CHALMERS
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Road design analysis of Lindholmsallén in Gothenburg

An evaluation with an in depth simulation using the software program VISSIM

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

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Cover:
Photograph of Lindholmsallén taken at the bus stop Pumpgatan by the authors of the report.

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ABSTRACT

The city of Gothenburg is growing and it is important to develop a sustainable transport system in order for the city to improve further. This includes evaluating existing roads and their design. The aim for this report is to analyse the road design for the existing road Lindholmsallén and to see if it fulfils the goals that were set for the road during the planning stage. The analysis is divided into several parts to get a wide evaluation of the road. The first is interviews and an initial literature study to learn which goals that were set on the road and its design. A site investigation is also carried out and the last part is to perform a simulation, focusing on bus stop Regnbågsgatan, using the software program PTV VISSIM. From interviews it was found that the main goals were good accessibility for the public transport, safe crossings for the pedestrians and improved orientation in the area. The results from the different evaluations shows that there are no larger problems at Lindholmsallén. From the design evaluation it is found that the road in general is well designed with respect to the parameters traffic safety, accessibility, orientation and security. Comparing the results with the goals that were set, it is seen that the areas around bus stops Regnbågsgatan and Lindholmen fulfils the goals better than the areas around bus stop Pumpgatan. This mainly has to do with the simpler design of the latter. From the evaluation it is found that the high frequency of buses combined with the public transport priority are causing interruptions for the road traffic, which leads to longer queues and delays. The pedestrian crossings in the area are mostly fulfilling the goal regarding traffic safety. The exception is at bus stop Pumpgatan, where the pedestrians need to cross two car lanes. Furthermore, not all of the crossings at the street are combined with traffic calming measures. The orientation in the area have been improved compared to the old design. But the unusual design of Lindholmsallén can be confusing for road users who are unfamiliar to the road. Therefore, better information about the structure of the area should be provided by for example signs. Some simplifications and assumptions are made in the simulation that might have affected the result. Traffic violations such as pedestrians crossing the street when it is red light, is not included. The geometry of the road is also simplified, which might have affected the formation of queues and the amount of conflicts.

Key words: Road design analysis, PTV VISSIM, Traffic simulation, Boulevard, Lindholmsallén.

Analys av vägdesign för Lindholmsallén i Göteborg
En utvärdering med en fördjupande simulering med hjälp av mjukvaruprogrammet VISSIM

Examensarbete inom masterprogrammet Infrastructure and Environmental Engineering

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SAMMANFATTNING

Göteborgs stad växer och det är viktigt att sträva mot ett hållbart trafiksystem för att fortsätta utveckla staden. Detta inkluderar utveckling av befintliga vägar och dess utformning. Syftet med rapporten är att analysera vägdesignen för den befintliga vägen Lindholmsallén för att utreda huruvida den uppfyller målen som ställdes när den planerades. Analysen är uppdelad i flera delar för att få en bred utvärdering av vägen. Den första delen består av intervjuer och en litteraturstudie för att undersöka vägens utformning samt vilka mål som sattes vid planeringen. Även en fältundersökning utfördes och som en sista del också en simulering med fokus på busshållplatsen Regnbågsgatan, med hjälp av programmet PTV VISSIM. Från intervjuer framgick att huvudmålen vid utformning av vägen var att prioritera framkomligheten för kollektivtrafiken, ha hög trafiksäkerhet för fotgängare som ska korsa vägen samt öka orienterbarheten. Resultaten från utvärderingarna tyder på att det inte finns några större problem på Lindholmsallén. Genom utvärderingen av gatans utformning framgår det att den är bra utformad med avseende på parametrarna trafiksäkerhet, framkomlighet, orienterbarhet och trygghet. När resultaten jämförs med målen som sattes observerades att delarna kring Regnbågsgatans och Lindholmens busshållplats uppfyller målen bättre än delarna kring Pumpgatans hållplats. Detta beror till största del på den lägre standarden på den senare. Utvärderingen visar att bussarnas höga turtäthet i kombination med prioriteringen av kollektivtrafik orsakar störningar i biltrafiken, vilket leder till längre köer och förseningar. Övergångsställena i området uppfyller till största del målen om trafiksäkerhet för fotgängare. Ett undantag är vid busshållplatsen Pumpgatan där gående behöver korsa två körfält. Dessutom är inte alla övergångsställen på vägen försedda med hastighetsdämpande åtgärder. Orienterbarheten i området har förbättrats jämfört med den tidigare utformningen av vägen. Den annorlunda utformningen av Lindholmsallén kan dock vara svår att förstå för trafikanter som är ovana till området. Därför behövs bättre information om områdets struktur genom till exempel skyltar. Ett antal antaganden och förenklingar har gjorts i simuleringen som kan ha påverkat resultatet. Vissa trafikförseelser som fotgängare som går mot rött har inte inkluderats i modellen. Vägens geometri har också förenklats, vilket kan ha påverkat köbildningen och antalet konflikter.

Nyckelord: Analys av vägdesign, PTV VISSIM, Trafiksimulering, Boulevard, Lindholmsallén

Contents

Preface

In this report, the road design of Lindholmsallén in Gothenburg have been analysed, with an in depth evaluation using the microscopic traffic simulation software PTV VISSIM. This Master Thesis is conducted at the Department of Civil and Environmental Engineering, at Chalmers University of Technology, in collaboration with Norconsult AB.

The study has been carried out by the authors Matilda Berg Mårtensson and Johanna Fridh between January and June 2016, with the support from the supervisor Claes Johansson at the Road and Traffic Research Group at Chalmers University of Technology. Valuable support has also been received from Anders Markstedt and Gunnar Lannér, from the same research group.

We would like to thank the people working at the divisions Trafik and Väg- & Järnvägsteknik at Norconsult AB for supporting us and contributing to a good workplace. A special thanks to our supervisor Johan Hultman, your guidance and experience have been very helpful throughout the project.

Finally, we would like to thank interviewed Jöran Bellman and Lars Hansson for their valuable information. We also want to thank our opponents Camilla Gustafsson and Annamaria Haag for their input and for a good opposition.

Gothenburg, June 2016
Matilda Berg Mårtensson & Johanna Fridh

1 Introduction

Traffic and transport systems has become a large and important part of the society. Thus, it is of interest to design and plan the traffic in a smart and sustainable way. Today there exists good and developed analytical methods that are quick and reliable to use in order to evaluate the traffic situation, by determining for example the capacity and accessibility for different traffic solutions (Trafikverket, 2014a). One specific tool that can be used when evaluating traffic sites is traffic simulations. The benefit with using simulations is that you can, using a computer, implement controlled experiments for different cases. Simulation models are effective for analysing the dynamics of how traffic situations evolve and also to see how different parts of the traffic network are affected by each other during congestion. It is also a good tool for visualising different traffic situations.

1.1 Background

Gothenburg is a growing city with more and more people transporting themselves in and out of the city every day (Göteborgs Stad, 2015a). Today, several initiatives are made to improve the traffic situation in Gothenburg to make it possible to face the future in a sustainable way. One of the important parts in this is to further develop the public transport. It is therefore of interest to look at existing roads and to see if they fit a more sustainable approach. One road that is located on Hisingen in Gothenburg is Lindholmsallén, its position shown in Figure 1. This road is important for the traffic on Hisingen since it belong to the public transport core network (Västra Götaland Region, u.d.). Lindholmsallén is designed as a boulevard with the public transport situated in the middle of the road, with lanes for the remaining modes of traffic on either side. Along the boulevard there are three bus stops named Pumpgatan, Regnbågsgatan and Lindholmen.

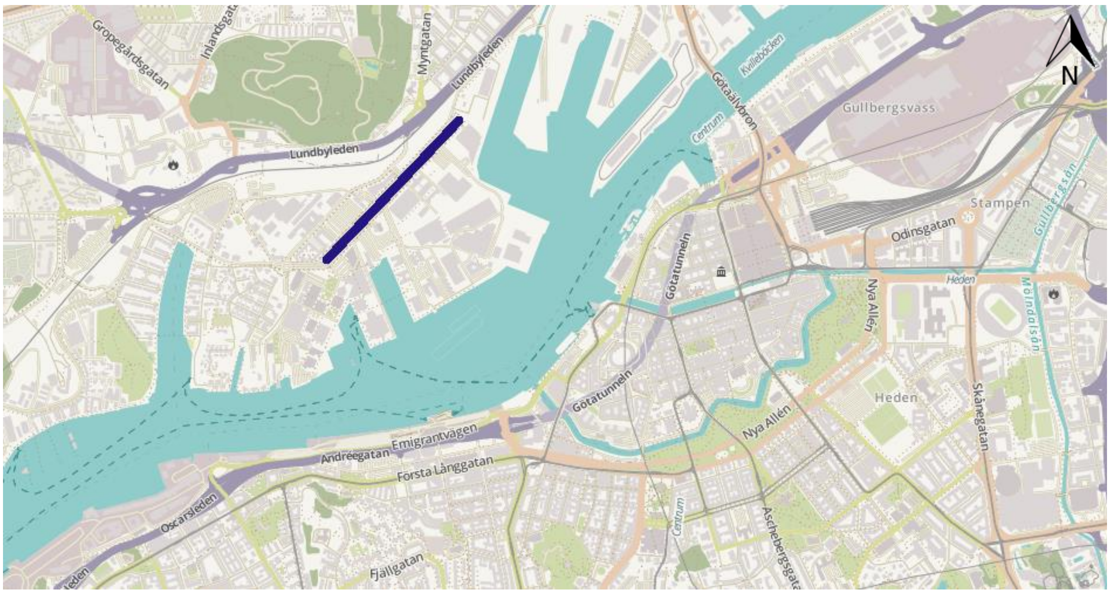

Figure 1 The location of Lindholmsallén in Gothenburg, marked in blue (OpenStreetMap contributors, 2016).

Lindholmsallén has a design which differs from others by having U-turns for crossing traffic instead of normal intersections. Together with the placement of the public transport in the centre of the road, it is of interest to see how well this design works. An evaluation of the road Lindholmsallén and all the transport modes operating here is therefore performed. This will be done to investigate whether the goals that were set on the road when planning it are fulfilled today. The investigation will also include an in depth evaluation of a selected area around bus stop Regnbågsgatan, where a simulation of the site will be made.

Today, some problem areas have been identified on Lindholmsallén and it is relevant to see how severe these problems actually are. This will include investigating how much it affects the traffic in the area and if the design of the road is the underlying cause of these problems. There are many people travelling to and from the areas around Lindholmsallén every day, especially using public transport. This means that there are large flows of pedestrians coming from the busses, which causes interruptions for the other traffic modes when they cross the bus, car and bicycle lanes. Hence, there are many interactions and interruptions among all the different traffic modes in the area, which could affect both the safety and efficiency for the travellers.

1.2 Aim

The aim of the report is to investigate the road design of Lindholmsallén in order to see if it fulfils the goals that were set for when planning the project. This includes evaluating the traffic safety, accessibility, orientation and security of the road. The investigation will be focusing primarily on the pedestrians but the other modes of transport will also be considered. An in depth investigation using the simulation software VISSIM will also be carried out, focusing on the area around the bus stop Regnbågsgatan.

1.3 Hypothesis

In order to describe and elaborate the aim of the report further, a number of questions have been developed. These will be answered during the work process and will also contribute to the analysis. The questions are the following:

- Which were the goals and objectives for the road design of Lindholmsallén?
- How is the traffic site structured and designed?
- How large quantity of every mode of transport are operating in the area?
- How do the road users behave in this traffic site?
- Are the goals that were set fulfilled?

1.4 Limitations

The investigation will primarily be focused on the pedestrians and secondarily on the public transport since these traffic modes stands for the largest modal share of the traffic on this road. All the transport modes operating on the road will be taken into account, but not with the same grade of detail. No categorisation of the transport modes has been done. The road traffic does for example include cars, trucks and motorcycles. Further on, the project will evaluate the full extent of Lindholmsallén. A part of the project will focus on the bus stop Regnbågsgatan and it is only on this specific part that the simulation will be performed. This is because it would be too complex and time consuming to look at the whole Lindholmsallén in detail. Also, focusing on one of the three bus stops will give results that are representative for the full extent of Lindholmsallén, since all parts of the road have a similar design.

The investigation will also be limited to the current traffic situation. Therefore, it will not include future projects and also not take past traffic flows on the road into consideration. The study will focus on the peak hour of the traffic in the morning, due to that the problems are believed to be worst during this time of the day. It is also assumed that the peak hour during the afternoon essentially has the same volume of traffic as the morning and that it is only of interest to look at one of the peaks. The peak hour is assumed to be at the weekdays, thus the weekends will not be taken into account.

In the process of building the model and performing the simulation of the selected area there are a number of assumptions and simplifications done. These are essential to limit the extent of the project. But it was also because some information was not possible to obtain. The assumptions and simplifications that are connected to the simulation is presented in detail in Chapter 4.

1.5 Method

Several procedures were used in this report to be able to reach the aim of this project. These methods are presented below in this chapter, in the order that they were conducted. First, to get a background and better understanding of the location being evaluated, two interviews and an initial literature study was made. This was followed by a site investigation to get a better understanding of the traffic situation on the road and also to check if the information that was received corresponds with the reality. The last part was a simulation on one of the three evaluated parts of the road. This was done to get an in depth look at the traffic situation and a detailed visualisation of the eventual problems on the road.

The results from these different parts of the analysis was combined and evaluated in Chapter 5. There the different goals that where set for Lindholmsallén when planning it are presented. With the help of the result from the different part of this report these goals was analysed to see if they are fulfilled today.

1.5.1 Interviews

To get a better understanding of the ideas behind this traffic solution and to comprehend the goals for this traffic site two qualitative interviews were carried out. The interviewees are former employees at the City Planning Authority of Gothenburg who worked with the planning and design of Lindholmsallén. The interviews were preceded by a literature study concerning Lindholmsallén and the surrounding areas. This was done in order to decide what information that would be of interest to get through the interviews. The questions were focused on the reasons behind the design of the boulevard and what goals that was to be achieved. Furthermore, questions regarding the goals of the design of the bus stops along Lindholmsallén were also asked.

The information gathered from the interviews were complemented by materials in the form of comprehensible plans and programs for the area. The local plans for different sections of Lindholmsallén were also studied to get an overview of the stages of the construction of the road.

1.5.2 Traffic safety statistics

Another method used to get a better understanding of the traffic situation on Lindholmsallén was by studying traffic accident statistics in the area. This study was done using the database STRADA (Swedish Traffic Accident Data Acquisition), which includes statistics consisting of reports of traffic accidents that are collected from the police and hospitals in Sweden (Transportstyrelsen, u.d.). To get a more detailed traffic accident investigation, Lindholmsallén was divided into three areas. These areas cover the surroundings of the three bus stops located on the road. The investigation was limited to the years between 2005 and 2014. This period was chosen because all parts of the road was not finished constructing until 2005 and all traffic accidents for 2015 may not have been reported at the time of writing.

1.5.3 Design evaluation

Another aspect that was studied is how the design of Lindholmsallén corresponds with the parameters regarding traffic safety, accessibility, orientation and security**.** The evaluation was focused on the areas around the three bus stops and was done in order to compare the bus stops to each other. When combined, the three separate areas cover most of Lindholmsallén and thus can be used together to get a good overview of the traffic situation on the road. This contributed to the general understanding of how the street works.

The parameters that were used in the evaluation of the design were based on the manual by the Swedish Transport Administration called TRAST (Transport for an Attractive City). It was modified to suit this site and the extent of the investigation. This was followed by a literature study were the parameters were studied further to decide which criteria to be used in the comparisons. The number of criteria for each parameter and mode of transport was limited to five and were not weighted against each other.

The evaluation was carried out by investigations on the site where the three areas was separately rated regarded how well the criteria were fulfilled. These ratings were then summarised and presented in two value diagrams. One is showing the total rating of the different parameters to be able to see if some parameter is better or worse than another. The other diagram shows the results but summarised into the different modes of transport. Thus resulting in two evaluations for each area:

how well it fulfils the chosen parameters and how well the different modes of transport operate in this specific area.

1.5.4 Simulation

A traffic microsimulation was carried out to study the traffic situation and to visualise the site in a better way. The simulation software PTV VISSIM 7.00-15 was used together with the additional program VISWALK, which focuses on pedestrians. The area that was simulated is located in the middle of Lindholmsallén, marked in Figure 2. This area was chosen both because it contains elements that are assumed to be representative for the entire road. But also because a large share of the traffic flow connects to the roundabout in this area, from a nearby highway. The simulation area also included the bus stop called Regnbågsgatan, located in the central part of the area, and the surrounding roads, pedestrian and bicycle paths. The simulation was done in order to distinguish what the problems are and their extent.

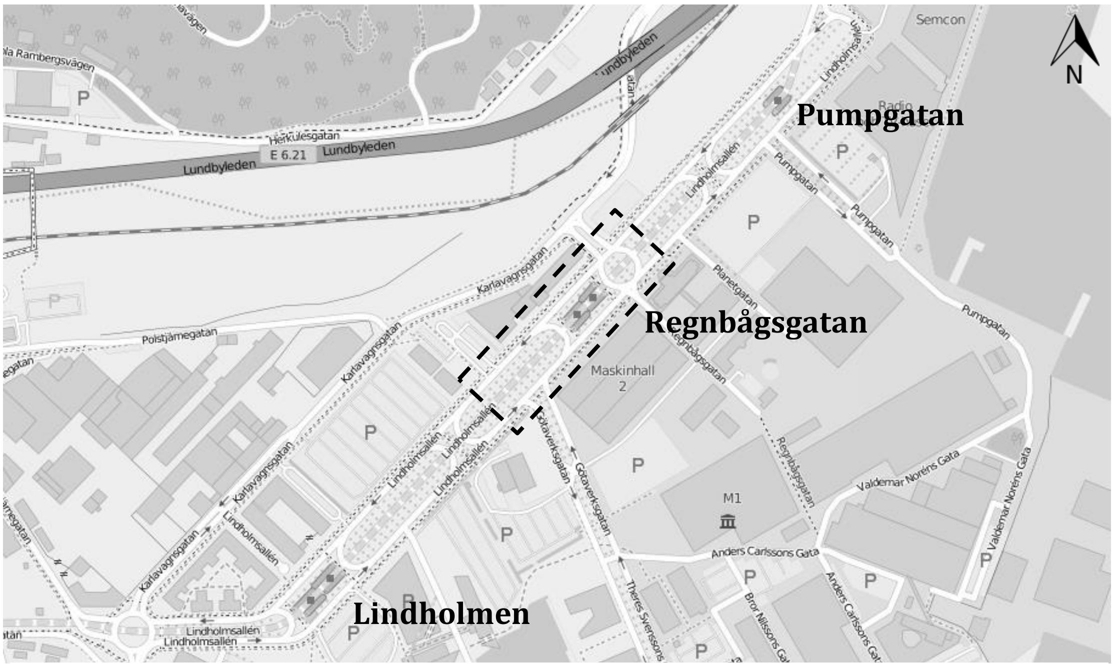

Figure 2 Map showing the locations of the three bus stops and also marks the simulation area (OpenStreetMap contributors, 2016).

The simulation and investigations required to accomplish this part is a large share of the entire project. Further on, the theories and processes in VISSIM are complex and will need a more detailed description. Thus an in depth presentation of the method and assumptions for this part are presented in Chapter 4.

2 Background information

Lindholmen is situated at southern Hisingen, an island located on the north-west side of the river Göta älv in Gothenburg. The area is a part of Norra Älvstranden which, except for Lindholmen, consists of the areas Färjenäs, Eriksberg, Sannegården, Lundbyvass and Frihamnen, located as presented in Figure 3. Placed strategically at the central parts of Gothenburg, Norra Älvstranden is an area that is currently developing from originally being a pronounced industrial area to becoming an area with a mixture of both residential buildings and companies (Göteborgs Stad, 2012).

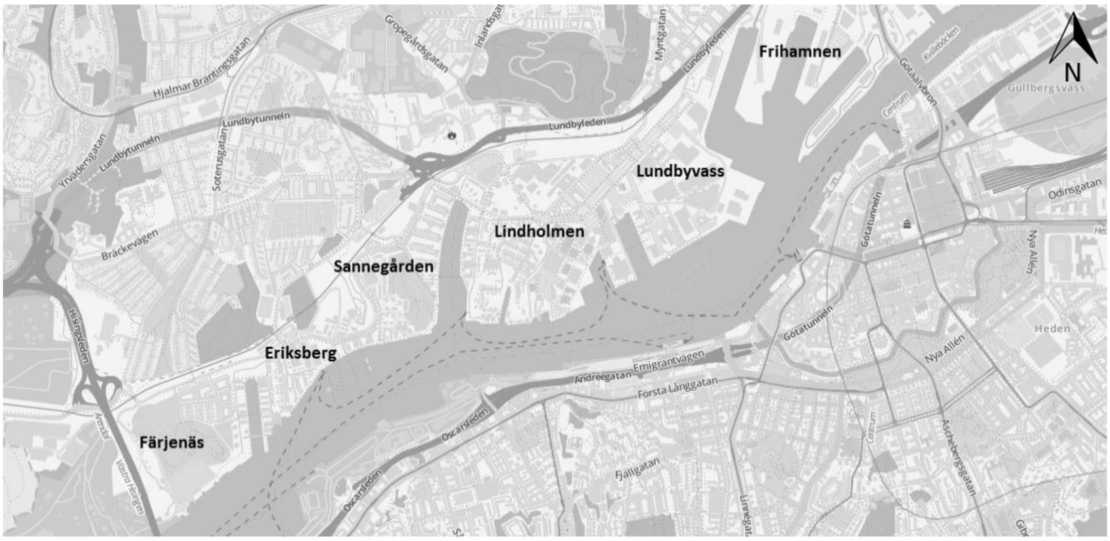

Figure 3 Map showing the areas of Norra Älvstranden (OpenStreetMap contributors, 2016).

Today, Lindholmen consists of mostly companies and industries (Älvstranden Utveckling, n.d. a). The large amount of workplaces and schools have led to that around 20 000 people travels to Lindholmen every day (Älvstranden Utveckling, n.d. b). The number of residential buildings are comparably low. In total, there are around 3000 residents in the area and a considerable amount of these are students (Göteborgs Stad, 2015b).

2.1 The history of Lindholmen

Historically, Gothenburg have always had a large and successful harbour with three shipyards, located on Norra Älvstranden (Göteborgs Stad Stadsbyggnadskontoret, 1999). Closest to the city the largest of the shipyards, Götaverket, was established in 1867. For 75 years the company was dominant and during their peak they had around 5 900 employees. The two other shipyards in the area, Lindholmen and Eriksberg, started around year 1850. The shipyards were growing and during the 1900s they were three of the largest shipyards in the world (Älvstranden Utveckling AB & Göteborgs Stad Stadsbyggnadskontoret, 2009). During this time Gothenburg also developed into Scandinavia's most important port. Due to several factors and changing circumstances the shipyards were closed down in the 1970s and Norra Älvstranden was successively emptied from activities.

Following this the two largest landowners in the area, the municipality of Gothenburg and Svenska Varv AB, the state company that took over all assets of the shipyards, started a project where they developed a vision for the redevelopment of the Norra Älvstranden (Älvstranden Utveckling AB & Göteborgs Stad Stadsbyggnadskontoret, 2009). The vision's first step was to once again have full employment in the area. Gradually the area of Norra Älvstranden was revitalised and a mix of businesses, housing, education, science and culture moved in to the old shipyard buildings. In the late 1990s the focus was on the central parts of the area. A new entrance to the once again established area was needed and the traffic going to the site needed to be managed in a better way. Thus the planning of a large boulevard lined with linden trees was started, called Lindholmsallén. A boulevard with possibility for both road traffic and public transport as well as pedestrian and bicycle paths. The construction was completed in 2002, and in 2003 the entire separated public transport lane going through Norra Älvstranden was opened.

2.2 The creation of Lindholmsallén

The idea of having a wide street through Lindholmen where all traffic modes are operating was first described in the outline to the comprehensible plan for Norra Älvstranden made 1987 by the City Planning Authority of Gothenburg (Göteborgs Stad Stadsbyggnadskontoret, 1987). The idea was to make an esplanade with the shape of a boulevard in which trams were placed in the middle, and with lanes for the other traffic modes placed on either side. The outline was followed by the comprehensible plan for Norra Älvstranden, which were released 1989.

However, since the recession in the beginning of 1990s stopped the construction and planning of new projects, the suggestions for the street in the comprehensible plan were not realised (Norra Älvstranden Utveckling AB & Göteborgs Stad Stadsbyggnadskontoret, 2001). The plans to make the boulevard were continued when the new municipally owned company Älvstranden Utveckling AB together with the City Planning Authority made a program for the Lindholmen area. The program, created in 1999, describes Lindholmsallén for the first time. Two existing buildings in the area, the old machine workshop M2 and the former office of Götaverken, were used as a base for the width of the boulevard, making the total span for the road 80 meters. The extent of the road and the location of the two buildings are displayed in Figure 4 . According to the local plan for Lindholmsallén, the estimated amount of traffic on the road when Norra Älvstranden was fully built was calculated to be between 8 000 and 12 000 vehicles per day in the south parts. In the north parts of the boulevard they were projected to be 23 000 vehicles per day.

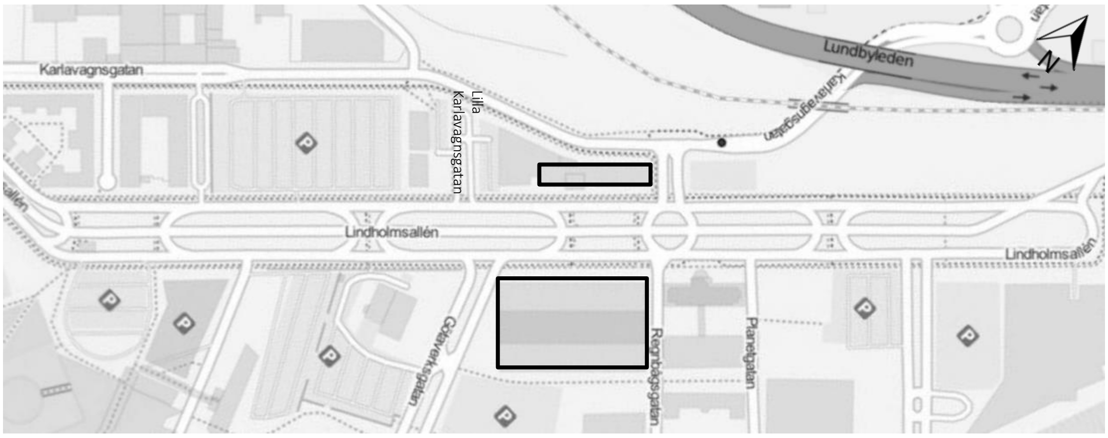

Figure 4 The extent of Lindholmsallén, the marked buildings is the old machine workshop M2 (bottom) and the office building (top), which were used to decide the width of the road (OpenStreetMap contributors, 2016).

The ideas for Lindholmsallén were not definite and an architect competition was held to decide the final design. The chosen entry was similar to the proposal made in the plan and was, according to Jöran Bellman[1], former architect at the City Planning Authority of Gothenburg, a confirmation that the design was suitable for the area. The local plan for Lindholmsallén was approved 2001 and the construction of the main part of the road was finished 2002 (Älvstranden Utveckling AB & Göteborgs Stad Stadsbyggnadskontoret, 2009). The north end of the road was not fully completed at this time. It was not until around 2005, when the new intersection connecting the highway to Lindholmsallén was built, that the road could be finalised. A map showing the stretch of Lindholmsallén from the local plan is presented in Appendix 1. The local plan is also displaying a suggestion for the construction of the final north part of the road. However, the final design does not entirely look like the suggestion. Bus stop Pumpgatan was for example not included from the beginning. The total cost for the first part of the project was 115 million SEK (Norra Älvstranden Utveckling AB & Göteborgs Stad Stadsbyggnadskontoret, 2001).

2.2.1 Goals

According to Lars Hansson[2], who worked with strategic traffic issues at the City Planning Authority of Gothenburg, Lindholmsallén was designed with two criteria in mind. The first was to prioritise the accessibility for the public transport. Lanes for public transport were placed in the middle of the road to reduce the conflicts with connecting roads and other traffic modes. The other criterion was to have safe passages for pedestrians across the road. This was done by designing the street so that the roundabout and the U-turn intersections create a section where the road traffic are only on one lane, see Figure 5. At these parts the bus stops are placed and thus the pedestrians just have to cross one lane of traffic, which enhances the traffic safety. In the local plan for Lindholmsallén it was stated that

[1] Jöran Bellman (Former architect at the City Planning Authority of Gothenburg) interviewed by the authors 4 February 2016.
[2] Lars Hansson (Senior adviser, Sweco) interviewed by the authors 5 February 2016.

the crossings along the street would be elevated to limit the speed of the road traffic to 30 km/h (Göteborgs Stad Stadsbyggnadskontoret, 2001).

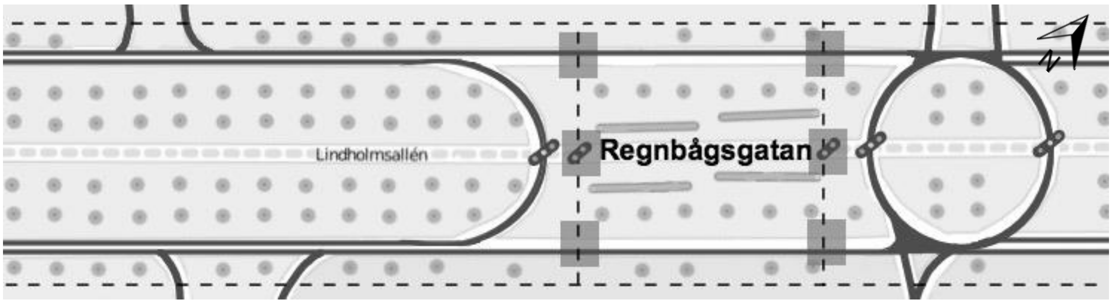

Figure 5 *The design of the road and lanes in detail, showing the area around bus stop Regnbågsgatan. The road traffic lanes are drawn with solid lines while the walkways and cycle paths are drawn with dark dashed lines. The squares show where the crossings are located (OpenStreetMap contributors, 2016).*

It was also of importance that the orientation in the area would be improved. The purpose of Lindholmsallén was to simplify the structure in the area, making it easier for travellers to orientate themselves. According to Bellman[3] the reason to why the road was made so wide and big was to make it clearer for people who arrived to the area. Before, the area consisted of many both large and small streets and it was hard to locate yourself and to find your destination. Therefore, Lindholmsallén was designed to increase the simplicity of the area's structure, with a larger road in the middle and smaller connecting roads that led down to the water. The aim of the road was to distribute the traffic within the area, and it would not be a street with much through traffic. Today, the boulevard is bordered on both sides by decorative orange pillars. According to Hansson[4], an idea from the beginning was that these would include street names to simplify the orientation in the area. However, the pillars ended up to have a mostly decorative purpose. Only the pillars placed in connection to larger entrances to the road have the writing Lindholmen on them.

Lindholmsallén is designed to allow trams in the public transport section of the road in the future (Göteborgs Stad Trafikkontoret, 2015a). There was no timeframe set when this would be realised. It would instead be decided when the bus traffic had reached its full capacity. Today, one of the longest busses that is operating in Gothenburg, bus line 16, traffics the street. The bus line works much like the bus rapid transit (BRT) concept and it also has one of the highest frequencies in the city. According to public transport company Västtrafik[5], the future plan is that this bus line will be made into a tram line instead.

[3] Jöran Bellman (Former architect at the City Planning Authority of Gothenburg) interviewed by the authors 4 February 2016.
[4] Lars Hansson (Senior adviser, Sweco) interviewed by the authors 5 February 2016
[5] Västtrafik. Mail correspondence 9 May 2016

According to both Bellman and Hansson the project ended up as planned and both the City Planning Authority and Älvstranden Utveckling were satisfied with the result.

2.2.2 Future

The area of Norra Älvstranden is today an established part of Gothenburg, but there are still development opportunities available for the future (Älvstranden Utveckling, n.d. b). According to Älvstranden Utveckling the aim for the area is to have about 1 000 new residences and 2 000 new workplaces before the 400th anniversary of Gothenburg in the year 2021. The old shipyard called Lindholmen has today a new appearance, with a mixture of old shipyard buildings and new modern parts. The area is today called Lindholmshamnen and the plan for this district is to increase the number of residences and businesses in the near future. A vision for this area is showed in Figure 6. Around 450 new homes and 3 000 m^2 of business space, together with a new preschool and a restaurant are some of the plans (Älvstranden Utveckling, n.d. a).

Figure 6 Vision of the area Lindholmshamnen, also showing the cable cars (Göteborgs Stad Älvstaden, 2015).

Another large project in the area that is in the planning phase is Karlavagnsplatsen (Älvstranden Utveckling, n.d. c). This district will have 15 new blocks containing a mixture of residences, offices, service and commercial areas. In total the plan is to build 2 000 new apartments at Karlavagnsplatsen. The plan is also to build the highest building in the Nordic countries in this area, called Karlatornet, with a height of 266 meters.

The City´s upcoming 400th anniversary has resulted in many suggestions and ideas for the celebrations. One interesting plan is a cable car system across the river Göta älv (Göteborgs Stad, n.d.). This would act as a supplement to the public transport and a new comfortable way of crossing the river. It is a project that needs little space and with a relatively low operation cost. The first route of the cable car is planned to be ready to the anniversary and would go between Järntorget on the south side of the river to Lindholmen in the north. This vision is also displayed in Figure 6 above.

A consequence is that with the continuous development of Norra Älvstranden, with new residences and jobs, there is a risk that the amount of car traffic will increase significantly (Göteborgs Stad Trafikkontoret, 2013). Even if the public transport would be increased as well it could be difficult to get the necessary capacity. This is because the amount of new houses and workplaces is planned to be high and since the capacity today is already almost at its limit, it could result in a large increase in car travel compared to today.

2.3 The design of Lindholmsallén

Lindholmsallén extends from the street Lundby Hamngata in the north-east to central Lindholmen in the south-west. Several smaller roads connect to the street, most of them leading to offices and schools in the area. The largest share of traffic connects to Lindholmsallén through a roundabout located near the bus stop Regnbågsgatan. This traffic is connecting from the highway Lundbyleden, which is passing close by. The speed regulation is 50km/h for the whole street but there are traffic calming measures in the form of level differences in connection to some of the crossings.

Lindholmsallén is designed as a boulevard with the public transport placed in the middle and with lanes for the remaining modes of traffic on either side, see Figure 7. In this figure, the total width of 80 meters can be seen. The street has one-way road traffic that is separated from the public transport lanes by two rows of trees. Similarly, the separation between the car lanes and the cycle and pedestrian paths consists of one line of trees. The road traffic is distributed on two lanes, with the exception for the parts that lies between the U-turn intersections and roundabouts. In these sections it is only one lane.

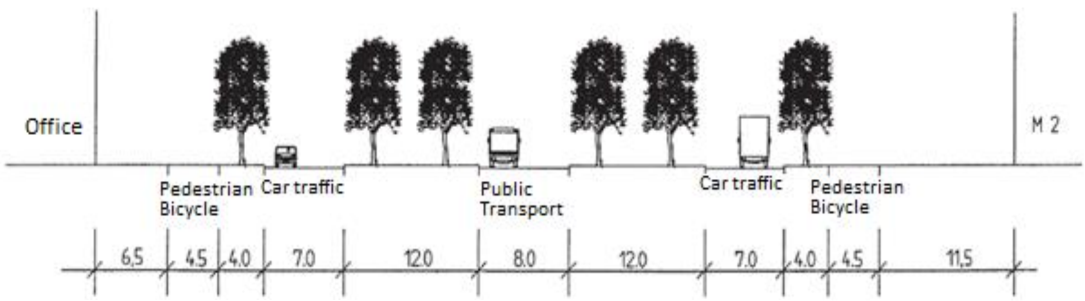

Figure 7 Cross section of Lindholmsallén (Göteborgs Stad Stadsbyggnadskontoret, 2001).

The paths for pedestrians and cyclists are located furthest away from the middle, with walkways and two-way cycle paths on both sides. The two traffic modes are separated with different types of surface material. The walkways are made of concrete tiles and the cycle paths are made of asphalt. The cycle paths are also marked with symbols in the ground.

The cycle paths on Lindholmsallén are connected to the larger cycle path along the more trafficked road Hjalmar Brantingsgatan via the street Lundby Hamngata. From there it is possible to reach the city center of Gothenburg. The street is also a part of the public transport core network in Gothenburg and one of the core buses traffics the street (Västra Götaland Region, u.d.).

2.4 Bus stops

There are three bus stops along the street of Lindholmsallén, shown earlier in Figure 2. They are placed at even intervals and they are all positioned in the bus file in the centre of the road.

2.4.1 Pumpgatan

Bus stop Pumpgatan is located in the north parts of the street and is the smallest, as it is the stop that has fewest travellers among the three. The design of the stop is shown in Figure 8 and is simpler than the other two since it only has one place where the bus can stop in either direction. It also lacks signalised and marked crossings for the pedestrians.

Figure 8 The design of the bus stop Pumpgatan (Photo by authors).

2.4.2 Regnbågsgatan

Regnbågsgatan bus stop is placed in the middle of the stretch and its design is presented in Figure 9. It has more travellers than Pumpgatan bus stop and is consequently also designed for higher pedestrian flows. The stop has two places where the busses can stop in either direction. The place at the front is reserved for bus line 16, the line with the highest frequency in the area. Even though there are two places for the bus to stop, it is only one lane. This leads to that it is not possible for the bus behind to pass an eventual bus in the front. It is one signalised crossing on either side of the stop, leading to four possible entrances/exits. This bus stop and the area around it are also what is to be simulated in this report.

Figure 9 The design of the bus stop Regnbågsgatan (Photo by authors).

2.4.3 Lindholmen

Placed at the south parts of the street, Lindholmen bus stop is the main stop in the area. It has a similar design to the Regnbågsgatan bus stop, with two places for the bus to stop on both sides. Due to the high number of schools and work places in the area, this stop has the highest pedestrian flows of the three bus stops at the street. When planning the area, the ambition was, according to Hansson[6], to make Lindholmen bus stop even bigger and clearer since there are so many that are using the stop. There were for example plans to have a bigger roof on the bus shelters or to make a bigger built-in public transport hub. The plans were however not realised and the design were instead made similar to Regnbågsgatan, as seen in Figure 10.

Figure 10 The design of the bus stop Lindholmen (Photo by authors).

[6] Lars Hansson (Senior adviser, Sweco) interviewed by the authors 5 February 2016.

2.5 Traffic safety statistics

In order to get an understanding of how the traffic safety situation is on Lindholmsallén, traffic accident statistics from STRADA have been studied. The timeframe was selected to be between 2005 and 2014, since the road was fully completed by 2005. The three areas that Lindholmsallén is divided into for this investigation is shown in Figure 11. As can be seen, these areas cover the surroundings of the three bus stops.

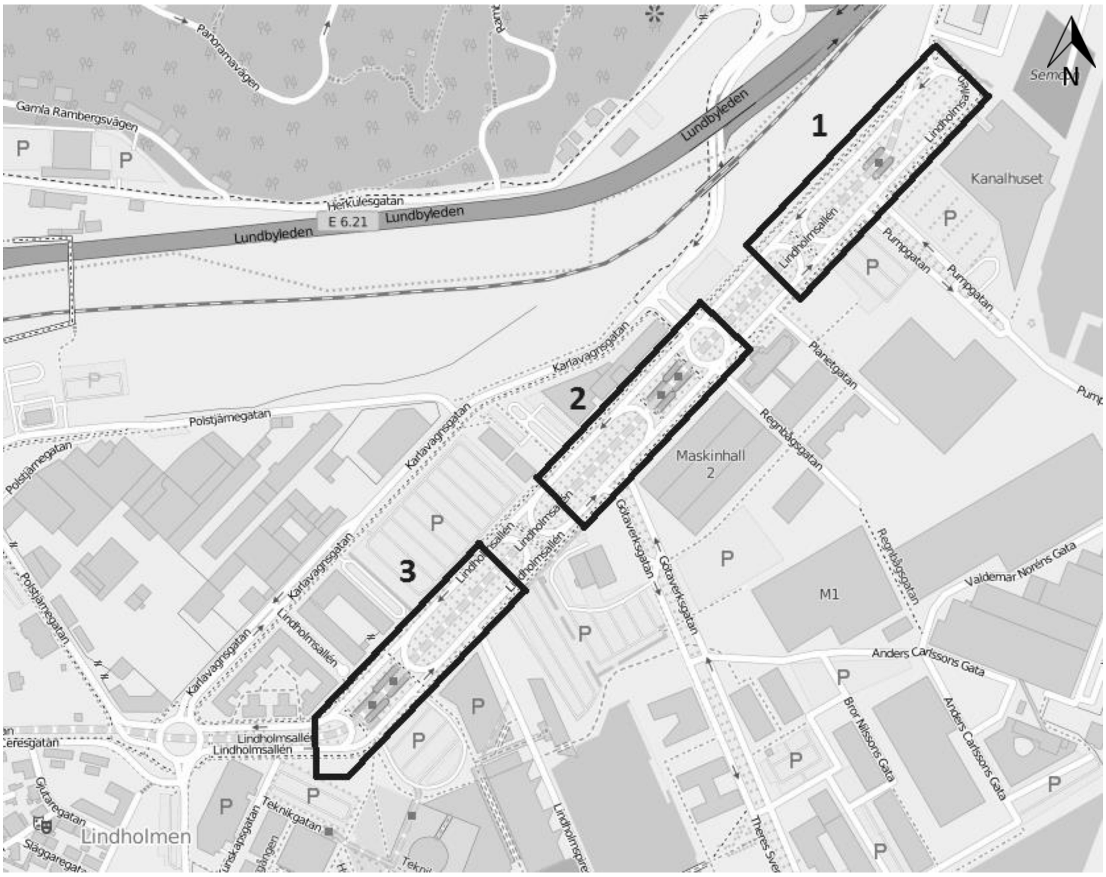

Figure 11 Map showing the selected areas of Lindholmsallén used for the traffic safety analysis and evaluation of the design (OpenStreetMap contributors, 2016).

The amount of traffic accidents during the studied period are too few to make it possible to draw any conclusions. However, some observations have been made from the material. The reports show that none of the accidents have been serious or fatal. The few amount of accidents gives an indication that the site is not prone to accidents. The statistics shows that some accidents happened on this road. Some of the accidents is more general, which means that this kind if accident can happen in other places. An example of this is an accident reported where a car drove into the rear of another car. But there are also accidents reported that are distinguished and linked to the design of the road.

The first area, around the bus stop Pumpgatan, has few accidents reported during this timeframe. The small amount of reported accidents is not possible to associate with the design of the road. The third area is around the bus stop Lindholmen and this part however has slightly more accidents and it is possible to distinguish a particular accident type that stands out. The bus stop Lindholmen in this area is larger than Pumpgatan and thus more people are moving on and around the bus stop. The type of accident that is distinguished here is collisions between motor vehicles and vulnerable road users. The area with the most conflicts reported is the second area, the one surrounding bus stop Regnbågsgatan. This site has just like area three accidents between vulnerable road users and motor vehicles reported, but also another type of accident is distinguished. Along the road Lindholmsallén there are crossing traffic, with several intersections between the bus lane in the middle of the road and the roundabout and U-turns with road traffic. In the intersections located in the area around Regnbågsgatan especially there are accidents reported between these crossing transport modes.

Something noteworthy is that the reported accidents are only coming from the police and hospitals. This means that minor accidents, other conflicts and averted accidents does not exist in the statistics. Further on, accidents between vulnerable road users, for example cyclists and pedestrians, are much unrepresented in the statistics (SKL, 2009). Some of the single accidents for vulnerable road users may also be caused by that cyclists have to swerve for pedestrians or vice versa (SKL, 2010). Thus there could exist conflict-zones in these areas that are not detectable with the help of accident statistics.

3 Evaluation of Lindholmsallén

Another way to describe the traffic situation on this specific site is by doing an evaluation on how well it fulfils several criteria. These criteria are guidelines on how a site should be designed and this evaluation is limited to four parameters: traffic safety, accessibility, orientation and security. The goal of the evaluation is to see how well the design of Lindholmsallén fulfils these parameters. In order to assess the full extent of the road it is divided into three parts, the same as the ones shown in Figure 11. In this way it will be possible to evaluate the three bus stops located on the road separately to see if any of them is better designed than another.

It is also of interest to look at the different modes of transport that operate in the area. Thus the evaluation is divided into pedestrians, cyclists, public transport and road traffic. Therefore, the different transport modes are evaluated in different areas within the divided parts. For pedestrians and cyclists, the area evaluated are the pedestrian and cyclist paths respectively. For public transport not only the bus stop is assessed, but also the way to and from the bus stop that the travellers take. For road traffic, the streets and parking lots are evaluated.

3.1 Design parameters

The parameters used in the evaluation are described in this chapter. Consideration was taken to the site and therefore only content relevant to Lindholmsallén in these parameters was included. For example, in traffic safety, to have a pedestrian and bicycle tunnel under the road are considered a safer option. But it is not relevant in this case because the evaluation is only for the existing road and is not considering alternative solutions.

3.1.1 Traffic safety

It is important to strive for as good traffic safety as possible. Sweden has a zero vision which intends to increase the traffic safety so that no one should be killed or seriously injured in the traffic (Trafikverket, 2014b). One of the most important aspect of traffic safety is the speed (Trafikverket, 2015b). It is therefore of importance to make sure that the speed regulations are followed and to reduce the speed to 30-40 km/h at places where vulnerable road users are interacting with road traffic. Improvements in traffic safety will often increase the security, accessibility and health for all road users (Trafikverket, 2015a).

3.1.1.1 Pedestrians and cyclists

The road users who often gets severe injuries in accidents are pedestrians and cyclists (Trafikverket, 2015b). The majority of these accidents are single accidents and out of these the most common for pedestrians are those caused by falling. It is therefore important that the roads are well maintained and that there are no obstacles in the way. Obstacles such as curb stones and obscuring bushes and other plants can increase the risk of accidents since they are blocking the view and the road users can collide or stumble on them (SKL, 2010).

For the traffic safety, the collision speed is the determining factor when it comes to how severe the accident will be (Trafikverket, 2015b). It is therefore important that the speed limits are followed. This is especially important where vulnerable road users and motor vehicles are interacting, such as crossings. In these zones it is recommended that the collision speed should be max 40 km/h, but preferably below 30 km/h. In areas where there are large flows of pedestrians and cyclists, the modes should be separated in a clear way (Trafikverket, 2015b). An example showing one way of separating pedestrians, cyclists and road traffic can be seen in Figure 12. It is also important that the areas that are used by vulnerable road users are well lit.

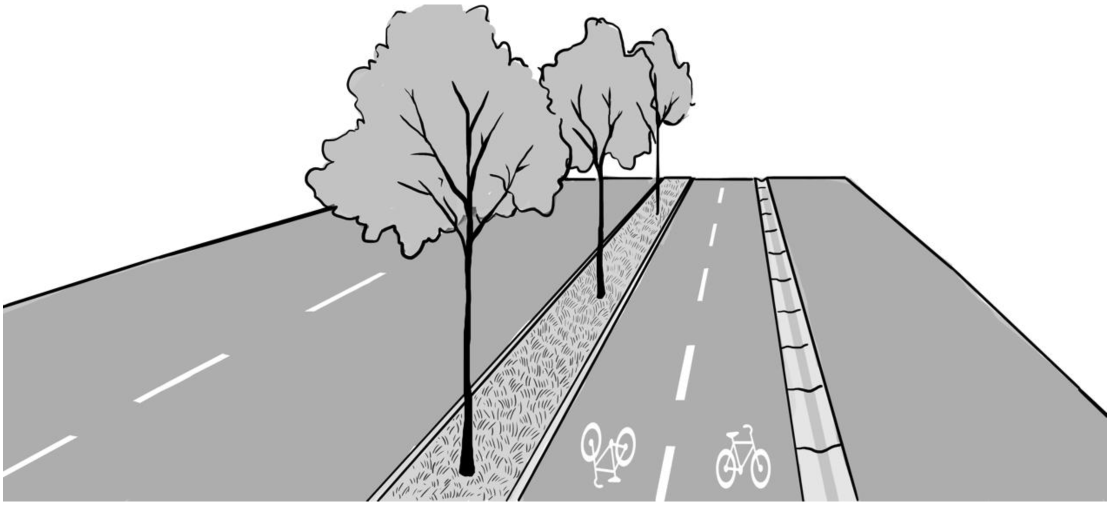

Figure 12 A road design with separated traffic modes (Illustration by authors).

3.1.1.2 Public transport

Bus stops are used by both pedestrians and cyclists. It is therefore important that the connecting roads and the stop itself are well maintained (SKL, 2010). The stop should be designed so that the traffic safety is prioritised (Trafikverket, 2015b) and so that the passing traffic have a speed below 30 km/h. This is also the case with traffic surrounding the bus stop. When people are moving to and from the stop it is important that the traffic that is crossed have low speed (SKL, 2009). A method to ensure this is to have traffic calming measures that will reduce the speed of the traffic and thus increase the traffic safety. One element of danger is when the traffic is passing a bus at the stop. The bus is then obstructing the view of the surrounding traffic and people coming from the bus is exposed to a risk.

The bus stop itself should be designed to manage the amount of people that will accumulate at the stop (SKL, 2009). If there is not enough room on the platform there is a risk that people coming to and from the bus might be injured. It is also important that the lighting is good at the bus stop and surrounding areas so that the people waiting on the bus is seen by the busses and the traffic. According to SKL (2009), studies performed in Gothenburg have shown that it occurs four times more accidents in the areas where public transport operates compared to other areas. It has also been shown that most pedestrian accidents take place close to bus stops.

3.1.1.3 Road traffic

The design of the road is important for the traffic safety for the users of motor vehicles. In general, intersections with roundabouts have a higher traffic safety than those without (Trafikverket, 2015b). It is also better with only one lane in the roundabout. Furthermore, the risk for accidents is decreased if the intersection is regulated with traffic lights. Fixed obstacles such as trees and lamp posts can increase the severity of the accidents.

Since the severity of the accident depends on the collision speed, it is essential that the speed regulations are followed (Trafikverket, 2015b). In areas where it is desirable to have low speeds, the through traffic should be steered away. Another way to decrease the speed is to have speed bumps in the road (SKL, 2009). This will mainly decrease the speed for those who drive fastest, which will reduce the speed distribution and thus also increase the traffic safety. Lighting is important, not only on the cars but the street lighting as well. This will help to detect other road users, pedestrians, cyclists and obstacles that might be on or close to the road (SKL & Trafikverket, 2013).

3.1.2 Accessibility

A simple definition for an accessible transport structure is that the traffic system is designed so that the basic transport needs for citizens and businesses are satisfied (Trafikverket, 2015a). The accessibility should be equal for everyone and not take into account gender, age and different social groups. The individual road user's capacity should also be taken into consideration. This means that children, elderly and people with disabilities need additional consideration.

There are two important parts of accessibility: usability and mobility (Trafikverket, 2015b). Usability is a measure of the efficiency and satisfaction, based on the user's perspective. The concept of mobility is linked to the traffic capacity of the system. It describes the consumption of time, regarding the movement in the transport network for pedestrians, cyclists, public transport users and car drivers, in relation to the expected time in the system.

3.1.2.1 Pedestrians and cyclists

There are several criteria that affect the accessibility for pedestrians and cyclists in the traffic system. One thing that reduces the accessibility is different types of barriers (Trafikverket, 2015b). Examples of these are highly trafficked roads and railways that pedestrians and cyclists need to cross. This could contribute to multiple and long stops during one trip, which is not only disturbing but also time consuming for the travellers. This is connected to the next part of an accessible transport system – it should have continuity. The pedestrian and bicycle routes should run continuously through almost every part of the city. This could be done by having crosswalks and marked bicycle crossings, seen in Figure 13.

Furthermore, related to the accessibility for cyclists is the possibility for parking throughout the city.

Figure 13 Crosswalk and marked bicycle crossing (Photo by authors).

The pedestrian and bicycle roads should also have good standard to facilitate for all who travels on them, especially for elderly and people with reduced mobility (Trafikverket, 2015b). This means that maintenance and reparations of the roads is of importance. Particularly during the winter period, the accessibility could be lowered because of bad snow clearing and gritting of the roads.

3.1.2.2 Public transport

The accessibility for public transport is mainly defined by the variations and number of routes and stops and by the frequency (Trafikverket, 2015b). It is also important to have good connections to the pedestrian and bicycle paths to support interchanges between transport modes. The maintenance of the bus stop and the connected paths is also important, especially during the winter period, to help both the bus and the travellers to reach and leave the bus stop.

In the design of the transport system in the city it is important to consider the accessibility for people with reduced mobility and people in wheelchairs or similar (Trafikverket, 2015b). This is significant in public transport design, where the stops and vehicles should be designed to be accessible and handicap-friendly. This means that the curb stones at the stops should be high enough so that there are no height differences between the bus stop area and the bus floor (SKL, 2009). The vehicles and stops should be designed so that people in wheelchairs, or similar, easily can move on and off (Västtrafik, u.d.). This could mean ramps on the buses and space for these to be used at the stops.

3.1.2.3 Road traffic

There are several aspects in the design of the roads that affect the accessibility for the road traffic (Trafikverket, 2015b). The capacity the road is designed for and the speed regulations influence the accessibility for the road users. Too low capacity can lead to congestions and thus lower accessibility. Measures like road tolls also adds a barrier in the trip.

A continuous road network is, as well as for the rest of the transport modes, important and one should be able to easily move around to the different parts of the city (Trafikverket, 2015b). Furthermore, it is essential with parking possibilities for road traffic similarly as for cyclists. If a destination is absent of parking spaces one might not do the trip. Not only can the existence of the parking, but also the design itself affect the accessibility. A restriction of the allowed parking time and if there are fees for parking at specific places will influence the accessibility to this certain location.

3.1.3 Orientation

In order for a city to be easily oriented some criteria should be fulfilled. Firstly, the city structure should be comprehensible and self-explanatory (Trafikverket, 2015b). Furthermore, the streets should have continuous guidance and easily understandable directions at major and important connection points. When planning an area, the road structure should also make use of natural landmarks to make it easier for the road users to orientate themselves.

3.1.3.1 Pedestrians and cyclists

To simplify the orientation for visually impaired persons it is of importance that the boundaries between the walkways, cycle paths and the road are clearly perceptible and visible (Trafikverket, 2015c). For people who are blind, tactile tiles or other guide paths can make the orientation easier. The design of the light sources along the road is also of importance. The field of vision should not be disturbed by the light and the light sources should be designed so that the directions and entrances into surrounding streets are clarified. Furthermore, they should be used in a way to increase the understanding of the surrounding for people with reduced mobility or orientation capacity. It is also of importance that there are clear directions to where to park your bicycle (Göteborgs Stad Trafikkontoret, 2006).

3.1.3.2 Public transport

It is of importance that the public transport stops provide the travellers with necessary information about the trip. At the stops there should be details about schedules and bus routes. It should also be possible to access the information for both those who are standing, sitting in a wheelchair and for people with impaired vision (Vägverket, 2004). Additional information that makes the trips more comprehensible are guidance for exchanges, real-time data for the following buses and information about eventual delays or disturbances. Further on, it is important that blind and visually impaired people also can orient themselves to, from and at the bus stops. It is therefore important to have tactile tiles or other guide paths here as well (Trafikverket, 2015c). An example of a bus stop with tactile tiles can be seen in Figure 14.

Figure 14 Tactile tiles at a bus stop. The white stones at the edge are in contrast to the darker stones and pavement (Photo by authors).

3.1.3.3 Road traffic

For the motor vehicle drivers it is of importance that the main road network is logical and that is has a simple structure (Trafikverket, 2015b). There should be good lighting on the roads and signs so that it is easy to orient yourself also during the dark hours of the day. The distance from the signs to the intersection should be long enough for the driver to comprehend the information and locate themselves. It should also be easy to find information about where to park. Moreover, information about control measures and allowed time and fees should be clearly described on signs in the parking area. It is important that the parking meters are easy to detect and not concealed or hidden. There should also not be any difficulties with reaching the parking meters, so they have to be placed close to the parking spaces (Göteborgs Stad Trafikkontoret, 2015b).

3.1.4 Security

City planning plays an important role when it comes to the security as we move around in the city (Trafikverket, 2015b). A well planned city can help to prevent crime and increase the security. How secure a place is perceived depends on which day of the week and what time of the day the site is visited, but also the lighting and how much people that are in motion there. The insecurity is also different between men and women, with three times more women than men that feel insecure when they go out late at night. There is also a difference in the perceived security depending on which mode of transport that are used (Boverket, 2010).

The road traffic is often more secure compared to walking, cycling and using public transport, where situations that seems insecure more often appear.

Several modes of transport are often used during one trip, which means that it is important to look at the whole extent of the trip, from door to door (Boverket, 2010). All parts of the trip should feel safe, e.g. pedestrian and bicycle paths, vehicles, parking lots and bus stops. Thus there are some criteria for a good security that applies more generally. It is important to have a good overview of the area. By removing obscure bushes and use transparent material it is possible to make a location feel more open and with a better view you feel safer (Trafikverket, 2015b). Another important measure is to have good lighting on the roads, bus stops and parking lots. This way it is possible to get a good overview also during the dark hours of the day. The lighting should be designed to help and guide and not be positioned so that they are blinding the road users. It is also important with a maintenance and management of the site that works well. For instance, garbage and graffiti makes a location feel less secure.

Further on, it is also possible to get a higher security by increasing the amount of people moving outdoors during all hours of the day (Trafikverket, 2015b). This could be done by having a high development density and by enhancing the mix of activities, businesses and residential areas. Another way is by gathering the various modes of traffic together and not place them far from buildings. Pedestrian and cycle paths next to roads are perceived as more secure at night as it is often movement on the roads.

3.1.4.1 Pedestrians and cyclists

In order to make the pedestrians and cyclists feel secure it is important that it should be possible to choose more than one road option to reach the destination (Boverket, 2010). This is especially important when it is dark outside and some places feel more secure than others. The cycle paths and walkways should be placed in connection to buildings and other roads since it makes the road feel less desolate. It also increases the likelihood that the pedestrian and cycle roads are used during a bigger part of the day, which increases the feeling of security. However, while car roads can increase the feeling of security, heavy traffic on the roads can make it feel less secure. Thus, it is important that the speed and the amount of cars on the roads are not too high. Some pedestrians are reluctant to use tunnels, especially during the dark hours. It is therefore of importance that they are designed to be straight and wide and that they are also well lit, as shown in Figure 15 (Trafikverket, 2015b).

Figure 15 An example of a well designed pedestrian tunnel (Trafikverket, 2015b).

The network of bicycle paths and lanes should be coherent and of good quality (Boverket, 2010). It should also be easy for the road users to orientate themselves in the area. Thus, it is important that the signs and information are easy to understand and are placed so that they are easily detected. The bicycle parking should be avoided to be placed at remote locations as it increases the uncertainty of the bike to be vandalised or stolen. A desolate place will feel more insecure and may result in that the cyclists chooses to park somewhere else or not take the bicycle at all.

3.1.4.2 Public transport

The bus stops are an important part of a trip as it is inevitable to use them if the traveller choose to go by public transport. It is therefore of importance that they feel secure to use during all parts of the day. The feeling of security is increased with a good design and no obscured or dark corners. One solution is to use transparent material on the bus stop (SKL, 2009). It is important that the area around the stop have a connection to other roads and buildings, since an area that feels desolated and isolated increases the feeling of insecurity. The accessibility to and from the bus stop should also be good. Otherwise, the travellers may feel that they cannot choose another way, which increases the feeling of being trapped.

3.1.4.3 Road traffic

When traveling with a car there are rarely situations when you feel unsecure (Boverket, 2010). The insecurity related to road traffic is often connected to the site where you go in and out of the car, the parking spaces. This means that it is important to design the parking in ways that make them feel more secure. This is done by the use of less material like concrete and instead using transparent materials. The parking lots should be well lit and not be placed at desolated locations. Parking garages often feels insecure because you can feel trapped and have less overview of the site. Thus, it is important to have several entrances and exits to the parking houses, together with good lighting and signs that makes it easier to find your way. Another measure to increase the feeling of security is to have the possibility of visual surveillance on the parking lots and in the parking houses.

3.2 Design criteria

From the four parameters that are presented earlier, specific criteria for the different modes of transport are developed. There are five criteria for each mode of transport and parameter, these are used to do evaluations on the three bus stops and the roads surrounding them. The different criteria for the transport modes are presented in Table 1 to Table 4. The evaluation is made in order to compare the three bus stops to each other and to see if any of them lack important parts of the parameters. The result will also show if there are some parameters or mode of transport that are better suited for this specific location. The purpose of having the same amount of criteria for each parameter and mode of transport is because this makes the evaluation and comparison of the three areas easier. Important to notice is that the ratings cannot be compared with other sites where a similar evaluation method is used, but with other criteria.

Table 1 Showing the different criteria chosen for pedestrians.

Pedestrians	
Traffic safety	High standard and well maintained roads
	Good lighting
	Maximum speed at crossings 30-40 km/h
	Clearly separated traffic modes
	No obstacles that can be tripped on or that restricts the view
Accessibility	No barriers (highly trafficked roads or railways)
	Continuity of walkways
	Good maintenance of the road
	The roads are connected with crosswalks
	The road is handicap-friendly
Orientation	Clear directions on where to walk
	Good lighting that clarifies the directions and entrances
	Clearly perceptible and visible boundaries between walkways, bicycle paths and roads
	Comprehensible directions at (larger) connection points
	Comprehensible and self-explanatory walkway structure
Security	Good overview of the area
	Good maintenance of the area
	Good lighting
	Walkways connected to buildings
	Several walkway options

Table 2 Showing the different criteria chosen for cyclists.

Cyclists	
Traffic safety	High standard and well maintained roads
	Good lighting
	Maximum speed at crossings 30-40 km/h
	Clearly separated traffic modes
	No obstacles that you can collide with or that restricts the view
Accessibility	No barriers (highly trafficked roads or railways)
	Continuity of cycle paths
	There exist possibilities to park the bike
	Good maintenance of the road
	The roads are connected with bicycle crossings
Orientation	Clear directions on where to bike
	Good lighting that clarifies the directions and entrances
	Comprehensible directions at (larger) connection points
	Comprehensible directions to where to park the bike
	Comprehensible and self-explanatory cycle path structure
Security	Good overview of the area
	Good maintenance of the area
	Good lighting
	Cycle paths connected to buildings
	Bicycle parking placed visible and are easily accessible

Table 3 Showing the different criteria chosen for public transport.

Public transport	
Traffic safety	High standard and well maintained roads
	Traffic calming measures in connection to crossings
	Enough capacity on the platforms
	No passing traffic when the bus is at the stop
	Good lighting at the bus stop and its surroundings
Accessibility	Good frequency of the public transport
	Good connections and easy access to pedestrian and bicycle paths
	Maintenance of the bus stop and connecting roads is good
	No level differences between the stop and the vehicle
	The design of the bus stop should be handicap-friendly
Orientation	Comprehensible and self-explanatory road and bus stop structure
	Good guidance and understandable directions to the bus stops
	There is necessary information about the trip on the stops (schedule and routes)
	Good lighting that clarifies directions and visibility at the stop
	Tactile tiles or other guide paths to assist blind and visually impaired people
Security	Good overview of the area
	Good maintenance of the bus stop
	Good lighting
	Accessibility to and from the bus so people do not feel trapped
	Good design where there are no obscured or dark corners

Table 4 Showing the different criteria chosen for road traffic.

Road traffic	
Traffic safety	High standard and well maintained roads
	Intersection with roundabout
	Intersection with traffic lights
	Speed bumps (or other traffic calming measures) to decrease the speed
	Good street lighting
Accessibility	Enough capacity of the road
	Few or no barriers (road tolls, traffic lights, etc.)
	A continuous road network
	Possibilities for parking
	Not too strict regulations for parking (time and fees) - possibility for commuter parking
Orientation	Main road network is logical and has a simple structure
	Good guidance and understandable directions at (large) important connection points
	Good lighting that clarifies directions and visibility on the roads
	Enough distance from signs to intersection for the driver to comprehend the information
	Good information about where to park and restrictions on the parking lot
Security	Good overview of the area
	Good maintenance of the area (Mainly parking lots and garages)
	Good lighting (Mainly parking lots and garages)
	Parking lots should not be places at desolated locations
	Parking lots and garages should have several entrances and exits

3.3 Design evaluation

Lindholmsallén is divided into three parts, representing one bus stop each. These are evaluated separately; the full list of evaluation ratings is found in Appendix 2. When evaluating the location, a rating between 0 and 5 is given for each parameter, depending on how well the five criteria are fulfilled. One individual criterion can get from 0 up to 1 point, with an interval of 0.25 points. This leads to that when summarising all ratings for one parameter, a rating of 5 means that all the criteria are completed, while a rating of 0 means that none of the criteria are accomplished.

3.3.1 Pumpgatan

The result from the evaluation of the area named Pumpgatan is presented in Table 5. The parameter that got the highest overall rating for all modes of transport was security. This is explained by that this site has an open design, with good lighting and maintenance.

The main reason why pedestrians got a lower rating is because the crossings to the bus stop is poorly designed, as displayed in Figure 16. The pedestrians need to cross two lanes with road traffic to reach the bus stop. There are no traffic calming measures in connection to the crossings, which reduces the traffic safety. The design of the crossings leads to that the accessibility is low since there are no marked crosswalks and no tactile tiles. This absence of good possibilities for crossing affect the rating for cyclists in both traffic safety and accessibility. But for cyclists there is also no parking available in the area, something that also impacts the ratings for the accessibility, orientation and safety parameters.

Figure 16 The pedestrian crossing at the bus stop Pumpgatan (Photo by authors).

For public transport the situation on Pumpgatan is good because the area around the bus stop is open and the design of the bus stop is sufficient for the amount of people traveling to and from it. The reductions in rating here is because there is no safe and easy way for crossing over to the bus stop, affecting both traffic safety and accessibility. Another thing that lowers the rating for traffic safety is that there are passing traffic in the bus lane when the bus is at the stop. Unlike the other bus stops this one lacks signalled crossing if you want to cross the bus traffic.

Road traffic is the transport mode with the highest total rating and the parameters is all relatively well achieved. There are however minor issues to mention. One thing that is seen along the entire Lindholmsallén is that the road network not has a good logical and simple structure and that it could be hard to orientate yourself if you are not familiar to the road. With the intersections that are designed as half roundabouts it is a bit difficult to know that you sometimes need to go "too far" and drive back to reach your destination. At Pumpgatan there is not enough signs and directions in connection to these roundabouts to make this traffic situation easy and understandable.

Table 5 Evaluation ratings for Pumpgatan.

	Traffic safety	Accessibility	Orientation	Security	Total
Pedestrians	3.75	3.5	4.25	4.75	16.25
Cyclists	4.25	3	3.25	3.75	14.25
Public transport	3.25	4.25	4.75	4.75	17
Road traffic	4.25	4.75	4.25	4.75	18
Total	15.5	15.5	16.5	18	

3.3.2 Regnbågsgatan

The results from the evaluation of Regnbågsgatan is presented in Table 6. At Regnbågsgatan almost all of the parameters are well met. Their ratings are about the same, except for traffic safety, which got a rating that is notably lower than the others. This is mostly because of the absence of well-designed traffic calming measures at the crossings. But there are also a few other defects that made this rating lower, for example some of the zebra crossings is in poor condition which lowers the accessibility.

This bus stop has more travellers than Pumpgatan and which was taken into account when designing this stop. This is also shown by that Regnbågsgatan got a higher rating on almost every point. One thing that reduces the rating for the traffic safety is that there are not enough traffic calming measures in connection to the crossings over to the bus stops, which affects all traffic modes. Unlike Pumpgatan, it exists four marked crossings both for pedestrians and cyclists to and from the bus stop. But the crossings are partly elevated, which might lead to that the road traffic does not slow down as much as if the crossings would be fully elevated.

The separation between pedestrians and cyclist could be made clearer. Today they are separated by different materials on the pedestrian and cycle paths. Due to the large flows of pedestrians moving to and from the bus stop it could be good to separate the paths further. Especially since it has been observed that many pedestrians are walking on the bicycle paths. Another thing that affect both accessibility and traffic safety is that on one side of Lindholmsallén there is a stairway to an office that goes out into the pedestrian and bicycle paths. This stair, which is shown in Figure 17, is an obstacle for both pedestrians and cyclists.

Figure 17 The stairway is an obstacle for both pedestrians and cyclists that has to share the walkway when passing the stairs (Photo by authors).

Compared to Pumpgatan the design of this bus stop is not as open. This mainly has to do with the lower concrete walls along the bus stop and the advertisement on the bus shelters that obstructs the view. For road traffic, the main reduction of the ratings is as in Pumpgatan due to the fact that the road network and signs are not logical and simple. In this case the rating of the orientation for the road traffic at Regnbågsgatan is lower than at Pumpgatan because at this site there are fewer signs. At Regnbågsgatan there is also several possible destinations and connecting roads and it is thus important to have good directions and a simple road structure.

Table 6 Evaluation ratings for Regnbågsgatan.

	Traffic safety	Accessibility	Orientation	Security	Total
Pedestrians	3.75	4.5	4.5	4.5	17.25
Cyclists	3.75	4.25	4.75	5	17.75
Public transport	4.25	4.75	4.75	4	17.75
Road traffic	4.25	4.75	3.75	5	17.75
Total	16	18.25	17.75	18.5	

3.3.3 Lindholmen

The third part of the evaluation was of the bus stop Lindholmen and its surroundings. The result is presented in Table 7. This bus stop is designed in a similar way as Regnbågsgatan and thus there are several ratings in the two areas that received the same score. One similar reduction in ratings is that the crossings from the bus stop lacks sufficient traffic calming measures here as well. There is also not enough separation between the traffic modes, especially between pedestrians and cyclists. In the area around bus stop Lindholmen it is observed to be even more people moving around. Thus it is important with a clear separation of the traffic modes. Figure 18 shows pedestrians coming from the buses and crossing the road. The majority of pedestrians in the picture is walking on the red marked bicycle lane instead of the pedestrian crossing. It is also visible in both Figure 17 and Figure 18 that the placement of some of the pillars is not good. One thing that differs compared to the other areas is that a convenience store, Pressbyrån, is located by the bus stop. The building reduces the overview of the area and thus affect the security one feel here. But one could also see the store as a security when moving around in the area, when the store is open.

Figure 18 Many pedestrians coming from the buses and the majority walks at the red bicycle lane instead of on the pedestrian path (Photo by authors).

At Lindholmen all of the parameters essentially gets the same total rating and there are only smaller comments that reduces the ratings.

Table 7 Evaluation ratings for Lindholmen.

	Traffic safety	Accessibility	Orientation	Security	Total
Pedestrians	4.25	4.5	4.75	4.5	18
Cyclists	4.5	4.5	5	5	19
Public transport	4.75	5	4.75	4	18.5
Road traffic	4.5	4.5	4	5	18
Total	18	18.5	18.5	18.5	

3.3.4 Visualisation of evaluation result

To visualise the result from the evaluations of the three bus stops and to compare them to each other, two value diagrams are made. The diagrams display the total ratings for the three areas. One diagram shows the result for the parameters, while the other diagram displays the total ratings for the different traffic modes operating in the different areas. Note however that even though the total rating could be between 0 and 20, there were none of them that got below 14. Thus the scale of the diagrams starts at 14 to make it easier to distinguish the characteristics of the different areas.

How well the three areas satisfies the criteria for the different parameters are displayed in Figure 19. Here it is shown that all three areas have good security and almost the same rating, while in the other parameters they differ. The area Pumpgatan has the lowest rating in all four parameters, with traffic safety and accessibility being the worst. The areas Regnbågsgatan and Lindholmen has similar characteristics, which supports their similar design and is visible also in the value diagram. The one parameter that differs between the areas is traffic safety since there are more remarks made on Regnbågsgatan and thus this area receives a lower rating.

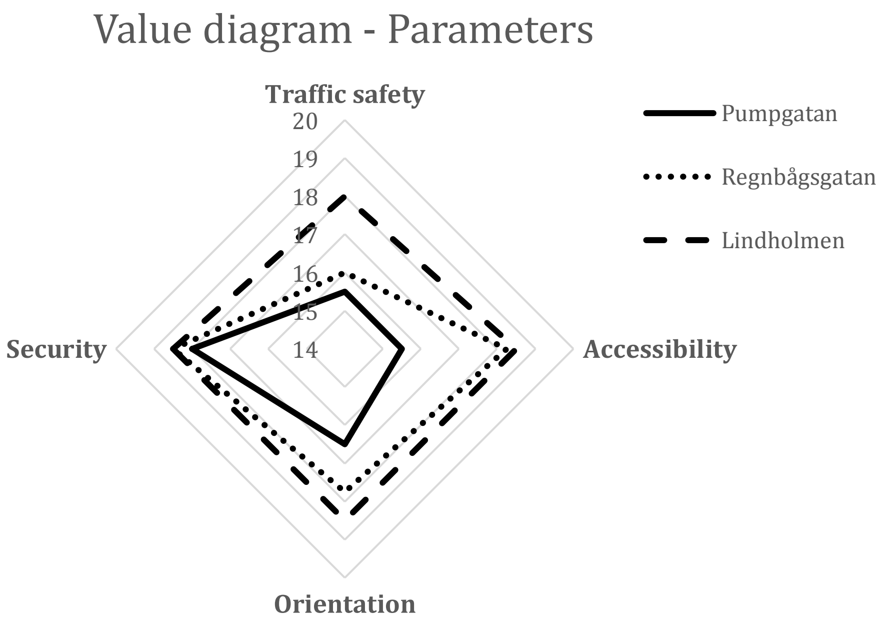

Figure 19 Value diagram of the total ratings for the different parameters evaluated.

The second value diagram, presented in Figure 20, displays how well the areas work for the different traffic modes that operate in the area. As seen, this diagram shows an altered characteristic for the three areas. For road traffic there are small differences between the areas, here Regnbågsgatan have a slight lower rating. The area Pumpgatan has the lowest rating for the rest of the transport modes. Interesting to notice is that for pedestrians and public transport there are not a big variation between the ratings of the areas. This difference is most likely explained by the different sizes and designs of the bus stops, from Pumpgatan which has a simple structure to Lindholmen which is larger and with more travellers. The most interesting difference is when looking at the bicyclists. Here it is a big difference between Pumpgatan and the other two. The main reason behind this is that around the area Pumpgatan, there are no possibilities for parking the bike whatsoever, which resulted in that the area got a rating of 0 on several criteria and conclusively a comparable low total rating for bicyclist.

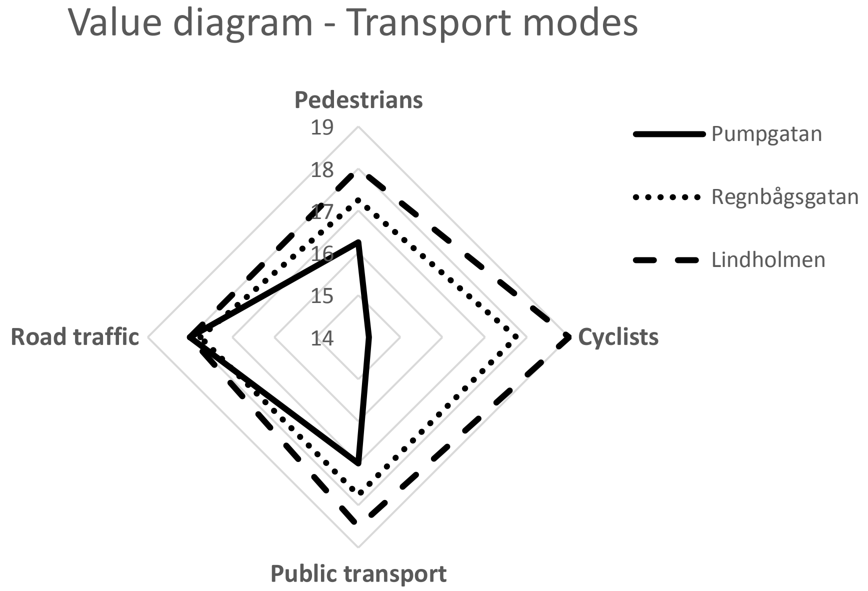

Figure 20 Value diagram of the total ratings for the different traffic modes evaluated.

As seen in the figures, bus stop Lindholmen has fulfilled the criteria best, while bus stop Pumpgatan received the lowest scores. The low result however, does not mean that the bus stop has a bad design. Pumpgatan has few travellers in comparison to the other two on the street and therefore has a simpler design. The accident statistics also indicates that the area is not prone to accidents. Bus stop Regnbågsgatan fulfils the requirements quite well but not to the same degree as Lindholmen, which got the highest rating of the three of them in all aspects. Regnbågsgatan and Lindholmen have a similar design and they both have more users than Pumpgatan. Bus stops Regnbågsgatan and Lindholmen are both representative for a simulation since they include the elements that are interesting to simulate. What differs between them is the roundabout situated close to the stop Regnbågsgatan, which increases the interactions between all traffic modes and makes the traffic situation complex. It is therefore of interest to look at this area in more detail using simulations, which will be described in the following chapter.

4 Simulation

As previously described, the simulation is carried out in order to get a visualisation of the area and the problems that may occur at this location. This chapter starts with an in depth presentation of the method and procedure used for the simulation. Further on, a detailed description of the assumptions and simplification in the model is presented. This is followed by a description of how the simulation model is built up. Lastly, the obtained results from the simulation is presented and analysed.

4.1 Method and work process

The first step in the simulation was to get to know the program that was used, PTV VISSIM 7.00-15. A study was made to get knowledge of how to use the program, build a model and perform the simulations. The work process used for this traffic simulation study is presented in Figure 21. This process is derived from a manual for capacity analysis using simulation, from the Swedish Transport Administration (Trafikverket, 2014a).

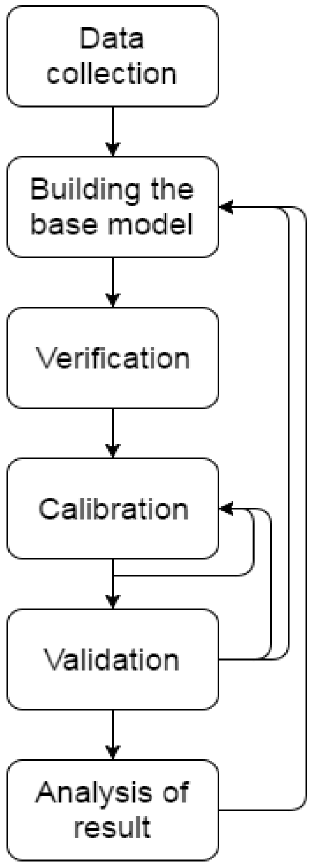

Figure 21 Work process for traffic simulation studies.

The simulation is run for the area around the bus stop Regnbågsgatan. The time that is chosen to be simulated is during a weekday and between 07:00 and 08:00. When looking at the different traffic modes separately the peak hour differs, but the combined hour that was chosen is representative for the morning peak traffic for all traffic modes. The three weeks that are chosen for the traffic counts are in the month of April. These weeks are normal and not disturbed by holidays or other occasions that may affect the amount of traffic. By counting the traffic in April the amount of cyclists on the roads has also started to increase, giving a better result as the amount of interactions between traffic is expected to be higher during this time.

4.1.1 Data collection

The work process starts with the data collection, to gather all the data and information needed about the modes of transport operating in the area. The volumes of the different traffic modes were counted on the site and used in the simulation.

Not all the data collection was carried out during the selected simulation time and the counting was concentrated to three weeks resulting in average values for the different traffic flows. This is done in order to get as low scattering of the data as possible. If the data collection would be carried out for a longer time period, the weather and thus also the preferred mode of transport used could change. The volumes of traffic on site was counted on Tuesdays, Wednesdays and Thursdays. This is because on Mondays and Fridays people may travel in a different way. It is for example more common with different schedules or taking the day off on these days. Thus the three chosen days for data collection are assumed to be more representative as weekdays. The results from the counts and the additional information that was gathered is presented in Appendix 3.

Several counts were made to get as much information as possible about the amount of traffic moving in the area. The counts were made at different locations in the area to be able to know which routes the road users take. The locations are placed at the boundaries of the area, where the amount of the different modes of transport moving in and out of the model was counted. In this way the volumes could be decided. Furthermore, information about the routes and behaviour were gathered at these data collections.

There were four extra counts done, placed at the four crossings around the bus stop. This is because a large share of the pedestrians is entering the model through the buses at the stop. It is therefore of interest to know which crossing the pedestrians use to get to and from the bus stop. The traffic at each location was counted three times, one each week, and an average value was obtained. The count on a specific location was also repeated on the same day of the week. This was done to avoid errors due to people that are changing the way they travel during the week.

4.1.1.1 Pedestrians and cyclists

The main focus of this report is to investigate the traffic situation for the pedestrians. There are no indexes available for recalculating the pedestrian flows if counted in another hour. Thus all the pedestrian counts were carried out between 07:00 and 08:00. The cyclists were mostly counted during this time as well.

In the simulation area there are several buildings which pedestrians is observed going to and from. The largest of these were included as starting points and destinations for a share of the traffic volumes. The amount of pedestrians that travel to these buildings was also observed during the data collection.

4.1.1.2 Public transport

The central part of the simulation is the bus stop Regnbågsgatan, located on Lindholmsallén. This bus stop is busy, with buses and pedestrians arriving and departing during the whole day. The data collection for the public transport in the simulation is divided into two parts. The first part was to research the timetables for the buses at the stop to determine the frequency of the different bus lines. To fit the chosen simulation time, the hour between 07:00 and 08:00 in the morning was studied.

The second part of the data collection was to count all the alighting and boarding passengers on the buses, in order to determine the share of people travelling with each of the bus lines. The count was done one time and it is assumed that this share does not change during the week and that the travellers use approximately the same bus line consistently. Both the directions on the bus stop was counted, the south direction with buses going towards Lindholmen and the north direction with the buses going toward Gothenburg city centre.

4.1.1.3 Road traffic

The data collection for the road traffic was done in a similar way as for pedestrians and cyclists. But for road traffic it exists indexes for recalculating the traffic from one hour to another. This means that it is possible to count these volumes during a later hour of the day, making the data collection more efficient. The amount of road traffic travelling in and out of the area was counted. Furthermore, also information about routes and behaviour were collected.

Another part of the data collection for the road traffic was to decide the share of heavy traffic operating on the roads in the simulation area. This was done by counting the amount of heavy traffic and normal traffic driving into the area during a specific period of time.

Additional information about the volumes of road traffic on Lindholmsallén was found in statistics from the Urban Transport Administration of Gothenburg. This data was compared to the result from the simulation, where two data points were placed at the one-lane part between Regnbågsgatan and Götaverksgatan.

4.1.2 Building the base model

The next step in the simulation work process was to build a base model of the area that was to be simulated. This model was based on maps over the area and the local plan of this specific area. From the maps, information about the roads were obtained, including the width and also how they turn and connect to each other. The model was structured so that all the different traffic modes was included and inserted on the correct lanes.

In VISSIM the roads that is drawn is called links, and these are joined to each other with connectors. After the links and connectors was drawn according to the maps, they are assigned input traffic. In this project, links and connectors was used for the road traffic, public transport and the cyclists. For these traffic modes a car following model by Wiedemann (1974) was used together with a lane changing model. The cyclists in this simulation are modelled as road traffic and thus follows the same behaviour. The settings for the roads can be changed when the links are drawn. These settings allow to decide which mode of transport that should drive on which link and also how the traffic should behave.

Not all the transport modes use links and connectors. The pedestrians use something called pedestrian areas, which are used to get more realistic movements and behaviour. This allows the pedestrians to move anywhere on the area and not in specific lanes as for the rest of the traffic. These areas are drawn either as links that are set to behave as pedestrian areas, or if the wanted area is not formed as a road the pedestrian area could be drawn with another shape. Pedestrian areas was done in VISSIM through an additional module called VISWALK, which focuses on pedestrians. VISWALK uses the social force model by Helbing & Molnár (1995), a model that takes into account different aspects that affects the pedestrian behaviour and thus makes the simulation more realistic. One example of this is how close the pedestrians walk to each other.

When all the traffic was placed in the model, the next step was to adjust the road and add regulations and measures so that the traffic moves more realistically. This includes traffic signals at the crossings in the area where these exists. In the simulated area the existing traffic lights are operating so that the public transport gets priority at the bus lane in the middle of the road. In order for these traffic signals to work so that the public transport has priority they were programed using another add-on module called VISVAP. A more detailed description on how the traffic signals works and how it was programmed is presented in Appendix 4.

Another regulation was at the locations where traffic cross each other and it needs to be specified which lane that should give way for the other. In VISSIM there are two options on how to work with this, priority rules and conflict areas. In this project only conflict areas were used. In VISSIM the different conflict areas generated in the model is automatically displayed and it was then easy to decide who should give way and who has priority at all the existing conflict areas. Another measure to get a more accurate driving is to have something called reduced speed areas. In reality when a car for example drives in a roundabout or over a raised pedestrian crossing it would not keep the set speed on the road. Instead, it would reduce its speed to get through in a safe way. This was modelled in VISSIM using reduced speed areas. At the locations on the roads where it was observed that the vehicles lower their speed, a reduced speed area was placed and a new speed was introduced to the traffic. More detailed descriptions of the modelling of the priority rule, conflict area and reduced speed area are presented in Appendix 5.

To get a more accurate simulation result, the roads leading into the simulated area were extended outside of the specific location. This will make it easier for the traffic coming into the area to keep the correct speed and to adjust to the simulation. These extended roads that were added outside of the simulation area was not drawn according to reality and possible intersections and other objects were ignored. This was because the purpose of the added roads was only to increase the road lengths leading into the simulation area and was not part of the simulation itself.

4.1.3 Verification, Calibration and Validation

When all the data was collected and the model itself was built up, the base model was verified to control that it worked properly and according to reality. The method for this was to go through the model in detail, to see that all the parameters and settings were correct.

The next step in the process was to do an iterative calibration and validation of the model. This can be done by comparing specific parameters with measurements of these values to see how well the reality corresponds to the simulation. Another method is to do a visual calibration and validation, where a test run of the simulation is carried out and compared with observations of the actual traffic. For this simulation only the visual calibration and validation was used. This was a restriction that was necessary as the simulation was not that extensive and the time was limited. Some aspects that was observed during the visual calibration and validation was:

- How close to the pedestrian crossings does the cars stops?
- Where does the cars start to slow down when approaching an intersection with traffic lights or right of way?
- Are the conflict areas accurately done and has the correct traffic right of way?
- Is the clearance time for the traffic lights correct?

4.1.4 Simulation

Before running the simulation, the last step was to change settings and parameters in the program that establish how the simulation should be run and what output the program should generate. These results were processed and analysed in order to be a part of the evaluation of Lindholmsallén.

The simulation was run once with a total time of 4 500 s, which is 1 hour and 15 minutes. The extra 15 minutes works as a warm-up for the model to fill it up with traffic. After the 15 minutes the program starts to record the simulation and the result from it. Another parameter was the simulation resolution which were set to 10 time step(s) / Simulation second. This parameter specifies how often vehicles and pedestrians are moving in a simulation second (PTV Group, 2015). The simulation was run with a specific random seed, which resulted in a stochastic variation of the input vehicles. This was done to imitate the natural variance that occur in traffic.

From all of the output results that was obtained from the simulation two main results was analysed. The delay and the density of the different transport modes. The delay results were divided into the different routes that were set for the transport modes. Thus the routes with the most interactions were identified. The public transport only has one route per direction as it is only one lane in each direction for the buses throughout the area. Therefore, the delay for these were divided into which bus stop the delayed bus stopped at, to see if there was a difference between the stops. The density was presented in a map showing the entire model and the density of the different transport modes in vehicle per kilometre.

4.2 Assumptions and simplifications in the simulation

When building the model assumptions and simplifications are made. These are divided in this chapter based on which part of the simulation that they affect. The assumptions and simplifications are derived from observations on the maps and local plan, but are also a result from observations in the area. There are simplifications made in order to make the process and the simulation itself easier.

4.2.1 Geometry

The model is constructed with no level differences. In the local plan of Lindholmsallén it is stated that the total level difference between the two ends of the road is 2 meters. Level differences can affect the acceleration of larger vehicles (Trafikverket, 2014a), but the actual difference is considered to be small so that the eventual impact on the result is assumed to be negligible. The dimensions of the road are mainly based on the cross section in the local plan of Lindholmsallén. Some of the dimensions are based on an aerial photograph, for example the width of the roundabout. It has been observed that the large width of the car lane here has led to that it is common for the road users to behave as if there would be two lanes. This is particularly visible when there is red light for the vehicles in the car lanes and two vehicles stop beside each other. In the model however, it has been modelled that there is one lane.

There are also simplifications made in the geometry of the road design. Since the geometry and placement of the roads are based on an aerial photograph, they may not be entirely corresponding to the real design of the road. Notable of these simplifications are the areas lining the walkways. These parts are irregular and consists of walking areas, building facades, entrances and different forms of vegetation. These have been simplified to be uniform along the road and therefore some of the entrances have been omitted. Furthermore, the pillars lining the street and the bus shelters at the bus stops are not included in the model. The large stair leading to the office building, on the north side of the bus stop Regnbågsgatan, is added into the model in the form of an obstacle. This means that pedestrians cannot walk on it, instead they have to walk around it. The pedestrians who have the office building as their destination leave the model at the bottom of the obstacle. Further simplifications are that the parking lots along the road are not included in the model. This may affect the formation of queues, but since the amount of traffic is considered to be low the simplification is reasonable.

At southern Regnbågsgatan and Lilla Karlavagnsgatan, there are two walkways, one on each side. This is simplified to only being one walkway, to facilitate the data collection. The remaining walkway is placed at the side situated closest to the bus stop since it is assumed that this is the one that is used most often. During the traffic counts it is also observed that this assumption is correct. The flow of pedestrians coming to and from the streets is estimated to be low. It is therefore assumed that this will not affect the results to any extent. The two aforementioned roads also lack cycle paths. The cyclists who are using these roads in reality are instead driving on the road with the cars. In the model cycle paths have been added to both roads. They have been situated next to the walkways, which means that they are placed at the side that is closest to the bus stop.

4.2.2 Traffic characteristics

In general, the ordinary traffic rules have been used to decide who has right of way in the simulation model. However, at some places it has been observed that the road user's behaviour differs from the traffic rules. At these locations the model is changed to better match the real situation. It is for example observed that the vehicles driving on the road often stop at the crossings to let the cyclists from the cycle path pass, even though the cars have right of way. The cyclists are therefore being given priority over the road traffic at these places. Another location where assumptions have been made regarding priority rules are at the areas where the pedestrian walkway coming from the crossings meets the cycle path that goes along the street. At these places it is unclear who has right of way, but it has been observed that the pedestrians often stop and wait for the cyclists to pass before they cross the cycle path. In the model, the cyclists therefore have priority over pedestrians at these locations.

Another simplification that is made is that the percentage of heavy traffic is set to be the same at all streets. The streets have similar characteristics and are therefore assumed to have the same distribution of traffic types. Further on, the share is expected to be low so any eventual differences between the streets would not affect the result much, especially since it is mostly the pedestrians that are of interest in the model. The traffic counting for the heavy traffic is not performed during the hour that is simulated. It is, however, assumed that the calculated percentage for the traffic counting hour will be the same during the entire day and therefore also during the simulated hour.

There are simplifications done when it comes to which traffic modes that are included in the simulations. The first is that mopeds driving on the bicycle or pedestrian lanes were neglected since the amount is low. The mopeds and motorcycles driving on the actual road were counted and simulated as cars. Further on, electric bicycles are counted as normal bicycles in the data collection, even though they often move faster. There are several types of people moving on the pedestrian areas. The largest share is people that walk normally, but there are also people with strollers or that is going by skateboards and rollerblades. These are all counted and simulated as "normal pedestrians".

The buses that traffic Lindholmsallén do not have the same size. Bus line 16 is often operated by 24–meter buses. In contrast, bus line 55 is just 11 meters (Volvo Buses, u.d.). In the model, however, the buses are of the same size, 11 meters.

4.2.3 Routes

The routes that are used in the model are based on the result from the data collections and observations. Some assumptions were made when distributing the routes, at locations where the collected data and observation not gave enough information. These are presented below, divided into the different modes of transport where routes were decided.

4.2.3.1 Pedestrians

When deciding the routes for the pedestrians, assumptions and simplifications were made. Firstly, it was assumed that pedestrians are using the shortest way when walking from one point to another. That means that those coming from the buses exit the bus stop via the crosswalk closest to the destination point. It is also assumed that the pedestrians not coming from the bus stop uses the first crossing when they cross the street. The assumption is confirmed by observations at the data collection, where this behaviour is noticed.

It is observed that pedestrians have a tendency to take a shortcut when walking. This behaviour is for example noticed at the crosswalk over the bus lanes at the bus stop. It is also observed that pedestrians sometimes walk straight over the tree plantings at Lindholmsallén and Götaverksgatan, instead of using a crosswalk. This behaviour is not added in the model. All pedestrians are instead modelled to always use the crosswalks and the walkways. It has also been observed that it is common for the pedestrians to walk when it is red light at the pedestrian crossings. This behaviour was also difficult to add in the model. Therefore, it is modelled that all pedestrians walk when it is green light.

Even though bus stop Regnbågsgatan is relatively large with a high amount of travellers it is not considered a transfer point between different bus lines. Thus, there are no travellers that change from one bus to another at this stop in the simulation and all people alighting the buses leave the bus stop. During the traffic counts it is also observed that this assumption is correct and that there is no or few transfers between buses on this bus stop.

4.2.3.2 Cyclists

It is assumed that the cyclists choose the fastest route when going from one point to another. This assumption is made both when deciding the routes and in the simulation model. Like the assumption for pedestrians, it is also assumed that the cyclists use the first crossing when they cross the street. The amount of entry and exit points are simplified to not contain bicycle parkings since it is observed that few cyclists were using the parkings on the street. It is instead common to park on some of the smaller streets connecting to Lindholmsallén that are situated closer to the destination.

4.2.3.3 Public transport

When calculating the amount of travellers using the different bus lines it is simplified that the arrivals of the busses are evenly distributed during the hour. This means for example that the arrivals of bus line 99, which according to the time table, seen in Appendix 3, arrives every 5th minute during the second half of the counted period but more infrequently during the first half, are evenly spread out during the hour. This simplification is also made when simulating the arrivals of the buses.

During the data collections it is observed that the buses do not always stop at the bus stop intended for the bus line. This behaviour is difficult to simulate as it is difficult to know the exact reason to why they choose to stop at another bus stop. In the model the buses are therefore set to always stop at the bus stop intended for the respective bus lines.

4.2.3.4 Road traffic

Assumptions and simplifications are done when calculating the route distribution for the road traffic. Firstly, it is assumed that the road users chose the shortest way from one point to another. An example of this is that the cars going from Götaverksgatan towards Lindholmen chose to go via the U-turn intersection instead of the roundabout further away. It is also assumed that there are no starting points for road traffic in the model, i.e. no parking lots.

4.3 Collected data

A detailed presentation of the collected data is found in Appendix 3. As described earlier in this chapter the data collection was carried out in different areas, located on the boundaries of the simulation area. The locations are presented in Figure 22, where pedestrian count locations are presented in letters, whilst road traffic and bicyclist are numbers. As can be seen there are four extra count locations for pedestrians, covering the crossings to and from the bus stops. The lowercase letters represent the four bus stops, where the data collection for the public transport were performed.

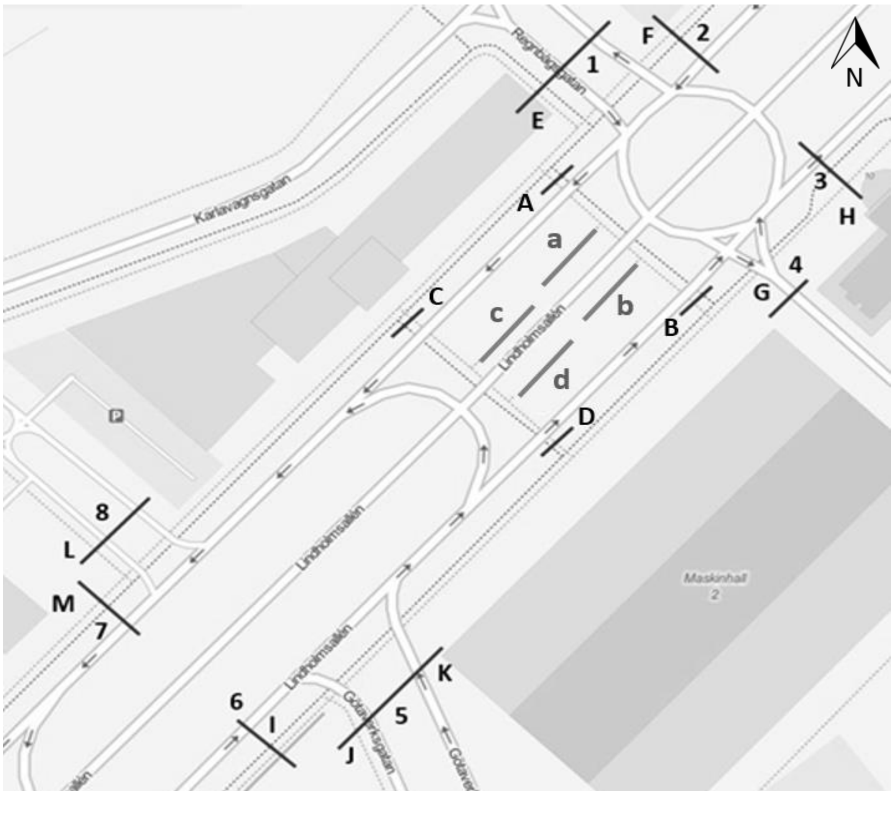

Figure 22 Locations where the data collection was performed.

The average traffic volumes obtained from the data collection are presented in the following chapters, divided into the different traffic modes that are included in the simulation. These numbers are corrected using indexes if necessary and the calculation is presented in Appendix 3. In the tables below the columns called "To" refers to the volume of traffic moving into the area, either over the surrounding boundaries but also entering from the buses. The "From" column is the traffic volumes that leaves the area, either by bus or driving or walking out of the model. In theory these two volumes, “To” and “From”, should be the same. But in this case, especially for cyclist and pedestrians, not the complete boundary of the area is observed and they could exit or enter on unsupervised locations. But the major roads, bicycle and pedestrian paths are supervised so possible differences in volumes due to that should not be that large. The differences are more likely to be a result of different weather in combination with that the locations for the data collection changed every day.

4.3.1 Pedestrians

The result from the pedestrian count is divided into two tables. Table 8, shows the four counting locations on the four pedestrian crossings connected to the bus stop. In this table the first two columns that present traffic volumes also include the pedestrians who walk all the way across, using two of the crossings. The last two columns exclude these people and only displays the pedestrians coming from or going to the bus, and using one of the four crossings.

In Table 8 it is clear that the largest volume of pedestrians coming from the buses uses the crossings named B and D. It is also seen that the volumes going to the buses are smaller and also more evenly distributed.

Table 8 Result from the pedestrian data collection at areas A to D.

Area	To	From	To (by bus)	From (By bus)
A	12	51	4	18
B	333	18	300	10
C	68	14	56	6
D	330	17	322	7
Sum			**682**	**41**

Table 9 shows the remaining nine counting locations. All of these are located on the boundary of the model area. The two largest exiting volumes of pedestrians is from the points called G and K. These results are linked to the table above as the crossings B and D leads to the south side of the model where the areas G and K is located. For the entering pedestrians, the largest amount comes from area E.

Table 9 Result from the pedestrian data collection at areas E to M.

Area	To	From
E	63	11
F	3	3
G	21	230
H	11	53
I	11	14
J	2	7
K	8	294
L	7	12
M	3	10
Sum	**129**	**634**

When summarising the amount of pedestrians coming in to the model, either by bus or over the boundaries, the total volume is 811 persons during the studied hour. The total amount that are moving out of the model is lower, summed to 675 pedestrians. This difference of 136 pedestrians can be explained by a number of factors. The first is that for the pedestrians it exists several buildings in the model where people can enter or exit. For some of these buildings it is observed that more people are entering, resulting in that people are "leaving the model" through these buildings. Another explanation for the difference in volumes is because this is average values. Each location is counted three times, on different days and during three weeks. The weather during these weeks differed some. During the first week it rained constantly and the two other weeks it was sunny and warmer. This may have resulted in that some routes were more frequently used, not depending on the weather and some only if the weather was good. The average calculation of the volumes could then result in a difference.

4.3.2 Cyclists

The counted traffic volumes of cyclists in the area are presented in Table 10, divided into the eight locations where the count are made. Here the largest flow of cyclists into the area come from location 1, where the north part of the road Regnbågsgatan connects to Lindholmsallén at the roundabout. Two other large flows are from the areas 3 and 6, located on the south side of Lindholmsallén. The volumes of traffic going out through the area is also large at these two locations. The results also show that while area 1 not has that high outflow, area 5 has one of the largest outflows of traffic. The fact that area 3 and 6 both has high incoming and outgoing traffic could mean that this bicycle path is a popular commuting lane for cyclists.

Table 10 Result from the cyclist data collection.

Area	**To**	**From**
1	80	12
2	10	14
3	51	41
4	1	21
5	6	40
6	59	55
7	13	22
8	3	2
Sum	**223**	**207**

When summarising the volumes of cyclists, the amount of travellers into the model is, like the pedestrians, higher than the amount leaving the area. In this case the difference is 16 cyclists. This difference is explained in a similar way as for pedestrians. The existing buildings in the area are also destinations, or origins, for the cyclists. It is observed that cyclists stop at these locations and go into the buildings. The weather has possibly influenced the cyclists and because the weather conditions differed during the data collection one could expect some difference in traffic volumes.

4.3.3 Public transport

The first part of the data collection for the public transport was to investigate which bus lines that operate in the area and at what frequency. Time tables for the busses that arrives in both directions are presented in Appendix 3. The second step was to count the amount of travellers that every bus line has and the result from this count is also presented in the same appendix. In Table 11 a summary of the collected data is presented. As seen, the south direction has the highest share of travellers. It has 56 buses arriving and in total 522 people alighting the buses this hour. The north direction also has a high number of buses arriving, 46 in one hour, but there are only 160 people alighting in this direction. The amount of boarding passengers are comparatively low in both directions during the morning peak. In total, 8 people are boarding in the south direction and 33 people in the north. This indicates that there are few residences in the area and that a small number of people travel from this location to work or school in the morning. The fact that more people board in the north direction is also reasonable as this is towards the centre of Gothenburg.

Table 11 Result from the public transport data collection.

	South direction				**North direction**			
Bus line	Arrivals 07:00-08:00	Bus stop	Alighting	Boarding	Arrivals 07:00-08:00	Bus stop	Alighting	Boarding
Bus 16	12	c	104	1	13	b	26	6
Bus 16X	15	c	115	2	0	b	-	-
Bus 99	9	a	83	3	9	d	52	3
Gul express	8	a	72	2	12	d	12	8
Bus 55	6	a	48	0	6	d	0	13
Bus 45	4	a	22	0	4	d	70	3
Bus 402	2	a	78	0	2	d	0	0
Sum	**56**		**522**	**8**	**46**		**160**	**33**

4.3.4 Road traffic

The road traffic was also counted at eight locations, situated at the boundary of the simulation area. The resulting traffic flows are presented in Table 12. Here it can be seen that four of the areas has one-way traffic and thus only traffic flow in one direction. The largest flow of road traffic into the model is from area 1 and 6, as seen in Figure 22 earlier in the chapter. The largest flows of traffic exiting the area is from location 5, a connecting road, and 7 where Lindholmsallén continue towards Lindholmen.

Table 12 Result from the road traffic data collection.

Area	To	From
1	791	165
2	296	
3		246
4	34	278
5	104	579
6	712	
7		675
8	4	19
Sum	**1941**	**1962**

The difference in the total volumes of road traffic is small compared to the amount of traffic that moves in the area during the counted hour. The data collection resulted in that 21 more vehicles was driving out of the area. For the road traffic all of the routes leading in or out of the area were observed and it exists few parking lots for the traffic inside the simulation range. This means that it should not be possible for the traffic to enter or leave unnoticed. The difference in entering and exiting traffic is only explained by the fact that not all the locations was counted at the same day and week. There exists traffic that does not drive the same route every day and this means that if not all the exit and entering points are counted at the same time, it might lead to a difference as in this case.

Another part that was counted during the data collection was the share of heavy traffic. The amount of motor vehicles travelling into the zone on the car lanes were counted. The vehicles were divided into normal road traffic and heavy traffic. Bus line 99, which connects to Lindholmsallén from the street Karlavagnsgatan via the roundabout near bus stop Regnbågsgatan, was not included in the counts. The result from this count is that the share of heavy traffic in this specific area is 3.1%.

4.4 Model design

Presented in this chapter are the input values and parameters used in VISSIM to be able to simulate the selected area. The first part includes information about the geometry of the area and the different structural parts found in the model. This part also describes values and parameters that is connected to the measurements and settings in the simulation. The second part of the chapter is dedicated to the design and the decisions behind the route distribution of the transport modes in the model. The simulation model is shown in Figure 23.

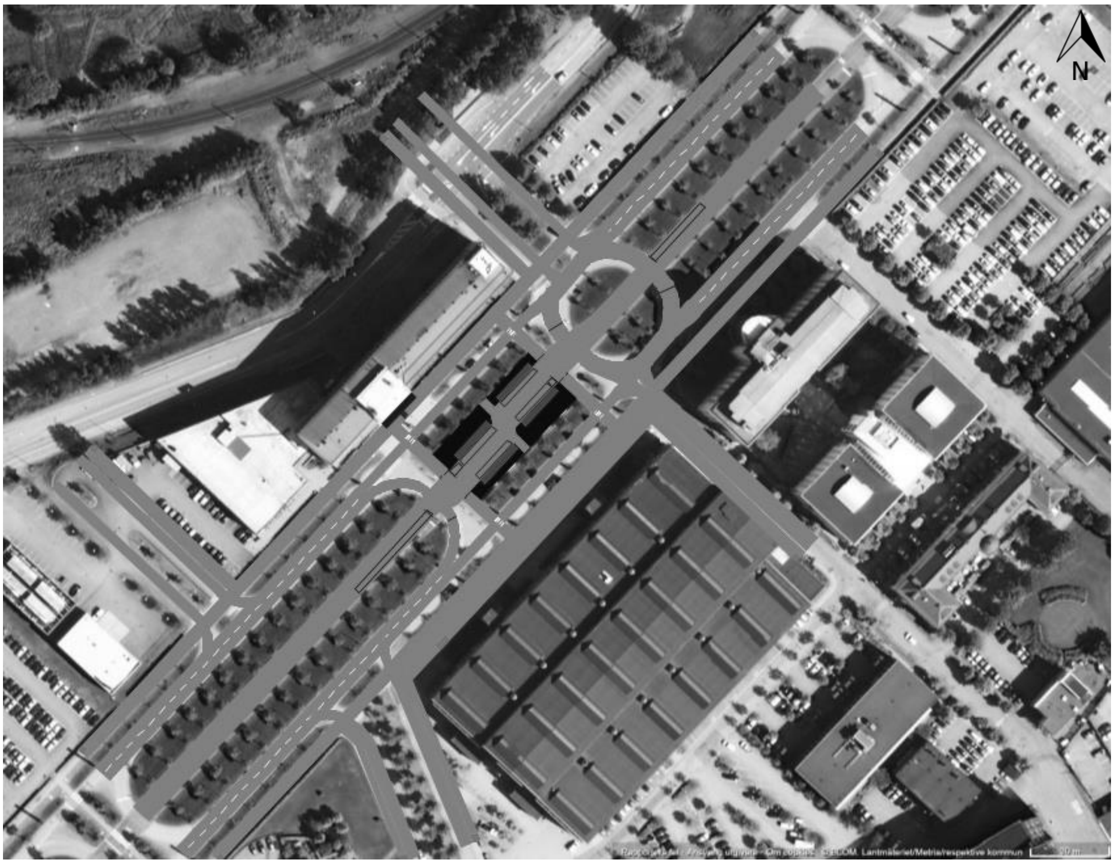

Figure 23 Simulation model in VISSIM, background picture from Eniro (2016).

4.4.1 Geometry

The widths of the different road types are gathered from the local plan and from maps over the area, and are presented in Figure 24. The links for the road traffic has a width of 3.5 meters per lane, in some parts of the model the road is two lanes wide with a total of 7 meters. For the bus lanes, located in the middle of the street, the width is set to 4 meters per lane. Throughout the simulation area there are two lanes for the buses, one in each direction, giving the road a total width of 8 meters. The bicycle and pedestrian paths are located at the outskirts of the area, with the bicycle paths closest to the road on both sides. The width of the bicycle lane is in total 2.25 meters, divided into two directions. The pedestrian paths are located furthest from the bus lanes. At most locations in the simulation they are modelled as roads with a width of 2.25 meters as well and assigned to be a pedestrian area. This is the case for the pedestrian path located in the top of the Figure 24. But at one specific location, outside of the building called M2, the walkway is in reality wider and stretches all the way to the façade. In the model the pedestrian area is extended to look the same, with the help of the map. In that way, the pedestrians in the model can walk the same route as in reality.

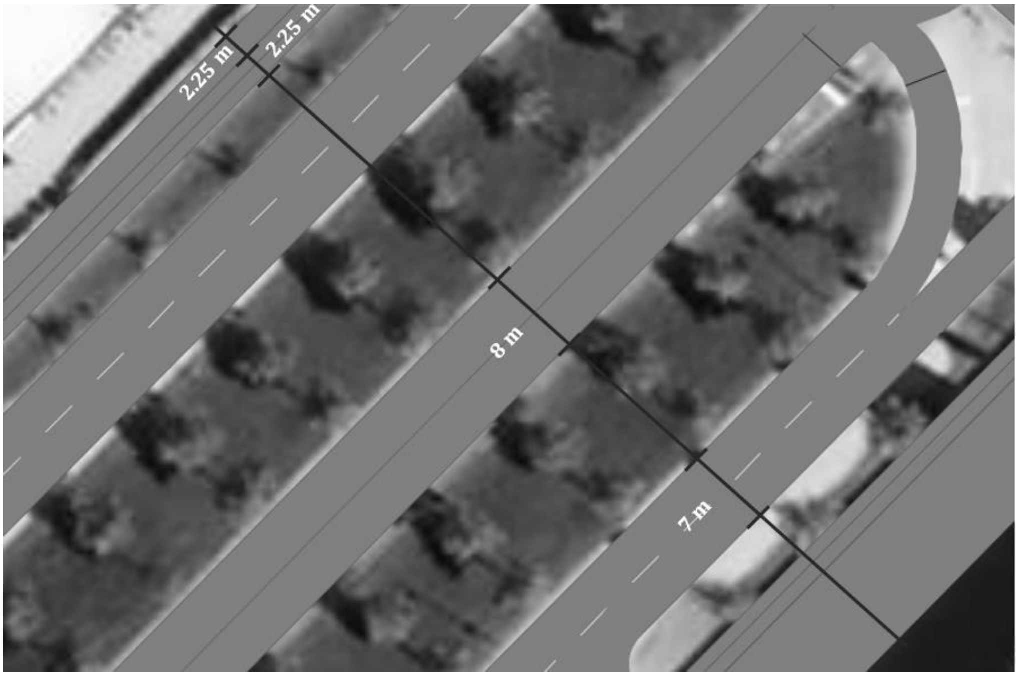

Figure 24 Widths of the pedestrian walkways, cycle paths, bus lanes and road traffic lanes in VISSIM.

The bus stop Regnbågsgatan is modelled as shown in Figure 25. There are two positions where the buses stop in each direction, depending on the bus line, which also is how it works in reality. These are displayed in the figure and the connecting Platform edges are where the pedestrians board and alight the buses. Each direction has a shared waiting area, joined to both of the platform edges in that direction. On the waiting areas there are in reality several bus shelters. These are not added in the model since they are not considered to be obstacles and thus not affect the simulation. The waiting area is according to the local plan 50 meters long and 4 meters wide at the most narrow section.

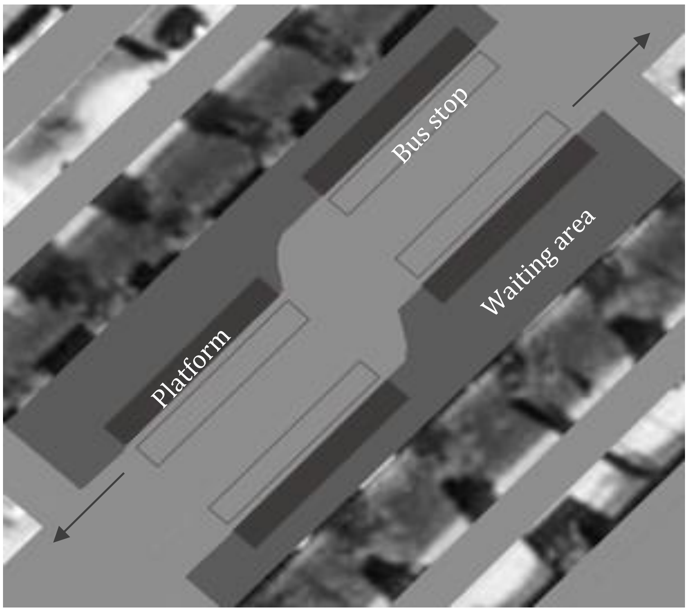

Figure 25 Picture showing the elements of bus stop Regnbågsgatan in the model.

According to the local plan of the area the road is designed to have a speed limit of 50 km/h. Locations with crossing pedestrians is designed with raised crosswalks that provide maximum speed of 30 km/h in order to increase the security. In the simulation the desired speed distribution for the vehicles is thus set to 50 km/h, which in VISSIM result in a distribution in speed between 48 km/h to 58 km/h. This excludes the cyclists which has a desired speed distribution of 15 km/h (15 km/h, 20 km/h). The pedestrians walking speed is set to 4.75 km/h (1.32 m/s), including a distribution to both faster and slower pace. The speeds for pedestrians and cyclists are approximated values from observations made of the two transport modes.

In locations where the traffic should move slower than the desired speed, reduced speed areas are used. In Figure 26, examples of the three reduced speed areas used in this simulation is presented. One location is on the pedestrian crossings, number 1 in the figure, where reduced speed areas are placed with an allowed speed of 30 km/h. This reduction is decided in the local plan of the area and it is also observed that the cars lower their speed when driving over the crossings. Other locations where the reduced speed areas are used is in curves in the roundabout, U-turn and where the connecting roads is linked to the main road, displayed as number 2 in the figure. These are locations where it is observed that the cars driving on the road are unable to keep the desired speed. Here the speed is reduced more as it is observed that the vehicles drive slower at these locations. For the roundabout and where the connecting roads cross the pedestrian and bicycle paths to link to the main road, the speed is set to 25 km/h. For the roundabout there is also a method to decide the general speed in a roundabout if no speed data is available. Using equation (1) by Swedish Transport Administration (2014a), the resulting speed was 24.2 km/h. In VISSIM the closest available speed was 25 km/h and therefore used in this case.

$$v = \sqrt{127 \times R \times (q + f_t)} \qquad (1)$$

$R = Radius\ minus\ half\ of\ the\ lane\ width$

$q = 0$

$f_t = 0.23$

There are locations in the area where it is observed that the cyclists reduce their speed. This is where the road traffic and the bicycle path cross each other, at the locations where the connecting roads link to the main road. One of these interaction points are presented in Figure 26 as number 3. With no speed measurements for the cyclists it is assumed that they lower their speed to around 12 km/h and the reduced speed is therefore set to that.

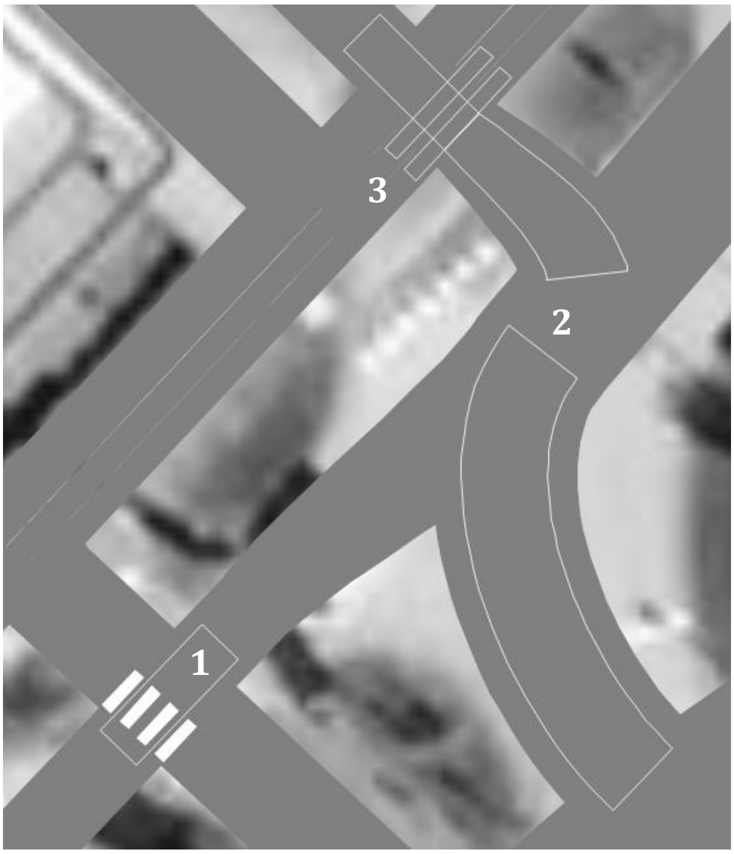

Figure 26 Reduced speed areas in the model.

When observing the heavy traffic in the area it is detected that it in general drives slower that the other traffic. In the locations where no reduced speed areas are placed it is assumed that the speed of the heavy traffic is approximately the same as the rest of the road traffic, because the difference is low. But in areas where the speed of the road traffic is reduced there is a noticeable difference for the heavy traffic. The reduced speed for the heavy traffic is therefore set to be 5 km/h lower than for the road traffic.

In order to decide which traffic has priority in a non-signalised intersection, conflict areas are used. The roundabout is modelled so that all the traffic that wants to drive into the roundabout must give way for the traffic that is already in it. It is also set so that the pedestrians have priority on all crossings and when other traffic crosses the pedestrian lanes. One special situation is where the pedestrian lane that is coming from the bus stop is crossing the bicycle lane. It is observed that the majority of pedestrians give way for the cyclists and thus it is simulated in that way. Another observation is that the majority of the cars give way if they see a cyclist at the crossings. It is therefore modelled so that the cyclists have priority here.

The traffic signals in this project are modelled in VISSIM using the add-on module called VISVAP. The reason to why this program is used is to be able to simulate so that the public transport has priority in the signalised crossings. In reality, the buses send a signal via radio to the traffic signals, which change to green so that they can pass. This is modelled in the program using detectors on the links that react when a bus drives on them and is connected to the signals. The files where the signal controllers are programmed are presented in Appendix 4 together with parameters regarding green and red times. Also in this appendix the settings regarding the signal controllers and how they are modelled are presented in detail.

Other parameters and settings in VISSIM are kept as standard values. It is observed during the visual calibration and validation that this works well for this model and that the traffic behaves according to reality.

4.4.2 Route distribution

From the data collection the routes for the different traffic modes was distributed. The public transport has one route in each direction as it has one lane throughout the modelled area. To assist with the route distribution, observation of the traffic in the area was also conducted during the data collection. The resulting routes for the different modes of transport are presented in Appendix 6.

When adding the possible routes assumptions were made. For all modes of transport, it was assumed that the traffic does not go into and out of the model at the same locations. An example of this for the road traffic is the route from Regnbågsgatan to the roundabout and back to Regnbågsgatan again, shown to the left in Figure 27. Another example of a route that was excluded for pedestrians and cyclists is shown to the right in Figure 27. It is assumed that if one would want to go to the other side of that road you cross at the pedestrian crossings located right outside of the modelled area and thus not going all the way out to Lindholmsallén and back again. Likewise, it is assumed that pedestrians and cyclists take shortcuts outside of the model and not necessarily take the larger paths that lead into the modelled area.

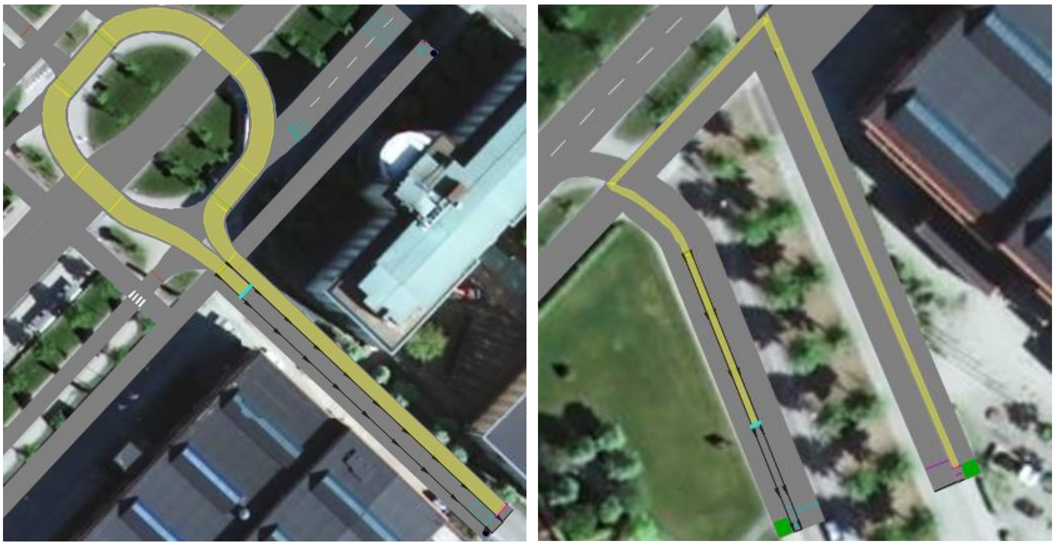

Figure 27 Unlikely route options in VISSIM. Left picture is an example for cars and the right is for pedestrians and bicyclists.

In the simulation area there are buildings where pedestrians can enter or exit. During the data collection it was observed that some of these locations were more frequently used than others. These locations were therefore added in the model to make it more realistic. One of these locations is on the north side of the road, the former office of Götaverken, which today holds another company. Here an entering and exiting location for pedestrian was added, but it was also observed that almost no one exited from this building during this hour. On the south side of Lindholmsallén there are several entrances in the old machine workshop called M2. These are in the model assumed as only one entrance and exit location, because one of them was more frequently used.

4.5 Simulation result

In this chapter the results obtained from the simulation is presented. There are three traffic modes that contain multiple routes, pedestrians, cyclists and road traffic. For these modes, the average delay per route is obtained and presented in diagrams. The delayed time is showed in percentage delayed compared to the optimal travel time, where 100 % means that there is no delay. Note however that the percentage starts at 80 % and not 0 in the diagrams, to better visualise the results. Some routes that was created in the simulation got a flow of 0 and is not included in the diagrams. The reason why they got a value of 0, even if they were assigned flows, is that the simulation was run with a random seed. That resulted in that the input values changes somewhat for each simulation, to imitate the randomness that exist in reality. As an example some routes with assigned low flows randomly got a lowered flow resulting in a 0-value. For the public transport there are only one route in each direction, as the road goes straight through the model with only one lane. Here the delay is presented in average delayed time for the buses arriving to each of the four bus stops. Furthermore, a density map for the road traffic in the simulated area is obtained, visualising the amount of road traffic that operates on the roads.

4.5.1 Pedestrian result

The average delayed times for pedestrian routes is separated into routes coming from the bus stops in the first diagram and the rest of the routes in the second. The routes are assigned a number in the figures and in the tables located below the diagrams the route number is presented along with the actual route.

In Figure 29 the delay for the pedestrians going from the bus stops is presented and in Table 13 the numbers and connecting routes are displayed. There are some routes that has noticeably higher delays than others. The four with the highest delays, number 11, 16, 25 and 33, are all routes going from each of the bus stops and crossing both the bus lanes and the car lanes as shown in Figure 28. When crossing the car lanes, the pedestrians has priority and is thus not delayed by this. But at the bus lanes there are traffic signals giving the buses priority leading to higher delays for the pedestrians. Thus concluding that the buses are the largest delay factor and barrier for the pedestrians.

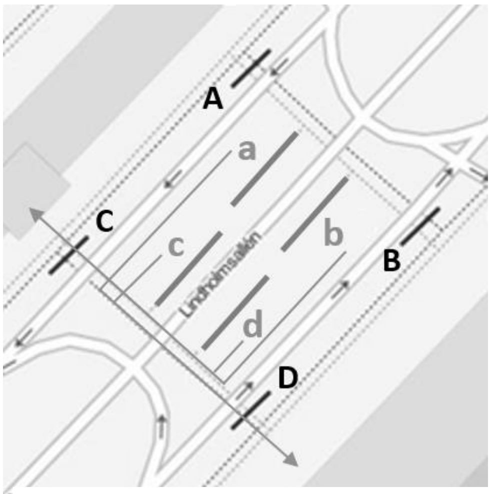

Figure 28 The pedestrian routes with the highest delay.

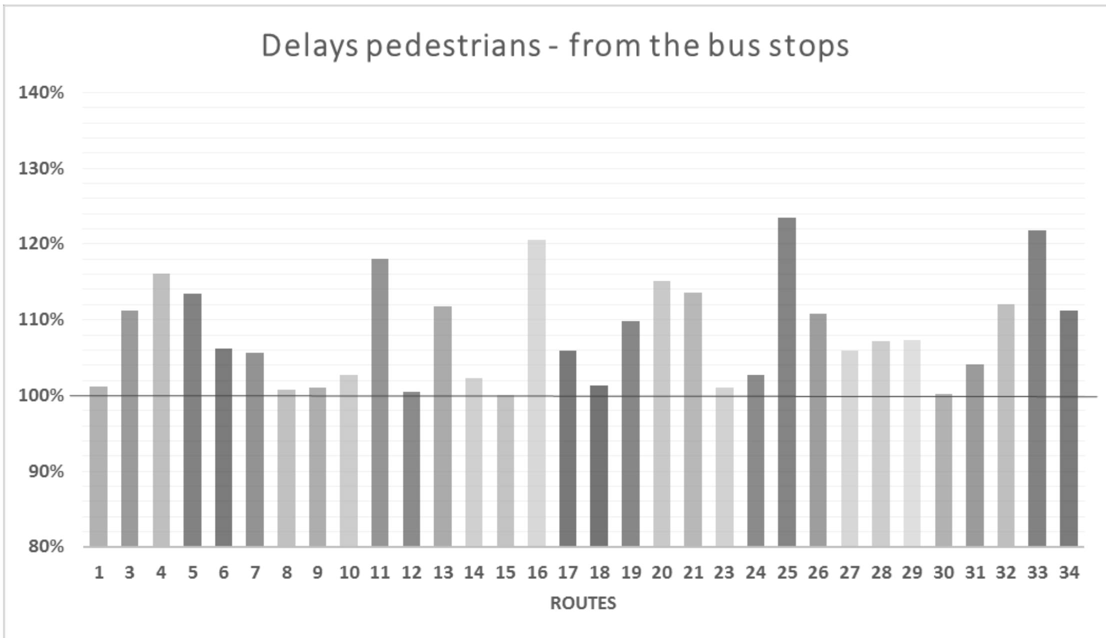

Figure 29 Diagram over the delay for pedestrian routes shown in percentage. First part entering from the bus stops.

Table 13 Presentation of route numbers from diagram and connecting route.

Route no.	Route	Route no.	Route	Route no.	Route	Route no.	Route
1	a-E	10	a-Off	18	c-E	27	d-H
3	a-H	11	a-M2	19	c-H	28	d-G
4	a-G	12	b-H	20	c-G	29	d-K
5	a-K	13	b-G	21	c-K	30	d-I
6	a-J	14	b-K	23	c-L	31	d-M
7	a-I	15	b-I	24	c-Off	32	d-L
8	a-M	16	b-Off	25	c-M2	33	d-Off
9	a-L	17	b-M2	26	d-E	34	d-M2

The rest of the routes in the simulation area are more uniform comparing the delays and most of them are low as can be seen in Figure 30. There are one that stands out from the rest, route 79 seen in Table 14 going from M2 to c. This is the reverse route to number 25 in the Figure 29, which also had a large delay, but route 79 was only used by one pedestrian during the simulation and the average may not be representative. The other routes that have delays in this diagram is also crossing the bus lanes to go to their destination, just like the previous diagram. Thus confirming that the buses cause delays for the pedestrians.

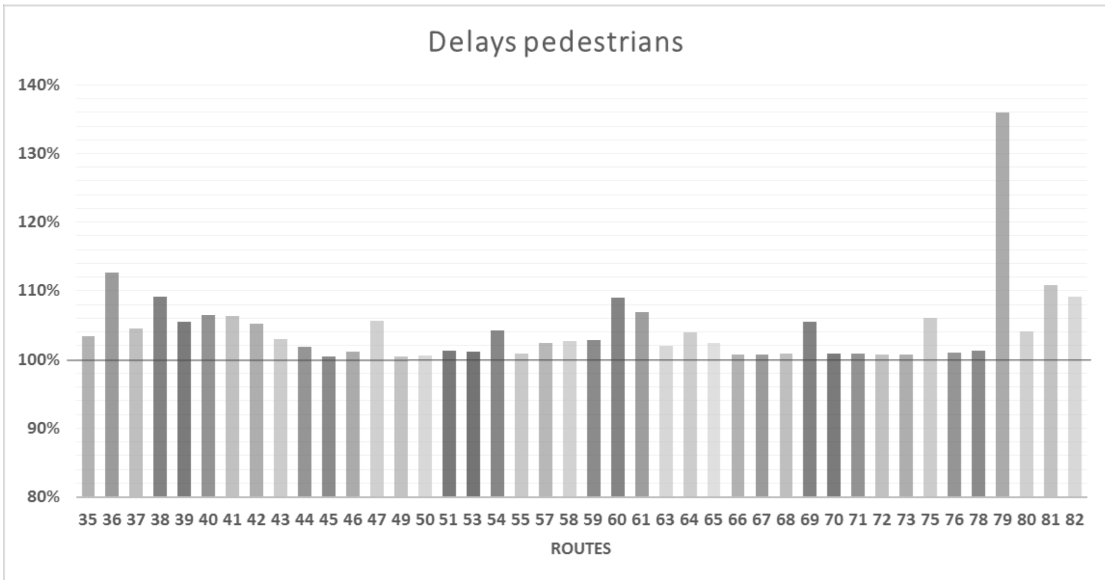

Figure 30 Diagram over the delay for pedestrian routes shown in percentage. Second part from the rest of the entering locations.

Table 14 Presentation of route numbers from diagram and connecting route.

Route no.	Route	Route no.	Route	Route no.	Route	Route no.	Route
35	E-a	46	E-Off	60	G-E	72	M-H
36	E-b	47	E-M2	61	G-H	73	M-Off
37	E-c	49	F-M	63	K-d	75	L-d
38	E-d	50	F-Off	64	K-Off	76	L-Off
39	E-F	51	H-b	65	K-M2	78	M2-b
40	E-H	53	H-d	66	J-I	79	M2-c
41	E-G	54	H-G	67	J-H	80	M2-d
42	E-K	55	H-Off	68	I-J	81	M2-K
43	E-I	57	G-a	69	I-Off	82	M2-Off
44	E-M	58	G-b	70	I-M2		
45	E-L	59	G-d	71	M-E		

4.5.2 Cyclists result

The average delays for the cyclist routes are presented in Figure 31, with the numbers and routes explained in the connecting Table 15. The resulting delays for the cyclists are much like the pedestrians'. The routes that has larger delays are those where the cyclist must cross the road at the bus stops and thus cross the bus lanes. At other locations in the area the cyclists have priority, both over the road traffic and the pedestrians. Thus there are little delays at the routes that do not need to cross the buses.

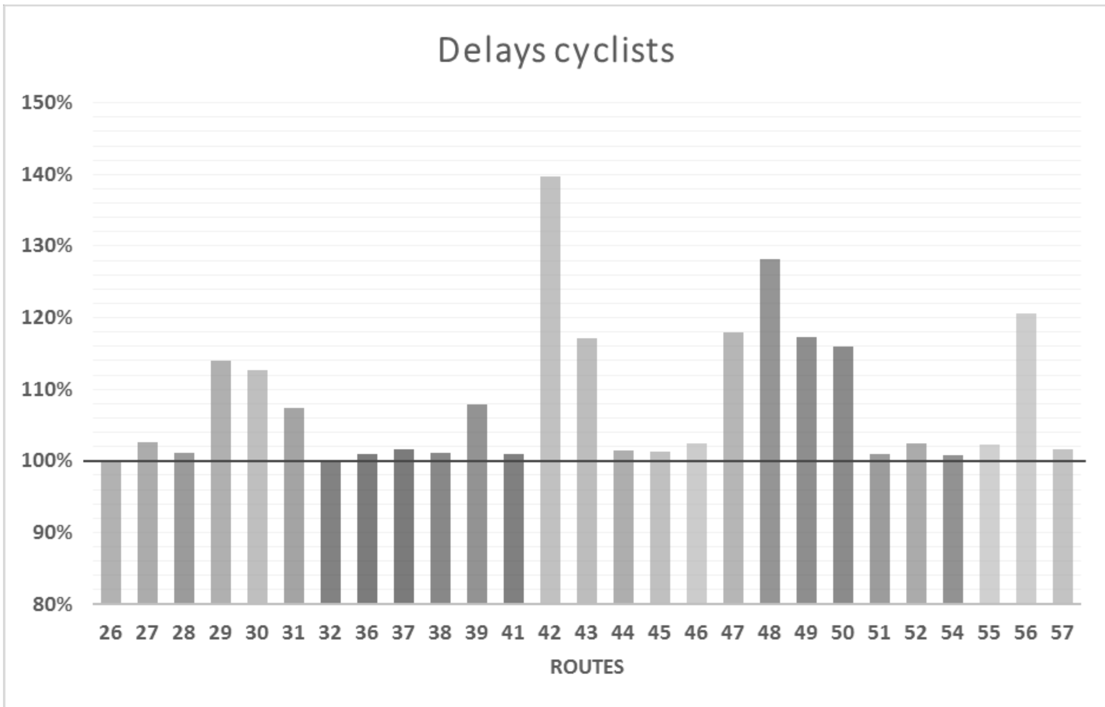

Figure 31   Diagram over the delay for bicycle routes shown in percentage.

Table 15   Presentation of route numbers from diagram and connecting route.

Route no.	Route	Route no.	Route	Route no.	Route
26	6-5	38	3-6	48	1-4
27	6-4	39	3-7	49	1-5
28	6-3	41	2-1	50	1-6
29	6-2	42	2-4	51	1-7
30	6-1	43	2-5	52	8-2
31	5-1	44	2-6	54	7-1
32	6-3	45	2-7	55	7-2
36	3-4	46	1-2	56	7-3
37	3-5	47	1-3	57	7-8

4.5.3 Public transport result

The delays for the public transport is low and this is because they have priory over the entire Lindholmsallén. But there still exists delays, mainly when a bus is stuck behind another bus and needs to wait for its turn into the bus stop. The average delayed time in seconds for each of the bus lines is shown in Figure 32. A combined average value for each bus stop is also displayed as lines in the figure with the resulting delay. Here it is visible that the two bus stops a and d, which are located behind the other two stops c and b at the rear part of the bus stop, has larger delays. One reason for this is the location of the bus stops. If another bus is standing on the front bus stop, the bus at the rear stop has to wait. Another reason is that the rear bus stops a and d also has slightly more buses arriving each hour, leading to that they sometime arrive at the same time and one of them needs to wait until it can drive into the stop.

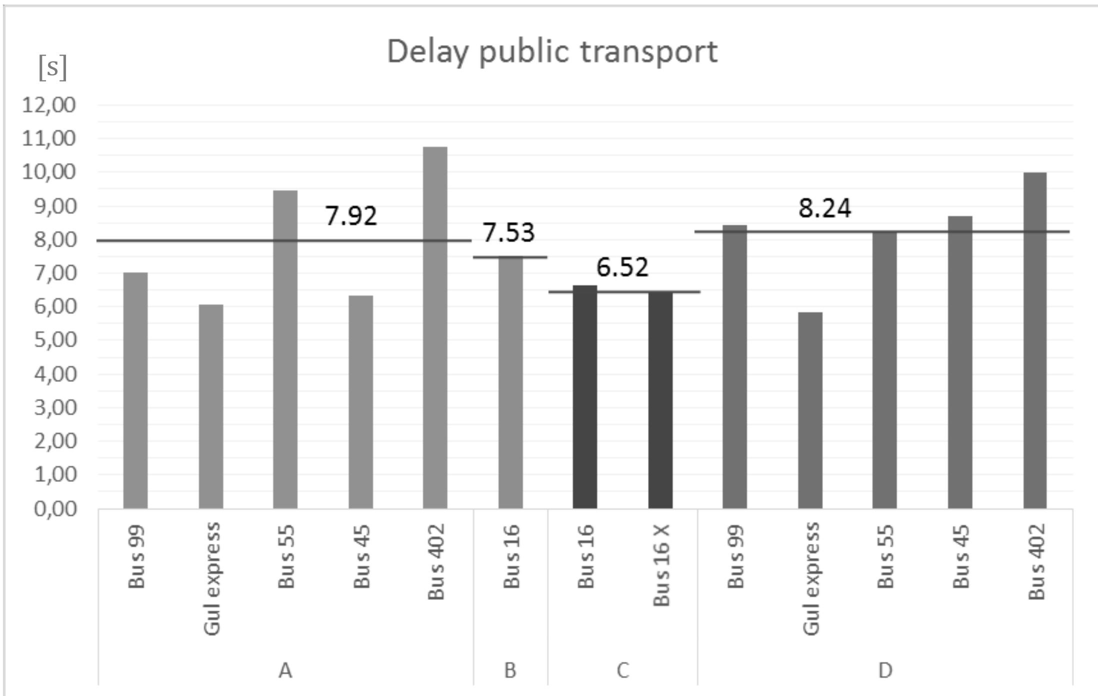

Figure 32 Average delay for public transport, divided into the four bus stops.

4.5.4 Road traffic result

When it comes to the road traffic, more results from the simulation are presented, to get a better understanding of the conflicts and difficulties that may exist in the area. Similar to the other transport modes, the delay for the road traffic is presented. Another result is a map showing the density of the road traffic in the area. A traffic count at two specific locations is presented and compared to obtained traffic counts from the Urban Transport Administration of Gothenburg. A problem that occurred during the simulation for the road traffic was that at one of the input locations, location number 1, not all of the traffic assigned there was able to enter the model during the simulated hour. This led to less traffic in the model and possibly errors in the result.

For road traffic, the delay times are presented in the same way as for pedestrians and cyclists. The average delay for each route is presented in Figure 33 and in Table 16 that follows the routes are shown. These results are notably higher than for both pedestrians and cyclists, with some routes taking two to three times longer time to complete. The four routes with the largest delay are all routes from location 1. At this point high volumes of traffic connect to Lindholmsallén, which leads to large delays for these vehicles. Another consequence of this is that the high volumes of traffic in the roundabout affect the other routes going through, causing them to have delays as well. This is also visible in the figure, where all the other routes with high delays are going through the roundabout.

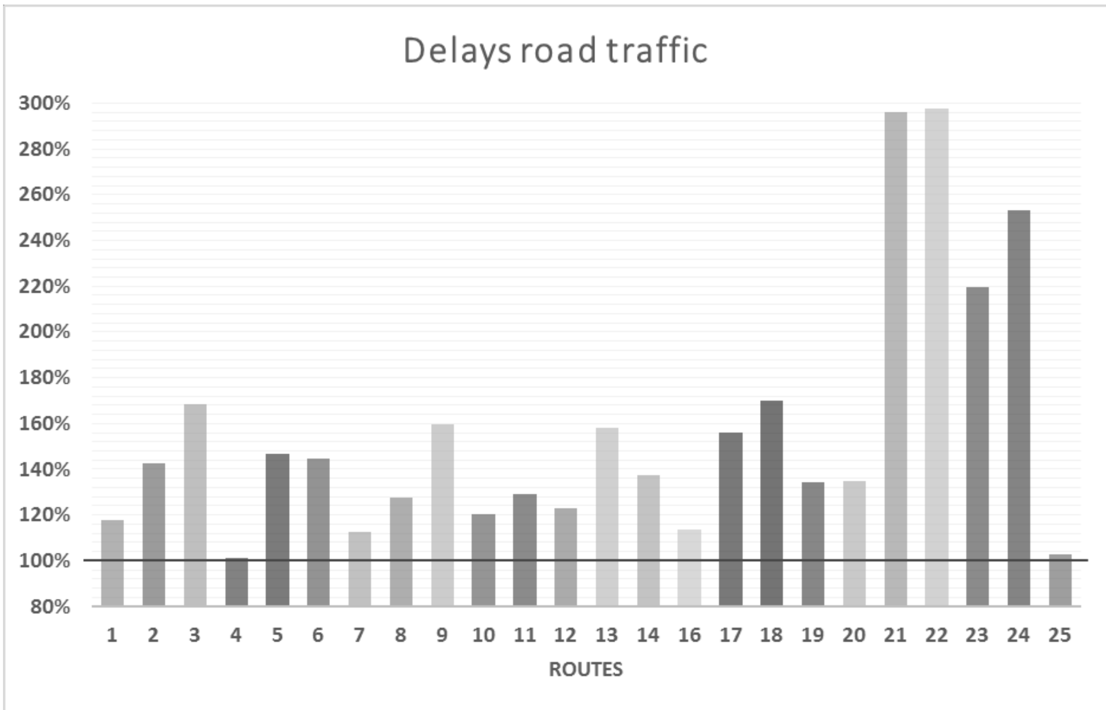

Figure 33 Diagram over the delay for road traffic routes shown in percentage.

Table 16 Presentation of route numbers from diagram and connecting route.

Route no.	Route	Route no.	Route	Route no.	Route
1	6-5	9	5-1	18	2-4
2	6-4	10	5-8	19	2-7
3	6-1	11	5-7	20	2-8
4	6-8	12	4-3	21	1-3
5	6-7	13	4-1	22	1-4
6	6-3	14	4-7	23	1-7
7	5-4	16	2-1	24	1-8
8	5-3	17	2-3	25	8-7

The density of the road traffic, busses and cyclists at the roads in the simulated area are shown in Figure 34. The density map displays the average amount of vehicles per kilometre during the simulated hour. The result shows that most of the lanes for road traffic and cyclists have values belonging to the lower end of the density range. The exception is the northern part of Regnbågsgatan where vehicles are coming from Karlavagnsgatan and going into the roundabout at Lindholmsallén. As can be seen in the density map, this part of the road has the highest values. During the simulation, and also during the data collection, it is observed that it was a constant queue at this stretch.

It can also be seen that the density tends to be higher at points where vehicles are slowing down or stopping. These areas are for example the parts in front of signals or places marked as reduced speed areas. The map also shows that the density at the road traffic lanes at the west side of Lindholmsallén is higher than the ones on the east side.

Figure 34 Density map of the average amount of vehicles per kilometre, spanning between 1 and 999 vehicles.

The amount of cars passing the one-lane stretch between Regnbågsgatan and Götaverksgatan is also counted during the simulation. The result is presented in Table 17 together with collected data from the Urban Transport Administration (n.d.) of the municipality of Gothenburg. The provided data about the amount of cars during the max hour are limited to year 2007 and earlier. There are however data available about the annual average daily traffic (AAWT) during year 2013. By assuming that the share of vehicles per hour in the two directions have been constant during the years 2007 to 2013 and that the amount has been changed in the same way as the AAWT, the amount of vehicles is calculated for year 2013. Since the data from the municipality are only for the afternoon max hour, the results from the simulation are reversed, i.e. the traffic going to the city centre at the morning is instead going from the city centre. To be able to do this, it is assumed that the percentage of traffic during the afternoon max hour are the same as during the morning max hour. The buses are not included in the data from the simulation and it is unknown if these are included in the provided data from the municipality.

The result in the table shows that the data from the simulation is in the same order of magnitude as the data from the Urban Transport Administration. There are, however, differences between the output from the simulation and the data from the municipality. The results show that there were fewer vehicles going in the city centre direction during 2013 than there are according to the results from the simulation. The simulation data is instead more similar to the numbers from 2007. In the other direction, from centre, the data from the simulation are closer to the data collected by the Urban Transport Administration from 2013.

Table 17 Comparison between the amount of road traffic from the simulation and from Urban Transport Administration of Gothenburg.

Regnbågsgatan – Götaverksgatan			Vehicles/hour at afternoon max hour	
	Year	Vehicles/day (AAWT)	To city center	From city center
Data from Gothenburg Traffic Office	2007	6 900	550	300
	2013	4 300	*342*	*186*
Data from the simulation	2016	-	536	199

5 Evaluation result

When combining the results from the different parts of the investigation it is seen that there are no larger problems at the Lindholmsallén. It is however noticed that some problems exist. The design evaluation shows that the south and middle parts of the road, including bus stop Lindholmen and Regnbågsgatan, got better results on all of the parameters than the north parts at bus stop Pumpgatan. The parameters that had the highest importance when designing the road were accessibility for the public transport, good traffic safety for the pedestrians and orientation. These are all found to meet the criteria well. The evaluation also shows that this road design works well for the security, which is the parameter that received the highest scores. In the following chapters it is discussed how the goals that were set when planning Lindholmsallén are fulfilled. It is also commented what works well on the road and what could be improved.

5.1 Good accessibility for public transport

One of the goals that were set when planning Lindholmsallén was that the accessibility for the public transport would be prioritised. The results of the design evaluation show that this goal is fulfilled. The placement of the bus files in the middle of the road leads to that the buses are not affected by the road traffic. This means that they avoid traffic congestion and other disturbances that might cause delays. The design and control of the traffic signals have also increased the accessibility for the public transport. Since the signals are controlled from within the buses, the public transport vehicles have priority at all the signals at the street. As a conclusion it can be said that the design of Lindholmsallén works well for the public transport with respect to accessibility.

The design of the road gives the public transport the highest priority. In combination with the high flow of buses, this leads to some consequences for the other traffic modes. As seen in the result from the simulation, some of the road traffic routes takes almost three times longer to drive compared to the optimal time. Since these routes go through the roundabout, they are affected by the signals there. The signals switch every time it comes a bus in either direction. Thus, the frequent stops for the road traffic have to do with the high frequency of buses that operates on the bus files. The frequent shifts to red light is also contributing to the queue that forms between Karlavagnsgatan and the roundabout at Lindholmsallén. Currently, most of the capacity of the public transport lanes are utilised. If vehicles with higher capacity are used, for example trams, this could reduce the amount of busses and also the number of signal changes. This would lead to less disturbances for the other traffic modes, especially the road traffic.

It is observed that the large amount of buses causes problems at the bus stops. The results from the simulation show that there is a difference in delay between the buses stopping at the front stop and the rear stop. In general, the buses who are stopping at the rear stop are more delayed than the ones stopping at the front. This is because it is relatively common, in reality and in the model, that several buses arrive to the bus stop within a short interval, leading to that the buses departing from the rear stop have to wait for the bus in the front to depart first. This is illustrated by a screenshot from VISSIM during the simulation, seen in Figure 35. Another problem that have been observed is that if two of these buses are going to a rear bus stop at Regnbågsgatan or Lindholmen, the one that arrives last often stops behind the other, i.e. blocking the pedestrian and bicycle crossing. For this reason, the bus stops would benefit from being made longer. It would also be better for the longer buses operating at the street, since they currently are too long to fit properly.

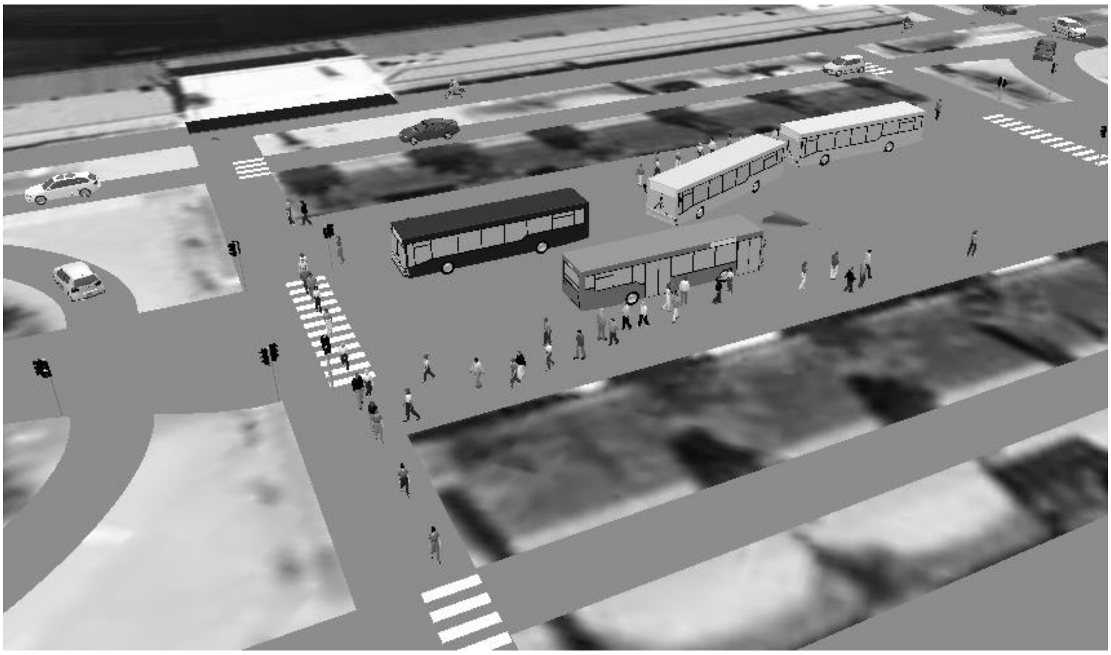

Figure 35 Screenshot of the model in VISSIM showing several busses at the bus stop.

Another observation is that if more than one bus arrives or departs with a short interval from the bus stops at Lindholmen or Regnbågsgatan, the second bus might choose to use the green light that is meant for the first bus. While the clearance time should cover this behaviour, it is observed that this sometimes leads to that the traffic lights have already switched to the next phase, i.e. green for the road traffic, when the last bus passes.

5.2 Safe crossings for pedestrians

Another goal that was set for Lindholmsallén was that it should be safe for the pedestrians to cross the road. The road was therefore designed so that it would only be one-lane road traffic at the places where the pedestrian and cyclist crossings are located. The results from the design evaluation show that this design works well with respect to traffic safety. In combination with the traffic calming measures at some of the crossings, the speed of the road traffic is reduced to 30 km/h. This speed is recommended at areas where vulnerable road users and road traffic are interacting, as it decrease both the risk for accidents and severity.

There are however no traffic calming measures at all of the pedestrian and cyclist crossings. In the local plan to Lindholmsallén it is stated that all the crossings at the street would be elevated to make sure that the maximum speed for the road traffic is 30 km/h. As it is today, the whole section behind the bus stops Regnbågsgatan and Lindholmen are elevated and not each individual crossing, see Figure 36. This results in that the cars only have to slow down when they reach the first crossing. In the picture it is also visible that these elevations are small and the cars do not need to lower their speed much. Some of these crossings are also in a bad condition and the surface is in need of maintenance.

Figure 36 Pedestrian and cycle crossing at bus stop Regnbågsgatan (Photo by authors).

At bus stop Pumpgatan the pedestrians have to cross two road traffic lanes, which means that the goal is not fulfilled in this part of the road. Furthermore, the standard of the bus stop is lower than the other two as it lacks marked crossings. The crossings are not elevated or combined with other traffic calming measures to reduce the speed for the road traffic. However, this part of the road is not included in the local plan for Lindholmsallén, which might be a reason to why the crossings are designed in a different way. This bus stop has fewer travellers than the other two and might not have been included in the plans from the beginning, as it is not included in the suggestion of the stretch in the local plan.

The traffic accident statistics from STRADA indicate that few accidents happen at Lindholmsallén. But since this data do not show small incidents or averted accidents, there might exist conflict-zones that is not visible in the statistics. It is observed both during the data collection and in the simulation that there are areas with much interaction between the pedestrians and the other traffic modes. One of these areas is where the walkway and cycle paths coming from the bus stops intersect with the walkway and cycle path going along Lindholmsallén, see Figure 37. The large flows of pedestrians coming from the buses are sometimes unaware of the cyclists coming from the other directions. At the same time, it is observed that cyclists sometimes do not slow down as they approach these areas. This increases the risk of incidents and accidents since this behaviour leads to that cyclists often have to swerve for pedestrians or vice versa.

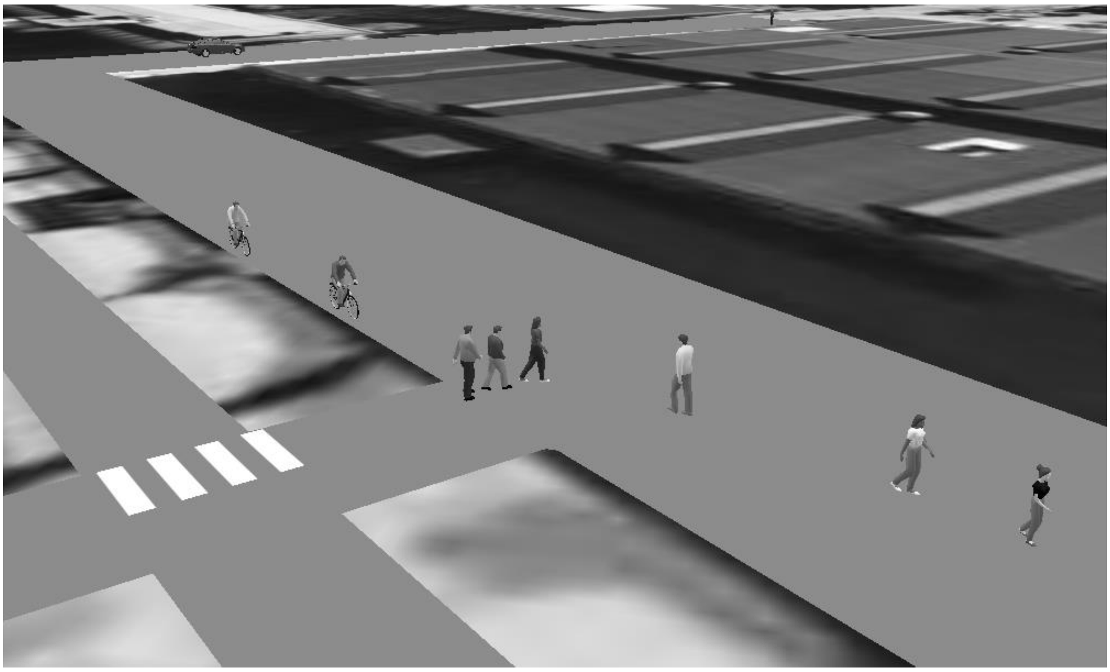

Figure 37 Screenshot from the simulation in VISSIM showing one of the areas with much interaction between pedestrians and cyclists.

During the design evaluation it is noticed that these areas lack a clear design for the pedestrians and cyclists. The surface material for the pedestrians continues over the cycle path, which indicates that the pedestrians have the right of way, see Figure 38. At the same time the pedestrians do cross a cycle path, where cyclists have right of way. If the design would be made clearer, it could reduce the uncertainty at the area and make it clearer for the road users.

Figure 38 One of the areas on Lindholmsallén where there is much interaction between pedestrians and cyclists (Photo by authors).

5.3 Improved orientation

It was also a goal to improve the orientation in the area. Before the construction of Lindholmsallén the area was poorly structured and it could be hard to find your destination. The creation of a large and wide road simplified the structure of the area and the goal can therefore be said to be fulfilled. The design evaluation also shows that orientation in general received high scores for the different areas and modes of transport.

While the results show that the orientation is overall good, it is observed that there are things that could be improved. The ratings for the road traffic at all the studied locations are reduced because of the unusual design of the road. The U-turn intersections are good for the traffic safety since this leads to that the vulnerable road users only have to cross one lane. But this design can also be confusing for road users since they sometimes need to travel “too far” and then drive back on the other side to reach the intended destination. This is probably an issue for road users who are not familiar with the road, but nevertheless a problem. During the design evaluation it is observed that the signs are too few to explain the structure of the road and how to reach the connected streets and destinations. Thus, better information by improving the signs would facilitate the orientation in the area.

To improve the orientation in the area one could make use of the orange pillars lining Lindholmsallén. As mentioned in chapter 2.2.1, an early idea was that these could provide information about the streets, entrances and larger destinations in the area. As it is today, only a few of the pillars have this design, while the others have a decorative purpose. To use the pillars for providing information about the street would make use of already existing structures which is an easy way to improve the orientation in the area.

5.4 Traffic prognosis

In the local plan it is stated that the expected amount of traffic in the south parts of Lindholmsallén would be between 8 000 and 12 000 vehicles per day and in the north parts 23 000 vehicles per day. These numbers were calculated for the case when Norra Älvstranden was fully built. It is, however, unclear what was meant by this as the maps only showed the future plans for the area around Lindholmen. When comparing these plans to how the area looks today, the difference is small since some of the buildings have already been built. When comparing the expected amount of traffic with the results from the data collection and the simulation, it can be seen that the collected numbers are lower than the expected ones. While it is not known how the AAWT from the Urban Transport Administration of Gothenburg have been calculated, it could be seen that the numbers are in the same order of magnitude as the measured ones. This means that the current amount of road traffic is several times less than the expected road traffic.

6 Discussion

In this chapter several different aspects and elements in this project, which could have affected the result in some way, are discussed. These discussions are divided into what origin the source of error have and which part of the project it belongs to. The last part of the chapter includes a discussion about continuing studies on this subject and how this project can be further developed.

6.1 Method

In this report several methods are used to accomplish the different parts of the project. Hence, these methods are discussed separately in the following chapter. The discussions are focused on problems that have occurred as a result of the method that was chosen for the specific task.

6.1.1 Design evaluation

For the design evaluation five different criteria are considered for each of the four design parameters, traffic safety, accessibility, orientation and security. When the three areas containing each of the bus stops at Lindholmsallén are rated, these criteria are given a value between 0 and 1. But this value is not specified beforehand and it is not decided in what would result in a value of 0 or a 1. This is instead done at the site, with an interval of 0.25 points. An example of this is for the criteria "Good maintenance of the roads". Here it is difficult to decide which parameters that would lower the rating for the area and also to define what good maintenance actually is. This balance is done consistently over the three areas and the locations are compared with how a flawless area would look like. How much reduction in rating the area gets is weighted to how much the defect is believed to impact the criterion. Take the example above that is part of the criteria for the design parameter accessibility for pedestrians. One defect could be that the road is a bit uneven, something that affect mostly people with difficulties to walk. Another defect could be a large hole in the ground, which affects all pedestrians and thus gets a larger reduction in the rating.

These ratings are therefore not suited to compare with other roads or areas outside of this report, as they are affected by our own view of the area. But the goal with the evaluation is to compare the three bus stops to each other and to do an internal assessment. In order to get a better overview of how the road is designed and if it correspond to the design goals of the road. Thus it is assumed that this did not affect the result that much.

6.1.2 Simulation

During the data collection it is noticed that the morning peak hour for this area probably is between 07:30 and 08:30. The reason for this is probably because the area mostly consists of offices and schools, where it is more common to start later. With more industries or houses in the area the peak hour might be different. For this simulation indexes are used and these are defined between full hours. It is therefore easier and more practical to simulate between 07:00 and 08:00 as much of the data collection also is carried out during this hour.

In reality, the traffic during this peak hour is probably not equally distributed and the traffic flows are not the same size throughout the hour. The flows are more likely concentrated during some periods. This difference is observed during the counts where the first 15 minutes have lower flows compared to the last 15 minutes of the data collection. This could be explained by the fact that many people start their day at even times, as 07.00 or 08.00, and thus there are more people at the bus stops right before these hours. But the difference is not large and it also differed between the various modes of traffic. To get a more accurate data collection and distribution of the traffic flows an interval of the count could have been done. If for example dividing the data collection into 15 minute periods a better distribution of the traffic could be obtained. But in this area the difference during the hour is observed to be low and not considered to affect the simulation result significantly.

The aim of the simulation is to determine and locate the existing conflict areas on Lindholmsallén and to visualise these interactions. The simulation is done on the area around bus stop Regnbågsgatan, located in the centre of the road. This bus stop is assumed to be representative for the entire stretch of the road, even though the two other bus stops in the area are slightly different compared to Regnbågsgatan. This may have resulted in both a better or worse evaluation than how the situation actually is. It might be so that some conflicts only exist at the simulated area and are not a problem for the entire road. But on the other hand there might exist conflicts on other locations at the road that are not included in the simulation. Since the simulation is quite simple it is assumed that a good enough evaluation of the road is obtained by only simulating one of the bus stops. If other results were to be acquired from the simulation a larger and more detailed model is acquired.

When calibrating and validating the simulation model only a visual method is used. The reason for this is also the aim of the simulation and that the model is quite simple. Thus a detailed calibration and validation are assumed to be unnecessary and a visual adjustment of the model is sufficient. One part of the validation is to do a sensitivity analysis of the model, to determine which parameters that has the largest influence on the result. This analysis is also neglected in this simulation for the same reason as above.

Another limitation is that this simulation is only run once. It is run with one random seed which results in a stochastic variation of the input vehicles and thus simulating the natural variance that occur. When using random seed, the simulation should be run several times to get better results. But one run of the simulation generates much data that need to be processed and analysed. Several runs would have given too much work in proportion to the magnitude of the simulation.

When building the model with its geometry and routes, there are input values lacking. When adding the routes, a simplified method is used and the decisions is based on observations and how pedestrians generally would walk in this area. This may result in that not all routes are like in reality and an uneven distribution of the traffic flows. Most of the geometry is based on aerial maps and information from the local plan. Thus, if the area differs to the maps and the local plan it might be that some roads and areas has the wrong geometry.

In the model two types of pedestrians are simulated, men and women. Both behaved the same way and walked with the same speed distribution and by themselves. In reality there is a larger mixture of pedestrians, where some walk in groups, other is jogging or walk with a stroller. During the observations it is noted however that many people in this area are on their way to school or work, coming from the buses. Hence, most of the pedestrians are walking by themselves and at an even speed. To get a more realistic result it could have been good to have better divergence in the types of pedestrians in the simulation.

6.2 The simulation program, VISSIM

The simulation program VISSIM is based on mathematical theories that explain how the traffic should move and act in the simulation. Together with the calibration and validation this gives a reasonably good representation of the reality. But there exist limitations in the program that restricts the modelling of certain occurrences in the traffic. Some problems occur as a result of these limitations in the software program. One example of this is that sometimes the pedestrians will take shortcuts and choose paths that are difficult to anticipate and define in the model. These paths are also difficult to get statistics about as pedestrians can walk almost everywhere. But the majority of the pedestrians in this area walk at the defined paths and even though it exists shortcuts there are no large flows observed at these.

It is also observed that it is common not to follow certain traffic rules in this area. This especially applies to the traffic signals. It is a relatively common occurrence that the road users drive or walk when it is red. This traffic violation is noticed to exist for all traffic modes, but it is most common for pedestrians. At the signalised crossings the majority of pedestrians walk as long as no bus is near. This means that right after the bus passes, people start to walk behind it. Or alternatively, if the light turns red and the bus is far away, many people walk anyway because they have time to cross. It is also observed that it happens that the buses drive when it is red light. This mostly occurs when several buses are driving together and all of them use the green light that was meant for the first bus. A behaviour that sometimes leads to that the signal has already switched when the last bus passes.

This example and other traffic violations are all problematic to simulate. At some locations it is not possible to simulate as the traffic rules say because almost everyone acts in another way. Here the model instead follows how people act in reality. But some violations, as running for red light, is not done by the majority of the traffic, which leads to difficulties when simulating. In this model these violations are therefore neglected and it is assumed that everyone follows the rules. But at some locations, where the majority of traffic acts in a specific way, the rules are changed to fit the reality better. The traffic signals are all modelled as they function in reality. But because many pedestrians walk also when it is red light it might have been better to model this as a priority rule instead. This would however miss the people that actually wait for green light.

Another source of error to the result in the simulation could be that the cyclists in VISSIM operate with the car following model that the road traffic uses. This model is not fully applicable to this traffic mode as the cyclists are more flexible compared to cars. It is for example observed that cyclists drive on the pedestrian paths, drive beside each other or against the direction of the traffic. These things are difficult to simulate as the model that the cyclists follow lacks these factors that are specific for cyclists. But if this had been included it could have resulted in more conflicts and interactions between cyclists and the other traffic modes in the area. These observations are however not that many and probably not affecting the simulation noticeable.

One error that occurs during the simulation is that the flow of road traffic from one of the input locations is lower than the value from the data collection. This means that the amount of cars that is supposed to enter from this point during one hour could not complete the flow, which lead to that too few cars are simulated. The reason for this error could be that in reality cars do not drive in the roundabout the way they should. As an example some cars drive as if the roundabout has two lanes and there are also some that drive faster to catch the green light. In the simulation however all the cars follow the traffic rules and drive in one lane and with the fixed speed distribution, as displayed in Figure 39. Hence, the driving style in the simulation does not fully match reality. This error could result in that the problems seem to be fewer or less severe than they actually are.

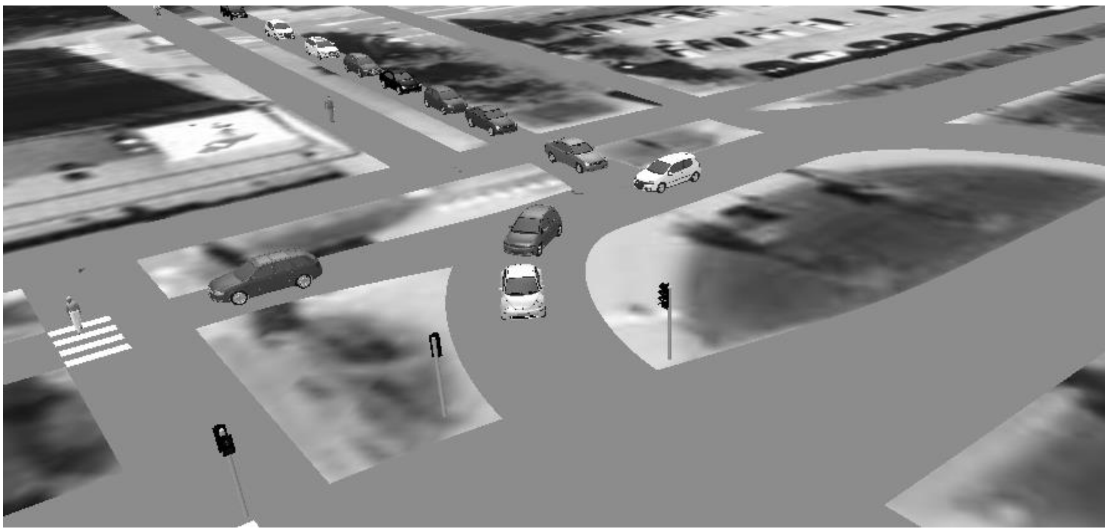

Figure 39 Screenshot from the simulation in VISSIM showing how the cars is driving through the roundabout.

6.3 Further studies

Since this project includes several parts in a combined evaluation, the execution of these parts is rather simple and general. Hence, further development could be done on several aspects.

When evaluating the road design of Lindholmsallén only four parameters are analysed with five criteria for each parameter. This could be increased to get a wider description of the areas and thus a better comparison. Further on, in this evaluation, only the three areas around the bus stops are analysed. This results in that some parts of the road, between these areas, are not evaluated. To get a more precise evaluation the full stretch of the road could be evaluated.

Other continuing studies could also be to learn about the opinions of the users to the different traffic modes that operate in the area, to investigate what they think of the traffic situation in the area. This project focus on the technical aspects of the road design and does not take into account people's opinions. But we still got indications from several sources that there are some things that do not work at this road. These opinions would be interesting to investigate further. Further on, this evaluation is only concentrating on the present time and how it works today. Some history is included in the project, but further investigation could be to analyse how the traffic situation appeared when the road was newly constructed or how it would work in the future with changing traffic characteristics.

The simulation part of this project is focusing on one of the bus stops on the road and an expansion of the simulation would be to include the entire road. This would give a better flow of the traffic and conflicts connected to several parts of Lindholmsallén could be discovered. The simulation could also include different improvement measures and comparisons between different traffic volumes, in order to investigate the capacity of the road and how it could be reconstructed to meet future demands.

7 Conclusion

The aim of this master thesis is to analyse the road design of Lindholmsallén in Gothenburg. Several hypothesis questions are presented in the introduction in order to get a methodical result of the evaluation. The general conclusions made during the study is presented according to these research questions.

Which were the goals and objectives for the road design of Lindholmsallén?
There were three main goals for the design of road: to have good accessibility for public transport, safe crossing for pedestrians and to improve the orientation in the area. In the local plan it is also stated a traffic prognosis for the road.

How is the traffic site structured and designed?
Lindholmsallén is designed as a wide road with a separate bus lane situated in the middle. On both sides there are road traffic, which alternates between one and two lanes. In total there are three bus stops, Pumpgatan, Regnbågsgatan and Lindholmen. The latter two is similarly designed, with two locations where the bus can stop in each direction. Whilst Pumpgatan has a simpler design and not as many travellers as the other two stops. Located outside of the car lanes are the combined pedestrian and bicycle lanes, with traffic in both directions. Lindholmsallén is designed with U-turns and roundabouts that allows the cars to cross the public transport lanes to the connecting roads. At these intersections it exists traffic signals which give the buses priority. Signals also exist where the pedestrians and cyclist cross the bus lanes.

How large quantity of every mode of transport are operating in the area?
The data collection is carried out around the area of the bus stop Regnbågsgatan. The result shows that around 800 pedestrians, over 200 cyclists and almost 2000 cars go through the area during the peak hour. In total it is also 102 buses arriving to the bus stop during this hour, looking at both directions.

How do the road users behave in this traffic site?
In the area around Regnbågsgatan it is observed that all transport modes have some behaviour that is different to how they should act. The most noticeable is that it is relatively common to walk and drive when it is red. This is most common for the pedestrians where the majority walks as long as no bus is near the crossing.

Are the goals that were set fulfilled?
The goals that were set for Lindholmsallén are essentially fulfilled. There are however some aspects in these objectives that could be more developed. Looking at the accessibility for the public transport the problem is that it today is too many buses and the design of the bus stops could be improved to reduce the congestion of buses. For the goal safe crossing for pedestrians, it is the crossings over to the bus stops that is the largest concern. Here the traffic calming measures are poorly designed and at Pumpgatan there are no measures at all. The orientation on the road has improved significantly since before the construction of the road. But the new design of the road could be difficult for road users that are not familiar to the area to understand. It is therefore important to improve the signage in the area.

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Appendix 1 – Local plan for Lindholmsallén

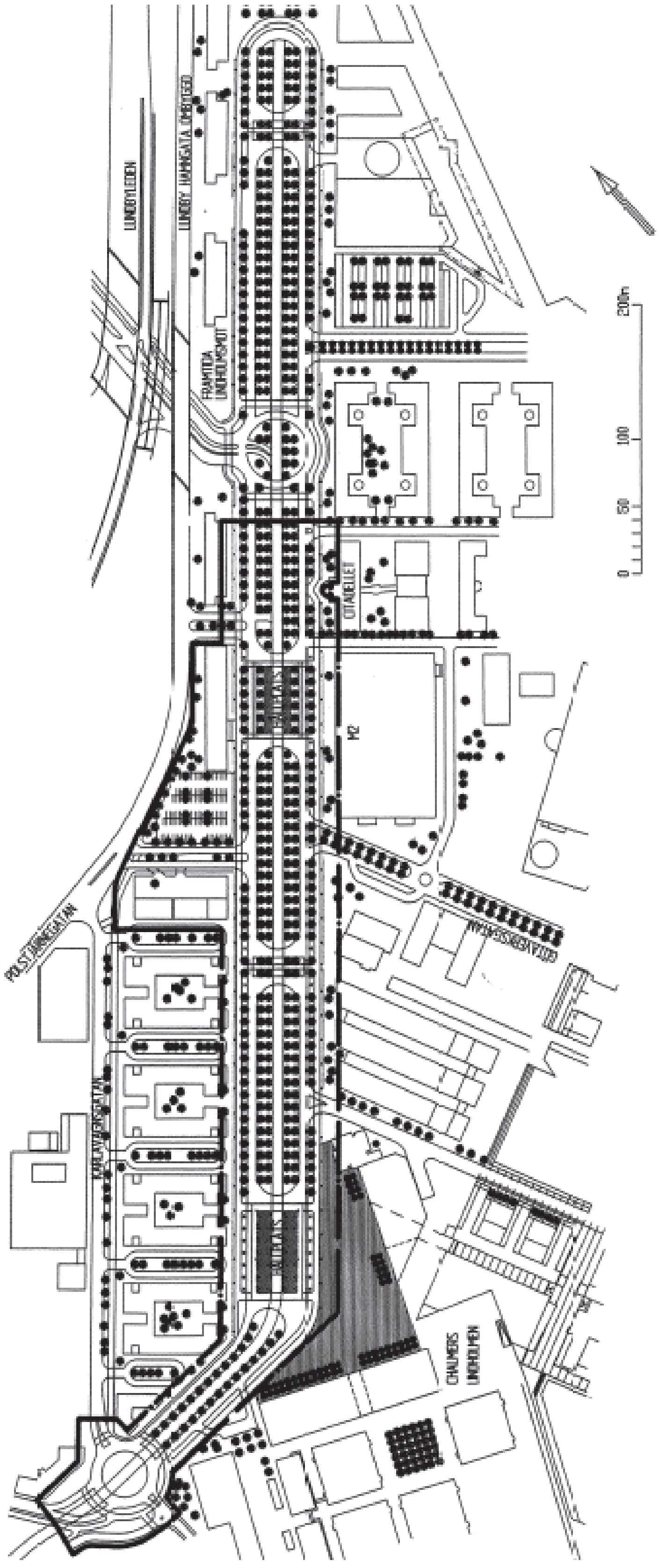


Figure 40 *Map showing the design of Lindholmsallén. The black line shows the area included in the local plan (Göteborgs Stad Stadsbyggnadskontoret, 2001).*

Appendix 2 – Evaluation result

Ratings from the evaluation of the three different bus stops and its surrounding areas. Numbered as: Pumpgatan (1), Regnbågsgatan (2) and Lindholmen (3).

Pedestrians	Criteria	1	2	3
Traffic safety	High standard and well maintained roads	1	1	1
	Good lighting	1	1	1
	Maximum speed at crossings 30-40 km/h	0.25	0.75	0.75
	Clearly separated traffic modes	0.75	0.5	0.75
	No obstacles that can be tripped on or that restricts the view	0.75	0.5	0.75
Accessibility	No barriers (highly trafficked roads or railways)	0.25	0.5	0.5
	Continuity of walkways	1	1	1
	Good maintenance of the road	1	1	1
	The roads are connected with crosswalks	0.5	1	1
	The road is handicap-friendly	0.75	1	1
Orientation	Clear directions on where to walk	1	1	1
	Good lighting that clarifies the directions and entrances	1	1	1
	Clearly perceptible and visible boundaries between walkways, bicycle paths and roads	1	1	1
	Comprehensible directions at (larger) connection points	0.5	1	1
	Comprehensible and self-explanatory walkway structure	0.75	0.5	0.75
Security	Good overview of the area	1	0.5	0.5
	Good maintenance of the area	1	1	1
	Good lighting	1	1	1
	Walkways connected to buildings	0.75	1	1
	Several walkway options	1	1	1

Cyclists	Criteria	1	2	3
Traffic safety	High standard and well maintained roads	1	1	1
	Good lighting	1	1	1
	Maximum speed at crossings 30-40 km/h	0.5	0.75	0.75
	Clearly separated traffic modes	0.75	0.5	0.75
	No obstacles that you can collide with or that restricts the view	1	0.5	1
Accessibility	No barriers (highly trafficked roads or railways)	0.5	0.5	0.5
	Continuity of cycle paths	1	0.75	1
	There exist possibilities to park the bike	0	1	1
	Good maintenance of the road	1	1	1
	The roads are connected with bicycle crossings	0.5	1	1
Orientation	Clear directions on where to bike	1	1	1
	Good lighting that clarifies the directions and entrances	1	1	1
	Comprehensible directions at (larger) connection points	0.5	1	1
	Comprehensible directions to where to park the bike	0	1	1
	Comprehensible and self-explanatory cycle path structure	0.75	0.75	1
Security	Good overview of the area	1	1	1

	Good maintenance of the area	1	1	1
	Good lighting	1	1	1
	Cycle paths connected to buildings	0.75	1	1
	Bicycle parking placed visible and are easily accessible	0	1	1

Public transport	**Criteria**	**1**	**2**	**3**
Traffic safety	High standard and well maintained roads	0.75	0.5	1
	Traffic calming measures in connection to crossings	0	0.75	0.75
	Enough capacity on the platforms	1	1	1
	No passing traffic when the bus is at the stop	0.5	1	1
	Good lighting at the bus stop and its surroundings	1	1	1
Accessibility	Good frequency of the public transport	1	1	1
	Good connections and easy access to pedestrian and bicycle paths	0.5	1	1
	Maintenance of the bus stop and connecting roads is good	0.75	0.75	1
	No level differences between the stop and the vehicle	1	1	1
	The design of the bus stop should be handicap-friendly	1	1	1
Orientation	Comprehensible and self-explanatory road and bus stop structure	1	0.75	0.75
	Good guidance and understandable directions to the bus stops	1	1	1
	There is necessary information about the trip on the stops (schedule and routes)	1	1	1
	Good lighting that clarifies directions and visibility at the stop	1	1	1
	Tactile tiles or other guide paths to assist blind and visually impaired people	0.75	1	1
Security	Good overview of the area	1	0.5	0.5
	Good maintenance of the bus stop	1	1	1
	Good lighting	1	1	1
	Accessibility to and from the bus so people do not feel trapped	0.75	1	1
	Good design where there are no obscured or dark corners	1	0.5	0.5

Road traffic	Criteria	1	2	3
Traffic safety	High standard and well maintained roads	1	0.75	1
	Intersection with roundabout	0.75	1	1
	Intersection with traffic lights	1	1	1
	Speed bumps (or other traffic calming measures) to decrease the speed	0.5	0.5	0.5
	Good street lighting	1	1	1
Accessibility	Enough capacity of the road	1	1	1
	Few or no barriers (road tolls, traffic lights, etc.)	0.75	0.75	0.5
	A continuous road network	1	1	1
	Possibilities for parking	1	1	1
	Not too strict regulations for parking (time and fees) - possibility for commuter parking	1	1	1
Orientation	Main road network is logical and has a simple structure	0.5	0.5	0.5

	Good guidance and understandable directions at (large) important connection points	0.75	0.25	0.5
	Good lighting that clarifies directions and visibility on the roads	1	1	1
	Enough distance from signs to intersection for the driver to comprehend the information	1	1	1
	Good information about where to park and restrictions on the parking lot	1	1	1
Security	Good overview of the area	1	1	1
	Good maintenance of the area (Mainly parking lots and garages)	1	1	1
	Good lighting (Mainly parking lots and garages)	0.75	1	1
	Parking lots should not be places at desolated locations	1	1	1
	Parking lots and garages should have several entrances and exits	1	1	1

Appendix 3 – Data collection

In this appendix the results from the data collection are presented. In the tables, all average numbers are rounded up to the nearest integer.

In the tables below "To" or "From" refers to the direction of the pedestrian, cyclists and road traffic. The direction called "To" is the traffic moving into the zone and "From" is the traffic leaving the area. The data collection was performed during three weeks in April. During the second and third week the weather was clear and quite warm while during the first week it was cold and rainy. This could explain some of the bigger differences in the data between the weeks.

Pedestrians

The locations where the pedestrian counts was performed are presented in Figure 41. The areas called A, B, C and D are located on the four zebra crossings at the bus stop. In the figure the four locations where the bus stops are also displayed in lowercase letters from a to d. The rest of the areas displayed in the figure, from E to M are located at the boundary of the simulation area.

Figure 41 The locations of the data collection for the pedestrian volumes.

All pedestrians were counted during one hour, between 07:00 and 08:00 in the morning. Area A, B, C and D were counted on Tuesdays, on the 5th, 12th and 19th of April. The areas E, F, G and H were counted on Wednesdays, 6th, 13th and 20th of April. The last five areas, I, J, K, L and M, were counted on Thursdays, on the dates 7th, 14th and 21th of April. The results from the pedestrian data collection can be seen in Table 18.

Table 18 Result from the pedestrian data collection.

	First count		**Second count**		**Third count**		**Average**	
Area	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**
A	57	11	45	13	50	10	51	12
B	19	344	19	323	15	332	18	333
C	13	67	15	66	14	69	14	68
D	12	318	14	306	24	366	17	330
E	40	9	75	15	72	7	63	11
F	1	0	4	3	3	4	3	3
G	21	243	22	209	19	238	21	230
H	10	59	10	50	11	48	11	53
I	9	6	14	21	10	14	11	14
J	1	5	2	7	3	7	2	7
K	8	268	7	302	7	311	8	294
L	6	12	7	13	7	11	7	12
M	1	3	4	14	2	12	3	10

The areas A, B, C and D are situated on the four pedestrian crossings connected to the bus stop called Regnbågsgatan. Thus if you would want to cross over to the other side of the road, you need to cross over two pedestrian crossings, either over A and B or over C and D. The majority of pedestrians counted on the crossings were coming from the buses. But there were also a few that were crossing the whole street and thus were counted two times. The amount of pedestrians that did not come to or from the buses are presented in Table 19 below, to be able to distinguish the different routes that are used.

Table 19 Amount of pedestrians crossing the whole street using crosswalk A-B or C-D.

Route	**First count**	**Second count**	**Third count**	**Average**
A → B	33	33	31	33
B → A	7	8	7	8
C → D	8	11	5	8
D → C	8	8	12	10

Cyclists

In Figure 42 the data collection locations for cyclists are presented. These are all located at the boundary of the simulation area and numbered from 1 to 8.

Figure 42 The locations of the data collection for the cyclist volumes.

The cyclists were counted during one hour, between 07:00 and 08:00. The exception was the first count, which was done during 08:00 and 08:30. The numbers from the first count have been recalculated by multiplying the results with two to get the amount of cyclists for one hour and then using the Equation 2 below. In the equation the values from the 8th hour were multiplied with weekday indexes provided by the Swedish Transport Administration, see Table 20. The data collection was performed during three weeks at Tuesdays, Wednesdays and Thursdays. This resulted in that the amount of cyclists at all points were counted three times, the result can be seen in the Table 21 below.

$$Cyclists_{hour\ 7} = Cyclists_{hour8} \times \frac{1}{Index_{cyclists,hour8}} \times Index_{cyclists,hour7} \quad (2)$$

Table 20 Table showing indexes for cyclists for each hour during weekdays, weekends and total (Trafikverket, 2015d).

Hour	Total	Weekday	Weekend
0	13,4	8,8	49,9
1	8,2	4,7	36,3
2	5,8	3,4	25,4
3	4,1	2,6	15,7
4	4,8	4,3	8,6
5	19,9	21,1	10,4
6	94,0	101,1	31,5
7	234,6	258,2	37,2
8	253,9	277,9	54,3
9	111,3	113,3	94,1
10	78,4	71,3	136,8
11	89,2	78,8	174,0
12	105,5	93,8	201,2
13	105,2	92,1	211,8
14	117,5	106,0	211,5
15	172,3	168,3	206,4
16	257,0	265,1	195,8
17	266,8	278,0	180,1
18	166,0	168,7	146,2
19	97,4	96,0	108,8
20	72,5	70,4	90,0
21	58,1	56,1	74,7
22	39,4	37,4	55,2
23	24,8	22,4	44,2
Sum	2400	2400	2400

Table 21 Results from the cyclist data collection. The data from the first count are recalculated to correspond with the data from the second and third count.

	First count		Second count		Third count		Average	
Area	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**
1	56	12	81	9	98	14	80	12
2	0	2	16	21	13	19	10	14
3	34	15	60	55	58	53	51	41
4	0	19	0	17	1	27	1	21
5	6	30	5	48	7	40	6	40
6	34	25	75	73	67	65	59	55
7	6	10	15	29	16	25	13	22
8	0	0	3	0	6	6	3	2

Road traffic

For the road traffic the data collection was as for cyclists only performed on the border of the simulation model. The areas where the volume of road traffic were counted are displayed in Figure 43.

Figure 43 The locations of the data collection for the road traffic volumes.

The road traffic was counted during 30 min, between 08:00 and 08:30. The results from these counts are presented in Table 23 below. The last two columns show the average values from the three counts but are recalculated to correspond to the time the pedestrian and cyclist data collections were made, i.e. between 07:00 and 08:00. To do this the results were multiplied with two to get the amount of traffic for one hour and then recalculated by using equation 3 below. In the equation the values from the 9th hour were multiplied with indexes for an average day for city streets. The indexes are provided by the Swedish Transport Administration, see Table 22.

$$Road\ traffic_{hour7} = Road\ traffic_{hour9} \times \frac{1}{index_{road,hour9}} \times index_{road,hour8} \quad (3)$$

Table 22 Indexes for road traffic each hour, the left column is state roads and the right is city street (Trafikverket, 2004).

	PERSONBILAR	
Timme	Statliga vägar	Citygator
1	16	7
2	10	4
3	7	4
4	7	3
5	15	6
6	34	23
7	120	103
8	137	156
9	129	130
10	120	115
11	127	124
12	133	138
13	139	167
14	144	157
15	153	154
16	174	176
17	230	228
18	188	201
19	154	175
20	110	114
21	88	87
22	76	75
23	57	37
24	32	16
Summa	2400	2400

Table 23 Result from the road traffic data collection.

	First count		Second count		Third count		Average	
Area	**To**	**From**	**To**	**From**	**To**	**From**	**To**	**From**
1	293	80	355	66	340	60	791	165
2	84		143		143		296	
3		102		93		112		246
4	18	123	10	106	14	118	34	278
5	52	240	36	243	42	240	104	579
6	310		290		289		712	
7		292		279		272		675
8	4	9	1	10	0	4	4	19

Heavy traffic

In order to decide the amount of heavy traffic in the area a separate count was made. It was conducted March 17th between 10:20-10.50. The count was carried out on the same areas as shown in the map above, but now only the "To" directions was counted, i.e. only the traffic moving into the zone. The total counts of light traffic (everything besides heavy traffic) and heavy traffic are presented in Table 24 below, together with the calculated share of heavy traffic for this specific area.

Table 24 Result from the heavy traffic data collection.

Light traffic	Heavy traffic	Percentage
283	9	3.1 %

Public transport

The results from the public transport data collection are shown below. The data collection was done the 16th of Mars between 07:30 and 08:00.

Time table

The time tables for the bus stop Regnbågsgatan is received from Västtrafik, who operates the public transport in Gothenburg. Both directions on the bus stop are investigated. The south direction refers to the busses going towards Lindholmen whilst the north direction is the buses that drives towards Gothenburg city centre.

Regnbågsgatan (South)		Regnbågsgatan (North)	
Arrival time	**Bus line**	**Arrival time**	**Bus line**
07:00	Bus 16	07:00	Bus 16
07:03	Bus 16X	07:01	Bus 55
07:04	Gul express	07:03	Gul express
07:05	Bus 16	07:05	Bus 99
07:06	Bus 55	07:05	Bus 16
07:06	Bus 99	07:07	Gul express
07:07	Bus 16X	07:10	Bus 16
07:09	Bus 45	07:11	Bus 55
07:10	Bus 16	07:12	Bus 45
07:11	Bus 16X	07:12	Gul express
07:12	Gul express	07:13	Bus 99
07:15	Bus 16X	07:15	Bus 16
07:16	Bus 55	07:17	Gul express
07:16	Bus 16	07:19	Bus 16
07:16	Bus 402	07:21	Bus 55
07:19	Bus 16X	07:22	Gul express
07:19	Gul express	07:23	Bus 402
07:20	Bus 16	07:24	Bus 16
07:21	Bus 99	07:26	Bus 99
07:23	Bus 16X	07:27	Gul express
07:24	Bus 45	07:28	Bus 45
07:25	Bus 16	07:29	Bus 16
07:26	Bus 55	07:31	Bus 55
07:27	Bus 16X	07:32	Gul express
07:27	Gul express	07:34	Bus 99
07:30	Bus 16	07:35	Bus 16
07:30	Bus 99	07:36	Gul express
07:32	Bus 16X	07:39	Bus 99
07:35	Gul express	07:40	Bus 16
07:35	Bus 99	07:41	Bus 55
07:36	Bus 16X	07:42	Gul express
07:36	Bus 55	07:43	Bus 45
07:36	Bus 16	07:44	Bus 99
07:39	Bus 45	07:45	Bus 16
07:40	Bus 16X	07:47	Gul express
07:40	Bus 99	07:49	Bus 99

07:41	Bus 16	07:50	Bus 16
07:43	Gul express	07:51	Bus 55
07:44	Bus 16X	07:52	Gul express
07:45	Bus 99	07:53	Bus 402
07:46	Bus 55	07:54	Bus 99
07:46	Bus 402	07:55	Bus 16
07:46	Bus 16	07:56	Gul express
07:48	Bus 16X	07:58	Bus 45
07:50	Gul express	07:59	Bus 99
07:50	Bus 99	08:00	Bus 16
07:51	Bus 16		
07:52	Bus 16X		
07:54	Bus 45		
07:55	Bus 99		
07:56	Bus 16X		
07:56	Bus 55		
07:56	Bus 16		
08:00	Bus 16X		
08:00	Gul express		
08:00	Bus 99		

Bus stop Regnbågsgatan is consisting of four different bus stops, named a, b, c and d presented in Figure 44 below. The names of the bus stop corresponds to the nearest pedestrian crossing, as also can be seen in the picture. b and c are reserved for bus line 16 and 16X, the rest of the bus lines are using bus stops a and d.

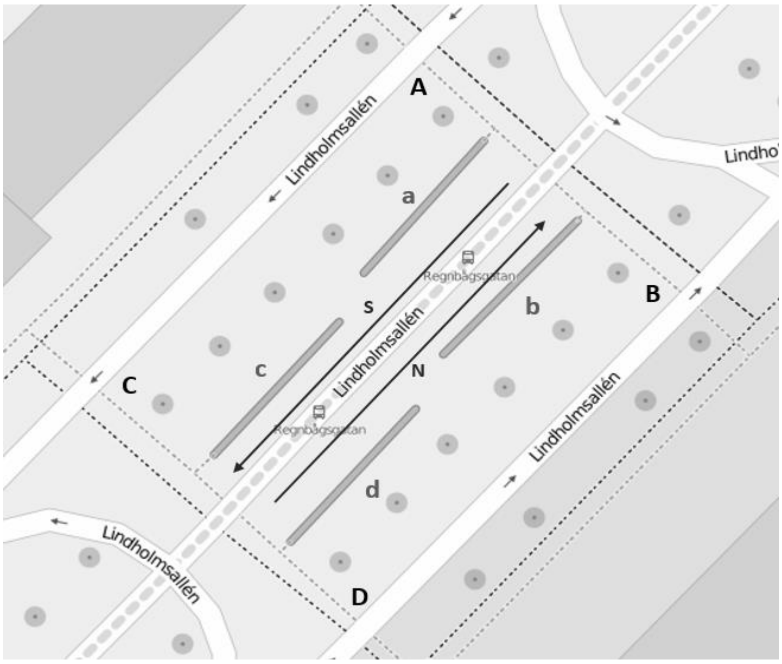


Figure 44 In this picture the four locations where the bus stops are displayed as lowercase letters a to d. The nearest crossing is also displayed with the corresponding letter.

Table 25 below shows the amount of buses for each line that arrives to the bus stops between 07:00 and 08:00. It also shows the counted average share of alighting and boarding passengers for each line, divided into south and north direction. As an example it can be seen that bus 16 and 16X together stand for 42.1 % of the alighting passengers in the south direction, whilst in the north direction it is bus 45 that stands for the largest share of alighting passengers. The bus line called 16X does not operate in the north direction in the morning. It is only driving in the direction with the highest volume of travellers, which in the morning is the south and in the afternoon the north.

Table 25 Result of the data collection for the public transport.

	South direction				**North direction**			
Bus line	Arrivals 07:00-08:00	Bus stop	Alighting	Boarding	Arrivals 07:00-08:00	Bus stop	Alighting	Boarding
Bus 16	12	c	20,0 %	18,5 %	13	b	16,4 %	19,4 %
Bus 16X	15	c	22,1 %	22,2 %	0	b	-	-
Bus 99	9	a	15,8 %	37,0 %	9	d	32,7 %	9,7 %
Gul express	8	a	13,8 %	22,2 %	12	d	7,3 %	22,6 %
Bus 55	6	a	9,2 %	0 %	6	d	0 %	38,7 %
Bus 45	4	a	4,2 %	0 %	4	d	43,6 %	9,7 %
Bus 402	2	a	15,0 %	0 %	2	d	0 %	0 %

From the amount of travellers using bus stop Regnbågsgatan it was calculated that 23.4 % of the alighting and 79.2 % of the boarding passengers are using bus stop a and c. Consequently, bus stops b and d together stand for 76.6 % of the alighting and 20.8 % of the boarding passengers.

Appendix 4 – Signal control

At Lindholmsallén the buses have priority at the signalised intersections. This means that the bus lane receives green light when a bus is approaching the bus stop and the other traffic modes get red. When no buses are present, the road traffic, pedestrians and cyclists constantly have green light. There are no detectors in the area for any of the traffic modes. Instead the bus drivers use the radio system Rakel to communicate with the traffic lights from inside the bus.

In the area it exists several traffic lights. In the model these have been simplified into four different signal groups. Two are for the buses and two for the other traffic modes, see Figure 45. The first group, named signal group 1 in the figure, includes the traffic lights controlling the pedestrians and cyclists on the north side of the bus stop and the road traffic in the roundabout. This signal group interacts with signal group 2 that are controlling the bus traffic that are arriving from and departing in the north direction. Signal group 3 and 4 are working in a similar way to group 1 and 2. Group 3 consists of the traffic lights controlling the pedestrians and cyclists using the south crossing at the bus stop and the vehicles turning left using the U-turn intersection. This group interacts with signal group 4 which consists of the traffic lights that are controlling the busses arriving from and departing in the south direction.

Figure 45 The location of the four different signal groups existing in the model.

Parameters

The minimum green time, minimum red time, red amber time and amber time for the signal groups were given from the Traffic planning office in Gothenburg. These are seen as standard values but varies depending on what type of intersection it is. The values did however work well in this kind of junction and were therefore used. The times used can be seen in Table 26. In reality the min red and min green times might be different for the different traffic lights since they are controlling different traffic modes. But when modelling the traffic signals they have been simplified to be the same for each signal group.

Table 26 Time settings for the signal groups in the model.

No.	Name	Min.Green	Min.Red	RedAmber	Amber
1	K1	4	0	2	3
2	K2	6	0	2	3
3	K3	4	0	2	3
4	K4	6	0	2	3

The clearance times, i.e. the amount of time all traffic lights have to be red to clear all the traffic in an intersection, have been calculated for the two pair of signal groups. The clearance time for group 1 and 3 have been calculated by taking the length of the pedestrian and cycle crossing and then dividing it with the speed for pedestrians, 1.4 m/s. The clearance time was then increased to 10 seconds since the crossings are longer in the simulation model. It also had to be increased since the modelled pedestrians who are walking on a crossing when the traffic light changes from green to red do not increase their speed, in contrast to pedestrians in reality. The clearance time for group 2 and 4 have been calculated in the same way, using the distance from the bus stop to the end of the roundabout, 60 meters. This was then divided by an assumed average speed for this stretch, 25 km/h. The clearance time was then increased to 11 seconds, when calibrating the model visually.

The signal controllers are programed in a software program called VISVAP. The output files from this program, together with a corresponding text file is then used in VISSIM to define the signal controllers and the different signal groups. These files are presented in Figure 46 - Figure 49.

Input files - Signal controller 1

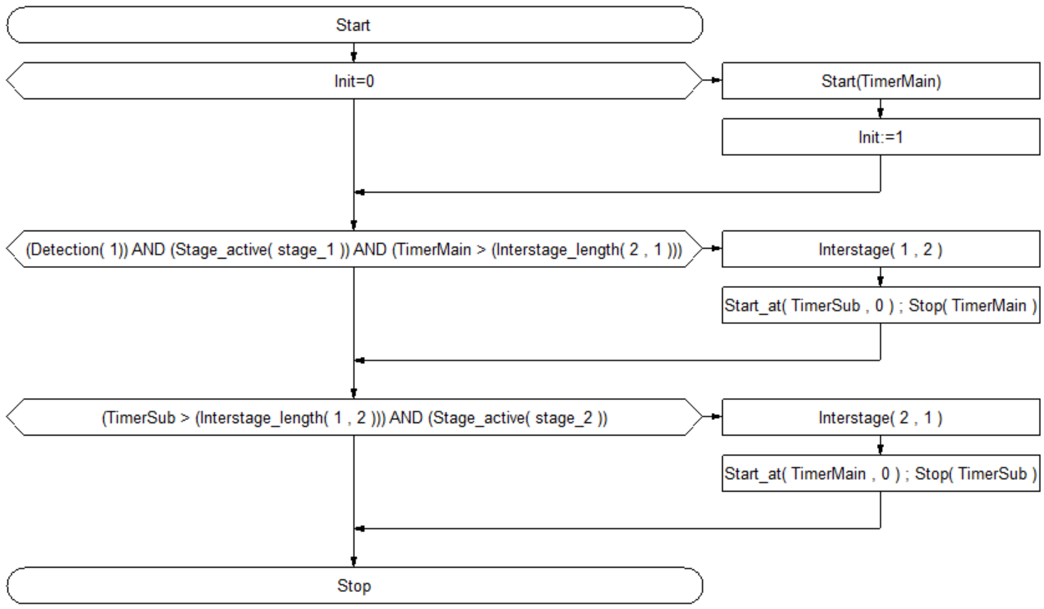


Figure 46 The flow chart used for programming signal control 1 in VISSIM, made in the program VISVAP.

```
$SIGNAL_GROUPS
$
K1     1
K2     2

$IGM
$
        K1      K2
K1      -127    5
K2      10      -127

$STAGES
$
Stage_1          K1
red              K2
Stage_2          K2
red              K1

$STARTING_STAGE
$
Stage_1

$INTERSTAGE1

Interstage_number       : 12
Length [s]              : 16
From Stage              : 1
To Stage                : 2
$
K1   -127 0
K2    10  127

$INTERSTAGE2

Interstage_number       : 21
Length [s]              : 9
From Stage              : 2
To Stage                : 1
$
K1   5 127
K2   -127 0

$END
```

Figure 47 Interstage file with interstages for VAP, for signal control 1.

Input files - Signal controller 2

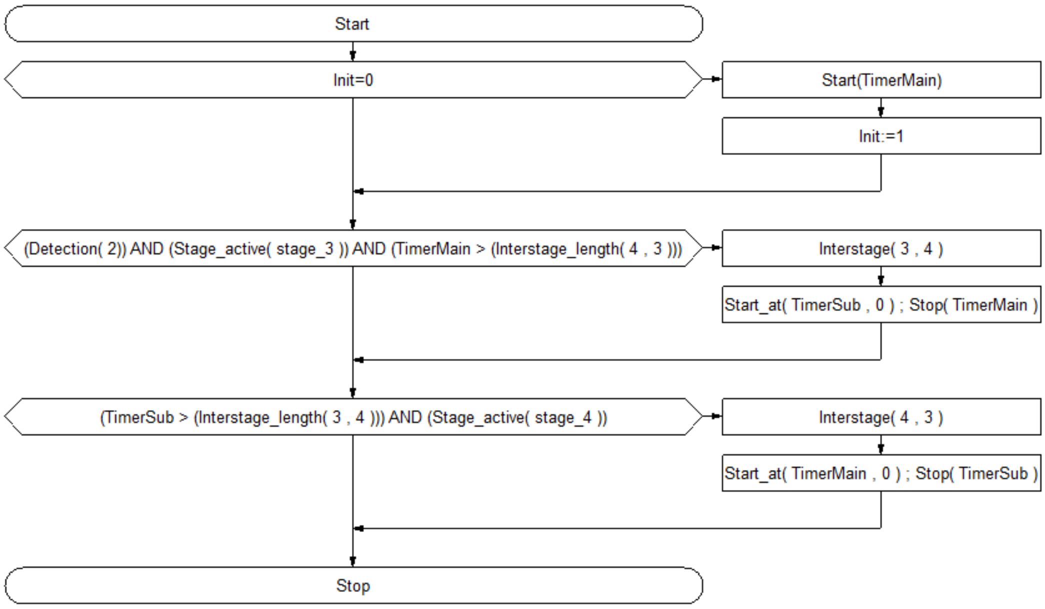


Figure 48 The flow chart used for programming signal control 2 in VISSIM, made in the program VISVAP.

```
$SIGNAL_GROUPS
$
K3     3
K4     4

$IGM
$
        K3      K4
K3      -127    11
K4      10      -127

$STAGES
$
Stage_3          K3
red              K4
Stage_4          K4
red              K3

$STARTING_STAGE
$
Stage_3

$INTERSTAGE3

Interstage_number        : 34
Length [s]               : 16
From Stage               : 3
To Stage                 : 4
$
K3   -127  0
K4    10  127

$INTERSTAGE4

Interstage_number        : 43
Length [s]               : 15
From Stage               : 4
To Stage                 : 3
$
K3   11 127
K4   -127  0

$END
```

Figure 49 Interstage file with interstages for VAP, for signal control 2.

Appendix 5 – Model settings in VISSIM

Here the different settings used in PTV VISSIM are presented and described.

Reduced speed areas

To be able to define a speed limit over a short distance reduced speed areas could be used, e.g. for a curve or over elevated crosswalks. The reduced speed areas are added in links or connectors and various speed reductions can be given to the different vehicle types on the road.

An example from the simulation made in this report of a traffic situation where reduced speed areas where used was in the roundabout presented in Figure 50. In this figure the yellow markings are the reduced speed areas. In a roundabout the cars do not drive in full speed and the heavy traffic is most often driving even slower. Also where different traffic flows crosses each other there are speed reduction, e.g. over elevated pedestrian and bicycle paths.

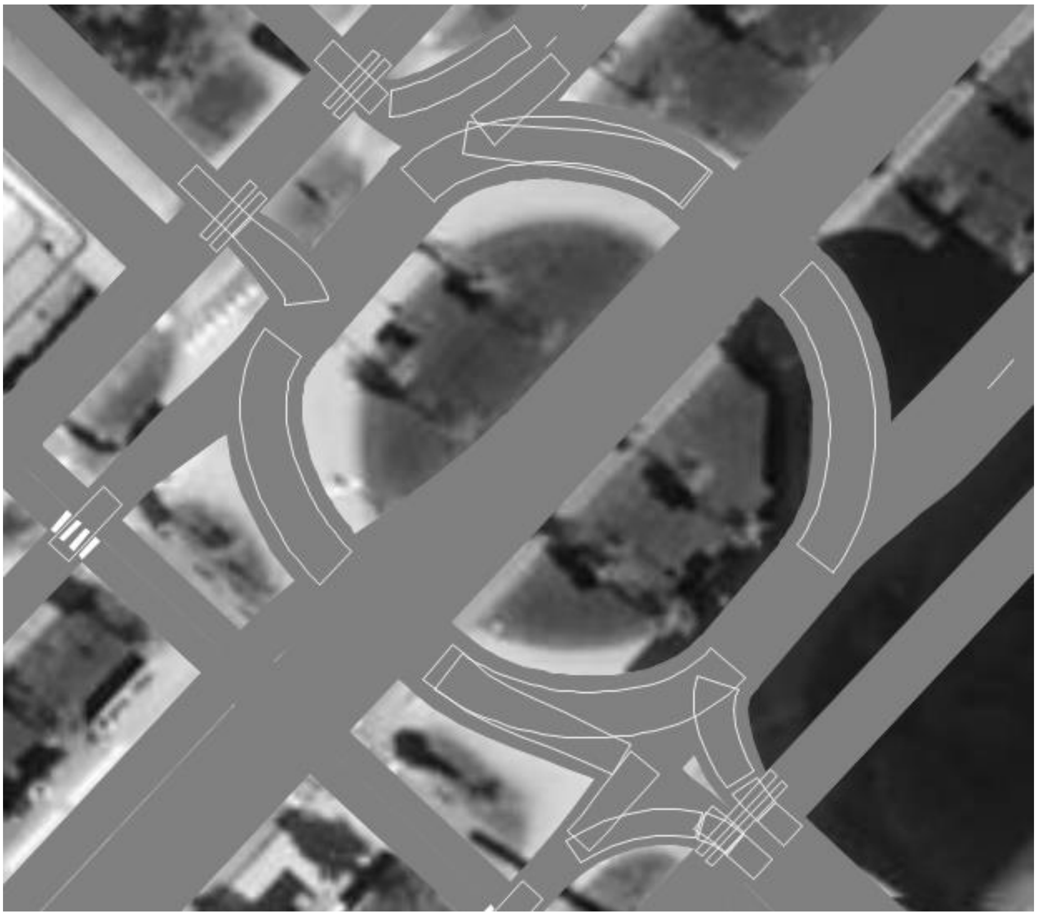


Figure 50 Examples of reduced speed areas in the model in VISSIM.

Priority rules

When several traffic flows intersect or cross each other in some way, conflicts between the different flows arises. For the simulation to work correctly, these flows have to be assigned rules of which should have priority and which should give way. This can be modelled in different ways, depending on the situation that is to be simulated. For intersections which are not controlled by traffic signals priority rules, conflict areas or stop signs could be used.

The priority rule, which is one way to solve conflicting traffic, is presented in Figure 51. The red stop line in the figure is placed on the link where the flow of traffic should give way. While the green mark, named conflict marker, is placed on the main road with priority. For the cars on the minor road to be allowed to cross the stop line several conditions must be fulfilled. The two main conditions are minimum headway and minimum gap time, which are optional and can be altered in VISSIM to fit reality. There should not be any car in the section called headway and it should also be sufficient time gap for the car to drive out on the road.

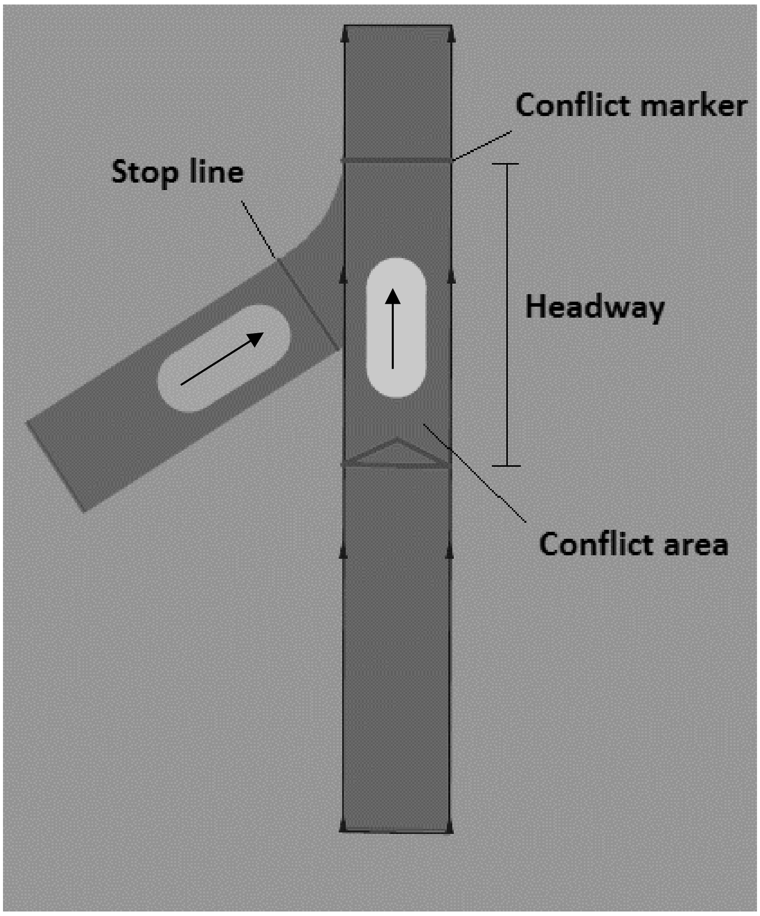


Figure 51 The concept behind priority rules in VISSIM.

Conflict areas

Another way of modelling conflicting traffic flows is using conflict areas. The areas where these conflicts occur are displayed automatically and the status for the conflict area is then easily changed. There are three different settings for conflict areas in VISSIM and the colour refer to which status that is set. Green is the lane that has right of way and the red the lane that should yield. Both red is used for branching conflicts, and is called undetermined meaning that the first to reach the conflict area has right of way. In Figure 52 the three settings are shown, a) is an undermined conflict where the first vehicle reaching the area has right of way b) the lanes going in the top/bottom direction have right of way and c) which is the opposite and the lanes with direction left/right has priority. If nothing is done to the displayed conflict area, it stays yellow in all directions of the conflict. This means that no rule is set to this conflict and the traffic does not react to the conflict area.

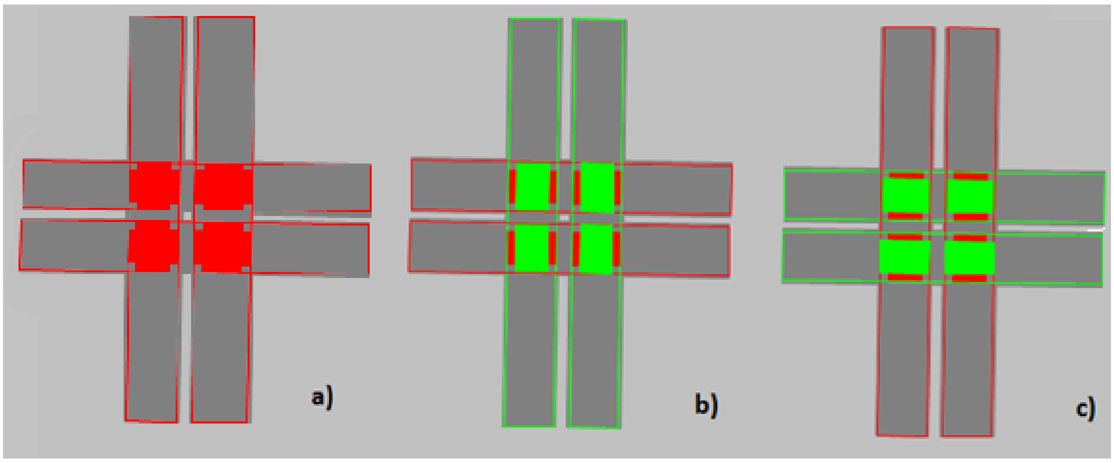


Figure 52 The three settings for using conflict areas in VISSIM.

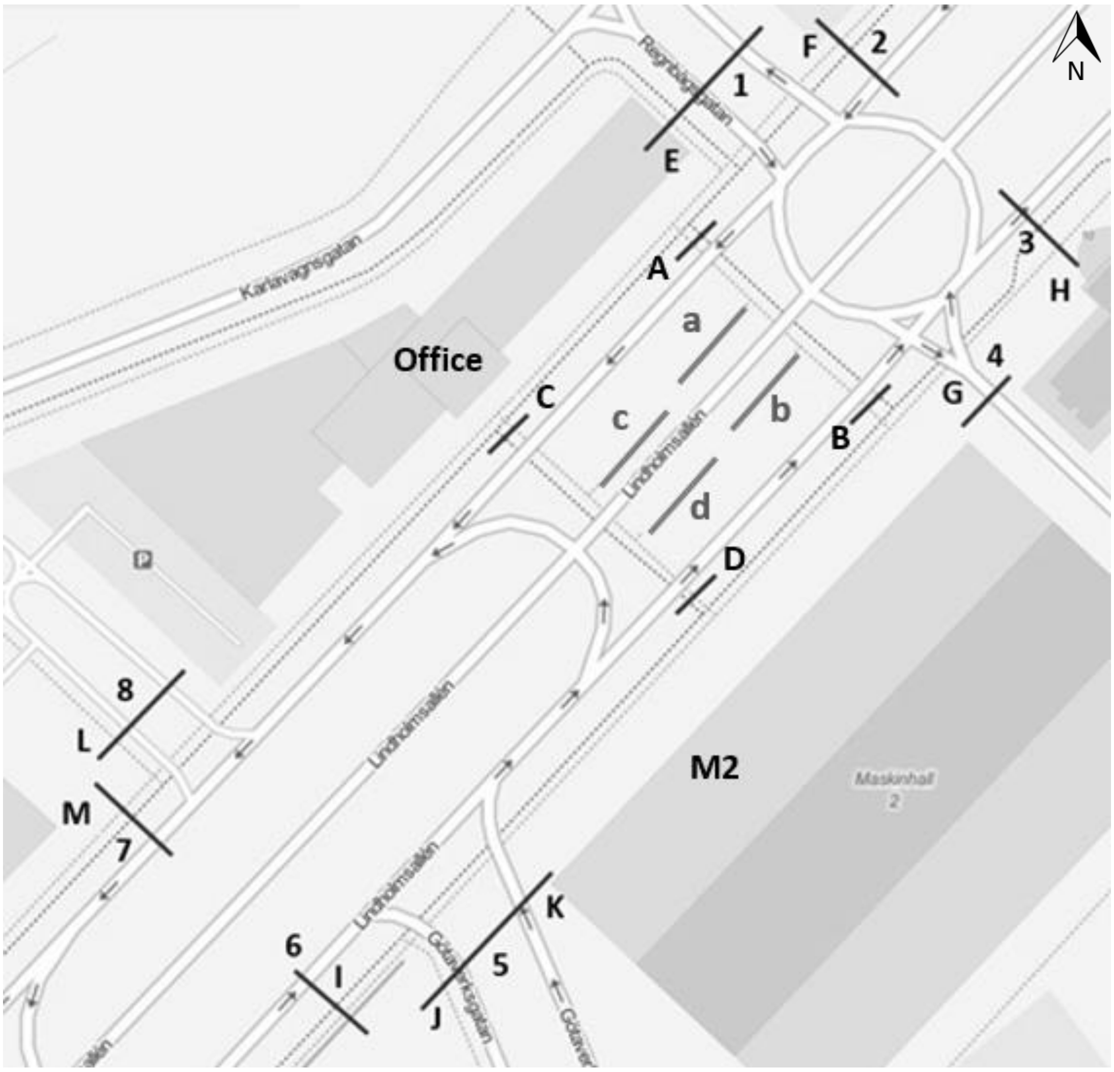
Conflict areas are easier to use compared to priority rules, both regarding editing parameters and it also gives a "more intelligent" driving behaviour during simulation. There are some options that can be adjusted for each conflict area, such as front and rear gap, safety distance factor and additional stop distance, to change so that the conflict areas behave as wanted.

According to PTV Group (2015, p.455) the recommended way of modelling conflicting traffic flows which are not controlled by traffic signals, is by using conflict areas. Priority rules in VISSIM should only be used if the conflict areas do not produce the required result and if the user has enough experience in modelling using priority rules.

Appendix 6 – Route distribution

In this appendix the route distribution of the collected traffic volumes is presented. Observations and also specific counts on several locations in the area was carried out to simplify the distribution. This information, together with some assumptions regarding how someone should move in the area, was used to determine the route distribution.

The routes are presented below consistent to their traffic mode. In the tables it is displayed from which area the flow enters the model and from which area it exits. The cells with a diagonal line in refers to routes that are seen as highly unlikely or that are not possible to take. Whilst a value of zero means that it is not observed any or very little traffic on these routes, but they are still likely. One assumption made is that the traffic does not turn in the model and exit the same way they entered. This means that all cells with the same enter point as exit point have a diagonal line drawn inside it.



Pedestrians

Table 27 shows the distributed routes for the pedestrians in the area. For this simulation 15 different entry locations were chosen, with the same amount of exits located at the same area. The first four, a to d, are the pedestrians who enter into or exit the model from the buses. E to M are locations on the boundaries of the simulated area were pedestrians enter or exit. The last two called Office and M2 are destinations or origins that is located inside the model and that are frequently used by pedestrians. M2 is the building located on the south side of the bus stop and the office is located on the north side.

As said before it is assumed that no pedestrians change from one bus to another. Thus the cells in the upper left corner contains lines, as the route from e.g. a to b means that you go from bus location a to b. There are also some other unlikely routes that are marked with a line in the table. It was observed that no pedestrians walked out from the office building, only in and thus the in column is zero all the way down.

Table 27 Route distribution for pedestrians.

		In															
	Area	**a**	**b**	**c**	**d**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**Office**	**M2**	**Sum**
Out	**a**					2	0	1	0	0	0	0	1	0	0	1	**5**
	b					3	0	1	1	0	0	0	0	0	0	1	**6**
	c					1	0	0	1	0	0	0	0	0	0	1	**3**
	d					14	0	7	1	0	0	1	2	0	0	2	**27**
	E	1	0	1	4		0	4	0	0	0	0		1	0	0	**11**
	F	1	0	0	0	2		0		0	0	0	0	0	0	0	**3**
	G	100	7	92	47	4	0		5	0			0	0	0	0	**255**
	H	15	2	12	9	9	1	6		0	1	0	0	1	0	0	**56**
	I	4	1	2	1	3	0	2	0		1	0			0	0	**14**
	J	2	0	0	0	0	0		0	5			0	0	0	0	**7**
	K	148	12	93	61	8	0		0	0			0	0	0	5	**327**
	L	5	0	3	2	2	0	0	0		0	0		0	0	0	**12**
	M	5	0	1	1	2	1	0	0				0		0	0	**10**
	Office	15	2	10	6	12	1	0	1	4	0	2	4	1		2	**60**
	M2	7	2	5	3	1	0	0	2	2	0	5	0	0	0		**27**
	Sum	**303**	**26**	**219**	**134**	**63**	**3**	**21**	**11**	**11**	**2**	**8**	**7**	**3**	**0**	**12**	

Cyclists

For the cyclists, all the entries and exits are possible and no routes was assumed to be impossible or unlikely. With the exception described earlier, where the traffic turns and leaves the model the same way they entered. The result of the distribution for the bicycle traffic is presented in Table 28.

Table 28 Route distribution for cyclists.

		In								
	Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Sum**
Out	**1**		1	1	0	2	6	4	0	**14**
	2	9		0	0	0	1	4	2	**16**
	3	11	0		1	2	25	3	1	**43**
	4	5	1	6		0	11	0	0	**23**
	5	13	2	11	0		16	0	0	**42**
	6	26	2	27	0	2		0	0	**57**
	7	16	4	4	0	0	0		0	**24**
	8	0	0	2	0	0	0	2		**4**
	Sum	**80**	**10**	**51**	**1**	**6**	**59**	**13**	**3**	

Road traffic

The route distribution for the road traffic is presented in the same way as for the other traffic modes and displayed in Table 29 below. The amount of possible routes for the road traffic is much lower compared to the pedestrians and cyclists. The reason behind this is that four of the locations where the traffic counts were made are on one way streets, two has only entering traffic and the other two only exiting. This results in that two columns and two rows are only containing lines. The design of the road also removes other possible routes in the model, but other than that all potential routes contained a share of the traffic flow.

Table 29 Route distribution for road traffic.

		In								
	Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Sum**
Out	**1**		40		14	45	66			**165**
	2									**0**
	3	186	20		5	15	20			**246**
	4	148	89			4	37			**278**
	5						579			**579**
	6									**0**
	7	461	149		14	39	8		4	**675**
	8	6	6		1	4	2			**19**
	Sum	**801**	**304**	**0**	**34**	**107**	**712**	**0**	**4**	