CHALMERS

Bicycle Safety in Gothenburg

A case study of bicycle – motor vehicle collisions on one- and two-way cycle paths at intersections

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

RAGNAR GAUTI HAUKSSON

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Department of Civil and Environmental Engineering
Division of GeoEngineering
Road and Traffic Research Group
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Cover:
A two-way cycle path at a non-signalized intersection in central Gothenburg, photo courtesy of Annika Nilsson.

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ABSTRACT

Cyclists are a vulnerable group of road users and hold a large share of all traffic related accidents. Many claim however that the health and economic benefits as a result of increased cycling outweigh the risk factor. Increased cycling is a positive sustainable development for cities and to make the bicycle competitive to other means of transportation the cycle infrastructure must be efficient regarding travel time and distance, as well as being safe. Most bicycle – motor vehicle collisions occur at intersections and the aim of this study is to compare one-way and two-way cycle paths at intersections, regarding bicycle safety. This is done as a case study in Gothenburg. Two-way cycle paths are favoured in Gothenburg but in the central area one-way cycle paths are also common.

Bicycle related accidents from the STRADA database for the years 2002-2013 were used for this study and the focus was on the central area of the city.

When all intersection bicycle – motor vehicle accidents are examined in GIS and compared to the bicycle network it revealed that two-way cycle paths have higher accident rate per kilometre than one-way cycle paths. Non-signalized crossings were identified on one-way and two-way cycle paths in the central area and categorized by intersection type; T-intersection, 4-way intersection and roundabouts. Bicycle – motor vehicle accidents were registered for each crossing with GIS. The result revealed that two-way cycle paths have higher accident rate for all intersection types.

The conclusion is therefore that one-way cycle paths are safer than two-way cycle paths at intersections in Gothenburg. Studies with similar focus from Finland have revealed that two-way cycle paths are dangerous for cyclists at intersections, especially for those arriving from the direction opposite vehicle traffic. Finnish researcher concluded therefore that one-way cycle paths should be preferred. Denmark and the Netherlands are leading bicycle nations and they favour one-way cycle paths. Since the millennium shift Gothenburg has managed to increase cycling while enhancing bicycle safety. Gothenburg is now one of Sweden´s safest bicycle municipalities. There is always room for improvement and when building new cycle facilities or renewing current ones one-way cycle paths should be considered to make cycling safer and a more attractive choice.

Key words: Bicycle safety, cycle path, intersection, non-signalized cycle crossing, bicycle – motor vehicle accident.

Cykelsäkerhet i Göteborg
En fallstudie av cykel – motorfordonsolyckor på enkel- och dubbelriktade cykelbanor i korsningar
Examensarbete inom Infrastructure and Environmental Engineering
RAGNAR GAUTI HAUKSSON
Institutionen för bygg- och miljöteknik
Avdelningen för Geologi och Geoteknik
Forskargrupp Väg och Trafik
Chalmers Tekniska Högskola

SAMMANFATTNING

Cyklister är en utsatt grupp i trafiken och står för en stor andel av alla trafikolyckor. Många hävdar dock att ökad hälsa och samhällsekonomiska vinster som resultat av ökad cykling uppväger trafiksäkerhetsrisken. Ökad cykling är en positiv utveckling för det hållbara samhället och för att göra cykling konkurrenskraftig mot andra trafikslag måste cykelinfrastrukturen vara effektiv avseende restid och avstånd samt uppfattas som säker. De flesta cykel – motorfordonskollisioner sker i korsningar och syftet med denna studie är att jämföra enkel- och dubbelriktade cykelbanor i korsningar, i fråga om cyklisters säkerhet. Detta görs som en fallstudie i Göteborg. Dubbelriktade cykelbanor föredras i Göteborg, men i centrala delen av staden är även enkelriktade cykelbanor frekventa.

Cykelolyckor från olycksdatabasen STRADA för åren 2002-2013 användes för denna fallstudie med fokus på centrala delen av staden.

När alla cykel – motorfordonsolyckor i korsningar granskades med hjälp av GIS och jämfördes med cykelnätet var det uppenbart att dubbelriktade cykelbanor har fler olyckor per kilometer än enkelriktade cykelbanor. Obevakade cykelöverfarter identifierades på enkel- och dubbelriktade cykelbanor i centrala delen av staden och kategoriserades efter korsningstyp; T-korsning, 4-vägskorsning och cirkulationsplatser. Cykel – motorfordonsolyckor registrerades för varje cykelöverfart med hjälp av GIS. Resultatet visade att dubbelriktade cykelbanor har fler olyckor för alla korsningstyper.

Slutsatsen är därför att enkelriktade cykelbanor är säkrare för cyklister än dubbelriktade cykelbanor i korsningar i Göteborg. Studier med liknande fokus från Finland har visat att dubbelriktade cykelbanor är farliga för cyklister i korsningar, särskilt för cyklister som cyklar mot motorfordons färdriktning. De finska forskarnas slutsats var därför att enkelriktade cykelbanor är att föredra. Danmark och Holland är ledande cykelländer och de föredrar enkelriktade cykelbanor generellt. Sedan millenniumskiftet har Göteborg lyckats att öka cyklingen samtidigt som cyklisters trafiksäkerhet har ökat. Göteborg är nu en av Sveriges säkraste cykelkommuner. Det finns alltid utrymme för förbättring och när nya cykelbanor ska byggas eller när gamla cykelbanor ska upprustas borde enkelriktade cykelbanor övervägas/väljas för att göra cykling till ett säkrare och mer attraktivt alternativ i Göteborg.

Nyckelord: Cykelsäkerhet, cykelbana, korsning, obevakad cykelöverfart, cykel – motorfordonsolycka.

Contents

Preface

This Masters' thesis is about bicycle safety in Gothenburg. The study compares bicycle safety for one-way and two-way cycle paths at intersections, mainly non-signalized intersections, in the central area of the city. The project has been carried out from January 2014 to May 2014, at the department of Civil and Environmental Engineering, Road and Traffic Research Group, Chalmers University of Technology, Sweden. The study has been performed at Trivector Traffic AB, Gothenburg.

The author of this report has been Ragnar Gauti Hauksson, and examiner has been Chalmers lecturer Gunnar Lannér. Supervisor at Chalmers has been Jan Englund and supervisor at Trivector Traffic AB has been Annika Nilsson.

I would like to thank the employees at Trivector for accepting my research subject proposal, welcoming me and providing me an office space. Special thanking to my supervisor Annika Nilsson for guidance and support and during this project. I would also like to thank Suzanne Andersson, Karin Björklind, Lars-Erik Lundin, Malin Månsson and Zeljko Simunovic, employees at Trafikkontoret, for providing me with data and valuable feedback. Finally I would like to thank Magnus Berg at Transportstyrelsen for providing me STRADA accident data.

Gothenburg, May 2014

Ragnar Gauti Hauksson

Notations

STRADA Swedish Traffic Accident Data Acquisition

Glossary

Swedish translation of key terms used in this report.

English	***Swedish***
Cycle crossing	Cykelöverfart
Cycle path	Cykelbana
Cycle lane	Cykelfält
Cycle passage	Cykelpassage
Cycle way	Cykelväg
Intersection	Korsning
Mixed traffic (among the traffic)	Blandtrafik
Municipality	Kommun
Primary cycle network	Stomcykelnät
Swedish Transport Agency	Transportstyrelsen
Traffic & Public Transport Authority in Gothenburg (Gothenburg Municipality)	Trafikkontoret (Göteborgs Stad)
Urban area	Tätort
Yield / give way	Väjningsplikt / lämna företräde

1 Introduction

Cyclists are a vulnerable group of road users and hold a large share of all traffic related accidents. However, many claim that the health and economic benefits as a result of increased cycling outweigh the risk factor. Increased cycling is of great importance for the cities strive to enhance sustainability and to make the bicycle competitive to other means of transportation the cycle infrastructure must be efficient regarding travel time and distance, as well as being safe (Svensson et al., 2011).

Two-way cycle paths are the favourable cycle infrastructure in Gothenburg. One-way cycle paths and cycle lanes are more common in Stockholm. Many cities in Denmark and in the Netherlands also favour one-way cycle paths, and many worldwide cities look towards these two bicycle nations when in need for inspiration regarding their current bicycle infrastructure.

In Sweden, bicycle – motor vehicle collisions hold 10 per cent share of all severe injuries and 69 per cent share of fatal injuries for the years 2007-2012 (VTI, 2013).

1.1 Background

Gothenburg is Sweden's second largest city located on the west coast with approximately 958 000 inhabitants in the metropolitan area (Statistics Sweden, 2013). The city is known for its high tech industries and top universities and the city has many people commuting to the central city every day. Car commuting is the most popular transport mode, followed by public transport, then by walking and cycling (WSP, 2013). Although the car is most popular, bicycles are often chosen for shorter trips and results show that more than 40 per cent of Gothenburg's inhabitants cycle 1-3 days per week, all year round (Trafikkontoret, 2012:1). Cycling accounts for 7 per cent of all trips made in Gothenburg, which is slightly lower than the national average of 9.2 per cent (Spolander, 2013).

Vulnerable road users, cyclists and pedestrians are exposed to great risk in traffic and account for most of deaths and seriously injured (City of Göteborg, 2007). It has also been stated that cyclists are involved in two times more accidents than people travelling by car (Trafikkontoret, 2009:1). When the travelling distance is compared between cyclists and car users, cyclists are 4 times more likely to get killed in traffic (Svensson et al., 2011). With all these accident statistics in mind, studies have also shown that increased cycling improves safety by reducing the segment of threatening surprises, regardless of the cycle paths layout design (Ekman, 1996 and Trafikkontoret, 2012:1). Also, studies in Sweden show that the risk for cyclists being in an accident at intersections decreases with increased number of cyclists (Spolander, 2014). The bicycle safety also improves with well-planned and structured bicycle infrastructure.

Gothenburg has Sweden's largest cycle network with a total length of 793 km. The cycle network consists of 486 km cycle paths, 150 km local cycle paths and 157 km mixed streets where the speed limit is 30 km/hour (Trafikkontoret, 2013). The cycle path network includes two-way cycle paths, segregated two-way cycle paths, one-way cycle paths and a few stretches of cycle lanes. These different cycle paths and lanes are explained further in chapter 2.1. Studies shows that in general are cyclists very satisfied (36%) with current cycle paths and only a small portion of users is dissatisfied (12%) (Trafikkontoret, 2012:2). One-way cycle paths are only a short link of the total cycle network with approximately 31 km in one direction.

1.2 Aim

The aim of this study is to examine on a detailed level the safety difference between one-way and two-way cycle paths at non-signalized intersections in central Gothenburg. The results will be based on accident data from bicycle – motor vehicle collisions for the years 2002-2013 regardless of the severity level and from both hospital and police reports. Bicycle crossings of interest will be viewed in GIS with accident data coordinates.

Presented literature study will support the subject with related studies from nearby countries. Current cycle situations and rules in nearby countries will also be presented to show the variance of cycle infrastructures in northern Europe.

1.3 Delimitations

For this study a chosen area inside Gothenburg municipality will be examined and not the whole metropolitan area. Accident type bicycle – motor vehicle will be used exclusively. Non-signalized cycle crossings where one-way and two-way cycle paths are aligned with roads will be examined, with the goal to document as many crossings as possible within the timeframe of the study. *Hisingen* area, north of the *Göta Älv* River, will be excluded to focus on the main land section.

2 Literature Study

This chapter will present current bicycle situations, rules and studies from Sweden and nearby countries, mainly in Scandinavia, regarding cycle safety on one-way and two-way cycle paths. The chapter will begin with definitions of cycle facilities.

2.1 Definition of cycle facilities

Cycle infrastructure has different layout forms and to clarify terms used in this report a short description is provided here. Figure 1 shows a one-way cycle, two-way cycle path and a cycle lane.

Cycle path

A road or a part of a road intended only for cycle and category-2 moped traffic (Trafikkontoret, 2008). Mopeds are divided into two categories; Category-1 with max speed under 45 km/hour and category-2 with max speed under 25 km/hour (Transportstyrelsen, 2013). Cycle paths are segregated from roads with curbs, barriers or buffer zones and are either one-way or two-way paths. Cycle paths can be aligned with roads or located through green areas, outskirts of the city and in rural areas when the speed limit increases.

Two-way cycle path

A two-way cycle path has bicycle traffic in both directions, usually located aligned with the road on one side in urban areas. In some cases in Gothenburg, there are two-way cycle paths on both sides of the road.

One-way cycle path

A one-way cycle path has bicycle traffic in only one direction, same direction as the motor vehicles, usually with paths on each side of the road.

Cycle lane

A specific road-marked lane on roads for cycle and category-2 moped traffic (Trafikkontoret, 2008). Cycle lanes are intended for bicycle traffic in one direction, same as the motor vehicles, usually with lanes on each side of the road. Sometimes cycle lanes are used for bicycle traffic against normal traffic direction, then with only one lane on one side.

Mixed traffic

In mixed traffic streets bicycle and category-2 moped traffic is integrated with motor vehicle traffic without separation (Trafikkontoret, 2008). These mixed traffic streets have a max speed limit of 30 km/hour.

Cycle crossing

Part of a road or path intended for cyclists to cross the road or path specified with road markings (Trafikkontoret, 2008). The bicycle crossing is either guarded with signals or not. If the latter the intersection is called a *non-signalized intersection*.

Cycle track

In some countries the term cycle track is used for segregated cycle paths. Cycle tracks and cycle lanes are then combined in the term cycle path. In this report however, the term cycle path will be used for segregated paths and cycle lanes will be used for paths that are not segregated.

Figure 1. Two-way cycle path, one-way cycle path and a cycle lane.

2.2 Bicycle Planning in Sweden

This subchapter will present a brief history of bicycle planning in Sweden followed by Gothenburg municipalities' visions and strategies regarding bicycle planning. Finally, traffic rules in Sweden at intersection will be explained.

2.2.1 A Brief history of bicycle planning in Sweden

The present Swedish and Finnish two-way cycle path network is based on SCAFT Nordic traffic planning guide from 1967. This guide focused on traffic safety and assumed cyclist and pedestrians to be a homogeneous group of vulnerable road users separating them from motor vehicle traffic. This separation causes conflicts between pedestrians and cyclist on cycle paths aligned with sidewalks. In the city centre, the aligned with road two-way cycle paths also causes conflicts with motor vehicles at cycle crossings.

In the 1960's Gothenburg's road network expanded in correlation with the cities growth (Trafikkontoret, 2009:1). When redirecting the traffic to right-hand traffic in 1967 the traffic safety issue got more attention in traffic planning. The establishment of appropriate speed limits, and legislation for the obligatory use of seatbelts followed the change to right-hand traffic (City of Göteborg, 2007).

2.2.2 Gothenburg municipality; Visions and strategies

Gothenburg has from the 1990's gone from being the countries municipality with most bicycle accidents to increase the safety for cyclists so that now it is one of the municipalities with least bicycle accidents (Trafikkontoret, 2009:1). In 1998 the Swedish Parliament suggested that Vision Zero should be superior policy for Sweden's transport politics (City of Göteborg, 2007). Vision Zero is an ethical standpoint that no one should be killed or injured for life in road traffic. The only acceptable number of people killed and seriously injured is zero. To strive for this zero vision, Gothenburg Municipality set a goal in 1999 to reduce seriously injured road users by 60 per cent to the year 2005, based on an average value for the years 1985-89. They also set a goal to improve traffic safety for cyclist by reducing the total number of injured cyclist by 25 per cent and the number of killed cyclist by 35 per cent before the year 2008. Later, in 2004, the Municipality raised their goal to reduce the total number of seriously injured and killed road users by 50 per cent before the year 2010, based on statistics for 2004, see Figure 2.

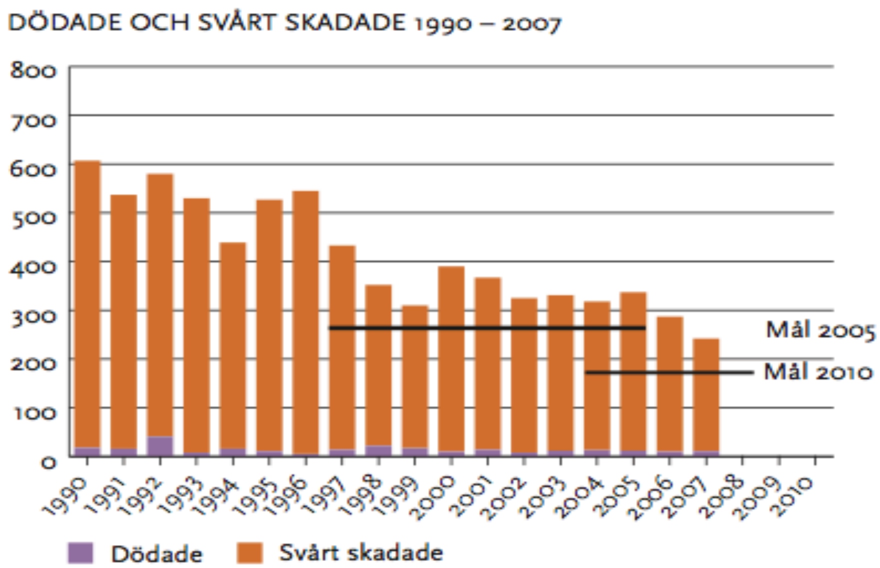

Figure 2. Deaths and severe injuries in Gothenburg 1990-2007 and visions for 2005 and 2010 (Trafikkontoret, 2009).

The safety goal was achieved for cyclist (63%) and pedestrians (61%) and nearly for people travelling in cars (46%) (Trafikkontoret, 2009:1). The current goal for the years 2010-2014 is to have fewer than 75 people seriously or moderately injured and fewer than 3 deaths in all traffic accidents (Trafikkontoret, 2009:2).

Measures to protect and enhance safety for vulnerable road users, cyclist and pedestrians, is prioritized as this group accounts for 70 per cent of deaths and hospital days in correlation to traffic accidents (Trafikkontoret, 2009:1). From 1978 Gothenburg municipality has improved traffic safety with traffic-calming countermeasures, such as road-humps, roundabouts as well as raised pedestrians and cycle crossings (City of Göteborg, 2007). For the last 36 years or so these traffic-calming measures are well over two thousand in numbers in Gothenburg. The traffic-calming countermeasures were implemented into the design and reconstruction of whole streets and areas separating vulnerable road users, I e cyclist and pedestrians, from motor vehicle traffic. This reconstruction influenced inhabitants of the reconstructed areas to walk and cycle more. Results show that the majority, threequarters, of improvements in traffic safety in Gothenburg are because of speed-reducing countermeasures and the separation of vulnerable road users from motor vehicle traffic. These measures and positive effects are presented in Figure 3.

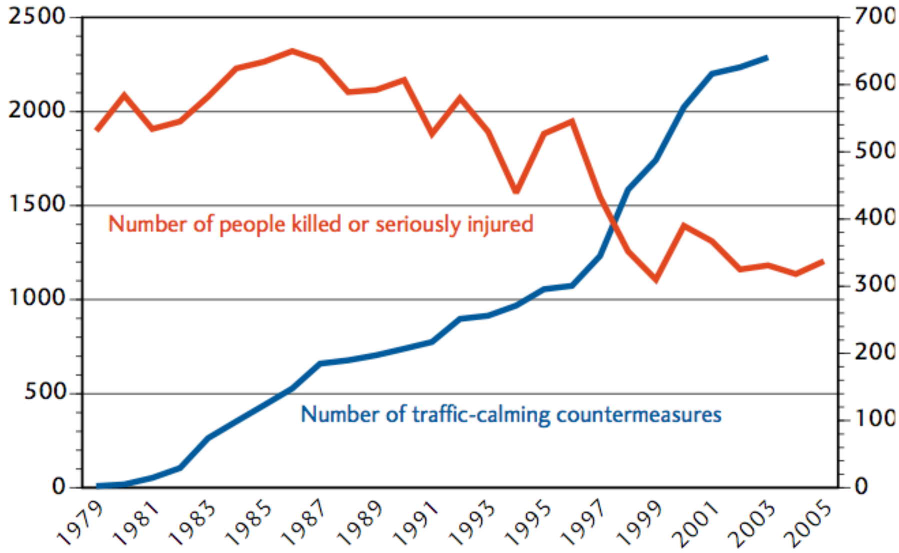

Figure 3. Number of people killed or seriously injured and number of traffic calming countermeasures in Gothenburg for the years 1979-2005 (City of Göteborg, 2007).

For the last several years Gothenburg has worked steadily towards being a cycle friendly city. From 2002 the city has worked with workplaces to inform and inspire the beneficial's from increased cycling amongst their co-workers (Trafikkontoret, 2013). In 2009 the municipality installed the first public bicycle pump in *Vasagatan* and in 2013 the total number of public pumps was 16. From 2010 the city has offered low-priced bike sharing system (Styr & Ställ) to reduce short car trips in the central city and the city has also increased the amount of parking stands for bicycles now with 8000 total parking stands in the central area. Gothenburg has also launched a smartphone app, *Cykelstaden,* which is a smart tool for every cyclist providing general information regarding cycling such as the location of pump stations, lend bike stands, parking stands, bike services and cycle paths.

In Gothenburg Municipality's manual for cycle paths it is stated that a good cycle network should primarily meet safety requirements (Trafikkontoret, 2008). This meaning that cyclists are separated from motor vehicle traffic (especially in the primary cycle-network) and intersections should be designed with cyclist safety in mind. Many elderly and disabled see the cycle traffic as a problem, particularly where cyclist and pedestrians share paths (GC-bana) and where the sidewalk and cycle paths are aligned. Cyclists are perceived as fast and silent and sometimes it is unclear where the separation between pedestrian- and cyclist path is. The manual also states that two-way bicycle paths in level with pedestrian streets are favoured. In exceptional cases cycle lanes and one-way cycle paths are constructed. At intersections with two-way cycle paths it should be made clear for drivers that cyclist are arriving from both directions. This can be done with separated level cycle crossing paths and with directional arrows cycle road signs for drivers. At congested streets, flashing-signals warning drivers for cyclist are often used. Two-way cycle paths are designed with widths 2.3-2.5 metres with minimum requirements of 2.0 metres and one-way cycle paths are designed with width 2.0 metres with a minimum of 1.2 metres.

In Stockholm cycle lanes have been used to a more extent because of lack of space and also because the interaction is considered to increase if cyclists are integrated with motor vehicle traffic, mainly at intersections (Trafikkontoret, 2008). This interaction is often also made with one-way cycle paths where the path becomes a cycle lane right before an intersection. Cycle lanes in Stockholm are seen to make cyclists more visible as they are forced into mixed traffic. This interaction though requires more experienced cyclists and a large number of unafraid cyclists. In Gothenburg the two-way cycle paths are favoured over cycle lanes. One reason is that they enhance the feeling of safety among all cyclists, including elderly and children.

2.2.3 Traffic rules at intersections in Sweden

The traffic rules in bicycle - motor vehicle intersections in Sweden are often perceived as confusing and unclear and there are many different views amongst drivers and cyclists of what applies for different situations (Pauna et al., 2009). Drivers have to yield for pedestrians at all marked pedestrian crossings (zebra-stripe crossings) (Trafikförordning, 1998:1276). Bicyclists and riders of category 2 mopeds arriving at a crossing should consider drivers approaching the crossing and only cross when it is safe. Drivers leaving roundabouts or turning over a cycle crossing have to drive slowly and let approaching bicyclist and mopeds ride through the intersection before crossing. In the case where there are no marked pedestrian crossing or cycle path or yield signs for drivers the general guidance is that everybody should consider each other and the first to arrive to the intersection should cross first. So, different rules apply for drivers crossing an intersection depending on where the driver is coming from and cyclists generally don't know what applies for the current driver (Trafikkontoret, 2008). However, cyclists should always follow applying rules for cyclists. In all cases the cyclist holds the responsibility, though the responsibility is sometimes shared with drivers.

Riding in bus lanes is allowed in some municipalities in Sweden, including Gothenburg. This is useful for experienced cyclists in the crowded central Gothenburg where there is a lack of cycle paths (*Inom Vallgraven)*, but not as useful for elderly and children.

2.3 Studies in Sweden

Many studies have been carried out in Sweden regarding bicycle safety. Presented in this chapter are two studies, one about safety at cycle crossings and the other about drivers yielding behaviour against cyclists at intersections.

2.3.1 Safety at cycle crossings and paths

The traffic safety of a cycle crossing is often in discussion, as the cycle crossing itself does not require drivers to yield (Svensson et al., 2011). One problem with this formation is that it gives cyclist deceptive expectations that they, like pedestrians at crossings, do not have to give way. That is why it is not recommended to design cycle crossings without speed reduction measures and/or yield or stop signs for cyclists. A cycle crossing without safety enhancements measures will always give low standards.

2.3.2 Drivers yielding behaviour against cyclist at intersections

Drivers in Sweden generally give way to cyclist on non-signalized cycle paths crossings, or in 58 per cent times (Pauna et al., 2009). This is significantly high as the traffic law in Sweden states that cyclist should always give way for cars when entering an intersection from a cycle path (if there is no yielding sign for cars). Note should be given that this study did not include Gothenburg, but nevertheless the results give a good idea of current general situations in Swedish cities.

More drivers give way for cyclist when the yield sign is located before the crossing cycle path than for situations where the yield sign is placed after it (Pauna et al., 2009). Also, more drivers give way for cyclist at crossings in roundabouts and 4-way intersections than in 3-way intersection. One reason for this is the current traffic rules. The least safe situation is where there is no yield signs at all, thus causing confusion amongst travellers (Svensson&Pauna, 2010).

2.4 Cycle facilities and rules in nearby countries

Since the 1970´s many municipalities in the Netherlands, Germany and Denmark have invested heavily in cycle infrastructure (WSP, 2011). These leading bicycle-commuting nations have set their goal for many years to increase cycling and at the same time decrease cycle related accidents. Many municipalities in Finland and Sweden have also set their goal to increase cycling and enhance cycle safety.

2.4.1 Denmark

Though Denmark is one of the leading nations for bicycle commuting, the share of cyclists has decrease in the last 15 years or so (WSP, 2011). Cycling is prohibited on sidewalks and children under the age of 6 are not allowed to cycle without the company of a 15 year old or older individual. Mopeds in category 2 (<30 km/hour) are allowed on cycle paths (Jensen, 2013). Cyclists arriving at crossings from segregated paths always have to give-way. The cycle network is based on one-way cycle paths with exceptional two-way paths. Two-way cycle paths are designed with a minimum width of 2.5 metres and one-way paths or lanes with minimum width of 1.7 metres.

2.4.2 Finland

In Finland cycling accounts for nearly 10 per cent of all trips, which is similar to Sweden (WSP, 2011). The goal is to increase cycling trips with 20 per cent. Current traffic rules are similar to Sweden´s with the exception that children under the age of 12 are allowed to cycle on sidewalks. As in Gothenburg, two-way cycle paths are more common than one-way cycle paths.

2.4.3 Germany

In Germany cycling account for 12 per cent of all trips but some leading bicycle commuting municipalities have up to 17-40 per cent share of all trips (WSP, 2011). Cyclists can choose to ride on roads even though there is an aligned cycle path and are also allowed to ride on bus lanes. Children up to the age of ten can chose to ride on the sidewalk and children under the age of 8 must do so, and consider pedestrians when doing so. Turning vehicles must give-way to cyclists at bicycle crossings (Jensen, 2013). Cyclists travelling on paths aligned with main routes have the right of way for crossing vehicles but cyclists on separated paths have to give way for vehicles when crossing a road. Two-way cycle paths are designed with a minimum width of 2.5 metres and one-way paths or lanes with minimum width of 1.6 metres.

2.4.4 The Netherlands

Cities in the Netherlands are densely build which has enhanced cycle commuting as there are shorter distances in peoples' daily routine (WSP, 2011). Some cities have up to 40 per cent of all trips done with bicycle. Bicycle crossing are marked with noticeable colours. Most of the serious bicycle accidents occur at intersections with the involvement of motor vehicles (55%). Drivers are always responsible for bicycle – motor vehicle accidents. Cyclists are not allowed to ride on sidewalk, regardless of age (Jensen, 2013).

It differs between municipalities how the cycle network is constructed but more often it is designed with segregated one-way cycle paths on each side of the road and there are also two-way cycle paths. Standard path widths are 2.5 metres for one-way cycle paths with a minimum of 2.0 metres and 4 metres for two-way pathswith a minimum of 2.5 metres (Jensen, 2013).

2.4.5 Summary

A summary is presented in Table 1 with a comparison of cycle facilities in nearby countries to those in Gothenburg.

Table 1. Cycle facilities in nearby countries and in Gothenburg.

	Gothenburg (Sweden)	**Denmark**	**Finland**	**Germany**	**Netherlands**
Are cycle paths normally one-way cycle paths?	No, two-way	Yes	No, two-way	Yes	Yes
Two-way cycle path width (minimum) [m]	2.3-2.5 (2.0)	2.5 (2.5)		3.0 (2.5)	2.5-4.0 (2.5)
One-way cycle path width (minimum) [m]	2.0 (1.2)	2.2 (1.7)		2.0 (1.6)	2-4.0 (2.0)
Are cyclists allowed to ride on sidewalks?	No	Only children 0-5 years old	Only children 0-12 years old	Only children 0-10 years old	No
Are cyclists obligated to use cycle paths when they are available?	Yes	Yes		No	Yes, but signs can allow to ride bicycles on roads

2.5 Studies from nearby countries

A cycle lane on the main road network makes drivers more aware of cyclist than segregated cycle paths, and it is easier to give cyclist continuous priority at intersections with minor roads and minimize conflictions with pedestrians (McClintock, 1996). Fully segregated cycle path can deceive cyclist into a false sense of security, hence they will not be prepared when the path eventually aligns with the main road network. Cycle lanes also need less space than cycle paths, which is a great plus in a dense urban area with little space available. Correspondingly motor vehicle speed tends to be lower thus reducing the need for the greater protection provided by cycle paths. However, in outer parts of cities the need for cycle paths will be greater as the average traffic speed is higher and there is more space available for cycle facilities. Studies from Canada show that there is an increased risk when cyclists arrive at an intersection in the direction opposite of traffic (Cycling in Cities Research Program, 2009).

Accident studies from the Netherlands show that one-way cycle paths are safer than two-way cycle paths where most dangerous accidents occur, at intersections, and therefore one-way cycle paths are favoured (SOU, 2012). Positive results have come from the measure which give cyclist more net advantage regarding time, distance and safety, and these measures include cycle infrastructures that are more direct and quicker than road routes (McClintock, 1996). Other measures that give cyclist their own space at traffic lights in front of motor vehicles have also shown significant results benefitting the cyclist.

It has been shown in the Netherlands that well-constructed cycle infrastructure decreases the accident rate (SOU, 2012). More than 80 per cent of all roads with max 50 km/hour speed limit have aligned cycle facilities but only 45 per cent of all cycle related accident occur at these facilities.

2.5.1 Denmark; Cycle Safety at intersections with two-way cycle paths

A study was performed in Denmark to clarify the link between design and the risk of accidents at intersections with two-way cycle paths aligned with roads. The study included all non-signalized cycle path - road intersections with two-way cycle paths in 17 municipalities throughout Denmark with annual average daily traffic with more than 100 vehicles (Jensen, 2013). A total of 776 intersections were registered and the accident data was police reported and accounted for 12 years, between 2000-2011. This long period was chosen to increase the amount of data, as there are less than 100 bicycle – motor vehicle accidents per year on two-way cycle paths in Denmark. The total number of accidents for these years was 384 for all registered intersections. The bicycle traffic flow was counted to elaborate models. The intersections with most accidents in relation with bicycle flow were located on cycle paths with highest frequency of intersections. At intersections where motor vehicles had did not have to give way, the accident rate was 20 times higher than where the cyclists had right of way, with regards to traffic flow. The bicycle - motor vehicle accident rate is significantly higher at T-intersections or roundabouts where the driver has right of way. The researcher also found that increased bicycle traffic increases safety at intersections. It was not mentioned if this increased safety differed between directions of arriving cyclist for the increased bicycle flow.

The conclusion of the study is that it is safer to design the cycle path as close to the main road as possible than to design the cycle path so drivers from the side road has to cross the cycle path first, before entering the main road (Jensen, 2013). Segregated cycle paths at intersections can also increase cyclists' sense of security and may make them more inattentive and careless.

2.5.2 Finland; Drivers' Visual Search and Behaviour Conflicts

Three studies from Helsinki, Finland, were made regarding bicycle safety on two-way cycle paths. The first study was performed to analyse car-cyclist collisions at non-signalized intersections (Summala et al. 1995). The study was carried out in the middle of the 1990´s and was based on accident data reported by the police between the years 1987-1989. The researchers identified 39 accidents at 25 intersections. Most of the intersections were three-way (or T-intersection), and a couple were four-way intersections. The gathered car-bicycle collisions data were split into 8 types according to actual direction of motion of the participants. A large majority of these accidents occurred when the driver was entering the intersection and planning a right turn and hitting a cyclist coming from the right. This type of accident occurred 27 times out of 39 total accidents, 69 per cent, so this "black spot" event (Type A), see Figure 4, appeared to be a specific safety problem.

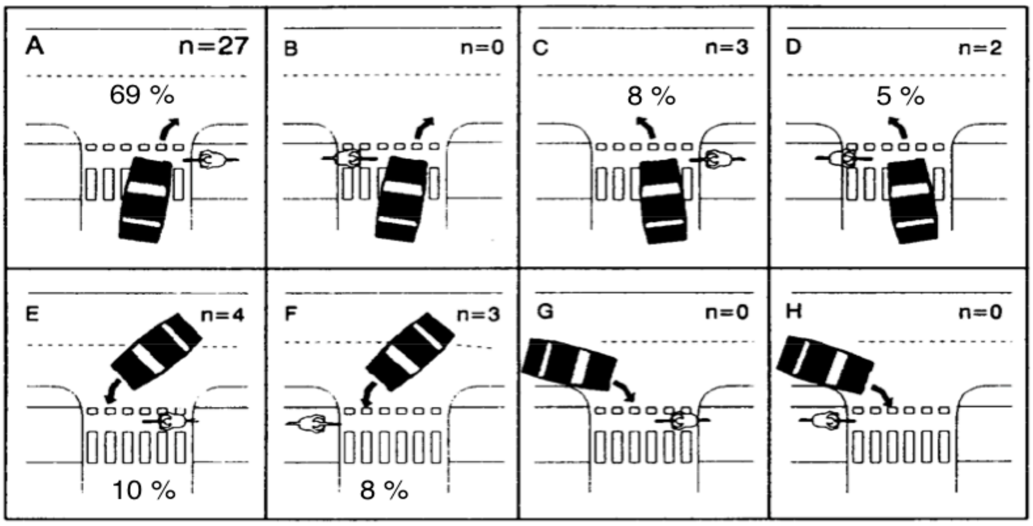

Figure 4. This study from Helsinki categorized accident types according to actual direction of participants. Type A occurred most times where the driver failed to notice the cyclist when entering an intersection with plans to turn right (Summala et al. 1995).

In the total of 30 cases when the driver is about to cross the bicycle path before entering the intersection and the cyclist is coming from the right the driver is about to turn right in 27 cases (Type A) against only 3 times when the driver is about to turn left (Type C), as seen in Figure 4 (Summala et al. 1995). The driver's task differs when turning right and left. When the drivers is turning left he or she has to be aware of motor vehicles coming from both directions but when turning right he or she only has conflicting paths with motor vehicles coming from the left. It is interesting that the drivers turning left manage to avoid collisions with cyclist better although they have to detect motor vehicles coming from both directions. The researchers hypothesized therefore that the explanation lied in the major difference in visual scanning behaviour when detecting motor vehicles; drivers turning right only scanned for cars coming from the left and missed cyclist coming from right and drivers turning left also scanning to the right and detecting cyclist from right doing so.

In direct continuation a second study was performed where the researchers recorded drivers' scanning behaviour when approaching two T-intersections with hidden video cameras (Summala et al. 1995). The results confirmed stated hypothesis at both intersections. Drivers turning right simply focus their attention on cars coming from the left and fail to see the cyclist from the right early enough.

The preliminary results also showed that speed-reducing countermeasures along with road markings changed the drivers' visual patterns in favour of the cyclist coming from the right, probably because the drivers were simply provided with more time to scan both directions. The result show that in a given environment or infrastructure driver's visual scanning differentiates according to their specific task and results in black-spot events, thus a behaviour that does not take into account certain hazards (Summala et al. 1995). Experienced drivers learn what is important in the traffic environment and where it is located, creating a visual strategy. This created visual strategy helps drivers avoid collisions with motor vehicles but at the same time may hide less frequent and less dangerous hazards, such as a cyclist coming from the right. This driver behaviour can be seen as fully rational as it takes into account the major threats, but he or she may not have learnt that there might come cyclist from the right, and if there is the driver has most likely learnt that cyclist usually give away. Drivers trade between speed and safety, meaning that they optimize their scanning behaviour to keep satisfying speed, thus selecting their attention to major threats and ignore minor threats. Then, when drivers are provided with more time with speed reducing countermeasures, the right-turn drivers don't need as much time scanning to the left for cars so the have time scanning right or *at least* forward which makes it possible to detect cyclist coming from the right. Finally, researcher made the statement that another strategy to remove these studied black spot events would be to remove cyclist coming from right unexpectedly, to avoid altogether two-way cycle paths.

The third study on the topic showed that two mayor behaviour differences between cyclists and drivers was the main reason for bicycle - collisions at two-way cycle path intersections (Räsänen&Summala 1998). One was attention failure, and the second was unjustified expectations about the behaviour of others. In 17 per cent of the accidents studied both participants did not notice the other at all before the collision. The most frequent accident type was when a driver was turning right at an intersection and collided with a cyclist coming from right, failing to see the cyclist coming. Only 11 per cent of drivers noticed the cyclist before the accident in this type of collision showing a significant lack in scanning performance. In contrast behaviour of the drivers, cyclist noticed the car in 68 per cent of the accident and 92 per cent of those thought the driver would give way as required by law. The cyclist noticed the car slow down and thus thinking the car would give way, wrongly interpreting the drivers' behaviour. An important note here is that the law was changed after the study, requiring cyclist to yield at intersections.

As presented before in this sub chapter, the most frequent collision type in Finland for bicycle – motor vehicle accidents is when the driver is turning right and cyclist is coming from the right (Räsänen&Summala 1998). This has also been shown in studies from Germany and the U.S.A. Finnish researchers have gone so far to claim that it is safer to cycle on a cycle lane than on two-way cycle paths along streets and that the risk is 3-times higher for cyclist crossing an intersection on a two-way cycle path than for those who are crossing on a cycle lane (Pasanen, 2001).

3 Method

This chapter will explain methods used to get reliable results. It will start with data gathering, followed by field observations and inventory and end with data analysis and calculation methods.

3.1 GIS data gathering

The Swedish Transport Agency (Transportstyrelsen) provided all bicycle related accident data in Gothenburg municipality for the years 2002-2013 from the STRADA (Swedish Traffic Accident Data Acquisition) database. Accidents have been registered into the STRADA database from hospital and police reports in Gothenburg since 1978 and has included geographical coordinates for each accident from the early 1990's, which is helpful when analysing accidents with geographical information systems, *or* GIS (Trafikkontoret, 2009:1). Accident data was provided in an excel spreadsheet and imported into GIS software ArcGIS as a shape file. Coordinate system used was Sweref-TM.

Gothenburg Municipality (Trafikkontoret) provided the city´s cycle network as GIS files, which included cycle paths and mixed traffic roads.

Aerial photos from 2008 were gathered from Chalmers A-database, with origin from the Swedish National Land Survey (Lantmäteriet).

3.2 Locating one-way cycle paths

Gothenburg municipality does not have separated digital data sets for one-way cycle paths. These paths were therefore located manually on a cycle map with the help of one of the municipality's traffic engineers, *Lars-Erik Lundin*. Thereafter the one-way cycle paths were drawn in GIS as a separate shape file, see Figure 5. Later on, after field observations, some additions and adjustments were made to the one-way cycle path shape file.

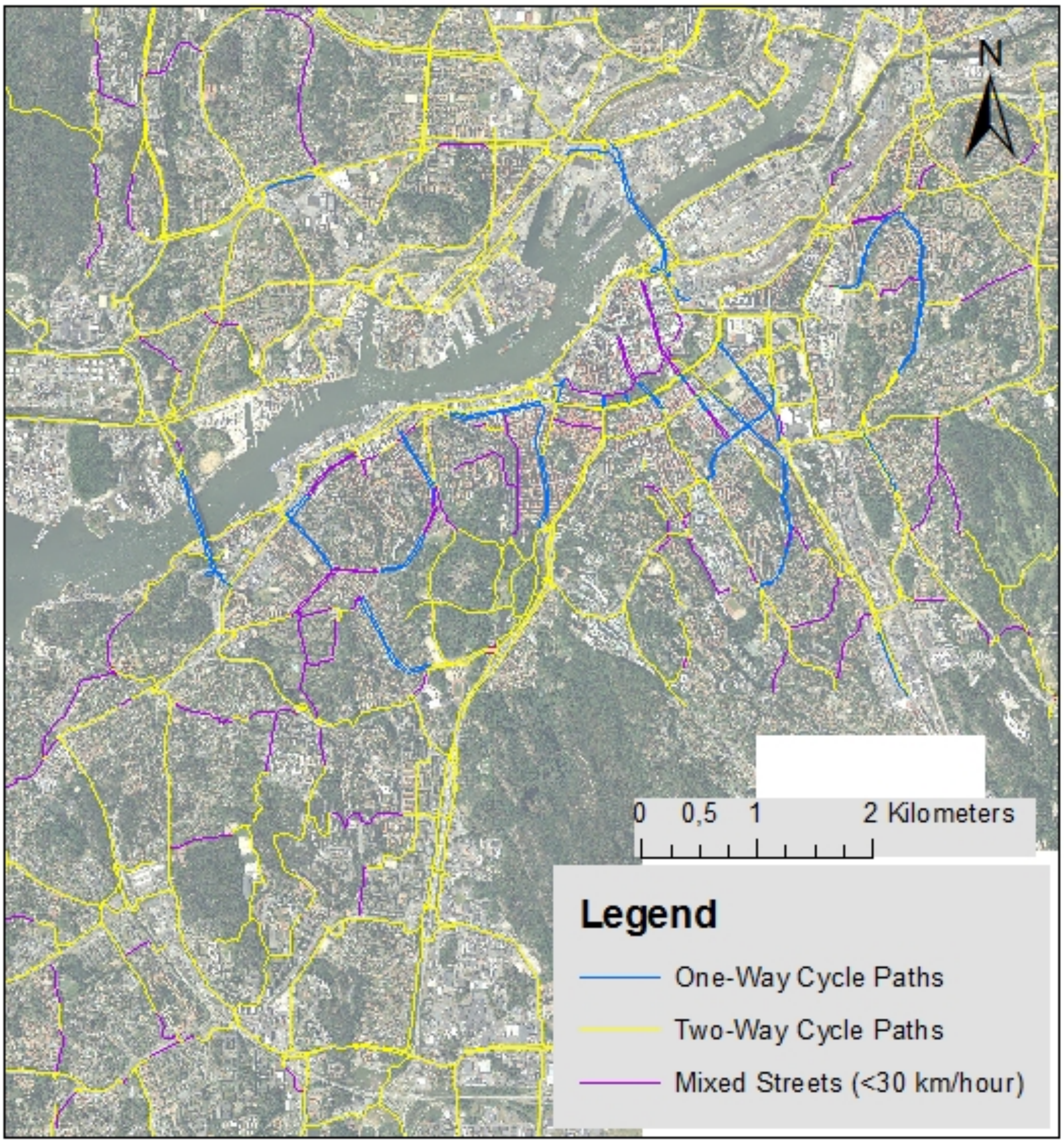

Figure 5. Bicycle paths in Gothenburg (zoomed area).

3.3 Selection of study area

A restricted central area was chosen for the study. The area was chosen with a 3 km radius from church *Haga* to include all one-way cycle paths of interest, see Figure 6. The area stretches from *Slottskogsgatan* and *Kungsladugårdsgatan* in the west to *Danska vägen* in the east. *Hisingen*, north of the *Göta Älv* River was excluded from the area as well as the two bridges (Älvsborgsbron and Göta älvbron) to focus on the mainland.

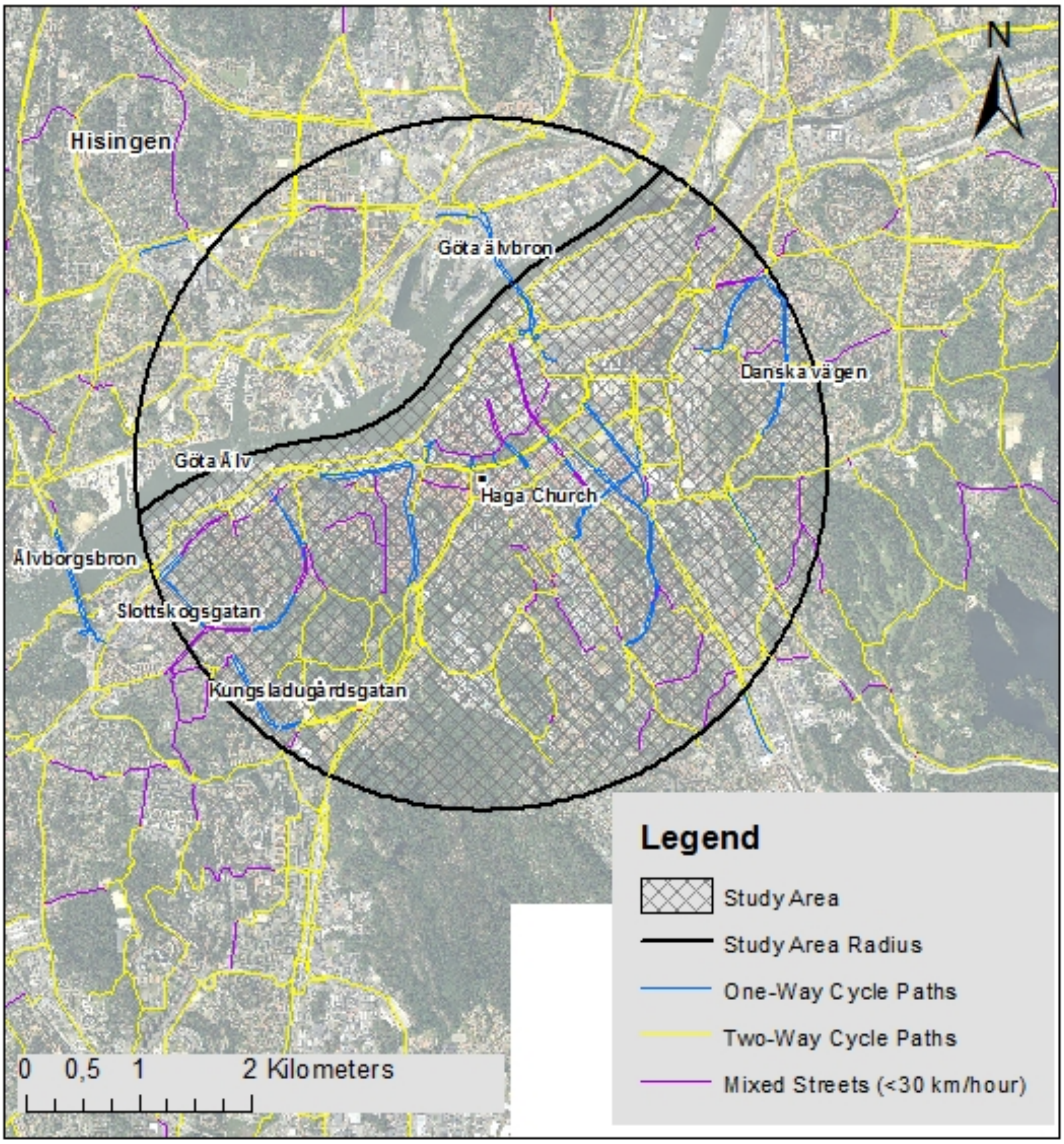

Figure 6. The study area with a 3 km radius from church Haga, excluding Hisingen.

3.4 Inventory of intersections

All non-signalized crossings with one-way cycle path were identified and categorized after environment (T-intersections, 4-way intersections and roundabouts). This documentation was performed with field observations. For comparison, crossings with two-way cycle paths were identified and categorized the same way with the goal to collect as many crossings as possible within the study area. Exits from bigger parking lots were included as intersections but exits from properties were excluded from the study. Figure 7 and Figure 8 present examples of intersection layout types. Other intersection types are presented in Appendix II: Intersection layout types.

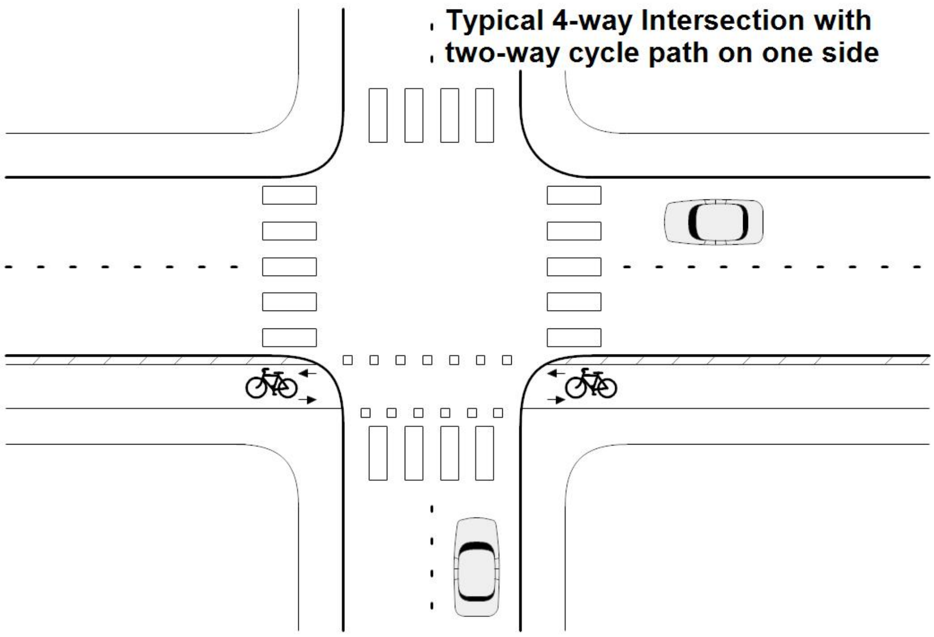

Figure 7. Example of an intersection layout; 4-way intersection with a two-way cycle path crossing.

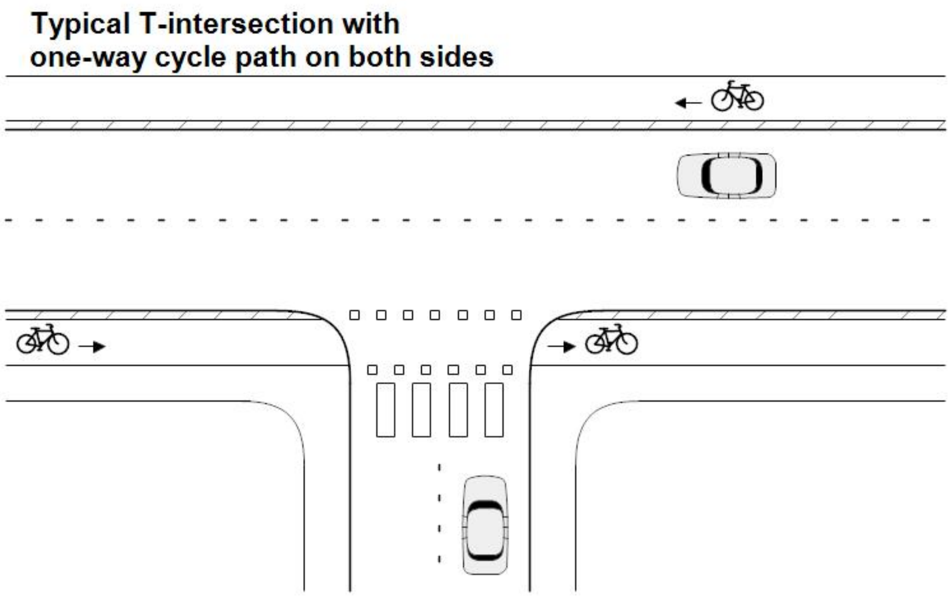

Figure 8. Example of an intersection layout: T-intersection with a one-way cycle path crossing.

3.5 Bicycle traffic flow data gathering

Gothenburg municipality has automatic bicycle traffic flow stations at 19 places in the city. The locations of stations located inside or nearby the study area are presented in Figure 9. A more detailed figure of these stations and the bicycle flow values are presented in Appendix IV: Bicycle traffic flow. The bicycle traffic flow for the years 2006 to 2013 during the summer period (2^{nd} and 3^{rd} quarter of the year) was used with the average value for passages per day. Cycle paths at these counting stations with more bicycle traffic flow then 2000 passages per day were considered with high bicycle traffic flow. All cycle paths without a counting station were assumed to have less than 2000 passages per day, or low bicycle traffic flow. The traffic safety at selected non-signalized crossings on these low bicycle traffic flow paths were than compared. It turned out that there is no counting station located on a one-way cycle path.

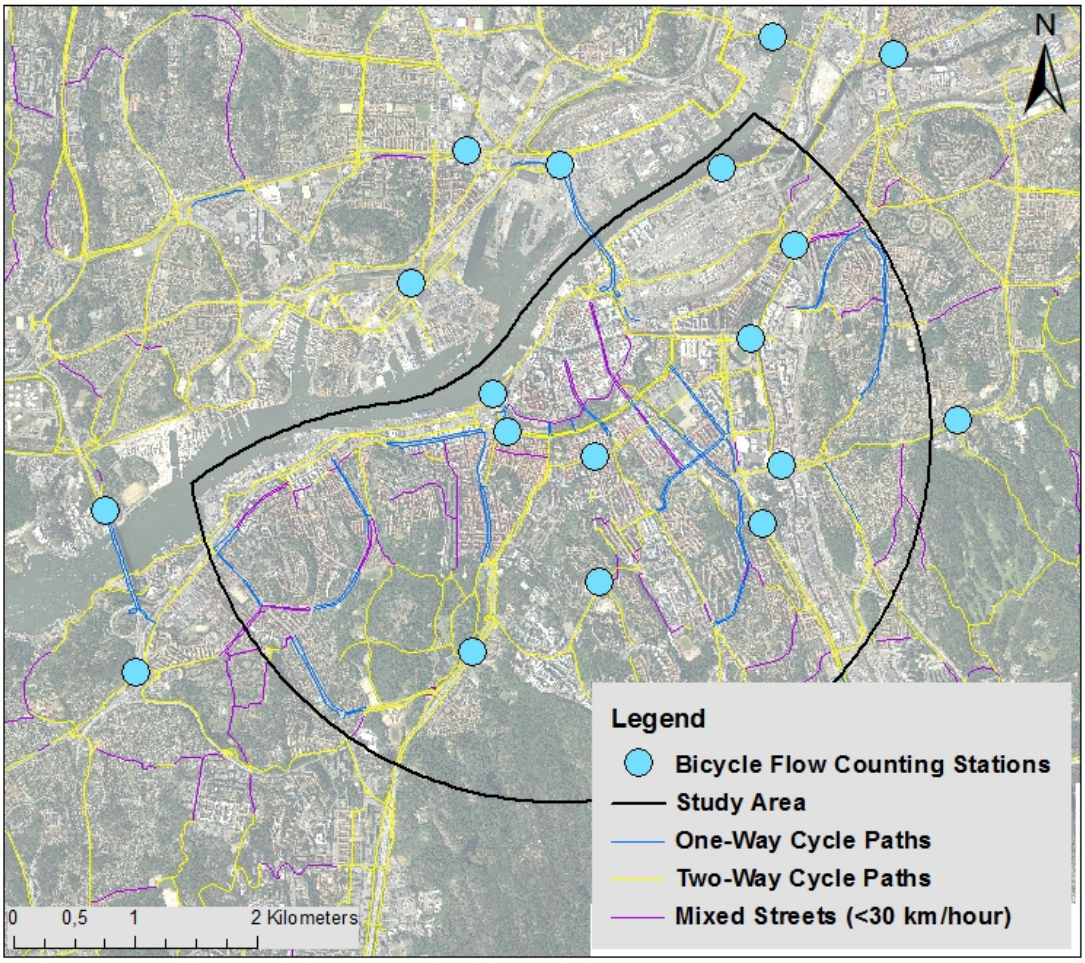

Figure 9. Bicycle traffic counting stations in Gothenburg.

3.6 Data Analysis

3.6.1 Accident data analysis

The accident data was examined and analysed in an excel spreadsheet for the years in question. Accidents were categorized after type of collision and the severity level. Accident data analysis for the whole Gothenburg municipality is presented in chapter 4.1. The same analysis was done for the studied area and is presented in chapter 4.3.

3.6.2 GIS data analysis

The length of one-way cycle paths, two-way cycle paths and mixed streets was calculated in GIS both for the whole municipality and for the study area. Inside the study area, the total length of one-way and two-way cycle paths aligned with the road network was also calculated.

The accident data shape file was divided into different accident categories in GIS. Bicycle – motor vehicle accidents were exported as a separated layer. Cycle path lengths within the study area were calculated in the GIS program.

Bicycle - motor vehicle accidents inside the study area were categorized manually if they occurred at one-way- or two-way cycle path, on mixed street or else where (other), as this information is not pre registered in the STRADA database. It is included in the database however if accidents occurred at intersection, roundabouts, road or path stretches or else where (School area, housing area, etc.). Some minor changes were made manually to these registrations. This information includes *all* intersections.

Selected non-signalized intersections were examined in GIS with bicycle – motor vehicle collisions accident shape file layer on top of an aerial photo. The total number of accidents for each crossing was counted and registered for each crossing. Intersection type was also registered and if the crossing is located on a one-way or two-way cycle path. This information was used to calculate accidents per crossing for the comparison between one-way and two-way cycle paths. The example presented in Figure 10 shows a T-right intersection with a two-way cycle path crossing. The accident to the left is registered and linked to the cycle crossing. The accident on the right occurred at a pedestrian crossing and is therefore not included.

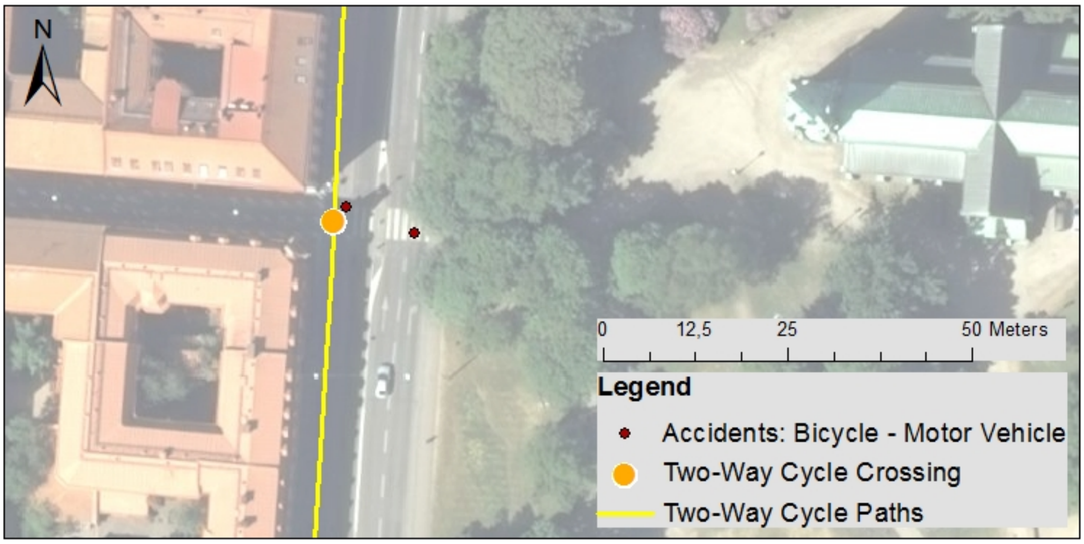

Figure 10. Example of intersection analysis (Sprängkullsgatan / Haga Östergata).

3.6.3 Calculations

Calculations for all intersections

To make the comparison fair, accidents on cycle paths were divided by direction because there are two direction paths on two-way cycle paths and only one direction on one-way cycle paths. The accidents are for a 12-year span so the comparison unit is also presented with accidents per year. The favoured comparison unit would be intersection accidents per direction per intersection, but the total number of intersections within the study area is unfortunately unknown. Therefore it is assumed that the intersection frequency is the same for one-way and two-way cycle paths and the length of cycle paths was used for the comparison. So the comparison unit is; intersection accidents per direction per kilometre per year.

Calculations for non-signalized intersections

Accidents were divided by direction and total amount of crossings for each intersection type (T-intersection, 4-way intersection or roundabout). The safety comparison between the paths in question is provided with the unit; bicycle – motor vehicle accidents per direction per non-signalized crossing. The accidents are for a 12-year span so the comparison unit is also presented with accidents per year.

Difference calculations

The difference value between cycle crossings at one-way and two-way cycle paths is calculated with Equation 1, both for the comparison of all intersections and for the comparison of non-signalized intersections.

$$Difference = \frac{Accidents\ per\ Direction\ per\ Crossing_{\ (two-way)}}{Accidents\ per\ Direction\ per\ Crossing_{\ (one-way)}} - 1 \qquad (1)$$

4 Case Study Results

This chapter will present results from the case study. It will start with a brief accident data analysis for the whole Gothenburg municipality followed by a short sub chapter presenting one-way cycle paths. The study area will be presented with a brief accident data analysis for the area sub seeded by results and comparison of one-way and two-way cycle paths at non-signalized intersections. Finally, a summary results chapter will close the chapter with the fundamental comparison values.

4.1 Bicycle accidents in Gothenburg

Accident data acquired from STRADA includes all bicycle related accidents for the years 2002-2013 in Gothenburg municipality. The total number of accident for the time period was 5012 and the categories are slight, moderate, severe and fatalities.

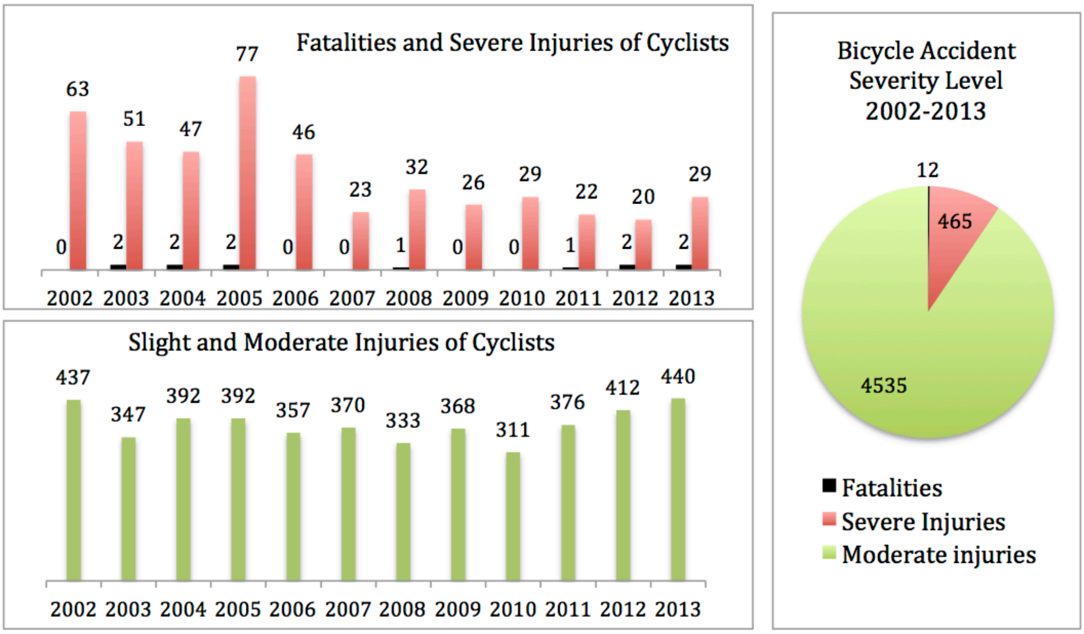

Figure 11. Bicycle accidents in Gothenburg 2002-2013.

As seen in Figure 11, most of bicycle related accidents are slight and moderate. Not all bicycle accidents are reported to the STRADA database and therefore it has to be taken into account that this accident group is under represented. There is an almost linear increase of slight and moderate accidents from 2010 to 2013. This can in part be explained by increased cycling and it is worth mentioning that the bicycling in Gothenburg increased by 22 per cent between the years 2012 and 2013 (Trafikkontoret, 2013).

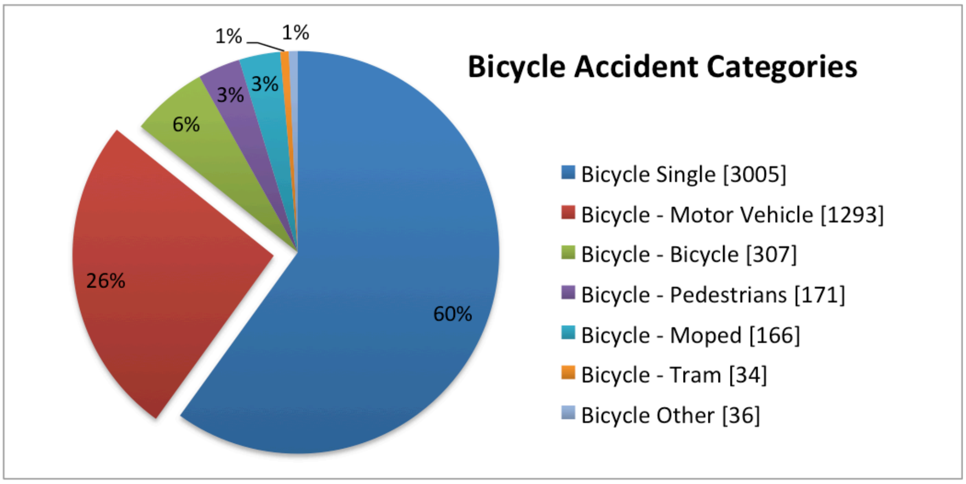

Figure 12. Bicycle related accident categories.

Figure 12 shows how the accidents are grouped by type of bicycle accident. Single related injuries are most common with 60 per cent.

The accident group of interests for this study is bicycle – motor vehicle accidents, where motor vehicles, include passenger cars, buses and trucks. This group has a high share of severe injuries and fatalities. The total number of reported bicycle - motor vehicle accidents for the years 2002-2013 was 1290, or 26 per cent of the total number of accidents within this group.

4.2 Cycle infrastructure in Gothenburg

One-way cycle paths are only 31 km in one direction. Compared to two-way cycle paths total length of 455 km, 157 km of mixed streets and 150 km local cycle paths, they hold up a small share of the total 793 km Gothenburg cycle-network, see Table 2. Listed in Appendix I: One-way cycle paths are registered locations of one-way cycle paths and there length.

Table 2. Lengths of cycle infrastructure in Gothenburg.

Cycle infrastructure	**Length [km]**	**Share [%]**
One-way cycle paths	31	4
Two-way cycle paths	455	57
Mixed streets (<30 km/hour)	157	20
Local cycle paths	150	19
Total	793	100

Table 3 presents lengths of one-way cycle paths, two-way cycle paths and mixed streets within the study area. One-way and two-way cycle paths are presented with total length and length of paths aligned with the road network. Cycle path GIS files from Gothenburg municipality did not include local streets.

Table 3. Lengths of cycle infrastructure within the study area.

Cycle infrastructure	Length [km]	Length [km] *Aligned with road network	Share [%]
One-way cycle paths	25.6	25.6	26
Two-way cycle paths	62.1	53.4	54
Mixed streets (<30 km/hour)	19.4	19.4	20
Total	107.1	98.3	100

4.3 Bicycle accidents in the study area

As seen in Figure 13 the share of bicycle - motor vehicle accidents inside the study area is higher than for the whole Gothenburg municipality, 30 per cent compared to 26 per cent for the whole municipality. The total number of bicycle – motor vehicle accidents for the time period 2002-2013 within the study area was 604.

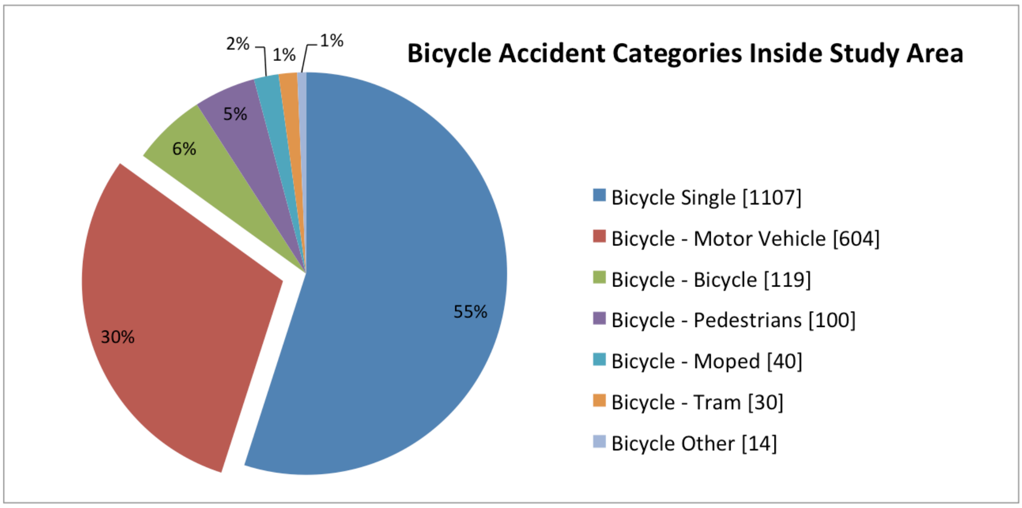

Figure 13. Accident categories inside the study area.

4.4 Bicycle – motor vehicle intersection accidents

Presented in Table 4 is the comparison of *all* intersection accidents with bicycle – motor vehicle collisions within the study area in Gothenburg for the years 2002-2013. Preferred comparison unit would be intersection accident per direction per intersection, but the total number of intersections within the study area is unknown and therefore it is assumed that the intersection frequency is the same for one-way and two-way cycle paths and the total cycle path length will be used to compare one-way and two-way cycle paths at intersections. The comparison unit used is intersection accident per direction per km of cycle path. The path lengths are calculated for cycle paths aligned with the road network so paths located through green areas (like *Slottskogen*) or newly constructed cycle paths (like *Odinsgatan*) are excluded for the length value. The comparison shows that there are more accidents on two-way intersections, with a value of 0.183 intersection accidents per km per year compared to the value 0.163 for one-way cycle path intersections.

Table 4. Bicycle - motor vehicle intersection accidents within the study area in Gothenburg for the years 2002-2013.

Cycle path	**Length [km]**	**Accidents**	**Intersection accidents**	**Intersection accidents / Direction**	**Intersection accidents / Direction / km**	**Intersection accidents / Direction / km / year**
One-way	25.6	90	50	50/1 = 50	1.953	0.163
Two-way	53.4	352	235	235/2 = 117.5	2.200	0.183
					Difference	13%

4.5 Non-signalized intersections and accidents

The total amount of non-signalized intersection accidents for both one-way and two-way cycle paths is presented in Table 5 to see the division between intersection types.

Table 5. Total amount of bicycle – motor vehicle accidents combined for both one-way and two-way cycle paths at non-signalized intersections.

Intersection type	**Non-signalized crossings**	**Share [%]**	**Accidents / Direction**	**Accidents / Direction / Crossing**	**Accidents / Direction / Crossing / Year**
4-way	34	21	16.5	0.485	0.0404
Roundabout	12	7	7.5	0.625	0.0521
T	69	43	35.5	0.514	0.0429
T-right/left	46	29	20	0.435	0.0362
Total	*161*	*100*	*79.5*	*0.494*	*0.0411*

The results for bicycle – motor vehicle accidents at non-signalized intersection is presented in Table 6 and Table 7.

Table 6. Non-signalized intersection accidents for one-way cycle paths.

Intersection type	**Non-signalized crossings**	**Share [%]**	**Total accidents**	**Accidents / Direction**	**Accidents / Direction / Crossing**
4-way	18	23	5	5/1 =5	0.278
Roundabout	7	9	3	3/1 = 3	0.429
T	30	38	14	14/1 = 14	0.467
T-right	23	29	8	8/1 = 8	0.348
Total	**78**	**100**	**30**	**30/1 = 30**	**0.385**

Table 7. Non-signalized intersection accidents for two-way cycle paths.

Intersection type	Non-signalized crossings	Share [%]	Total accidents	Accidents / Direction	Accidents / Direction / Crossing
4-way	16	19	23	23/2 = 11.5	0.719
Roundabout	5	6	9	9/2 = 4.5	0.900
T	39	47	43	43/2 = 21.5	0.551
T-right / left	23	28	24	24/2 = 12	0.522
Total	**83**	**100**	**99**	**99/2 = 49.5**	**0.596**

Table 8 presents the difference between the accidents rates for one-way and two-way cycle crossings for each intersection type. The greatest difference is for 4-way intersections and the lowest for T-intersections. The total difference between one-way and two-way cycle crossings for all non-signalized intersections combined is 55 per cent.

Table 8. The difference between the accidents rates for one- and two-way cycle crossings for each intersection type.

Intersection type	Accidents / Direction / Crossing		Difference [%]
	One-way	Two-way	
4-way	0.278	0.719	159
Roundabout	0.429	0.900	110
T	0.467	0.551	18
T-right/left	0.348	0.552	50
Total	0.385	0.596	55

It was not easy to document roundabouts as their layout form varied a lot. Many roundabouts were excluded for the reason that it would be unfair to compare them together. One example of excluded roundabout is *Korsvägen* where there are different layout forms for every bicycle crossing. Newly constructed roundabouts were also excluded if it was clear that they had been constructed later than 2002. Example of this is the newly constructed roundabout near *Heden*, where *Bohusgatan* intersects *Sten Sturegatan*. Only 5 roundabouts were registered for two-way cycle paths and 7 for one-way cycle paths. To enhance the reliability of the study the accident values were also presented without roundabouts in Table 9.

Table 9. Bicycle - motor vehicle accidents without roundabouts.

Bicycle path	**Non-signalized crossings**	**Total accidents**	**Accidents / Direction**	**Accidents / Direction / Crossing**
One-way	71	27	27/1 = 27	0.380
Two-way	78	90	90/2 = 45	0.577

4.6 Results regarding bicycle traffic flow

There were 5 two-way cycle paths within the study area with more than 2000 cycle passages per day and therefore considered high bicycle traffic flow cycle paths. These paths and related number of non-signalized intersections are presented in Table 10. Bicycle traffic flow for all counting stations is presented in Appendix IV: Bicycle traffic flow.

Table 10. High bicycle traffic cycle paths within the study area (>2000 passages/day).

Cycle path (aligned street name)	Average cycle flow [passages/day]	Non-signalized crossings
Delsjövägen	2423	5
Nya Allén	2990	1
Redbergsvägen	2187	1
Södra vägen (east of Korsvägen)	2106	3
Örgrytevägen	2590	2
Total		12

Non-signalized intersection with more than 2000 cycle passages per day are 12 and all of them are located on two-way cycle paths. These intersections are excluded in the comparison of low cycle traffic paths. The amount of bicycle - motor vehicle accidents on two-way cycle paths for each intersection type is presented in Table 11.

Table 11. Bicycle - motor vehicle accidents on non-signalized intersection on two-way cycle paths with low bicycle traffic flow within the study area.

Intersection type	Non-signalized crossings	Share [%]	Total accidents	Accidents / Direction	Accidents / Direction / Crossing
4-way	14	20	18	18/2 = 9	0.643
Roundabout	5	7	9	9/2 = 4.5	0.900
T	34	48	37	37/2 = 18.5	0.544
T-right / left	18	25	22	24/2 = 12	0.611
Total	**71**	**100**	**86**	**86/2 = 43**	**0.606**

The comparison between low bicycle traffic cycle paths on one-way and two-way cycle paths is presented in Table 12.

Table 12. Bicycle - motor vehicle accidents on non-signalized intersection on one-way and two-way cycle paths with low bicycle traffic flow.

Bicycle path	Non-signalized crossings	Total accidents	Accidents / Direction	Accidents / Direction / Crossing
One-Way	78	30	30/1 = 30	0.385
Two-Way	71	86	86/2 = 43	0.606

The comparison between low bicycle traffic cycle paths on one-way and two-way cycle paths and without roundabouts is presented in Table 13.

Table 13. Bicycle - motor vehicle accidents on non-signalized intersection on one-way and two-way cycle paths with low bicycle traffic flow and without roundabouts.

Bicycle path	Non-signalized crossings	Total accidents	Accidents / Direction	Accidents / Direction / Crossing
One-Way	71	27	27/1 = 27	0.380
Two-Way	66	77	77/2 = 38.5	0.583

4.7 Results – summary

Tables presented in chapters 4.5 and 4.6 are summarized in Table 14. Values are presented per year in

Table 15. Figure X shows the comparison on a graphic chart.

Table 14. Bicycle - motor vehicle accidents at non-signalized intersections within the study area for the years 2002-2013.

Accidents / Direction / Crossing	One-way	Two-way	Difference [%]
Total	0.385	0.596	55
Without roundabouts	0.380	0.577	52
Without high bicycle traffic flow cycle paths	0.385	0.606	57
Without high bicycle traffic flow cycle paths and roundabouts	0.380	0.583	53

Table 15. Bicycle - motor vehicle accidents at non-signalized intersections within the study area calculated per year.

Accidents / Direction / Crossing / Year	One-way	Two-way	Difference [%]
Total	0.0321	0.0497	55
Without roundabouts	0.0317	0.0481	52
Without high bicycle traffic flow cycle paths	0.0321	0.0505	57
Without high bicycle traffic flow cycle paths and roundabouts	0.0317	0.0486	53

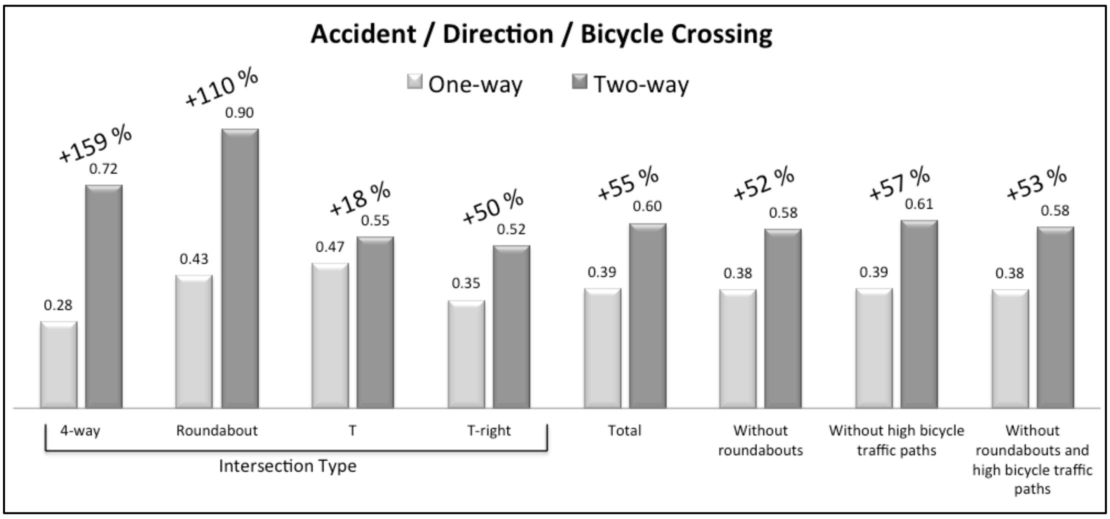

Figure 14. Summarized results on a graphic chart.

5 Discussion

This chapter will discuss results, critique method used and discuss about further studies that could be conducted regarding bicycle safety in Gothenburg.

5.1 Discussion of results

Results from this case study reveal that one-way cycle paths are safer than two-way cycle paths at intersections in the central area of Gothenburg.

Intersection accidents for all intersections within the study area

When all intersections within the study area are examined it is assumed that the intersection frequency for one-way and two-way cycle paths is the same and the cycle paths are compared with regards to the total length of each path type. The results show that intersections with two-way cycle paths have higher accident rate with the value of 0.183 intersection accidents per direction per km per year, compared to the value of 0.163 for one-way cycle paths. The difference is approximately 13 per cent. This is a fairly rough comparison between the cycle paths in question that indicate that one-way cycle paths are safer at intersections within the study area.

Non-signalized intersection accidents within the study area

The classification of intersection was done with recommendations from Gothenburg municipality. The layout form were T-intersections, T-right/left, 4-way intersections and roundabouts. Some intersections had restrictions from intersecting side streets.

Table 5 presents one-way and two-way non-signalized intersections combined to show the share each intersection layout holds. It is interesting that T-intersections (regular, not T-right/left) have higher accident rate per crossing than 4-way intersections with the value 0.0429 compared to 0.0404. The values are though very similar for all intersection layouts, except for roundabouts, which has a value of 0.0521 accidents per direction per crossing.

The most common intersection layout for non-signalized intersection is the T layout. One reason is that it is more common for 4-way intersection to be guarded, or signalized. The comparison shows that the accidents per direction per crossing values are higher for two-way cycle paths for all intersection layouts. This reflects studies that have been made in other countries as presented in the literature study. The difference between one-way and two-way cycle paths is greatest for 4-way intersections followed by roundabouts. The total value for one-way cycle paths is 0.0321 accidents per direction per crossing per year compared to 0.0497 for two-way cycle paths.

Bicycle traffic flow

It is very hard to measure bicycle flow because the flow variation between days is great. Accident data used for this case study is for a 12-year span and it is almost impossible to calculate or estimate the bicycle flow for each documented non-signalized crossing during this time period. Gothenburg municipality automatic counting stations are placed at 19 locations and give a good average value of passages per day at these locations, even though there are missing values for some years (see Appendix IV: Bicycle traffic flow). The reason for comparing low bicycle traffic paths was to see if the bicycle flow had any impact on the values. The accident values were higher on two-way paths with lower bicycle traffic flow. As presented in the literature study, other studies have shown that increased cycling increases safety in numbers. More cyclists result in more accident events but the accident rate per cyclist decreases. So it is surprising that when excluding high bicycle traffic paths the accident value is actually lower.

Reliable results

In the authors opinion the most reliable results are when comparing one-way and two-way cycle paths without roundabouts (see Table 14 and

Table 15) and disregarding bicycle traffic flow values. It so happens that this comparison also gives minimum difference between the cycle paths in question. The accident per direction per crossing per year value is approximately 52 per cent higher for non-signalized intersection on two-way cycle paths compared to one-way cycle paths, 0.0317 versus 0.0481.

Gothenburg Municipalities visions and strategies

Gothenburg favours two-way cycle paths in level with sidewalks, as mentioned in the literature study and they have planned to reconstruct one-way cycle paths into two-way cycle paths on two stretches this year. On stretch is located on *Södra vägen*´s east side between *Korsvägen* and *Engelbrektsgatan*, and the other stretch is located on *Berzeliigatan*´s north side between *Södra vägen* and *Sten Sturegatan*.

The cycle paths in Gothenburg are narrow compared to Denmark, Germany and the Netherlands, both one-way and two-way cycle paths. During field observation it was noticed that cyclists often ride the wrong way on one-way cycle paths. The minimum design width of one-way cycle paths is 1.2 metres, which does not give much room to meet cyclists. The minimum design width for two-way cycle paths is 2.0 metres. The Netherlands has a minimum design width of 2.0 metres for one-way cycle paths and 2.5 metres for two-way cycle paths. This is something that Gothenburg should aim for in future cycle infrastructure planning to improve cycling in the city.

5.2 Critique of method

The study area was chosen with a radius to include all one-way cycle paths in the central area of the city. It would have increased the workload to examine the whole municipality region, wasting valuable time. Another reason is that one-way cycle paths are only within the central region of the city, thus it would not improve the results to compare crossings located on paths outside the chosen study area as they are in neighbourhoods with two-way cycle paths. *Hisingen* area on the other side of the *Göta Älv* River was excluded to focus on the mainland. There is also only one short stretch of one-way cycle path north of the River located at *Hjalmar Brantings gatan* and therefore unnecessary to include this area to enhance the reliability of the case study. To improve the reliability of the study however, the radius could have been made longer so the study area would have included more two-way cycle paths for the comparison. With more time this would have been possible.

It is not obvious where all non-signalized cycle path intersections are located and some were likely overseen during field observations. The author is certain that the greater share of all intersections of interest within the study area were included in the case study.

When dividing accidents per direction it is in the favour of two-way cycle paths at some instances. This is because at some places there are two-way cycle paths located on both sides of the road (example *Övre Husargatan*) and at other places there is a two-way cycle path on one side and one-way cycle path on the other side (example *Sankt Sigfridsgatan*).

Gothenburg municipality does not have registered on digital format where one-way cycle paths are located. These one-way cycle paths were manually drawn on a map and then imported in GIS and edited during field observations. It is possible that some short one-way cycle path stretches are missing.

Accidents in the STRADA database are under represented because not all hospitals and health centres (*Vårdcentral*) report accidents to the database. It is also worth mentioning that one-way cycle path accidents are over represented for T-intersection in comparison because three of the accidents involved a cyclist riding the wrong way on the cycle path. The way accidents are registered in the accident database lacks consistency. Some events are registered with information about the direction of vehicles and bicycles involved in the collision and speed and other details as well as accurate geographical position. Other events are poorly registered and some have incorrect coordinates. Events reported by the police have usually correct coordinates.

5.3 Further studies of bicycle safety in Gothenburg

It would be interesting to conduct a similar study as was done in Helsinki regarding non-signalized T–intersections with two-way cycle paths. Directions of drivers and cyclists before the collisions would be compared to see if one instance is more likely than others, like driver turning right and colliding with a bicyclists coming from the right. This would require a lot of data gathering, as the STRADA database would not be enough to conduct this sort of study because, sadly, the STRADA does not include the direction of vehicles before collision for all accident events.

There is a lack of consistency in the cycle network in Gothenburg and it is hard to cycle the right way the first time one tries a new cycle way and at some places it is difficult to know if one is cycling on a one-way cycle path or a two-way cycle path. During field observation it was noticed that cyclists were frequently riding the wrong way on one-way cycle tracks. Three documented accidents for this case study did also include a cyclist going the wrong way on a one-way cycle path. It would be interesting to conduct a study with observations on one-way cycle paths to see the rate of cyclist riding the wrong way. It would also be interesting to ask wrong way riding cyclists if they know what rules apply for the cycle path, or if they are simply disregarding the rules.

This study did only examine bicycle – motor vehicle collisions at intersections. Cyclists colliding with other cyclists have they same share of accidents for the whole municipality as inside the studied area, with 6 per cent. It would be interesting to study if bicycle – bicycle collisions are more common at two-way cycle paths where meeting bicyclists is more common than on one-way cycle paths.

6 Conclusions

The conclusion of this study is that one-way cycle paths are safer than two-way cycle paths at non-signalized intersections in the central area of Gothenburg. The comparison shows that the accident per direction per intersection value is higher for two-way cycle paths for all intersection layouts. The total value for one-way cycle paths is 0.0321 accidents per direction per non-signalized intersection per year compared to 0.0497 for two-way cycle paths. More reliable results are when roundabouts are excluded from the study with values 0.0317 accidents per direction per non-signalized intersection for one-way cycle paths compared to 0.0481 for two-way cycle paths. These results reflect studies carried out in other countries where one-way and two-way cycle paths were compared regarding bicycle safety at non-signalized intersections.

Bicycle traffic flow did not affect the case study results. When excluding high bicycle traffic path from the study it favoured one-way cycle paths.

When all intersections are examined within the study area in central Gothenburg it revealed that more accident occur where two-way cycle paths are in place compared to one-way cycle paths. The value for one-way cycle paths is 0.163 compared to the value 0.183 for two-way cycle paths, with the unit intersection accidents per km per year.

The literature study presented that there is a general uncertainty amongst drivers and cyclist in Sweden what traffic rules apply for cycle crossings. Field observations during the case study made clear that it is common for cyclists to ride the wrong way on one-way cycle paths and the accident data showed that this caused several bicycle – motor vehicle collisions for the years 2002-2013.

Gothenburg favours two-way cycle paths and have planned to reconstruct one-way cycle paths into two-way cycle paths later this year. The cycle paths in the city are to narrow compared to cycle paths in cities in Denmark, Germany and the Netherlands.

It is an expensive and unnecessary solution to rebuild all of Gothenburg's cycle system but when building new cycle facilities or renewing current ones one-way cycle paths should be considered.

Many municipalities in Finland and Sweden have set their goal to increase cycling and enhance cycle safety. It seems however that these northern Scandinavia countries are one step behind the leading countries Denmark, Germany and the Netherlands. Gothenburg have come along way in their cycle planning and have increased cycling while enhancing bicycle safety. But there is always room for improvement of the cycle infrastructure to make cycling safer and a more attractive choice.

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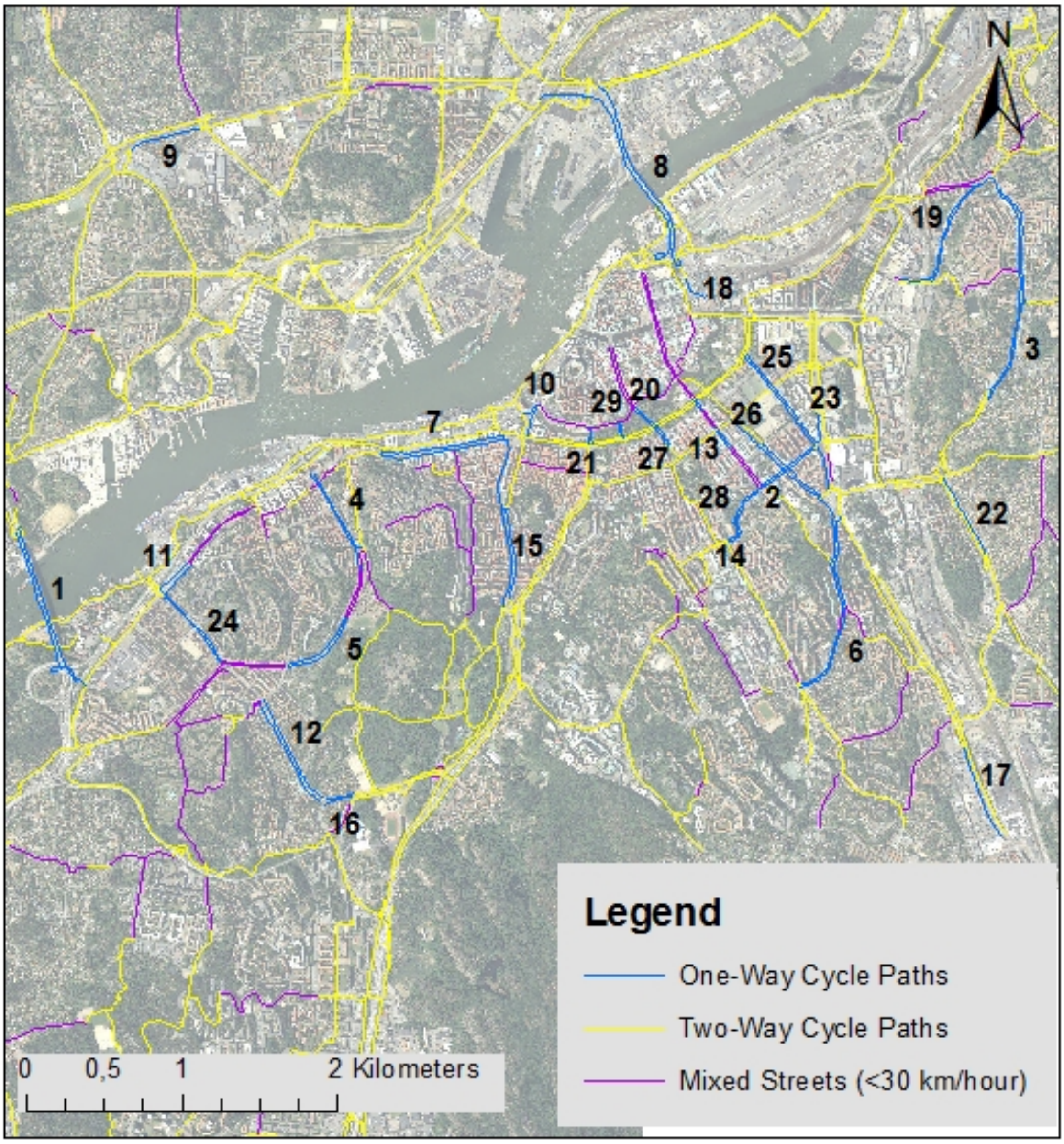
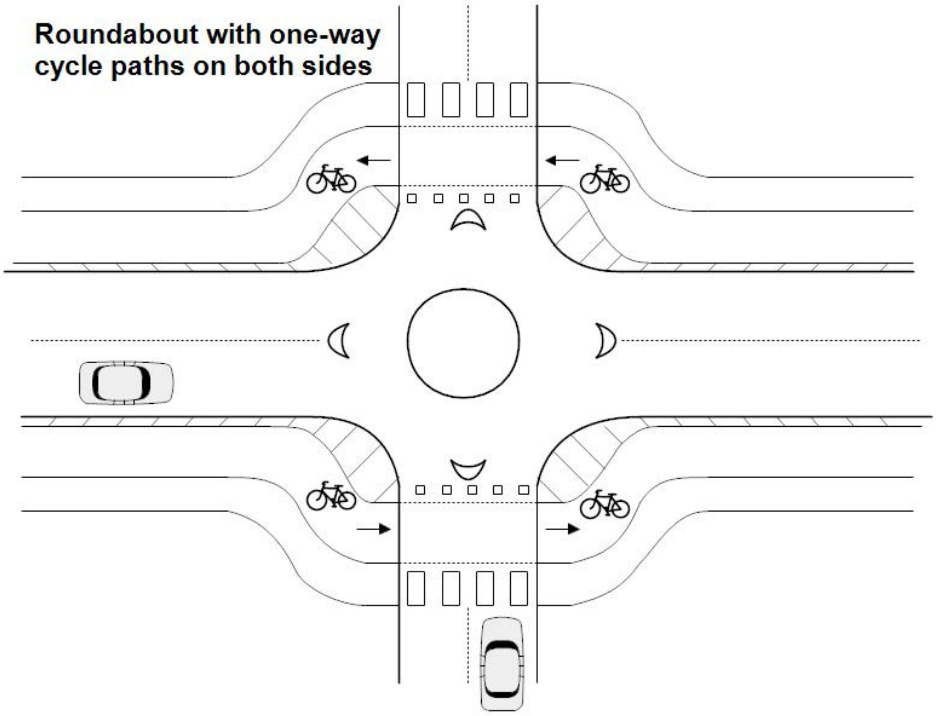
Appendix I: One-way cycle paths

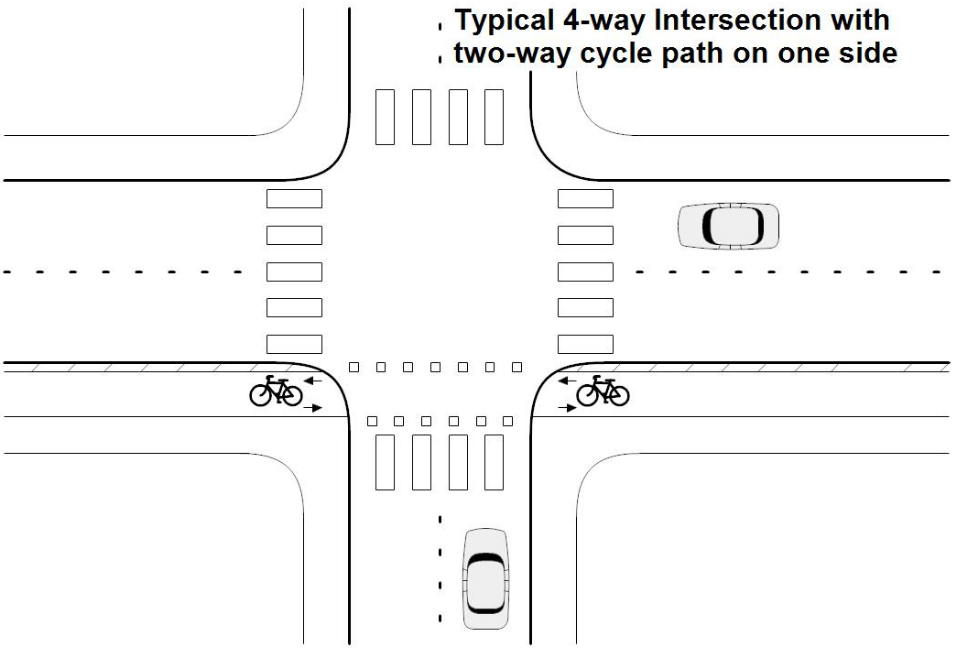
#	Aligned Street Name	Location	Length [m]	Non-signalized Crossings
1	Älvborgsbron	Both sides	2355	*Outside study area*
2	Berziliigatan	Both sides	851	5
3	Danska vägen	Both sides	3014	8
4	Djurgårdsgatan	Both sides	1287	7
5	Ekedalsgatan	Both sides	1052	0
6	Eklandagatan	Both sides with exceptions	2499	8
7	Första Långgatan	Both sides	1641	4
8	Götaälvsbron	Both sides	3117	*Outside study area*
9	Hjalmar Brantingsgatan	One side	474	*Outside study area*
10	Järntorgsgatan	Both sides with exceptions	332	0
11	Karl Johansgatan	Both sides	554	0
12	Kungsladugårdsgatan	Both sides	1527	11
13	Kungsportsavenyn	Both sides (stretches)	498	0
14	Läraregatan	Both sides	201	0
15	Linnégatan	Both sides with exceptions	1749	9
16	Margretebergsgatan	Both sides	384	0
17	Mölndalsvägen	One side	630	0
18	Nils Ericssongatan	One side	197	0
19	Norra Gubberogatan	Both sides	1711	2
20	Raoul Wallenbergs gata	Both sides	384	0
21	Rosenlundsbron	Both sides	205	0
22	Sankt Sigfridsgatan	One side	572	4
23	Skånegatan	One side (stretches)	504	2
24	Slottsskogsgatan	Both sides	1115	8
25	Sten Sturegatan	Both sides	1522	1
26	Södra vägen	Both sides with exceptions	1246	4
27	Vasaplatsen	Both sides	275	2
28	Viktor Rydbergsgatan	Both sides	731	3
29	Viktoriabron	Both sides	196	0
		Total	30823	78

Gothenburg cycle network with one-way cycle paths numbered

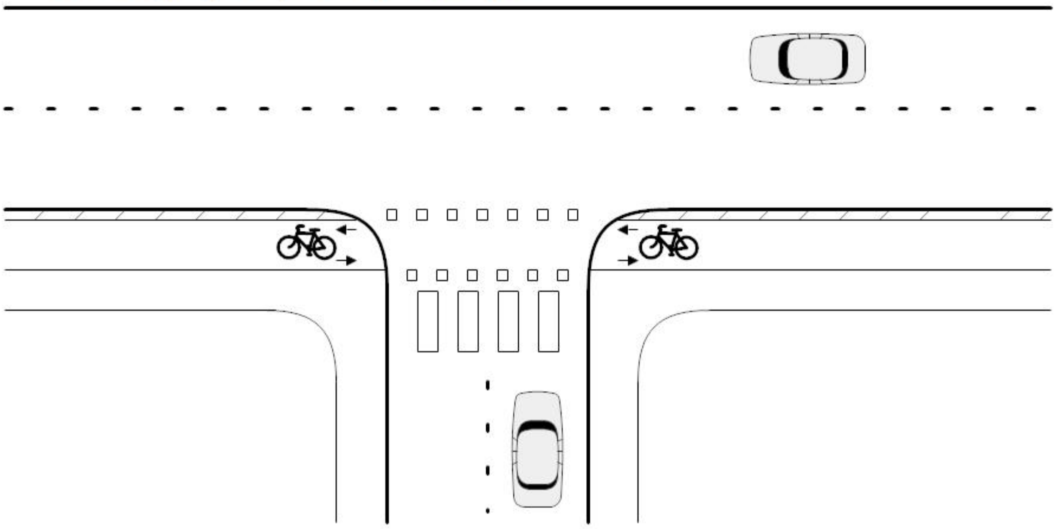


Appendix II: Intersection layout types

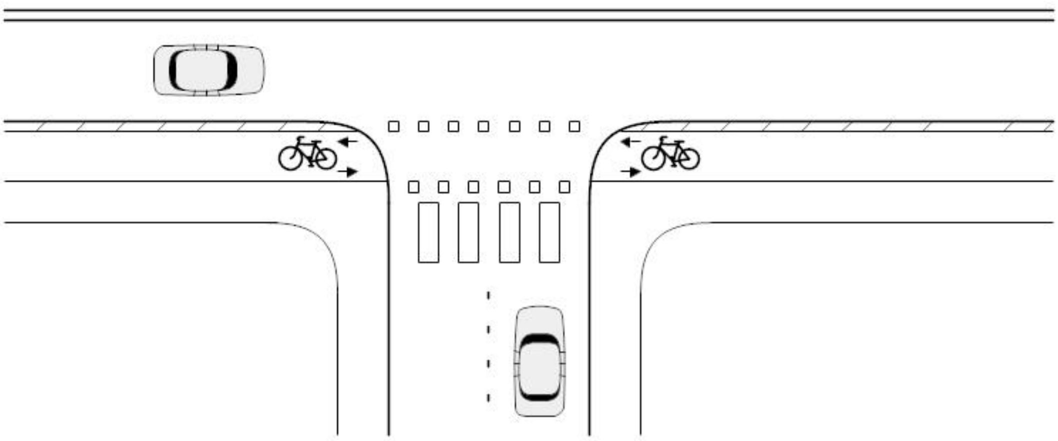


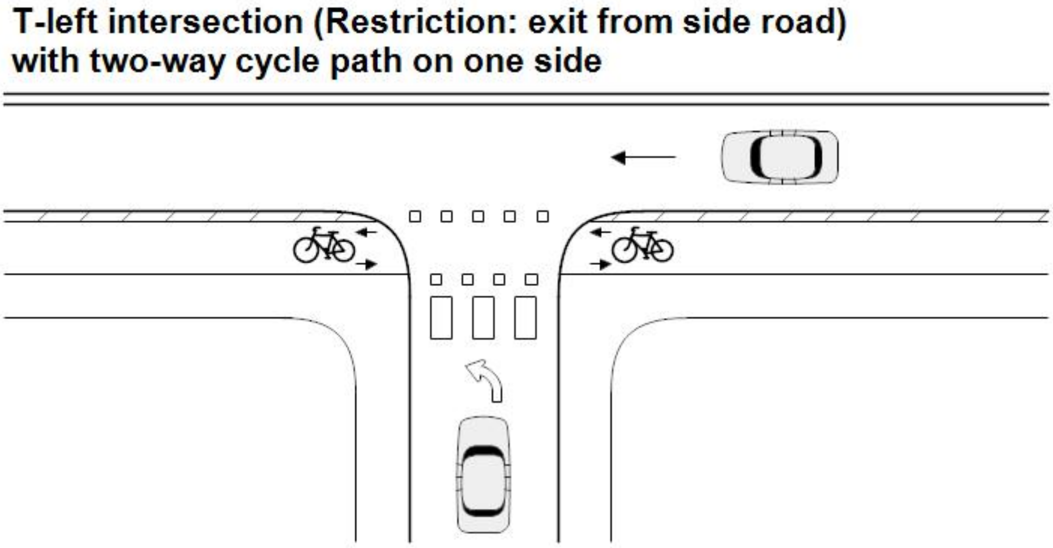


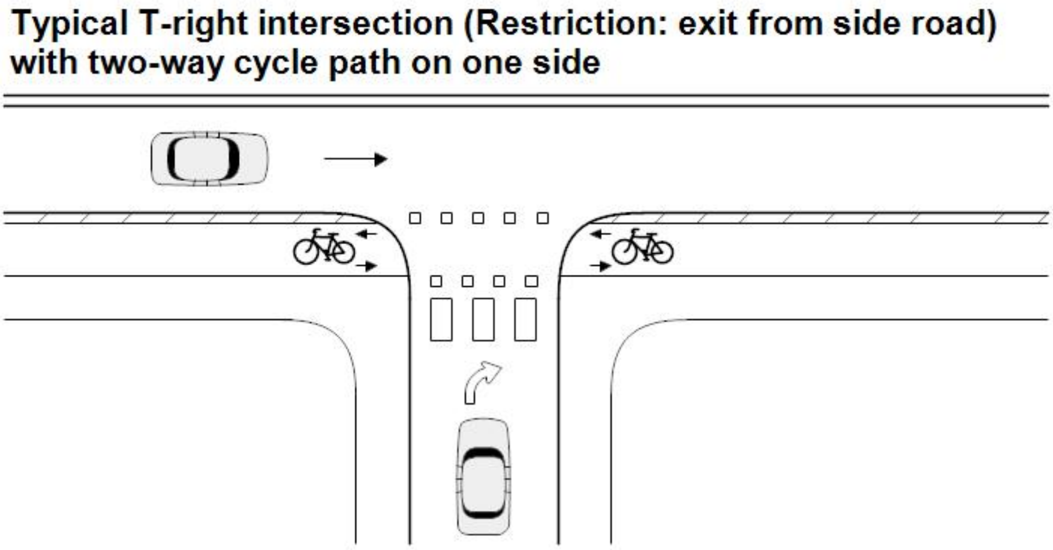
Typical T-intersection with two-way cycle path on one side

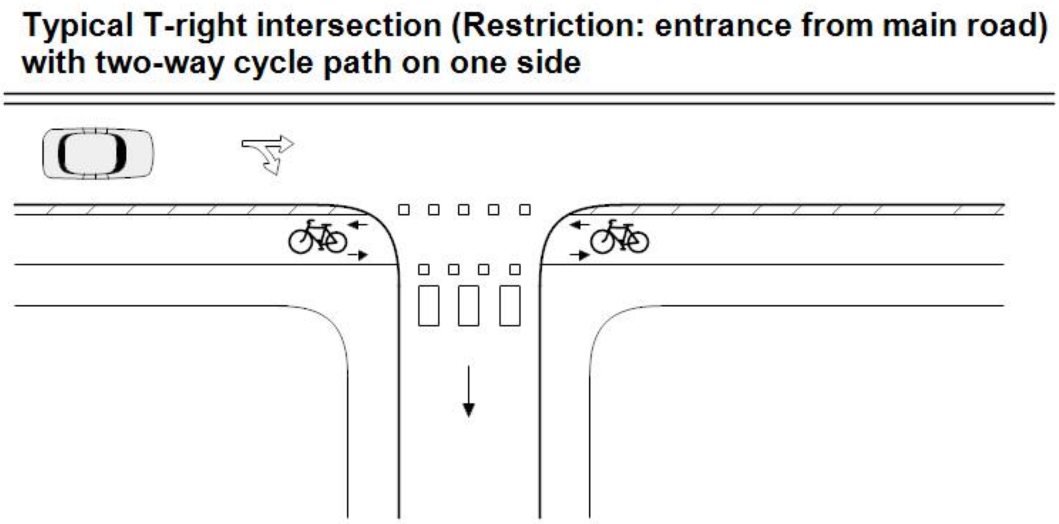


Typical T-right intersection with two-way cycle path on one side




T-left intersection (Restriction: exit from side road)
with two-way cycle path on one side


Typical T-right intersection (Restriction: exit from side road)
with two-way cycle path on one side


Typical T-right intersection (Restriction: entrance from main road)
with two-way cycle path on one side

Appendix III: Non-signalized crossings

Non-signalized crossings on one-way cycle paths

#	Aligned Street Name	Side	Intersecting Street	Type	Restriction	Accidents	Comments
1	Berzeliigatan	N	Hedåsgatan	4-way		0	
2	Berzeliigatan	N	Götaplatsen	T		0	
3	Berzeliigatan	N	Wadmansgatan	T	Exit	1	Cyclist going wrong way
4	Berzeliigatan	S	Hedåsgatan	4-way		0	
5	Berzeliigatan	S	Johannebergsgatan	T		1	
6	Danska vägen	E	Kärralundsgatan	Roundabout		0	
7	Danska vägen	E	Prästgårdsgatan	T		0	
8	Danska vägen	E	Pärlstickaregatan	T		0	
9	Danska vägen	E	Torkelsgatan	T		0	
10	Danska vägen	E	Räntmästaregatan	T		0	
11	Danska vägen	E	Nobelplatsen	T		0	
12	Danska vägen	W	Lilla Danska vägen	Roundabout		0	
13	Danska vägen	W	Ingeborgsgatan	T		0	
14	Djurgårdsgatan	E	Amiralitetsgatan	4-way		1	
15	Djurgårdsgatan	E	Oljekvarnsgatan	4-way		0	
16	Djurgårdsgatan	E	Almänna vägen	4-way	Exit	0	
17	Djurgårdsgatan	W	Almänna vägen	4-way		0	
18	Djurgårdsgatan	W	Amiralitetsgatan	4-way		0	
19	Djurgårdsgatan	W	Oljekvarnsgatan	4-way	Exit	0	
20	Djurgårdsgatan	W	Koopmansgatan	T		0	
21	Eklandagatan	E	Carlenders platsen	4-way		1	
22	Eklandagatan	E	Utlandagatan	T		3	
23	Eklandagatan	E	P-plats	T		2	
24	Eklandagatan	E	Gyllenkrooks gatan	T	Exit	1	
25	Eklandagatan	E	Cederbourgsgatan	T	Exit	0	
26	Eklandagatan	W	Carlandersplatsen	4-way		0	
27	Eklandagatan	W	Volrat Thomsgatan	T		0	
28	Eklandatagatan	E	P-plats	T		2	
29	Forsta Långgatan	N	Johannesplatsen	Roundabout		0	
30	Forsta Långgatan	S	Johannesplatsen	Roundabout		3	
31	Forsta Långgatan	S	Masthuggstorget	T-right	Entrance	1	
32	Forsta Långgatan	S	Masthuggstorget	T-right	Exit	1	
33	Kungsladugårdsgatan	E	Godhemsgatan	4-way		0	
34	Kungsladugårdsgatan	E	Stathallaregatan	4-way	(Tram)	2	
35	Kungsladugårdsgatan	E	Högsbogatan	Roundabout		0	
36	Kungsladugårdsgatan	E	Margretebergsgatan	Roundabout		0	
37	Kungsladugårdsgatan	E	Klintens väg	T-right		1	
38	Kungsladugårdsgatan	E	Sundhagsgatan	T-right		0	
39	Kungsladugårdsgatan	E	Gatsmygen	T-right	Entrance	0	
40	Kungsladugårdsgatan	W	Ståthållaregatan	4-way	(Tram)	0	
41	Kungsladugårdsgatan	W	Högsbogatan	Roundabout		0	
42	Kungsladugårdsgatan	W	Klintens väg	T-right		0	

#	Aligned Street Name	Side	Intersecting Street	Type	Restriction	Accidents	Comments
43	Kungsladugårdsgatan	W	Snäckvägen	T-right		0	
44	Linnégatan	E	Olivedalsgatan	T-right		0	
45	Linnégatan	E	Majorsgatan	T-right		0	
46	Linnégatan	E	Djupedalsgatan	T-right		1	
47	Linnégatan	W	Plantage gatan	T-right		1	Cyclist going wrong way
48	Linnégatan	W	Övre Majorsgatan	T-right		1	Cyclist going wrong way
49	Linnégatan	W	Olivedalsgatan	T-right		0	
50	Linnégatan	W	Tredje Långgatan	T-right	Entrance	0	
51	Linnégatan	W	Fjärde Långgatan	T-right	Entrance	0	
52	Linnégatan	W	Andra Långgatan	T-right	Exit	0	
53	Norra Gubberogatan	E	Mintensgatan	T		0	
54	Norra Gubberogatan	W	Lagerströmsplatsen	T		1	
55	Norra Gubberogatan	E	Årbogatan	4-way		0	
56	Norra Gubberogatan	E	Pipblåsaregatan	4-way		1	
57	Norra Gubberogatan	E	Jättegrytsgatan	4-way	Entrance	0	
58	Norra Gubberogatan	E	Olof Skotkonungsgatan	T-right		0	
59	Skånegatan	W	Burgårdsgatan	T-right	Entrance	0	
60	Skånegatan	W	Tegnérsgatan	T-right	Exit	1	
61	Slottskogsgatan	E	Lilla gatan	4-way		0	
62	Slottskogsgatan	W	Carnegiegatan	4-way		0	
63	Slottskogsgatan	W	Kustroddaregatan	T		0	
64	Slottskogsgatan	W	Högergatan	T		0	
65	Slottskogsgatan	W	Ostindiegatan	T		0	
66	Slottskogsgatan	W	Tranegatan	T	Entrance	0	
67	Slottskogsgatan	W	Långlandia	T	Entrance	0	
68	Slottskogsgatan	W	Peter Bagges gata	T	Entrance	0	
69	Södra vägen	N	Tegnersgatan	T	Entrance	0	
70	Södra vägen	N	Burgårdsgatan	T-right	Exit	0	
71	Södra vägen	S	Kristinelundsgatan	T-right		0	
72	Södra vägen	S	Olof Wijksgatan	T-right		0	
73	Sten Sturegatan	E	Hallandsgatan	T		0	
74	Vasaplatsen	E	Storgatan	T-right		1	
75	Vasaplatsen	W	Storgatan	T	Entrance	0	
76	Viktor Rydbergsgatan	N	Arkivgatan	T	Entrance	0	
77	Viktor Rydbergsgatan	S	Läraregatan	T		2	
78	Viktor Rydbergsgatan	S	Ekmansgatan	T		1	
					Total	30	

Non-signalized crossings on two-way cycle paths

#	Aligned Street Name	Side	Intersecting Street	Type	Restriction	Accidents
1	Amund Grefwegatan	N	Kapellgatan	T		1
2	Bangatan	W	Amiralitetsgatan	T		0
3	Bangatan	W	Parkering, hus	T		0
4	Carl Skottsbergs gata	E	Storängsgatan	4-way		3
5	Danska vägen	E	Bäckeliden	T		1
6	Danska vägen	W	Överåsgatan	T		1
7	Delsjövägen	E	Tandåsgatan	T		2
8	Delsjövägen	S	Orangerigatan	4-way		3
9	Delsjövägen	S	P-plats	T		1
10	Delsjövägen	S	Skårsgatan	T		1
11	Delsjövägen	S	Storagårdsgatan	T		0
12	Dr Allards gata	N	Syster Estrids gata	T		0
13	Ehrenströmsgatan	E	Doktor Allards gata	4-way		3
14	Fridkullagatan	E	Burås Kyrkbacke	4-way	Entrance	1
15	Fridkullagatan	E	Liljeforsgatan	4-way	Exit on opposit side	2
16	Fridkullagatan	E	Framnäsgatan	T		0
17	Fridkullagatan	E	Pilbågsgatan	T		1
18	Friggagatan	E	Alströmaregatan	T		0
19	Gibraltargatan	W	Fysiken	4-way		2
20	Gibraltargatan	W	Vera Sanbergs Allé	T		0
21	Gibraltargatan	W	Hugo Gruers gata	T		1
22	Gibraltargatan	W	P-plats Närhälsan	T		0
23	Gibraltargatan	W	Kemivägen	T		1
24	Gibraltargatan	W	Chalmers, P-plats	T		1
25	Gibraltargatan	W	Engdahlsgatan	T		0
26	Gibraltargatan	W	Borraregatan	T		0
27	Gibraltargatan	W	Mossen, P-plats	T		2
28	Gibraltargatan	W	Chalmers Tvärgata, nord	T	Entrance	2
29	Gibraltargatan	W	Chalmers Tvärgata, syd	T	Exit	0
30	Guldhedsgatan	E	Doktor Saléns gata	T-right		3
31	Guldhedsgatan	E	Ehrenströmsgatan	T-right	Exit, one-way road	1
32	Guldhedsgatan	N	Reutersgatan	Roundabout	Wavrinskys Plats	2
33	Guldhedsgatan	S	Norra Porten E (Sahlgrenska)	T		3
34	Guldhedsgatan	S	Norra Porten W (Sahlgrenska)	T		4
35	Guldhedsgatan	S	Blå stråket (Sahlgrenska)	T-right		3
36	Guldhedsgatan	S	Gröna stråket (Sahlgrenska)	T-right		2
37	Guldhedsgatan	S	Apotekaregatan	T-right		0
38	Guldhedsgatan	W	Wavrinskys Plats	Roundabout		3
39	Gullbergs Strandgata	N	P-plats, båtar	T		2
40	Gullbergsbrogatan	S	Garverigatan	T-right	Entrance	0
41	Gullbergsbrogatan	S	Lilla Garverigatan	T-right	Exit	0
42	Karl Johansgatan	N	Bensin station	T-right	Entrance	1
43	Landalagatan	E	Amund Grefwegatan	T		1

#	Aligned Street Name	Side	Intersecting Street	Type	Restriction	Accidents
44	Landsvägsgatan	E	Bergsgatan	4-way		1
45	Landsvägsgatan	E	Haga Nygata	4-way	One-way road	0
46	Landsvägsgatan	E	Lilla Risåsgatan	T-left	One-way road	1
47	Landsvägsgatan	E	Frigångsgatan	T-left	One-way road	0
48	Margretebergsgatan	N	Slottskogspromenaden	T		1
49	Margretebergsgatan	S	Dag Hammarskjöldsleden	4-way		1
50	Margretebergsgatan	S	Parkering	T		2
51	Mäster Bengtsgatan	E	Fredriksdalsgatan	T		1
52	Mäster Bengtsgatan	E	Fridkullagatan	T		0
53	Masthamnsbron	W	Stora Badhusgatan	T		2
54	Molinsgatan	E	Vasa Kyrkogata	4-way		1
55	Molinsgatan	E	Hvitfeldtska gymnasiet, P-plats	T		1
56	Mölndalsvägen (Södra vägen)	E	P-hus	T-right		0
57	Mölndalsvägen (Södra vägen)	E	P-plats, Världskulturmuseet	T-right		0
58	Mölndalsvägen (Södra vägen)	E	Getebergsled	T-right	Entrance	0
59	Mölndalsvägen (Södra vägen)	W	Nedre Buråsliden	T-right		1
60	Nils Ericssongatan	W	Köpmansgatan	T		3
61	Nils Ericssongatan	W	Spannmålsgatan	T-right		0
62	Nya Allén	N	Stora Teatern	T-right		0
63	Örgrytevägen	N	Mässans gata	T		2
64	Örgrytevägen	N	Svenska Mässan, p-plats	T-right		2
65	Övra Husargatan	W	Nordenskjöldsgatan	Roundabout		0
66	Övre Husargatan	E	Nordenskjöldsgatan	Roundabout		0
67	Per Dubbsgatan	E	P-plats, Annedalskyrkan	T-right		1
68	Per Dubbsgatan	W	Askimsgatan	T-right		0
69	Redbergsvägen	E	Lilla Olskroksgatan	4-way		2
70	Sankt Sigfridsgata	W	Kallebäcksmotet	T-left	Exit	1
71	Sankt Sigfridsgatan	W	Årbogatan	4-way		1
72	Sankt Sigfridsgatan	W	Pipblåsaregatan	4-way		0
73	Sankt Sigfridsgatan	W	Jättegrytsgatan	4-way		1
74	Sankt Sigfridsgatan	W	Kallebäcksmotet	4-way	Entrance	1
75	Sankt Sigfridsgatan	W	Skårsgatan	Roundabout		4
76	Sankt Sigfridsgatan	W	Betaniagatan	T	Entrance	0
77	Sankt Sigfridsgatan	W	Kallebäcksmotet	T-right	Exit	4
78	Sprängkullsgatan	E	Lilla Bergsgatan	T		3
79	Sprängkullsgatan	W	Haga Nygata	T-right		3
80	Sprängkullsgatan	W	Haga Östergata	T-right	Entrance	1
81	Stora Badhusgatan	E	Heurlins Platsen	4-way		1
82	Sven Rydells gata	E	Vallhallagatan	T		1
83	Vallhallagatan	N	p-plats	T		2
					Total	99

Appendix IV: Bicycle traffic flow

Bicycle traffic flow values for the years 2006-2013 are presented in the Table IV. Values are provided from Gothenburg Municipality and the unit is passages per day during the 2nd and 3rd quarter of the year. The location of each automatic counting station is presented on a figure in the continuing page.

Table IV. Bicycle flow counting stations. Values are in passages/day.

#	Location	2006	2007	2008	2009	2010	2011	2012	2013	Average flow
1	Artillerigatan	0	0	810	870	790	740	740	930	813
2	Dag Hammarskjöldsleden	2770	2480	2710	2510	2390	2320	2240	0	2489
3	Delsjövägen	2640	2500	2630	0	2010	2330	2330	2520	2423
4	Guldhedsgatan	0	0	0	1600	1540	1410	1390	1590	1506
5	Gullbergs Strandgata	0	0	850	980	960	960	1000	1080	972
6	Götaälvbron	3680	0	3100	3570	3150	2910	2780	3300	3213
7	Hjalmar Brantingsgatan	1230	1270	1280	1320	1030	1050	1000	0	1169
8	Karlavagnsgatan	630	590	660	740	670	710	770	0	681
9	Långedragsvägen / Kungsten	0	0	0	1690	1560	1460	1520	1720	1590
10	Marieholmsbron	0	0	1310	1280	1190	1150	1160	1270	1227
11	Nya Allén / Pustervik	0	0	0	3010	2730	2840	2900	3470	2990
12	Redbergsvägen	2660	2340	0	2050	1790	1780	2070	2620	2187
13	Skeppsbron	2560	0	2770	2980	3010	3440	0	4600	3227
14	Säröleden	0	0	0	0	800	0	740	0	770
15	Södra vägen	2360	1920	0	2070	2020	2030	2030	2310	2106
16	Ullevigatan	3600	0	3120	0	3270	3240	3330	3460	3337
17	Vasagatan	5130	4630	4550	4570	3900	3890	3610	0	4326
18	Älvsborgsbron	0	0	0	0	0	1100	1140	1390	1210
19	Örgrytevägen	2800	0	2600	2650	2460	2440	0	0	2590

Automatic bicycle flow counting stations in Gothenburg