CHALMERS

Accessibility evaluation of Kungsmässan shopping centre with traffic simulation

A case study in Kungsbacka municipality, Sweden

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

IGNASI FAURA

Department of Civil and Environmental Engineering
Division of GeoEngineering
Road and Traffic Research Group
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2012
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Department of Civil and Environmental Engineering
Division of GeoEngineering
Road and Traffic Research Group
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

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Kungsmässan´s emblem. [Own source (2012)]

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ABSTRACT

Kungsbacka is a municipality situated approximately 30 km south from Göteborg, the second biggest city of Sweden. Due to the connexion of the west coastal cities through the E6 motorway, a large volume of traffic takes place and will be even increased in the near future according to the authorities.

Kungsmässan is a large shopping centre in Kungsbacka. Nowadays, there is only one entry for motorized vehicles with a signalized T-junction. As a result, the local authorities are proposing to improve its accessibility to have two entries instead with several roundabouts.

The purpose of this Master Thesis is to quantify the benefits of implementing a proposed solution, made by Norconsult AB Company, by comparing it with the current situation and being able to accept or decline the project.

VISSIM 5.40 is the software used to conduct the traffic simulation and together with the help of MS Excel and AutoCAD 2011, will assess the outputs obtained from the modelling process.

The results of the report show that the proposed solution, except for few cases in the highest traffic flow scenario, can handle in a more efficient way the demand of the users.

In general terms and after weighting the output parameters with the number of vehicles used in each case, the proposed solution comes up to be 6.9/10 if the current situation is rated 5/10.

Key words: Actuated signal control, follow-up time, headway gap, LHOVRA-technique, performance measure, roundabout, traffic simulation, traffic volume, VISSIM.

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Preface

This study-research has been carried out from April to September 2012 in Norconsult AB. The aim of it was to quantify and assess the possible benefits of conducting a proposed solution to improve the accessibility of Kungsmässan´s shopping centre of Kungsbacka municipality, Sweden.

All the praise to all the workers of Trafik division of Norconsult AB, especially my two supervisors Anders Axenborg and Erland Kjellsson, for their valuable and trustworthy knowledge in some points of the report. I really appreciate the opportunity of having a working place there and gaining a rewarding experience in the office during these months. Without them it would have been much harder to reach the goal.

I would also like to give a deepest gratitude to Gunnar Lannér, my examiner and supervisor in Chalmers University of Technology, whose contribution helped me to find both a useful master thesis and a suitable company to work with.

Heartiest thanks to Syed Danial Ali for his disinterested assistance of VISSIM programming during several days and his immediate response when needed.

Finally, I dedicate this work to my parents who have given me every tool to grow and to be where I am.

To Pau Albornà, a former fellow student who left us in a fatal traffic accident while this thesis was being written.

Göteborg, September 2012
Ignasi Faura

“De här två åren i Sverige har varit ett underbar erfarenhet i mitt liv.”

Glossary

Swedish to English

Gatan	Street
Gård	Yard
Göteborg	Gothenburg
Mässan	Fair
Trafikverket	Transport Department
Vägen	Road

Definition

ADT	Average Daily Traffic
CS	Current Situation
ESC	Electronic Stability Control
EuroRAP	European Road Assessment Programme
FCFS	First Come First Served
GR	Göteborg Region
K2020	Long Term Strategy for Public Transport in GR
Kungsmässan	Shopping Centre of Kungsbacka Municipality
LPI	Logistics Performance Index
Norconsult AB	Norconsult Ltd
PHT	Peak Hour Traffic
PS	Proposed Solution
PT	Public Transport
RSEM	Ramps Stairways Escalators Moving walkways
T1	Half the Maximum Traffic in 2012
T2	Maximum Traffic in 2012
T3	Maximum Traffic in 2020
VAP	Vehicle Actuated Program

1 Introduction

In this chapter the objectives, the background, the method used and the limitations of this thesis are presented in order to obtain a quick overview of what has been studied and developed.

The report describes the study of the current situation of Kungsmässan shopping centre and a proposed alternative regarding its accessibility. The area of interest is located in Kungsbacka municipality, Hallands Län, Sweden. Figure 1 shows the aerial view of Kungsmässan shopping centre nowadays. Varlavägen and Varlagård roads will be modelled with VISSIM software. Although Borgmästaregatan is not included in the models, it is tagged here because it is mentioned in Section 1.4 as one limitation of this project.

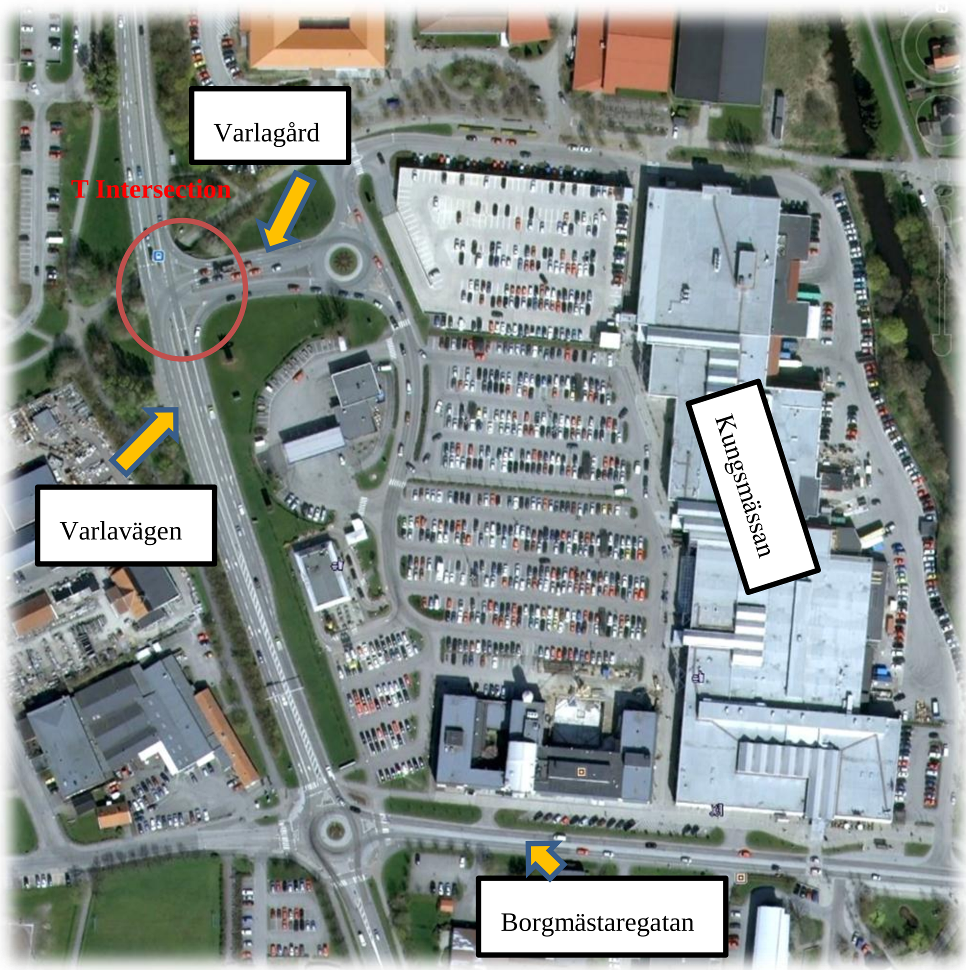

Figure 1. Aerial view of Kungsmässan shopping centre, its parking lot and the modelled T intersection on the left hand side. [Source: Google Earth 6.0 (2012)].

1.1 Background

Among more than 150 countries all over the world, Sweden is ranked the third one in terms of Logistics Performance Index (LPI). In other words, Sweden has a high quality and efficient logistic operations. LPI is strongly related with trade expansion, export diversification, attraction of foreigners´ investments and, as one can imagine, economic growth, Arvis et al., (2010).

Regarding the population, Gothenburg is the second biggest city of Sweden and the fifth one of Scandinavia being only behind Stockholm, Copenhagen, Helsinki and Oslo, all of them the capitals of their respective countries, Citypopulation (2012).

Consequently, the surrounding area of Gothenburg, where Kungsbacka is located, needs special attention when taking into consideration the transportation throughout it. Owing to this, a large volume of traffic is demanded due to the connexion of the west coastal Swedish cities through E6 motorway. This means that both new and renovating projects are an important aspect to be considered in order to obtain an efficient and effective road network facing these demands.

As mentioned before, the report focuses in Kungsmässan shopping centre of Kungsbacka municipality, which is located 30 Km. south of Gothenburg, see Figure 2.

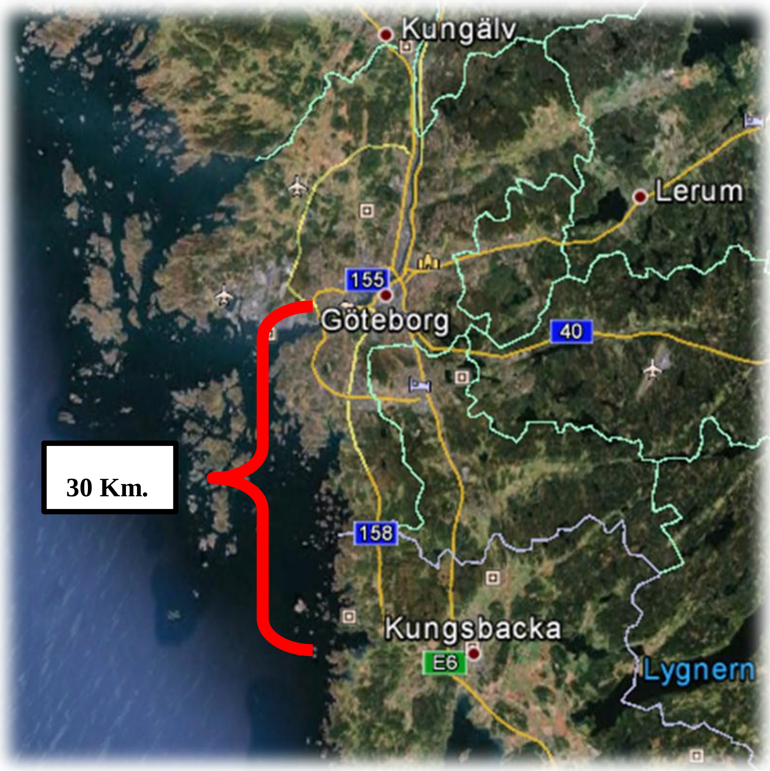

Figure 2. Aerial view of part of Gothenburg Region. [Source: Google Earth 6.0 (2012)].

Nowadays, there is a big concern to enhance the accessibility of Kungsmässan due to both the experienced and the expected growth of population within Kungsbacka in the coming years. As it is shown in Figure 3, a continuous increase of population during more than 40 years has taken place in Kungsbacka.

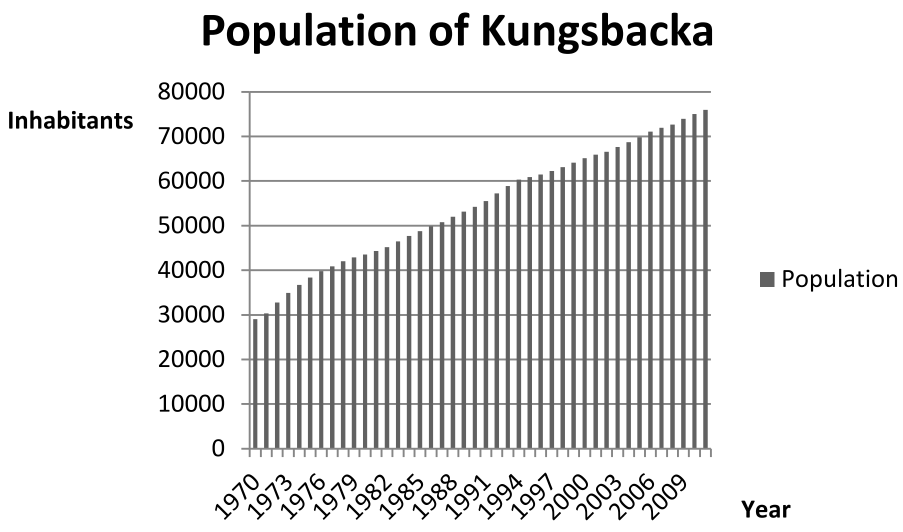

Figure 3. Kungsbacka´s population during the last 40 years. [Source: Statistics Sweden (2012)].

In addition to this, according to the Statistics of Sweden (2012), the yearly growth during this period has always been positive, see Figure 4.

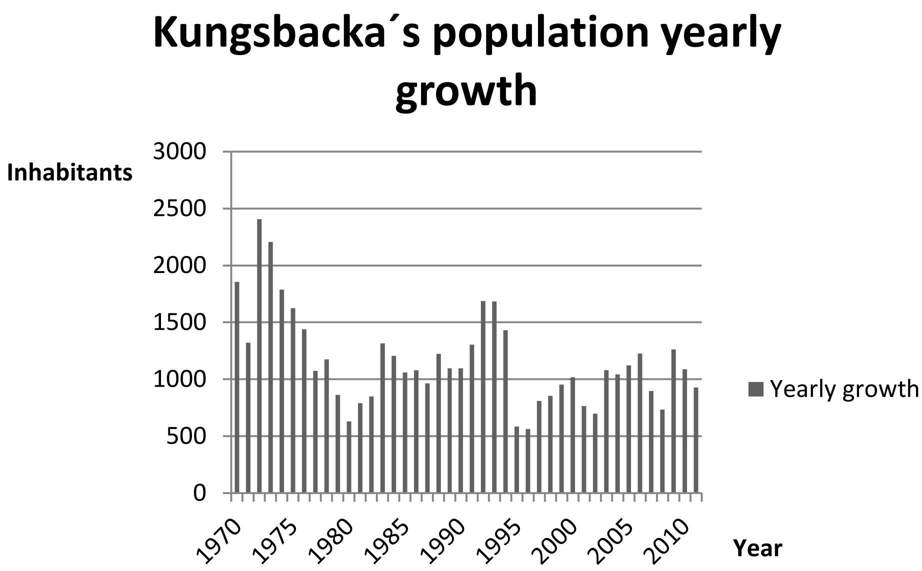

Figure 4. Kungsbacka´s yearly growth population during the last 40 years. [Source: Statistics Sweden (2012)].

Certain projects such as: "K2020 Public transport development program for the Gothenburg Region" are related to this area and are under consideration by the Swedish Traffic Administration (Trafikverket), see Section 2.1 for further details. These approaches reflect that the planners are working to make the Gothenburg

Region even more sustainable. They try to achieve that goal by improving its mobility, accessibility and traffic safety among other aspects. This will most probably affect Kungsmässan´s accessibility in the future basically in terms of an increased traffic flow, K2020 (2008).

Owing to this, Norconsult AB (2012) has proposed a solution to improve the accessibility of Kungsmässan, see Figure 5. Comparing the left and right hand sides, it can be noticed that there will be two entries instead of just the one used in the present scenario. Nevertheless, it is of big importance to quantify the proposed solution is and at the same time, if it is good enough to be conducted in the near future. Chapter 4 is facing this point and shows the results acquired.

Figure 5. Current situation (left) and proposed solution (right) plans of Kungsmässan. [Source: Norconsult AB (2012)].

It must be pointed out that in the proposed plan, a new parking lot will be built and that neither of the new entries will be the one used in the current situation. Moreover, the traffic lights that are present today will not be used in the future as roundabouts will control the traffic flow.

1.2 Objectives

The main objective of this report is to quantify how suitable is a proposed solution of Kungsmässan´s accessibility made by Norconsult AB Company. A comparison between that solution and the current situation will be assessed, which will be an assistive tool for a proper decision in terms of accepting or declining the project. Additionally, three traffic prognoses will be analysed due to their uncertain accuracy that they possess intrinsically.

1.3 Limitations

The limitations of this thesis according to the author are mentioned below:

- This study does not consider what happens inside the parking areas and if queues are generated there.

- The Current Situation´s model does not take into consideration possible queues in the roundabout connecting Varlavägen and Borgmästaregatan located further south of the T intersection.

- Only one alternative proposed by Norconsult AB is considered.

- There is not a large volume of information from the studied area. Therefore, manual counting of traffic volumes is considered as the only source of data and just some weekdays from 16:00h to 17:30h were used as input.

- The models are carried out considering the area completely flat. Although the ground is somehow like that, there are probably different elevations that can change some parameters of the model such as the acceleration/deceleration rates of the vehicles.

- The widths of the roads in the model are supposed to remain almost constant even it is not like that in the reality.

- The pedestrians´ data is not collected. However, it is included in the model to simulate the crosswalks´ interaction with the motorized vehicles.

- Although the driving behaviour can be extremely complex, this report has not focused in depth in very small details that can happen just in rare situations.

1.4 Method

Literature review, stated in Chapter 2, was read for better understanding of the important parameters that have to be considered and extracted from the modelling process. Moreover, different books, papers and older theses related to this one were taken into account.

Apart from this, a traffic simulation computer program, known as VISSIM 5.40, was used to model both the current situation and the proposed solution conducted by Norconsult AB. Furthermore, AutoCAD 2011 and MS Excel were also used to assist some parts of the report such as the background used to implement VISSIM and the data extracted from the models respectively, all are commented in Chapter 3.

Last but not least, some data collection of traffic flow from the case study from 16:00h to 17:30h during different week days was gathered.

All the data supposed to be relevant was included in the VISSIM models, being further discussed afterwards in Chapter 3.

Three different traffic volumes were conducted when running the models to see how the outcomes vary between each other. As a result, T1, T2 and T3 representing half of the maximum traffic volume of 2012, the maximum traffic volume gathered from 2012 and the maximum traffic prognosis deducted for 2020 respectively were introduced in VISSIM.

In addition, the procedure to achieve the final results was the following: First, a model of the current situation with one entry and several traffic lights controlling the T intersection was carried out with current characteristics, i.e. maximum traffic in 2012 noted as T2. Next, the same model using the maximum traffic prognosis in 2020 (T3) was conducted to realize the problematic points and the need of proper changes to be introduced into the model to make it even more accurate, i.e. get better synchronization between road users. After that, it was turn to model the proposed solution network with both current and future traffic data. Finally, the outcomes of the different amounts of traffic used T1, T2 and T3 were examined after the simulating process and are debated in Chapters 4 and 5.

2 Literature Review

Under this chapter, different concepts regarding traffic issues are included in case some terms described are not familiar for the reader.

2.1 Project involving the Göteborg Region, K2020

In Section 1.2 it was explained that the project K2020 will probably affect Kungsmässan´s accessibility. More in depth, K2020 is a long term sustainable strategy that tries to plan an attractive public transport development within the Göteborg Region (GR). Kungsbacka is one of the 13 municipalities of this involved GR.

According to the K2020 project (2008), one of the goals is that at least 40% of the journeys should be made by public transport, which means that this value will be doubled from nowadays situation. To achieve it, not only an improvement of public transportation should be implemented but also a change in people´s attitudes, incentives and market communication must be done in parallel.

The main transport structure involving the different municipalities is based on commuter trains, trams and buses. It is estimated that travelling to and from Göteborg by train can be quadrupled by 2025, K2020 (2008), see Figure 7.

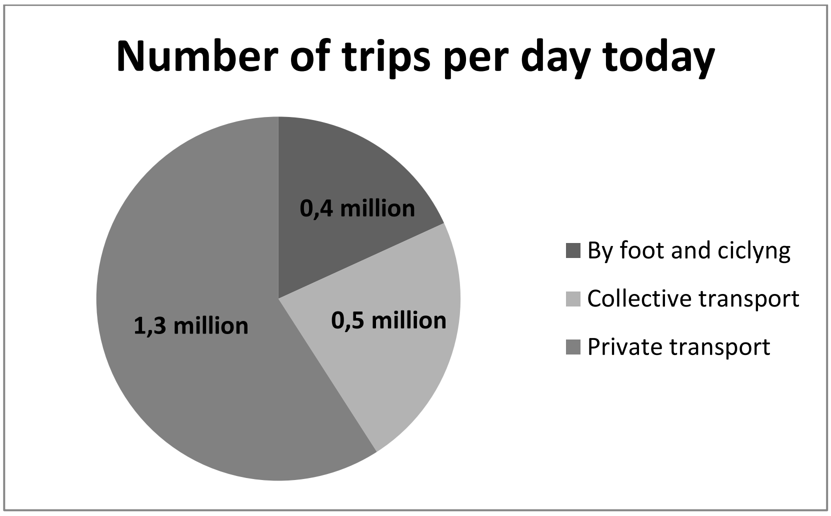

Figure 6. *Number of trips per day today*. [Source: K2020 (2009)].

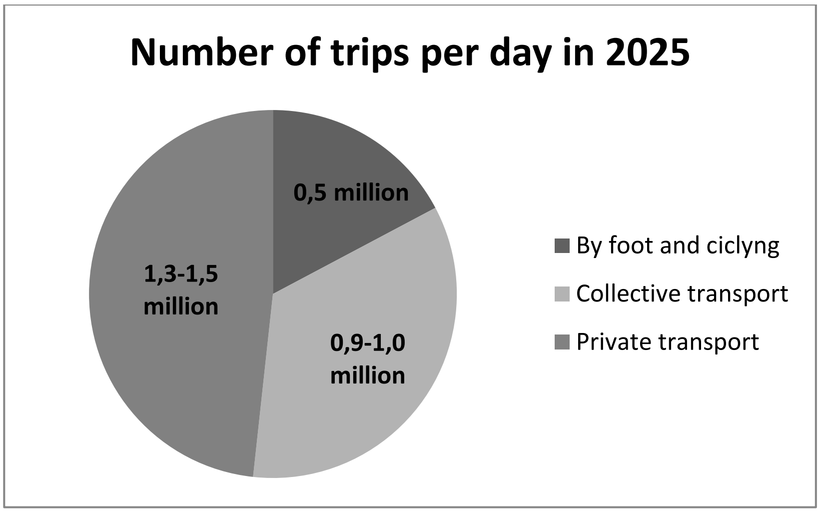

Figure 7. Prediction of number of trips per day in 2025. [Source: K2020 (2009)].

It can be noticed that the number of trips made by private transport will remain almost the same while the other ones will increase. In global, less proportion of private transport comes up to take place in 2025.

All in all, the public transportation´s success will arise whether short travel times, an ease of its use, reliability and safety take part in simultaneously.

Last but not least, the Vision Zero initiative that started in Sweden in 1997 states that no fatal or serious injuries on Swedish roads might happen due to any loss of life in traffic is unacceptable. In addition to this, its slogan is: "People might fail, the road system should not", Vision Zero (20??).

In relation to this point, EuroRAP (European Road Assessment Programme) tries to ensure well equipped vehicles that will be able to interpret as much as possible the road in where they circulate. To accomplish this goal, better signalization in roads as well as an Electronic Stability Control (ESC) for the cars is supposed to reduce by 10% the European road deaths, Trafikverket (2011).

Therefore, there are many reasons to perform a new project to improve Kungsmässan´s accessibility for the future.

2.2 Design of crossing roads

It is obvious that the major problems involving possible traffic accidents are located in crossing roads. Regarding this part of the roads, either intersections or roundabouts are the most common types than drivers will face during their travel journey.

2.2.1 Types of intersections

Intersections are points of potential vehicle conflicts. There are several manners to control their governance when different vehicles share a common space. On one hand, a signalized intersection consists on signal controllers that give priority according to their green, amber or red lights. On the other hand, stops, give way or roundabouts can also control by themselves an intersection but in these cases the drivers must decide for themselves when to cross it.

Ali and Mirza state in their master thesis (2012) that engineers should plan and design any kind of intersection in a way that it becomes efficient but at the same time safe for all road users. In addition to this, engineers might allow space in case of formed queues for not collapsing the system.

Intersections are usually designed for peak traffic volumes in order to handle the traffic demands in a great time span. Moreover, the possible turning movements, the operating speeds, the interaction of pedestrians and bicyclists with the motorized vehicles, the public transport requirements and the needs of oversized vehicles are contemplated when designing an intersection.

According to Ali and Mirza (2012), the most common types of intersection are the following:

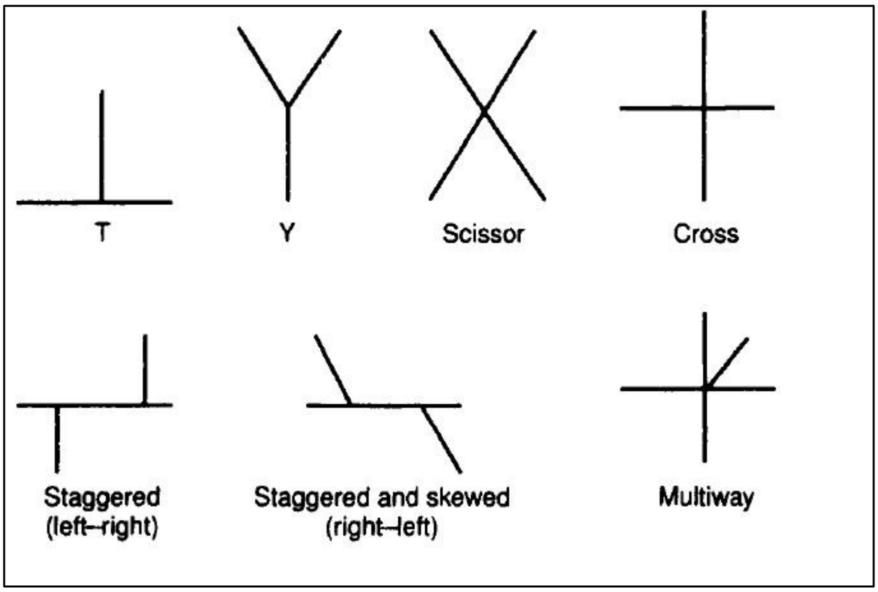

Figure 8. Different types of intersections. [Source: Ali and Mirza (2012)].

In this report, T-intersection is the one handled as Kungsmässan accessibility operates with it in the current situation. Regarding the future scenario, roundabouts will be governing the conflict areas, see Section 2.3.

2.2.2 Roundabouts

Roundabouts are a type of intersection where vehicles are guided onto a one way circulatory road with a central island. The traffic flow goes counter clockwise in most countries like Sweden, but not in UK where it is clockwise.

The main objective of roundabouts is to ensure a secure interchange between different approaching traffic obtaining the minimum delay as possible. Furthermore, its capacity will depend on the accepting headway gaps and the follow-up time of the waiting queue to enter it, HCM (2000).

According to HCM (2000), an estimated capacity of a roundabout is given by the following equation:

$$C_a = \frac{V_c \cdot e^{-Vc \cdot tc / 3600}}{1 - e^{-Vc \cdot tf / 3600}} \tag{1}$$

Where:

C_a = Approach capacity (veh/h)

V_c = Conflicting circulating traffic (veh/h)

t_c = Critical gap (s)

t_f = Follow-up time (s)

A recommended range of values for t_c and t_f are as following, see Table 1:

Table 1. Critical gap and follow-up time for roundabouts. [Source: HCM (2000)].

	Critical gap (s)	Follow-up time (s)
Upper bound	4.1	2.6
Lower bound	4.6	3.1

The corresponding relationship between the approach capacity and the circulating flow is as Figure 9 illustrates:

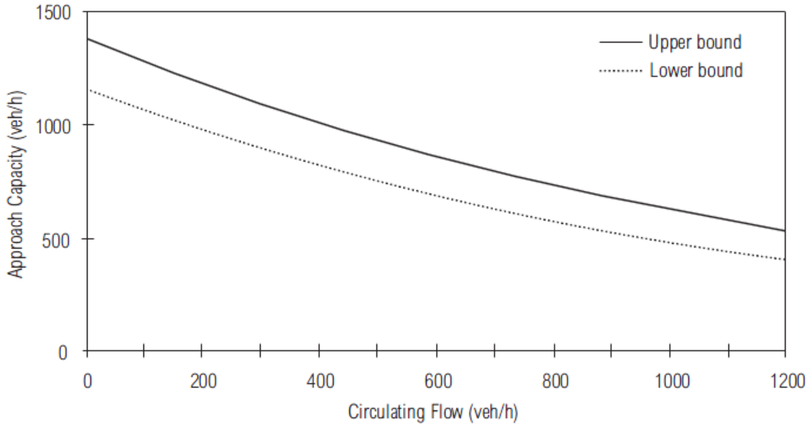

Figure 9. Approach capacity in roundabouts for upper and lower boundaries. [Source: HCM (2000)].

The outputs used in this project rely on how VISSIM 5.40 simulates the different scenarios. These parameters are included in the driving behaviour selected beforehand, which are in good concordance with the real situation of the area. A minimum gap time of 3.5 seconds is utilized in the northernmost roundabout due to its major impact in queue forming. It will be explained in Section 2.6.2.

2.3 Traffic volume characteristics (forecast)

As it is said in types of intersections (Section 2.2), any of them should be designed with peak hour conditions. Depending upon the specific region and location, the peak hour of the day will vary from 10 to 15% of the 24-hour volume, Roess et al., (2004). This value will be used afterwards in Section 3.1.1 when calculating the traffic volumes to introduce in VISSIM.

Normally, there are two peak hours during a weekday, one in the morning (from 7am to 10am) and one in the afternoon (from 4pm to 7pm) which are dominated by the commuters going and coming back from work. Figure 10 illustrates the percentage of daily traffic from different types of routes in three different days, Wednesday, Saturday and Sunday.

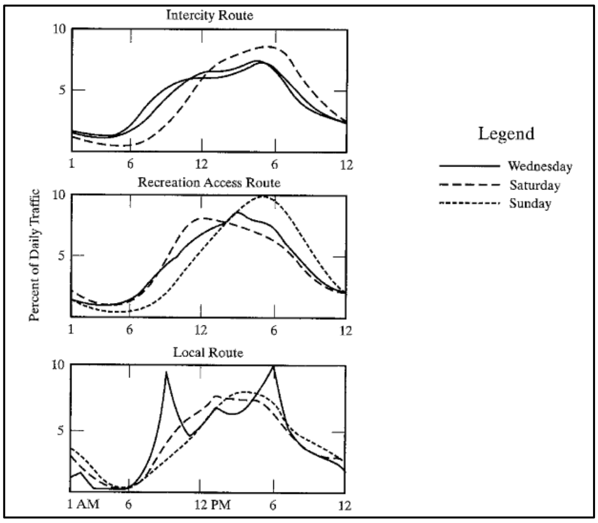

Figure 10. Variation of typical rural routes. [Source: Roess et al. (2004)].

Relating Figure 10 above with the area of study, one can note that obtaining data between 4pm and 7pm should be enough to gather a rather good image of what is going on during peak hours in Kungsmässan shopping centre. Moreover, an employee of Norconsult AB, who knew very well the trend of the maximum traffic volumes there, affirmed that this period of the day was perfect and suitable to study the area.

2.3.1 Techniques for volume studies

According to Roess et al. (2004), there are three different techniques for counting traffic volumes:

1. Manual count techniques
2. Portable count techniques
3. Permanent counts

Manual count as mechanical hand counter is used in this thesis as the site was not difficult to assess with it and there were no other types of counting techniques available to assess the area at that time. The main disadvantage of this method is that the data gathered is only from a period of time and it requires man hours and continuous attention of the observers. What is more, a high probability of distraction and counting error can occur if the observers are not aware of the procedure to be followed. On the other hand, high precision of two operators with enough experience handled the situation in a good way.

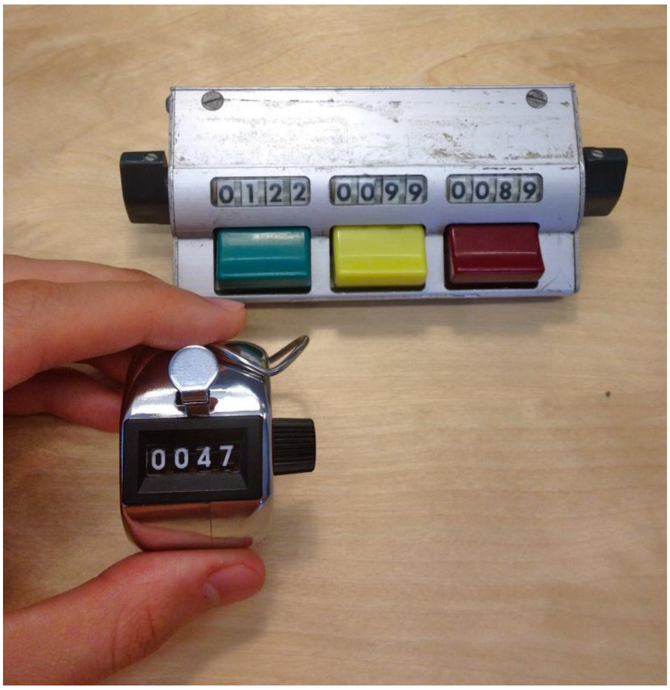

Figure 11. Traffic counters used on site. [Own source (2012)].

From above, each button represents a lane and the number states the amount of vehicles that have passed through an imaginary line on the pavement at a certain time.

Talking about portable count techniques, a pneumatic tube fastened across the pavement is the most common one used for counting traffic issues. Figure 12 below shows different methodologies for obtaining traffic data.

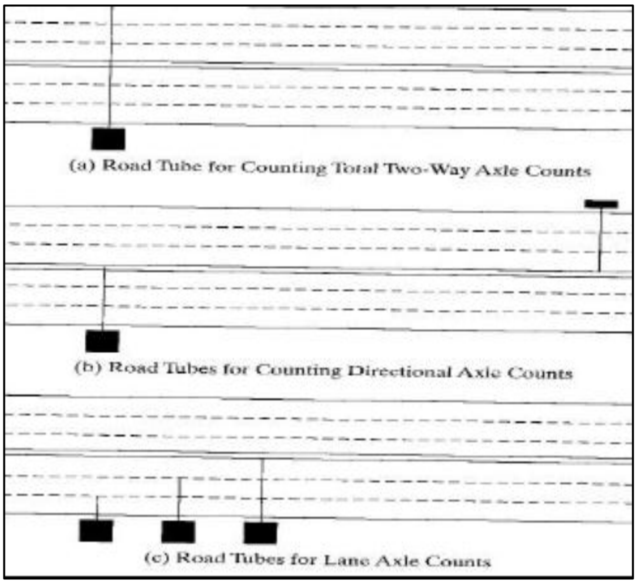

Figure 12. Different methodologies of detecting vehicles. [Source: Roess et al., (2004)].

The later technique, permanent counts, is used for counting data during 24 hours a day and 365 days. Consequently, the purpose is to use the data for real time monitoring.

2.4 Actuated signal control at an intersection

Since the very beginning, intersections have been controlled by signal controllers that had been defined beforehand. These predetermined signal controllers are characterized by their constant cycle length and phase sequence which remain equal from cycle to cycle. On the contrary, in recent years actuated signal controllers can be programmed to modify their cycle lengths according to the current traffic flow demand at every moment. That information is taken from detectors located along the intersection area which requires proper installation in all approaches to detect the presence of vehicles. Therefore, actuated signal control helps to fulfil the variable demand of traffic in a more efficient way, e.g. LHOVRA technique in Sweden, which is explained later on in Section 2.6, Roess et al. (2004).

According to Roess et. al, actuated signal controllers should be designed by defining the variable phase sequences, the variable green times for each phase and the variable cycle length. Figure 13 below points out how the variable demand of an intersection can be improved by implementing an actuated signal control.

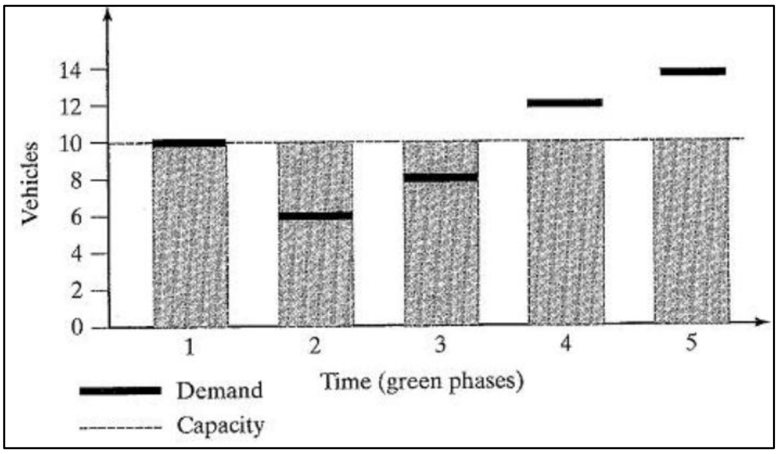

Figure 13. Random arrival demand approaching an intersection. [Source Roess et. al, (2004)].

From above one can easily see that the system has a constant capacity of 10 vehicles during 5 time intervals whereas the demand varies during these 5 time steps. The sum of both is 50 vehicles but if there is not an actuated signal control adapted to the demand, queues will be formed.

2.4.1 Detectors

Since it is explained in Section 2.5 above, detectors are essential when using actuated signal controllers. They are the ones giving the information of which demand is arriving to the intersection. Consequently, the traffic light will show the corresponding sign phase if possible.

The Federal Highway Administration (FHWA, 2008) has studied that detectors can be set up into two modes: pulse mode or presence mode.

The first one detects the vehicle in a point just by motion. Then, a pulse between 0.10 and 0.15 seconds is sent to the controller. The latter one can measure the occupancy, i.e. the actuation starts when a vehicle enters the detection zone and ends when it leaves it. For that reason, the duration of this pulse will of course vary depending on the vehicle length, the detection zone length itself and the vehicle speed passing through it, look at Figure 14 (FHWA, 2008).

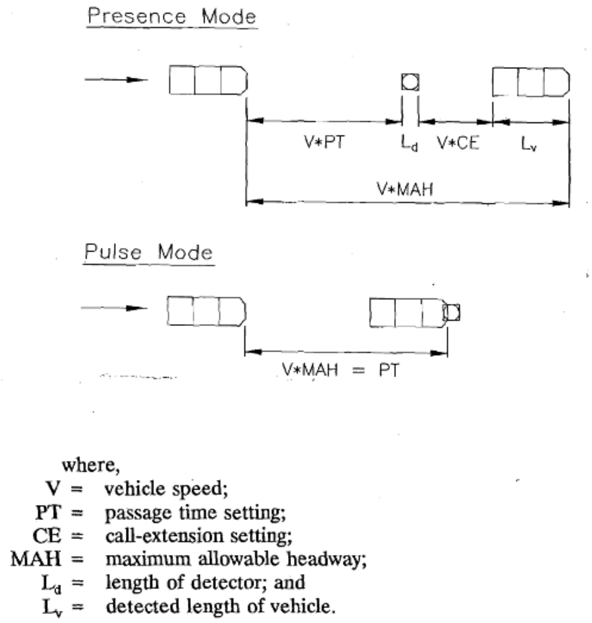

Figure 14. Maximum allowable headway for presence and pulse modes. [Source: Bonneson and McCoy (2005)].

2.4.2 Dilemma zone

Dilemma zone is defined as an area close to the stop line where a driver might not be able neither to stop before that line with an acceptable deceleration rate nor to clear the intersection while the amber takes place, see Figure 15, Al-Mudhaffar (2006).

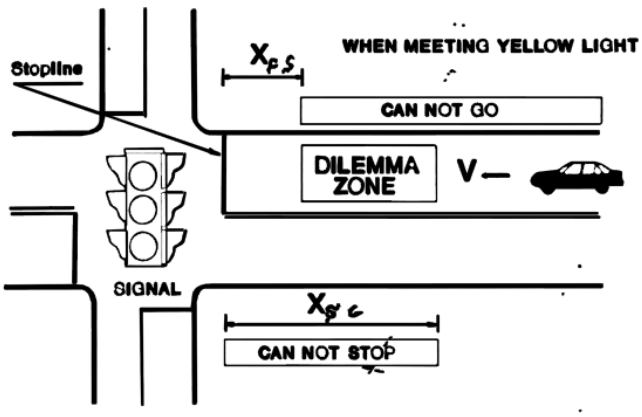

Figure 15. Schematic representation of a dilemma zone. [Source: Al-Mudhaffar (2006)].

The limits of the dilemma zone have been further studied and they are defined as follows:

$$X_{ps} \leq \tau \cdot v_0 \quad ; \quad \text{Maximum distance for a passing vehicle} \qquad \textbf{(2)}$$

$$X_{sc} \geq \delta \cdot v_0 + \frac{{v_0}^2}{2g \cdot r} \quad ; \quad \text{Minimum stopping distance} \qquad \textbf{(3)}$$

Where:

v_o = Approaching speed (m/s)

X_{sc} *and* X_{ps} = Approaching distances (meters)

δ = Reaction time for braking plus the time to start braking itself (seconds)

τ = Time length of the amber light (seconds)

r = Required retardation (dimensionless)

g = Gravity (m/s^2)

Common values are: $\delta = 0.75$ seconds, $\tau = 5.0\ seconds$ and $r = 0.5$.

It must be stated that the amber time can vary if LHOVRA technique is implemented. The common range in Sweden goes from 3 to 5 seconds, Miao and Tong (2010).

2.5 Innovative traffic control

European countries use a number of innovative traffic control devices to improve safety when driving upon an intersection. Under this heading, the Swedish LHOVRA technique has an important role.

2.5.1 LHOVRA technique

In Sweden the so called LHOVRA technique is a predominant tool used to increase the road safety and to reduce the lost time and the number of stopped vehicles at signalized intersections along high speed roads. Its application is closely related to the actuated signal controllers exposed previously.

After its trial period, the accident rate was decreased from 0.7 to 0.5 accidents per million incoming vehicles. Therefore, this technique was widely implemented not only in Sweden but also in other Scandinavian countries, first with 70 km/h and then with 50 km/h speed limit, Al-Mudhaffar (2006).

According to this author, LHOVRA stands for:

Table 2. LHOVRA technique definition. [Source: Al-Mudhaffar, 2006].

Acronym	Swedish name	English translation
L	Lastbil prioritering	Truck, bus priority
H	Huvudväg prioritering	Main road priority
O	Olycka reduktion funktion	Incident reduction
V	Variabel tid	Variable amber time
R	Rödkörning kontroll	Red driving control
A	Allrödvänding	All red turning

To implement this technique, it is assumed that several data and characteristics of the traffic flow from different approaches to an intersection are known. Owing to this, several detectors are required, as explained before, that will be located according to which function they might inform to. The following Figure 16 represents the average location of the detectors in a 70 km/h intersection approach.

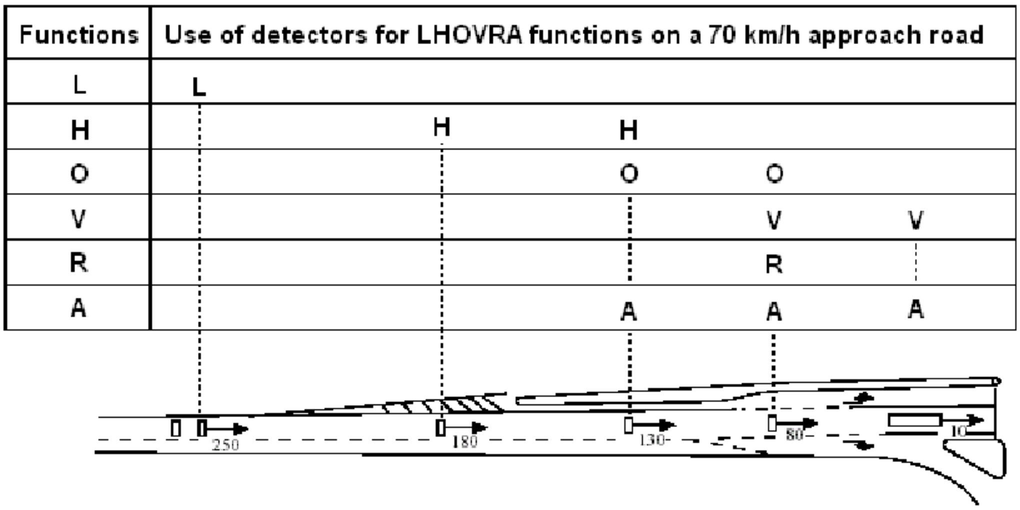

Figure 16. Use of different detectors when implementing the LHOVRA technique. [Source: Al-Mudhaffar (2006)].

L function

Used when truck priority is desired on a primary road. Due to its long distance installation from the intersection, high costs are expected, Al-Mudhaffar (2006).

H function

Function used in major and primary roads where priority is necessary. It takes primary roads as priority ones. Specific safety aspects are not considered within this function, Al-Mudhaffar (2006).

O function

This function is the one that should be used normally. The difficult part of this function is to determine the dilemma zone. This means that O function should permit the last extending vehicle to pass through the dilemma zone in a safe way before the traffic light changes from green to red, Al-Mudhaffar (2006).

V function

This function reduces the considerable delays that exist when the traffic light switches from green to red. In case of no coming vehicles, the amber time is shortened, Al-Mudhaffar (2006).

R function

This function should be used in combination with O one. If not, a risky situation comes up. As a result, R function allows some vehicles to pass through an intersection when the traffic light shows red with just minimum chances of collision. In any case can this function decrease the number of vehicles driving through red, Al-Mudhaffar (2006).

A function

The aim of this function is to reduce as much as possible the number of green-amber-red-green cycles and if they occur, ensure that the vehicle is far enough from the approaching area. The purpose is to diminish unnecessary changes that can disrupt the smooth driving, Al-Mudhaffar (2006).

2.6 Traffic simulation

Traffic simulation is a model building widely spread for planning, designing and a useful tool for decision makers. It is also becoming a major instrument within the Intelligent Transport Systems (ITS). In addition, the simulation of models allows proper dealing with variable traffic.

Researchers think that it is a useful tool to get a closer and a better understanding of different traffic phenomena as well as a good opportunity to conduct virtual alternatives and know in advance if they would be helpful or not, Barceló (2010).

According to Barceló (2010), different kinds of typical complex traffic situations can be visualized with high level of detail.

As a particular example, "VISSIM is a microscopic, time step and behaviour-based simulation model developed to model urban traffic and public transport operations and flows of pedestrians", PTV (2011).

2.6.1 Performance measures

Performance measures are parameters used to evaluate the effectiveness of a designed road or, in particular, an intersection. A comparison between different alternatives is another important feature that serves engineers to make a decision in what to choose among several options.

On the other hand, other qualitative parameters such as public feedback can also be valid when planning. Notwithstanding, as it is shown in Chapter 4, in this project the performance measures extracted from the VISSIM program are: travel times, delays and queue lengths. Some reasons are exposed below:

- Travel time: Real time needed for vehicles to cross two predetermined sections, the origin and the destination, PTV (2011).

- Delay: Extra or additional time that is experienced by the driver when passing through a section of a road. In fact, the travel time delay (D_3) is obtained by subtracting the desired time (T_a) to the travel time (T_b), see Figure 17.

- Queue length: It is the distance, measured in meters, of motorized traffic with null or really low speed (<5Km/h set in VISSIM) waiting to be served. The flow rate of the front of the queue determines the average speed of it. To achieve this measurement, queue counters must be used in VISSIM. They provide the average and maximum queue length, PTV (2011).

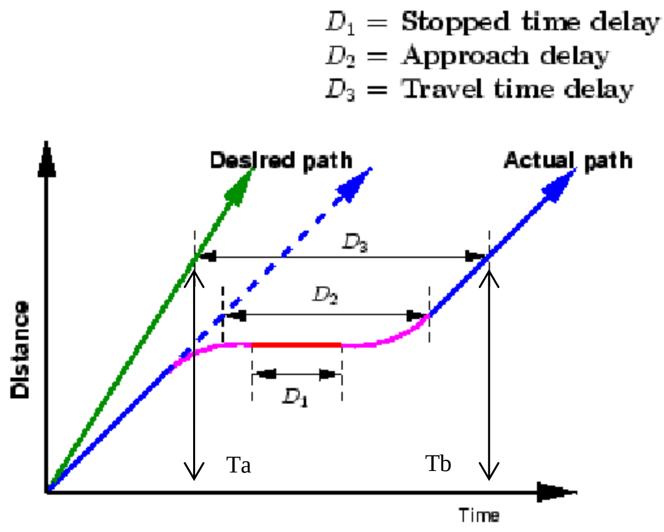

Figure 17. Different delays appreciated when crossing two sections. [Source: Ali and Mirza (2012)].

These three parameters can be measured with VISSIM whether they are selected before running the simulation. As a result, several files are generated by the software and will be commented in detail in Chapter 4.

2.6.2 Driving behaviour

According to the user manual of VISSIM, VISSIM uses a psycho-physical driver behaviour model developed by Wiedemann in 1974. The basic concept of this model is that a faster vehicle will decelerate as it reaches its individual perception threshold when approaching to a slower vehicle. After that, since the vehicle that brakes cannot determine the exact speed of the preceding vehicle, its speed will drop to a lower value until it starts to accelerate again after reaching another perception threshold. As a result, an iterative process of acceleration and deceleration takes place.

In addition, the Wiedemann approach states that a driver can be in one of the following four driving modes:

1. Free driving: The driver tries to keep the desired speed although some oscillations will appear due to imperfect throttle control.

2. Approaching: The driver applies a deceleration in order to obtain the same speed as the previous vehicle within a desired safety distance.

3. Following: The driver follows the preceding vehicle. He keeps the desired safety distance quite constant but with some oscillations. The speed differences vary around zero.

4. Braking: The driver applies from medium to high deceleration rates if the distance is much smaller than the desired one. This situation can happen when the preceding car brakes abruptly, change its speed suddenly or a third vehicle changes the lane in front of the observed vehicle.

A tricky point of the proposed solution is that there will not be traffic lights governing the traffic flow. Therefore, the drivers´ criteria when facing the roundabouts will become an important part of the modelling process. In this way, 3.5 seconds are set as the minimum gap acceptance required to enter a roundabout.

In addition to this, the parameters that affect how the drivers will react against different situations are the speed, the speed difference, the distance and the individual characteristics of each driver and vehicle.

3 Methodology

This chapter focuses in the followed procedure to achieve the goal of this master thesis, which is to evaluate the improvement of Kungsmässan´s accessibility with a proposed solution made by Norconsult AB.

It includes a site description, how the data collection was picked up on site, the estimated traffic prognoses made, the usage of VISSIM 5.40 software, how the models were conducted step by step, the data set into VISSIM both for motorized vehicles and for pedestrians, the manner of inserting 3D objects into the models, the evaluation files utilized as outputs, and the simulation of these models itself.

Nevertheless, a generic VISSIM scenario will be introduced briefly to show the reader how he or she can model their particular cases from the very beginning.

3.1 Generic VISSIM scenario

Let´s define a tensor $T_{i,j,k,l,m,n,o,p}$ where the subscripts represent:

- i: Driving behaviour. 1 = Urban, 2 = Right-side rule, 3 = Freeway, 4 = Footpath, 5 = Cycle-Track.
- j: Simulation period (in minutes).
- k: Number of vehicles in the system during the simulation period.
- l: Number of routes.
- m: Number of lanes.
- n: Traffic lights or not. 0 = no, 1 = yes.
- o: Number of PT stops.
- p: Number of PT lines.

Although this tensor can define many different cases, the reality possesses much more details that are extremely difficult to model. VISSIM can handle quite a lot of small details that each user might know meticulously. As an example, a part of these 7 subscripts defined, one could also think about if there are any desired speed decisions, reduced speed areas, priority rules or conflict areas that need to be introduced in the model.

An important aspect when modelling the traffic is that one can do the well-known trial error process. Thus, changing minor features of the model and see if the new one is closer to the reality than the former one.

As a result, a complex situation takes part in this modelling process where the personal perception and the knowledge of the area to be modelled are an important role of “the game”.

The particular cases of this report include two scenarios: the current situation (CS) and the proposed solution of Norconsult AB (PS).

The first one (CS) has the following properties:

- i = 1
- j = 60
- k = 1312, 2624, 3500 (for T1, T2 and T3 traffic volumes respectively)
- l = 6
- m = 1
- n = 1
- o = 2
- p = 2

The latter one (PS) has the following properties:

- i = 1
- j = 60
- k = 1312, 2624, 3500 (for T1, T2 and T3 traffic volumes respectively)
- l = 14
- m = 2
- n = 0
- o = 2
- p = 2

The outputs of the simulation will depend on the travel time sections and the queue counters defined beforehand.

3.2 Site description

In this section of the report, the Current Situation and the Proposed Solution will be introduced more in detail.

3.2.1 Current situation

As it has been explained in Section 1.2, the case study has been performed in Kungsmässan, Kungsbacka municipality. Traffic simulation of Varlavägen and Varlagård roads using VISSIM software is the tool used to describe the current situation. These roads permit the access to the shopping centre with private transport. However, public transport such as buses and trains are also able to stop nearby the area, see Figure 18.

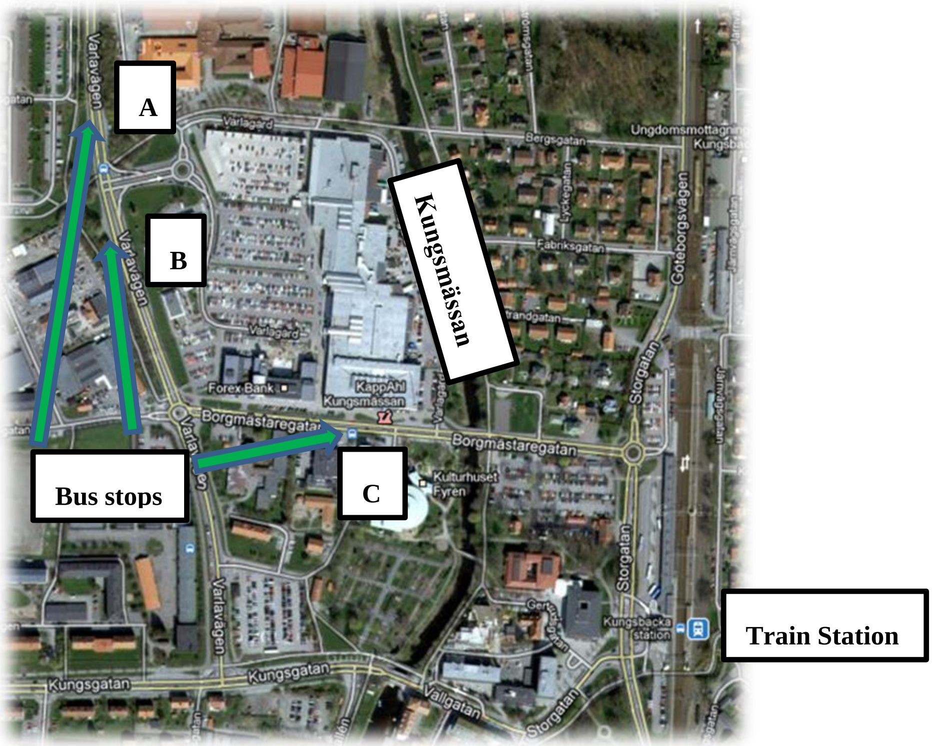

Figure 18. Location of different PT stops nearby Kungsmässan. [Source: Google Maps (2012)].

Figures 19, 20 and 21 illustrate in detail these PT stops. All the PT stops have their own lane. Therefore, less congestion and stopped vehicles behind the buses will occur when they are picking or alighting people. In the proposed solution, this characteristic will still be fulfilled. Figure 22 shows Kungsbacka´s train station.

Figure 19*. Lindälvsskolan east bus stop (A).* [Source: Street View (2012)].

Figure 20. Kungsbacka Lindälvsskola bus stop (B). [Source: Street View (2012)].

Figure 21. *Kungsbacka Kungsmässan bus stop (C).* [Source: Street View (2012)].

Figure 22. *Kungsbacka station, train station.* [Source: Street View (2012)].

The different directions/options that the vehicles have when approaching the intersection can be checked in the next Figure 23 taken out from the VISSIM´s model of the Current Situation, which are represented with numbers going from 1 to 6. The green and red bars represent the traffic lights.

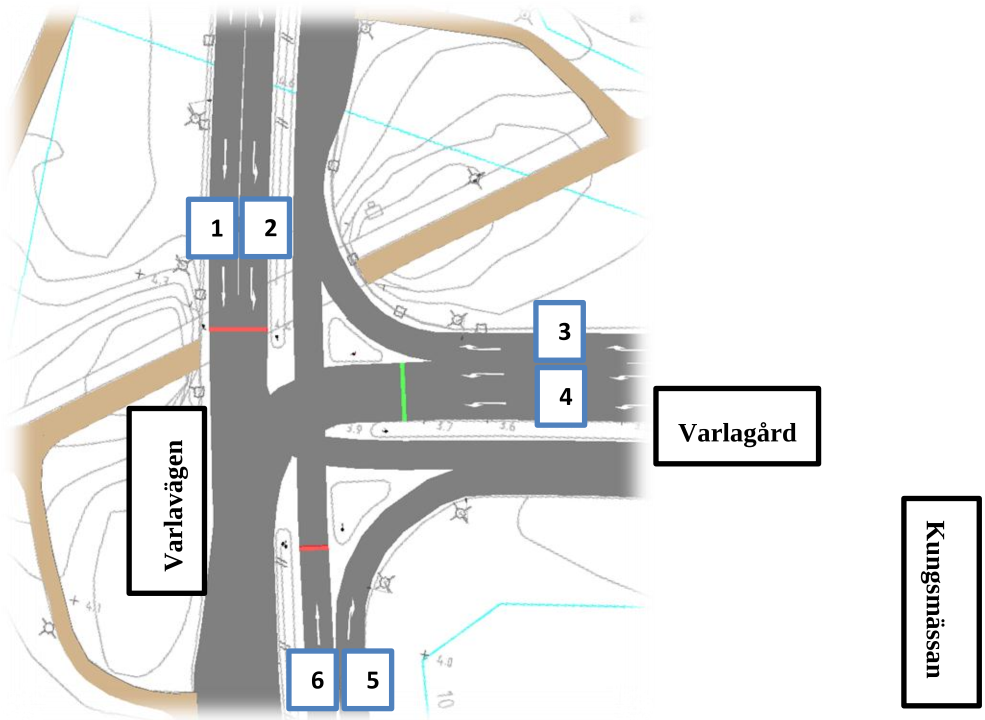

Figure 23. *Six direction alternatives for the vehicles when approaching the T intersection in the current situation model.* [Source: VISSIM 5.40 (2011)].

The pedestrian area, which a part of it is marked in brown above, does not differentiate between walking areas and bicycle paths. This means that bicyclists cannot go as fast as they would like because any pedestrian can stand by in their way abruptly. In other words, they have to be aware of sudden movements induced by the pedestrians. This fact is improved in the Proposed Solution by adding a special lane for bicyclists at some strategic points of the network and will be commented afterwards in Section 3.2.2.

Nowadays, the area does not present a huge amount of traffic. According to GF Konsult AB (2007), the former name of Norconsult AB, the amount of traffic in both directions is set to be between 12,900 and 19,900 vehicles/weekday approximately.

However, a prognosis carried out in the area shows that these values will be easily increased by 20% of this current situation, GF Konsult AB (2007). This magnification of traffic will be mainly produced by an increase of population in the surrounding area, showed in Section 1.2. The number of vehicles per weekday of Varlavägen north and south for both periods of time is shown in Table 3. The notation north and south is just done in order to differentiate when the road is either on the northern or the southern part of the T intersection. Unfortunately, there is no data from Varlagård. However, it was counted on site by the researcher and added into the VISSIM´s model.

Table 3. Amount of traffic in Varlavägen road access to Kungsmässan shopping centre and their respective increase. [Source: GF Konsult AB (2007)].

	Now (2012) [veh/weekday]	Prognosis (2020) [veh/weekday]	Increase (%)
Varlavägen North	12,930	19,140	48
Varlavägen South	19,940	23,970	20

According to the literature review in Section 2.3, at around 10% of the 24-hour traffic volume (ADT) corresponds to the peak hour traffic (PHT) of the day, see Equation 4.

$$PHT = 0.1 \cdot ADT \qquad (4)$$

Where:

PHT = Peak Hour Traffic (veh/hour)

ADT = Average Daily Traffic in weekdays (veh/hour)

This formula is used to compare the data collected with the data provided by GF Konsult AB (2007) to see if the values gathered on site are not so far from the reality ones.

3.2.2 Proposed solution

There is only information on paper for the proposed solution to be implemented in the near future but one can have a close idea of what will be the situation, see Figure 5 again.

In this case, the road users have two possible entries to reach the several parking lots that will be available for them. This aspect is of a great importance since they will be able to choose between these two entries in order to minimize their total waiting time in the system depending on the congestion at every moment. This will also happen when leaving the area. On the contrary, it is quite difficult to model this type of behaviour and it will not be carried out in this report as it is discussed in Chapter 5.

Turning to the non-motorize area, a bicycle path will be distinguished from the pedestrian area as shown in red in Figure 24 below.

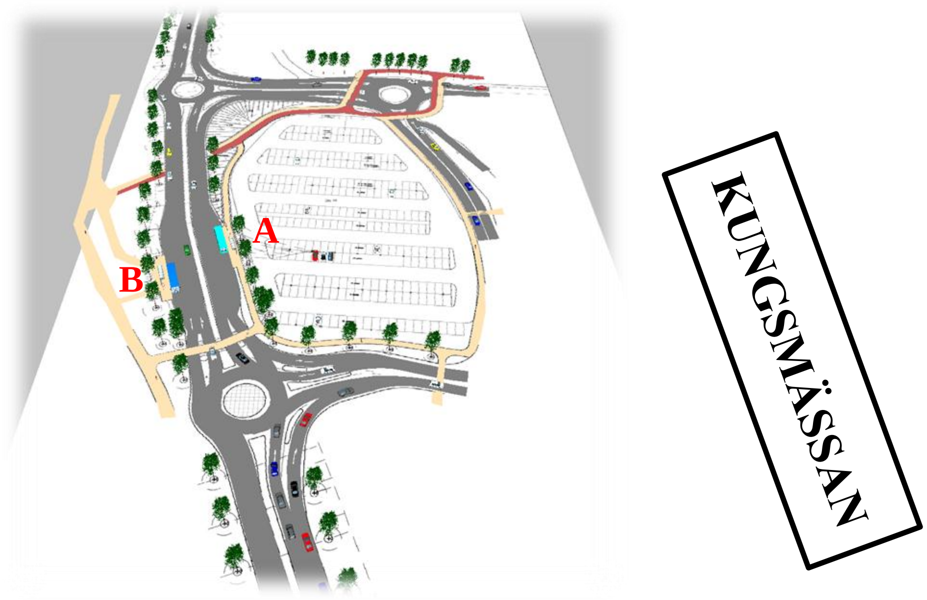

Figure 24. Different paths for pedestrians (brown) and bicyclists (red). [Source: VISSIM 5.40 (2011)].

From the Figure 24 above, it can also be depicted the two PT stops (A and B) serving the area, one in front of the other one. There will be the same lines of buses with the same frequency of a bus every 15 minutes during peak hours, Västtrafik (2012). The aerial view is smaller than the current situation one and for that reason, the PT stop, called Kungsbacka Kungsmässan (C), and the train station are not included but they will remain there too.

Another differential feature between the two models is that in this Proposed Solution, the drivers have plenty of alternatives to reach their destination. Furthermore, they must decide for themselves when to enter the several roundabouts that they will face. Consequently, their attention should be kept during the whole time while in the current scenario, the drivers can disconnect a bit when the traffic light shows red.

3.3 Data collection

The site has been visited several times during the thesis to obtain data. The different parameters gathered are explained in the following sections.

3.3.1 Manual counting to model the current situation

Manual counting has been performed to measure vehicle inputs during the considered peak hours, in this case on Tuesday 24th April and on Monday 7th May 2012 from 16:00h to 17:30h.

The procedure was the following:

- The six possible directions were divided into two groups of three each.

- A group of three paths were assigned to one person whereas the other one to another person to count the number of vehicles flowing through them separately.

- Eight intervals of 15 min each were conducted.

- The maximum value of the conducted intervals was considered as the demand in vehicles per hour after multiplying it by 4 to get the data in a block of an hour.

The data collected is summarized in the following Tables 4, 5 and 6.

Table 4. *First data collection of traffic volumes according to their direction.* [Own source (24th April 2012)].

Time	Directions, Traffic volumes [veh]					
	1	2	3	4	5	6
16:00-16:15	110	73	65	85	84	113
16:15-16:30	130	84	97	91	85	116
16:30-16:45	129	74	75	101	89	81
16:45-17:00	95	90	68	70	81	95
17:00-17:15	95	88	81	98	68	74
17:15-17:30	92	68	77	96	94	77

During the second day just one person could count the traffic. For this reason, half of the table is empty.

Table 5. Second data collection of the traffic volumes according to their direction. [Own source (7th May 2012)].

Time	Directions, Traffic volumes [veh]					
	1	2	3	4	5	6
16:00-16:15	-	-	-	100	78	119
16:15-16:30	117	86	87	-	-	-
16:30-16:45	-	-	-	126	90	92
16:45-17:00	100	83	78	-	-	-
17:00-17:15	-	-	-	114	81	79
17:15-17:30	94	79	71	-	-	-

As it is showed above, the marked cells have been considered the design values of this thesis as they are the maximum traffic volumes registered. Moreover, by using these values one will be quite sure to be designing in a safe side because just in very rare cases, the situation will be worse than the modelled one. In other words, only a few hours per year larger amount of traffic and queues will occur.

Regarding the traffic lights of the T intersection, it was noticed that they use the LHOVRA-technique stated in Section 2.5.1. The duration of the different traffic lights is presented in Table 6 below. The numeration of them corresponds to the direction of the traffic flow defined in the T intersection in Figure 23.

Table 6. Data collection of the traffic lights to model the current situation. [Own source (7th May 2012)].

# Traffic light according to their directions											
1			**2**			**4**			**6**		
G	A	R	G	A	R	G	A	R	G	A	R
						18	3	53			
47	3	24	20	3	51						
									22	3	49

These values are in seconds and are considered as the median ones, since in every cycle they were varying according to the traffic demand of each moment. Figure 25 clarifies how the traffic lights interact with each other.

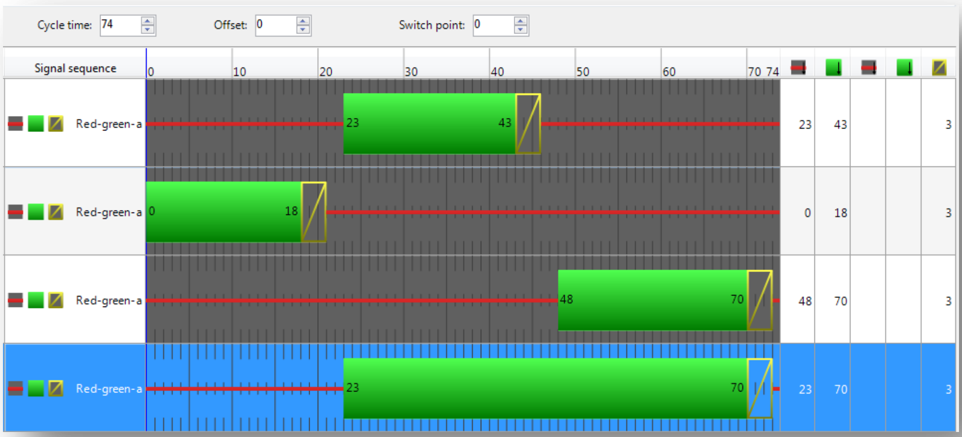

Figure 25. Cycle of the traffic lights that control the T intersection in the current situation. [Source: VISSIM 5.40 (2011)].

As it can be seen in Figure 25 above, the rows correspond to the traffic lights number 2, 4, 6 and 1 from up to down respectively. In addition, after the green times, three seconds of amber are set, being this value between the range of amber time allowed in Sweden mentioned in Section 2.4.2. After those three seconds, other two are introduced as red for every traffic light that shares common areas of vehicle interaction. It is done for safety reasons to keep the clearance zone sought by the A function of the LHOVRA technique. Finally, the last second of the cycle is also set as red for all the traffic lights with the same purpose.

It should be pointed out again that the traffic lights have fixed times in the model. In reality, they are programmed according to the LHOVRA-technique, meaning that the capacity of the real system will be higher than the one presented in the model.

3.3.2 AutoCAD files provided by Norconsult AB

To be able to perform both models in VISSIM, AutoCAD files from the site provided by Norconsult AB were used as background. As a result, after scaling the imported files, the road´s length, width and other characteristics could be drawn directly with VISSIM without any need of measuring them at each step of the process.

The AutoCAD files can be checked in Appendixes 1 and 2.

3.4 Traffic prognoses

According to Tables 4 and 5 presented before, the traffic flows corresponding to a peak hour are shown in Figure 26 below. Each direction has its own values, the current and the future traffic. The red numbers represents the increase adopted according to “Trafikledsplan för Kungsbacka stad”, GF Konsult AB (2007).

All the calculations are made in the Current Situation scenario, which will be extrapolated to the Proposed Solution afterwards.

The following Figure illustrates both the current traffic and the future traffic set in the VISSIM´s models.

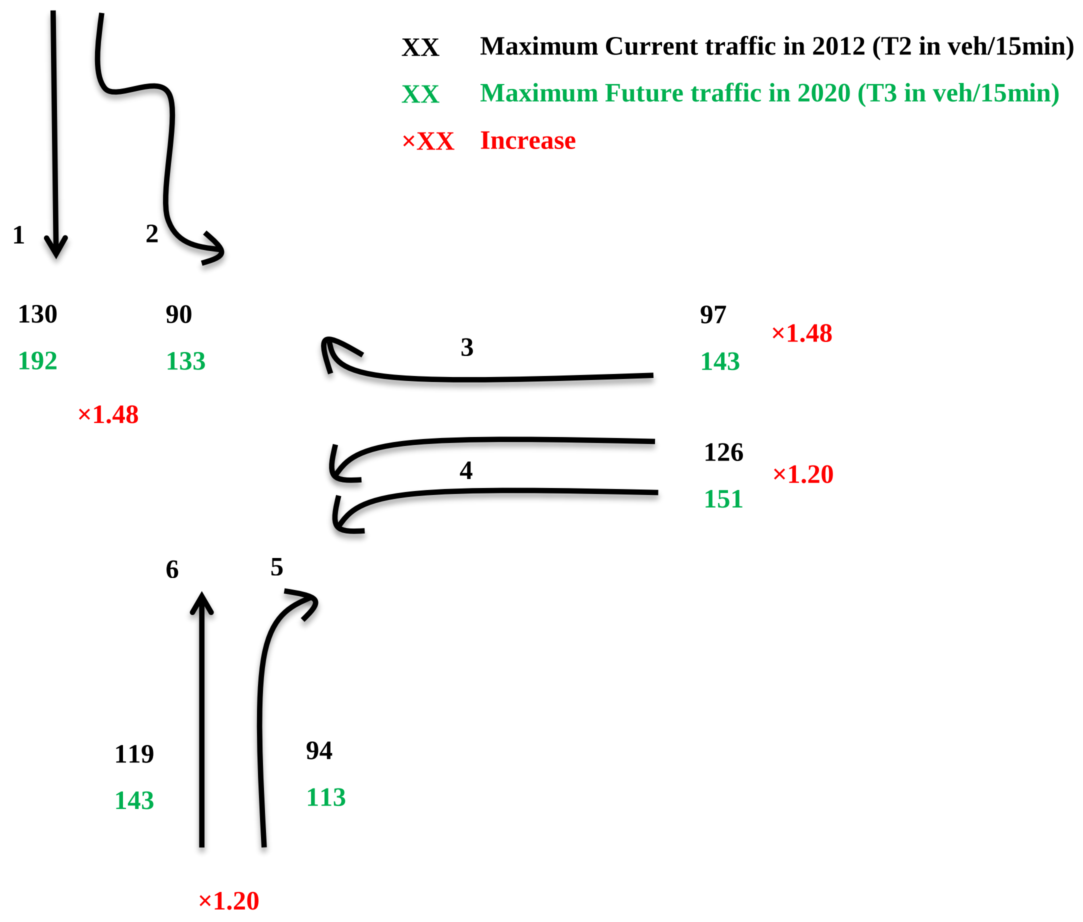

Figure 26. Current and future traffic volumes using the current network. [Own source].

The numbers 1 to 6 are the direction alternatives when reaching the T intersection in the nowadays network.

From the Figure above, it is possible to calculate which traffic volume should be inserted in VISSIM. Calculations for the maximum current traffic in 2012 (T2) are the followings, see Equations 5 to 7:

$$Direction_{1+2} = (130+90)\times 4 = 880\,\frac{veh}{hour} \tag{5}$$

$$Direction_{3+4} = (97+126)\times 4 = 892\,\frac{veh}{hour} \tag{6}$$

$$Direction_{5+6} = (94+119)\times 4 = 852\,\frac{veh}{hour} \tag{7}$$

Calculations for the maximum future traffic in 2020 (T3) are the followings, see Equations 8 to 10:

$$Direction_{1+2} = (192+133)\times 4 = 1300\,\frac{veh}{hour} \tag{8}$$

$$Direction_{3+4} = (143+151)\times 4 = 1176\,\frac{veh}{hour} \tag{9}$$

$$Direction_{5+6} = (113+143)\times 4 = 1024\,\frac{veh}{hour} \tag{10}$$

It should be pointed out already that the extrapolation of the future scenario is done by inserting the vehicle inputs calculated here in certain links of the new model. In other words, what it is considered in this project is that the future traffic demand will enter the system through the same links as in the current situation, see Appendix 4.

In Chapter 4, three traffic volumes will be used to make a comparison and see the diversity of results that both models present. Owing to this, half of the maximum current traffic flow, the maximum current traffic flow itself and the calculated maximum traffic flow for the future scenario will be modelled and commented, noted as T1, T2 and T3 respectively.

3.5 Model construction

For completing the present thesis, VISSIM software was used as it is a very helpful software for extracting characteristics of a traffic flow such as travel times, delays and queue lengths produced after passing throw the T intersection in the current situation and the roundabouts in the proposed solution for the future scenario.

In addition, VISSIM can model urban traffic and pedestrian flows, although the latter one is not that important in this report. Therefore, this thesis is suitable to quantify motorized transportation and to compare how the changes of traffic flow affect the output parameters stated.

In the next figure the desktop window of VISSIM is illustrated.

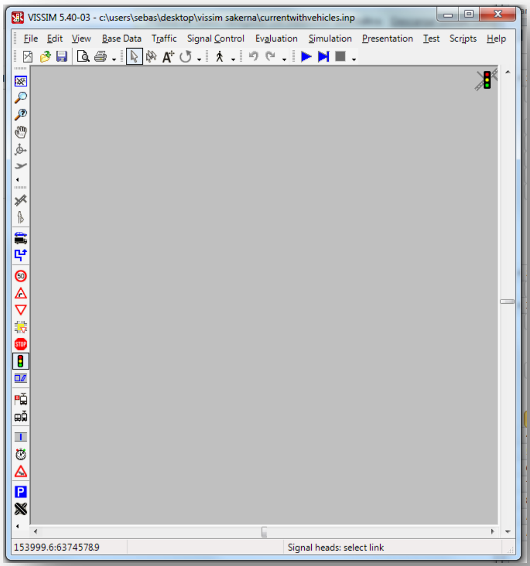

Figure 27. Overview of VISSIM´s desktop window and tools needed for constructing the model. [Source: VISSIM 5.40 (2011)].

First of all the AutoCAD files were imported into VISSIM 5.40. Next, the files were scaled accordingly to be used as background for the road network. Then, two models were conducted, one representing the current scenario and another one representing the proposed solution of Norconsult AB. After that, links & connectors, vehicle inputs, routes, pavement makers, PT stops, PT lines, priority rules, conflict areas, desired speed decisions, reduced speed areas, signal controllers and pedestrians were introduced in the models and are explained further in the report from Section 3.6 to Section 3.10. Finally, output parameters are exported after simulating the created models.

A remarkable feature of the models that simplifies quite much the work is that the studied area is almost flat except for a runway that is used for pedestrians to cross Varlavägen from underneath. For that reason, the elevation of the entire network was assumed to be constant and at zero level, neglecting the different altitudes between different elements. Although VISSIM has an option, called gradient tool, that can change the acceleration of the vehicles when passing through a specific part of the network with a kind of slope, it has not been used due to its minor impact on the results.

3.6 Input data for motorized vehicles

In the following section, each step to perform the model will be explained in detail.

3.6.1 Links & Connectors

As it is said in Section 3.5, before starting to create links & connectors, the background used needs to be scaled. After that, one can be secure of working with appropriate measures in correlation to the reality.

Links represent the roads where vehicles will flow. Each link can have one or more lanes. Therefore, one have to be sure of how many lanes should be included when creating a link. It is not possible to create a link which has more than one lane and each lane has different widths. In that case, several links must be created.

Connectors are used to connect different links such as in intersections. Another important purpose is to connect a link of one lane to another with more than one.

Figure 28 shows the properties that can be defined when creating a link.

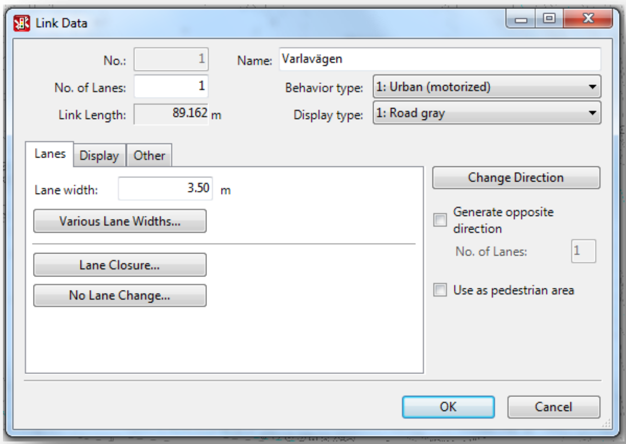

Figure 28. Link properties. [Source: VISSIM 5.40 (2011)].

In this example, a link with one lane called Varlavägen is created. Its width is set to be 3.50 meters. Moreover, no opposite direction is generated and the pedestrians will not be able to use that link as pedestrian area. The behaviour and the display type can also be chosen among different options. In this thesis, urban (motorized) behaviour is preferred due to the location and characteristics of the area of Kungsmässan.

Lane closure is also possible to implement. In this case, all vehicle classes marked will not be given pass to this link. In other words, one can avoid the entrance to certain vehicle types that cannot flow in a link.

Changing to the connectors, they can just be created if two or more links are established before. To have a clear view, Figure 29 shows how they can be modified according to each situation.

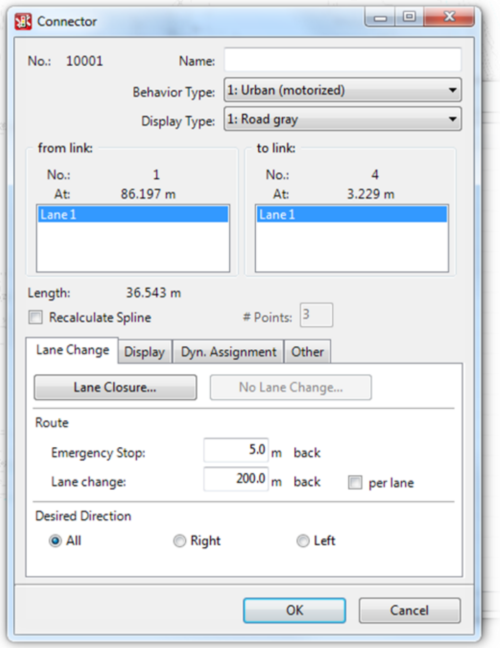

Figure 29. Connector properties. [Source: VISSIM 5.40 (2011)].

In this particular case, the connector is used to join links number 1 and 4. The number of points needed for setting up the spline between these links depends on the required smoothness wanted.

The vehicles will try to change to de desired lane since 200 meters before the connector. If that is not possible, they will do an emergency stop 5 meters upstream of the mentioned connector.

3.6.2 Vehicle inputs

This function represents the traffic volumes (vehicles per hour) that would be used in the models. In Section 3.4 it was explained that three different traffic volumes will be studied to compare their results. The six figures, three for each model, can be checked in Appendix 4.

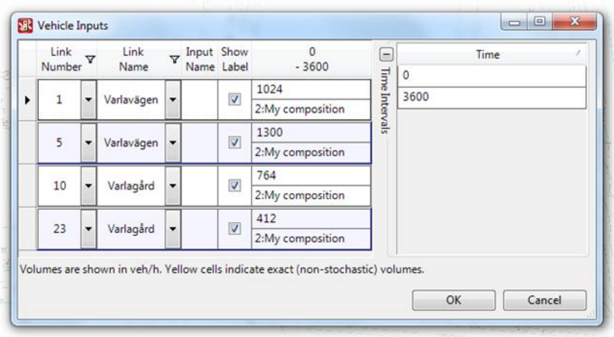

Figure 30. Vehicle inputs for modelling the current situation. [Source: VISSIM 5.40 (2011)].

In the Figure 30 above, 4 links are selected to introduce the vehicle inputs during the period of time that appears on the right hand side, in this case 3600 seconds simulation. It should be noted that this hour can be divided in different intervals if different demands of traffic volumes take place. In this thesis, one type of demand is considered during the entire time interval with the maximum traffic volume calculated in Section 3.4.

The label "2:My composition" means that a vehicle composition named "My composition" is used instead of the default one of the program. To create a new vehicle composition, three steps need to be followed:

1. Add a vehicle type
2. Add a vehicle class
3. Add a vehicle composition

A new vehicle composition was then created in order to add more types of vehicles such as motorbikes and special cars (the fastest ones). However, these vehicle classes have a low share of the vehicle composition as in reality they seldom appear in the network.

3.6.3 Routes

Every vehicle that is in the network will follow different links and connectors according to the route decision applied for it.

During the simulation process, each vehicle that passes a routing decision point (red bar in the program) is assigned a specific route unless it has already assigned one previously. This means that when the vehicles cross a red bar, they will follow their route until they arrive to the end point of the assigned route (green bar in the program). This type of routes is defined as static routes, see Figure 31.

Figure 31. Different static route decisions when passing the red bar in the lower part. [Source: VISSIM 5.40 (2011)].

The route decisions going to the right and straight ahead, marked in yellow, have 22% and 55% share of the total traffic volume respectively that crosses the decision point in the lower part. On the next figure, it can be seen the different shares in the last column governing the decision number 1.

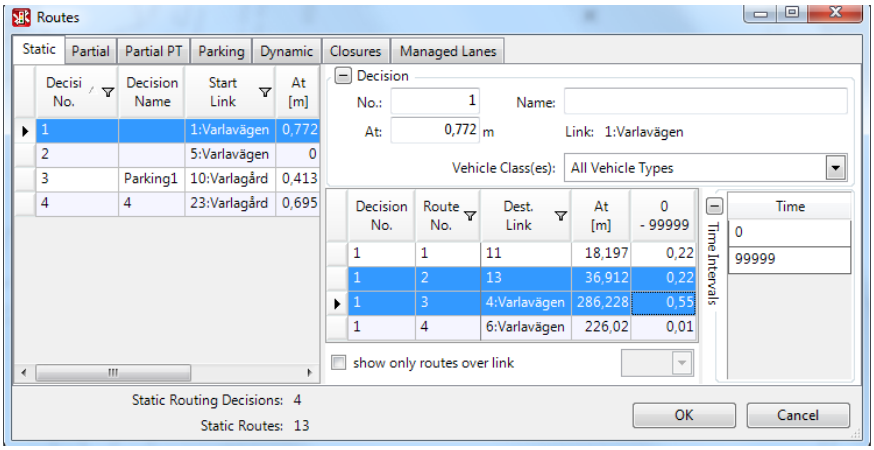

Figure 32. Different features of static routes. [Source: VISSIM 5.40 (2011)].

3.6.4 Pavement markers

Despite the fact that pavement markers do not affect the behaviour of the vehicles, this option allow the viewer to see which directions should have and will have the users of the road. They are in fact just 3D objects to be seen during the simulation, see Figure 33.

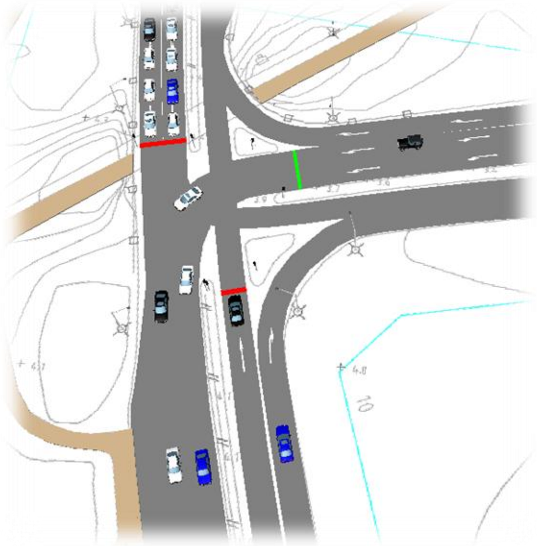

Figure 33. Several pavement makers in the current situation model. [Source: VISSIM 5.40 (2011)].

3.6.5 Public Transport

Public transport is defined separately in VISSIM from all the other traffic. To accomplish the PT network, two steps are required to import data on it:

1. Create PT stops
2. Create PT lines, including routes, served stops, PT vehicles and their schedule

PT stops

PT stops can either be defined as street stops or as lay-by stops. In the first ones, the PT stops in the same lane from where they come whereas the latter ones are located in a specific link next to the lane. Thus, in this case the traffic flow is not interrupted when passengers are boarding or getting off from it since the other vehicles have at least a lane to keep on going. Such stops are the ones presented in the area of study.

By default, a bus leaving from a lay-by stop will have priority against other vehicles coming behind it. In this thesis this property will not be changed.

Once PT stops are defined, then PT lines can be assigned to these PT stops.

PT lines

PT lines are assigned to PT stops. In addition, a specific route, a PT vehicle and a schedule must be implemented for the PT line as well. For instance, Figure 34 below shows that the created PT line, called PT line north, will appear in the network at second 20 and will have a 900 seconds rate until the end of the simulation. Finally, its occupancy will be of 50 persons per vehicle.

The latter feature is important when selecting the rate of passengers going out from the PT.

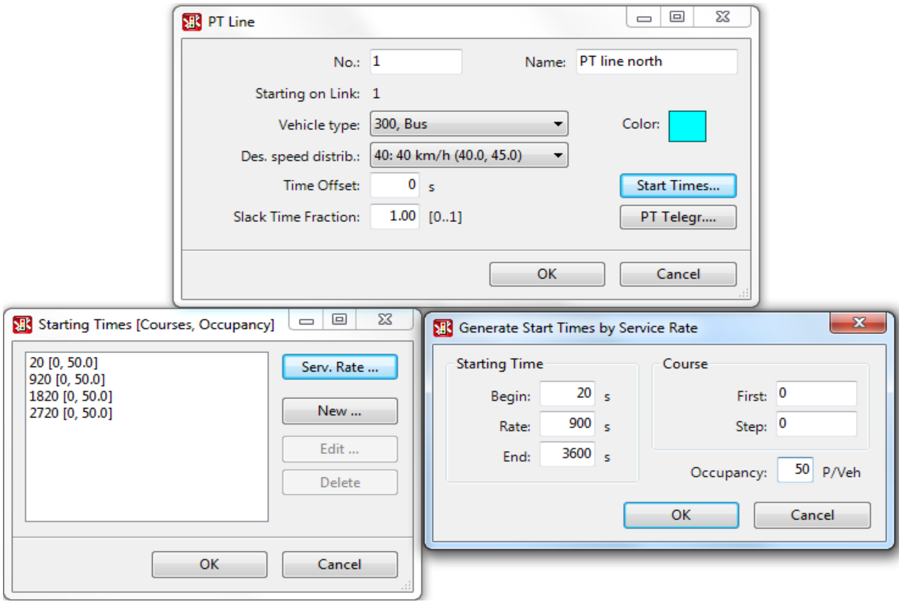

Figure 34. Data of a PT line defined in the proposed solution of Norconsult AB. [Source: VISSIM 5.40 (2011)].

3.6.6 Giving priority

In any place where two different roads share space, the users should know who has right of way and who should give priority to the other user.

In VISSIM, the priority rules and conflict areas functions are the ones in charge with this fact.

Priority rules

Priority rules are useful when the area to be modelled has non-signalized intersections.

On one hand, the current situation has traffic lights in the T intersection but not the roundabout located at Varlagård. On the other hand, the proposed solution for the future scenario has no traffic lights at any intersection.

Therefore, some priority rules would be helpful to avoid vehicles to block some lanes in case of an extremely high traffic volume.

To define a priority rule, a minimum headway and a minimum gap time are required. The first one defines the length of the conflict area. During the simulation, the headway is determined between the conflict maker (green bar) and the first vehicle approaching it. Whenever the current headway is less than the minimum headway, the corresponding stop line (red bar) will prevent any approaching vehicle to enter this area as a red traffic light was. Figure 35 below clarifies what is intended to be explained.

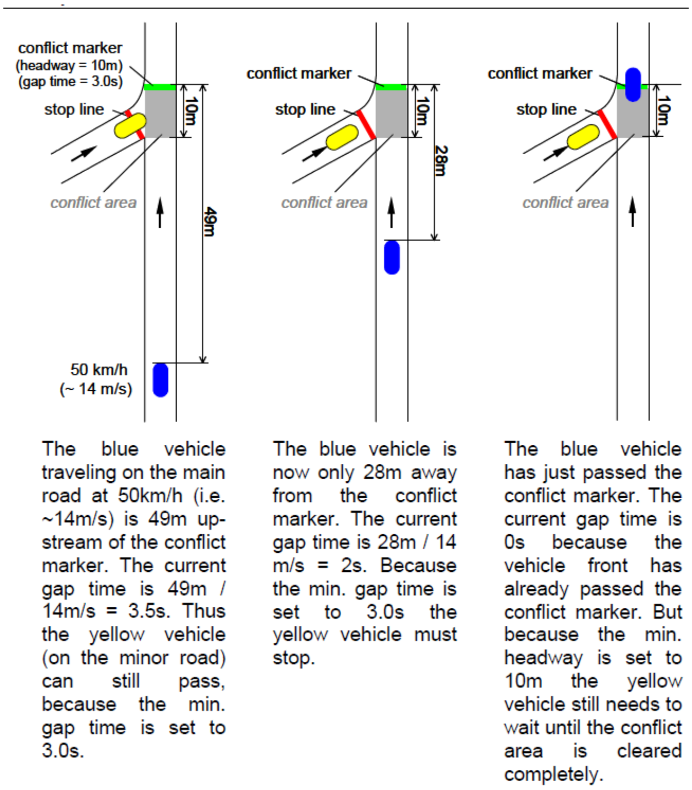

Figure 35. Procedure when a priority rule is implemented in a non-signalized intersection. [Source: PTV (2011)].

In the VISSIM model performed, just in few cases priority rules are preferred rather than conflict areas. Figure 36 display some examples in both the current scenario and the proposed solution. The lighter paths represent pedestrian areas. On the left, the roundabout is in Varlagård and on the right the roundabout is the first one coming from the south.

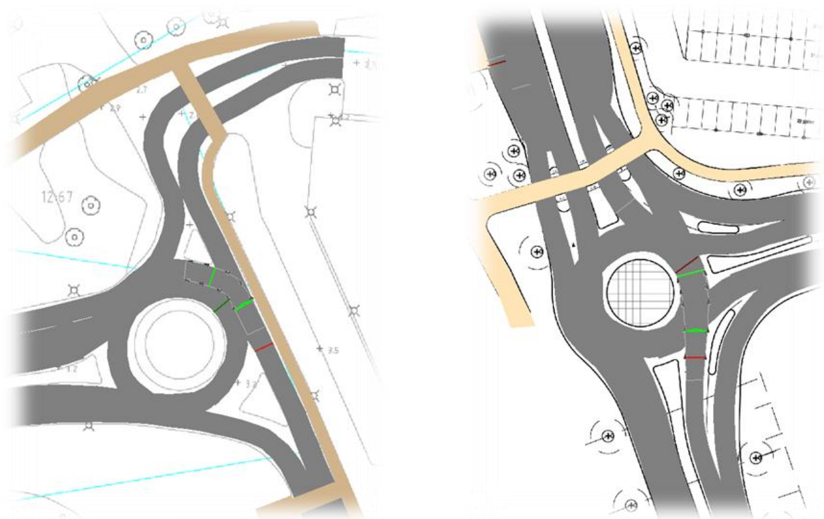

Figure 36. Two examples of implemented priority rules in the current situation and the proposed solution models. [Source: VISSIM 5.40 (2011)].

Conflict areas

Conflict areas are the most used option to model priorities between vehicles. According to the user manual of VISSIM, they can be modelled more easily and the resulting vehicle behaviour seems to be more in accordance to what happen within the roads. For that reason, conflict areas are an appropriate solution in most cases.

Conflict areas are and can set wherever two or more links/connectors overlap. There are 3 ways of constructing a conflict area.

1. Yellow/yellow: Passive behaviour. No vehicle has preference from another; they will overlap in the simulation if it is not changed (unrealistic).

2. Green/red: Priority/yield behaviour. The vehicle approaching from the green link/connector has right way against the other approaching from the red one.

3. Red/red: Yield/yield behaviour. Each vehicle will yield the way to other vehicles whether they are already inside the conflict area. Similar to the first come first served rule (FCFS).

The most typical situations containing conflict areas are: crossing, merging and branching conflicts. In particular, the two modelled situations contain mainly crossing conflicts in roundabouts.

In the Figure below, several conflict areas are modelled in a roundabout where the most colourful ones show that the green area has preference against the red one.

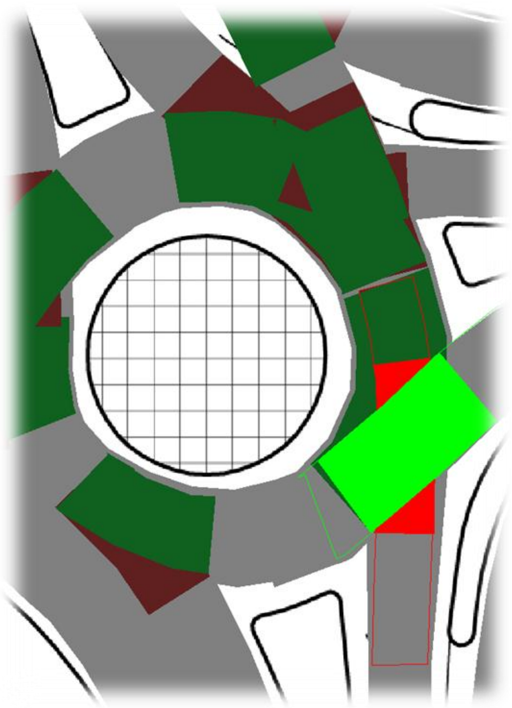

Figure 37. Conflict areas modelled in VISSIM´s model. [Source: VISSIM 5.40 (2011)].

3.6.7 Desired speed changes

Wherever the free flow speed is changed, an alteration of the vehicles´ speed distribution may be done.

In VISSIM, this can be achieved by two different options:

1. Desired speed decisions (permanent change).

2. Reduced speed areas (temporary change).

The main difference between them is that in the first one, vehicles will change their velocity when passing the decision cross section whereas in the latter one, vehicles will automatically adjust their velocity prior to the beginning of the reduced speed area.

In both cases, the purpose is to modify vehicles´ velocity due to curves of small radius, a presence of a zebra crossing, etc.

Desired speed decisions

By using this option, permanent changes will occur in the model. This means that whatever vehicle crossing this type of signal will have to follow a desired speed limit until further notice.

In both models, desired speed decisions are set at the beginning of the routes, analogous to an entrance of a village.

The different characteristics that can be selected when designing the desired speed decision are shown below.

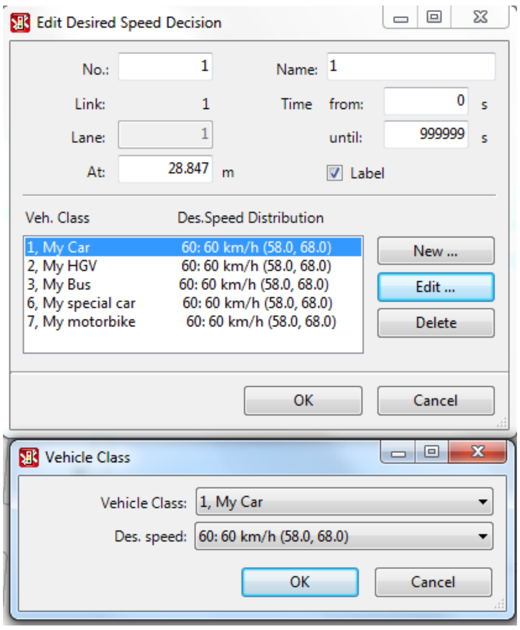

Figure 38. Characteristics when editing desired speed decisions. [Source: VISSIM 5.40 (2011)].

In the Figure above, a desired speed decision is made in Varlavägen for the current scenario. In this case, 60 Km/h (range going from 58 to 68 Km/h) is set for all vehicle classes during the whole time simulation (0-999999 sec). The 28.847 meters depicts the distance from the origin of link number 1.

Reduced speed areas

As it is mentioned before, reduced speed areas are only a temporary change. That is, after having passed the reduced speed area, the vehicles will try to get the free flow speed again. Consequently, they are used basically in turning movements as one can perceive in Figure 39. In the future scenario, these turning movements are mainly located nearby roundabouts.

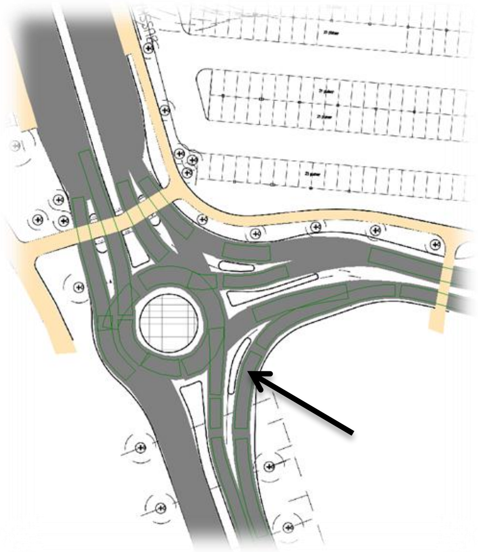

Figure 39. Reduced speed areas in the proposed solution model. [Source: VISSIM 5.40 (2011)].

3.6.8 Signal controller

In the current situation there are several traffic lights that govern the T intersection. For that reason, a signal controller needs to take part in. The signal controller will take care of several signal groups, which are represented by signal heads. In addition, these signal heads are coded in VISSIM for each travel lane, so there will be as many signal heads as number of lanes following the same rule. For instance, signal group 2 has two signal heads, 3 and 4.

Let´s have a look to Figure 40 that shows the numeration of both signal groups and signal heads defined by the researcher.

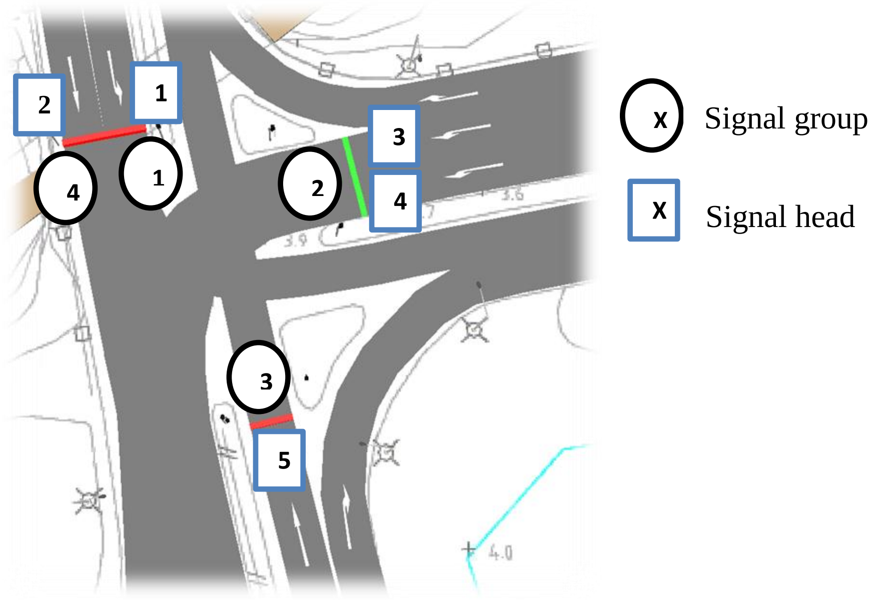

Figure 40. Definition of the different signal heads and signal groups modelled in the current situation. [Source: VISSIM 5.40 (2011)].

Figure 25 from Section 3.3.1 showed how the several traffic lights of the T intersection work and are interrelated between each other.

As a small detail, vehicles will wait 0.5 meters behind a signal head when it displays red. In case they cannot brake before it when amber light is displayed, they will keep on passing the traffic light.

3.7 Input data for pedestrians

This section referring to pedestrians has plenty of differences compared to what has been explained until now.

First of all, it must be clarified that this thesis is not focused in pedestrian simulation. This means that no counting of pedestrians has been carried out. Moreover, some discrepancies might appear relating this point. However, they are included in the models´ simulation due to their obvious interaction with motorized vehicles. As a result, the focused areas of interest will be the zebra crossings and the PT stops since they can affect the traffic flow properties. For example, producing more queues in certain/random moments of the simulation.

According to the VISSIM user manual 2011, the behaviour features of pedestrians modelled with the software is hierarchically organized in three different levels:

1. Strategic level (minutes to hours): Pedestrians plan their route.

2. Tactical level (seconds to minutes): Pedestrians decide their route among some destinations.

3. Operational level (milliseconds to seconds): Their movement itself. Note that this level is occurring during a really short period of time, which was introduced in Section 3.2.1 talking about the care that bicyclists should have with respect to pedestrians in case of sharing the same path.

In this project, three types of pedestrians have been defined: men, women and bicyclists. Naturally, each of these pedestrian classes has their own dimensions, weights, velocities and appearances. Predictably, pedestrians need their pedestrian/walkable area to move through the network, which is achieved with the construction elements function of the program, which will be commented in the next point.

3.7.1 Construction elements

When having the pedestrian mode activated in VISSIM´s desktop window, other functions will appear in it. These are:

- Pedestrian areas made with rectangles or polygons.
- Obstacles.
- Ramps/Stairways/Escalators/Moving walkways (RSEM).

Nevertheless, as the VISSIM license had limited access to some parts of the software, RSEM were not implemented in any model. What is more, the obstacles are defined as parts of the walkable areas where pedestrians cannot go through. For that reason, it was decided to draw nothing where pedestrians could not go through instead of adding a pedestrian area and an obstacle on it. Accordingly, only the pedestrian areas are going to be commented.

Pedestrian areas

As explained before, pedestrian areas are created with rectangles or polygons according to the area that wants to be represented. The latter ones are more common due to the flexibility that they possess.

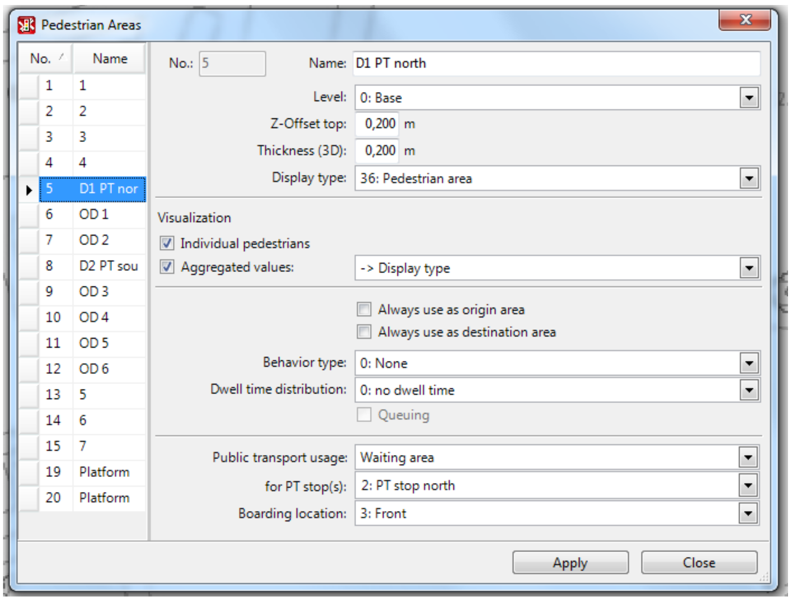

Figure 41. Editing pedestrian areas. [Source: VISSIM 5.40 (2011)].

Having a look in the figure above, many data can be introduced to edit pedestrian areas. The level cannot be changed because of the license limitation; the Z-Offset top represents the position of the pedestrian area in the Z-axis; the display type is just for viewing colour properties when simulating. The most important part is when a waiting area or a platform edge needs to be inserted for public transport usage. In this example a waiting area is defined for PT stop named “north”, referred to the direction of the traffic flow in that stop. Last but not least, the boarding location is set to be on the front part of the vehicle.

3.7.2 Pedestrian inputs

Pedestrian inputs work similar as vehicle inputs do with motorized vehicles, which were explained in Section 3.6.2.

In this case, no specific data of pedestrians has been gathered. Consequently, the values introduced are just a mere approximation according to what has been perceived when visiting the site.

Moreover, the main objective of introducing pedestrians is to see their interaction with the motorized traffic. Therefore, the most important parts of the modelled pedestrians are the zebra crossings and the PT stops. In other words, there is no interest in viewing or knowing where these pedestrians are going or coming from.

In addition to this, the VISSIM license used has a limited number of 100 pedestrians at the same time of the simulation. See the message shown in VISSIM when selecting a big amount of pedestrians to be simulated, see Figure 42.

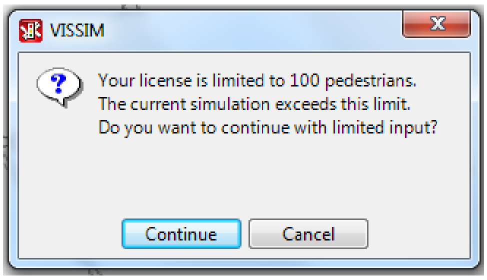

Figure 42. Pedestrians´ limitation when running VISSIM´s simulation. [Source: VISSIM 5.40 (2011)].

Current situation

The data used for the simulation is depicted in Table 7. Note that the origin node corresponds to the red dots marked in Figure 43 further below:

Table 7. Pedestrian inputs when simulating the Current Situation. [Own source].

Origin node	0-3600 simulated seconds [pedestrians per hour]
1	10
2	10
3	10
4	10
5	10
6	10

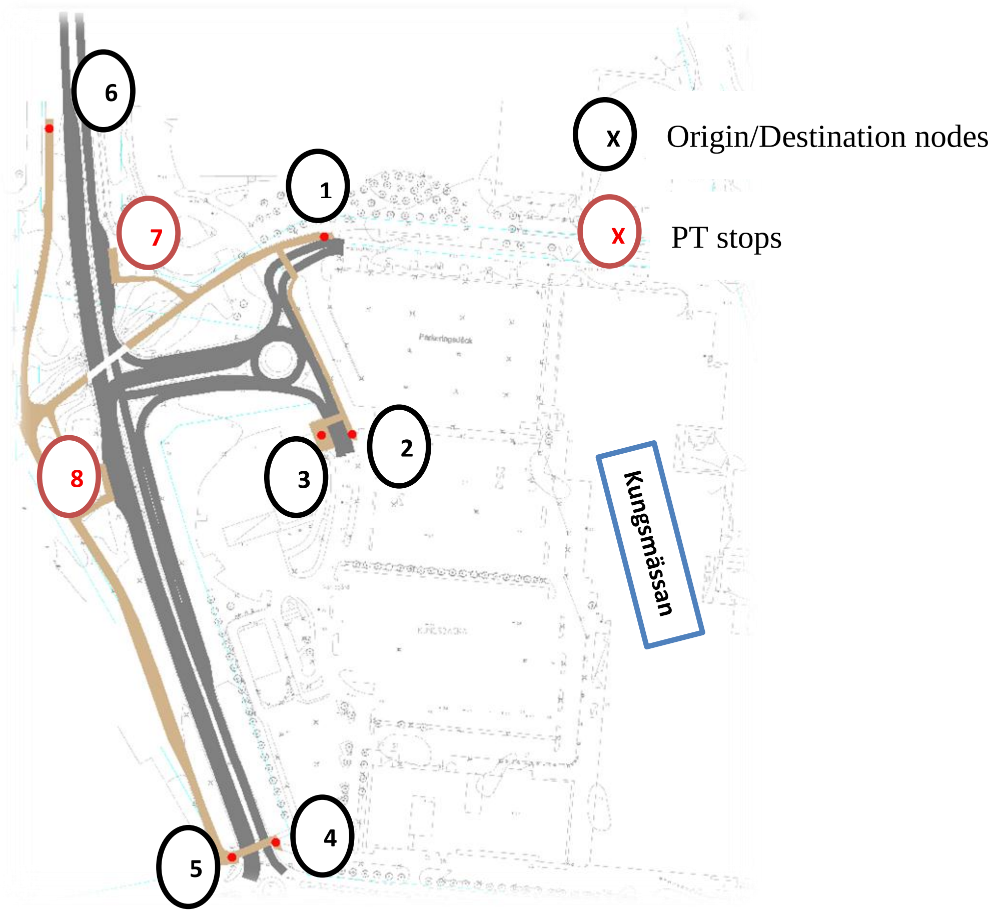

Figure 43. Origins of pedestrian inputs used to simulate the current situation. [Source: VISSIM 5.40 (2011)].

Proposed solution

The data corresponding to the proposed solution is as follows; see Figure 44 in Section 3.7.3 to know the exact location of each node:

Table 8. Pedestrian inputs when simulating the Proposed Solution. [Own source].

Origin node	0-3600 simulated seconds [pedestrians or bicycles* per hour]
A*	4
B	7
C	7
D*	4
E	7
F	7
G	7
H	7
I*	4
J	7

3.7.3 Pedestrian routes

This section is parallel to the commented routes for vehicles. As stated above, all the data introduced here do not have any supported material neither in terms of data collection nor in any other type of source. However, some engineering judgement has been applied such as common sense when sharing the routing decisions, see Tables 9 and 10.

Current situation

It must be said that in reality pedestrians can walk from the red spots number 2 and 3 to the spot number 4. Nonetheless, since the pedestrians´ output is not wanted in this project, the pedestrian area has been simplified as it is illustrated in Figure 43.

Table 9. Share in % of different pedestrian routes in the current situation. [Own source].

Origin node	Destination node							
	1	2	3	4	5	6	7	8
1		1.0	4.0	5.0	30	30	15	15
2	1.0		10	30	9.0	30	10	10
3	10	10		29	20	29	1.0	1.0
4	10	10	1.0		20	30	15	14
5	10	20	1.0	20		30	10	9.0
6	20	15	5.0	20	20		10	10

Proposed solution

Changing to the proposed solution for the future scenario, the modelled situation will differ a little bit since there is a special lane for bikes. As a result, some origin/destination nodes are located in the middle of paths in order not to overlap the bicycle lanes with the pedestrian areas. It is made like that because VISSIM recognizes the same path when pedestrian areas overlap each other. Consequently, some paths would not be used if there is another one shorter.

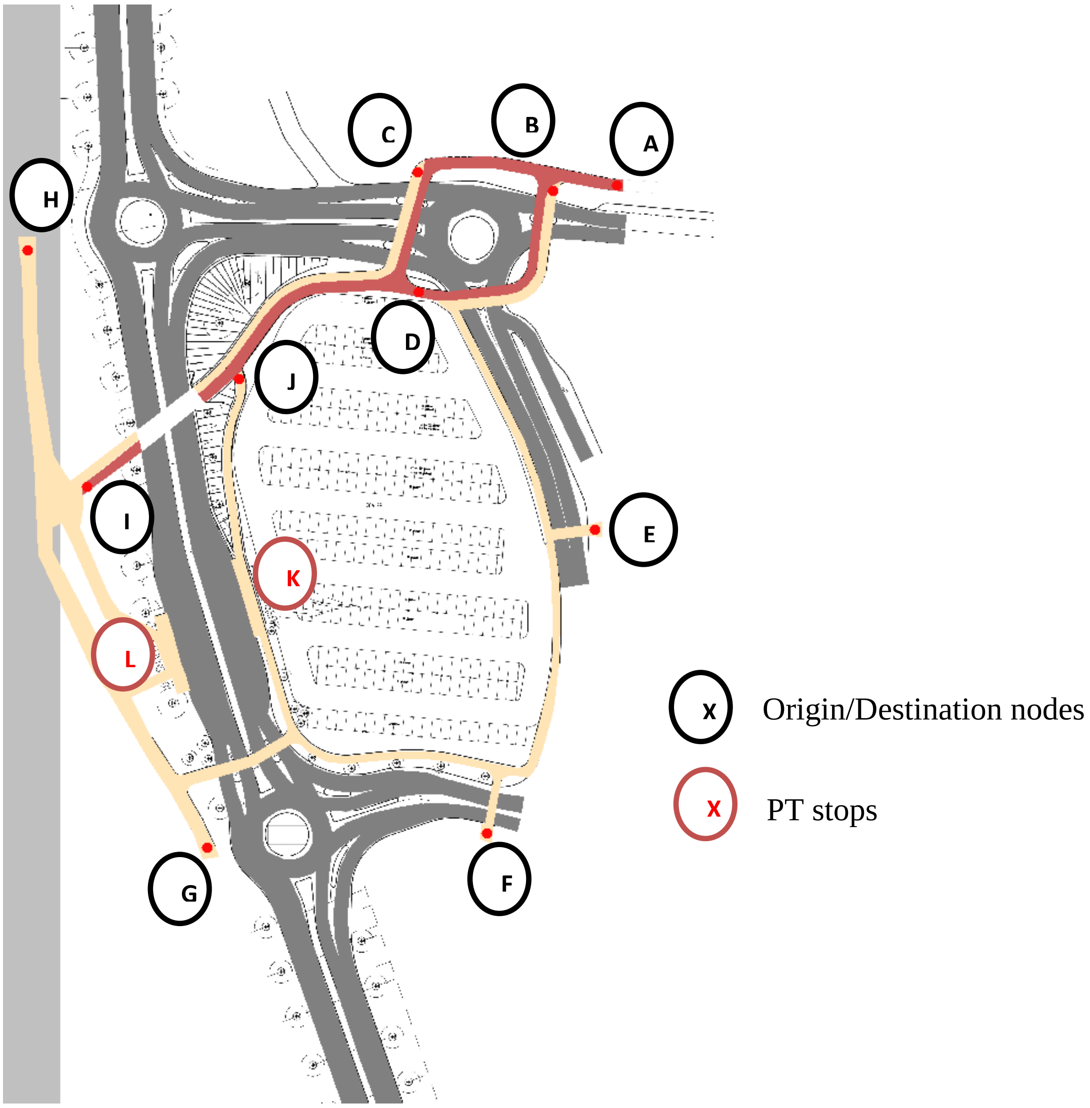

Figure 44. Origins of pedestrian inputs used to simulate the proposed solution. [Source: VISSIM 5.40 (2011)].

Table 10. Share in % of different pedestrian routes in the proposed solution. [Own source].

Origin node	Destination node											
	A	B	C	D	E	F	G	H	I	J	K	L
A		-	-	30	-	-	-	-	70	-	-	-
B	-		-	-	30	40	30	-	-	-	-	-
C	-	-		-	-	-	40	40	-	-	-	20
D	100	-	-		-	-	-	-	-	-	-	-
E	-	20	-	-		30	30	-	-	-	10	10
F	-	15	-	-	20		20	20	-	5.0	10	10
G	-	10	-	-	30	5.0		30	-	5.0	10	10
H	-	-	20	-	-	20	40		-	-	-	20
I	100	-	-	-	-	-	-	-		-	-	-
J	-	-	-	-	-	10	40	-	-		50	-

3.8 Inserting 3D objects

In this section, the methodology of inserting 3D objects into the VISSIM´s models will be presented. As one can imagine, they do not modify the results of a simulation process but on the other hand, they make the 3D view more realistic in the observer´s eyes.

After saying that, it is time to explain the steps required to insert 3D objects:

1. Through 3D warehouse (Google sketchup), search for any object to be inserted, e.g. tree.
2. Choose the tree that seems more suitable to the modelled area.
3. Download the image as *.skp files and save it in the corresponding folder.
4. Insert the 3D object by right clicking in the place of the model where it should be inserted and select the saved file from the folder selected beforehand. Note that VISSIM´s model must display the 3D mode.

To edit the inserted object, VISSIM has several functions to make it either bigger/smaller, rotate it or adjust its elevation in relation to the ground level. The functions are:

- Shift + Alt = Modify the objects elevation
- Shift + Ctrl = Make them bigger or smaller
- Shift = Move the objects and place them in the desired position
- Ctrl = Rotate the objects

At the end, the model will look like Figure 47 from Section 3.9.

3.9 Simulation of models, evaluation files

Before simulating the models, one have to select the evaluation files that will provide the output parameters mentioned in Section 2.6.1, i.e. delays, travel times and queue lengths.

For each of these parameters, the corresponding configuration of the demanded file should be fulfilled. As an example, when creating the queue lengths file, the queue definition is a prerequisite for the program to know when to consider a vehicle in a queue, see Figure 45.

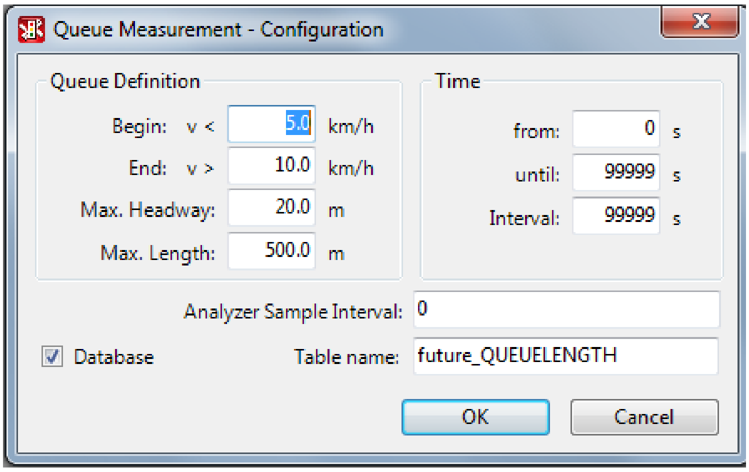

Figure 45. Queue measurement configuration when creating its file. [Source: VISSIM 5.40 (2011)].

In this case, a vehicle is considered to be in a queue as long as its speed is slower than 5.0 Km/h and after that it is not faster than 10.0 Km/h. Moreover, the maximum possible headway allowed to be considered in a queue state is 20.0 meters and the maximum acceptable length of the queue will not be longer than 500.0 meters.

After having completed and fulfilled all these steps, one can run and simulate the created models. Such simulation process can be carried out by either single step or continuous simulation. The latter one is the one followed in this project. Furthermore, the simulation parameters processed are the followings:

- Right-side traffic as takes place in Sweden.
- 3600 seconds of simulation.
- 5 time steps/sim. sec. The higher it is the smoother will be the simulation although the velocity is inversely proportional to that value.
- The random seed determines the way the vehicles will appear in the network. The same random seed number will produce exactly the same results after the simulation process. For that reason, a 5-times multirun is performed where this value is incremented by 10-times every each simulation to obtain stochastic spread of results.
- Different results can then be computed in an excel file where the arithmetic mean is the recommended value for meaningful outcomes.
- The maximum speed simulation is set but at any time one can decrease or increase it by using the + or – buttons. Note that with the 3D mode, the speed of the simulation will be lower than in the 2D mode.

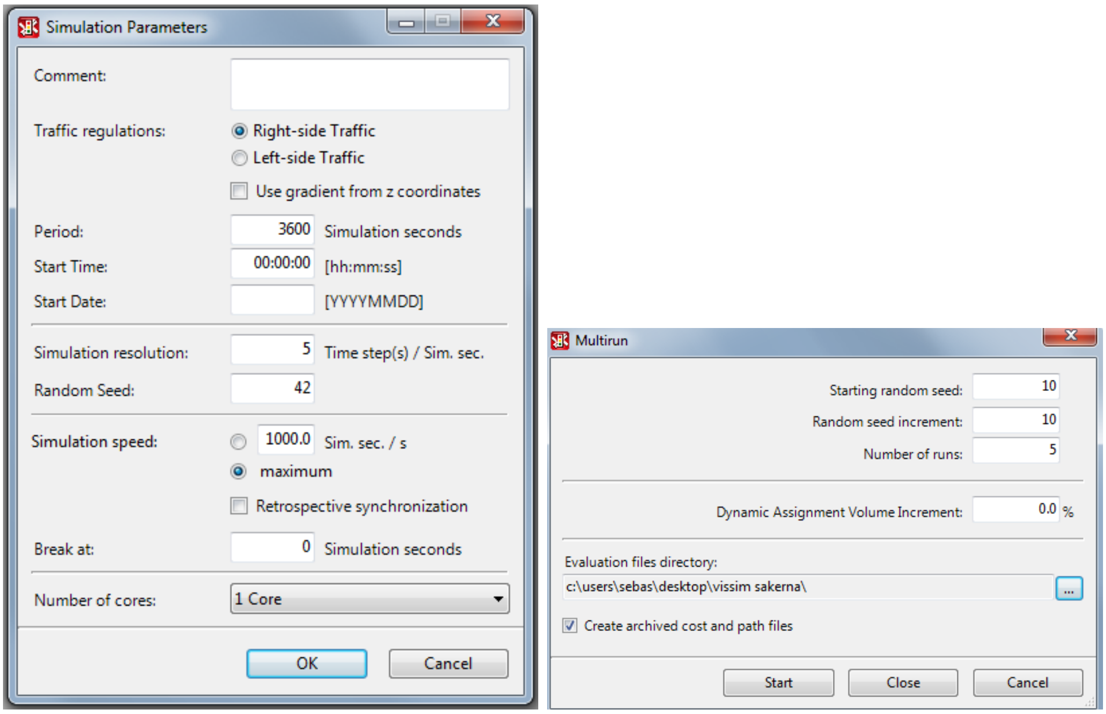

Figure 46. Simulation parameters when running both models just once (left) and Multirun modelling (right). [Source: VISSIM 5.40 (2011)].

Next Figure 47 depicts the differences of both models. P and Q points are introduced for easier comparisons. The 3D mode is activated.

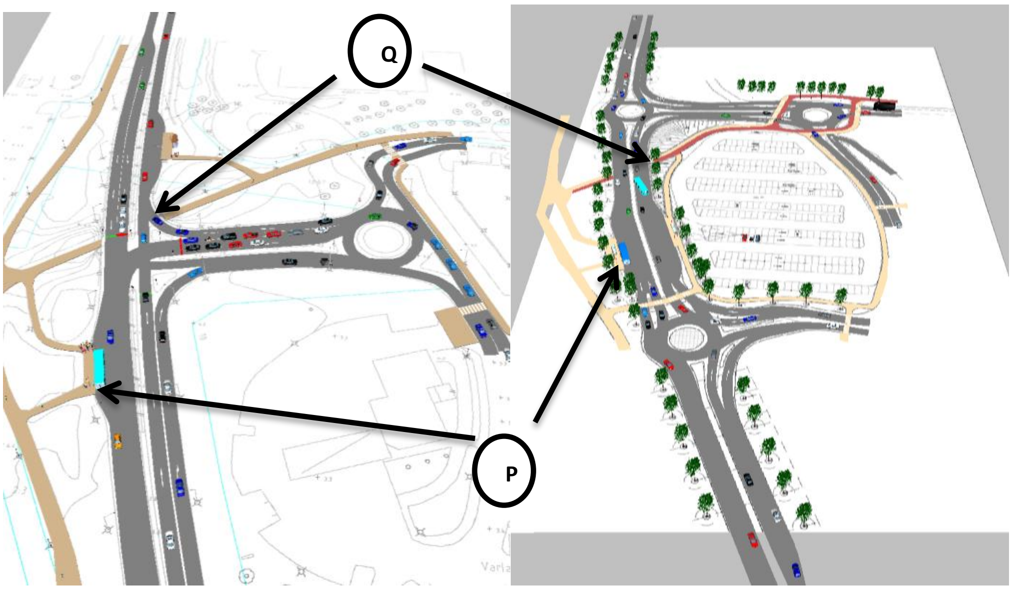

Figure 47. On the left hand side, model of the Current Situation. On the right hand side, model of the Proposed Solution of Norconsult AB. [Source: VISSIM 5.40 (2011)].

The three different traffic volumes that are introduced to simulate the different scenarios can be checked in Appendix 4.

4 Results

Under this chapter, the results of the performance measure parameters (delays, travel times and queue lengths) are shown as cited in Section 2.6.1. Owing to this, several simulations regarding the current situation and the proposed solution layout models have been carried out and will be explained more in detail in the coming/following parts.

First of all, the simulation processes include three different amounts of traffic:

1. Normal traffic assumed to be half of the maximum traffic in 2012 (T1).
2. Maximum traffic registered in 2012 (T2).
3. Maximum traffic forecasted for 2020 (T3).

Then, 5 iterations are set with a different random seed number of coming vehicles to make it more real in each of these simulations. After that, the outputs are handled in MS Excel in order to use and compare them in an easier way. In other words, one must be sure of putting together and contrasting the appropriate values of both models. Finally, the results displayed below are a result of weighting the data obtained with the number of vehicles choosing the same direction, which are grouped in 6 main directions, see Figure 23.

4.1 Delays

Through this section, the delays counted with the VISSIM´s simulation processes are commented and displayed. The direction numbers are related to the ones mentioned before. The green and red values marked in the coming tables pretend to show the lower and the higher value respectively within the same amount of traffic. It is considered almost the same case when there is less than 3 seconds difference between them.

Table 11. Compiled delay data for both the current situation and the proposed solution within the 6 possible directions. [Source: VISSIM 5.40 (2011)].

Direction		Delay [seconds]	
		Current situation	Proposed solution
1	T1	7.3	3.6
	T2	8.9	9.5
	T3	11.0	33.4
2	T1	22.4	2.3
	T2	27.5	6.2
	T3	41.2	17.3

3	T1	3.4	1.9
	T2	11.6	7.3
	T3	23.7	18.6
4	T1	24.3	2.2
	T2	32.4	9.0
	T3	46.5	25.1
5	T1	1.1	2.2
	T2	6.3	5.0
	T3	10.3	10.7
6	T1	23.2	2.9
	T2	29.9	8.6
	T3	38.2	33.2

From the results above, it is possible to affirm that the proposed solution made by Norconsult AB seems to possess better alternatives for the coming vehicles (more green values in the table) in terms of delays presented when running the models. That is, the difference between the desired travel time without any cars in the system and the real travel time experienced in it.

The dark point that must be underlined is that the first direction, coming from the north and going to the south, has a relatively higher delay in the proposed solution than in the current situation when a T3 takes place in the area. A probable explanation and maybe the most suitable one, is that in the current scenario there is a traffic light governing this direction and almost all the time it is showing green for these vehicles. Moreover, the path is straight and has a relatively high speed in the Current Situation.

On the other hand, this direction has to go through two roundabouts in the Proposed Solution. In addition, these users may have to yield other vehicles in a higher percentage when a high traffic flow (T3) occurs, as vehicles inside the roundabouts are the ones having priority.

In general terms, the Proposed Solution is considered to be better than the Current Situation, see Chapter 5.

To gather a better vision of what is going on, see Figure 48 summarizing what is discussed just above.

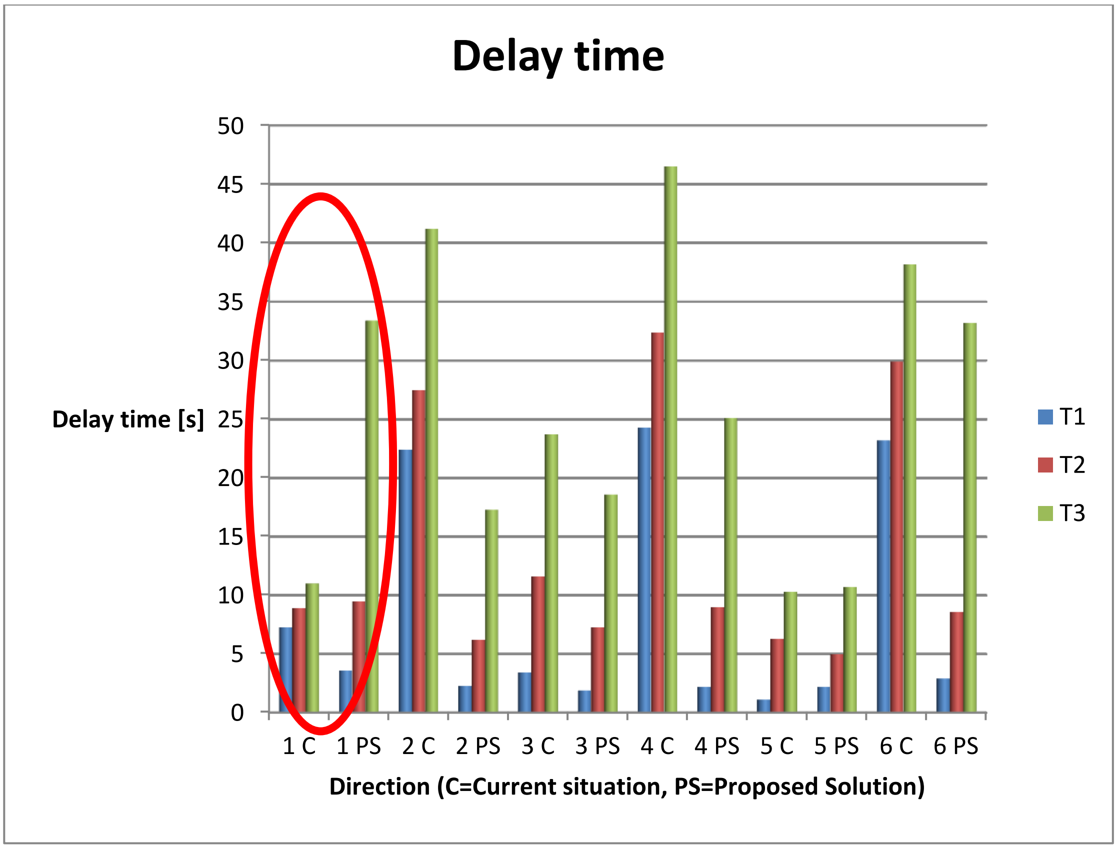

Figure 48. Comparison of the delay time between the current situation and the proposed solution in each direction and each amount of traffic simulated. [Source: VISSIM 5.40 (2011)].

The red circle pretends to show that in the first direction and under T3 traffic flow, the Proposed Solution is much worse than the Current Situation´s scenario.

4.2 Travel times

Through this section, the travel times counted with the VISSIM´s simulation processes are commented and displayed. As in the delays section, the direction numbers are related to the ones illustrated in Section 3.2.1., see Figure 23. The feature of the coloured data is the same as in delay times.

Table 12. Compiled travel time data for both the current situation and the proposed solution within the 6 possible directions. [Source: VISSIM 5.40 (2011)].

Direction		Travel time [seconds]	
		Current situation	Proposed solution
1	T1	33.8	40.1
	T2	35.2	46.2
	T3	37.2	70.3
2	T1	49.7	35.5
	T2	54.8	39.4
	T3	68.6	50.5
3	T1	32.9	32.9
	T2	41.6	38.9
	T3	53.8	50.4
4	T1	62.1	34.2
	T2	70.5	41.4
	T3	84.7	57.7
5	T1	34.8	22.7
	T2	39.8	25.6
	T3	45.0	31.4
6	T1	48.9	37.6
	T2	55.6	43.4
	T3	63.9	67.9

When talking about the travel times registered with VISSIM 5.40, one can get the impression that the results are quite similar than in delays. The slight difference here is that whatever the traffic flow is, higher travel times are registered in direction 1 and that with the highest traffic volume, the travel time for direction 6 is also longer in the proposed solution.

Predictably, both directions have lost some priority without the traffic lights. In other words, the more traffic in the area going around, the more time yielding vehicles inside the roundabouts will occur.

Nevertheless, as it is explained in Chapter 5, the benefits of the proposed solution make it more suitable to assess the accessibility of Kungsmässan shopping centre.

Following the same scheme, see Figure 49 which follows.

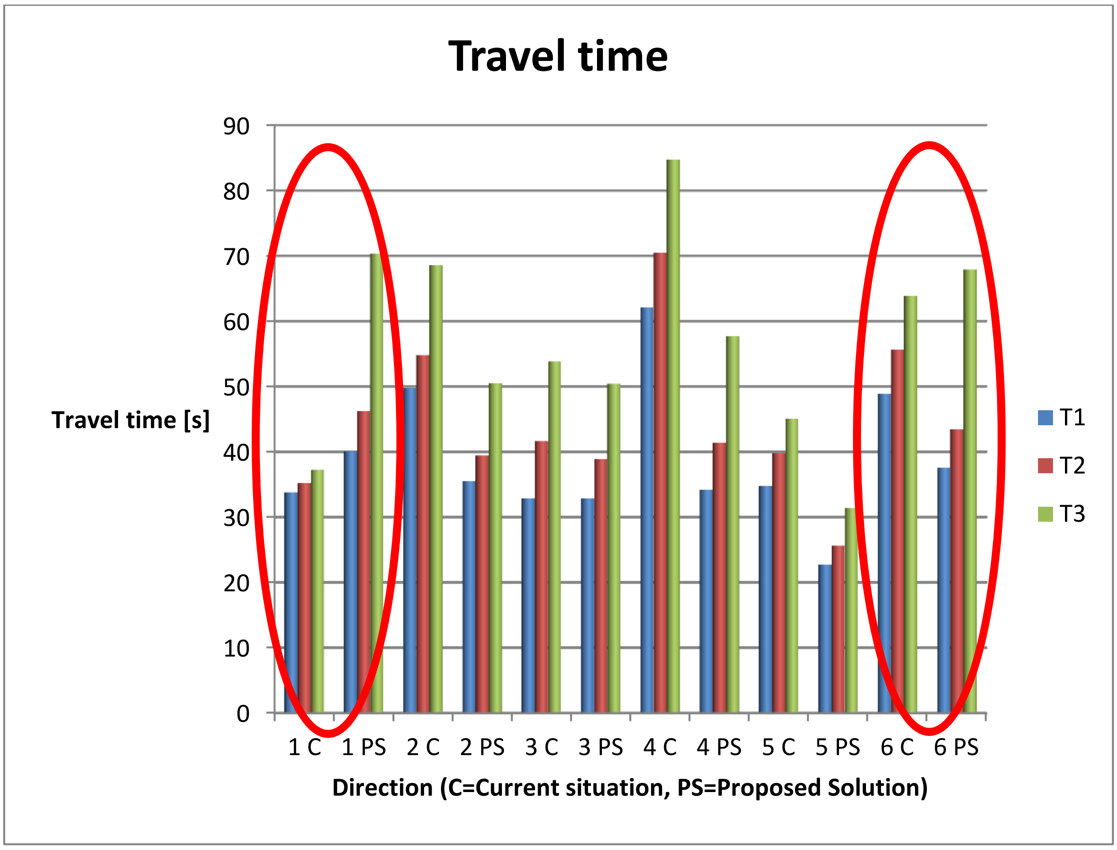

Figure 49. Comparison of the travel times between the current situation and the proposed solution in each direction and each amount of traffic simulated. [Source: VISSIM 5.40 (2011)].

In this case, the travel times are always higher in direction 1, and with T3 traffic flow the direction 6 becomes also worse in the proposed solution.

4.3 Queue lengths

In this section, the queue lengths registered in several points of interest of both networks are presented. The units are in meters, not in number of vehicles considered to be in a queue as it is defined in Section 2.6.1. For the coming results, the queue counters mentioned with numbers are the ones pointed out in the following Figure 50.

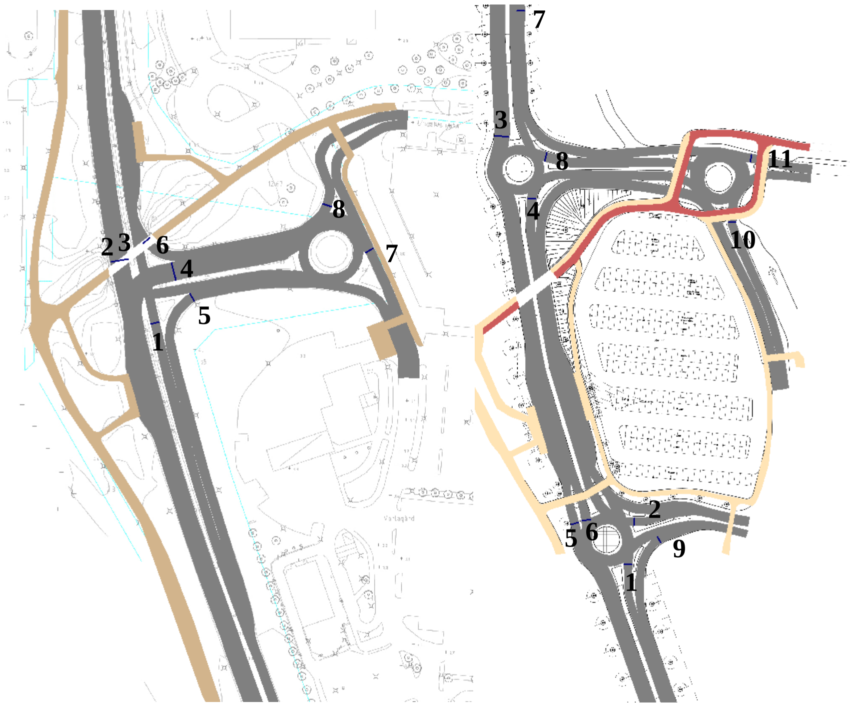

Figure 50. Location of queue counters in the Current Situation (left) and the Proposed Solution (right) models. [Source: VISSIM 5.40 (2011)].

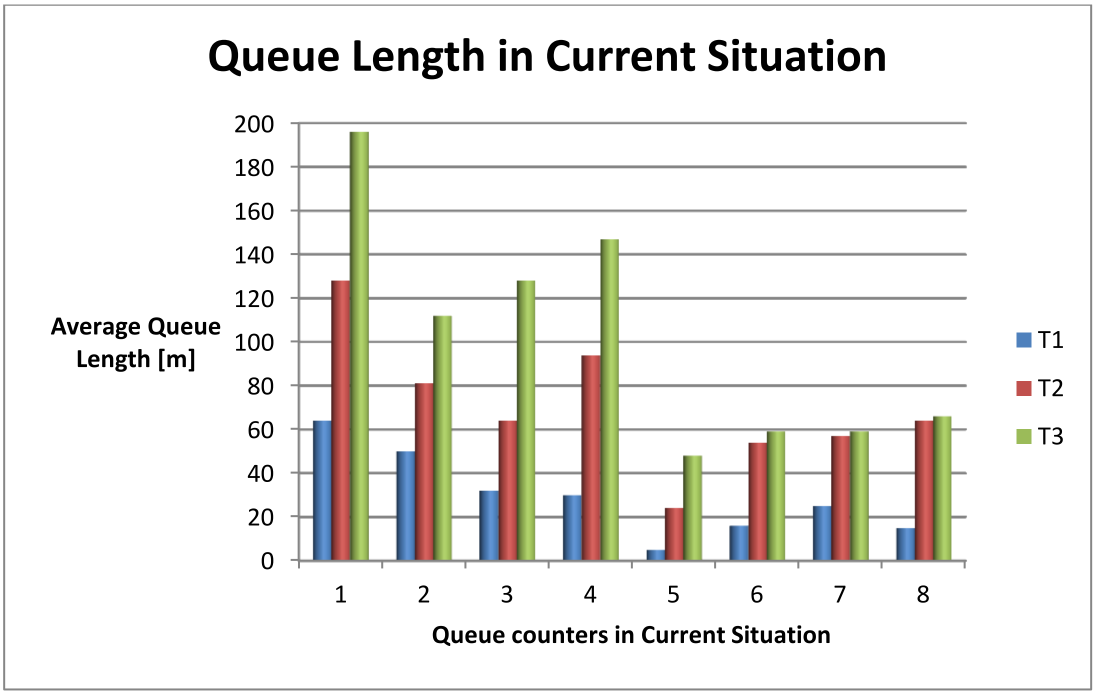

Figure 51. Registered Queue Lengths in different points of the Current Situation model. [Source: VISSIM 5.40 (2011)].

From figure above, it is easy to say that the queue lengths increase proportionally with the amount of traffic. In addition, the place with longer queues is in the queue counter number 1 which is the traffic light 6, defined as signal head number 5 in signal group 3, see Sections 3.3.1 and 3.6.8. Queue counter number 4 is the one experiencing the highest change since it is going from the fourth position in T1 to the second position in T3. It is then a sensitive point of the network.

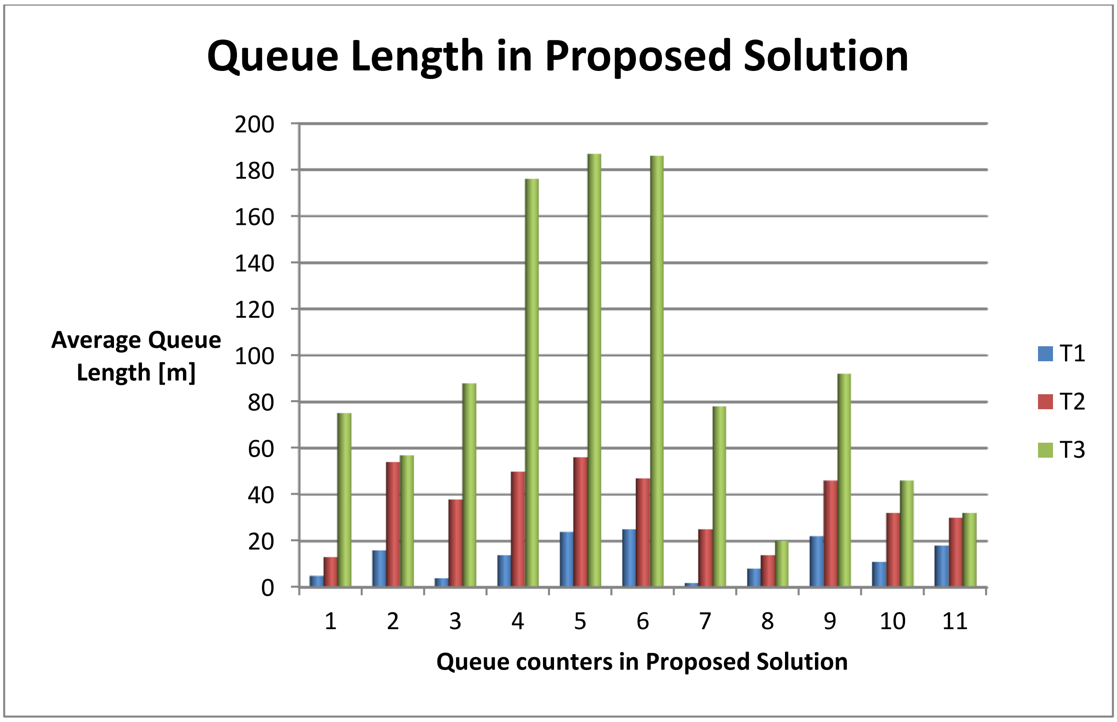

Figure 52. Registered Queue Lengths in different points of the Proposed Solution model. [Source: VISSIM 5.40 (2011)].

Changing to the proposed solution, queue counters 4, 5 and 6 are standing out from the rest. Analysing the situation and thinking a bit about it, one can affirm that queues are produced mainly in these two directions (north-south and south-north or, in other words, directions 1 and 6) due to the loss of priority produced by the roundabouts.

These directions are the ones having higher traffic. Moreover, these vehicles do not have priority although they circulate through the main road.

Apart from the mentioned queue counters, numbers 1, 3 and 7 suffer the relatively highest increase between T1 and T3. Predictably, they are also located in the north-south direction stated before.

4.4 Final quantitative result

Once these 3 performance measure parameters have been studied in detail, it is time to try to summarize all of them in one to obtain a final result of the PS. The method followed is:

1. Obtain a total average value for each traffic volume weighting each average value of the 6 possible directions with the number of vehicles traveling on it.

2. Once this is done for the delays and the travel times, 12 total average values (6 for the CS and 6 for the PS) will be used to calculate 6 ratios dividing the total average value of the PS by the total average value of the CS corresponding to the same traffic volume and differentiating between delays and travel times.

3. These 6 ratios will be pondered at the same time with the number of vehicles.

4. The qualification of the PS is then get by dividing the qualification imposed to the CS by the final weighted ratio.

The queue lengths are not included in this calculation because there are more queue counters in the PS. In addition, it is thought that as traffic lights are replaced by roundabouts, it would not be appropriate to mix them with the delays and travel times.

To sum up, in this case the weighted ratio is equal to 0.72. Therefore, if the CS is set to be 5 out of 10, the PS appears to be 6.9 out of 10, see Appendix 3.

5 Discussion and Conclusions

After completing this project, it is time to discuss some procedures carried out, the results obtained with them and the conclusions extracted after the completion of this report.

First of all, the two models performed with VISSIM do not have exactly the same lengths of the routes. Thus, when comparing the travel times calculated they can be displaced few seconds. For this reason, delay times are also considered as an important performance measure to evaluate both scenarios. For instance, direction 5 has registered almost the same delays in both the current situation and the proposed solution models, but in the latter one a majority part of the vehicles choosing this direction has less distance to travel.

In general, the Proposed Solution seems to handle better the traffic demands in both approaches. An error log from VISSIM states that the Current Situation with the T3 traffic flow, 80 vehicles cannot enter the system due to the congestion formed.

In addition, although the data gathered on site appears to have a lack of consistency, it was checked up with other official information of the area made in 2007. Therefore, there has not been any insanity in quantitative terms. Experienced supervisors have approved its validity both in paper and by looking into the 3D simulator of VISSIM.

Moreover, 3 types of traffic flow (T1, T2 and T3) and 5 iteration processes are set up when simulating the 2 models. This is done to have more than one point of view and to see the evolution of the performance measures (delays, travel times and queue lengths), which are the output parameters of the simulation. However, one must keep in mind that, as VISSIM is just a simulator program, the reality can hide some small details that might affect the general characteristics of the modelled network.

It must be pointed out that there are some key parameters which make the whole simulation process to vary depending on their selected values. That is, a qualitative sensitivity analysis shows that the gap acceptance for entering the roundabouts and the decided criteria to judge whether a vehicle is considered inside a queue or not are the main parameters affecting the models´ outputs. In both cases, these parameters were set by considering the driving behaviour in the 3D simulation mode close enough to the reality.

The conclusions are that if the proposed solution is decided to be built, the users will gain road response in case a vehicle breaks down and blocks an entire lane. Fortunately, the road users will have the opportunity to change their preselected route by another one ending at the same desired destination. This flexibility has not been handled in the simulation process. The current situation is much more rigid regarding this point.

Despite the fact that in some cases the Proposed Solution presents worse results, it is just in some directions and in extremely rare cases of huge traffic flow in relation with the common one.

A drawback of the proposed solution is that the road users will experience a higher stress when driving through the area because more attention is required when crossing the roundabouts. Nowadays, several traffic lights do this job for them and they have just to focus when their traffic light shows green to be able to keep their route.

To sum up, the researcher considers that the proposed solution is more suitable for each of the traffic amounts considered in this report. Especially, the lower the traffic flow is, the better the proposed solution is in terms of the performance measures focused.

A final quantitative result shows that if the CS is set to be 5 out of 10, then the PS comes up to be 6.9 out of 10.

6 Recommendations and Future Research

This report has achieved the objective of quantifying how better a proposed solution was in comparison with the current situation network. However, it is not an ending document of the research. The real world possesses a lot of complex features that models cannot tackle or, in other words, guarantee the full operation of the created system.

In addition to this, more parameters can be added or improved to the ones utilized in this project in order to reach more accurate findings. One way to get to know if the results are in accordance to the real life situation is to check out periodically the area and see the evolution presented there.

The possible future research to keep this investigation up to date could be to take into consideration the following aspects:

- Get a quantitative point of view of economic and environmental features of both scenarios.

- Include how the vehicles´ velocity changes from one to another situation.

- Propose more alternatives for the future scenario such as an addition of more lanes in a specific direction, an inclusion of traffic lights in some roundabouts when high traffic flow occurs, etc. and see if even better outcomes are possible.

- Use dynamic assignment when simulating the models to cover the flexibility of having different routes to reach the desired destination when the shortest one is not the fastest one.

- Include the LHOVRA-technique in traffic lights by using VAP (Vehicle Actuated Program) in VISSIM.

- Study the pedestrians´ characteristics more in detail.

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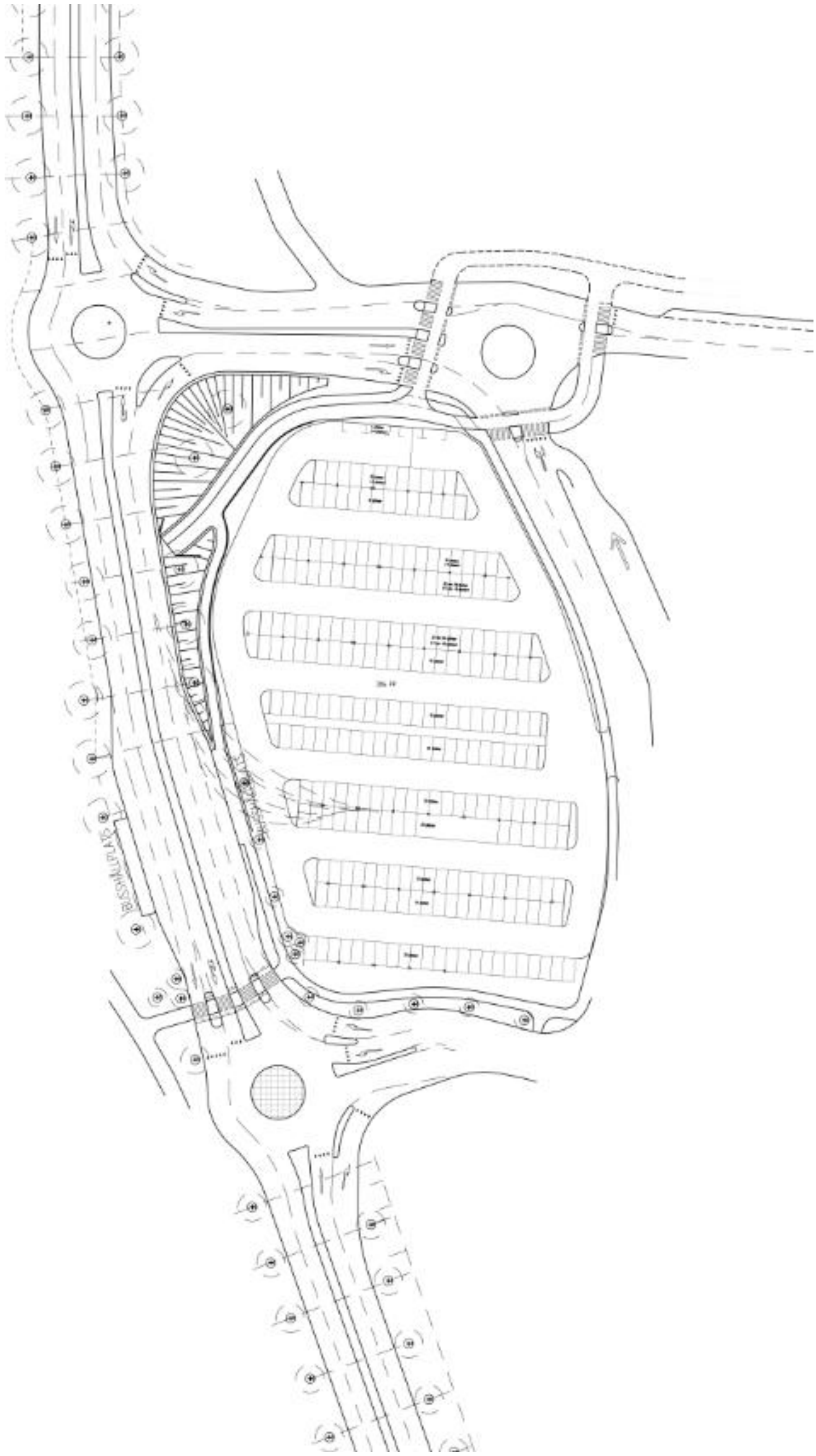
Appendix 1 (AutoCAD file Current Situation)

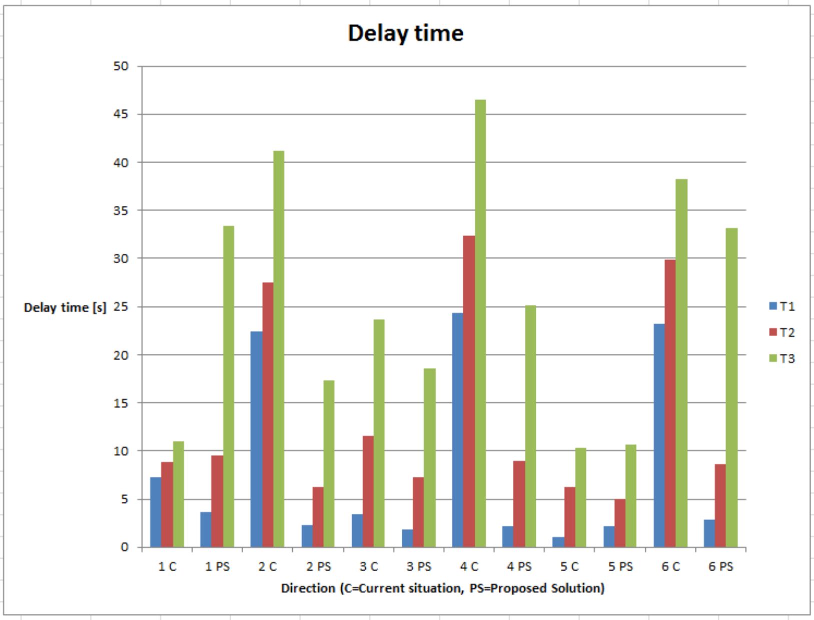
Appendix 2 (AutoCAD file Proposed Solution)



Appendix 3 (MS Excel files)

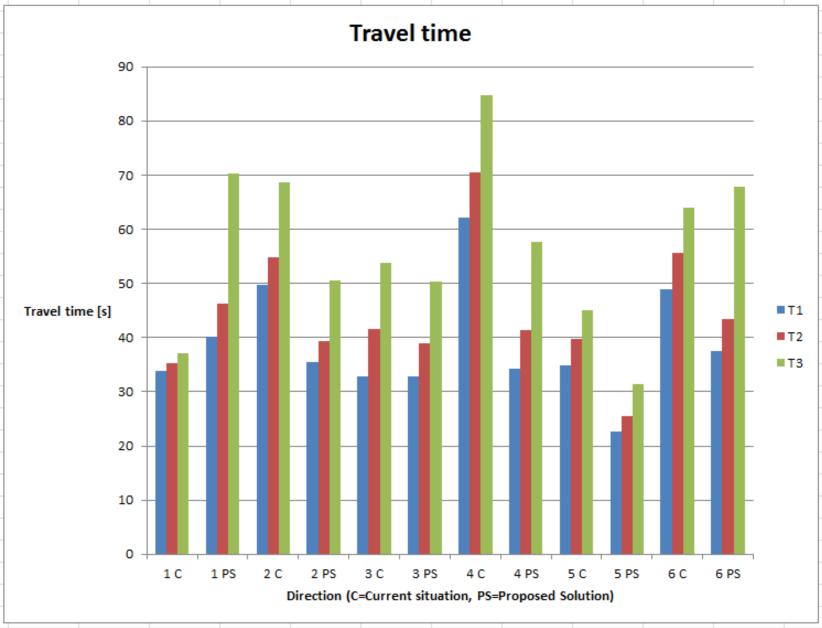
Delay Current situation & Proposed solution

Direction	1 C	1 PS	2 C	2 PS	3 C	3 PS	4 C	4 PS	5 C	5 PS	6 C	6 PS
T1	7,3	3,6	22,4	2,3	3,4	1,9	24,3	2,2	1,1	2,2	23,2	2,9
T2	8,9	9,5	27,5	6,2	11,6	7,3	32,4	9	6,3	5	29,9	8,6
T3	11	33,4	41,2	17,3	23,7	18,6	46,5	25,1	10,3	10,7	38,2	33,2

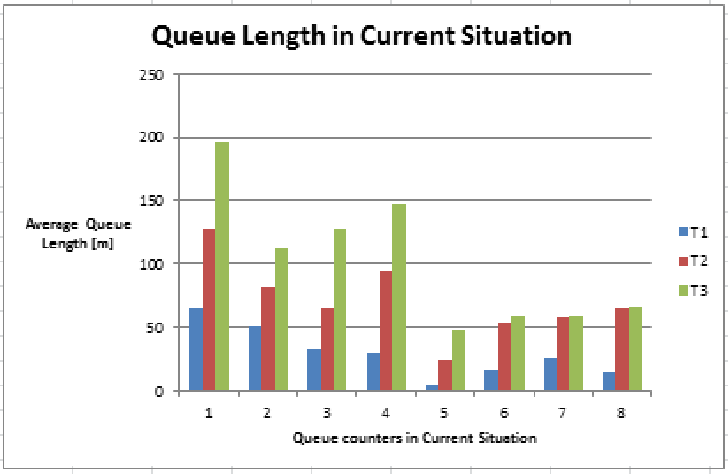


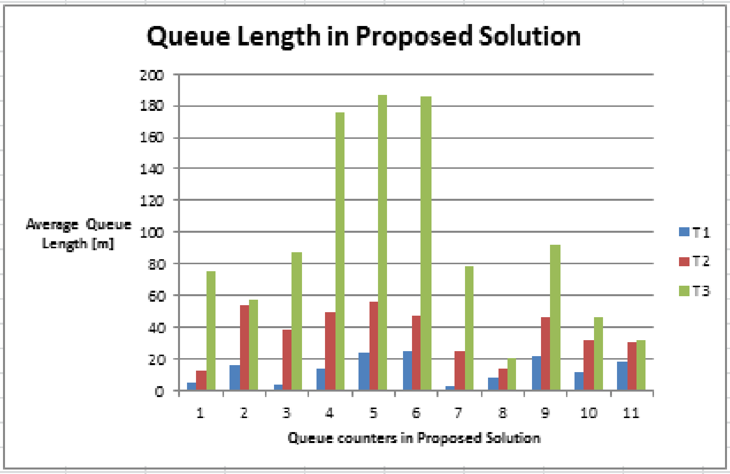
Travel time Current situation & Proposed solution

Direction	1 C	1 PS	2 C	2 PS	3 C	3 PS	4 C	4 PS	5 C	5 PS	6 C	6 PS
T1	33,8	40,1	49,7	35,5	32,9	32,9	62,1	34,2	34,8	22,7	48,9	37,6
T2	35,2	46,2	54,8	39,4	41,6	38,9	70,5	41,4	39,8	25,6	55,6	43,4
T3	37,2	70,3	68,6	50,5	53,8	50,4	84,7	57,7	45	31,4	63,9	67,9



A	B	C	D	E	F	G	H	I	J	K	L	M	N
Queue lengths													
Current situation													
		1	2	3	4	5	6	7	8				
	T1	64	50	32	30	5	16	25	15				
	T2	128	81	64	94	24	54	57	64				
	T3	196	112	128	147	48	59	59	66				
Proposed solution													
		1	2	3	4	5	6	7	8	9	10	11	
	T1	5	16	4	14	24	25	2	8	22	11	18	
	T2	13	54	38	50	56	47	25	14	46	32	30	
	T3	75	57	88	176	187	186	78	20	92	46	32	

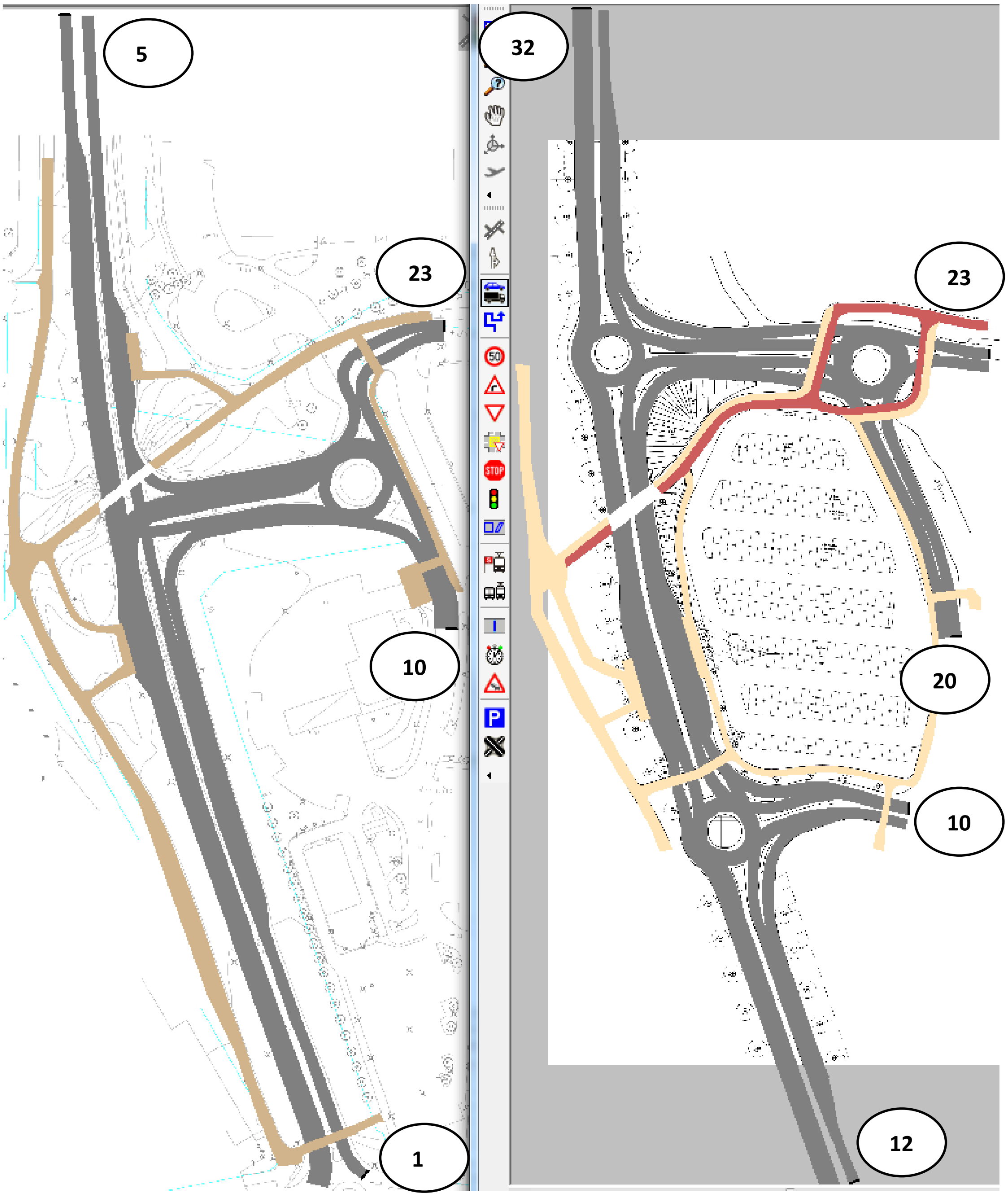




		Total Averages (s)					
		Delays	**Travel Times**	**Ratios**			**Weighted ratio**
	T1	14,02	44,15	0,18	0,78		0,72
CS	**T2**	19,55	49,77	0,40	0,80		
	T3	28,15	58,31	0,85	0,96		
				# vehicles			**Qualification to the PS**
	T1	2,55	34,27	6508	6554		6,94
PS	**T2**	7,74	39,68	13006	13041		**Qualification to the CS**
	T3	23,87	56,1	17039	17342		5

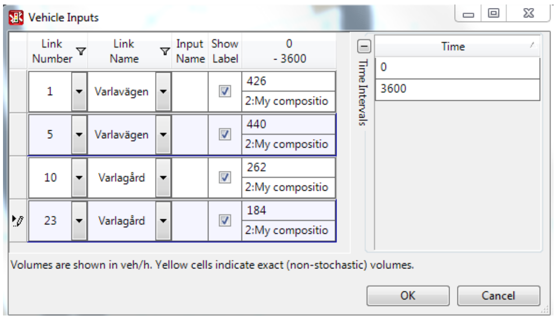
Appendix 4 (VISSIM data)

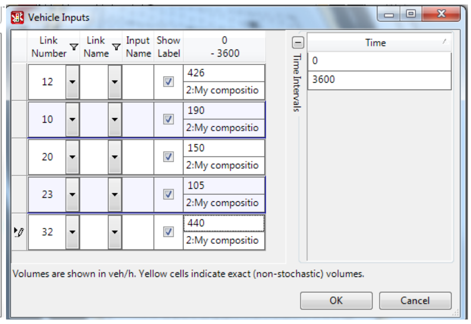
Current Situation (CS) & Proposed Solution (PS) 2D models



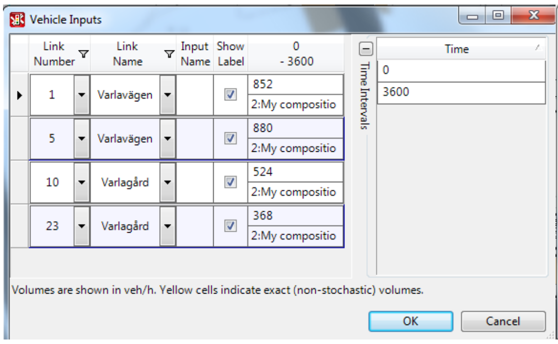
Vehicle Inputs

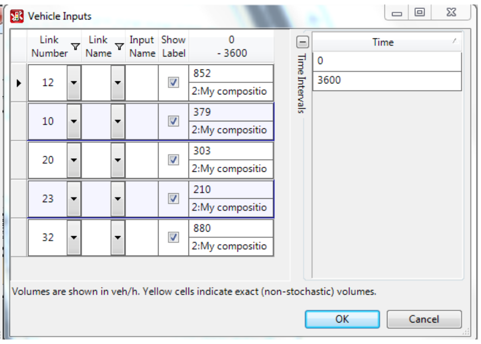
Traffic Volume T1





Traffic Volume T2





Traffic Volume T3