisations when working with bicycling and bicycle planning. It is based on the goal for transport, including the functional goal regarding accessibility and the consideration goal on safety, environment and health. The strategy is planned to be presented before the summer of 2016.

2.4 Bicycling in Gothenburg

A total of 73 000 bicycle trips were made every day in Gothenburg in 2011 (Göteborgs Stad, 2015). According to the latest travel survey from 2014 made in the West Swedish Region, where 7000 inhabitants between the years of 15-84 were included, the bicycling in the City of Gothenburg has increased with 2 percentage points, from 6 % to 8 %, between 2011 and 2014 (Trafikkontoret, 2015). During the same time period there has been a 4 % increase in total population. In the summer months (April-September) the number of trips made by bike is 9 %. Nevertheless, in 2011 the bicycle share during winter was only half as large as in summer (Göteborgs Stad, 2015). The redistribution to bicycling during summer comes mainly from people who used to travel with public transport (Trafikkontoret, 2015).

The average bicycle trip is four kilometres long and the average travel time with bicycle is 15 minutes (Trafikkontoret, 2015). Furthermore, 10 % of all trips with a maximum travel distance of five kilometres are made by bike, which corresponds to the national average. More than 90 % of all bicycle trips have a distance below 10 kilometres (Göteborgs Stad, 2015).

The modal share of bicycling is 14 % for commuter trips between the residence and work place (Trafikkontoret, 2015). This share has increased with 4 percentage points since 2011. Furthermore, more than 50 % of all bicycle trips are commuter trips (Göteborgs Stad, 2015). For shorter commuting trips below 10 kilometres the modal share of bicycling is 19 %.

2.4.1 The bicycle network in Gothenburg

The bicycle network in Gothenburg is divided into three different network types: bicycle commuting network, general bicycle network and local bicycle network (Göteborgs Stad, 2015). The classification is based on the need for a fast and coarse network supplemented with a more fine-meshed network which takes the bicyclist all the way to the destination. The lowest average speed on the commuting network should be 20 km/h, while the general network should allow for an average speed of 15 km/h.

The commuting network is characterized by very high availability and few or no conflict points with other transport modes (Göteborgs Stad, 2015). Furthermore, the availability for bicyclist should be prioritised, especially at intersections. The bicycle paths on the commuting network are wide, allowing bicyclists that are travelling at different speeds and with different conditions to feel safe and secure. The commuting network connects designated nodes and major destinations.

The general bicycle network forms the basis of the bicycle network and creates a fine structure of coherent and well-designed bicycle paths (Göteborgs Stad, 2015). The design of intersections and paths should be adapted to the bicyclists' needs in order to create a city with high accessibility. The function of the local network is to connect real estate, jobs and destinations in the neighbourhood, and link these to the rest of the bicycle network. A map of the bicycle network in central Gothenburg, showing its characteristics, can be seen in Figure 5.

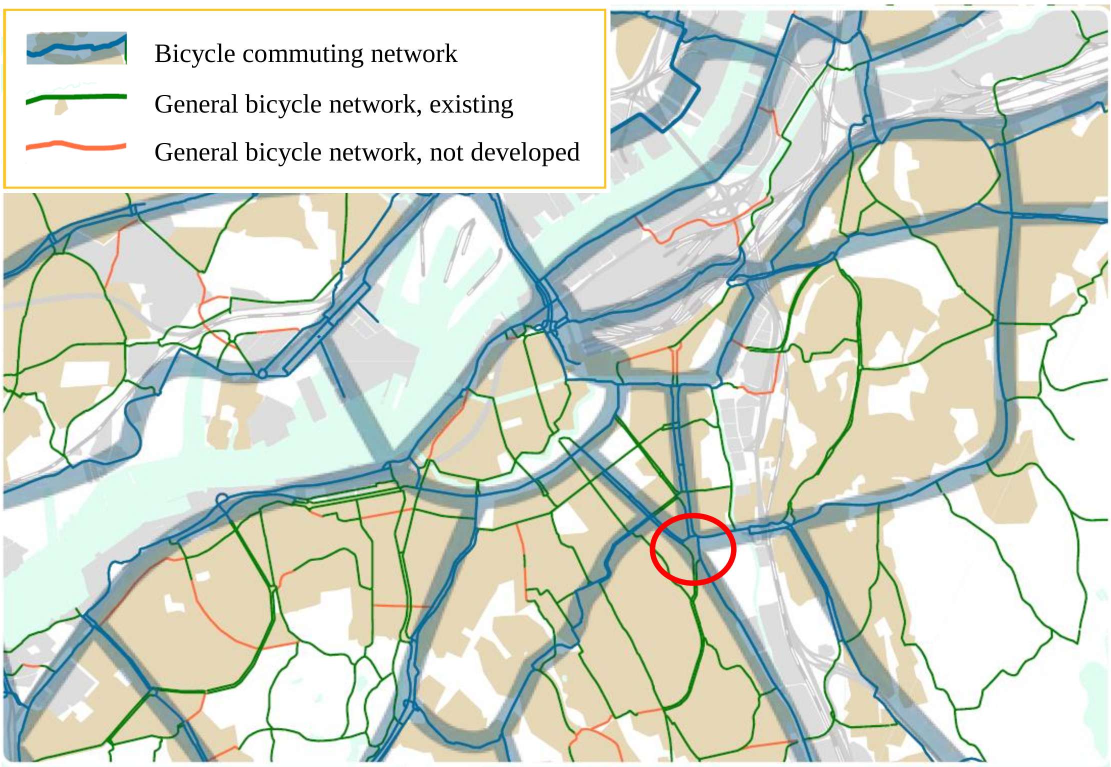

Figure 5 Map of the bicycle network in the center of Gothenburg. The red circle shows the location of Korsvägen (Göteborgs Stad, 2015).

There are two types of bicycle paths in Gothenburg; bidirectional and one-way. Bidirectional bicycle paths are, in C*ykelprogram för en nära storstad 2015-2025*, recommended to be used in the outer edges of the city where intersections are far apart from each other or if destinations are located only on one side of the road. One-way bicycle paths should be used in dense city environments since they are beneficial for the availability and traffic safety, since the number of conflict points decreases.

As a bicyclist in Gothenburg it is not uncommon to come across tram tracks. The crossing of a tram track is sometimes equipped with a warning signal or traffic signal (Göteborgs Spårvägar, 2016). Even though the crossing is not equipped with traffic lights the bicyclists always have to give way to a tram, this include roundabouts and non-signalised bicycle crossings, which might lead to long waiting times and prevents signal priority for bicyclists (Göteborgs Stad, 2015). Furthermore, it reduces the ability to create a good flow for bicyclist. Thus, traffic signals and intersections must be designed to minimise the number of stops and increase the bicyclists' accessibility and flow.

The bicycle network in Gothenburg is equipped with a bicycle-sharing system named Styr & Ställ. It was implemented in the central areas of Gothenburg in August 2010 in order to reduce the load on public transport and offer a flexible transport mode in the city centre (Göteborgs Stad, 2015). The system includes 50 stations spread around the central areas where inhabitants as wells as tourists can hire bicycles.

2.4.2 Vision to increase bicycling in Gothenburg

The vision of the City of Gothenburg is to be an attractive city for bicyclists. The bicycle is stated to be a competitive transport mode since it is fast, easy and safe to use to both sites close by and far away. The goal is to triple the number of trips done by bicycle from 2011 to 2025 (Göteborgs Stad, 2015). It is estimated that the increase could be even greater in the city centre.

Another goal in the work of increasing the quality of the bicycle network is that three out of four citizens in Gothenburg should regard Gothenburg as a bicycle friendly city (Göteborgs Stad, 2015). Interviews preformed in 2013 showed that 42 percent of the respondents think that Gothenburg is a bicycle friendly city. Until the year 2025 the goal is to increase that number to 75 percent. The overall goal is to make bicycling in Gothenburg fast, easy and secure. In order to achieve these goals Göteborgs Stad (2015) clarifies that good accessibility and sufficient capacity, both on paths and intersections, is a prerequisite for the bicycle traffic to be able to increase and at the same time be safe.

Moreover, Gothenburg as well as the whole region is predicted to grow and when this happens the total number of trips will increase with 27 percent (Göteborgs Stad, 2015). The goal is to reduce the number of trips done by car with 25 percent compared to 2011. This means that the increase in number of trips made by bicyclist should both be due to the predicted growth in number of inhabitants and also from the change of transport mode from car to bicycle.

Since the time horizon of the goal coincides with the planned construction period of several major projects in the West Swedish Agreement and other urban development projects the traffic in central parts of the city will differ significantly from its normal conditions (Göteborgs Stad, 2015). However, the goal remains during the construction, which puts high demands on temporary bicycle paths and redirections as well as guidance and information.

The temporary bicycle paths, which are often needed during construction, cannot have the same standard as the ordinary bicycle network (Göteborgs Stad, 2015). However, the following general requirements must always apply:

The guidance should be good and signs regarding redirections should be visible from all directions, even in darkness, at every crossroad. The paths for redirection must be safe and secure in terms of traffic situation, lightning and surface material. Moreover, they should have sufficient width by the number of bicyclists, the duration of the construction and the conditions at the construction site. The comfort on the bicycle paths should be good, which can be obtained by even surface layers. The selection of surface material should be related to the duration of the redirection.

2.5 Bicycle planning

The number of people choosing to go by bicycle instead of taking the car is increasing because it is more time efficient, convenient, cheaper and improves the health (Trafikverket, 2014c). Cities have therefore chosen to give the bicycle a higher prioritisation than the car when planning the urban areas. The priority of bicycle usage will increase the number of people in the public room, which further leads to lower speeds and create safer and more secure environments. The foremost focus of bicycle planning is fast tracks for bicycle commuters and several municipalities have increased their maintenance of the fast tracks. Pucher and Buehler (2007) states that most cities that have experienced an increase in bicyclist are improving their bicycle infrastructure.

The work to improve the knowledge, planning methods and analyse methods is a constantly ongoing process. The importance of the planning policies are second by Pucher and Buehler (2007) that states that it is necessary to make the bicycling safe and feasible for a broad spectrum of people. They also state that the key to an increased amount of bicyclists is a coordinated multidimensional approach.

In the area of bicycle planning the Netherlands, Germany and Denmark is often described as prodigies. But according to Pucher and Buehler (2008) bicycling has not always been thriving in these countries. From 1950-1975 the number of people travelling by bicycle dropped in all three countries. And it was not until the massive reversal in the transport and urban planning policies in the middle of the 1970s that bicycling was revived to today’s current high and successful state.

Most of the policies and regulation used to plan and design the bicycle infrastructure in Sweden are created by The Swedish Transport Agency which is a Governmental authority operating under the Ministry of Enterprise and Innovation. The Swedish Transport Agency has an overall objective to provide a long term sustainable and socio-economically efficient transport system. To be able to achieve these objectives The Swedish Transport Agency develops regulations, issues permits and conducts inspections. The Swedish Transport Agency often collaborate with The Swedish Association of Local Authorities and Regions (SALAR), which primary role is to support and evolve the counties, regions and municipalities (Sveriges Kommuner och Landsting, 2016).

One policy created by SALAR and The Swedish Transport Administration is Traffic for an Attractive City, in Swedish: Trafik för en Attraktiv Stad (TRAST). TRAST is meant to work as guidance when developing the traffic and create an attractive city (Sveriges Kommuner och Landsting, 2007). SALAR has together with The Swedish Transport Administration also created the GCM-handbook, which includes recommendations for pedestrian, bicycle and moped infrastructure in Sweden.

One of the regulations created by The Swedish Transport Administration together with SALAR is a new version of the already exciting rules for the design of the streets and roads, in Swedish: Vägar och gators utforming (VGU). The Swedish Transport Administration is obligated to follow VGU in city planning on a national level, which is not the case for municipalities. However, it should be seen as guidelines (Trafikverket & Sveriges Kommuner och Landsting, 2015).

Besides using urban planning policies and regulations, evaluation of areas where the most accidents occur can be used to identify where investments are profitable. One existing program is STRADA (Swedish Traffic Accident Data Acquisition), which is an information system with data about accidents throughout the whole traffic system (Transportstyrelsen, 2016b). Data is reported into the system by both police and healthcare, which reports traffic accidents and emergency care. The location of the accident is reported and since STRADA is a GIS-based program maps showing areas with numerous accidents can be used when planning for a better traffic safety. Furthermore, the basis for traffic safety in Sweden is the Vision Zero, which is established by the Government (Trafikverket, 2014a). The Vision Zero strives for a future where nobody is neither fatally nor severely injured in a traffic accident. The work with traffic safety should do everything in order to prevent these types of accidents. However, people can make mistakes and not all accidents are possible to prevent. Thus, the Vision Zero accepts that accidents will occur but they should not cause any severe injuries.

2.5.1 Design of bicycle infrastructure

The regulations presented above are used when designing the infrastructure of the bicycle network. Recommended widths of bicycle paths depending on the level of flow and the number of side obstacles according to VGU are presented in Table 2. A moderate flow is defined as 360-1440 bicyclists/hour/direction (Trafikverket & Sveriges Kommuner och Landsting, 2015). A low flow is below 360 bicyclists/hour/direction and a high flow above 1440 bicyclists/hour/direction. Examples of a side obstacle are bushes or smaller trees. The recommended width if there is no side obstacles is also the smallest allowed width.

Table 2 Recommended width of bicycle path depending on the level of flow and the number of side obstacles (Trafikverket & Sveriges Kommuner och Landsting, 2015).

Type of infrastructure	Flow	Recommended width of the bicycle path [m]		
		No side obstacle (the smallest allowed width)	Side obstacle one side	Side obstacles on both sides
Bidirectional bicycle path	Low	2.4	2.7	3.0
	Moderate	3.3	3.7	4.0
	High	4.5	4.8	5.1
One-way bicycle path	Low	1.3	1.7	2.1
	Moderate - High	2.0	2.25	2.5

Recommended widths of the bicycle path are also presented in the GCM-handbook. Depending on the flow the recommendation of the width for one-way bicycle paths vary from 1.6 if the flow is low and 2.0 if the flow is high (Sveriges Kommuner och Landsting, 2010). A high flow is defined as larger than 200/maximum hour or 1500-2000/day on a one-way lane. The same flow for a bidirectional path is defined as larger than 300/maximum hour or 2000-3000/day. A bidirectional bicycle path should be at least 2.5 meters wide if the flow is high and 2.25 metres if the flow is low.

Furthermore, it is important not only to have well-functioning bicycle paths but also to make sure that the infrastructure is safe and simple at places where bicycle paths cross ordinary roads. In Sweden there are, since the 1st of September 2014, two different ways to design the infrastructure of bicycle crossings.

First, there is the *bicycle crossing* which is recognised by its white marks in the shape of a square in the street (Göteborgs Stad, 2014). In these crossings bicyclists are obligated to give way to cars. They should adjust their speed and only cross if the action can be taken without causing any risk. However, if a car is crossing a bicycle crossing when it is about to exit a roundabout or is turning the car should slow down and make sure that bicyclists that are on the crossing or about to enter the crossing can pass. If the bicycle crossing is combined with a zebra crossing the cars are obligated to give way to the pedestrians.

Secondly, is the recently introduced *bicycle priority crossing*, which must be marked with painted squares and triangles on the surface of the road together with a road sign (Göteborgs Stad, 2014). Furthermore, the design of the crossing should allow a maximum speed of 30 km/h for vehicles travelling on the road (Transportstyrelsen, 2016a). A bicyclist that is entering a bicycle crossing shall take the distance and speed of the vehicle travelling on the road into consideration. However, vehicles are obligated to give way to a bicyclist that is just about to enter or is already on the crossing. The intention with the new crossing is to favour the availability for bicyclists (Göteborgs Stad, 2014).

2.5.1.1 Recommendations in the City of Gothenburg

The City of Gothenburg has its own recommendations of the widths of the bicycle paths depending on the number of bicyclist passing during the maximum hour (Göteborgs Stad, 2015). Maximum hour is in this case the hour with the highest load during a normal weekday. These recommendations, for the bicycle commuting network and general bicycle network, can be seen in Table 3. The commuter network has a higher priority than the general network and has therefore broader paths. At the bicycle commuting network the recommended width of the one-way bicycle path varies from 2 to 3 metres and the width of the bidirectional bicycle path varies from 3 to 4.8 metres. The flow is divided in three different steps; less than 500 bicyclist/maximum hour, 501-1000 bicyclists/maximum hour or more than 1000 bicyclist/maximum hour. The intention with the recommended widths is that is that it should be possible to pass slower bicyclists even though there is traffic in the oncoming lane.

Table 3 Recommended width of bicycle path depending on the number of bicyclists passing during the maximum hour (Göteborgs Stad, 2015).

Bicycling commuting network	**One-way bicycle path**	**Bidirectional bicycle path**
Less than 500 bicyclists/maximum hour	2.0 m	3.0 m
501-1000 bicyclists/maximum hour	2.4 m	3.6 m
More than 1000 bicyclists/maximum hour	3.0 m	4.8 m
General bicycle network	**One-way bicycle path**	**Bidirectional bicycle path**
Less than 500 bicyclists/maximum hour	1.6 m	2.4 m
501-1000 bicyclists/maximum hour	2.0 m	3.6 m
More than 1000 bicyclists/maximum hour	2.4 m	4.8 m

Furthermore, the design of bicycle paths in the municipality of Gothenburg should follow the technical instructions and standard sections presented in Teknisk Handbok

(TH). The standard sections provides instructions on how wide the paths should be. Each standard section can have two standards, normal or low, and different width intervals are given for each standard (Teknisk Handbok, 2016b).

According to the standard section a bidirectional bicycle and pedestrian path in central parts of the city with normal standard should have a 2 metres wide pedestrian path and 2.4-4.8 meters wide bicycle path. Low standard corresponds to a total width of 4 meters, where the pedestrian path is 1.7 metres wide and the bicycle path is 2.3 metres wide. If the design deviates from the standard described in TH a special approval from The Traffic and Public Transport Authority in Gothenburg is needed.

2.5.2 Mobility management

Mobility management (MM), which is a concept dealing with behavioural impact in the transport sector, can be used as a compliment to the more traditional traffic planning (Trivector, 2016b). MM is meant to work as a complement to physical measures and the aim is to use “soft” measures to affect the behaviour and attitude to a more sustainable usage of transport modes. MM has been developed at a European level, first of all in a number of EU-project but also through European Platform on Mobility Management (EPOMM). EPOMM is a non-profit organisation with a network of governments in European countries that are engaged in MM, with headquarters in Brussels (EPOMM, 2016). The “soft” measures in MM consist of information and communication, organization of services and coordination of the different parties’ involvement. The measures are supposed to improve and optimize the physical measures at a low cost. The overall aim is to affect the trip before it has started.

2.5.2.1 Mobility management at construction sites

Delays often occur at construction sites and there are three tactics to handle the disturbances (Trafikverket, 2013a). One action is to maintain the capacity by either adapting the construction site or change the construction hours. Secondly a suggested action is to redirect the traffic to alternative paths. And thirdly, the implementation of mobility management during the construction phase.

MM is supposed to change the road users’ behaviour and reduce the number of single motorists by making them choose public transport, carpooling, biking or walking among other things (Trafikverket, 2012). If the road users’ new way of travelling is smooth, fast and secure hopefully the road user will continue to use the new transport mode even after the construction.

Trafikverket (2012) explains that MM is not only “soft” measures and suggests that MM is divided in to two parts:

1. Measures to develop sustainable transportation choices through improved design and range of sustainable transport modes.
2. Measures that affects the behaviour of the travellers by guidance and information.

The guidance can consist of both nice and pushing measures (carrots and sticks) (Trafikverket, 2012). Pushing measures could be a congestion fee system or an increased price on parking. A nicer way of convincing people to use other transport modes, than the car, is by having cheaper price on the public transport system during a short period or the possibility to bring the bike on the train, tram or bus or offering rental bikes in the city centre.

One of the most important things at a construction site is to inform the road users about upcoming changes (Trafikverket, 2012). When choosing the most appropriate MM measures it is important to remember in which way the road users prioritise their actions when there are disruptions on the traffic. First the road users change their route, secondly travel at a different time, thirdly use another transport modes, and lastly the road user change their destination or cancel the trip.

What is common for all road users are that they all need to get the information in advance (Trafikverket, 2012). It is also more efficient if the information is specific for the transport mode and spread out at specific times otherwise the risk of the information drowning in the daily flow of information is huge. Efficient ways of spreading the information is trough Internet, SMS, radio, television, phone calls, and newspapers. A big part is also the Intelligent Transport System (ITS) that uses Internet, SMS, Smartphones and digital signs to spread the information about changes due to the construction.

2.5.2.2 Mobility management in the construction phase of Västlänken

Västlänken is the largest investment in the West Swedish Agreement which contributes to the expansion of public transport. It is an 8 kilometre long double-track commuter train tunnel under central Gothenburg. It includes three underground stations; Station Centralen, Station Haga and Station Korsvägen. The construction of the tunnel will begin in 2017/2018 and the commuter trains will start to operate in 2026 (Trafikverket, 2015c). The traffic in Gothenburg will be affected by the construction of Västlänken at many locations and to a varying extent (Trafikverket, 2014e). The main challenge will be to mitigate the consequences of the construction as much as possible. Furthermore, the following efficiency goals within the West Swedish Agreement should be aimed to be fulfilled:

- a more attractive public transport with increased capacity
- a higher share of public transport
- decreased amount of car traffic travelling to and within the region core
- fast, safe and easy pedestrian and bicycle paths
- improved quality of trade and industry transports
- reduced amount of emissions
- reduced noise levels
- more public areas and vivid city life

Mobility management will be used during the construction of Västlänken. An investigation as wells as an implementation plan has been compiled in order to specify the needs and possible measures. The MM work within Västlänken aims to decrease the traffic disturbances at the construction sites by decreasing the amount of tips done by car and increase the modal share of walking, bicycling and public transport (Trafikverket, 2015). The accessibility and availability should be maintained for passenger and freight transports.

However, Trafikverket (2014e) states that the availability for car traffic may change during construction, which will also affect its competitiveness against bicycling. Trafikverket has conducted an investigation where the travel time ratio between car and bicycling has been compared for the current situation at Korsvägen and the situation during the construction of Västlänken. It indicates that some areas will have a changed travel time ratio and thereby have good opportunities to travel by bike instead of car to Korsvägen. It is especially some parts of Frölunda, Mölndal and Biksopsgården where the travel time ratio to Korsvägen gets below 1.5 during construction, i.e. the travel time by bicycle is maximum 50 % longer than the travel time by car.

In the implementation plan it is stated that the paths that exist during the construction shall have the same high standard as a permanent path (Trafikverket, 2015a). The permanent standard at bicycle paths is motivated due to a planned increase in number of bicyclist. One way to create this increase in number of bicyclist is by promoting bicycling and to do so some measures has been created in the implementation plan. The first measure is an interactive bicycle map for the area around Västlänken. The map show the bicyclist how the route will change over time when the construction area changes and creates new paths for the bicyclist. This map can be used by individual bicyclist to plan their route but also to raise questions about the priority of the bicyclists. Another suggested way to inform the bicyclist about their new route is by creating short movies where someone bikes the route and explains certain situations and signs and why the redirection has been made. This will hopefully lead to acceptance and an easier transaction can lead to less disturbances. Västlänken will, according to the implementation plan, work to increase the accessibility.

2.6 Bicycle capacity and availability

Capacity is not a well-used term when it comes to bicycling and little research has been done. Furthermore, the number of capacity studies on bicycling is few. However, Allen (1998) has defined the capacity on a 1-1.2 meter wide bicycle lane as 1500 to 5000 bicyclists per hour. This wide range can be seen also when comparing capacity of bicycle lanes in different countries. In the Netherlands a 0.78 meter wide bicycle lane is assumed to have a capacity of 3000 to 3500 (Raksuntorn and Khan, 2003). While a 2.5 meter wide bicycle lane in Canada is assumed to have a capacity of 10.000 bicyclists an hour. A Swedish study states that the capacity on a 1.2 meter wide bicycle lane is about 1500 bicyclists per hour (Ljungberg, 1986). However, the width of the bicycle path as well as the number of lanes in each direction is influencing the capacity.

In TRAST the capacity of the bicycle network is described as the ability to offer a high standard of availability during peak flows, on stretches as well as at crossings (Sveriges Kommuner och Landsting, 2007). It is also stated that it should be possible to bicycle at a speed of 30 km/h in the main networks and 15-20 km/h in the local network. According to a study dealing with congestion on bicycle paths made by Vectura (2010) the capacity is started to get affected when the number of bicyclists reaches 30-40 per minute. The study was performed on bicycle paths with varying width and it was therefore not possible to determine a general measure of capacity.

Further on, Vecturas definition of lack of capacity is when a bicyclist, willingly or unwillingly, leaves the bicycle path because of limited availability. Limited availability on bicycle paths could be due to high traffic flows, interference with other transport modes, mainly pedestrians, or narrow bicycle lanes.

One existing definition of availability is the simplified description: "*That it is possible to go there*" (Firth, 2012). In everyday life availability is often described as "*It is easy to go there to a reasonable price and within a reasonable timeframe*". However, there is no standard definition of availability on bicycle paths and one reason to these rather unclear definitions of availability is that the perceived availability is changing depending on the situation (Firth, 2012). Envall and Koucky (2013) describe availability as how fast it is possible to travel from point A to B and were the slow passages and forced stops are located.

Crossings and intersections can be the cause of forced stops and slow passages. However, the required time to travel through different types of crossings is an area where few studies have been performed. In Elvik (1998) the time requirements are based on an American analysis where the waiting time for pedestrians in different crossings was examined. The analysis showed that zebra crossings give the shortest waiting time and signalised crossings the longest. The waiting time is also dependent on the traffic flow and can vary between 0.5 to 30 seconds. Trivector (2013) used this study to estimate the average waiting time for bicyclist in different types of crossings (see Table 4).

Table 4 Average waiting time for bicyclists through different types of crossings (Trivector, 2013).

Time requirement	Seconds
Grade separation	0
Signalised intersection	30
Signalised intersection – signal priority	15
Raised crossing –give way for bicyclist	10
Raised crossing –give way for motorized vehicle	5
Non raised crossing – give way for bicyclists	20
Non raised – give way for motorize vehicle	10

Another factor affecting the capacity is the ability to move freely. It is also stated to be an important factor when evaluating the standard of the bicycle path (Botma, 1995). The ability to move freely is affected by *hindrance,* which includes how the bicyclists are limited or hindered on along the path, often due to meetings or passages. Meetings or passages are often inconvenient and may result in conflicts or accidents. A great amount of hindrance is an indication of low availability, however is does not mean that the capacity limits are reached.

3 Case study of Korsvägen

This chapter is divided into two parts. The first part consists of background information about the case study area and presents reported accidents at Korsvägen and the inhabitants' opinions about Korsvägen. The second chapter, Chapter 3.2, is the field study which includes results from a traffic count, measurements of travel time and delay time and observations of capacity and availability.

3.1 Background information about the case study area

Korsvägen is an intersection and public transport node in central part of Gothenburg, south of the city centre. The area surrounding Korsvägen consist of a lot of buildings related to different events e.g. Universeum (Science Centre) , Liseberg (theme park), The Swedish Exhibition and Congress Centre (Svenska Mässan), The National Museum of World Culture (Världskulturmuseet), Scandinavium (sport and concert arena), Valhalla Sports Centre and Valhalla Swimming Hall. All these together has a total of six million visitors every year (Trafikkontoret, 2016).

Korsvägen is designed as a roundabout with traffic in five different directions; Södra Vägen in the southeast and northwest, further on referred to as Södra Vägen S and Södra Vägen N, Skånegatan in the north, Örgrytevägen in the east and Eklandagatan in the south. Located further down at Örgrytevägen is the exit and entrance ramp to the European road E6 and highway 40. Thus, Korsvägen is a big part of the infrastructure and an important traffic junction for car in Gothenburg (Trafikverket, 2014b). Korsvägen is also one of the major access points into the city centre. About 2500 vehicles passed Korsvägen during the maximum hour in the afternoon in 2014, which corresponds to 30 000 vehicles on an average day (Trafikkontoret, 2016).

Bicycle paths are entering and exiting Korsvägen from all five directions. All of them belong to the commuting bicycle network (see Chapter 2.4.1), they have a pedestrian path running next to them and most of them are bidirectional. One exception is the bicycle paths running along each side of Eklandagatan, which are one-way. The bicycle path on the east side of Eklandagatan is used when travelling towards Korsvägen and the one on the west side when travelling from Korsvägen. Furthermore, the bicycle path on the south side of Södra Vägen N is one-way in the direction of Korsvägen, the path on the north side is bidirectional. Alongside Skånegatan the bicycle path on the east side is bidirectional but the one on the west side is one-way in the direction of Korsvägen.

Approximately 7000 bicyclists passed Korsvägen every day in 2014 and about 800 of them passed during the maximum hour (Trafikkontoret, 2016). More than 2000 bicyclists are expected to pass Korsvägen during the maximum hour in 2035. This is equivalent to the target set by the municipality to triple the bicycling between 2011 and 2025 and a subsequent increase of 3 % per year until 2035.

Furthermore, there are two Styr & Ställ stations located close to Korsvägen. One in the south part of Södra Vägen N and another in the north east corner of Korsvägen, just south of Örgrytevägen along the walk way leading to Liseberg.

Moreover, a total of six tramlines and 18 bus lines are passing through Korsvägen, with numerous departures and arrivals every day, making it an important interchange stop for public transport. The number passengers starting and ending their trip at Korsvägen was about 40 000 per day in 2014 and 4000 during the maximum hour according to

Västtrafik (Trafikkontoret, 2016). About half of the passengers have Korsvägen as their destination while the other half changes to/from tram or bus to continue their travel.

The public transport can pass straight through the roundabout and the stops are located within it. The car traffic is located in the outer edges of the roundabout, outside of the public transport, while separated bidirectional bicycle paths are located along the outside of the roads (see Figure 6). Car traffic and bicyclists are controlled by traffic signals at Eklandagatan and Södra Vägen S.

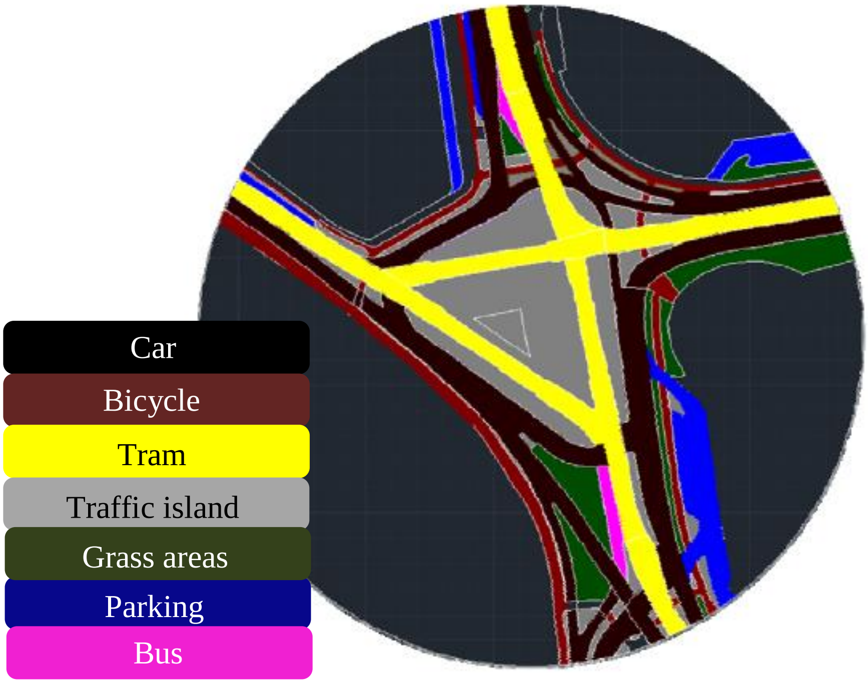

Figure 6 The different transport modes and their assigned areas at Korsvägen (Hermansson and Ekström, 2014).

In a study made by Hermansson and Ekström (2014) where the space requirement for different transport modes was investigated at Korsvägen, it was found that cars are occupying the largest area. The space requirement is based on both safety and comfort perspective. It is defined as the area required by one passenger in a moving vehicle. At Korsvägen the area for cars corresponds to 13.35 % of the total area. The second largest area by 8.86 % is dedicated to trams, while bikes and busses have the smallest area with 4.56 % respectively 0.54 %. The rest consists of areas not meant for transport modes e.g. grass areas and buildings. Several areas are also used by multiple transport modes. In those cases the transport mode that everyone else has to give way to was said to be the primary user of the area.

3.1.1 Reported accidents at Korsvägen

According to STRADA 35 accidents related to bicycling happened at Korsvägen between the years 2003 and 2015. The location of the accidents and their level of severity and accident type can be seen in Figure 7. None of the accidents were lethal, only one was serious, five was moderate and the dominating degree of injurie were minor, with 29 accidents. The dominating accidents type is the one between bicyclist and motor vehicles with a total number of 24 accidents. Single bicycle accidents happened eight times, accidents between bicyclist and bicyclist two times and between bicyclist and pedestrians once. The majority of accidents occur at bicycle crossings, and only 8 out of the 35 happened on a stretch.

All three accidents that occurred at the crossing of Södra Vägen S happened because of the confusion that occurs when the car drivers turning right from Eklandagatan to Södra Vägen S has a green light at the same time as the bicyclist. The accidents at Örgrytevägen are all collisions between bicyclists and cars. In some cases, is it stated that the southernmost bicycle crossing, with a width of two car lanes, is especially problematic. Accidents have occurred when one car has stopped and blocked the view of the car in the other lane, which then collides with the bicyclist on the crossing.

The crossing at Skånegatan has also caused numerous accidents between bicyclists and cars. Some of the single accidents are related to fall and one is stated to be due to the tram track. Four accidents have occurred at the crossing of Södra Vägen N and all of them were collisions between cars and bicyclist, with minor injuries.

Along the bicycle path on the west side of Korsvägen two accidents has occurred. One accident occurred due to too high speed and the other due to biking on the wrong side of the path. The latest mentioned accident was the only one within these 13 years that lead to serious injuries.

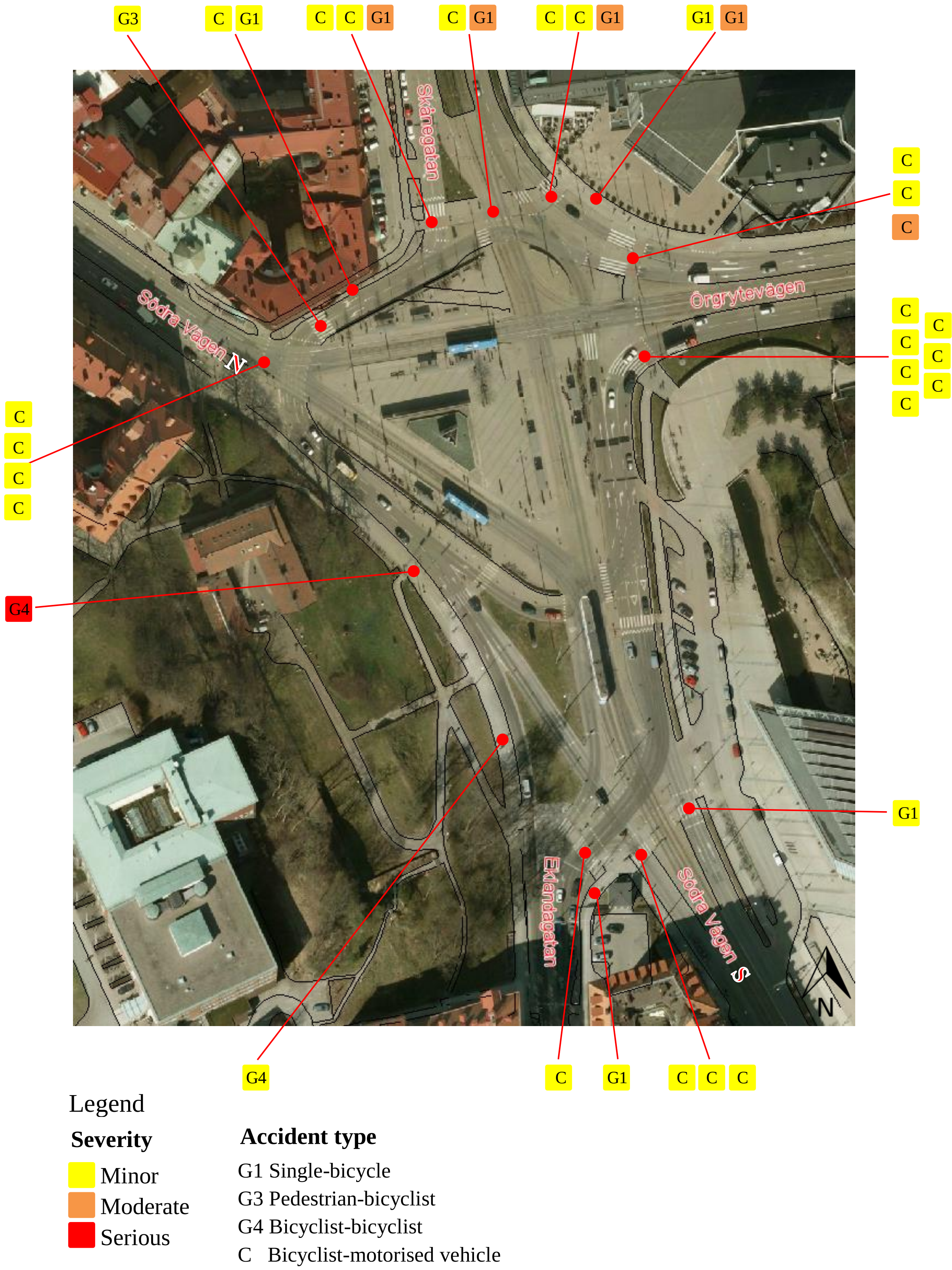

Figure 7 *Map showing data from STRADA on accident type and level of severity of bicycle related accidents at Korsvägen, between the years 2003-2015.*

3.1.2 The inhabitants' opinion on bicycling around Korsvägen

Göteborgs-Posten the local newspaper had, during the spring of 2015, an article on their website where inhabitants could write about problems in the bicycle network in Gothenburg and mark the location on a map (Göteborgs-Posten, 2015). In this article there are several comments related to Korsvägen.

At numerous sites people experience problems with pedestrians on the bicycle paths, especially along the bicycle path on the east side of Korsvägen. At the same time the pedestrians complains about the aggressive behaviour of bicyclists. Furthermore, risky situation is particularly experienced at crossings where many different transport modes interact. A lot of people are unsure whether the bicyclist or the car drivers should give way at bicycle crossings. The interaction with public transport is also confusing and as for cars people are not sure who has to give way to whom.

Another confusing situation which has been identified in the article is the fact that the pedestrian's traffic signal at Södra Vägen S can be red, but the bicyclists are allowed to pass. Some car drives are not aware of that the signals for pedestrians and bicyclists can differ and therefore think that the bicyclists are bicycling through red lights.

Moreover, the two-lane crossing at Örgrytevägen has been pin-pointed as unsafe. At this crossing it happens that cars in one lane stops and when doing so block the sight for the cars in the other lane.

There are also some comments related to the design and construction of the bicycle paths. For example the left turn, when bicycling on the west side of Södra Vägen N towards Skånegatan, is very sharp. Another revealed problem is a non-functioning gully pot at a bicycle path at Skånegatan. During heavy rainfalls it gets flooded and a pool of water is created on the bicycle path.

Furthermore, a survey made by the municipality in 2012, where questions about the attractiveness of bicycling in Gothenburg was asked, showed that 45 % of the answers had to do with that people were satisfied with the network of bicycle paths (Göteborgs Stad, 2015). When asked what makes Gothenburg a less attractive city to bike in low availability, proximity and flow was mentioned by 31 %. When Göteborgs Stad (2015) interprets the result they find that the bicyclists are satisfied with the structure of bicycle network, however the quality of the bicycle paths does not meet their expectations.

This image has been confirmed by other quantitative studies, which furthermore showed that bicycling in Gothenburg is often perceived as complicated and complex (Göteborgs Stad, 2015). Moreover, in a study where bicyclist recorded their trips it was revealed that bicyclists often took calculated risks and deliberately choose different paths than the designed in order to maintain their speed, avoid stops and get better availability.

3.2 Field study of the bicycle conditions around Korsvägen

The bicycle paths around Korsvägen are, in this study, divided into eight stretches, A-H (see Figure 8). Identified conflicts point, where the bicycle path crosses other traffic modes tracks and vice versa, are marked with yellow (bicycle to vehicle) and blue circles (bicycle to pedestrian). Signalised and non-signalised intersections with public transport are marked with yellow diamonds.

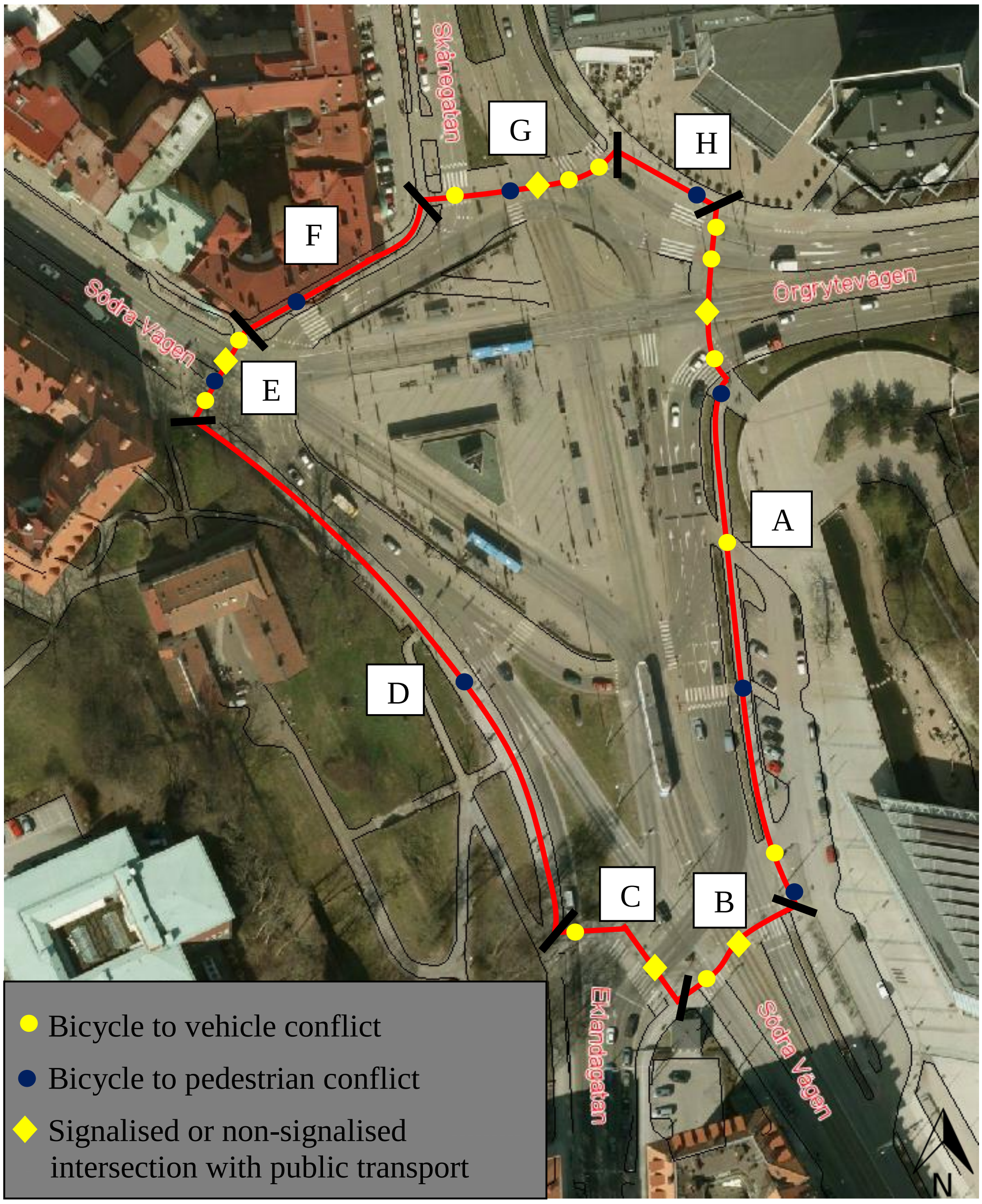

Figure 8 Map of Korsvägen showing the different stretches and the location of the identified conflict points and crossings.

Stretch A is a 170 metres long and 3.0 metres wide bidirectional bicycle path going, clockwise, from Örgrytevägen alongside Södra Vägen towards Mölndal. The majority of the stretch is completely separated from the pedestrian path, which runs on the east side of the parking area. On the northern part of the stretch, where it crosses Örgrytevägen, the pedestrian path is located next to the bicycle path.

There are several conflict points with other transport modes on this part of the stretch. Most of them are raised bicycle crossings combined with zebra crossings. The southernmost crossings has a width of two car lanes, while the other two cross one car lane at a time, separated with a traffic island. There is also a non-signalised intersection with tram tracks at Örgrytevägen where trams as well as busses are operating. Another conflict point on this part of the stretch is where pedestrians have to cross the bicycle path to reach the pedestrian path.

Some conflict points has also been identified along Stretch A, where the bicycle path is completely separated from the pedestrian path. On this part there are two raised bicycle crossings, where cars are crossing the bicycle path to enter and exit the parking lot area east of Korsvägen. Another conflict point along the stretch is with pedestrians, who cross the bicycle path to go between the parking area/pedestrian path and a zebra crossing. A similar conflict point with pedestrians occur where they have to cross the bicycle path going to/coming from the zebra crossing at the eastern part of Södra Vägen S. In total eight conflict points with other transport modes have been identified along the stretch and one non-signalised intersection with public transport.

Stretch B is the 2.8 metres wide bidirectional path from the east to the west side of Södra Vägen S, crossing a four-lane road, two lanes in each direction, with tram tracks running in the middle. The intersection is regulated by traffic lights, where priority is given to trams and busses if they are about to pass. However, the traffic signals are programed so that the maximum waiting time for bicyclists is 70 seconds[1]. Bicyclists and pedestrians have the ability to affect the time interval of the traffic lights by pushing the button. However, if this action is not performed and the traffic signals within the same group has green light, this signal swishes to green automatically.

Green light is given to car traffic turning right form Eklandagatan at the same time as the bicyclists are allowed to cross Södra Vägen N, which creates a conflict. There is a LED-sign warning the motorists of crossing bicyclists. The total length of the bidirectional bicycle path is 34 metres. The bicycle path and pedestrian path run alongside each other the whole stretch.

Stretch C is a 40 metres long and 2.9 metres wide bidirectional bicycle path through the crossing of Eklandagatan. One part of the crossing, the southernmost, is regulated by traffic lights that gives priority to public transport. The pedestrians and bicyclists cannot affect the waiting time by pushing a button. Furthermore, the signals are not programmed to give the bicyclists a certain maximum waiting time, it could in theory be endless[1]. The signalised crossing is divided, with a traffic island, into two parts where one part is two lanes wide and the other has the width of one traffic lane. The part which is one lane wide is a bus lane, where bus number 52 is operating. The stretch also includes a raised bicycle crossing combined with a zebra crossing, which is the only conflict point that has been identified. A pedestrian path runs alongside the bicycle path throughout the whole stretch.

Stretch D is a 140 metres long and 2.4 metres wide bicycle path running from Eklandagatan to Södra Vägen N. The bicycle path is bidirectional and the lane in each direction is separated by a dashed line. A pedestrian path runs alongside the bicycle

[1] Andersson, Thomas. Project leader, Swarco Sverige AB. Email contact. 2016-04-14

path and they are separated by a solid white line. The pedestrians needs to cross the bicycle path at one point to get to/from a zebra crossing located along the stretch. This is the only conflict point that has been identified along the stretch.

Stretch E consists of the crossing of Södra Vägen N. The crossing includes two non-signalised two-lane bicycle crossings separated with a traffic island. On one of the lanes in the two lane crossing to the north-east the car traffic is directed to drive on the same area as where tram tracks are located, thus car traffic is mixed with public transport. There is also a conflict point with pedestrians which has to cross the bicycle path to get to/from a zebra crossing. Giving a total of two conflict points and one non-signalised intersection with public transport along the stretch. The total length of the bidirectional bicycle stretch is 31 metres and it has a width of 2.5 metres.

Stretch F is a 49 metres long and 3 metres wide bidirectional stretch from Södra Vägen N to Skånegatan. A pedestrian path run alongside the bicycle path and they are separated by different pavements. One conflict point has been identified along the stretch where pedestrians have to cross the bicycle path to get to/from a zebra crossing.

Stretch G consists of the crossing from the west to the east side of Skånegatan. The stretch is a total of 48 metres long and 3 metres wide. A total of four conflict points with other transport modes and one non-signalised intersection with public transport have been identified. The bidirectional bicycle path is crossing a two lane road on the west side of the stretch, two tram tracks and two single lane roads on the east side of the stretch. Separations between the different crossings are made with traffic islands. All bicycle crossings are raised and non-signalised. A pedestrian path runs alongside the bicycle path. One conflict point between bicyclists and pedestrians occur where pedestrians cross the bicycle path to get to/from a zebra crossing along the stretch.

Stretch H, is a 22 meter long and 2.75 meter wide bidirectional stretch from Skånegatan to Örgrytevägen located outside the entrance of The Swedish Exhibition and Congress Centre. The lanes on the bicycle path are separated with a continuous line in the middle of the path. A pedestrian path runs alongside the bicycle path and they are separated by different pavement. One conflict point occurs between pedestrians and bicyclists since the pedestrians needs to cross the bicycle path to get to/from a zebra crossing along the stretch.

3.2.1 Traffic count

A traffic count was performed on two consecutive days in March 2016 in the hour with the maximum bicycle flow. When analyzing the data from 2015 the maximum hour occurred between 7.00 and 8.00 a total of 492 times, followed by 16.00-17.00 with 220 times. Since the traffic count was about to be performed in March data from this month from 2013-2015 was studied thoroughly. It showed that 60-80 % of all maximum hours during weekdays occur between 7.00 and 8.00 in March (see Appendix I). Thus, the counting was performed between 7.00 and 8.00. Furthermore, since the weather is affecting the bicycling days with similar conditions were chosen. The weather on the actual days was sunny and about 4 degrees Celsius and therefore no correction factor had to be used.

There are also variations in the number of bicyclists over the year. The analysis shows that there is a fairly distinct correlation in distribution over the year between the different years (see Figure 9). The month with the lowest flow is January and a gradually increase in flow can be seen during spring and early summer. There is an apparent drop in July, while the highest number of bicyclist travels occurs in September. A gradually decrease in bicycle travels can be seen between September and December.

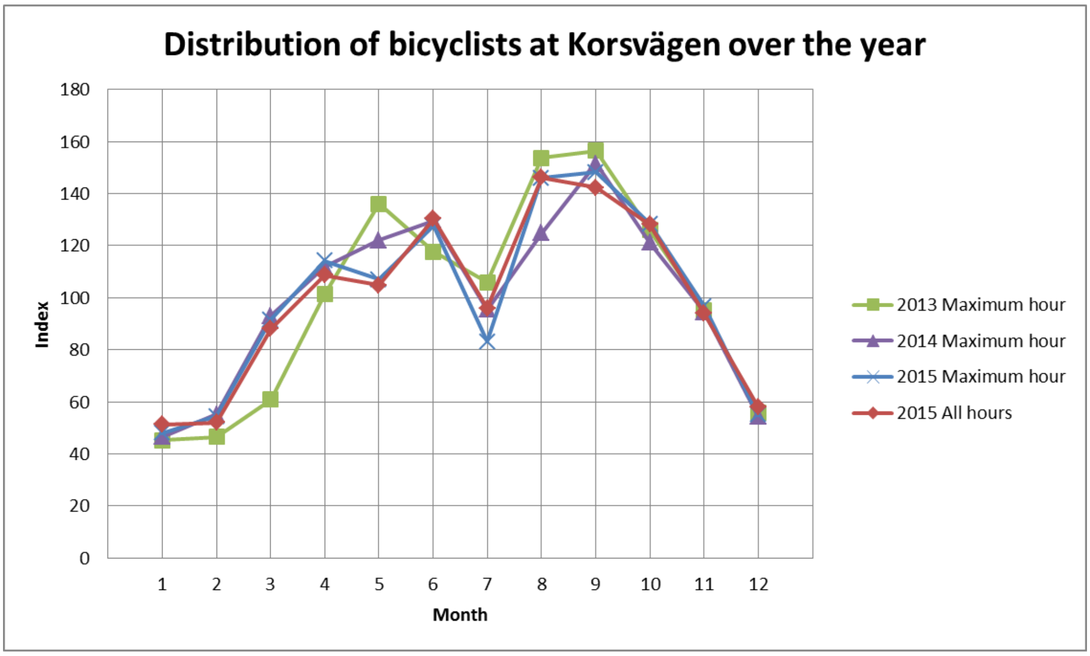

Figure 9 Index showing the monthly variation of bicycle traffic at Korsvägen.

3.2.1.1 Results from traffic count

The result from the counting can be seen in Table 5. The stretch with the highest load is Stretch H, with 425 bicyclists, followed by 315 bicyclists on Stretch A. Stretch E and Stretch C are the stretches with the lowest amount of bicyclists, 72 and 81 bicyclists. All stretches except Stretch E has a higher flow in the counter-clockwise direction, towards the city centre, compared to clockwise.

Due to some non-predictable events most of the values from the traffic count on the 14^{th} of March could not be seen as reliable. The invalid values are written in red in Table 5. However, the data from the two stretches which was counted correctly (Stretch G and H) during the first counting can be used to verify the results of the second counting. It can be seen that the results from the two separate traffic counts differs with around 5 %. This is considered to be an acceptable variation and the values from the second count will be used further on.

Table 5 Results from bicycle traffic count on Korsvägen, on two consecutive days.

Stretch/Day		**Monday 14th of March**		**Tuesday 15th of March**	
A	Clockwise	79	277	94	315
	Counter-clockwise	198		221	
B	Clockwise	33	120	33	136
	Counter-clockwise	87		103	
C	Clockwise	29	80	36	81
	Counter-clockwise	51		45	
D	Clockwise	22	80	37	103
	Counter-clockwise	58		66	
E	Clockwise	-	-	48	72
	Counter-clockwise	-		24	
F	Clockwise	50	258	39	278
	Counter-clockwise	208		239	
G	Clockwise	67	284	64	294
	Counter-clockwise	217		230	
H	Clockwise	86	411	81	425
	Counter-clockwise	325		344	

The result from the traffic count is also presented in a schematic map in Figure 10. It can be seen that the main flow is going from Södra Vägen S towards Södra Vägen N, passing Örgrytevägen and Skånegatan, in a counter-clockwise direction. If looking at the flow in the north-south direction, i.e. the flow on Stretch A and Stretch D, it can be seen that 25 % of the total flow is located on Stretch D and 75 % on Stretch A.

During the traffic count it was also observed that most of the bicyclists travelling from Mölndal continues straight ahead on Stretch A. Furthermore, the majority of the bicyclist travelling on Stretch H continued on Stretch G and Stretch F. The fact that some of the stretches leading towards Korsvägen are one-way makes it possible to, based on the traffic count, tell the flow distribution in some nodes provided that the bicyclists are following the traffic rules and only bike in the allowed direction on the one-way paths. Based on this, it can be seen that most of the bicyclists travelling on the west side of Södra Vägen N continues straight ahead on Stretch D and that the majority of the bicyclists travelling on the east side of Eklandagatan continue straight ahead on Stretch B. Moreover, the main part of the bicyclists travelling on the west side of Skånegatan turns left onto Stretch G.

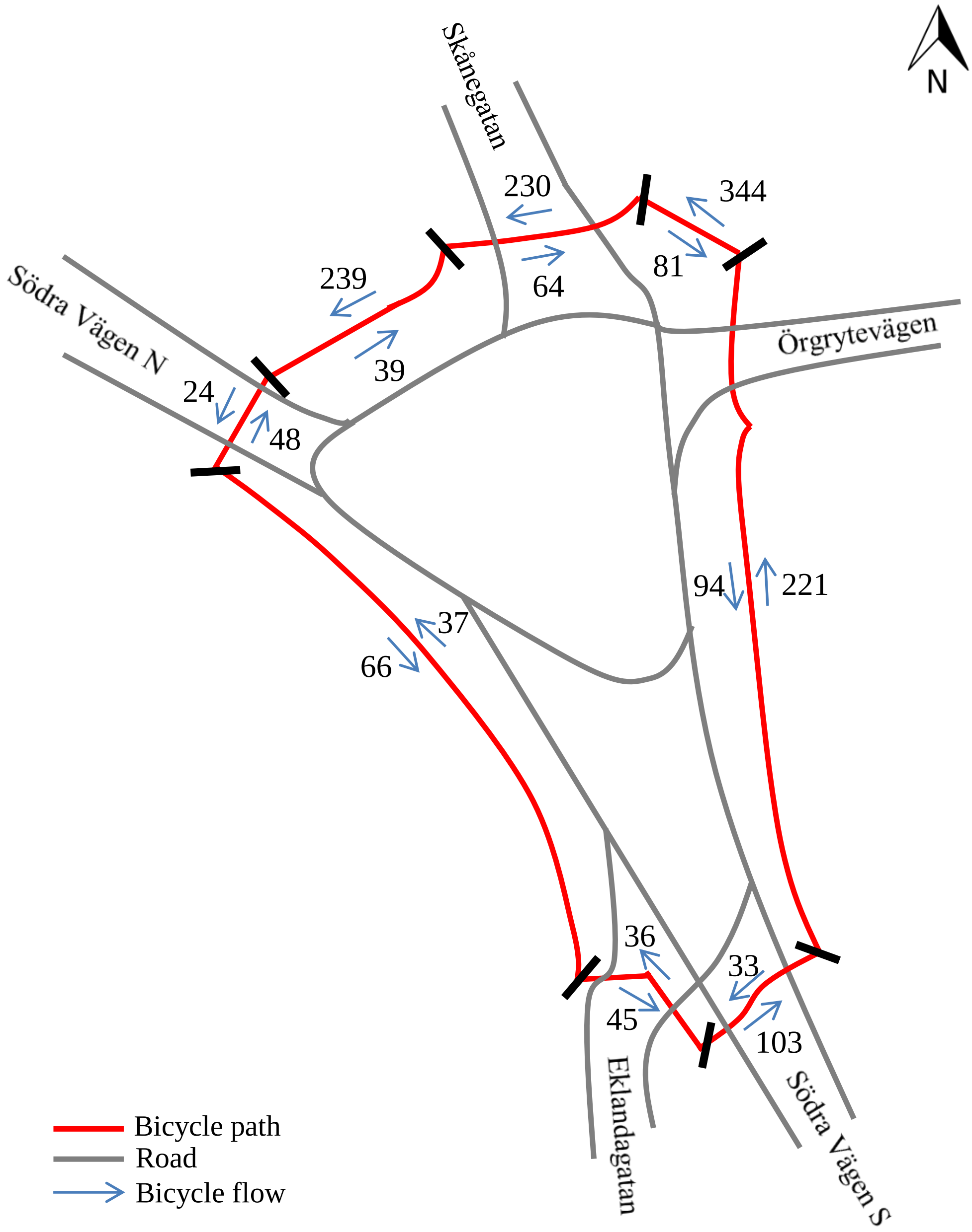

Figure 10 Schematic map of Korsvägen showing the magnitude and direction of the bicycle flows.

In order to get the overall maximum flow at Korsvägen the measured values from the counting in March was divided by the mean index for March and then multiplied by the mean index for September. The mean indices for March and September corresponds to 83 and 150. The maximum flow on all stretches is presented in Table 6.

Table 6 Measured and maximum flow on each stretch at Korsvägen.

Stretch/Day		**Tuesday 15th of March**		**Maximum flow**	
A	Clockwise	94	315	170	569
	Counter-clockwise	221		399	
B	Clockwise	33	136	60	246
	Counter-clockwise	103		186	
C	Clockwise	36	81	65	146
	Counter-clockwise	45		81	
D	Clockwise	37	103	67	186
	Counter-clockwise	66		119	
E	Clockwise	48	72	87	130
	Counter-clockwise	24		43	
F	Clockwise	39	278	70	502
	Counter-clockwise	239		432	
G	Clockwise	64	294	116	531
	Counter-clockwise	230		416	
H	Clockwise	81	425	146	768
	Counter-clockwise	344		622	

3.2.2 Measurements of travel time

The measurements of the travel time was performed on each stretch during three separate days in March (8^{th}, 9^{th} and 14^{th}). In order to estimate the maximum hour for car traffic random weekdays were picked from the data set provided by the City of Gothenburg. The analysis shows that, when a total of 15 random weekdays were picked, 60 % of these days had the maximum hour between 16.00 and 17.00, one third between 8.00 and 9.00 and 6.67 % between 15 and 16. In all cases when 16.00-17.00 was not the maximum hour it had the second largest flow during the day. Thus, the measurements were performed in the afternoon between 16.00 and 17.00.

3.2.2.1 Results from travel time measurements

The result from the bicycling where the travel time for each stretch was investigated is presented in Table 7. More detailed results for each measurement are found in Appendix II. It can be seen that the speed on the different stretches varies between 11-20 km/h. In most cases the average travel time increases with increased length of the stretch. However, Stretch F is an exception which is longer than Stretch G but takes 2 seconds less time to travel. Furthermore, Stretch B, Stretch C and Stretch F have the same average travel time of 11 seconds but the length of the stretches varies. Stretch B is 34 metres, while C is 40 metres and Stretch F is 49 metres.

Table 7 The average travel time, length and speed for all eight stretches.

STRETCH	A	B	C	D	E	F	G	H
Average travel time [s]	40	11	11	26	10	11	13	4
Length [m]	170	34	40	140	31	49	48	22
Average speed [km/h]	15	11	13	19	11	16	13	20

3.2.3 Measurements of delay at intersections

The delay due to signalised and non-signalised intersections with public transport was measured at five locations during one week in the middle of March. The measurements were performed at the intersections of Stretch A (Örgrytevägen), Stretch B (Södra Vägen S), Stretch C (Eklandagatan), Stretch E (Södra Vägen N) and Stretch G (Skånegatan). A total of six tram lines and 18 busses including the bus to the airport are passing through Korsvägen. The total number of bus lines and tram lines operating on each stretch is presented in Table 8.

Table 8 Total number of bus lines and tram lines operating on the different stretches.

STRETCH	A	B	C	E	G
Number of bus lines	15	2	1	18	0
Number of tram lines	1	5	0	2	4

3.2.3.1 Results from measurements of delay at intersections

The distribution of the delay on the non-signalised intersection at Örgrytevägen on Stretch A is displayed in Figure 11. More than 50 % of the measured delays lie within the interval of 5 to 10 seconds. The average waiting time is 9 seconds and the maximum measured waiting time is 37 seconds. During the measurements a total of 394 bicyclists passed the intersection and 76 were affected by the public transport and had a delay of 2 seconds or more. Thus, about every fifth bicyclist (19%) was delayed due to the intersection with public transport at Örgrytevägen. Detailed results for each stretch can be found in Appendix III.

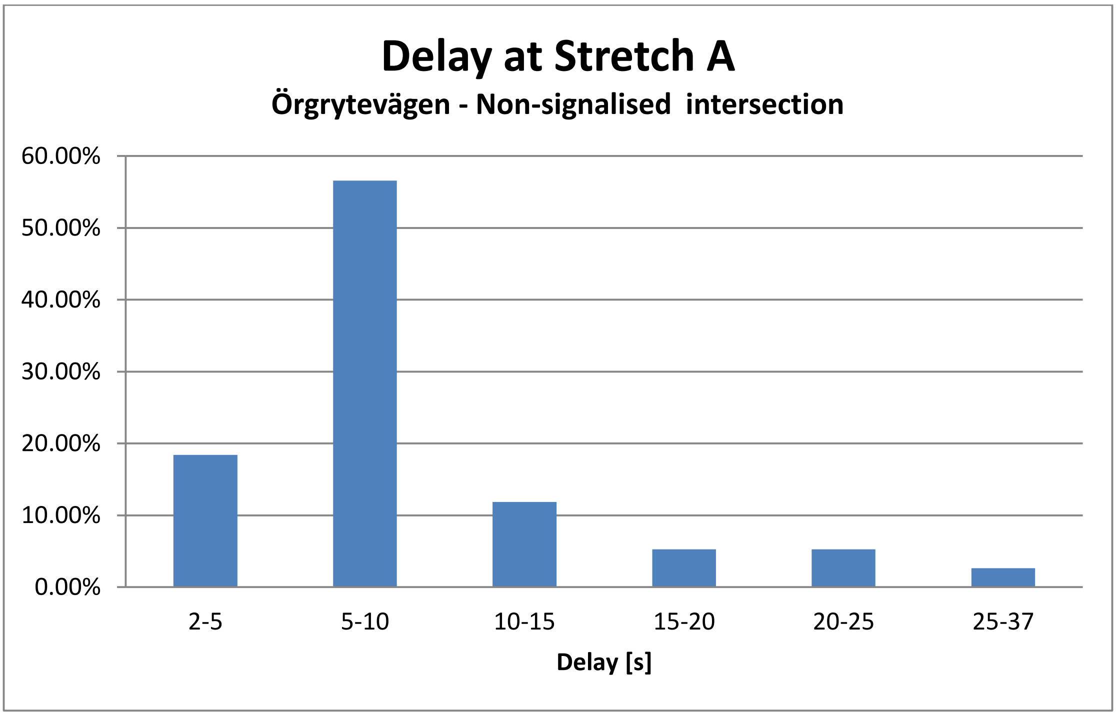

Figure 11 Pivot diagram showing the delay distribution on Stretch A.

On the signalised intersection at Södra Vägen S on Stretch B about 30 % of the measured delays lied within the interval of 5 to 10 seconds (see Figure 12). However, the average delay is 14 seconds. The maximum measured waiting time is 44 seconds and less than 5 % are affected by such delay. However, due to the programed intervals on the signals the actual maximum waiting time can reach 70 seconds[2].

During the measurements a total of 130 bicyclists passed the intersection and 66 were affected by the traffic signal and had a delay of 2 seconds or more. Thus, every second bicyclist (51%) had to stop. However, 15 bicyclists or 12 % were driving through red lights. If it is assumed that all of them would have a delay of 2 seconds or more if they would have stopped, a total of 62 % would be affected by a delay in this intersection.

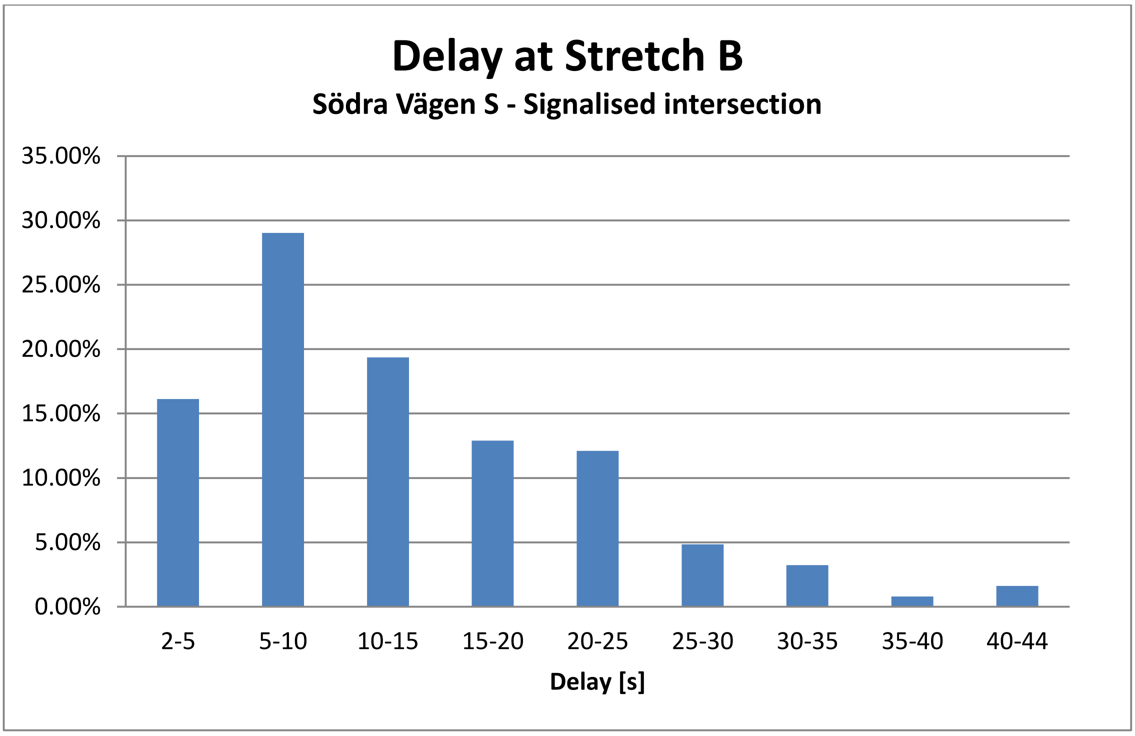

Figure 12 Pivot diagram showing the delay distribution on Stretch B.

[2] Andersson, Thomas. Project leader, Swarco Sverige AB. Email contact. 2016-04-14

Over 30 % of the measured delays are in the interval of 5 to 10 seconds on the signalised intersection at Eklandagatan on Stretch C (see Figure 13). Almost as many were delayed 10 to 15 seconds and together these time intervals stand for 60 % of the total delays. About 15 % of the delays are 2-5 seconds or 15-20 seconds. The average delay is 11 seconds and the maximum measured delay is 32 seconds. The traffic signals at this intersection is not programed with a maximum waiting time for bicyclists, thus in theory it could be endless since priority is always given to public transport.

During the measurements a total of 108 bicyclists passed the intersection and 33 were affected by the traffic signal and had a delay of 2 seconds or more. Thus, about every third bicyclist (31%) had to stop. However, 14 bicyclists or 13 % were driving through red lights. If it is assumed that all of them would have a delay of 2 seconds or more if they would have stopped, 44 % of the bicyclist would be affected by a delay in this intersection.

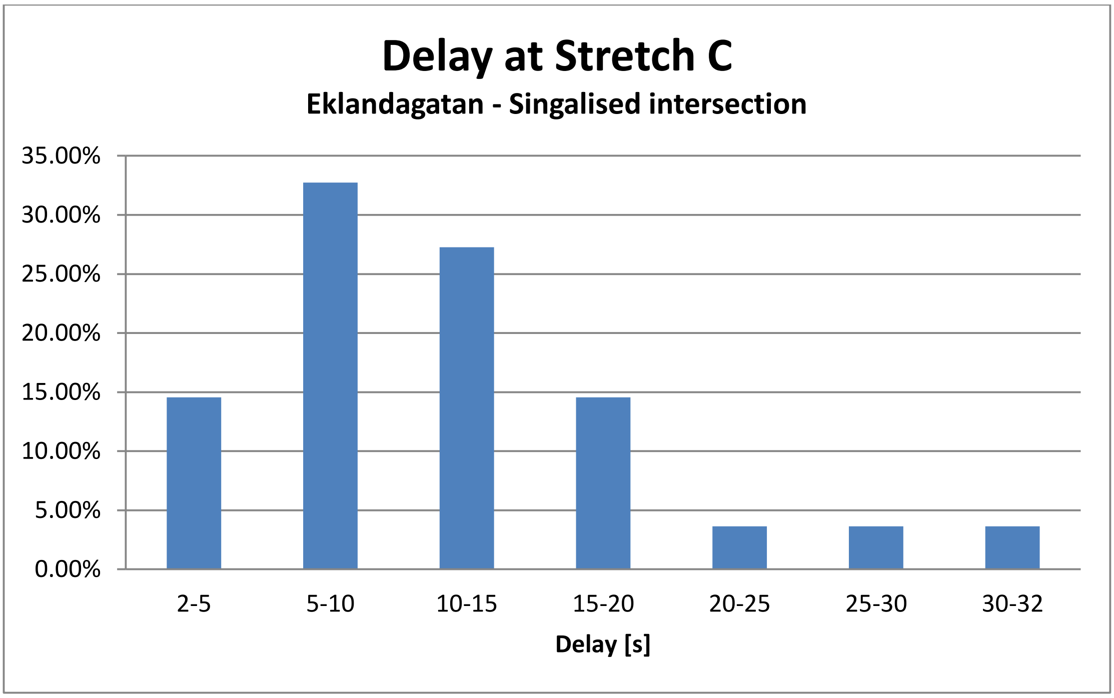

Figure 13 Pivot diagram showing the delay distribution on Stretch C.

On the non-signalised intersection at Södra Vägen N on Stretch E about 30 % of the measured delays are between 5 and 10 seconds (see Figure 14). This is also the most common interval. About 20 % of the measured delays are 2-5 seconds or 10-15 seconds. However, the average delay is 12 seconds, while the maximum waiting time is 42 seconds. During the measurements a total of 146 bicyclists passed the intersection of which 33 were affected by the traffic signal and had a delay of 2 seconds or more. Thus, 23 % of the bicyclists had to stop due to the intersection with public transport at Södra Vägen N.

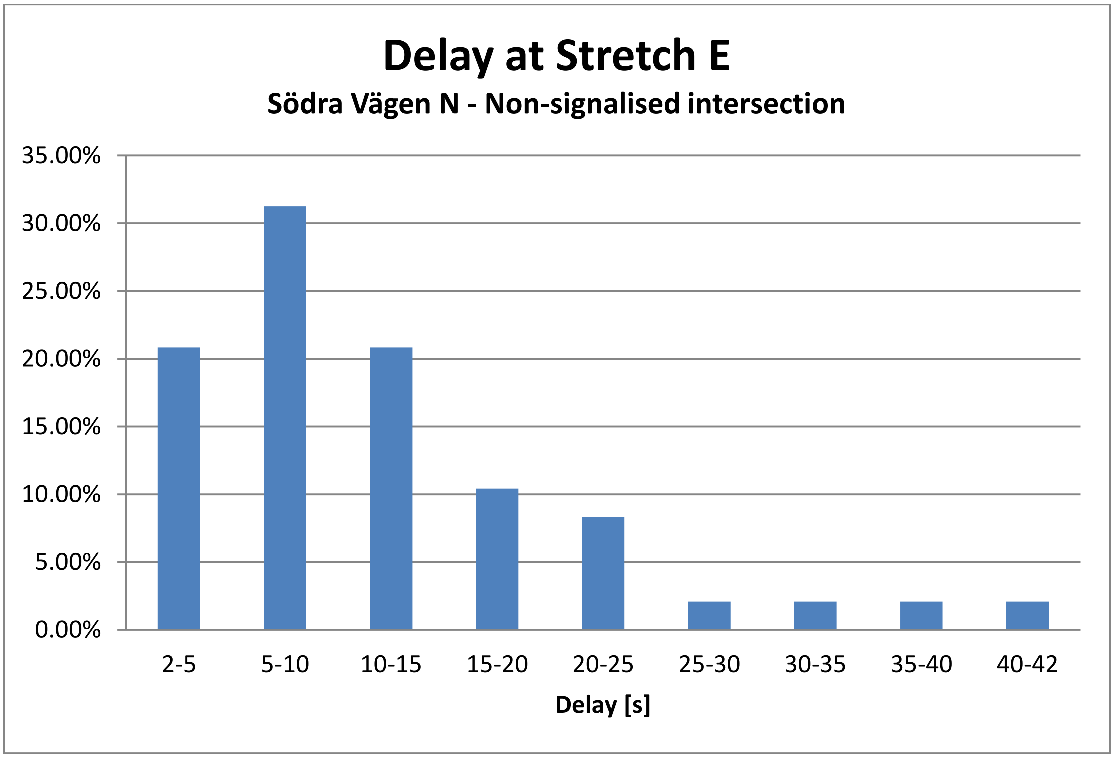

Figure 14 Pivot diagram showing the delay distribution on Stretch E.

The most common delays at the non-signalised intersection at Skånegatan on Stretch G are between 2-5 seconds and 5-10 seconds, which both correspond to about 35 % of the measured delays (see Figure 15). One fifth of the delays are between 10 to 15 seconds. The average delay is 8 seconds while the maximum waiting time at this intersection is 23 seconds. During the measurements a total of 481 bicyclists passed the intersection of which 43 were affected by the traffic signal and had a delay of 2 seconds or more. Thus, 9 % of the bicyclists had to stop.

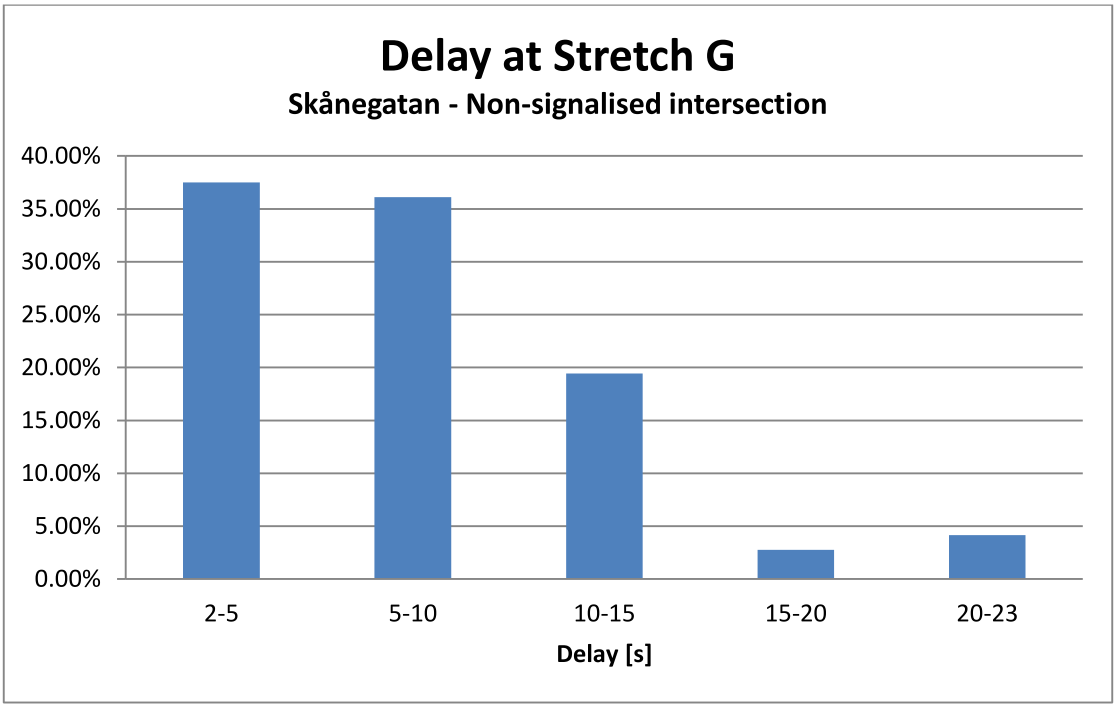

Figure 15 Pivot diagram showing the delay distribution on Stretch G.

3.2.4 Summary of results from measurements

The result from the traffic count shows that the main flow is going from Södra Vägen S towards Södra Vägen N, passing Örgrytevägen and Skånegatan, in a counter-clockwise direction (see Chapter 3.2.1). If looking at the flow in the north-south direction, i.e. the flow on Stretch A and Stretch D, it can be seen that 25 % of the total flow is located on Stretch D and 75 % on Stretch A.

The capacity limit of 1500 bicyclists/hour on a 1.2 metres wide bicycle lane stated by Ljungberg (1986) is not reached on any of the investigated stretches at Korsvägen (see Table 9). Worth noting is that this capacity limit is given for a bicycle lane, and not a bidirectional bicycle path. According to the GCM-handbook the flow on Stretch A, F, G and H is considered as high flows (more than 300 bicyclists/maximum hour). The same stretches have a moderate flow (360-1440 bicyclists/hour/direction) in the counter-clockwise direction according to VGU. Stretch B, C, D and E are considered to have low flows according to both the GCM-handbook (less than 300 bicyclists/maximum hour) and VGU (less than 360 bicyclists/hour/direction).

The average speed on all stretches are between 10-20 km/h during free flow (see Table 9). The highest speed, around 20 km/h, can be held on Stretch H and Stretch D. These are both stretches with only one bicycle to pedestrian conflict each. The second fastest speed can be held on Stretch F and Stretch A, with 16 km/h respectively 15 km/h.

Stretch A has several conflict points with cars as well as one intersection with public transport. Stretch F has no conflict point but has a slight inclination from east to west. Stretch C and Stretch G has an average speed of 13 km/h, while the speed on Stretch B and Stretch E is 11 km/h.

The intersection with the longest average delay of 14 seconds is Stretch B. This intersection is controlled by traffic signals which gives priority to public transport. A total of 2 buses and 5 trams are passing this intersection. This is also the intersection with the longest measured maximum delay of 42 seconds. The actual maximum delay can reach 70 seconds, after which a guarantee function makes sure that the bicyclists are given green lights even if public transport is approaching the intersection. Furthermore, every second bicyclist had to stop at this intersection during the measurements.

On Stretch C, which is also a signalised intersection with prioritised public transport, the average delay is 11 seconds. The maximum measured delay is 31 seconds. Furthermore, about one third of the bicyclists had to stop at this intersection, which is the second largest share.

Out of the non-signalised intersections, Stretch E is the one with the longest average delay, maximum delay and highest percentage of bicyclists that has to stop. Furthermore, this intersection has the highest load of public transport, with a total of 2 trams and 18 busses operating. On the non-signalised intersection at Stretch A where a total of 15 busses and 1 tram line are operating the average delay is 9 seconds and the maximum delay is 27 seconds. The shortest delay was measured on Stretch G, where 4 trams lines are operating. The average delay on this stretch is 8 seconds, while the maximum delay is 22 seconds. An increased amount of public transport leads to increased average and maximum delay and a higher percentage of bicyclists that has to stop.

Table 9 Summary of results from measurements at Korsvägen.

STRETCH	A	B	C	D	E	F	G	H
Maximum flow [bicyclists/hour]	569	246	146	186	130	502	531	768
Width [m]	3.0-3.1	2.8	2.9	2.4	2.5	3	3	2.75
Travel time [s]	40	11	11	26	10	11	13	4
Average speed [km/h]	15	11	13	19	11	16	13	20
Average delay [s]	9	14	11	-	12	-	8	-
Maximum delay [s]	27	42 (70)	31	-	37	-	22	-
Bicyclists that had to stop [%]	20	50	31	-	23	-	9	-

3.2.5 Observations of capacity and availability

The observations were done between 16.00 and 17.00 on the 11th of April and between 7.00 and 8.00 on the 12th of April.

3.2.5.1 Results from observations of capacity and availability

During the observations it was noted that none of the pedestrian crossings (Stretch A, B, C, E and G) around Korsvägen has a part where the kerbstone is lowered to the same level as the road. This limits the accessibility for disabled people, which has to use the bicycle path in order pass the crossing since the kerbstones on the walk way creates obstacles. During the observations it was also noted that people with strollers and trolleys often use the bicycle path to cross these crossings. This affects the availability of bicyclists and might increase the risk of accidents.

Moreover, it occurred relatively often, that pedestrians were walking in the bicycle path on Stretch A during the times that the observations were made (see Figure 16). The number of pedestrians walking in the bicycle path was larger in the afternoon compared to the morning. Which also lead to that more conflicts between bicyclists and pedestrians arose. The conflicts occurred both along the stretch, where the bicyclists had to brake and swerve to not run into the pedestrians, and at a pedestrian crossing at the middle of the stretch, where pedestrians walked into the bicycle path without watching out for bicyclists.

Figure 16 Pedestrians walking in the bicycle path at Stretch A.

Along this part of Stretch A it also emerged that there is a number of bicyclists who takes a shortcut over the parking area and thereafter continues on the walkway past Liseberg towards Örgryte, and vice versa in the other direction. According to Vectura

(2010) it can be an indication of limited availability when a bicyclists choose to willingly or unwillingly leave the bicycle path.

The interaction between vehicles and bicyclists was observed to be well-functioning and the majority of the vehicles gave way to bicyclists at the bicycle crossings at Örgrytevägen. However, it happened several times that vehicles stopped and blocked the bicycle crossing due to queues or to let pedestrians pass at the crossing, which affects the availability for bicyclists (see Figure 17). It was also observed that busses sometimes stopped and blocked the bicycle passage over the tram tracks. In some situations the bus only blocked parts of the crossing, and it was observed that some bicyclists became unsure if they should pass the crossing or not in this situation.

Figure 17 Picture showing a bicyclist that need to change route in order to get past the withe vehicle, which had stopped on the bicycle crossing.

In the three-way intersection, where Stretch A and Stretch H meet, the capacity was sometimes limited which affected the availability. It was observed that when the number of bicyclists increased queues form since bicyclists with different routes has to cooperate and use the same limited amount of space in the intersection. The problem is particularly present when there is a meeting between bicyclists with different routes (see Figure 18). During the observation there were situations where bicyclists from all three directions came towards the intersection at the same time. This sometimes led to that the bicyclists had to stop completely since a small queue formed due to the limited space in the intersection. Some bicyclists had to stop on the bicycle crossing, which shows that the three-way crossing restricts the availability.

Figure 18 Three-way intersection where Stretch A and Stretch H meet.

During the observations several bicyclists taking a short cut at Stretch B, when travelling towards Örgrytevägen via Stretch A, were spotted (see Figure 19). Instead of using the bicycle path when turning left the bicyclists bike on the road and connect to the bicycle path further north at Stretch A. It was also observed that some of the bicyclists that takes the short cut chooses to bike at the area inside the parking lot.

The design of the bicycle infrastructure at this location forces the bicyclists that are using the bicycle path to make a sharp turn. It was observed that the speed of the bicyclists is low through the curve. Since only one bicyclists at a time can travel through the curve queues were often formed during high flows. The situation was observed to get even more complicated when there was a high flow of bicyclists travelling on Stretch A.

Figure 19 A bicyclist in a bright green jacket is using the short cut at the east part of Stretch B.

The same design flaw also made it crowed when travelling the opposite way. Often when bicyclist were standing and waiting to cross to Eklandagatan they were blocking the way for those travelling at Stretch A towards Mölndal. The observations showed that if there is more than two bicyclists waiting the third will probably choose to stand and wait in the bicycle path since the space on the waiting area is limited (see Figure 20).

Figure 20 The area at the east end of Stretch B where the bicyclist are standing and waiting to pass the crossing.

During the observations of Stretch B it was also detected that bicyclists tend to form a queue side by side on the waiting areas on both sides of the crossing, while waiting for green light. This leads to conflicts and confusion when the bicyclists get moving again. Furthermore, the waiting area on the west side of the crossing gets crowded during high flows. Since the bicycle path at the east side of Eklandagatan makes a small curve right before the waiting area the bicyclists travelling on this path has limited sight. They are also travelling in a high speed, thus there is a risk of conflicts.

Stretch B is believed to be designed in such a way that the pedestrians know where they should go and not to go. This is assumed since no pedestrians were observed in the bicycle crossing. The same pattern is observed at Stretch C, which supports the previous theory.

A good interaction with the car traffic at the non-signalised bicycle crossing on the west part of the stretch was observed at Stretch C. At the curve in the west end of the stretch, when the stretch is turning in to Stretch D, no congestion is observed but on the other hand is there a really tight curve. This forces the bicyclist to slow down to a low speed and when there is oncoming traffic there is a risk of conflicts.

No pedestrians were observed to walk in the bicycle path at Stretch D. However, it sometimes happened that pedestrians were inattentive on their way to the zebra crossing, at the middle of the stretch, to catch a bus or a tram. It happened that bicyclists had to slow down and swerve to avoid collision due to this.

At the north part of the stretch the curve is built in favor of the bicyclist that travels from the south at Stretch D and crossing to Stretch E or the other way around. The design is not in favour for the bicyclist that are travelling south at the one-way bicycle path and turning on to Stretch E, due to the turn angel is more than 90 degrees and that the bicyclist has the traffic at the road in their back (see Figure 21). The tight curve slows down the bicyclist, which lowers the availability on the stretch. In this area it was also observed that bicyclists bike against the one-way bicycle path.

Figure 21 Bicyclist travelling from north and turning left on to Stretch E in the curve with a turn angle of more than 90 degrees.

Some pedestrians were observed to walk in the bicycle path at Stretch E. However, overall the interaction between pedestrian and bicyclists worked well. Some situations occurred due to that pedestrians crossed the bicycle path to go to/from the zebra crossing in the middle of the stretch.

During the observations the interaction with the car traffic was good and the cars often stopped and gave way to the bicyclist, even though they did not have to. This helped the bicyclist to have an even speed through Stretch E. However, there is limited space at the waiting area in the middle of the stretch. It was perceived as crowded when approximately four bicyclists were standing on the waiting area.

The observations of Stretch F indicates that the majority of the pedestrians are walking on the walkway and not in the bicycle path. Conflicts between pedestrians and bicyclists arise mainly when pedestrians cross the bicycle path in order to get to the pedestrian crossing, which is located along the stretch that leads to the bus stop. However, the number of pedestrians using this crossing was rather low during the observations. At the three-way intersections where Stretch F and E meet and where Stretch F and G meet no conflicts occurred during the time of observation.

Since most of the bicyclists were heading in the same direction, towards the city center in the morning (counter-clockwise), the flow or availability was not affected to any significant extent at the three-way intersection where Stretch G and Stretch H meet.

Moreover, the flow to and from Skånegatan was observed to be small compared to the other flows in and out of the intersection in other directions.

Furthermore, some pedestrians were walking in the bicycle path on Stretch G. This affected the availability for the bicyclists. The flow of pedestrians who crosses the bicycle path just before the tram crossing to get to the pedestrian crossing leading to the bus stops was rather large, which led to conflicts between bicyclists and pedestrians.

During the observations of Stretch G it was also detected that bicyclists who stop at the non-signalised intersection to wait for a tram to pass tend to form a queue side by side, especially on the east side of the crossing. The area where the bicyclists stop had limited amount of space and only two bicyclists fit ahead of each other. The third bicyclist arriving stopped next to the other two (see Figure 22). This led to conflicts and confusion when the bicyclists got moving again, especially if the bicyclists on the other side had been queuing next to each other as well. However, the waiting area on the west side has the same width but is significantly longer and allow more bicyclists to queue ahead of each other.

Figure 22 Queue formation observed on Stretch G.

The observations of Stretch H showed that the majority of the pedestrians were walking on the walkway. However, some conflicts between pedestrians and bicyclists occurred. Especially when inattentive pedestrians crossed the bicycle path when coming from or going to the two zebra crossings along the stretch.

It was also observed that a couple of bicyclists chose to bike in the road instead of using Stretch H to get to Stretch G. It was not possible to determine in which situations this behavior occurred, since it could for example happen both when it was a high and low flow of bicyclists on Stretch H.

As a summary of the observations it can be said that none of the stretches fulfils the requirements of the City of Gothenburg stated in the report *Cykelprogram för en nära* *storstad 2015-2025* (see Table 10). All the stretches are too narrow based on the flow, some a few centimetres too narrow but some up to serval decimetres. Further on, it can be said that half of the stretches (Stretch A, B, G and H) had observed lack of capacity. The stretches that lacked capacity also had problems with congestions that often occurred due to lack of space. The lack of space leads to queueing which leads to stops and limited availability. Conflicts were observed at all the stretches both between bicyclists and between bicyclists and pedestrians.

Table 10 Summary of the observations (b = bicyclist, p = pedestrian).

Stretch	A	B	C	D	E	F	G	H
Width	3.0–3.1	2.8	2.9	2.4	2.5	3	3	2.75
Maximum flow [bicyclists/hour]	569	246	146	186	130	502	531	768
Measured lack of capacity	No	No	No	No	No	No	No	No
Fullfils width requirements set by the City of Gothenburg	No	No	No	No	No	No	No	No
Observed lack of capacity	Yes	Yes	No	No	No	No	Yes	Yes
Congestion in terms of	Lack of space in three-way intersection, where Stretch A and H meet	Lack of space on the waiting areas	-	-	-	-	Lack of space at the eastern wating area before tram tack	Lack of space in three-way intersection , where Stretch A and H meet
Effects of congestion	Queuing, sometimes even a need to stop. Que in the bicyele crossing	Bicycle queues blocking the availibility of other bicyclists	-	-	-	-	Bicyclists queing side by side, conflicts with oncoming traffic	Queuing, sometimes even a need to stop.
Observed conflicts	b-b and b-p	b-b and p-b	b-b	b-b	b-p	b-p	b-b and b-p	b-b and b-p

From the obervations done on the 11th and 12th of April, when the bicycle path along the east side of Korsvägen (Strech A), was closed the following critical areas were identified. Most of the identified problems had to do with limited amout of spce on the waiting areas at signalised intersections. In some situations this leads to that bicyclists were standing in the way for intersecting traffic.

During the observations it was especially the waiting area between Eklandagatan and Södra Vägen S that was precived to have limited amount of space (see Figure 23). It often became crowded when the bicyclists had to wait for green light (see Appendix IV). Furthermore, bicyclists that are approcing this area has limited sight since the bicycle path makes a small curve right before the waiting area. The sight is also limited by a small house located in the inner curve.

Figure 23 Area between Södra Vägen S and Eklandagatan where the space is perceived as limited.

Furthermore, the waiting area on the east side of the intersection of Södra Vägen S is precieved to have lack of space (see Figure 24). Already when a total of three bicicylsts were waitning for green light one of them was partly standing in the way for intersecting traffic (see Appendix IV). Moreover, capacity problems were observed on the bicycle path on the east side of Södra Vägen S. The right turn that bicicyle crossing Södra Vägen S travelling towards Mölndal has to do is sharp and has limited space. It is only possible to go one by one trough the turn and long queues forms. Sometimes it happened that bicyclists were still on the crossing waiting to turn right when the cars were given green lights.

Figure 24 Area on the east side of Södra Vägen S where the waiting space for bicyclists is perceived as limited.

Capacity problems were also identified on the three-way intersection where Stretch G and Stretch H meet (see Figure 25). When the flow of bicyclists increased the availability through this area decreased, which led to a reduction in speed among the bicyclists. This was observed to be caused mainly by the fact that bicyclists that are heading in different directions meet in this area. The white arrows show possible routes/directions in and out of the intersection.

Figure 25 Three-way bicycle intersection at Skånegatan where the availability is decreasing with increased flow.

The same problem was observed in two other three-way bicycle intersections at Korsvägen; on the east ends of Stretch E (Södra Vägen N) and where Stretch C and D meet (see Figure 26 and Figure 27).

Figure 26 Three-way intersection on the east side of Södra Vägen N (Stretch E).

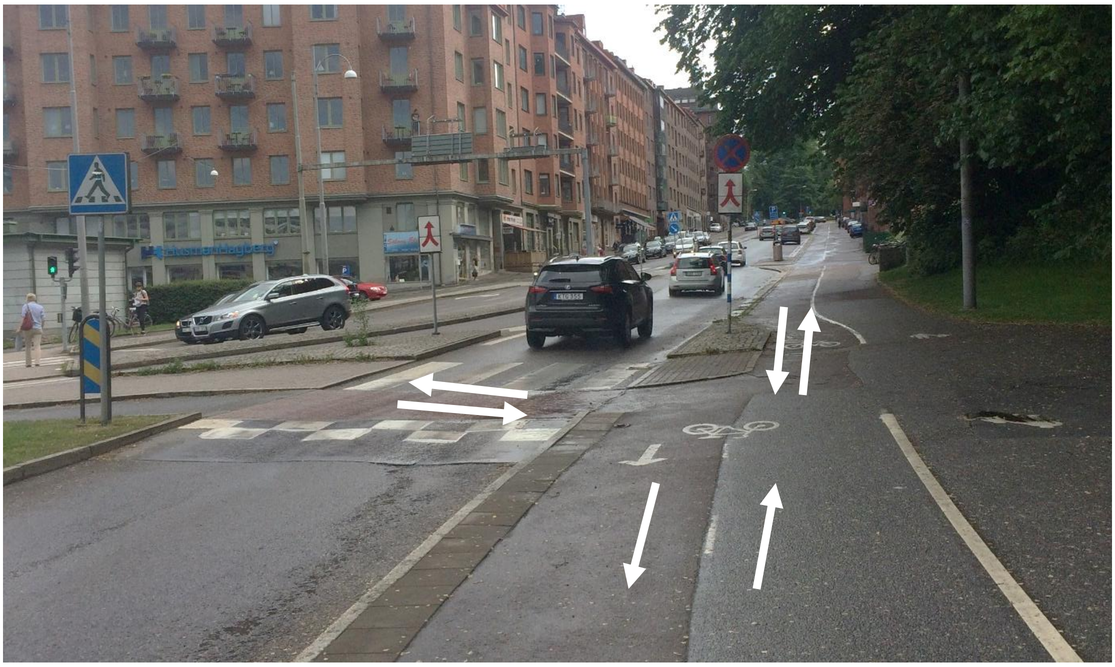

Figure 27 Three-way bicycle intersection where Stretch C and Stretch D meet.

4 Analysis

This chapter is divided into three parts. The first part describes the situation during Stage 1 of construction of Station Korsvägen and analyses the change in travel time for the bicyclists affected by the closing of Stretch A. The second chapter, Chapter 4.2 describes and analyses the situation for the bicyclist during Stage 2 of the construction of Station Korsvägen. Thirdly an investigation of alternative routes is presented in Chapter 4.3.

4.1 Bicycling around Korsvägen during Stage 1

According to a proposal from ÅF, who are responsible for the tender documents for Station Korsvägen, the construction will be divided into two different stages, Stage 1 and Stage 2. The layout proposal for Stage 1 is presented in Figure 28. The construction will begin in 2018 and Stage 1 runs until to 2020[3].

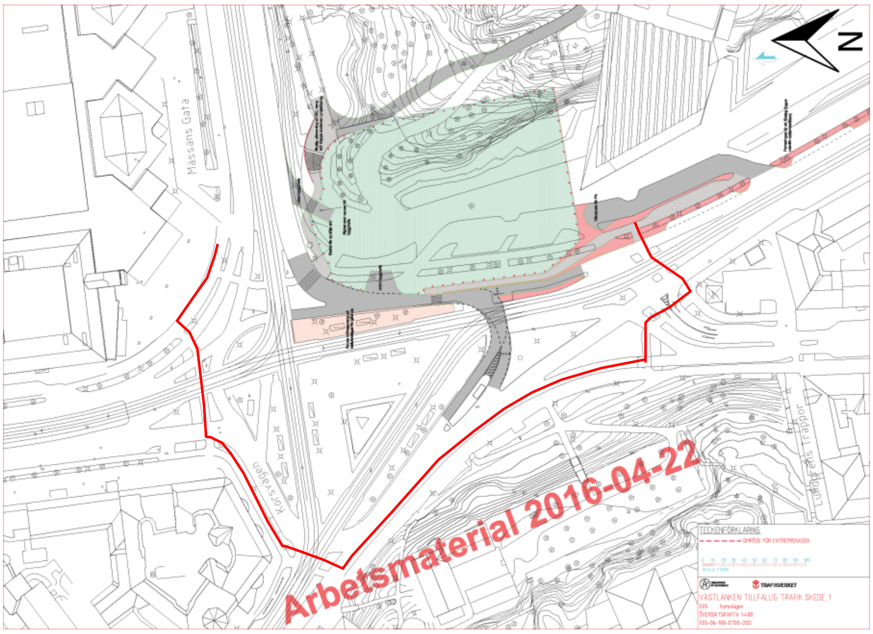

Figure 28 Layout proposal of the traffic around Korsvägen during construction stage 1 of Västlänken by ÅF. The construction area is coloured in light blue and the bicycle path is marked with a red line.

The first stage will consist of an open excavation in the south-eastern part of Korsvägen, between Örgrytevägen and Södra Vägen S. The general structure of Korsvägen is kept during Stage 1 and no significant changes are made. The biggest change is that the present bicycle path, which connects Södra Vägen S and Örgrytevägen (Stretch A), will be closed for bicycle traffic. However, there will be a pedestrian path allowing pedestrians to pass the construction site.

[3] Bergdahl, Styrbjörn. Traffic Analyst, ÅF Infrastructure AB. Email contact. 2016-04-22

4.1.1 Analysis of the change in travel time during Stage 1

An analysis of how the travel time change during Stage 1 has been conducted. The analysis was only performed for routes that will change due to the construction, i.e. routes that are passing Stretch A today. The travel time and delay from the measurements together with the probability of delay at the intersections with public transport was used to analyse if the availability changed on the different routes due to Stage 1.

4.1.1.1 Södra Vägen S-Södra Vägen N

Today is it possible to travel between Mölndal (Södra Vägen S) and the city centre (Södra Vägen N) in two different ways. During Stage 1 only one of the routes will be possible to use (see Figure 29). The bicyclists that are using this route today will therefore be affected.

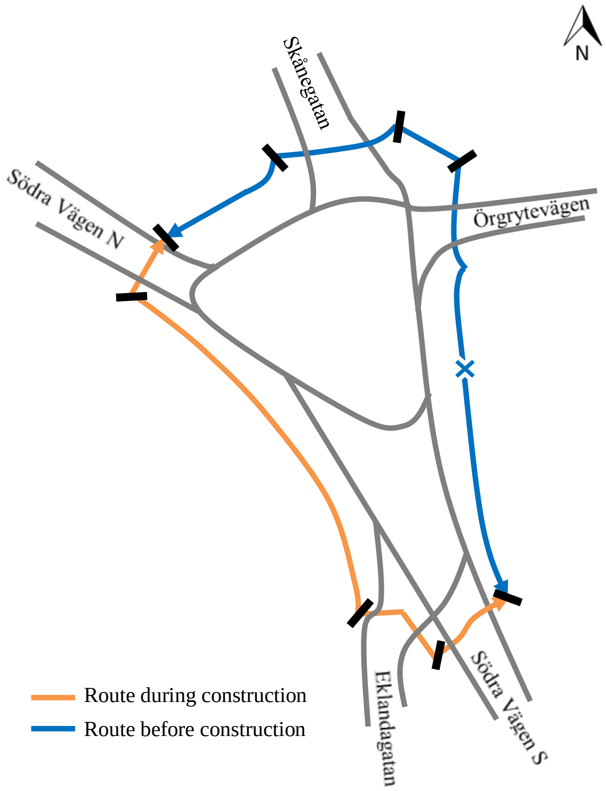

Figure 29 Route between Södra Vägen S and the Södra Vägen N before and during construction.

The bicyclists travelling between Mölndal and the city centre, via Örgrytevägen and Skånegatan, has a current travel time of 68 seconds without including the delay. If the delay is included the total travel times is 85 seconds. The route passes two non-signalised intersections where 20 % (Örgrytevägen) respectively 9 % (Skånegatan) of the bicyclists needs to stop for more than 2 seconds.

During the construction, with the new route via Eklandagatan, the travel time is estimated to be 58 seconds if there is no stops and a total of 95 seconds if the average delay for each passed intersection is included. The new route, during Stage 1, has three intersections. Two of them are regulated by traffic lights and one is a non-signalised intersection. The two signalised intersections has 50 % (Södra Vägen S) and 31 %

(Eklandagatan) risk of stop and the non-signalised has 23 % (Södra Vägen N) risk of stop. These three intersections are also the ones with the longest maximum delays.

To summarise, the new route has a longer total travel time and also more intersections where the probability of delay is high. Furthermore, both the average and maximum delay is longer for all intersectios passed on the new route (Södra Vägen S, Eklandagatan and Södra Vägen N) compared to the current route (Örgrytevägen and Skånegatan). All intersections that are passed on the new route has a higher probability of stop compared to the intersections on the current route. All this combined results in a longer travel time on the new route with an estimated increased probability of delay. Thus, the availability will decrease for the bicyclists who used to travel between Mölndal and the city centre via Örgrytevägen and Skånegatan during Stage 1.

4.1.1.2 Södra Vägen S-Örgrytevägen

The bicyclists travelling between Södra Vägen S and Örgrytevägen will be affected by the construction at Stage 1 since they have to change route through Korsvägen (see Figure 30).

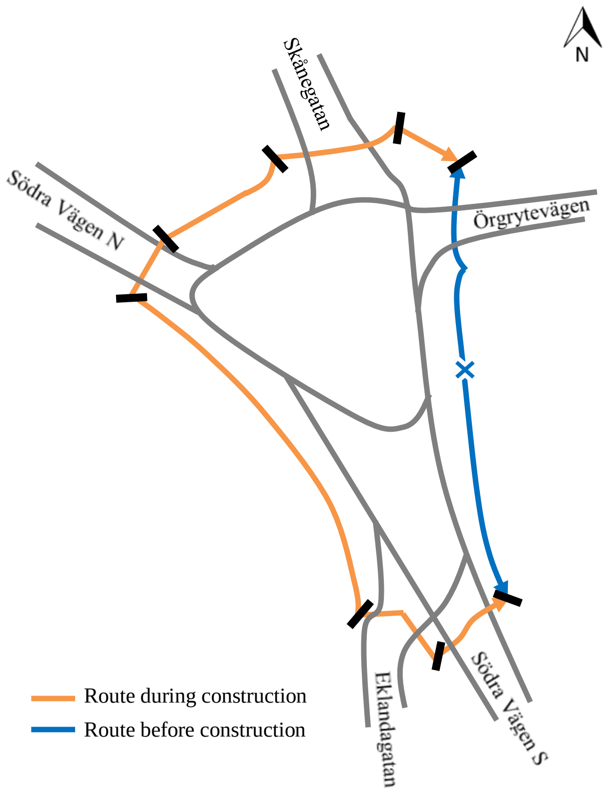

Figure 30 Route between Södra Vägen S and Örgrytevägen before and during construction.

The bicyclist that travels between Södra Vägen S and Örgrytevägen has at the moment a travel time of 40 seconds without delay included. If the average delay due to the non-signalised intersection with public transport is added, the total travel time is 49 seconds. At this intersection every fifth bicyclist needs to stop.

This route will, however, not be available during Stage 1 and the new route will have a travel time of 85 seconds, with two non-signalised and two signalised intersection. If the average delay of these intersections are added to the travel time it sums up to a total travel time of 130 seconds. The probability of having to stop at the intersection on the original route is 20 % (Örgrytevägen), while the risks of stop at the intersetions on the new route is 50 % (Södra Vägen S), 31 % (Eklandagatan), 23 % (Södra Vägen N) and 9 % (Eklandagatan).

The new route affects the travel time trough Korsvägen for the bicyclists since it increases with more than 100 %. The number of intersections with public transport increases from one to four and if the average delay on these intersections are added the difference in total travel time increases even more. In conclusion, all the analysed parameters indicates that the availability decreases during Stage 1.

4.1.1.3 Eklandagatan-Örgrytevägen

Stage 1 will also affect the bicyclists who are travelling from Eklandagatan to Örgrytevägen, via Södra Vägen S. These bicyclists will not be able to use the same route through Korsvägen, but will have to bike via Södra Vägen N and Skånegatan (see Figure 31).

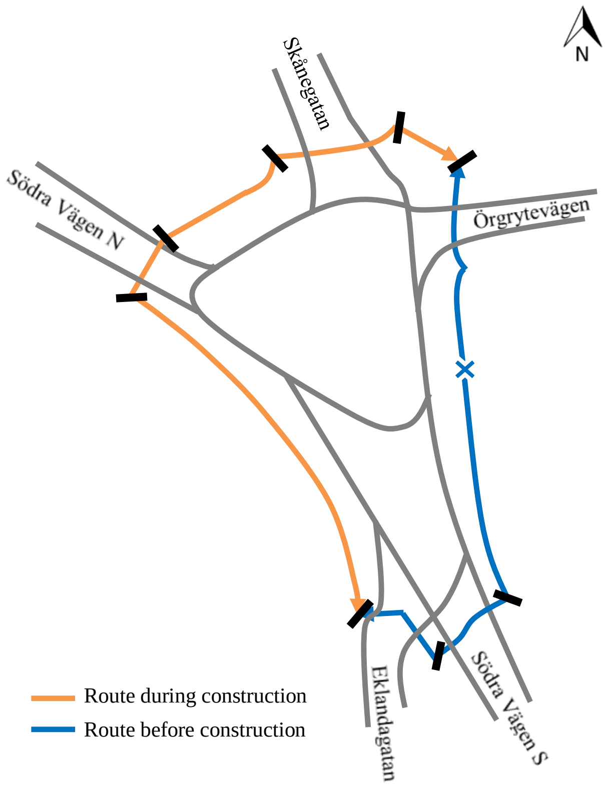

Figure 31 Route between Eklandagatan and Örgrytevägen before and during construction.

The travel time on the route via Södra Vägen S is 51 seconds in free flow and 74 seconds when the average delay of the intersections is included. The route has two intersection, one non-signalised and one regulated by traffic lights. At the non-signalised intersection at Örgrytevägen every fifth bicyclist need to stop, while every second bicyclists has to stop at the signalised intersection at Södra Vägen S.

Since the bicycle paths on Eklandagatan are one-way the bicyclists travelling towards Korsvägen will bike on the east side of the street. Instead of using the signalised intersection it is assumed that these bicyclists will choose to cross Eklandagatan at a bicycle crossing slightly south of the signalised intersection. With the new conditions during Stage 1 the travel time will be 64 seconds without delay. If the average delay is included the total travel time is 84 seconds. The new route has two intersection which are both non-signalised. The probability of delay at these are 23 % and 9 %.

The travel time for the route during construction Stage 1 is longer both during free flow and when the average delay is included. However, the intersectios passed on this route has a lower probability of delay compared to the current route. This results in an overall status of the new route from Eklandagatan to Örgrytevägen as having lower availability compared to the current route via Södra Vägen S.

The bicyclists who used to travel between the same destinations but in the opposite direction (Örgrytevägen to Eklandagatan, via Södra Vägen S) will also be affected by Stage 1, but in a slightly different way. The route before the construction has a travel time of 62 seconds in free flow and 96 seconds if the average delay is added. The travel time is longer in this direction since they have to use the signalised intersection at Eklandagatan. Besides the non-signalised intersection at Örgrytevägen where every fifth bicyclists needs to stop, the signalised intersection at Södra Vägen S where every second bicyclists has to stop this route includes the signalised intersection at Eklandagatan where 31 % has to stop. During the construction of Stage 1 the bicyclists travelling from Örgrytevägen to Eklandagatan will use the exact same route as the ones travelling in the opposite direction. The travel time will be 64 seconds and if the average delay is included the total travel time is 84 seconds.

In conclusion, the travel time without including delay will hardly change due to Stage 1 and is therefore considered to be unchanged. However, the risk of delay as well as the total travel time (travel time + average delay) has decreased for bicyclists travelling from Örgrytevägen to Eklandagatan during Stage 1. This results in a better situation, with better availability, for the bicyclist travelling this route during the construction Stage 1 compared to the ones currently travelling via Södra Vägen S.

4.1.1.4 Södra Vägen S-Skånegatan

It is possible to travel between Mölndal (Södra Vägen S) and Skånegatan in two ways today. The bicyclist can either travel via Örgrytevägen or via Södra Vägen N. Due to the closing of Stretch A during Stage 1 the bicycle path via Örgrytevägen will not be possible to use (see Figure 32). Thus, bicyclists who are currently travelling via Örgrytevägen will be affected.

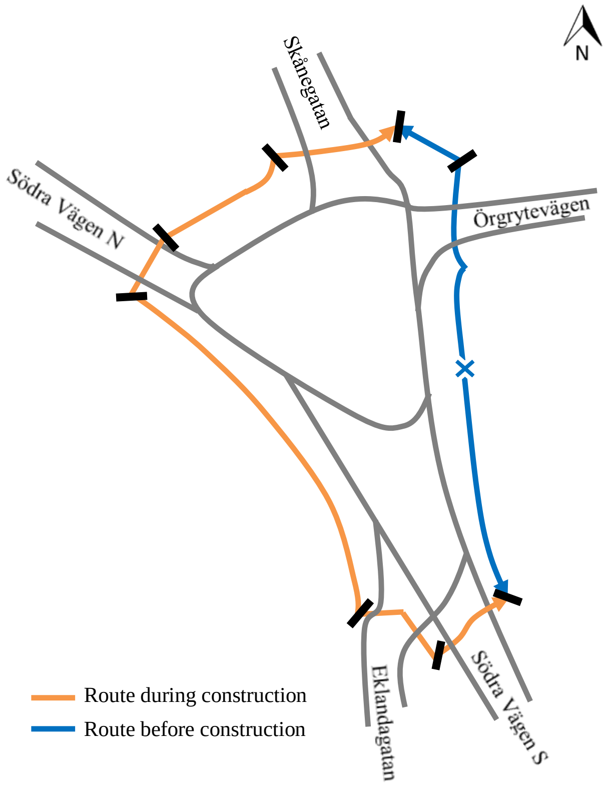

Figure 32 Route between Södra Vägen S and Skånegatan before and during construction.

Today, they have a travel time of 44 seconds without the delay and a total travel time of 53 seconds if the average delay is included. There is only one intersection which is non-signalised at this stretch, where 20 % of the bicyclists need to stop. The new route has a travel time of 82 seconds without the delay and 127 seconds in total travel time. There is a total of four intersections with public transport at the new route, two non-signalised and two signalised.

The travel time is almost 100 % longer during Stage 1 compared to the current situation. When the delay is included the total travel time is more than doubled. During Stage 1 the bicyclist has to cross four intersections with public transport instead of one and they all have a high percentage of bicyclists who need to stop. The longer total travel time and the increase in the number of intersections sums up to a decrease in availability during of Stage 1.

4.1.1.5 Eklandagatan-Skånegatan

Currently, the bicyclist travelling from Eklandagatan to Skånegatan can either travel via Örgrytevägen or Södra Vägen N. During Stage 1 the route via Örgrytevägen will not be available and the bicyclists travelling this route today will have to change route (see Figure 33).

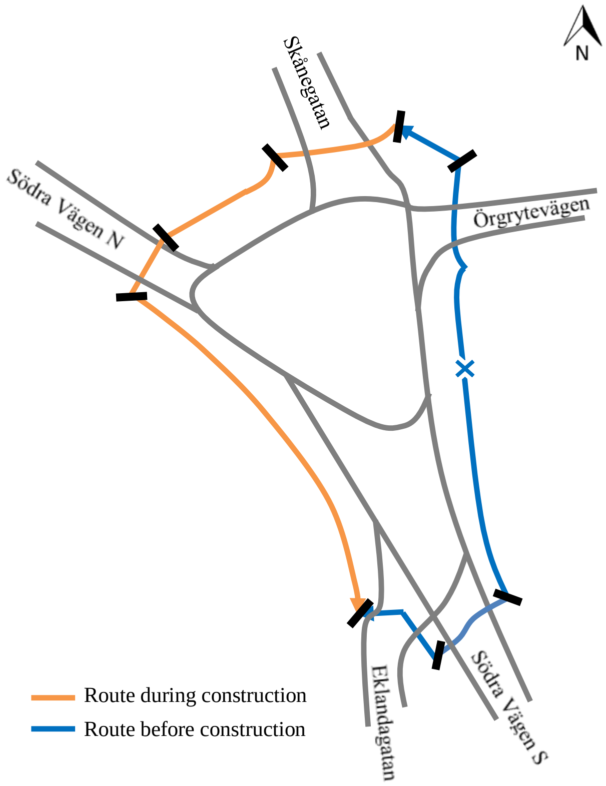

Figure 33 Route between Eklandagatan and Skånegatan before and during construction.

Today, these bicyclists has a travel time of 55 seconds without delay and 78 seconds if the average delay for the two passed intersections is added. At the intersections passed on this route 50 % (Södra Vägen S) respectively 20 % (Örgrytevägen) of the bicyclist has to stop. The new route has a travel time of 60 seconds without delay and 80 seconds with delay. It has two non-signalised intersections with public transport instead of one signalised and one non-signalised as the current route. On the intersections at the new route 23 % (Södra Vägen N) and 9 % (Skånegatan) of the bicyclists has to stop. In conclusion, the travel time without delay will not be substantially longer nor will the total travel time. However, the risk for needing to stop will decrease since the signalised intersection will not be passed. Overall, based on the analysed parameters the availability will be unchanged when comparing the current situation with Stage 1.

The bicyclists who used to travel between the same destinations but in the opposite direction (Skånegatan to Eklandagatan, via Örgrytevägen) will also be affected by Stage 1, but in a slightly different way. The route before the construction has a travel time of 66 seconds in free flow and 100 seconds if the average delay is added. The travel time is longer in this direction since they have to use the intersection with traffic lights at Eklandagatan. The current route passes two signalised and one non-signalised intersection. During the construction of Stage 1 the bicyclists travelling from Skånegatan to Eklandagatan will use the exact same route as the ones travelling in the opposite direction. The travel time will be 60 seconds and if the average delay is included the total travel time is 80 seconds.

In summary, the travel time during construction will be shorter, both with and without delay included, and instead of passing two signalised and one non-signalised intersection, only two non-signalised intersections will be passed. The bicyclists who are currently travelling between Skånegatan and Eklandagatan via Örgrytevägen will have improved availability during Stage 1.

4.1.1.6 Summary of Stage 1

Table 11 shows a summary of how the status changes for the routes, which will be affected by Stage 1 in any way, compared to the current route. The routes are comparted with regard to travel time, travel time with average delay included and the number and type of intersections with public transport that are passed on the route. A plus means that the route during Stage 1 is better than the current route, i.e. has shorter travel time and/or shorter travel time with average delay, and vice versa. If the difference between the current route and the route during Stage 1 is substantial a double plus/minus is given. Furthermore, a few number of intersections is better and non-signalised intersections are preferable since the number of bicyclists that has to stop at a signalised intersection is higher compared to non-signalised.

Table 11 Summary of how the different routes will be affected in terms of travel time, travel time with average delay and number and type of intersection with public transport by Stage 1.

	Travel time	Travel time with average delay	Number and type of intersection with public transport	Sum
Södra Vägen S – Södra Vägen N	+	-	-	-
Södra Vägen S-Örgrytevägen	--	--	--	--
Eklandagatan-Örgrytevägen	-	-	+	-
Örgrytevägen-Eklandagatan	+/-	+	+	+
Södra Vägen S-Skånegatan	--	--	--	--
Eklandagatan-Skånegatan	-	+/-	+	+/-
Skånegatan-Eklandagatan	+	+	+	+

4.1.2 Analysis of the bicycle network design during Stage 1

The above analysis only examine the travel time on the routes that changes due to Stage 1. However, the conditions will also be different on routes that does not change since the flows of bicyclists will change during construction. Stage 1 will affect 75 % of the bicyclists that are travelling in a north-south direction since Stretch A is no longer available. These bicyclists will have to use Stretch D to travel in a north-south direction and the flow on this stretch will increase. This may also affect the bicyclists that are currently using Stretch D since new or worse conflict points may arise as a consequence of the increased flow.

Thus, in addition to the analysis of changed travel time a study of the tender documents produced by ÅF, focusing on how the availability for bicyclists is affected by the design of the bicycle network will be presented below. The observations performed during a couple of days in April 2016 and the observations conducted when Stretch A was closed is the basis for the positive and negative feedback that will be presented.

It was observed, during the observations in April, that the area between Stretch B and Stretch C often became crowded. Especially when bicyclists were waiting at the signalised intersection to cross Södra Vägen S (Stretch B). This is the intersection with the highest share of bicyclists that has to stop and the longest average and maximum delay (see Chapter 3.2.3). The observations that were performed when Stretch A was closed showed that the situation got worse with an increased flow. It is assumed that this will be an area where the capacity is limited due to lack of space during construction since the current design of the area will not change in Stage 1.

Furthermore, the waiting area at the east end of Stretch B was observed to be crowed during the observations when Stretch A was both opened and closed. Based on suggestions from the writers of this report this area was made larger when the layout proposal was revised in order to mitigate the problem with queuing bicyclists in the longitudinal bicycle path. Furthermore, the longitudinal path will no longer be a bicycle path but a pedestrian path. However, the number of bicyclists passing this area will increase and since the signalised intersection at Södra Vägen S has a high share of bicyclists that has to stop, there is a risk that the new area will become crowded as well and block the way for pedestrians. Furthermore, the availability for bicyclists was observed to be limited in this area due to a sharp turn created by orthogonally placed kerbstones (see Figure 24). The design is not changed in Stage 1, which limits the capacity and availability through the curve.

Another waiting area where the availability for bicyclist was affected due to lack of space during the observations was the area on the east side of the tram tracks at Skånegatan (see Figure 22). An increased flow of bicyclists on this stretch will most probably result in that the capacity limit on the waiting area is reached more often.

It is also assumed that three-way intersections is limiting the capacity of the bicycle network around Korsvägen, since capacity problems was observed at several three-way intersections when Stretch A was closed. The three-way intersection at the eastern part of Stretch G, the western part of Stretch C and east side of Södra Vägen N will have an increased flow of bicyclists since Stretch A is not available. The observations showed that the availability decreased with increased flow at these locations. Even if it is not possible to tell how the distribution of the flow will change at these intersection it can be assumed that an increased flow leads to more conflicts. Thus, a decreased availability is expected in these intersections during Stage 1.

4.2 Bicycling around Korsvägen Stage 2

The second construction stage will begin in 2020 and the transition from the first stage will be done during the summer[4]. It is planned that Stage 2 will be finished in 2023.It will consist of an open excavation in the south-western part of Korsvägen (see Figure 34). A consequence of the open excavation will be that there will be no bicycle connection between Södra Vägen N and Eklandagatan, i.e. Stretch D will not exist.

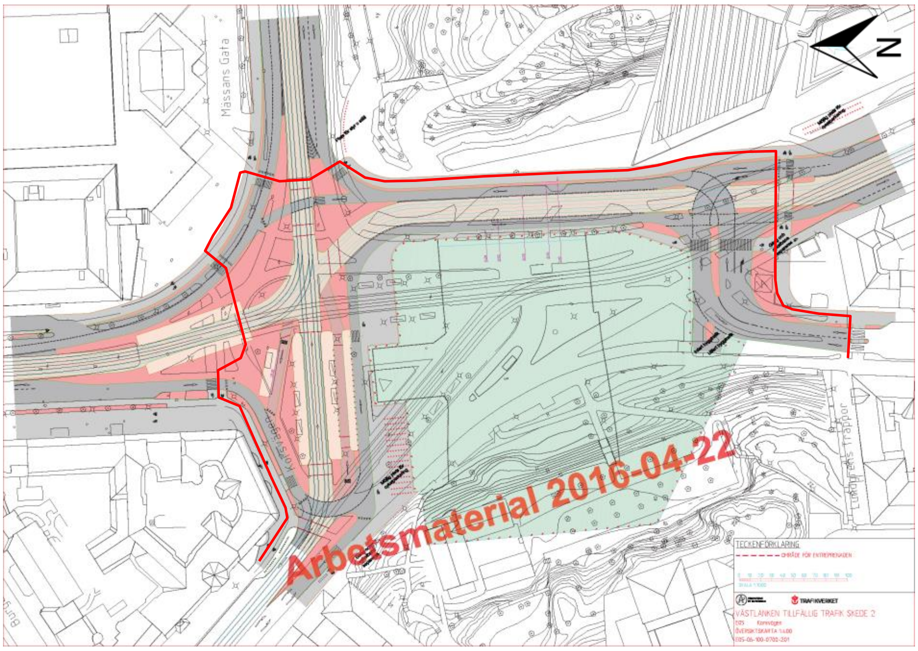

Figure 34 Layout proposal of the traffic around Korsvägen during construction stage 2 of Västlänken by ÅF. The construction area is coloured in light blue the bicycle path is marked with a red line.

Furthermore, the bicycle path on the west side of Eklandagatan will be removed to make room for the excavation. The first couple of meters of the bicycle path on the east side of Eklandagatan will become bidirectional, and bicyclists travelling south will have to cross the street at an existing bicycle crossing. The bicycle paths on each side of Eklandagatan will remain one-way south of this bicycle crossing.

Another consequence of the construction will be that the tram track, roads and bicycle path in the south part of Korsvägen will be moved a couple of metres to the east. Stretch A, which is currently a separated bicycle path will in Stage 2 be a 4 metres wide combined pedestrian and bicycle path, where the separation between the two is done by a solid line in the ground. The current bicycle crossings on the north side of Örgrytevägen (Stretch A), where one car lane is crossed at a time and separated with a traffic island, will during Stage 2 be merged into a bicycle crossing with the width of two car lanes. The same thing will happen at the crossing on the east side of Skånegatan (Stretch G).

[4] Bergdahl, Styrbjörn. Traffic Analyst, ÅF Infrastructure AB. Email contact. 2016-04-22

Moreover, a new stop for public transport will be built at the south part of Skånegatan and the stops in the south part of Korsvägen will be removed. A bicycle crossing will allow the bicyclists to pass the stop just south of the new platform.

4.2.1 Analysis of the bicycle network design during Stage 2

Stage 2 will affect 25 % of the bicyclists that are travelling in a north-south direction since Stretch D is no longer available. These bicyclists will have to use Stretch A to travel in a north-south direction and the flow on this stretch will increase. This may also affect the bicyclists that are currently using Stretch A since new or worse conflict points may arise as a consequence of the increased flow.

The design of the bicycle network around Korsvägen during Stage 2 differs a lot from the current design, which made it difficult to compare today's state with the state during the construction, in terms of change in travel time, in the same way as for Stage 1. The analysis of Stage 2 is entirely based on a study of the tender documents produced by ÅF, focusing on how the availability for bicyclists is affected by the design of the bicycle network. Positive and negative feedback will be presented, which is based on the observations from the field study.

Stretch A will be a bidirectional bicycle path with a pedestrian path that runs alongside the bicycle path, which are separated with a solid white line during Stage 2, instead of being completely separated from the pedestrian path as today. The observations show that pedestrians tend to walk in the bicycle path with the current design. This behaviour might mitigate with the new design since the pedestrians will have a continuous straight path instead of having to make a detour to follow the pedestrian path. The observations also showed that a solid white line is enough to make the pedestrians walk on their assigned path.

The bicycle and pedestrian path along Stretch A is according to the tender documents 4 meters wide. If it is assumed that the design follows the recommendations in TH (Teknisk Handbok) the pedestrian path will be 1.7 metres wide while the bicycle path will be 2.3 meters wide. This does not fulfil the lowest recommended standard in *Cykelprogram för en nära storstad 2015-2025,* where it is stated that a bicycle path with less than 500 bicyclists in the maximum hour which belongs to the bicycle commuting network should have a width of 3.0 metres.

Furthermore, the two bicycle crossings along Stretch A, were cars where entering and exiting the parking area east of the stretch, will no longer exist since the parking area is removed. This change might increase the availability for the bicyclists since there will be two conflict points less along the stretch.

According to the accident data from STRADA the location where the most accidents between bicyclists and motorised vehicles has occurred is at the crossing with a width of two car lanes at Örgrytevägen (see Chapter 3.1.1). This crossing is also a place where bicyclists feel unsafe according to the article in Göteborgs-Posten. The previous one lane crossings at the north of part of Stretch A and east part of Stretch G will during Stage 2 become crossings with a width of two car lanes. Thus, the new design might increase the risk of accidents and the feeling of an unsafe traffic environment. Furthermore, a high flow of car traffic can also affect the availability for bicyclists since the bicyclist have to wait until both lanes can be crossed.

The one-way bicycle path on the west side of Eklandagatan is replaced with a bidirectional bicycle path on the east side. During the observations it was noted that the bicyclists that are travelling on Eklandagatan towards Korsvägen has a high speed down the hill. These bicyclist will now have meeting traffic, which could increase the risk of accidents. However, the curve in Stage 2 has a smaller radius which might lower the speed of the bicyclists and therefore also decrease the availability.

Moreover, according to the tender documents the sight through the curve will be improved since the bicycle path is moved to the south and the small building in the inner curve no longer exist. If it is to be moved/rebuilt it is of importance that it is place in such a way that it does not block the bicyclists' sight.

One of the sites that was observed to have lack of space during the observations was the waiting area on the east side of the intersection at Södra Vägen S. During Stage 2 this area will become even smaller and the width will be 1 meter. This waiting area is located at a signalised intersection, where every second bicyclists has to stop according to measurements of the present situation. The high percentage of bicyclists that need to stop and the lack of space often led to that queueing bicyclists blocked parts of the longitudinal bicycle path. This situation is likely to worsen with the new design, which will affect the availability for bicyclists in a negative way.

The placement of the bicycle crossings at Skånegatan makes the path for the bicyclists unclear, since the crossing at the east side is directed in towards Korsvägen while the crossing at the west side is placed due east further north. However, the placement of the crossing at the west side of Skånegatan will be modified in order to improve the situation according to ÅF[5]. It is important than a turn angel of more than 90 degrees is avoided when the crossing is modified based on the observation of decreased availability in the crossing on the west side of Södra Vägen N.

4.3 Alternative routes during construction of Station Korsvägen

According to Trafikverket (2012) the first thing that road users do when there are disruptions in the traffic is to change their route. Stretch A and Stretch D will be especially affected during the construction of Station Korsvägen, which will affect the flow in the north-south direction. Stretch A is the shortest link between Södra Vägen S and Örgrytevägen while Stretch D is the shortest link between Eklandagatan and Södra Vägen N. These will be closed in the different stages and according to the theory presented above one possible effect of longer travel time and the loss in availability is that the bicyclist chooses another path. Investigations was therefore performed to see if there are any alternative routes between these destinations and evaluate possible advantages and disadvantages.

An alternative route between Södra Vägen S and Örgrytevägen during Stage 1 is via Vörtgatan and Nellickegatan/Sofierogatan, marked with a red line in Figure 35. There is no bicycle path along the stretch and the bicyclists have to bike in mixed traffic. Furthermore, there are a couple of curves with limited sight and several entrances and

[5] Bergdahl, Styrbjörn. Traffic Analyst, ÅF Infrastructure AB. Email contact. 2016-04-22

exists to industries used by heavy duty vehicles. Thus, this is not considered as a suitable alternative route between Södra Vägen S and Örgrytevägen.

The purple line in Figure 35 shows an alternative route between Eklandagatan and Södra Vägen N during Stage 2. Bicyclists travelling on Eklandagatan are already guided by road signs to take this route towards the city centre. The route consists of a 2.65 metres wide bidirectional bicycle path. In parts of the stretch the lanes in different direction is separated with a dashed white line. A pedestrian path runs along the bicycle path and there is a level difference between the two on the part between Eklandagatan and Olof Wijksgatan. On the rest of the stretch, towards Götaplatsen, the pedestrian path and bicycle path are separated by different pavements. On this part of the stretch there are periodical transverse rows of cobblestones in the bicycle path that are supposed to lower the speed of the bicyclists. The bicycle path ends close to Götaplatsen and from there a short part has to be biked in mixed traffic.

It is also possible to reach Södra Vägen N by travelling via Olof Wijksgatan in mixed traffic. There are residential and paid parking lots along both sides of the street, which might pose a risk to the bicyclists. By using a bicycle crossing in connection to Olof Wijksgatan it is possible to reach the bidirectional bicycle path on the east side of Södra Vägen N for onward travel.

The alternative route between Eklandagatan and Södra Vägen N/the city centre is seen as suitable since the majority of the stretch has a good standard with a bidirectional bicycle path. However, there are some risk associated with biking in the mixed traffic on Olof Wijksgatan.

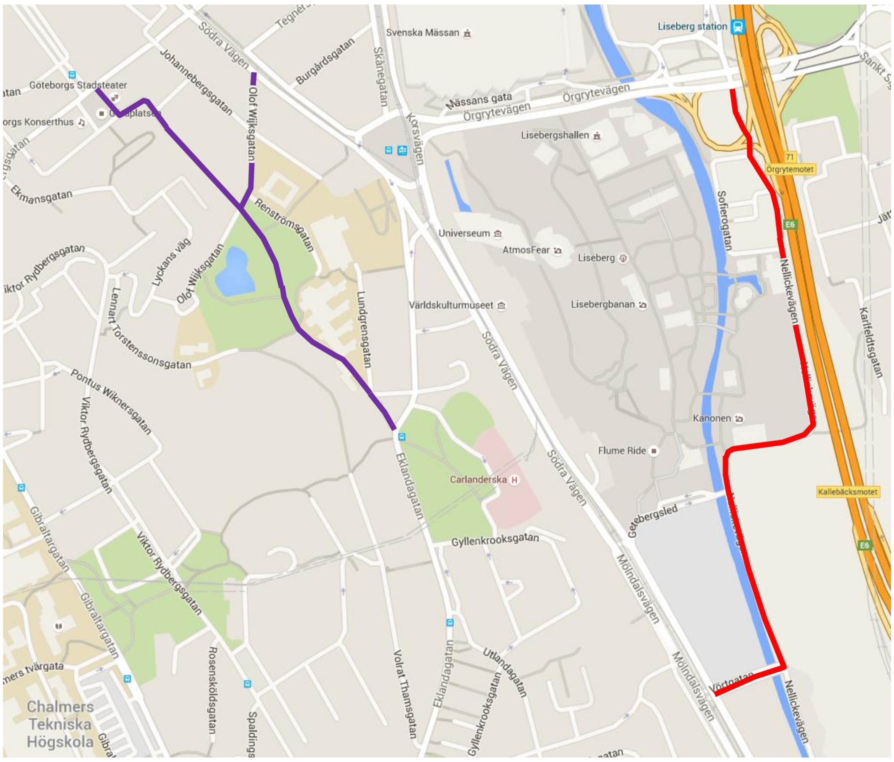

Figure 35 *Alternative route between Södra Vägen S and Örgrytevägen (red line) and Eklandagatan and Södra Vägen N (purple line) during construction of Station Korsvägen.*

5 Proposals for measures

None of the studied stretches around Korsvägen has a sufficient width by the flow of bicyclists since the recommendations in *Cykelprogram för en nära storstad 2015-2025* are not fulfilled. There are a lot of transport modes that coexist at Korsvägen and the amount of space is limited. The layout proposal has been revised several times and in some previous designs the bicyclists were given higher priority and more space, at the expense of the car. While today's layout makes it possible for all transport modes to travel through Korsvägen during construction. Because of this, proposal for measures related to broadening of the bicycle paths will not be suggested in this study. Instead some simple measures to improve the availability for bicyclist during the construction are suggested.

One suggestion of improvement is to convert the bicycle crossings to bicycle priority crossings. And thereby increase the availability for bicyclists, which is the intention with the new crossings according to Göteborgs Stad (2014). The bicyclists would have priority in the crossings with vehicles, which has to give way to bicyclists. Furthermore, bicycle priority crossing would create uniformity. Korsvägen is a roundabout and with the current bicycle crossings vehicles that are exiting the roundabout has to give way to bicyclists. Thus, different conditions apply on different bicycle crossings around Korsvägen. A better flow and availability for the bicyclists would therefore be created if bicycle priority crossings were implemented.

Moreover, a bicycle crossing combined with a zebra crossing complicates the give way relationship for all road users. Since the motorists must give way to pedestrians on the zebra crossing while the bicyclist on the bicycle crossing must give way to motorists. Thus, there is a risk of collision. A bicycle priority crossing would therefore be preferable in a traffic safety aspect. It would especially be preferable in Stage 2 on the two-lane wide bicycle crossings, since the statistics from STRADA show that several accidents have happened on such crossings.

When suggesting to convert the bicycle crossings to bicycle priority crossing it should be noted that the City of Gothenburg has not yet decided on how do design them. The Swedish Transport Agency has suggested that a bicycle priority crossing in combination with a zebra crossing should be designed as presented in Figure 36.

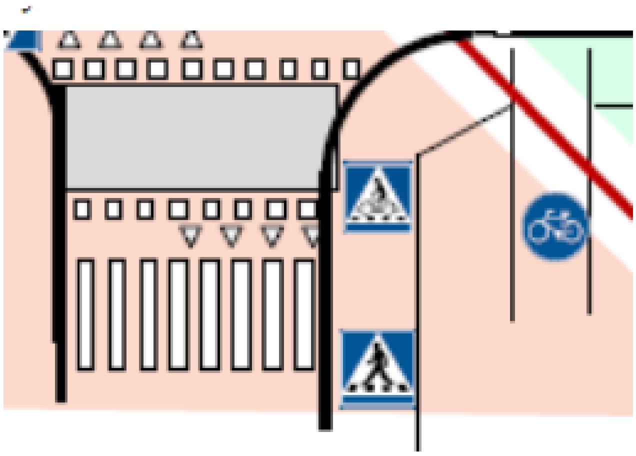

Figure 36 Suggested design of bicycle priority crossing according to The Swedish Transport Agency (Sveriges Kommuner och Landsting, 2015).

This design has been questioned by SALAR. One of their arguments is that the design forces the vehicles to stop on the zebra crossing in order to get a good view of the bicycle priority crossing, which is not permitted. SALAR has therefore developed an alternative design of a bicycle priority crossing (see Figure 37). Their design requires that there will be a directive that gives permission to place road signs for pedestrian or bicycle crossings elsewhere than immediately ahead of the road marking.

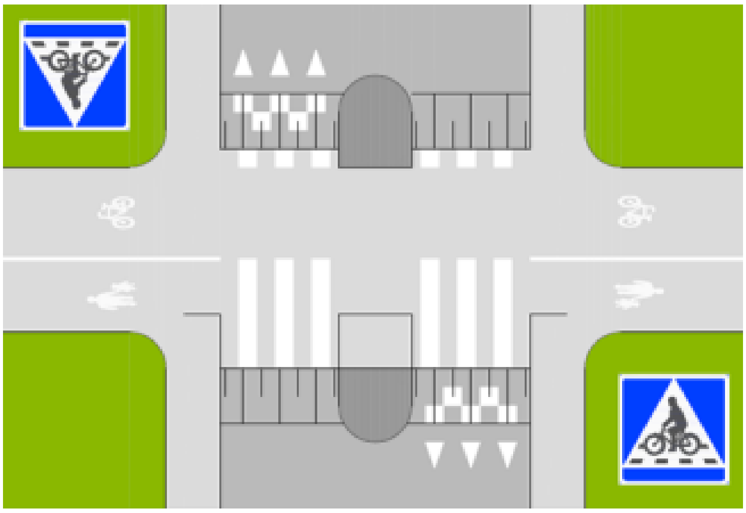

Figure 37 Suggested design of bicycle priority crossing according to the SALAR (Sveriges Kommuner och Landsting, 2015).

The City of Gothenburg has done an inventory of 70 bicycle crossings throughout the city to see if it is possible to turn them into bicycle priority crossings according to the different designs. The conclusion was that generally it would not be possible to adjust bicycle crossings that are located next to zebra crossings according to the design by The Swedish Transport Agency (Hauksson, 2015). Since it would require reconstruction of traffic island and connecting pedestrian paths, which there is often no room for. With the design suggested by SALAR it would be possible to adjust most of the bicycle crossings by adding road markings and signs. All bicycle crossings at Korsvägen are located next to a zebra crossing and with the design suggested by SALAR it could be possible to turn them into bicycle priority crossings.

Another proposal for measures to improve the availability for bicyclists at Korsvägen is to make the zebra crossings accessible for disabled by having a part where the kerbstone is lowered. This because it was observed that pedestrians, especially the ones with strollers, walkers and suitcases with wheels, walk in the bicycle path on the crossings. Since the current design of the zebra crossing has no part without inconvenient edges. It has been estimated that all zebra crossings at Korsvägen has sufficient width in order to be rebuilt according to the design in Figure 38. When the flow of bicyclists increase due to closed stretches and an increased bicycling over all according to the vision it will be even more important to make this adjustment so that conflicts between bicyclists and pedestrians are avoided at crossings.

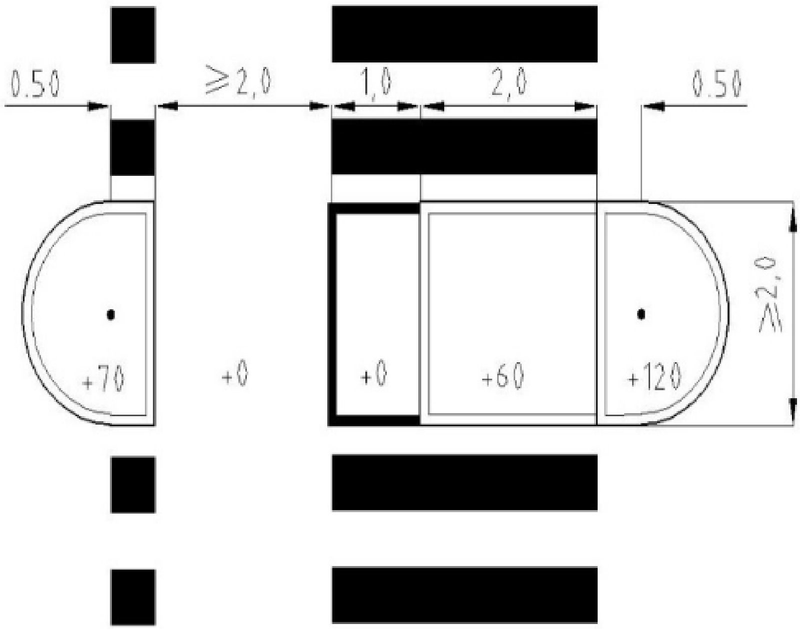

Figure 38 Design of bicycle crossing and zebra crossing with good accessibility for disabled (Teknisk Handbok, 2016a).

The three-way intersection between Stretch A and Stretch B has also been observed to be a position where a lot of conflicts occur due to lack of space. To improve the availability for bicyclist in this area it is suggested that the kerbstone is adjusted to make the right cure (when coming from Stretch B and turning towards Mölndal) less sharp. This would be done by placing the kerbstones in a quarter of a circle instead of orthogonally (see Figure 39). This type of design exists at the intersection between Stretch G and Stretch H. This is assumed to be especially beneficial in Stage 1 when all bicyclists that are travelling in a north-south direction through Korsvägen will pass this area. It would be desirable to adjust the kerbstones on both sides of the path but it is assumed that post with traffic signals has an unfavourable placing.

Figure 39 Adjustments of kerbstone to make the turn less sharp.

6 Discussion

In today's society there is no doubt to the importance of a sustainable development of the transport system to reduce its impact on the environment. Bicycling has several advantages, both environmentally and in terms of space. Increased bicycle traffic in cities can be part of the solution to create more sustainable cities. This is confirmed in several studies that emphasize the importance of an increase in the number of bicycle trips. One important factor to increase the bicycling is the design of the bicycle infrastructure. Significant factors related to the bicycle infrastructure are capacity and availability. Insufficient capacity and availability of the bicycle infrastructure will affect the bicycle's competitiveness against other transport modes. Hence, the relevance of studying capacity and availability for bicycling.

6.1 The definition of capacity and availability

This study shows that there is no general way to describe the capacity on a bicycle path and that it can be interpreted in different ways. It can be defined in numbers, in terms of bicyclists/hour, as well as in words. Several countries have defined the capacity for bicyclists in numbers, but the values varies a lot in different countries. One possible reason to this could be due to different cultural preferences of when there is congestion. In Sweden, the maximum capacity is considered to be a flow of 1500 bicyclists per hour on a 1.2 meters wide bicycle path according to Ljungberg (1986). In relation to other studied values, the capacity limit in Sweden is one of the lowest, i.e. a few number of bicyclists is needed before the capacity limits is reached.

Instead of using numbers Vectura (2012) has defined the capacity for bicyclists in words and states that there is a lack of capacity when a bicyclists, willingly or unwillingly, leaves the bicycle path because of limited availability. This could indicate that it is difficult to measure capacity for bicyclists in numbers since the capacity is influenced by the availability, which is complex and varies for each unique situation. However, the definition may also indicate that the existing numerical value to describe capacity problems in the bicycle network is not enough. Vectura's definition can serve as a complement to the numerical value until more extensive studies have been carried out.

According to Firth (2012) a standard definition of availability on bicycle paths does not exist. One simplified description is "that it is possible to go there". Envall and Koucky (2013) described availability as how fast it is possible to travel from point A to B and were the slow passages and forced stops are located. Firth (2012) underlines that the availability is changing depending on the situation. It is reasonable to think that the intention and importance of the trip sets completely different demands on availability.

6.2 Capacity and availability for bicyclists at Korsvägen

The capacity and availability for bicyclist at Korsvägen is discussed below. The chapter is divided into two parts. The first part deals with the current situation and the second treats the situation during construction of Station Korsvägen.

6.2.1 The current situation

None of the bicycle paths that were investigated in this study has lack of capacity according to Ljungberg's definition of capacity. However, it should be mentioned that the bicycle paths investigated are bidirectional and mostly wider than 1.2 meters in each direction. Thereof, Ljungberg’s definition is not completely applicable. Furthermore, it is assumed that Ljungberg's measure of capacity is defined for one-way bicycle paths and the capacity of a bicycle path varies with both the width and number of lanes in each direction.

On the other hand, the measurements from the field study indicates that none of the investigated stretches has sufficient widths according to *Cykelprogram för en nära storstad, 2015-2025*, where widths to ensure good and safe availability are given. Furthermore, the results from the observations showed that there are problems with congestion and limited availability on several sites at Korsvägen. The observed limited availability is more related to the perceived lack of capacity, as stated by Vectura (2012). This study shows that there are some capacity and availability problems on the bicycle paths around Korsvägen, even though the flow of bicyclists does not reach the numerical value for maximum capacity on a bicycle path. This may seem contradictive and is believed to be due to lack of knowledge in terms of capacity for bicycling.

The results from the observations show that availability problems occur first and foremost at three-way intersections and waiting areas. The availability problems can partly be explained by the design of the bicycle network. Car traffic has long been the primary transport mode when planning and designing the city. This also applies for Korsvägen, where the car is the mode of transport that has the most space. In many places, the bicycle paths have been established afterwards and has therefore to some extent been adapted to the available remaining space. Many different transport modes coexist at Korsvägen, which limits the amount of space that the different transport modes can be assigned. This could explain why the bicycle network has insufficient design at some locations e.g. at intersections and waiting areas.

Furthermore, the bicycle network at Korsvägen consists mainly of bidirectional bicycle paths. This leads to that bicyclist that are heading in different directions meet in the three-way intersections, where it has been observed that conflicts and confusion easily arise when there is a high flow of bicyclists. According to the observations in this study the three-way intersection with the highest flow (between Stretch A and Stretch H) was the intersection with the most problems. It is therefore assumed that an increased flow will lead to that more conflicts arise at locations with similar design. The conflicts in the three-way intersections lowers the availability of the bicycle network. Moreover, this indicates that the existing ways to measure capacity is not applicable in intersections since other conditions apply at intersections compared to stretches due to the fact that bicyclists with different directions cross each other’s paths.

Botma (1995) argues that a great amount of hindrance is an indication of low availability, however this does not mean that the capacity limits are reached. An alternative way to study the standard of a bicycle path would therefore be to study the hindrance along the path that limits the bicyclist’s availability. Meetings or crossings are often inconvenient and may result in conflicts or accidents, which restricts the availability for the bicyclists and affects the travel time. This is consistent with the results from this study which shows that the average speed, and thus the travel time, on a stretch is affected by meetings and crossings. The stretches where the lowest speeds has been measured are also the routes with the most crossings, while stretches with few crossings has the maximum measured speeds. It is possible to travel at a speed of about the average speed for bicyclists at these stretches. On Stretch A, which includes an intersection and a straight path with few crossings, the average speed is in between the average speed for the stretches with a lot of crossings and the stretches without, which is reasonable.

The measured average delay at the different intersections at Korsvägen are shorter than the values stated by Trivector (2013). This is believed to be due to that the delay is strongly connected to the design and programming of the traffic signals, which varies for every individual situation. Trivector's values are also an interpretation of a study made on pedestrians delay at different intersections. In order to gain knowledge about how the travel time and availability for bicyclists are affected by different types of crossings and intersections more research within this field is required.

6.2.2 During construction of Station Korsvägen

There are several guidelines and goals concerning how the bicycle paths should be designed and how the bicycle traffic should be prioritised during the construction of Västlänken. The goals within the West Swedish Agreement, which Västlänken is a part of, is to have fast, safe and easy bicycle paths. The implementation plan for Västlänken states that the paths that exist during the construction shall have the same high standard as a permanent path and that the accessibility and availability should be maintained for passenger and freight transports (Trafikverket, 2015a). The overall goal of the municipality of Gothenburg is similar and states that bicycling in Gothenburg should be fast, easy and secure. Furthermore, in 2025 three out of four citizens in Gothenburg should regard Gothenburg as a bicycle friendly city.

This study shows that these guidelines are not always followed. Most bicyclists will get a longer travel time through Korsvägen during the construction. Some will even get nearly a twice as long travel time through Korsvägen. These bicyclists will also get a more complicated route since the easiest and fastest connection between certain destinations is closed in the different construction stages. During the first construction stage, 75 % of the bicyclists that are travelling in a north-south direction will be affected due to closing of a bicycle path.

It was found, with statistics from STRADA that most accidents happen on a bicycle crossing that has a width of two car lanes. This crossing was also identified as unsafe by the inhabitants and the fear of getting injured deters risk averse and vulnerable groups form riding bicycles. Pucher and Buehler (2012) state that people would bicycle more if the risks introduced by motorized traffic were diminished. Thus, to improve the safety of bicycling is not only important to reduce the risk of injuries but it would also encourage people to bicycle more. In Stage 2, two new bicycles crossing that has a width of two lanes will be built. Based on the above, this is not in line with the guidelines to have safe and secure bicycle paths. It can, in addition to an increased risk of accidents, mean that fewer people choose to bicycle and that fewer people have a positive attitude towards bicycling.

Overall, this study indicates that some of the effects that arise during the construction of Station Korsvägen do not comply with the guidelines set by the West Swedish Agreement and the City of Gothenburg. It can therefore be an advantage to complement these guidelines that currently include descriptive words with measurable criteria and examples to make them more substantial. For instance by creating criteria on acceptable changes for bicycling due to construction sites. It is also important that not only the actual safety is taken into consideration, but also the perceived security.

6.3 Measures to increase the capacity and availability for bicyclists

In order to deal with the problems of low capacity and availability on bicycle paths both physical (hard) and mobility management (soft) measures can be used. The primary physical measure is to provide more space to the bicyclist. However, it should be emphasized that capacity and availability problems occur mostly at intersections and waiting areas and not along stretches. Thus, to only increase the width of the bicycle paths according to the standards specified in *Cykelprogram för en nära storstad, 2015-2025* is not sufficient. More space is needed mainly at the waiting areas. However, as mentioned earlier, there is limited amount of space on Korsvägen.

Another way to reduce the problems, in addition to the proposed measures in Chapter 5, would be to have one-way bicycle paths instead of bidirectional. It would be beneficial from a capacity point of view since the number of directions which meet at crossings/intersections decreases. This measure is in line with the guidelines set by the City of Gothenburg, where one-way bicycle paths are preferred in dense city environments. However, the accessibility can be negatively affected by one-way paths in cases when the destination is located on the wrong side and the number of crossings are few. There is also a risk that bicyclists bike against one-way bicycle paths, which was observed several times at the one-way paths around Korsvägen. It is therefore important to have clear signs and road markings and a continuous placing of crossings. Otherwise, there is a risk that it will be both capacity and availability problems. An investigation whether it is possible or not to have one-way bicycle paths at Korsvägen has not been conducted in this study. However, it can potentially be problematic since Korsvägen is designed as a roundabout.

Physical measures are often expensive, with high costs for materials and labour. No cost estimation has been conducted for the proposals of measures suggested in this study (see Chapter 5). However, it is estimated that the measures can be kept at a low cost because most of the locations where measures are proposed are already supposed to be rebuilt. The changes can therefore be made in the layout proposals. Thus, the additional cost for these measures is assumed to be low. It would be preferable to convert the existing bicycle crossings to bicycle priority crossings and make the zebra crossings accessible for disabled already during Stage 1, when the current design is not planned to be rebuilt. To adjust the bicycle crossings has been considered to be relatively easy, with new road markings and signs (speed reduction measures may be needed at some locations). Provided that the design suggested by SALAR is approved for use in Gothenburg. To adjust the zebra crossings and make them accessible for disabled in Stage 1 is also considered to be a rather cheap measure, since it only requires some adjustments of the kerbstones.

Soft measures are often less expensive and focuses on changing the behaviour and attitude of the road users. They can also be used in places where there is limited amount of space because these measures rarely require any space. There is a detailed plan for how to work with mobility management in Västlänken, which focuses primary on how to inform the bicyclists about changes. Since the first thing that road users do when there are disruptions in the traffic is to change their route, alternative bicycle connections around Korsvägen were investigated. It shows that the alternative route between Södra Vägen S and Örgrytevägen is not a suitable alternative route. It is therefore important to inform the bicyclists about changes and how they will be affected in order to avoid that these bicyclists choose to take a less suitable and safe route. It could be useful to inform the bicyclists about the alternative route between Eklandagatan and the city center to reduce the disturbance for the bicyclists that would otherwise pass through Korsvägen. To reach all bicyclists that are affected by the changed conditions, a combination of different information channels is considered beneficial.

6.4 Uncertainties of the study

It is important to emphasize that the choice of method can have a major impact on the results in a study of this character. First of all, the evaluation of capacity and availability from the observations is based on the authors' subjective experiences. However, the assessment of Korsvägen was based on the occurrence of conflicts or congestion that led to the bicyclists' behavior changed and has been consistent throughout all observations in order to affect the evaluation as little as possible. The observations can therefore be used to indicate where congestion and conflicts, and thus also availability problems, arise. Since the performance of the observations were consistent and that each stretch was observed several times, the results are considered to be valid.

Uncertainties also occur in the traffic count and the measurements of dimensions of the stretches due to the human error. To reduce the risk that the traffic count was performed on a day of abnormal flow measurements were carried out during two days. It would be preferable to perform the traffic count more than two times, however time was limited. Since the difference in flow between the two days was only about 5 % the results are considered to be reliable with an acceptable margin of error. Furthermore, the number of cyclists who passed Stretch A was counted on the southern part of the stretch and it is possible that the flow in the northern part of the stretch was slightly higher due to additional bicyclists traveling to/from Styr & Ställ. This share is considered to be small relative to the total flow on the stretch and does therefore not affect the result in any significant way.

When measuring the travel time at the different stretches, the authors themselves biked the individual stretches which may have affected the result. The floating car principle was used to get as reliable results as possible. The method is considered to be applicable when measuring the travel time of bicyclists since a clear pattern in the travel time for each stretch appeared.

There is also some margin of error when measuring the delay because of the difficulty to determine when a bicyclist was influenced by the delay if it did not stop completely but slowly rolled toward the intersection. In order to be consistent and not judge each case different the delay was measured when the bicyclists was standing completely still. Moreover, the travel time of the bicyclist is affected both before and after it has stopped due to braking and acceleration. This loss of travel time was difficult to measure with the resources that were available in this study.

Furthermore, the secondary data from the bicycle barometer was not complete and assumptions and adjustments had to be done which lead to some margin of error. The adjustments are believed to be reasonable and the margin of error small since measurements from different years follow the same pattern according to the calculations of indices over the year.

It has also been assumed that conditions over the year at the bicycle barometer correspond to the conditions at Korsvägen. This simplification was necessary due to constrain of time. To get a get a broader understating of the exact conditions it would be desirable to study the bicycle traffic on Korsvägen for a longer period of time. However, the assumption is reasonable since the factors that influence bicycling are similar at the location of the bicycle barometer and Korsvägen, the bicycling would thereby vary according to the same pattern.

Although this study of capacity and availability for bicyclists is performed as a case study of Korsvägen it is assumed that the discovered problems, related to capacity and availability, can be an indication of where problems might occur in the bicycle network at other places.

6.5 Further studies

The City of Gothenburg has a vision to increase the bicycling during the same period as many construction projects will be conducted. This study shows that the travel time and availability for bicyclists will be affected due to the construction of Station Korsvägen. It would therefore be important to do further studies of the bicycle network in Gothenburg with regard to capacity and availability in order to identify possible problems, which can reduce the chances of achieving the vision.

There is currently not enough knowledge within the field of capacity and availability for bicyclists and more studies are needed. Above all, more knowledge is needed about which impact intersections and waiting areas has on the capacity and availability for bicyclists. Furthermore, in order to achieve the goals of increased bicycling and to have a sustainable development of the transport sector knowledge about the capacity and availability for different bicycle infrastructure designs is required. To study and develop numerical values on capacity for different designs of infrastructure is therefore important.

Further knowledge of how the travel time for bicyclists is affected for different types of intersections is needed. The studies that are available today are based on studies performed on pedestrians. Availability and travel time for bicyclists in an important parameter in order for bicycling to be a competitive transport mode.

7 Conclusion and recommendations

This thesis has aimed to study the capacity and availability for bicyclists. The capacity and availability for bicyclists at Korsvägen has been investigated in a case study and an analysis of the situation during construction of Station Korsvägen has been conducted. Proposals for measures have been presented for identified problems.

This study shows that there is no general way to describe the capacity on a bicycle path and that it can be interpreted in different ways. It can be defined in numbers, in terms of bicyclists/hour, as well as in words. Furthermore, there is no standard definition of availability for bicyclists. Travel time, slow passages and forced stops can be used to evaluate the availability on a bicycle path.

Based on the numerical value for capacity and the current maximum flow of bicyclists there is no lack of capacity on the bicycle network at Korsvägen. However, the observations indicates that there are problems with congestion and queues on waiting areas and at intersections, which limits the availability for bicyclists. Thus, the availability and perceived capacity may be limited even though there is no measured lack of capacity. The conclusion is that it is important to identify the locations with limited availability to assess the quality of the bicycle network.

Furthermore, the travel time through Korsvägen will increase for many bicyclists during the construction of Station Korsvägen. The travel time is an important factor regarding the bicycle's competitiveness against other transport modes. In conclusion, the vision to increase bicycling and the positive attitude towards bicycling in Gothenburg does not benefit from an increased travel time and several places with limited availability.

In order to improve the capacity and availability during the construction of Station Korsvägen a proposal of measure is to convert the bicycle crossings into bicycle priority crossings. This would increase the availability and safety since the motorized vehicles has to give way to the bicyclists. Moreover, bicycle priority crossings are beneficial since it takes away the confusion of who should give way to who and creates uniformity. Another proposal for measures to improve the availability for bicyclists at Korsvägen is to make the zebra crossings accessible for disabled by having a part where the kerbstone is lowered. With the intention to decrease the number of pedestrian walking in the bicycle path. The proposed physical measures in combination with soft measures, in terms of information, is considered to be simple and cost-efficient in order to improve the capacity and availability at Korsvägen during construction.

In-depth analyses and cost estimations are needed before the proposed measures can be implemented. This report can hopefully be used to improve the situation regarding capacity and availability for bicyclists during the construction of Station Korsvägen in particular and serve as a guidance and inspiration in general.

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Appendix I

The following tables show the number of maximum hours for different hours at Korsvägen in March and September in 2013-2015.

	Number of maximum hours in March		
Hour/Year	2013	2014	2015
7-8	16	16	17
8-9	0	0	0
16-17	0	4	2
17-18	4	1	3

	Number of maximum hours in September		
Hour/Year	2013	2014	2015
7-8	17	8	17
8-9	0	2	0
16-17	3	1	3
17-18	1	11	1

Appendix II

The following tables show the results for all stretches for the measurements of the travel time.

Stretch A		
Date	Direction	Time [mm:ss]
2016-03-08	counter-clockwise	00:45
2016-03-08	clockwise	00:41
2016-03-08	counter-clockwise	00:41
2016-03-09	counter-clockwise	00:39
2016-03-09	clockwise	00:41
2016-03-09	counter-clockwise	00:38
2016-03-09	clockwise	00:44
2016-03-09	counter-clockwise	00:36
2016-03-09	clockwise	00:41
2016-03-14	counter-clockwise	00:40
2016-03-14	clockwise	00:39
2016-03-14	counter-clockwise	00:39
2016-03-14	clockwise	00:40
2016-03-14	counter-clockwise	00:40
2016-03-14	clockwise	00:40
	Average:	00:40

Stretch B		
Date	Direction	Time [mm:ss]
2016-03-08	Clockwise	00:10
2016-03-08	counter-clockwise	00:14
2016-03-08	Clockwise	00:11
2016-03-08	counter-clockwise	00:11
2016-03-09	Clockwise	00:11
2016-03-09	counter-clockwise	00:10
2016-03-09	clockwise	00:10
2016-03-09	counter-clockwise	00:10
2016-03-09	clockwise	00:09
2016-03-09	counter-clockwise	00:10
2016-03-14	counter-clockwise	00:11
2016-03-14	Clockwise	00:11
2016-03-14	counter-clockwise	00:10
2016-03-14	Clockwise	00:11
2016-03-14	counter-clockwise	00:10
2016-03-14	Clockwise	00:13
	Average:	00:11

Stretch C		
Date	Direction	Time [mm:ss]
2016-03-08	Clockwise	00:11
2016-03-09	counter-clockwise	00:12
2016-03-09	clockwise	00:11
2016-03-09	counter-clockwise	00:10
2016-03-09	clockwise	00:10
2016-03-09	counter-clockwise	00:11
2016-03-09	clockwise	00:11
2016-03-14	counter-clockwise	00:12
2016-03-14	Clockwise	00:10
2016-03-14	counter-clockwise	00:11
2016-03-14	clockwise	00:10
2016-03-14	counter-clockwise	00:11
2016-03-14	clockwise	00:10
	Average:	00:11

Stretch D		
Date	Direction	Time [mm:ss]
2016-03-08	clockwise	00:28
2016-03-08	counter-clockwise	00:27
2016-03-08	clockwise	00:26
2016-03-08	counter-clockwise	00:26
2016-03-09	counter-clockwise	00:26
2016-03-09	clockwise	00:25
2016-03-09	counter-clockwise	00:25
2016-03-09	clockwise	00:25
2016-03-09	counter-clockwise	00:25
2016-03-09	clockwise	00:24
2016-03-14	counter-clockwise	00:25
2016-03-14	clockwise	00:28
2016-03-14	counter-clockwise	00:26
2016-03-14	clockwise	00:27
2016-03-14	counter-clockwise	00:28
2016-03-14	clockwise	00:27
	Average:	00:26

Stretch E		
Date	Direction	Time [mm:ss]
2016-03-08	clockwise	00:11
2016-03-08	counter-clockwise	00:11
2016-03-08	clockwise	00:10
2016-03-08	counter-clockwise	00:11
2016-03-09	clockwise	00:10
2016-03-09	counter-clockwise	00:09
2016-03-09	clockwise	00:09
2016-03-09	clockwise	00:09
2016-03-09	counter-clockwise	00:10
2016-03-09	clockwise	00:09
2016-03-14	counter-clockwise	00:09
2016-03-14	clockwise	00:09
2016-03-14	counter-clockwise	00:09
2016-03-14	clockwise	00:08
2016-03-14	counter-clockwise	00:10
2016-03-14	clockwise	00:09
2016-03-14	counter-clockwise	00:09
	Average:	00:10

Stretch F		
Date	Direction	Time [mm:ss]
2016-03-08	clockwise	00:11
2016-03-08	counter-clockwise	00:12
2016-03-08	clockwise	00:11
2016-03-08	counter-clockwise	00:13
2016-03-09	counter-clockwise	00:11
2016-03-09	clockwise	00:10
2016-03-09	counter-clockwise	00:11
2016-03-09	clockwise	00:10
2016-03-09	counter-clockwise	00:10
2016-03-09	clockwise	00:10
2016-03-14	counter-clockwise	00:12
2016-03-14	clockwise	00:10
2016-03-14	counter-clockwise	00:11
2016-03-14	clockwise	00:11
2016-03-14	counter-clockwise	00:12
2016-03-14	clockwise	00:11
	Average:	00:11

Stretch G		
Date	Direction	Time [mm:ss]
2016-03-08	Clockwise	00:12
2016-03-08	Counter-clockwise	00:13
2016-03-08	Clockwise	00:14
2016-03-08	Counter-Clockwise	00:13
2016-03-09	clockwise	00:13
2016-03-14	counter-clockwise	00:13
2016-03-14	clockwise	00:13
2016-03-14	counter-clockwise	00:13
2016-03-14	clockwise	00:12
2016-03-14	counter-clockwise	00:13
2016-03-14	clockwise	00:12
	Average:	00:13

Stretch H		
Date	Direction	Time [mm:ss]
2016-03-08	clockwise	00:04
2016-03-08	counter-clockwise	00:04
2016-03-08	clockwise	00:05
2016-03-08	counter-clockwise	00:04
2016-03-08	clockwise	00:04
2016-03-08	counter-clockwise	00:04
2016-03-08	clockwise	00:04
2016-03-08	counter-clockwise	00:05
2016-03-08	clockwise	00:04
2016-03-08	counter-clockwise	00:04
	Average:	00:04

Appendix III

The following tables show the results from the measurements of delay at all stretches individually.

Stretch A - Örgrytevägen			
Measurement	1	2	Sum
Min	2	2	2
Max	26	27	24
Average	10	9	9

Stretch B - Södra Vägen S			
Measurement	1	2	Sum
Min	2	2	2
Max	41	44	44
Average	14	13	14

Stretch C - Eklandagatan				
Measurement	1	2	3	Sum
Min	3	3	3	3
Max	32	32	28	28
Average	9	12	13	11

Stretch E - Södra Vägen N				
Measurement	1	2	3	Sum
Min	2	2	4	2
Max	30	39	41	41
Average	12	13	12	12

Stretch G - Skånegtatan				
Measurement	1	2	3	Sum
Min	2	2	4	2
Max	21	21	23	23
Average	8	7	8	8

Appendix IV

Bicyclists waiting on the west side of Södra Vägen S to cross the intersection, seen from Eklandagatan.

Bicyclists waiting on the east side of Södra Vägen S to cross the intersection.