CHALMERS

Analysis of Design Alternatives of Sörredskorsningen

A road intersection in Gothenburg

Master of Science Thesis in the Master's Programme Geo and Water Engineering

SAAD NUSRULLAH MIRZA
SYED DANIAL ALI

Department of Civil and Environmental Engineering
Division of GeoEngineering

Road and Traffic Research Group

CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2012
Master's Thesis 2012:10

MASTER’S THESIS 2012:10

Analysis of Design Alternatives of Sörredskorsningen

A road intersection in Gothenburg

Master of Science Thesis in the Master’s Programme Geo and Water Engineering

SAAD NUSRULLAH MIRZA

SYED DANIAL ALI

Department of Civil and Environmental Engineering
Division of GeoEngineering
Road and Traffic Research Group
CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2012

Analysis of Design Alternatives of Sörredskorsningen
A road intersection in Gothenburg

Master of Science Thesis in the Master's Programme Geo and Water Engineering

SAAD NUSRULLAH MIRZA
SYED DANIAL ALI

Examensarbete / Institutionen för bygg- och miljöteknik,
Chalmers tekniska högskola 2012:10

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

Chalmers Reproservice / Department of Civil and Environmental Engineering
Göteborg, Sweden 2012

Analysis of Design Alternatives of Sörredskorsningen
A road intersection in Gothenburg

Master of Science Thesis in the Master's Programme Geo and Water Engineering

SAAD NUSRULLAH MIRZA
SYED DANIAL ALI
Department of Civil and Environmental Engineering
Division of GeoEngineering
Road and Traffic Research Group
Chalmers University of Technology

ABSTRACT

The growth of versatile traffic on a yearly basis in the city of Göteborg requires proper planning and measurements to avoid accidents and congestions at the intersections in the future. Hence, the traffic authorities are working on projects like K2020 aiming to develop the public transport and Vision Zero project targeting no serious injuries in the traffic environment in Gothenburg.

The topic of this thesis is to evaluate and predict traffic congestion situation at Sörreds intersection located in the vicinity of the Volvo area. Moreover, this work is aimed to predict the congestion situation at Sörreds intersection. Two alternatives were proposed by SWECO with the possibility of building a ring road either at Sörredsvägen or at Road-155 i.e. Torslandavägen, as there is a forecast of 200% increase in traffic at the junction by 2035. In this thesis, a discussion is made in order to select the more feasible alternative out of them.

The case study has been performed using German traffic simulation software, VISSIM. VISSIM has been used to represent the actual situation of the traffic for the Sörreds intersection by considering the present scenario as well as future scenario of the intersection. For the purpose, different microscopic simulation models were created to resolve the congestion issue at Sörreds intersection, including simulation models for the actual situation supported by VISSIM. Also simulation of the same model with future vehicular input has been checked to justify whether a ring-road/flyover is needed or not.

Finally, the comparisons of alternatives made by SWECO has discussed in the last part. The results gained by both comparisons are debated to give a good decision. Further studies are recommended because of certain limitations of this study in terms of limited data availability for the particular junction.

Key words: VISSIM, VisVAP, LHROVA technique, traffic volumes, simulation model, signalized intersection, signal control, performance measure.

Contents

Preface

All praise to Allah Almighty with whose abundance and unlimited blessing we were able to complete our Master's thesis.

Deepest gratitude to our supervisor and examiner Gunnar Lannér whose reliable and trustworthy knowledge become a source of enlightened path for us to proceed in the research area. Without his sincere and genuine contribution it was hard to endure our achievements.

We would like to pay thanks to Bertil Hallman at Traffic Authority, to give support and guidance about the work. We can't forget the cooperation of Stefan Andersson and Berglund Charlotte from SWECO, to provide us valuable information and necessary data for the project.

A heartiest gratitude to Edwards Santana, instructor for VISSIM, who guided us a lot during the whole period. Very warm thanks to Tong Wo, our classmate in the master program, who assisted us in the VisVAP programming.

Finally, we dedicate our work to our parents who always encouraged us to forward ahead in the race of life and excavate positives effects in our lives.

Gothenburg, January 2012

Saad Nusrullah Mirza

Syed Danial Ali

Glossary

English to Swedish

Gothenburg	Göteborg
Swedish Transport Administration	Trafikverket
Sörreds intersection	Sörredskorsningen
Sörreds road	Sörredsvägen
Torslanda road	Torslandavägen

Swedish to English

Västtrafik	Public Transport Company
Göteborg	Gothenburg
Trafikverket	Swedish Transport Administration
Sörredskorsningen	Sörreds intersection
Sörredsvägen	Sörreds road
Torslandavägen	Torslanda road

Definition

Öckerö	An island in the west of Gothenburg
K2020	A Public Transport development program for Gothenburg
AADT	Annual average daily traffic

1 Introduction

In this chapter the aim, method, background and limitation of the study will be discussed. The report describes the study of the Sörreds crossing, the intersection of Sörredsvägen and Torslandavägen in Gothenburg as shown in Figure 1.1.

Figure1.1 Aerial view of Sörredskorsningen along with Torslandavägen. (Source: Google Earth 6.0)

1.1 Background

Among 150 countries of the world, Sweden is ranked number four due to its quality and efficient logistic operations (Arvis et.al, 2010). Gothenburg is the second largest city of Sweden and fifth largest in Scandinavia. One reason of the importance of Gothenburg is because of the presence of the largest seaport of Nordic countries. It can be named as logistic hub of Scandinavia.

Consequently, the need of import and export of goods and materials within the country and with other countries demands an efficient and effective road network within the city of Gothenburg. Owing to the fact that the Swedish Transport Administration of Gothenburg region is keen, in the reformation of road networks and adding new roads which will be required in the near future. In this respect, altering Sörreds intersection is one of the main projects under consideration at the moment.

The Sörreds intersection is at the outskirt of the city Gothenburg, connected with the industrial area of the city, i.e. Volvo Headquarter and other industries. It also connects the Torslanda and Öckerö with the centre of the city. Continuous flow of raw material, goods and limited private vehicles are the important aspects that need to be fulfilled. Thus, for the purpose, the road network within the location of Sörreds intersection needs to be highly fluent and efficient.

Moreover, population in Gothenburg is expanding on yearly basis. By analysing previous statistics of growth rate it can be assumed those outskirts of the city including Sörreds intersection would be among highly populated areas in near future.

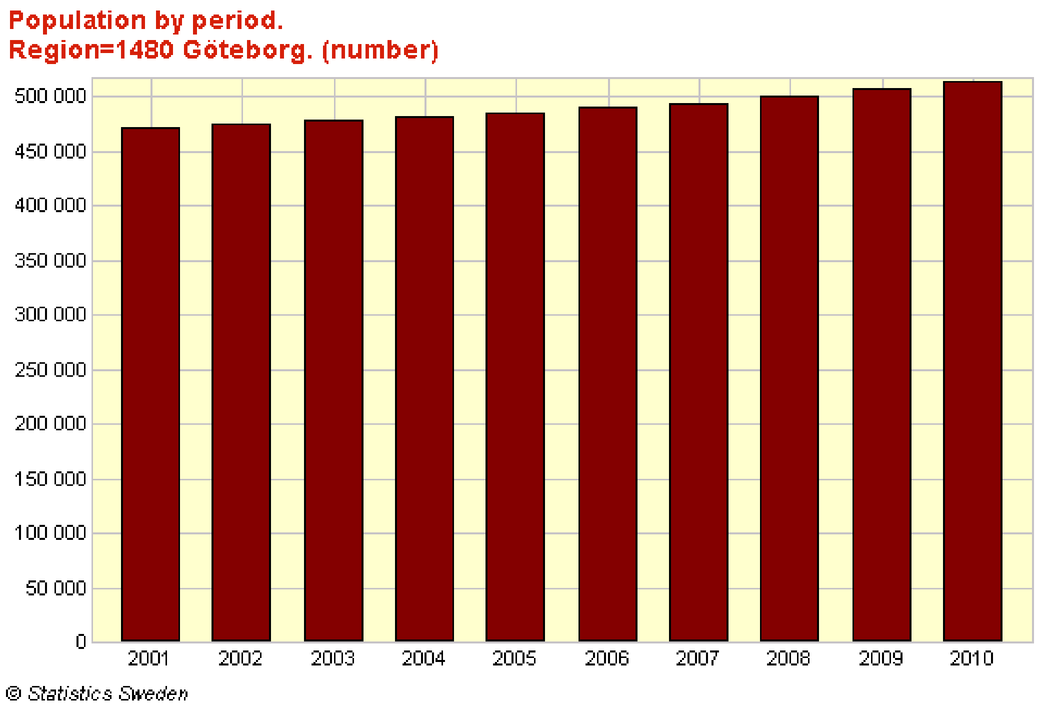


Figure 1.2 Graphical presentation of 10 year population record (Source: Statistics Sweden, 2011)

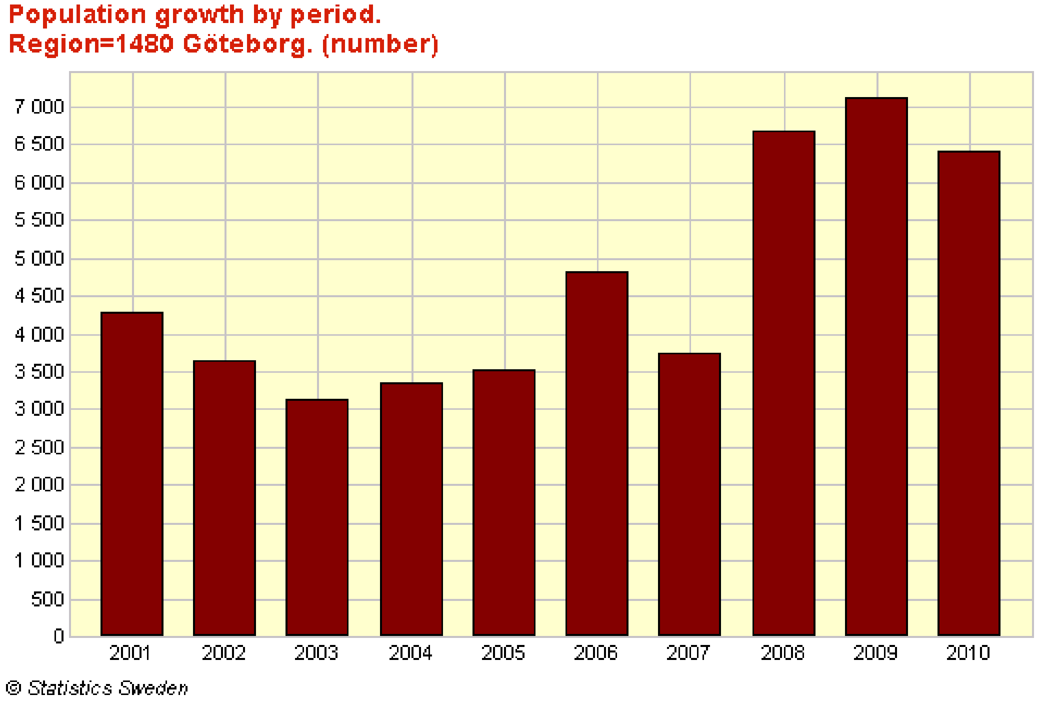


Figure 1.3 Graphical presentation of 10 year population growth (Source: Statistics Sweden, 2011)

In addition to this, certain projects including K2020 are also under consideration by Swedish Transport Administration, Trafikverket. These approaches reflect that planners are thinking to make Gothenburg a more sustainable area in terms of mobility, accessibility and traffic safety. Moreover, Trafikverket is willing to study the Sörreds- junction to enhance its capacity to fulfil the future need. A plan for the future is to study the possibility of new road or addition of a flyover at the intersection, i.e. if it is required and study for best possible design of Sörreds crossing for an actual scenario.

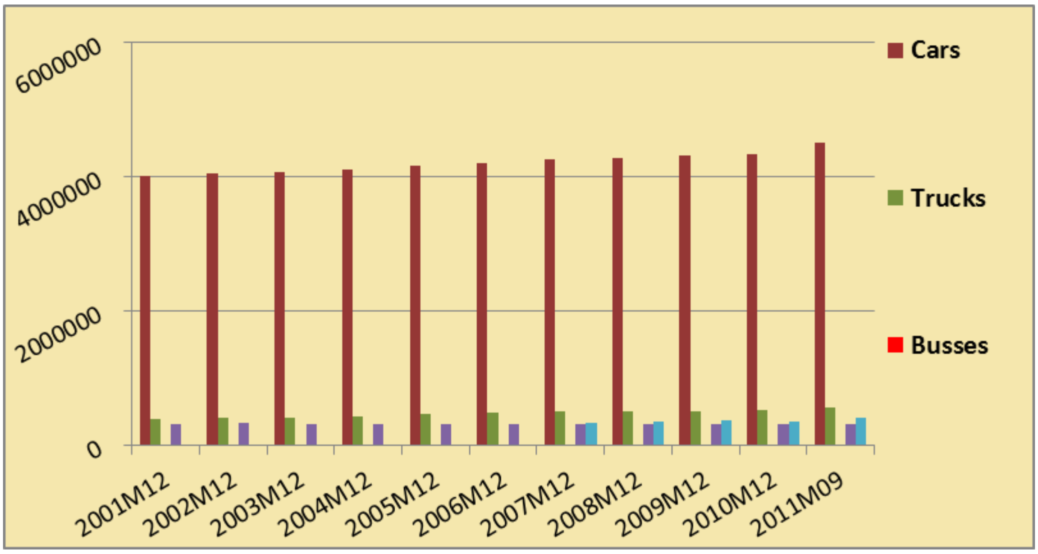


Figure 1.4 Above chart represents the traffic statistics of Gothenburg (Data source: Statistics Sweden, 2011)

In order to avoid the gridlock and accidents at a particular junction, it is essential to study and analyze it. Therefore, the intersection has already been studied by SWECO, a civil engineering consultant company. According to the SWECO's proposal, ''*purpose of commissioning SWECO is to investigate an alternate solution that can be accommodated within the framework of the allocated budget''* (translated from SWECO, 2011).

Two alternatives named as Alternative-2 and Alternative-3A, have been proposed by SWECO which are based on to build a flyover and a ring road. The alternative-3A is an advanced or modified form of alternative-3, which is somehow different with the alternative-3A. SWECO's study is based on the comparison analysis of alternative-2 and alternative-3. Alternative-3A is a new design and it is now consider in place of alternative-3.

Alternative-2, as shown in Appendix 1A, will consist of a flyover on Sörredsvägen which crosses the Torslandavägen or Road-155. Volvo track will remain on ground level and thus would not be affected by Sörredsvägen. Alternative-3A is in consideration of a flyover on Torslandavägen. Sörredsvägen and Volvo track will remain on ground level. Appendix 1C showing the drawing of alternative-3, which is not considering in this debate.

In both alternatives, Raffinaderivägen, Kärrlyckegatan and Arendalsvägen will closed for direct entrance to the Road-155. However these roads will merge as Sörreds south as shown in Appendices 1A and 1B. (SWECO, 2011)

SWECO has examined both alternatives by using "*CAPCAL*" traffic capacity analysis software. History of the intersection, volume characteristics of the intersection, comparison analysis by considering different parameters has been studied by SWECO. (SWECO, 2011)

1.2 Aim of the study

The aim of this assignment is to study the current scenario of Sörreds intersection in terms of accessibility, traffic safety and to discuss the future perspective of the intersection by considering the increasing amount of traffic. The two design alternatives for the intersection will be a major task to study and to make their comparison. A more suitable alternative would be recommended after the comparison analysis. The proposal would also provide an assistive document for the public transport to make a traffic plan for the implication of K2020.

1.3 Method of the study

Initially, a comprehensive literature study was performed including different books, papers, previous thesis of traffic engineering and traffic planning. A traffic simulation computer program *VISSIM version 5.3* was used to analyse the intersection and also for its alternatives. MS Excel and AutoCAD 2011 used as major assistive tools. Field survey and data collection of one hour traffic flow from 16:00 – 17:00 in a weekday was done by the researchers.

The collected data and other related information which was gained during survey, utilized in VISSIM. Firstly, a model having current situation of the intersection is developed and initialize in VISSIM. Secondly,same model having future amount of traffic is developed just to realize the importance of the new design plan. Finally, models of both alternatives were developed on VISSIM platform and then simulated. The outcomes which were gained through simulation process were then examined and used in the results.

1.4 Limitations of the study

During the development of the study, certain limitations were considered and are mentioned below:

- The study has been made, by comparing the study of only one intersection i.e. Sörredskorsningen, in Gothenburg.
- Only two alternatives i.e., 2 and 3A, as SWECO proposed were considered to examine.
- Manual counting and video counting has been made only during the hours16:00 – 17:00 by considering it as peak hour of a week day. This data was used to compare with the SWECO's data.
- The traffic flow data from the report of SWECO used as input data in VISSIM. This is because the purpose of this project is to compare the results obtained with CAPCAL to the results with VISSIM.
- Drawings of the current scenario and both alternatives provided by SWECO, was then imported in VISSIM to draw the links and connectors of roads and flyovers.There might be a limited possibility to differ somehow with actual situation in terms of elevation and size.
- Model representing the present scenario of the intersection don't includes the rail road traffic.
- The models for the alternative designs are only considers the selected motorized traffic excluding rail road, pedestrian and bicyclists.
- The conversion from Swedish to English version for the SWECO report while using *Google translate* might have changed some of the terminologies or criteria, being originally used in the study by SWECO.

2 Literature Review

This chapter gives an overview about the basics of intersection design, methodology of traffic volume studies, signal control design and other related functions i.e. vehicle actuated controllers, traffic detectors and Swedish signal control technique-LHOVRA.

2.1 Intersection design and capacity

"Intersections, where two or more roads meet, or point of potential vehicle conflict". A signalized intersection can be defined as "*The signal controlled intersection is a location in the road network where road users of different types are focused to share a common road surface*". It is also stated that engineers should plan and design any intersection in a way that it becomes safer, efficient for road users. (O'Flaherty, 1997)

Intersections design varies not only from cities to cities but also from countries to countries. An example is presented to clarify above statement. In designing intersection in China, an important thing to consider while designing is the large number of pedal-driven vehicles and pedestrians alongside buses, trucks, taxis and growing number of cars. On other hand, in Europe the problem is associated to the design of an intersection, considering large number of cars alongside buses and trams.(O'Flaherty, 1997)

Moreover, any intersection consists of three or more approaches, each of which contains one or more lanes. When there are more lanes these are separated by a broken white line painted on the surface of the road, each lane being 3m to 5m wide. At the intersection , each lane ends at a stop line, a thicker unbroken white line across the end of the lane indicating the point beyond which the car at the front of the queue should not be proceed when the signal is red. Where the lane is reserved for one or more movements, this is indicated by one of two-headed arrows, painted in the white in the centre of the lane on the approach of the stop line. These arrows should be located sufficiently far from the stop line to avoid being obscured by the queue. (O'Flaherty, 1997)

In addition to this, intersections are resigned in a way that they provide adequate spaces for queues. Also at signal heads there must have clearly visible locations. Suggested space requirement for queues is 1.2 multiplied by the mean arrival rate over the cycle, multiplied by 6 m per vehicle. Concerning the visibility, a distance of 70 m is recommended for signal location besides if the maximum allowed speed is 50 km/h or a distance of 125 m if the maximum allowed speed is 70 km/h. (O'Flaherty, 1997)

In UK and European countries, three lamps i.e. green, yellow and red, are vertically arranged having red at the top for long distance visibility, following yellow and then green at bottom. There is a black board behind the lamp to make the signals clearly visible from larger distances. The height of the signal lamp should be 2m from ground. The arrangement of signal in Japan is a bit different, as they are arranged horizontally above the road.(O'Flaherty, 1997)

The principles of intersections design are illustrated below in Figure 2.1,

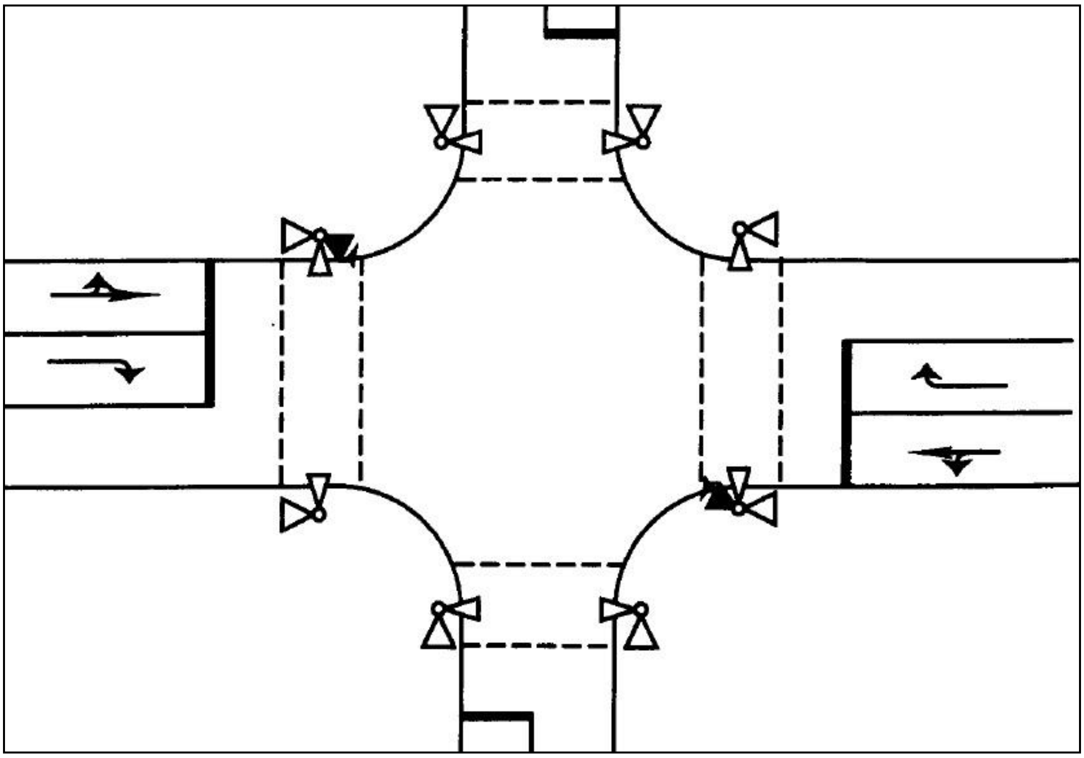


Figure 2.1 Simple four-arm intersection (O'Flaherty, 1997)

In Figure 2.1,it can be visualized that lanes are about 4 to 5m wide and vehicle stop position is also indicated with stop line. In Germany primary signal head is about 2.5 to 3.5 m downstream of the line making it clearly visible for vehicles in first queue. Also pedestrian lines are shown that are supposed to be 1m downstream of stop line having 3 to 12 m width (O'Flaherty, 1997)

Signals can be further divided in uncontrolled, priority controlled Stop; give way, space sharing i.e. roundabouts, time sharing i.e. traffic signal controlled, or grade separated including interchanges. (O'Flaherty, 1997).

Some basic intersections forms are illustrated below:

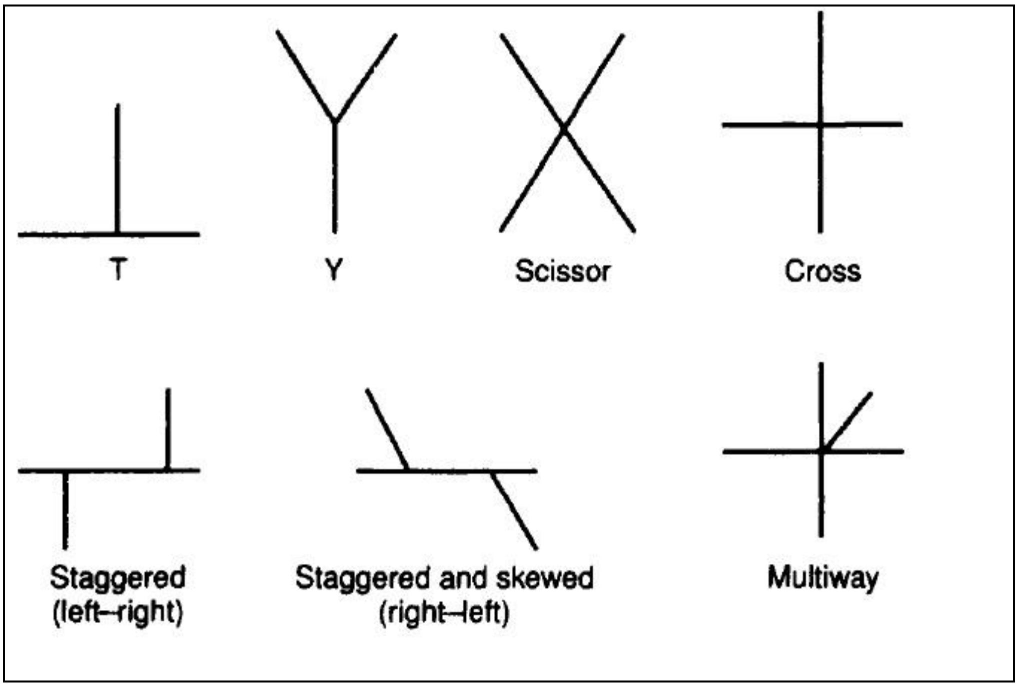


Figure 2.2 Illustration of some basic forms of intersections (O'Flaherty, 1997).

In early stage, data collection is made for site as well as for traffic condition in "at-grade design process". After that, the preliminary design is prepared from which the layout has been selected. The last step is the development of the final design using appropriate design standards. (O'Flaherty, 1997)

It is explained that traffic data collection for design purposes normally include peak period traffic volumes, turning movements and composition for the design year, vehicle operating speeds on intersecting roads, movement of pedestrians and cyclists, public transport requirements, accident experience, parking practices and special needs of oversize vehicles. (O'Flaherty, 1997)

For the site data it should be included topography, land usage, and drainage and related physical features, public and private utility services, horizontal and vertical alignments of intersecting roads, and adjacent necessary accesses (O'Flaherty, 1997).

More recently, O'Flaherty (1997) has issued guidelines for intersection design stated below:

- Minimizing the carriageway area where conflicts can occur
- Reduce points of conflicts
- Traffic streams should merge/diverge at flat angles and cross at right angles
- Encourage low vehicle speeds on the approaches to right-angle intersections
- Decelerating or stopping vehicles should be removed from the through traffic stream
- Favor high-priority traffic movements
- Discourage undesirable traffic movements
- Provide refuges for vulnerable road users
- Provide reference markers for road users

- Control access in the vicinity of an intersection
- Provide good safe locations for the installation of traffic control devices
- Provide advance warning of change
- Illuminate intersections where possible

2.2 Volume studies and characteristics

According to Roess et al (2004), a traffic engineer must have in mind for designing purposes, what are the reasons for designing a road or an intersection i.e. either the road will be used for public or for industrial use. It is quite necessary to understand the traveller's demand of using any road or intersection.

Moreover, important things while designing intersection are volume studies, speed studies, travel-time studies, delay studies, accident studies, density studies and calibration studies. Under the heading of volume studies more focus has been given to volume characteristics. Roess et.al (2004) found in their research that important things under volume characteristics are volume, rate of flow, demand and capacity.

2.2.1 Volume calculation periods

Any intersection should be designed considering peak hour conditions. During weekdays peak hours usually are from 7am to 10am in the morning. In the evening, the range is usually between 4pm to 7pm. (Roesset.al, 2004)

Figure 2.3 illustrates the percentage of daily traffic on different rural routes in different days of a week.

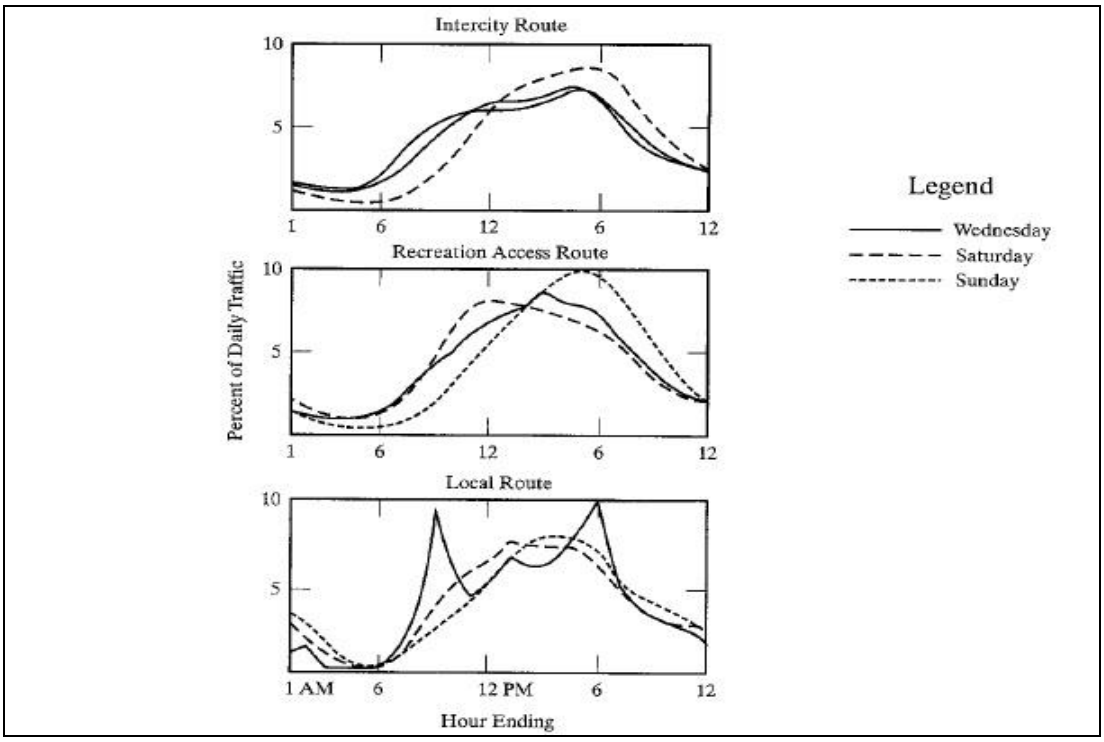


Figure 2.3 Variation for rural typical routes has been shown during different days of a week (Roess et.al, 2004).

From figure 2.3, gradual rise can be observed during hours 7am until 3pm for all three days shown (i.e. Wednesday, Saturday and Sunday). After attaining peak position at hour 6pm for curve representing Saturday graph started plunging down. This indicates maximum activities on Saturday are around 6pm.Curves shown in graph represents that intercity routes are being used at their peaks during hours 12pm to 6pm during three different days representing maximum activities having some fluctuation during the week days. In the hour ending graph peak hours for routine days show that maximum traffic at local route is at 9am in morning and 6pm in evening.

Similarly, daily variation in traffic in various hours can be seen below in Figure 2.4.

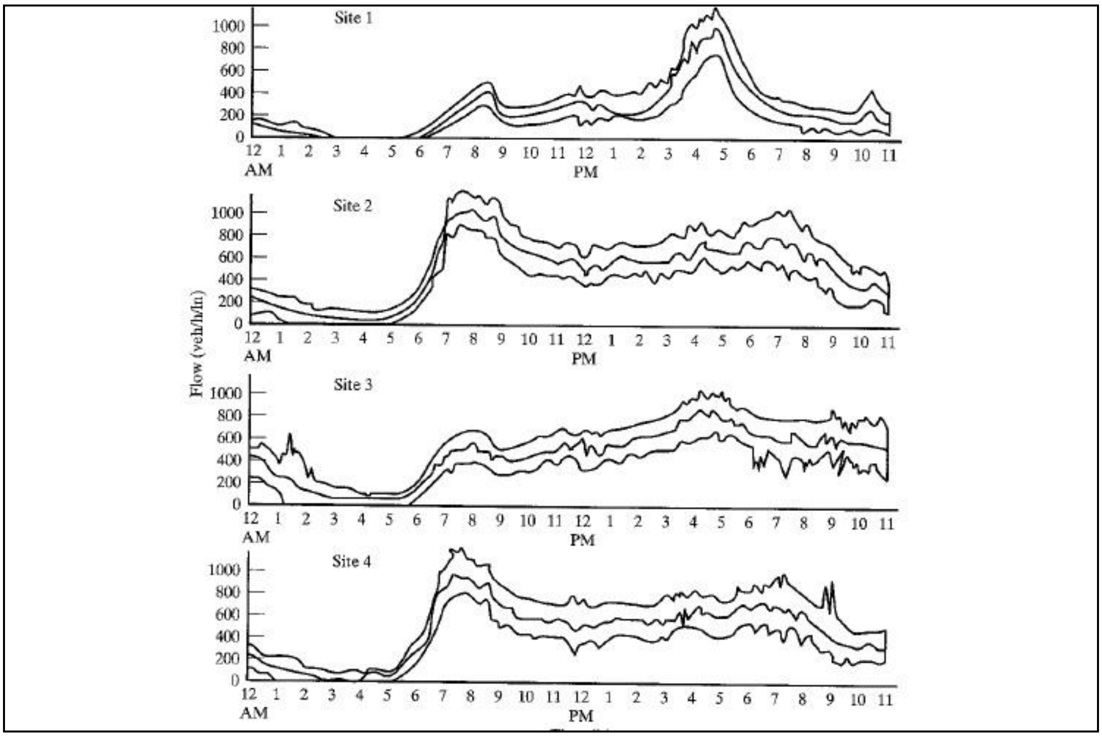


Figure2.4 Variation in traffic during different hours in a day (Roess et.al, 2004)

From figure 2.4, it can be observed that peak hours during the week days are from 7am to 9 am in the morning and in the evening, the peak hours are from 4pm to 7pm. The reason could be people going to offices and schools in the morning and in the evening returning to their homes. In addition, it is also explained that geographical conditions, weather conditions are also important factors responsible for traffic variation in volumes. (Roess et al, 2004). It can be seen in Figure 2.5.

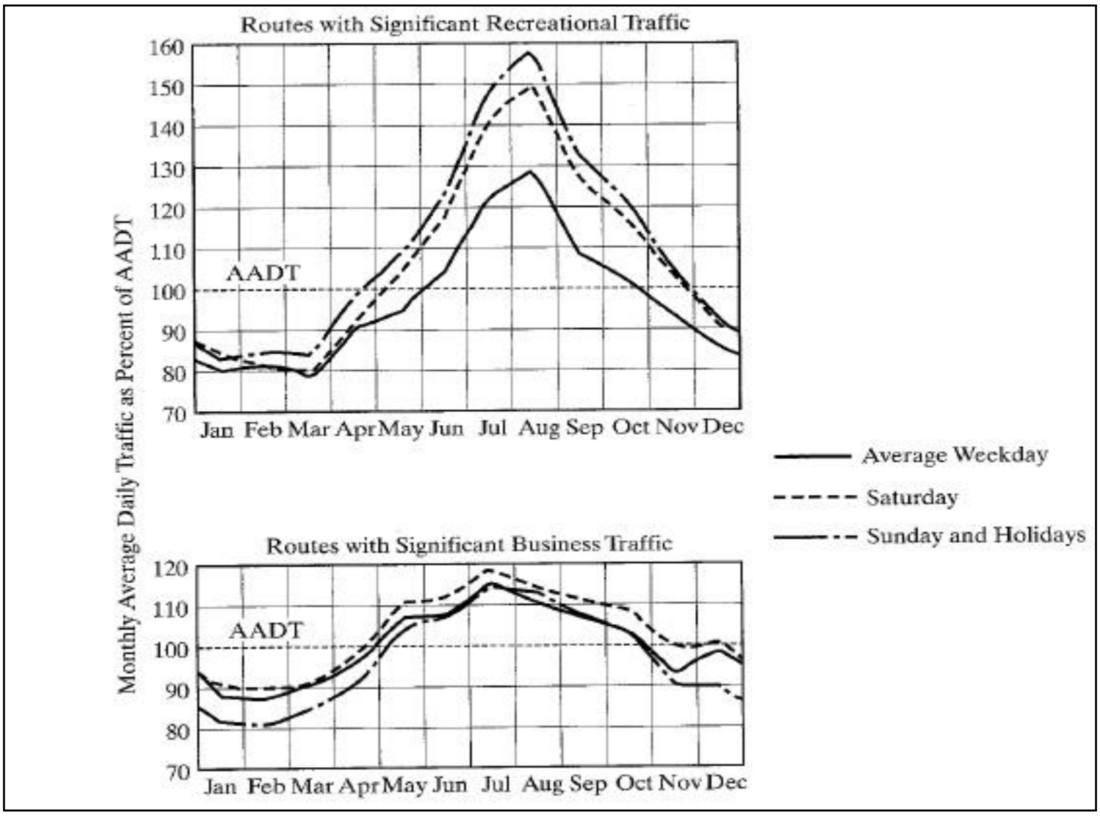


Figure 2.5 Illustration of monthly variation in traffic as percent of AADT (Roess et al., 2004)

The curve shown above for AADT maximum plateau can be observed for the month of August. So, indicating peak trend in traffic during a year in month of August. So, AADT it can be concluded that any intersection or road can be designed considering months of July and August, with maximum activities going on.

2.2.2 Techniques for volume studies

Further research in the continuation of above explains many techniques for volume studies in the field. There are three different ways of counting traffic volumes mentioned below. (Roess et al., 2004)

- Manually counted techniques
- Portable count techniques
- Permanent counts

For manual counters the simplest one is mechanical hand counter. The disadvantage of manual counts is that the data is manually recorded periodically in the field(Roess et al., 2004). Moreover, it requires man hours and continuous attention of observer. Also there is high probability of human error during counting and distraction in traffic could be among another disadvantage if counting person is not quite well aware of procedure and rules.

In the case of portable techniques, the mostly used one is the pneumatic tube that is fastened across the pavements. Whenever any vehicle passes above it, a pulse is generated and can be sensed by counters attached to it. Figure 2.6a displays the installation of pneumatic portable counters and their working (Roess et al., 2004).

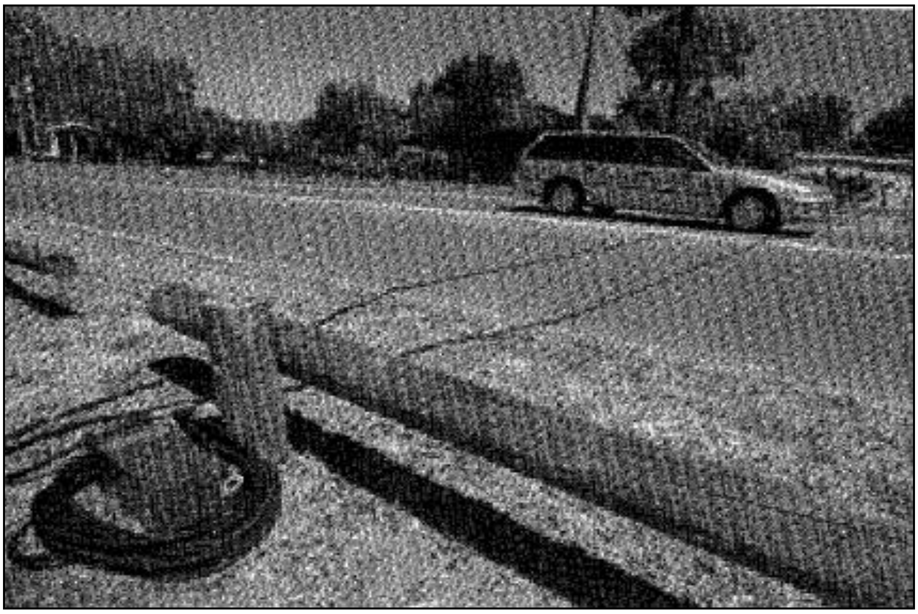


Figure 2.6a Installation pattern of pneumatic tube (Roess et.al, 2004).

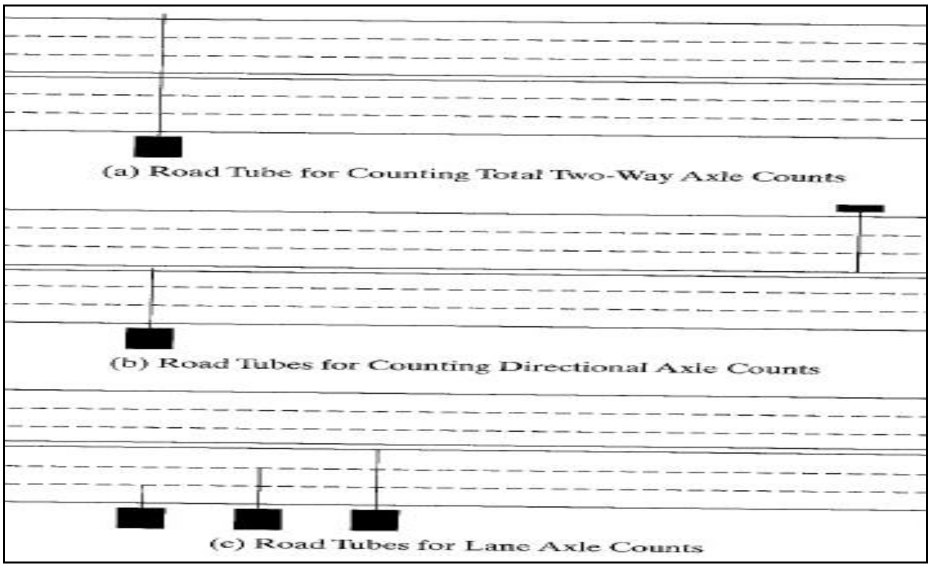


Figure 2.6b Illustration of Pneumatic tubes counting and detection for a vehicle (Roess et al., 2004).

Later research demonstrated that permanent counters are installed at different locations to count the data for 24 hours a day and 365 days. The purpose is to use the data for real time monitoring (Roess et al., 2004).

2.3 Signal control at the intersection

Traffic signals are used to regulate and control the clash between opposing directed traffic and pedestrian as well. Traffic signals are helpful to improve the junction capacity and also improve the road safety (Slinn, Matthews and Guest, 2005). On the other hand, the disadvantages of the traffic signals are longer stopped delays and complex consideration requires while making the design. Despite the fact that, the overall delay may be lesser, but a user is more concerned about the stopped delay.(IIT-Bombay, 200?)

Some common and useful terminologies related to traffic signals are; (IIT-Bombay, 200?)

Cycle	It is one complete rotation with respect to the all provided indications.
Cycle length	It is the time in seconds in which a signal control complete one cycle of indications.
Interval	It is the change from one stage to another stage. It consists of two types – change interval and clearance interval. Change interval is the interval between green and red signal indications, also called yellow time indication. Clearance interval is the interval after each yellow interval indicating a period in which all signals showing red, used to for the clearing-off the vehicles at the intersection.
Green interval	The actual turned on duration of green light.
Red interval	The actual turned on duration of red light.
Phase	It is the green interval plus the following clearance and change interval.
Lost time	It is the time during which an intersection is not effectively utilized for the movement of vehicles.

2.3.1 Signal phase design

The development of an appropriate signal phase plan is the most critical aspect of signal design. If this is done, many other steps of related to signal timing can be treated analytically in a deterministic way. (Roess et al., 2004)

The purpose of the phase design is to divide the conflicting movements in an intersection into different phases. There would be large number of phases required if all the conflicting movements need to be separate. (IIT-Bombay, 200?)

A signal design mainly consists of six major steps. (IIT-Bombay, 200?)

1) Phase design
2) Determination of amber time
3) Determination of cycle length
4) Green time allocation
5) Pedestrian crossing requirement
6) Performance evaluation of the design

The design methodology of the phases can be guided by the geometry of the intersection, traffic flow pattern especially the turning movements, the relative magnitude of flow. As there is no precise methodology for designing the phases, a trial and error method by choosing these parameters often adopted. (IIT-Bombay, 200?)

2.3.2 Actuated signal control

Pre-timed signal controllers have uniform phase sequence, cycle length and all interval timings and remain constant from cycle to cycle. In this situation, each signal cycle is exact replica of the other signal cycle. On the other hand, actuated signal control utilizes the current information of traffic flow, received from the detectors within the intersection, and each signal cycle may be different from the other. It is assisted to fulfil the current demand of traffic signal. The actuated traffic controllers can range from semi-actuated, to full actuated and to volume-density control. (Roess et al., 2004)

Al-Mudhaffar (2006) states that in Sweden, some form of vehicle actuated control is applied at virtually all isolated intersection because of its flexibility to short term traffic variations. However, vehicle actuated control requires to proper installation of detectors in all the way/approaches for the purpose of detection of vehicle presence.

Actuated signal controllers may be design by selecting; (Roess et al., 2004)

- Variable phase sequences
- Variable green times for each phase
- Variable cycle length

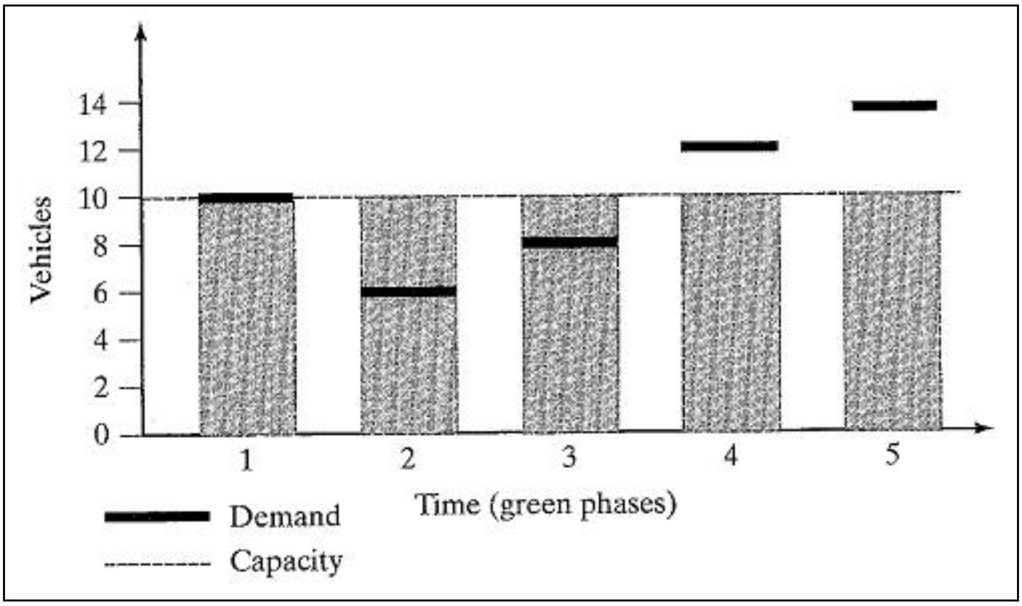


Figure 2.7 Variation in arrival demand of a signalized intersection (Roess et al.,2004)

There are five consecutive cycles shown in Figure 2.7, it is important to note that the signal has the discharging capacity of 50 vehicles and the total demand during the five cycles is also 50 vehicles. As a result of this, over the five cycles as shown, total demand equals to the total capacity. (Roess et al., 2004)

2.3.3 Detectors

Traffic detectors are primary instrument for actuated signal controllers as they transmit the data in to the local intersection controller in order to achieve the motorized and non-motorized traffic demand. The traffic controller is then display the appropriate signal indications according to the data which is received by detectors.

There are various types of detectors usually selected according to the operational requirements and physical layout of the area to be detectorized. (Kell and Fullerton, 1998)

The operating mode refers to the principles on behalf of detectors' noticing the motorized and non-motorized traffic. The mode affects the duration of the actuation submitted to the controller by the detection unit. There are two modes commonly applied as discussed below; (FHWA, 2008)

Pulse mode

By the selection of this mode, the detector will detects the passage of a vehicle by motion only (point detection). A short “on” pulse of 0.1-0.15 seconds duration sent to the controller. Actuation will start with the arrival of vehicle in the detection zone and finish with end of pulse duration. (FHWA, 2008)

Presence mode

This mode is used to measure the occupancy. Actuation starts with the arrival of the vehicle to the detection zone and ends with the vehicle leaves the detection zone. Duration of the time in the presence mode depends on the detection zone length, vehicle length, and vehicle speed. This mode measures the time that a vehicle is within the detection zone and will require shorter extension or gap timing with its use. Typically, it is used with long-loop detection located at the stop-line. (FHWA, 2008)

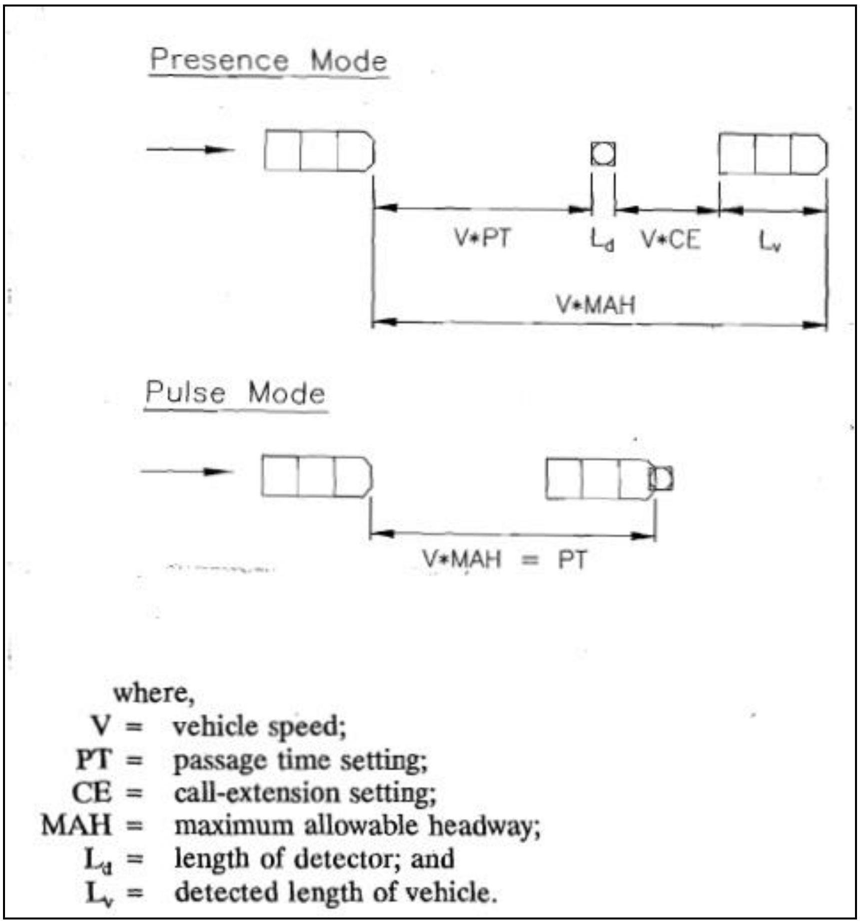


Figure 2.8 Maximum allowable headway for presence and pulse detector modes. (Bonneson and McCoy, 2005)

Location of Detectors

There are many standards have established by several agencies and department related to the effective placement of longitudinal location (setback) of detectors relative to the stop line. It should be ideal condition for detector placement that speed, type, and volume of approaching vehicles as well as the type of controller unit are considered. The detector requirements for low-speed arrivals differ from the requirements related with high-speed arrivals. (Kell and Fullerton, 1998)

An example of possible detector setbacks is expressed in Table 2.1.

Table 2.1 Safe stopping distance and detector setback (modified from Kell andFullerton, 1998)

Deceleration rate, ***d***	10 ft^2/s
Deceleration Time, ***t***	*V/d, sec*
Speed[a], ***V***	mph or ft/sec
Reaction time, ***r***	1 second
Reaction distance, ***R***	*r x V* feet
Deceleration distance, ***D***	*½ Vt* feet
Safe stopping distance, ***S***	S = *R + D* feet S = *½ Vt + r x V*

Speed[a], V(mph)	Deceleration Time, t (sec)	Reaction Distance, R (feet)	Deceleration Distance, D (feet)	Total Distance, S (feet)	Detector Setback (feet)
15	2.2	22	24.2	46.2	45
20	2.93	29.3	42.9	72.2	70
25	3.67	36.7	67.3	104.4	105
30	4.4	44	96.8	140.8	140
35	5.13	51.3	131.6	182.9	185
40	5.87	58.7	172.3	231	230
45	6.6	66	217.8	283.8	b
50	7.33	73.3	268.6	341.9	b
55	8.07	80.7	325.6	406.3	b
60	8.8	88	387.2	475.2	b
65	9.53	95.3	454.1	549.4	b

[a] Design speed or high pace speed

[b] Use multiple detectors or volume density modules

2.3.4 Dilemma zone

Dilemma zone is an area close to stop line, where there is a high potential of accident at a high speed signalized intersection. Figure 2.9 explains clear concept of dilemma zone at any signalized intersection. This is defined as *´´an area in the approach to the stop-line where a driver on seeing amber may not be able to stop in advance of the stop line with an acceptable deceleration rate, or to clear the intersection during the change interval´´*. (Al-Mudhaffar, 2006)

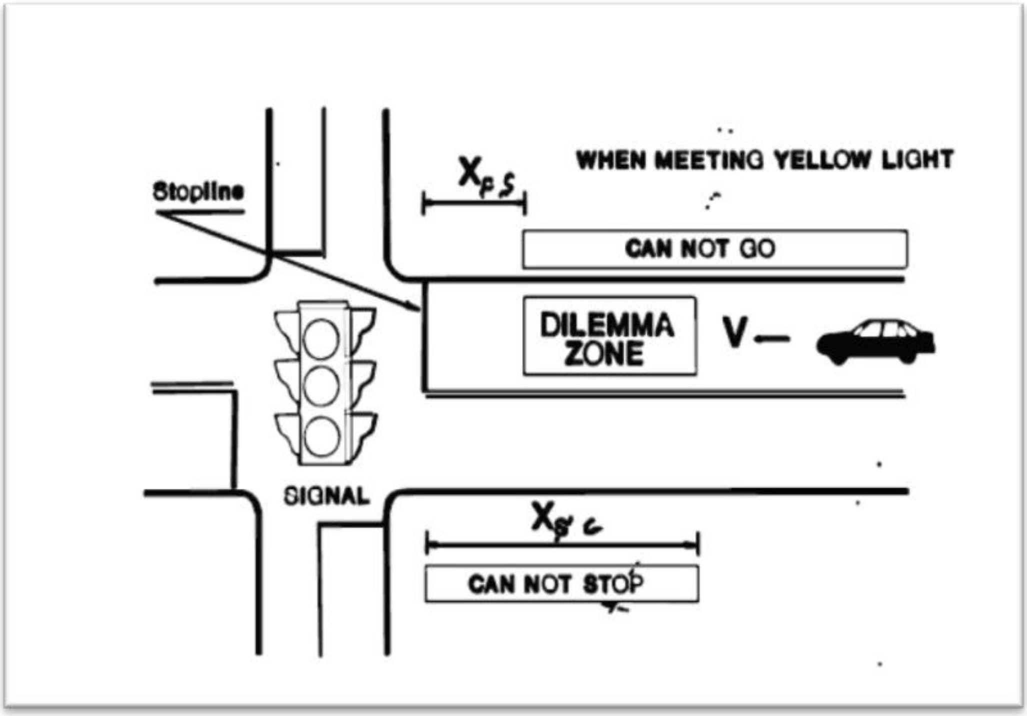


Figure 2.9 Illustration showing systematic scheme of a dilemma zone (Al-Mudhaffar, 2006).

However, in continuation with the study, the limits of the dilemma zone have been defined (Al-Mudhaffar, 2006).

$x_{max_p} \leq \tau \,.\, v_\circ$; for the maximum distance of a passing car (2.1)

$x_{min\_s} \geq \delta_2 v_\circ + \frac{v_\circ^2}{2r}$; for minimum stopping distance (2.2)

Where:

v_0 = Approaching speed in m/s

x = Approaching distance in m.

δ_2 = Reaction time for braking + time to start braking

r = Required retardation

τ = Time length of the amber light

It has been stated that dilemma zone problems can be reduced by advance signals with or without flashers and also by amber interval timings.

Moreover, it is also stated that the ranges of dilemma zone for vehicles approaching with speed of 70km/h are between 97 and 53 meters upstream of a stop line. In this case driver can proceed without red light infringement from a distance of 97m upstream of a stop line. Also he can take a decision whether to stop or not from a distance of 53m upstream of a stop line. Zone ranging from 97 to 53 meter is known as dilemma zone. (Al-Mudhaffar, 2006)

Stop distance can be thus calculated by the formula below,(Al-Mudhaffar, 2006)

Stop distance = reaction distance + deceleration distance

Figure 2.10 illustrates the concept of stop distance and dilemma zone at any intersection with vehicles approaching with a speed of 70km/h.

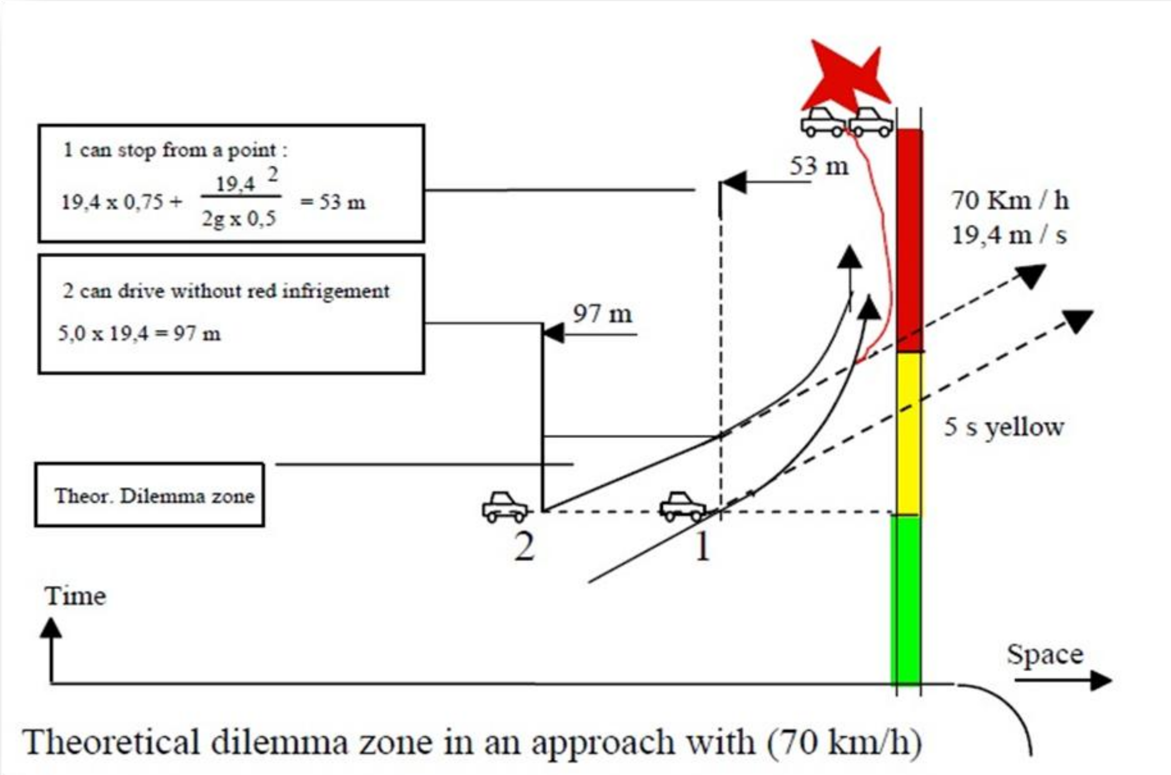


Figure 2.10 Illustration of a dilemma zone with vehicles approaching having speed of 70km/h. (Al-Mudhaffar, 2006)

2.3.5 LHOVRA technique

LHOVRA is predominant techniques used to increase safety and reduce lost time in Sweden. In the initial stage LHOVRA was implemented, during trial period accidents rate has been reduced from 0.7 accidents per million vehicle incoming to 0.5. After this successful implementation, LHOVRA technique has been widely implemented in Sweden as well as in other Scandinavian countries; first with speed limit of 70km/h in rural areas and then also with lower speed limit of 50 km/h. (Al-Mudhaffar, 2006)

According to Al-Mudhaffar (2006) word “LHOVRA “is described below in Table 2.2,

Table 2.2 Illustration of LHOVRA acronym description (Al-Mudhaffar, 2006)

Acronym English	English Translation with Swedish meaning
L	Truck, bus priority (Lastbilprioritering)
H	Main road priority (Huvudvägprioritering)
O	Incident reduction (Olycka function)
V	Variable amber time (Variabelgul)
R	Red driving control, variable red time (Rödkörning control)
A	All red turning (Allrödvänding)

Implementation of LHOVRA signals and their locations at any intersection are shown in Figure 2.11.

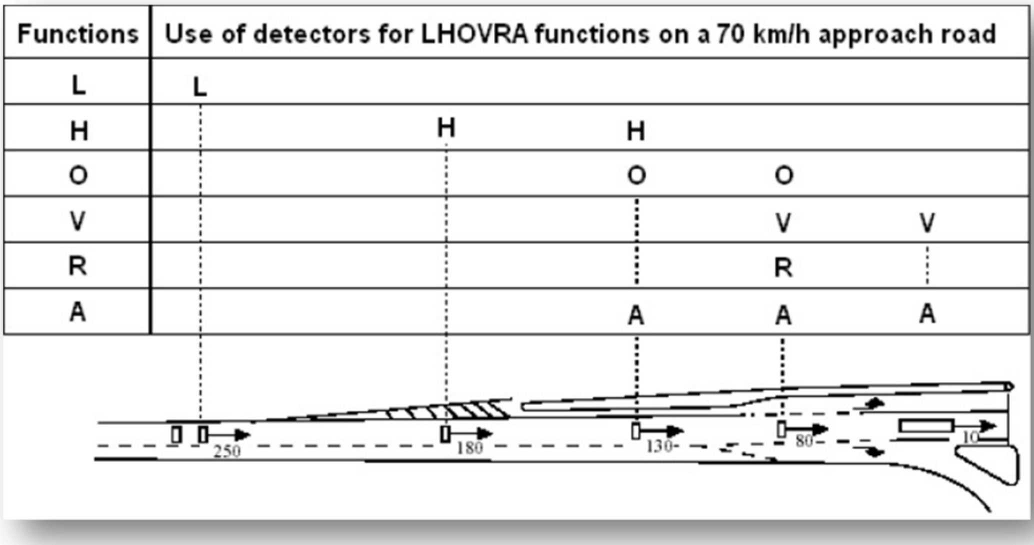


Figure 2.11 Illustration of detectors for LHOVRA functions and specific locations for their implementation. (Al-Mudhaffar, 2006)

LHOVRA functions are described below,

L function

L-function is used where truck priority is required on any primary road. One of the disadvantages is far away installation of detectors which makes it much costly/expensive (Al-Mudhaffar, 2006).

H function

H-Function is used on major as well as on primary roads that requires any priority. It takes primary roads as priority ones. In this function disadvantage is not consideration of safety aspects. (Al-Mudhaffar, 2006)

O function

O-function is normally used function. Difficult aspect of O function is the determination of practical dilemma zone. Determination of practical dilemma zone is important, as it should allow the last extending vehicle to pass through before lights turn red. (Al-Mudhaffar, 2006)

V function

V-functions are used at sub roads/links having maximum speed limit of 50km/h. In V function detectors are installed at 80 m distance. (Al-Mudhaffar, 2006)

R function

Using R function alone is quite risky, so R function is used combined with O function. This function allows some of vehicles to pass through red signal with minimum chances of collision (Al-Mudhaffar, 2006).

Figure 2.12 illustrates the working of R function along with O function at a signal.

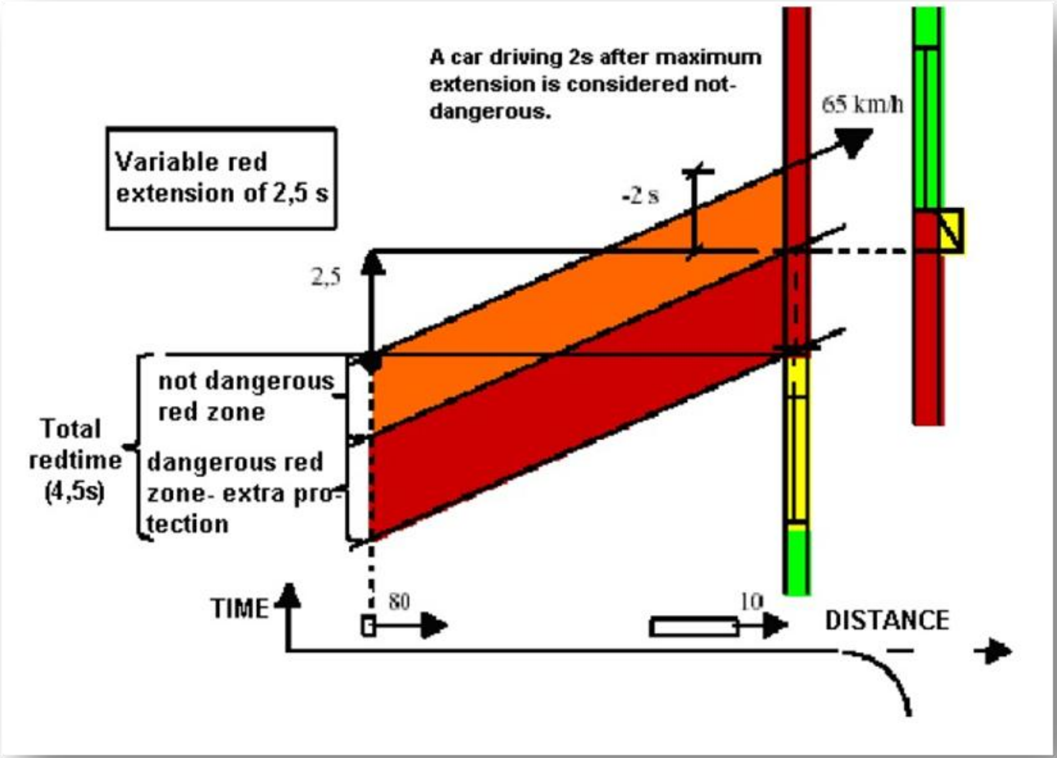


Figure 2.12 Illustration of R function along with O function on a signal (Al-Mudhaffar, 2006).

In Figure 2.12, a variable red extension is about 2.5s. It means that a car driving 2s after maximum extension is considered not dangerous and minimum possibility of collision exists in this scenario/region.

A function

Al-Mudhaffar (2006), defines A-function as,

"*This function aims to reduce as far as possible the number of instantaneous green-amber–red-green cycles and to ensure that the approaching vehicle is far enough away if they occur*".

The purpose of A-function is to detect following vehicles in system and avoid unnecessary changes also reduce stress on the drivers mainly before red signals occurrence (Al-Mudhaffar, 2006).

The research has also defined that the data required for the implementation of LHOVRA techniques in VISSIM simulation are summarized as: (Al-Mudhaffar, 2006)

- Car following model parameters,
- Stop distance at the stop line,
- Acceleration and retardation,
- Probability to drive or stop at change from green to amber,

- ➢ Arriving traffic generation (time gap),
- ➢ Flow and turning flows through the time,
- ➢ Traffic composition,
- ➢ Queue length,
- ➢ Lane distribution,
- ➢ Saturation Flow

2.4 Performance measures

Performance measures in traffic engineering planning and design generally termed as the parameters which are used to evaluate the effectiveness of design. There are many parameters involved in this evaluation but most common parameters are delay, queuing and stops. (IIT-Bombay, 200?)

In general, performance measures are used to evaluate the different alternative effectiveness on the basis of program objective. These measures are mostly applied to quantifying an objective; however they can be measured in less quantitative way. Public feedback and responder observation have been used as qualitative performance measures by measures. (Kutz, 2003)

Delay is generally focused to extra or additional travel time which is experienced by driver, or pedestrian. It is the time which is consumed during the traversing of intersection. Figure 2.13 explained this phenomena by consider one vehicle. (IIT-Bombay, 200?)

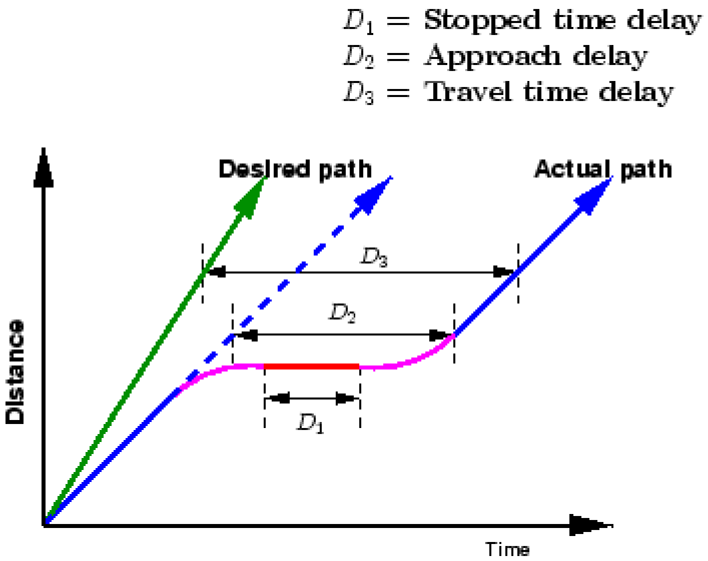


Figure 2.13 Illustration of delay measures (IIT-Bombay, 200?).

Queue is another parameter used the performance measures in traffic planning and design. It is a line of motorized or non-motorized traffic waiting to be served by a phase in which flow rate from front of the queue determines the average speed within the queue. However a faster-moving queue usually referred as platoon or moving queue. (FHWA, 2008)

Stop is however the third parameter used to measure the performance in traffic planning and design. There are two main reasons to show its importance, as discussed below (FHWA, 2008);

- Stops have greater impact on emission than Delay does because an accelerating vehicle emits more pollutants and utilizes more fuel than an idle vehicle.

- Motorists are usually frustrated when they have to face several stops. As Stops are referred as the measures of the quality of progression along an arterial. As a reason of this, some signal timing softwares are able to give relative importance of stops and delays through the use of weighting factors. By assigning high level of importance to stops, effectiveness on arterials will improve although the result may be as overall delay. Vehicular Stops can recurrently play a bigger role than Delay in the perception of effectiveness of signal timing plan of a network.

All the parameters can be measured by VISSIM. The software generates files having different formats when these parameters are selected before starting the simulation. The software describes these parameters a below.

2.4.1 Travel time and delays

Travel time sections comprises of start and destination cross section. These section counts the time when a vehicle travel between them. It is necessary for the measurement that the vehicles pass both cross sections. (PTV, 2011)

Delay time segments are based on one or more travel time sections. The vehicles types that are selected in delay time calculation are captured by the segments when they pass these travel time sections. (PTV, 2011)

2.4.2 Queue counters

Queue counter in VISSIM used to count the following parameters,

- Average queue length
- Maximum queue length
- Number of vehicle stops within the queue

Queue length show in the unit of not in number of vehicles. The most suitable places for queue counters are the stop lines of a signalized intersection. The counter measures the queue length of vehicles that are coming from upstream side. If there is more incoming way towards the counter, then the counter counts for each way and report the longest as the maximum queue length. Number of stops within the queue represents the number of events when a vehicle enters in the queue. (PTV, 2011)

3 Methodology

Literature chapter has revealed some of important parameters used in research for Sörreds intersection study. The VISSIM input parameters, signal control strategy and other model building functions will be discussed in this chapter.

3.1 Site description

The case study has been performed in area of Sörreds intersection. Intersection is located in industrial zone close to the vicinity of Volvo area. There is continuous flow of heavy traffic with considerable number of private and public transport. Below shown Figure 3.1 provides close view of intersection characterizing present scenario of Sörreds intersection along with number of PT stops located at site of study.

Figure 3.1 Overview of present scenario at Sörreds intersection along with PT stops (SWECO, 2011).

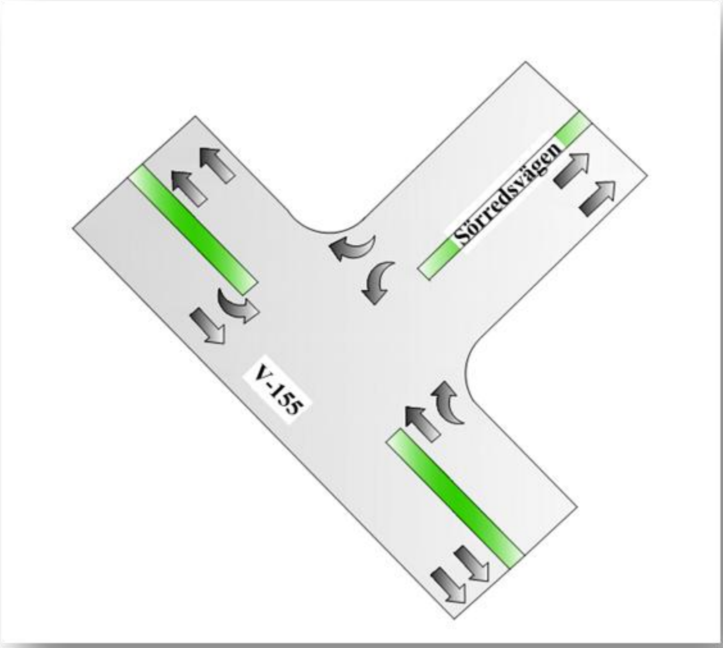


Figure 3.2 Traffic flow directions around the intersection.

Overview of Figure 3.1, illustrates that four PT-stops are located close to intersection. However, model representing the present scenario has been made considering three PT-stops namely Läg A, Läg B andLäg C. Existence of Läg D is not debated due to its minor influence to the intersection traffic. Roads linked to intersection are named as Torslandavägen or V-155, Sörredsvägen and Monteringsvägen.

3.2 Data collection methods

Site has been visited for several times during study period for data collection. Methods for collecting data are discussed below briefly;

3.2.1 Manual and video counting

Manual counting has been performed for measuring vehicle inputs at the intersection during different peak hours more specifically ranging from hours 1600 to 1900. Manual data was cross verified by means of video capturing in similar time interval. It covered various directions also the type of vehicles was individually spotted. Video counting also helped in characterizing driver behaviour. Further it can be used for later reference and other extraction of other useful data.

Attached Appendix 2A gives number of counted vehicles proceeding in different directions at the intersection. In construction of simulation model, data used for vehicle input is taken from SWECO report shown in Appendix 2B and 2C. The reason for collecting the data is just to compare the vehicle quantities given by SWECO.

3.2.2 Site drawings provided by SWECO

Site data has been extracted from AutoCAD files provided by SWECO. Some of the irrelevant data e.g. presence of vicinity constructions including buildings, was neglected. The purpose behind was to make file process-able for VISSIM as heavy files effect by slowing down the simulation process. Appendix 1A and 1B are drawing on AutoCAD used as source files for alternatives and altered accordingly for importing into VISSIM.

3.3 Use of VISSIM

Traffic simulation is a model building and analysis technique widely useful in planning, design and also assists in decision making for professionals. Traffic simulation is also becoming a major instrument in the Intelligent Transport Systems (ITS), its design and evaluation. The reason behind this is its dealing with time dependencies of traffic phenomena especially when real-time management operations are a critical feature of the system. These simulation models are also suitable tools for properly dealing with the variable traffic over time. For researchers, it is a helpful tool to get understanding of traffic phenomena and to conduct experiments in their virtual laboratories. (Barceló, 2010)

Due to modernization in Traffic studies, Traffic simulation is becoming an essential tool for traffic engineers and traffic planners. VISSIM is a microscopic, behaviour-based multi-purpose traffic simulation tool widely used to analyze and optimize traffic flows. It offers a broad range of its applications in urban and highway planning, analyzing and also for the public and private transportation as well as for pedestrian movement. Different kind of complex traffic conditions can be visualized with high level of detail supported by realistic traffic models. (Barceló, 2010).

For study purpose VISSIM version 5.30 is utilized. VISSIM is a step and behaviour based software used for modelling urban (including public and local transport operations) as well as pedestrian flows (PTV, 2011).

Visualization of VISSIM desktop window can be seen in Figure 3.3 illustrating different tools being used for development of Model.

Figure 3.3 *Overview of VISSIM desktop window and tools used for construction of model (PTV, 2011)*

3.4 Model construction

The altered AutoCAD files were imported in VISSIM 5.30, scaled according to the software interface and used as background to draw road networks. Models representing intersections for present scenario and two alternatives provided by SWECO had been drawn using VISSIM.

All roads and pedestrian way networks which were on ground supposed to be at zero level for the interface by neglecting the elevation difference. The reason behind this is to show the clearer picture of networks and to distinguishing the roads with fly over. However, gradient tool is used to change the acceleration of vehicles in the low/high regions.

3.5. Data input

3.5.1 Car following model

Car Model used in constructing VISSIM is based on WIDEMANN (1974) Theory (PTV, 2011). WIDEMANN (1974) theory is based on idea, that a vehicle with high acceleration starts decelerating as they reach in their individual perception threshold of vehicle with slow speed. After reaching another perception threshold, vehicle starts to slightly accelerate again. Since, this is iterative process of continuous acceleration and deceleration (PTV, 2011). Later on WIDEMANN (1999) approach has also been added in VISSIM latest versions. Approach adopted in WIDEMANN (1999) is the Modelling of RTI-Elements on multi-lane roads (PTV, 2011).

Example of WIDEMANN (1999) approach and different parameters and their properties are stated in Table 3.1.

Table 3.1 Different properties used in WIDEMANN (99) approach in different scenarios (PTV, 2011).

Scenario	Right-side rule	Lanes	Speed cars*	Speed HGV*	% HGV
99-1	no	2	80	n.a.	0%
99-2	no	2	80	85	15%
99-3	yes	2	80	n.a.	0%
99-4	yes	2	80	85	15%
99-5	yes	2**	120	n.a.	0%
99-6	yes	2	120	85	15%

** As defined in the VISSIM defaults*

*** Lane 2 closed to all HGV (PTV, 2011)*

From Table 3.1, it is quite clear that right hand rule is being utilized while using default settings. Speed limits are ranging from 80 to 120 mph maximum for cars. Also for HGV maximum speed limit is defined as 85 mph.

3.5.2 Technical specification of vehicles

Technical specifications of vehicles required for VISSIM model construction purpose is mentioned below. (PTV, 2011)

- Length
- Maximum speed
- Potential acceleration
- Actual position in the network
- Actual speed and acceleration

Furthermore, rail route is located as well in area of study. Hence, data required for rail track is shown below in Figure 3.4 extracted from VISSIM rail properties window;

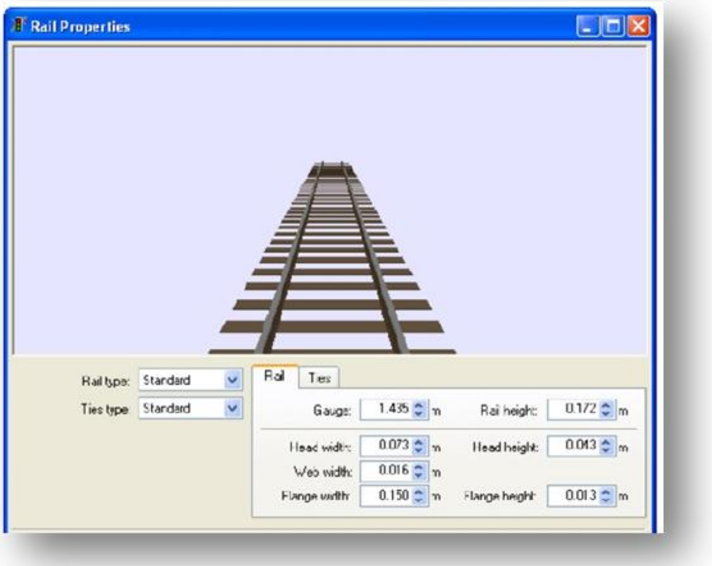


Figure 3.4 Overview of technical specifications required for rail road parameters used in VISSIM model construction (PTV, 2011).

All the parameters used for construction of rail road track for site of Sörreds intersection are standard with default values of widths and heights (i.e. gauge and rail height properties).

As there are separates lines for PT are considered in both of the alternatives, the PT-stops are created accordingly as illustrate in the alternatives drawing. There are 4 PT-stops are supposed in the alternatives around the intersection.

The model related to current traffic scenario, location of three PT stops in area needs to be defined. The PT-time table has been collected from site during different peak hours ranging from hour 1600 to 1900 and also verified it with Västtrafik schedule, PT-service provider in Gothenburg. Figure 3.5 a & b, shows VISSIM window and parameters required for allocating PT lines**.**

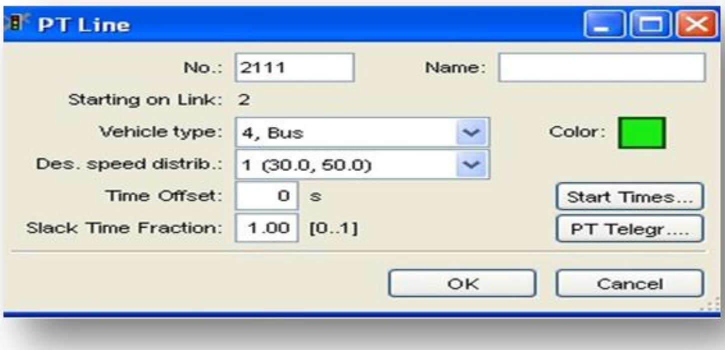


Figure 3.5a Overview of VISSIM window for PT Lines and parameters required (PTV, 2011).

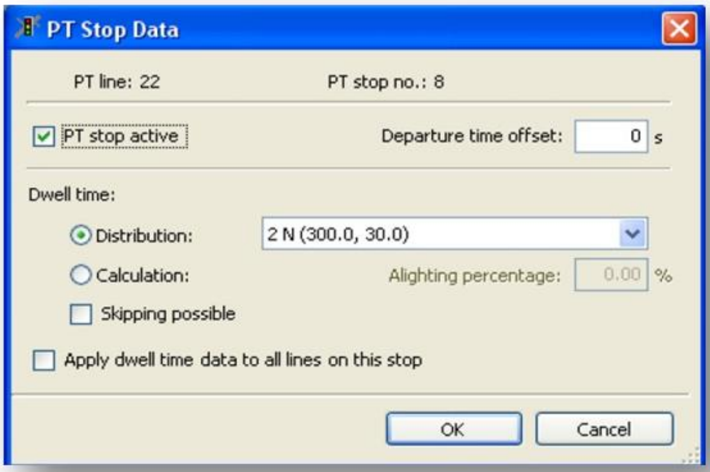


Figure 3.5b Overview of VISSIM window for PT Lines and parameters required (PTV, 2011).

3.5.3 Pedestrian data input

As the intersection also deals with pedestrian and cyclists, the routes for pedestrian and cyclists is however been created for the present scenario model. The pedestrian routes is somehow differ with the other routes (motorists) as it need a random and non-uniform movement of pedestrian, and it is also connected to the PT-stops. Pedestrian mode of the software is therefore used to build this route.

3.6 Signal timing parameters

Signal timing parameters needs to be defined while preparing the controller settings. Following parameters are important to consider in this stage. Figure 3.6 illustrates some of the parameters, which will discuss below;

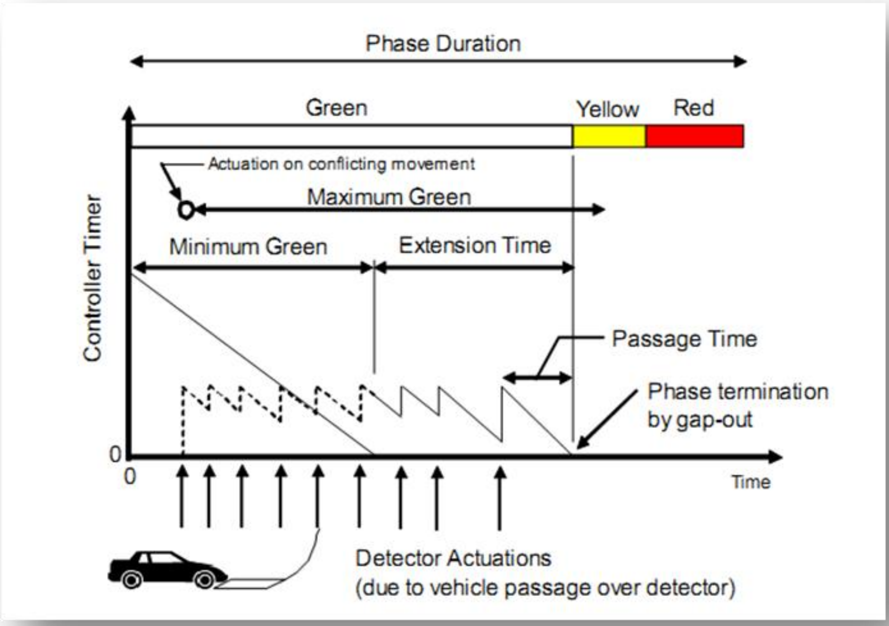


Figure 3.6 *An actuated signal phase Intervals definition. (Bonneson, Sunkari& Pratt, 2009)*

3.6.1 Minimum green time

Minimum green time must be considered for each signal phase while adopting actuated control signal control. It is usually based on type and the location of the detectors. (Roess et al., 2004)

Point or passage detector usually located to a distance *d* meters from the STOP line. If the vehicles occupies the area between the STOP line and the detector location, the minimum green time should be a long enough to clear these vehicle queue. (Roess et al., 2004)

Following expression can be used to estimate the minimum green time. (Roess et al., 2004)

$$G_{min} = l_1 + 2 * Int(\frac{d}{6.1}) \tag{3.1}$$

Where $Gmin$ = Minimum green time in seconds

l_1 = Startup lost time in seconds

d = distance between the detectors and the STOP line in meters

6.1 = Assumed head-to-head spacing between vehicles in queue, in meters.

The startup lost time ranges 2-4 seconds are often used. (Roess et al., 2004)

If the pedestrians are also present in the case, the minimum green time should be long enough for crossing time of pedestrian.

The expression is useful in this case. (HCM, 2000)

$$G_p = 3.2 + \frac{L}{S_p} + (0.27N_{ped}) \quad \text{for } W_E \leq 3.05\text{m} \tag{3.2}$$

$$G_p = 3.2 + \frac{L}{S_p} + \left(2.7\frac{N_{ped}}{W_E}\right) \quad \text{for } W_E > 3.05\text{m} \tag{3.3}$$

Where

G_p	= Minimum pedestrian green time in seconds
3.2	= Pedestrian startup time in seconds
L	= Crosswalk length in meters
S_p	= Walking speed of pedestrian crossing during an interval
W_E	= Effective crosswalk width in meters

3.6.2 Maximum green time

It is the maximum green time allowed for a green phase. A phase will adopt this time when it has sufficient demand. (Kutz, 2003)

It is a user defined parameter, local practices usually considered an important factor to determine this parameter (HCM, 2000). However a typical range is selected to define in the each signal phase of the model by considering the influence of traffic. The range is about 10-50 seconds. Site visits was also helpful to select this range.

3.6.3 Amber and amber/red time

Amber time is the time interval in which driver alerts because the signal light is going to change from green to red. In Sweden, according to the V-function of LHOVRA technique, a variable amber time is used within the limits of 3-5 seconds. The amber/red time is however set as 1 second according to the Swedish standards. (Li M. &Wo T., 2011)

3.6.4 Allowable gap

It is the time elapsed between the departure of a vehicle and arrival of the next vehicle, observed by detector. In Sweden, it is practicing that this time should be less than 5.6 seconds, according to the O-function of the LHOVRA technique. (Li M. &Wo T., 2011)

3.7 Vehicle actuated programming

VisVAP program is used to define the signal control logics by using the VAP programming language (vehicle actuated programming). It is comfortable tool to assign the signal control logics by considering the VAP language. The control logic i.e. *.pua file, is assigned first in a text file also called inter-stages file. The main logic file *.vap file is then created by using VisVAP interface.

3.8 Signal groups and signal control

The signal control is assigned to each signalized intersection in the models. Similarly, signal groups as assigned in *.pua file, are then added in VISSIM signal control, and assign it to each individual signal head as shown in drawings provided by SWECO. The *.pua and *.vap files are then imported in the signal control menu to execute the signals during simulation.

The signal control window can be seen in Figure 3.8.

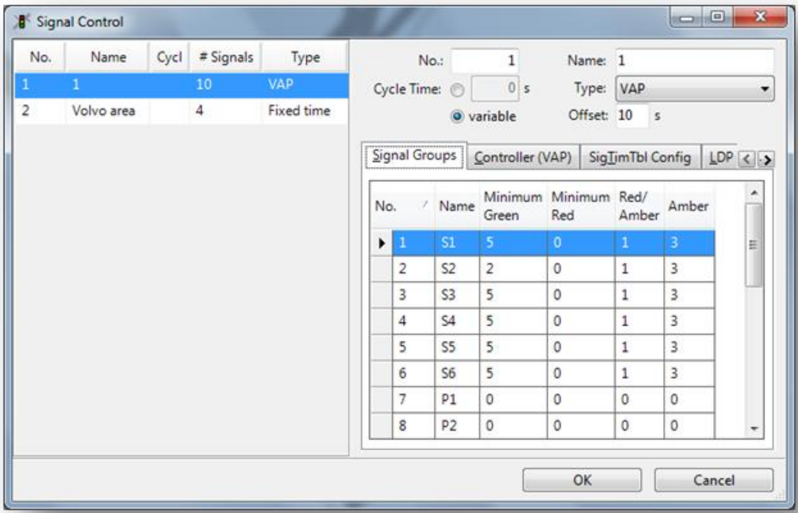


Figure 3.8 Signal control window showing signal groups.

3.9 Simulation of models

Next step is to run the simulation. In VISSIM one step or continuous simulation can be made. Also option of toggling from single step to continuous step is available. VISSIM simulation window is illustrated in Figure 3.9.

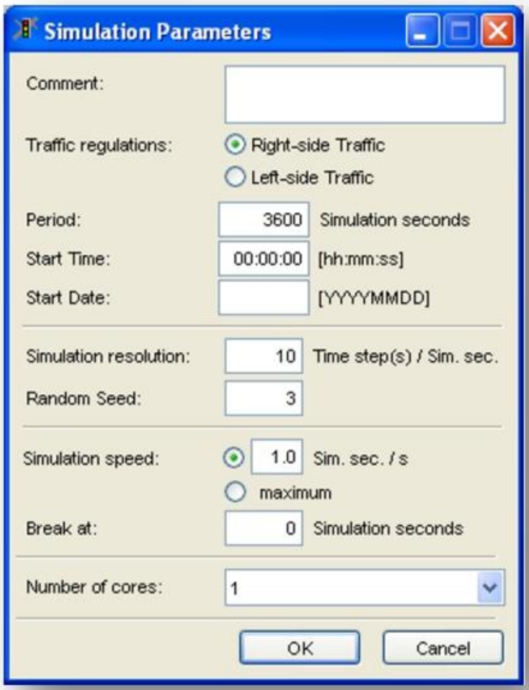


Figure 3.9 Overview of VISSIM simulation window and parameters need to be filled (PTV, 2011)

It can be seen in figure 3.9, that times used for running simulation is about 3600 seconds. Simulation speed is 1.0 sim.sec./s. in addition right hand side traffic is being utilized i.e. as practiced in Sweden.

3.10 Models representing different scenarios

Three different models are drawn discussing three different scenarios.

3.10.1 Model – Current scenario

First model discusses present scenario of Sörreds intersection. Figure 3.10 gives present scenario of Sörreds intersection.

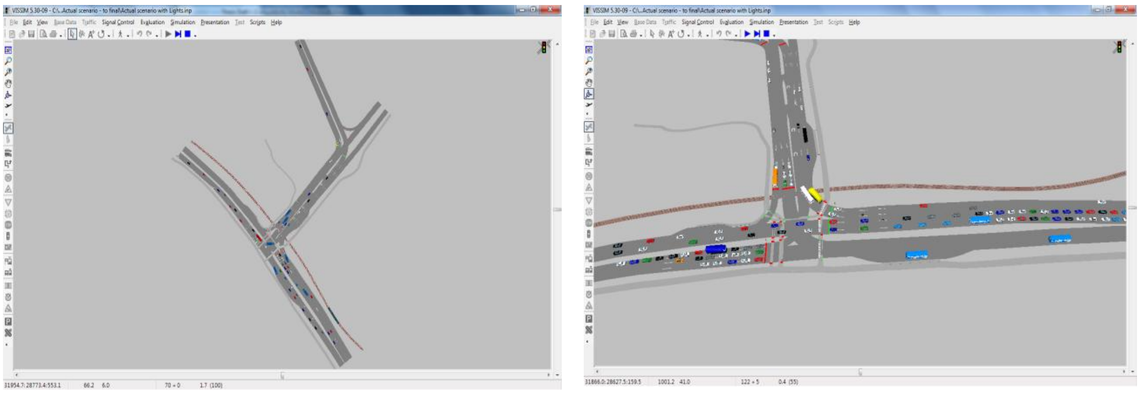


Figure 3.10 Simulation model for the current traffic scenario.

3.10.2 Model - Alternative 2

Model for alternative-2 has been created as shown in Figure 3.11. Torslandavägen proceeds under the flyover with no interruption from Sörreds link.

In the model, the roads which are on ground are located at 0m elevation while flyover maximum height is 6m regardless of elevations related to sea level. Figure 3.11 illustrates the model of alternative-2 having flyover at Sörredsvägen.

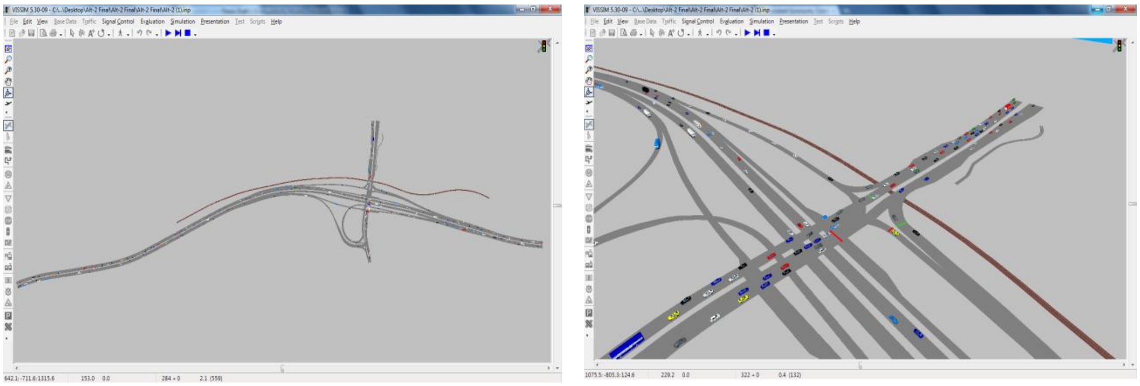


Figure 3.11 Simulation model for the Alternative-2, Sörredsvägen over the Torslandavägen.

3.10.3 Model - Alternative 3A

As discussed earlier, alternative-3A consists the flyover on Torslandavägen. Sörredsvägen is therefore will be on ground level. Elevations used in developing the model are same as used in model of alternative-2. Illustration of model of alternative-3A is presented in Figure 3.12.

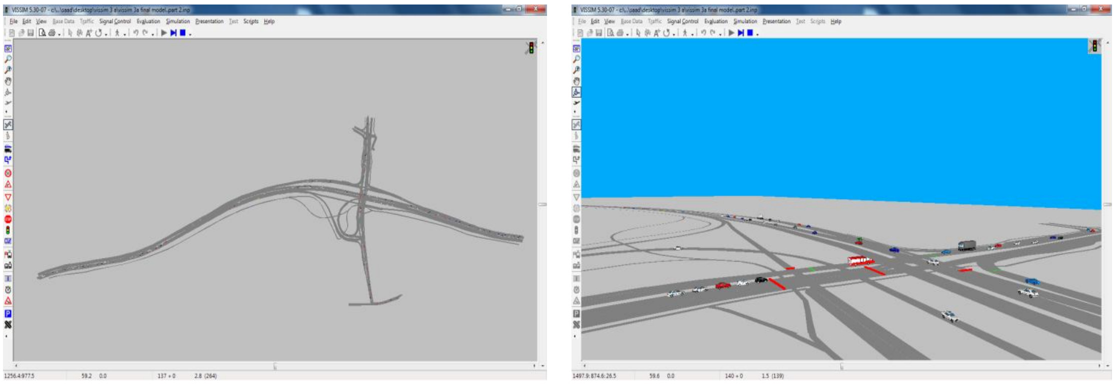


Figure 3.12 Simulation model for the Alternative-3A, Torslandavägen over the Sörredsvägen.

4 Analysis of results

The chapter includes the results based on the performance measure parameters as discussed in the previous chapter. Simulations were made for all the models representing the current scenario of intersection with present and future amount of traffic and traffic flow situation in the alternatives. The results were then generated in tabular forms as a result of one hour simulation.

It has been discussed earlier that the traffic amounts for the present situation and for the alternatives were used as provided in SWECO's report. However on the other hand, the amount of public transport is set as doubled to the present amount.

4.1 Present situation

The results for the selected parameters concerned to the traffic flow are then plotted in graphical format. Results for each traffic route are shown in a separate illustration.

4.1.1 Delays

Delay in traffic flow for each traffic route as recorded by VISSIM are plotted as illustrate below. A red horizontal line in every illustration shows the average of all delays.

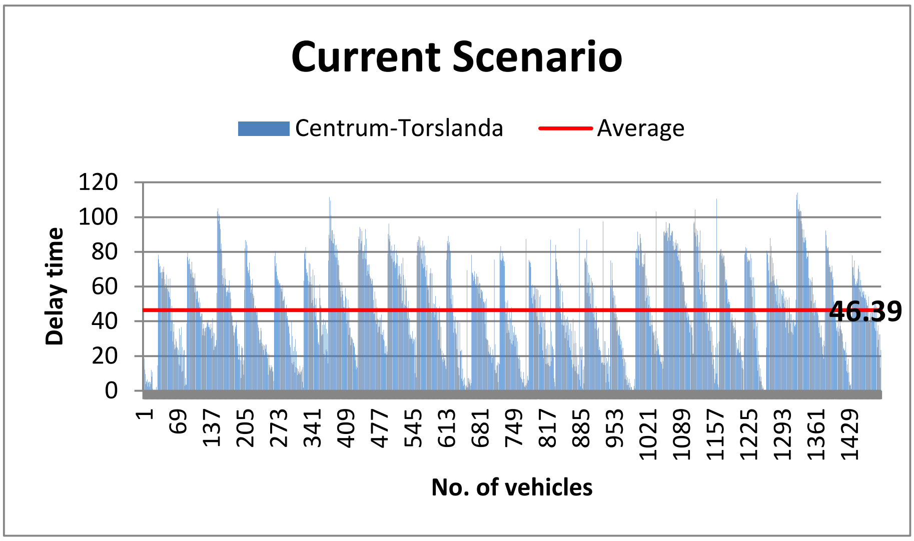


Figure 4.1 Delay times of vehicles and their average are plotted for Centrum to Torslanda route.

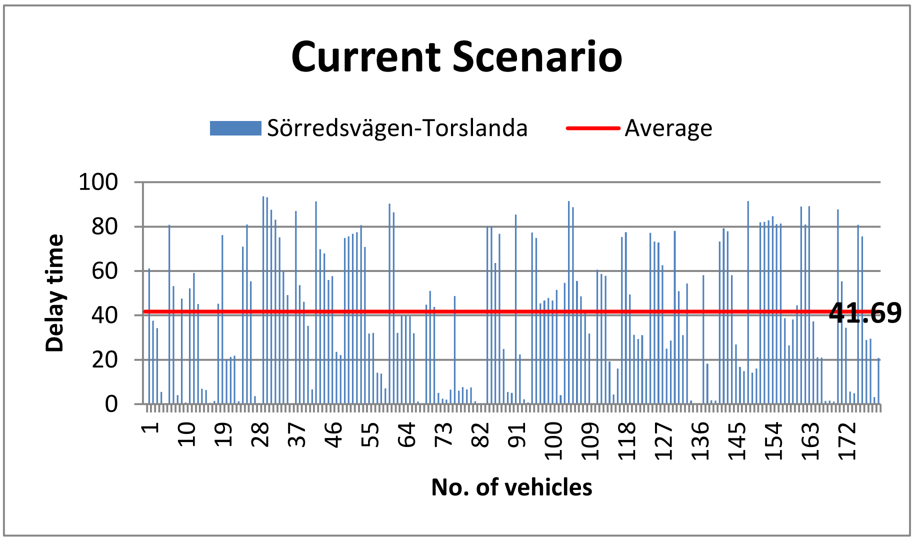


Figure 4.2 *Delay times of vehicles and their average are plotted for Sörredsvägen to Torslanda route.*

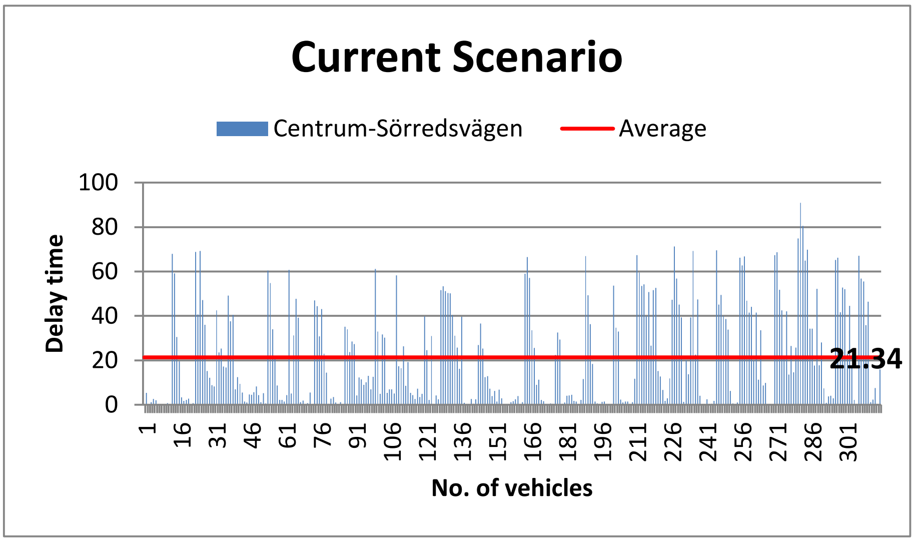


Figure 4.3 *Delay times of vehicles and their average are plotted for Centrum to Sörredsvägen route.*

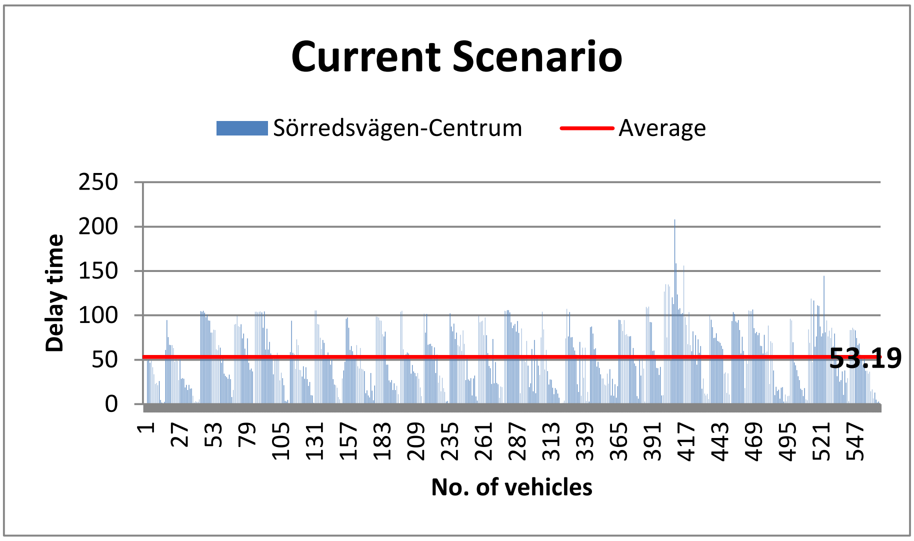


Figure 4.4 Delay times of vehicles and their average are plotted for Sörredsvägen to Centrum route.

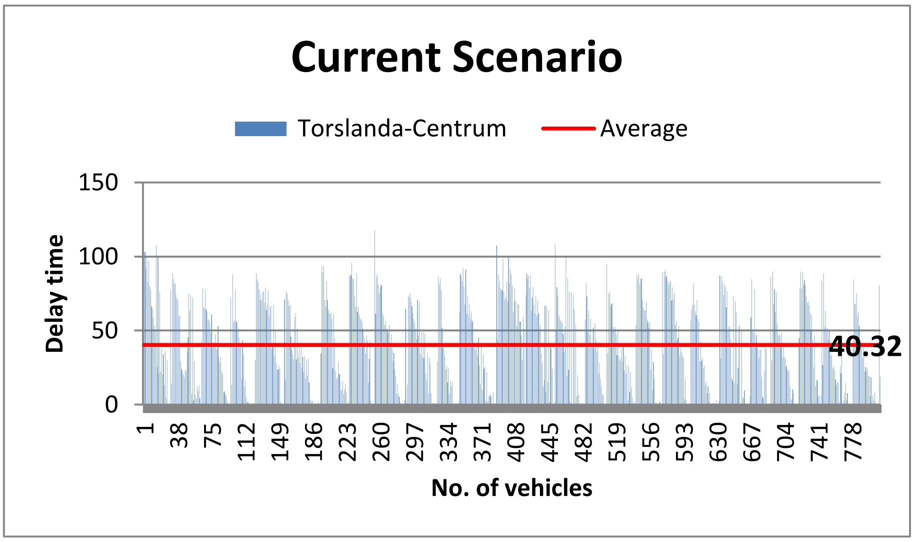


Figure 4.5 Delay times of vehicles and their average are plotted for Torslanda to Centrum route.

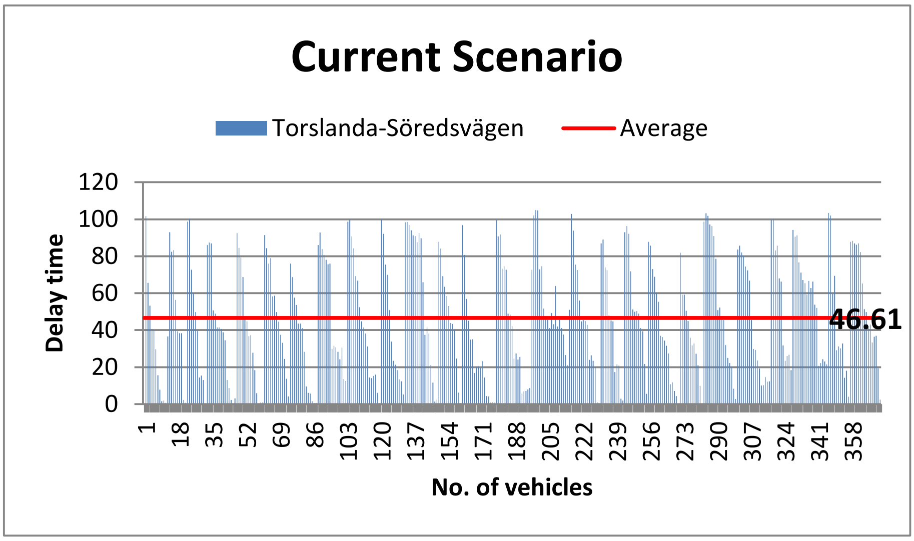


Figure 4.6 *Delay times of vehicles and their average are plotted for Torslanda to Sörredsvägen route.*

4.1.2 Travel times

Travel times for each traffic route as recorded by VISSIM are plotted as illustrate below. A red horizontal line in each illustration showing the average of all travel times.

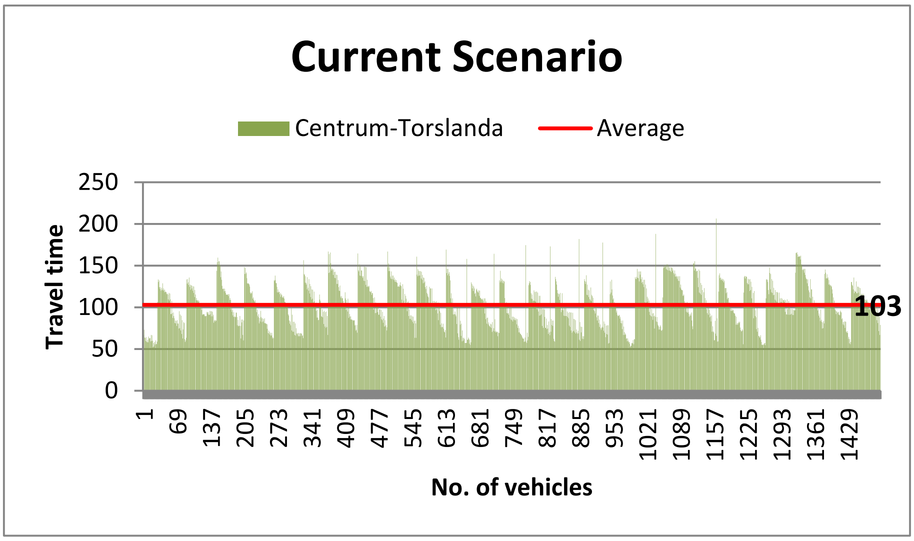


Figure 4.7 *Travel times of vehicles and their average are plotted for Centrum to Torslanda route.*

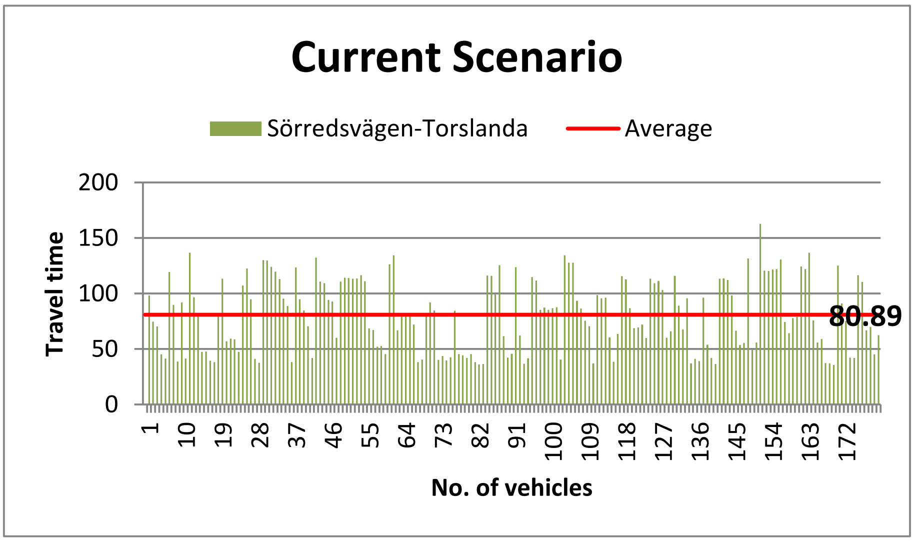


Figure 4.8 Travel times of vehicles and their average are plotted for Sörredsvägen to Torslanda route.

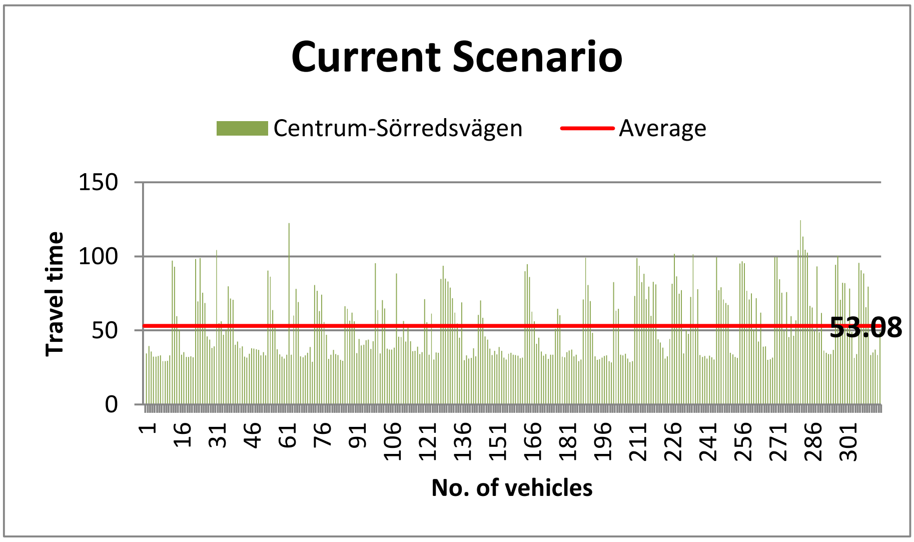


Figure 4.9 Travel times of vehicles and their average are plotted for Centrum to Sörredsvägen route.

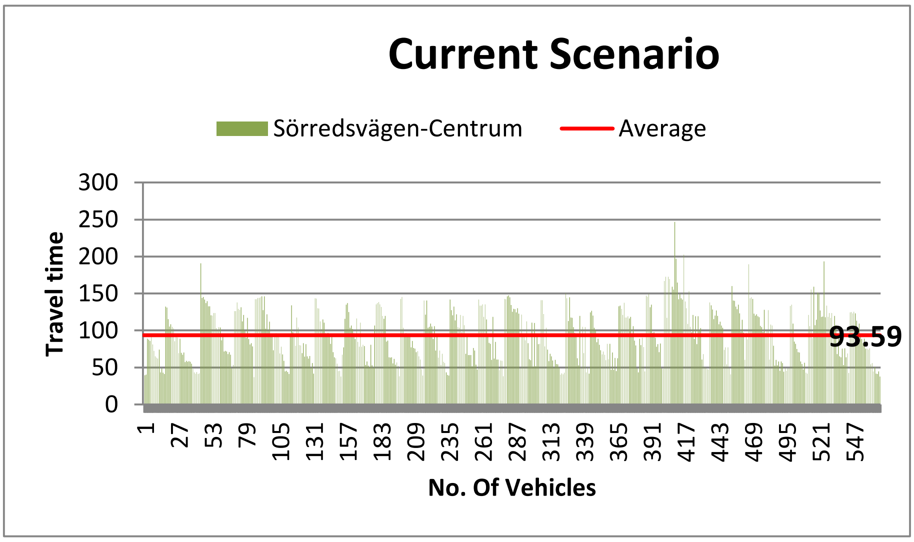


Figure 4.10 Travel times of vehicles and their average are plotted for Sörredsvägen to Centrum route.

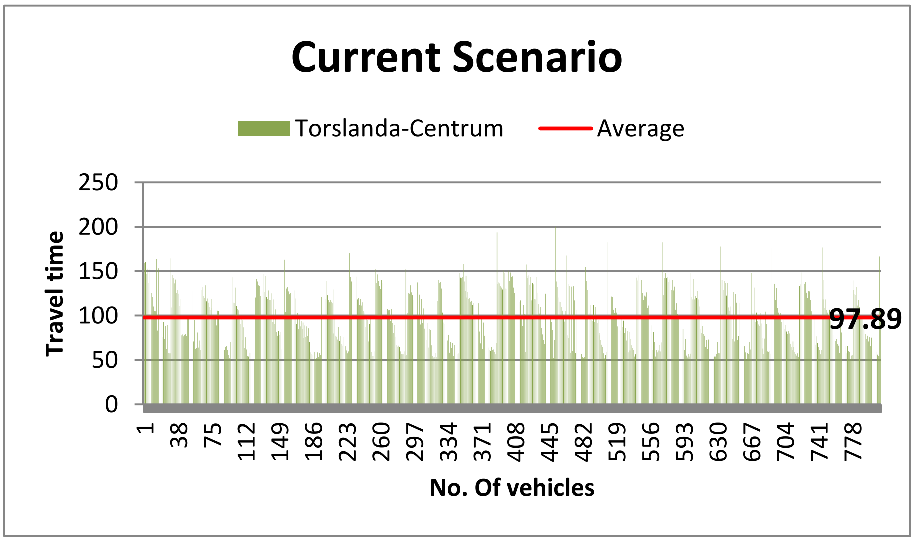


Figure 4.11 Travel times of vehicles and their average are plotted for Torslanda to Centrum route.

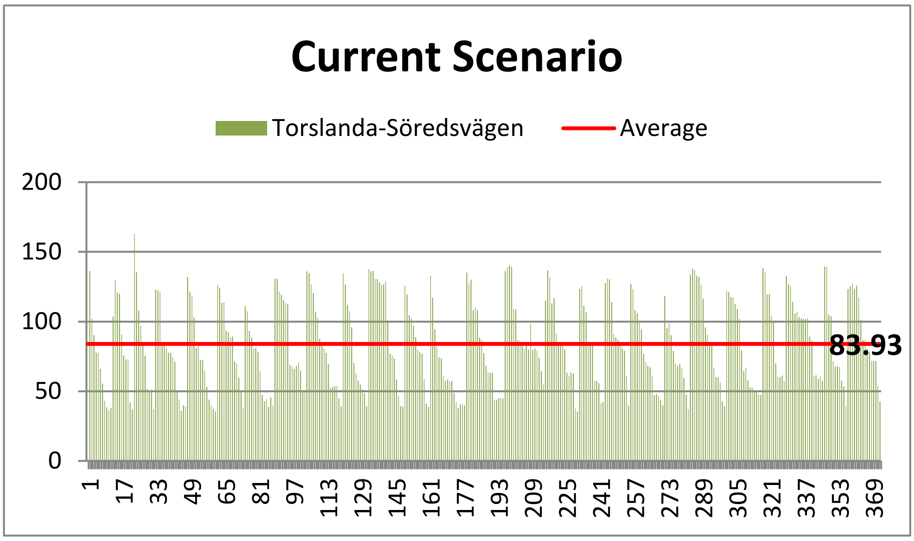


Figure 4.12 *Travel times of vehicles and their average are plotted for Torslanda to Sörredsvägen route.*

4.1.3 Queue record

The average and maximum values of the queue generated around the intersection and the number of stops are presented below.

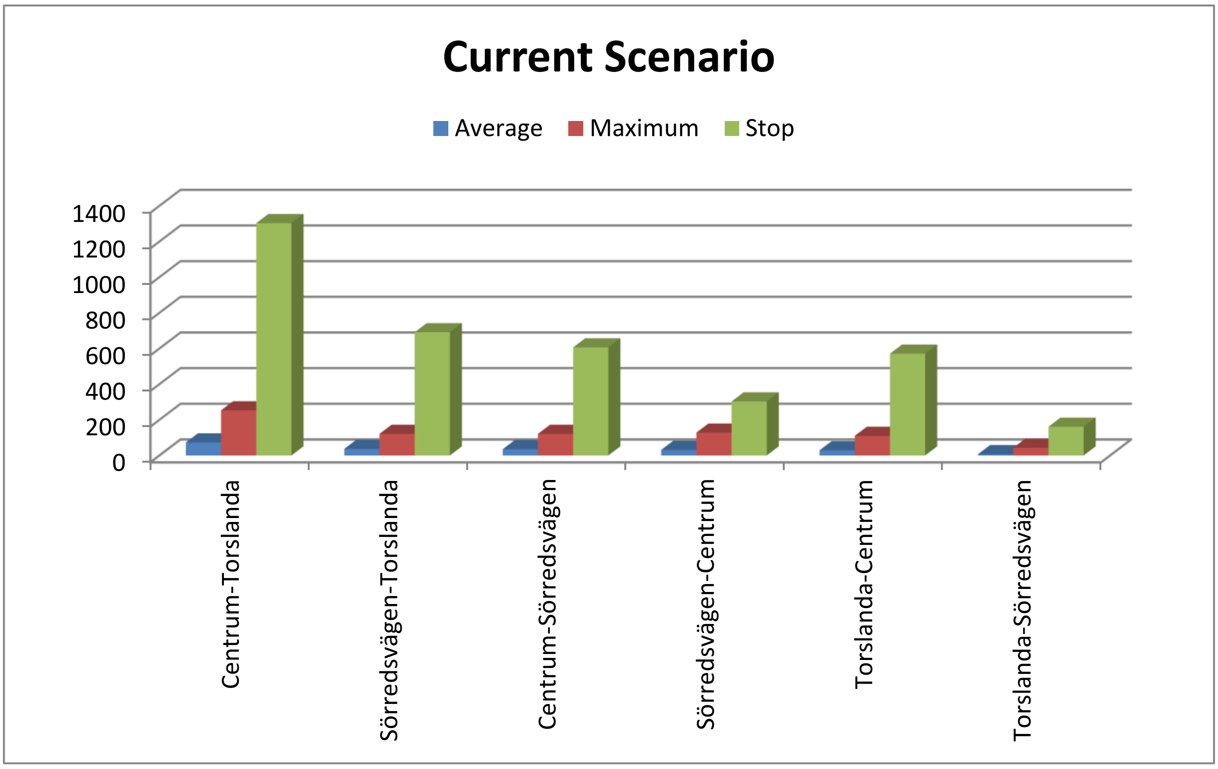


Figure 4.13 *Traffic queue values with their respective junction.*

4.2 Present situation with future traffic inputs

Developed model of Sörreds Intersection was checked for future vehicular input for year 2035 shown in Appendix 2C. As a result of this, a grid lock situation werecreated in the model and more than 2000 vehicles could not enter in the model due to the long queues and stops of vehicles.

However a comparison is made to represent this situation with the current flow of traffic.

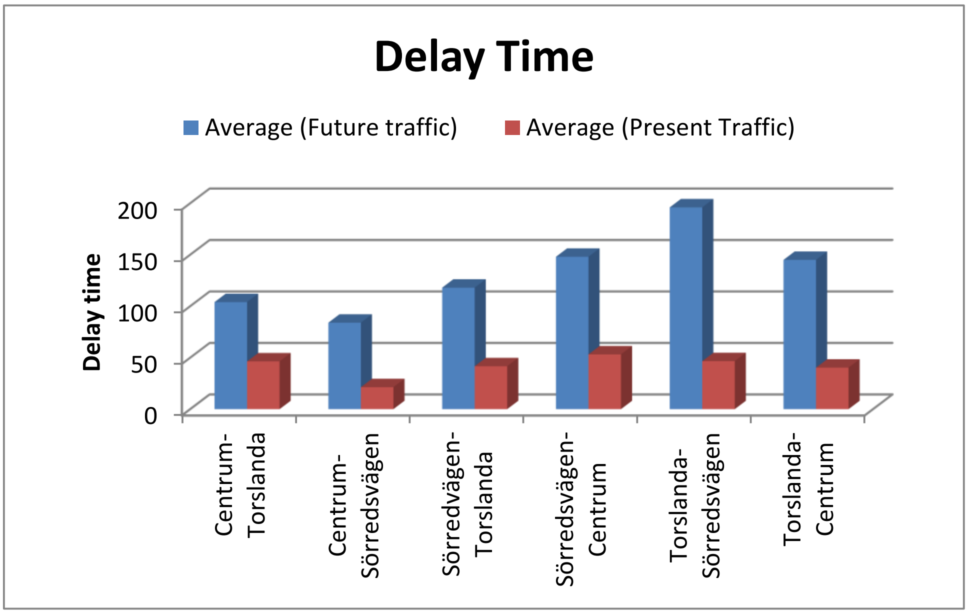


Figure 4.14 Comparison in Delay timing considering the present and future amount of traffic.

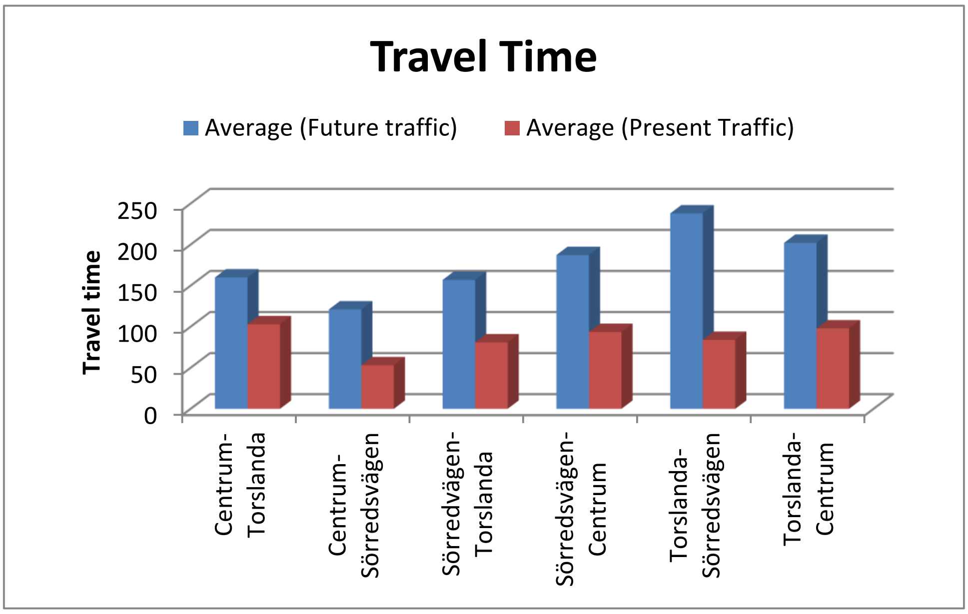


Figure 4.15 Comparison in Travel timing considering the present and future amount of traffic.

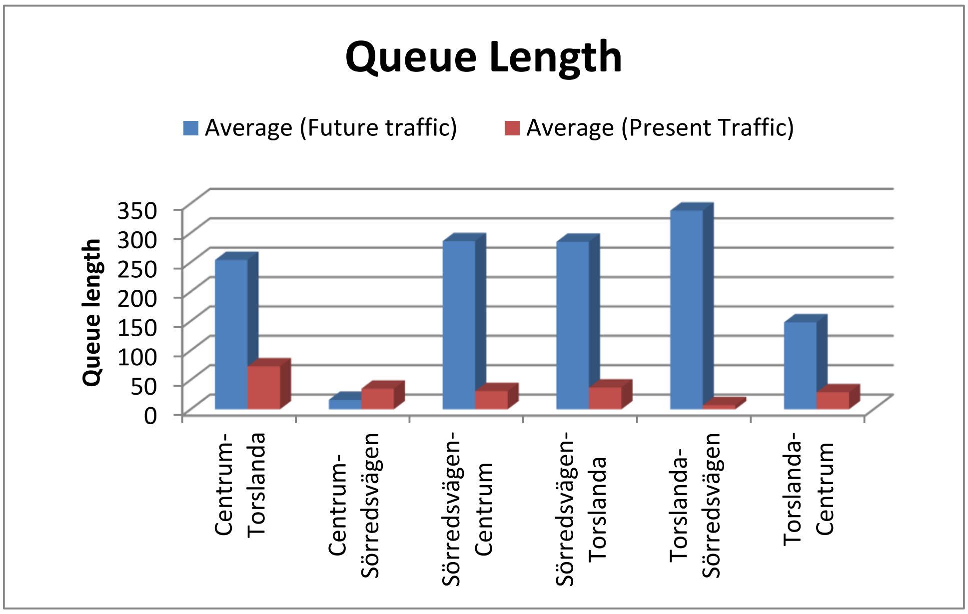


Figure 4.16 Average queue length comparisons by considering the present and future amount of traffic.

4.3 Alternative 2

Alternative-2 model was simulated in VISSIM and to get following results for analysis.

4.3.1 Delays

Delay in traffic flow for each traffic route that recorded by VISSIM are plotted as illustrated below. A red horizontal line in each illustration showing the average of all delay times

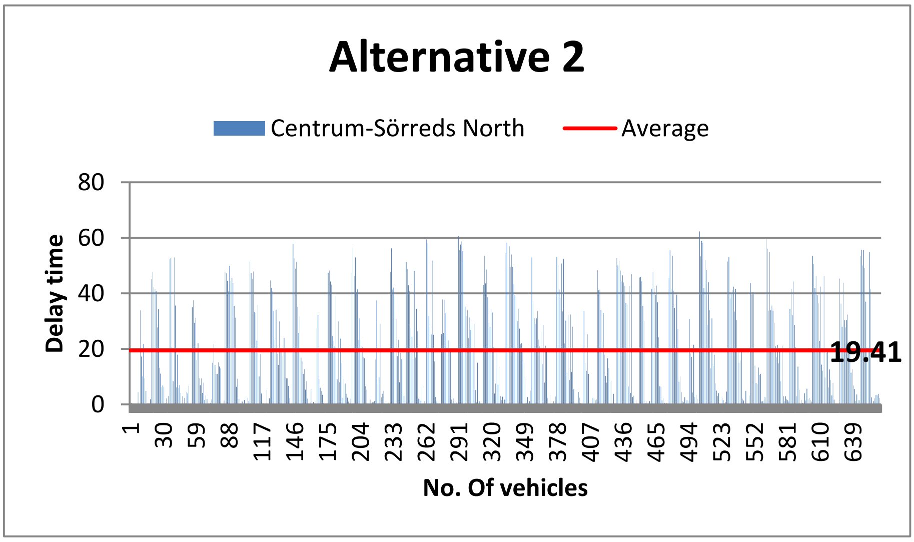


Figure 4.17 Delay times of vehicles and their average are plotted for Centrum to Sörreds North route.

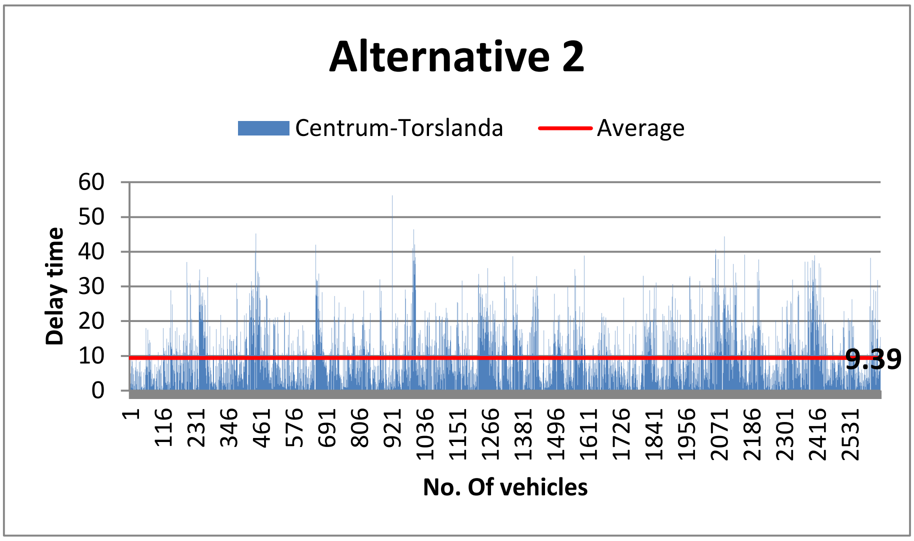


Figure 4.18 Delay times of vehicles and their average are plotted for Centrum to Torslanda route.

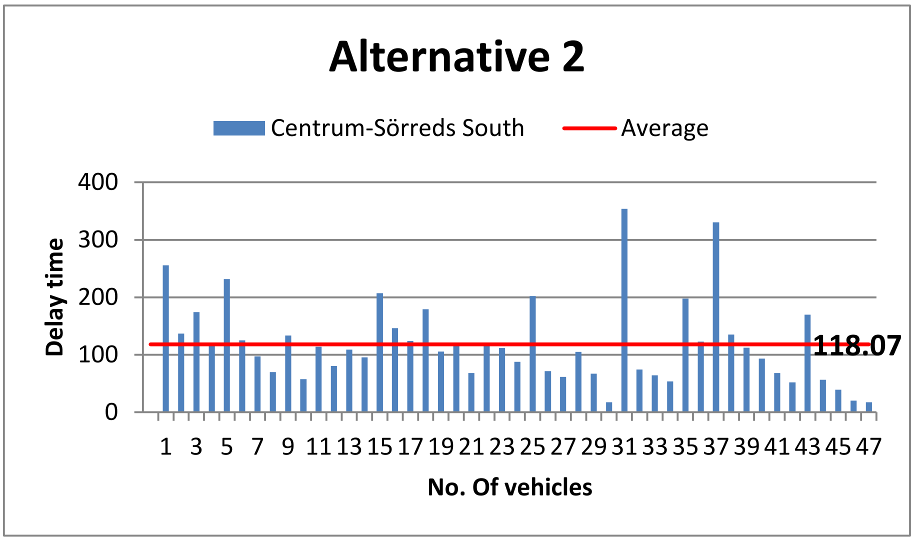


Figure 4.19 Delay times of vehicles and their average are plotted for Centrum to Sörreds South route.

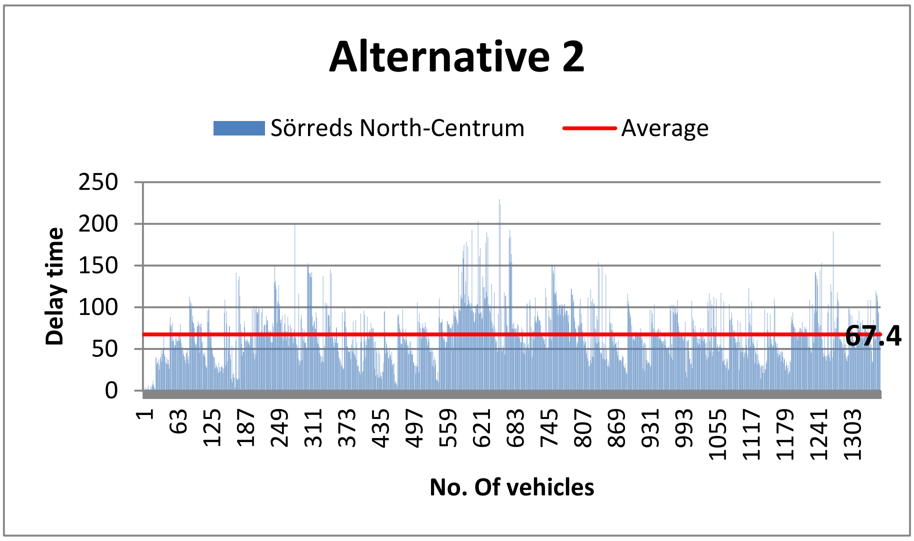


Figure 4.20 *Delay times of vehicles and their average are plotted for Sörreds North to Centrum route.*

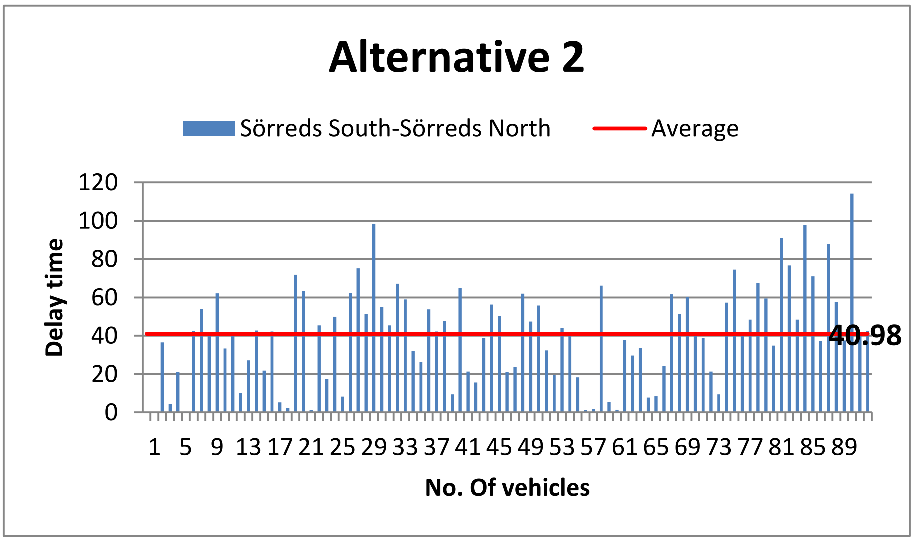


Figure 4.21 *Delay times of vehicles and their average are plotted for Sörreds South to Sörreds North route.*

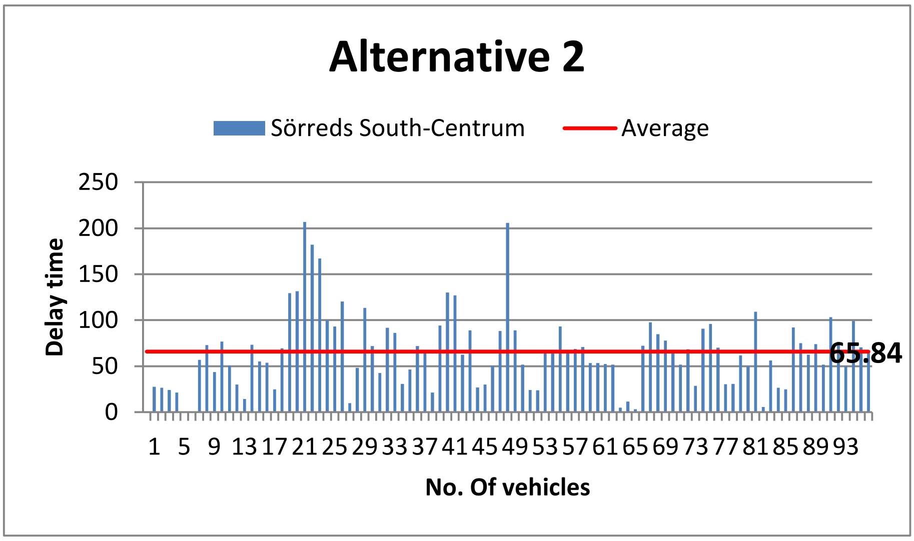


Figure 4.22 Delay times of vehicles and their average are plotted for Sörreds South to Centrum route.

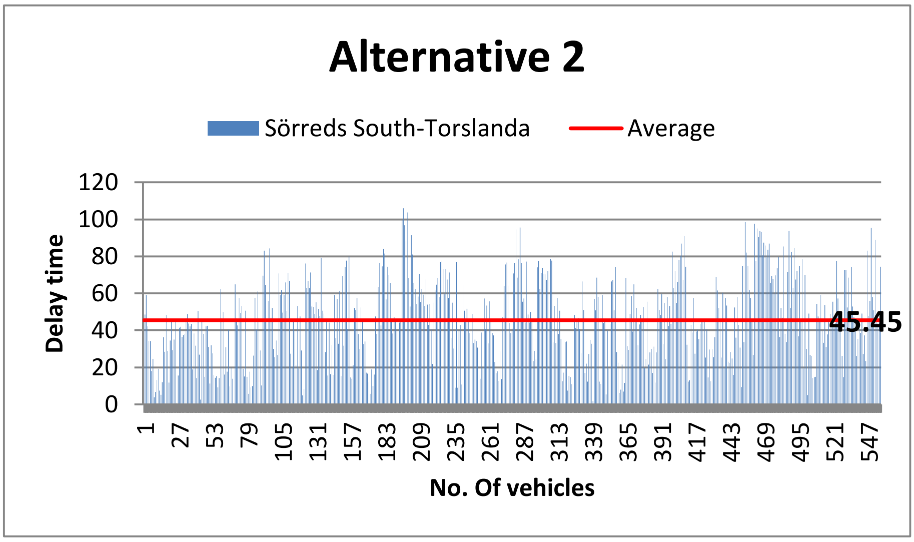


Figure 4.23 Delay times of vehicles and their average are plotted for Sörreds South to Torslanda route.

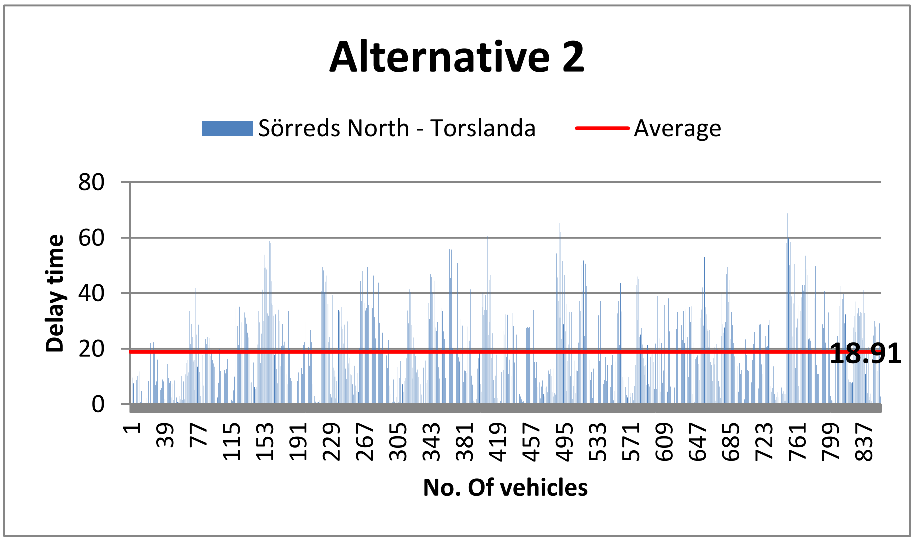


Figure 4.24 Delay times of vehicles and their average are plotted for Sörreds North to Torslanda route.

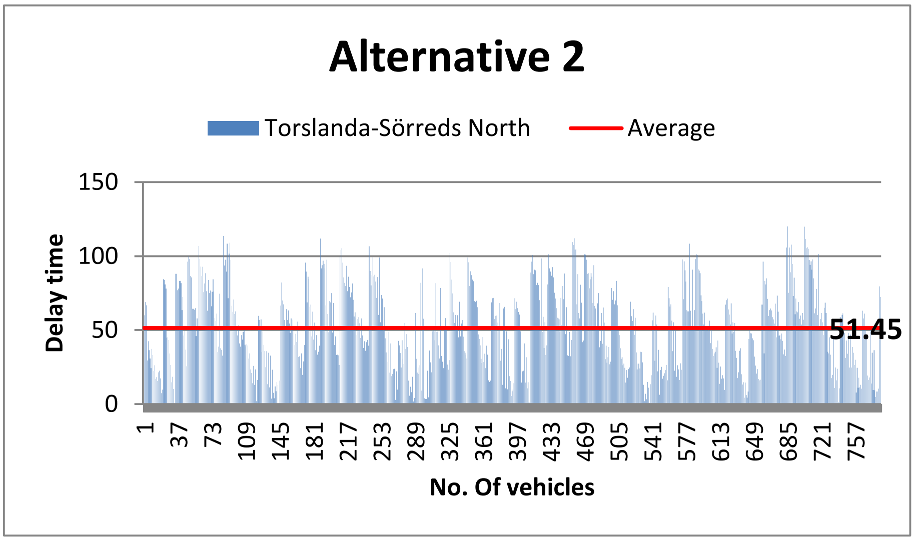


Figure 4.25 Delay times of vehicles and their average are plotted for Torslanda to Sörreds North route.

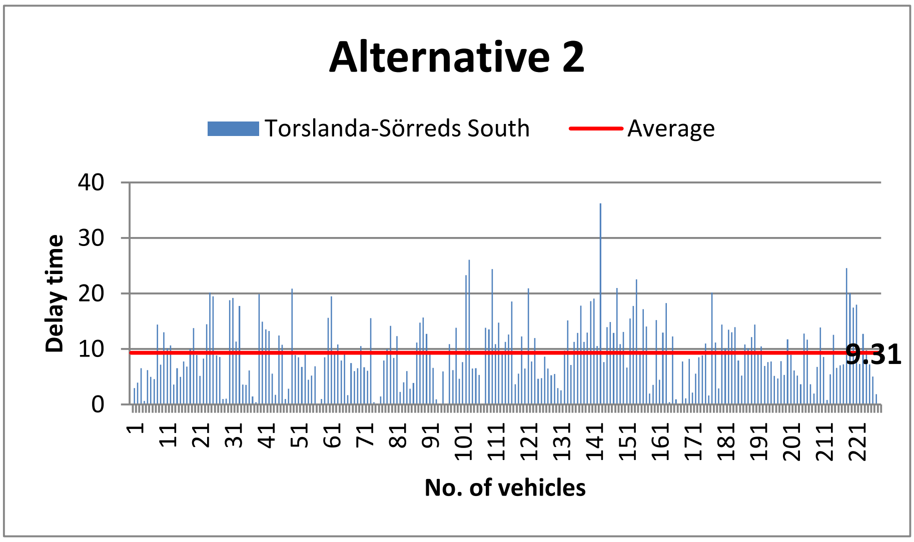


Figure 4.26 Delay times of vehicles and their average are plotted for Torslanda to Sörreds South route.

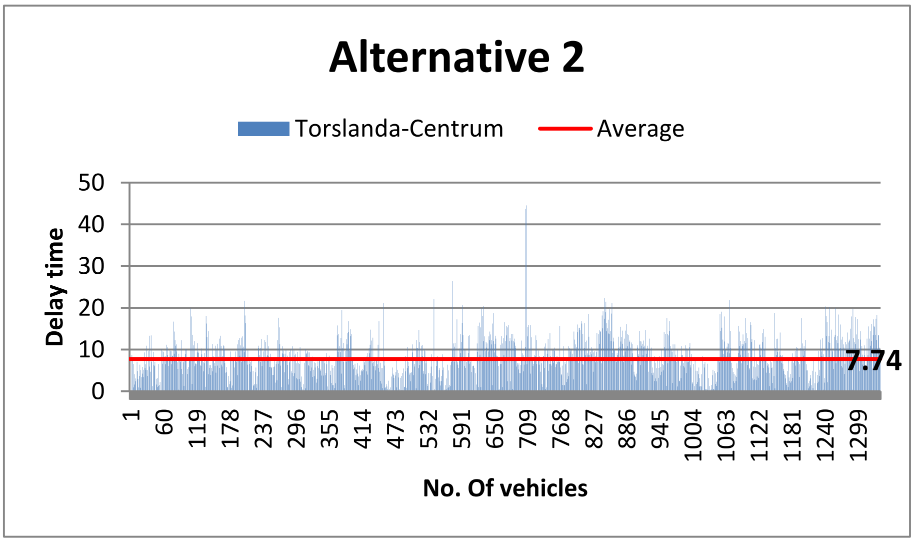


Figure 4.27 Delay times of vehicles and their average are plotted for Torslanda to Centrum route.

4.3.2 Travel times

Travel times for each traffic route as recorded by VISSIM are plotted as illustrate below. A red horizontal line in each illustration showing the average of all travel times.

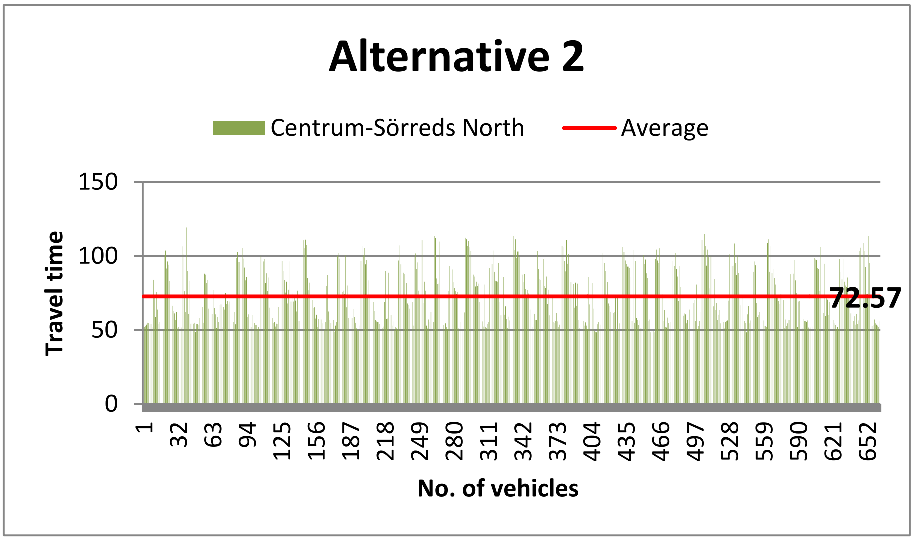


Figure 4.28 Travel times of vehicles and their average are plotted for Centrum to Sörreds North route.

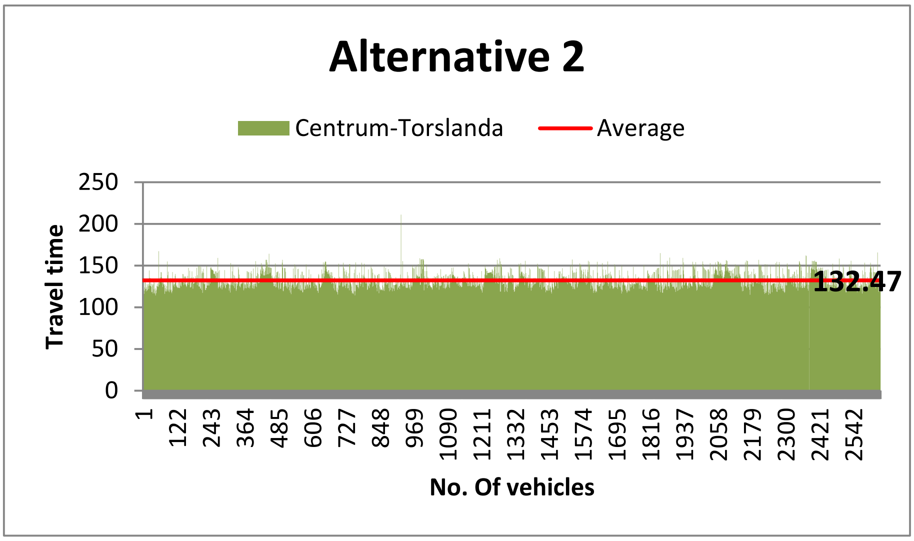


Figure 4.29 Travel times of vehicles and their average are plotted for Centrum to Torslanda route.

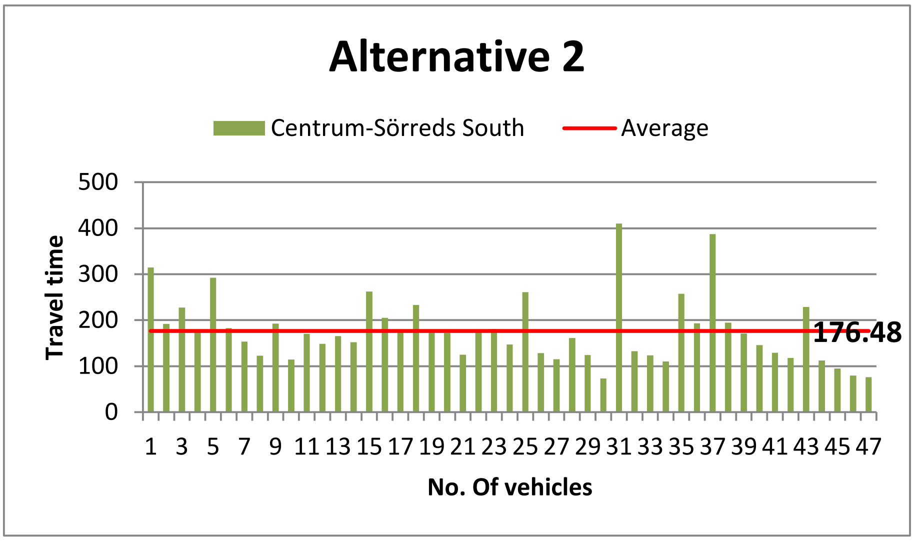


Figure 4.30 *Travel times of vehicles and their average are plotted for Centrum to Sörreds South route.*

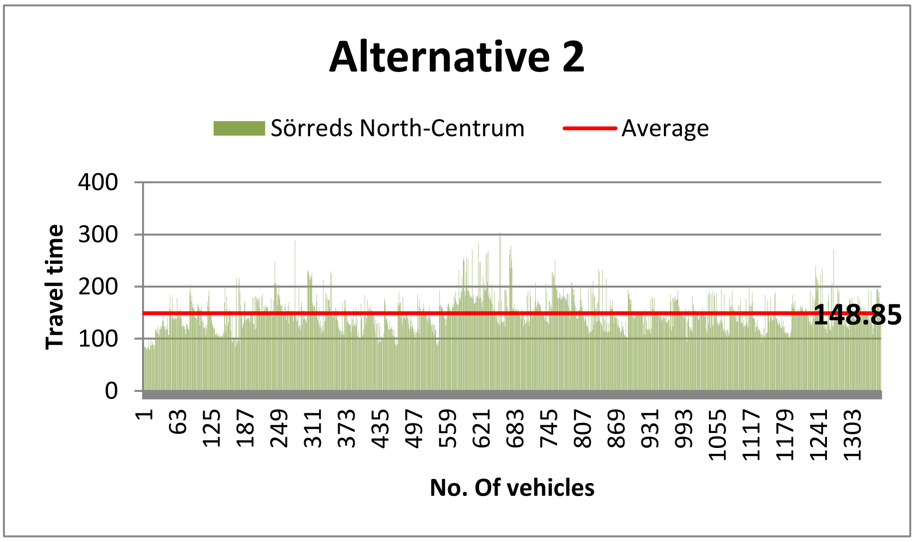


Figure 4.31 *Travel times of vehicles and their average are plotted for Sörreds North to Centrum route.*

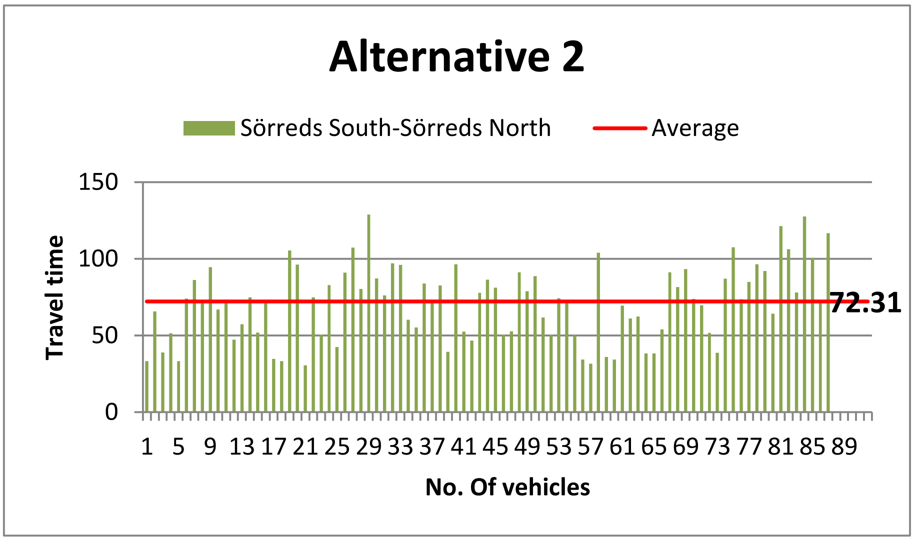


Figure 4.32 Travel times of vehicles and their average are plotted for Sörreds South to Sörreds North route.

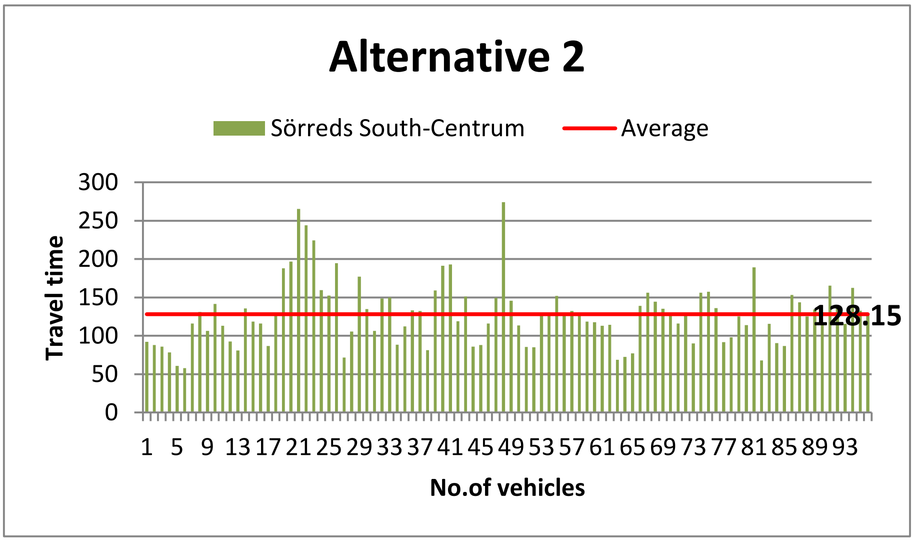


Figure 4.33 Travel times of vehicles and their average are plotted for Sörreds South to Centrum route.

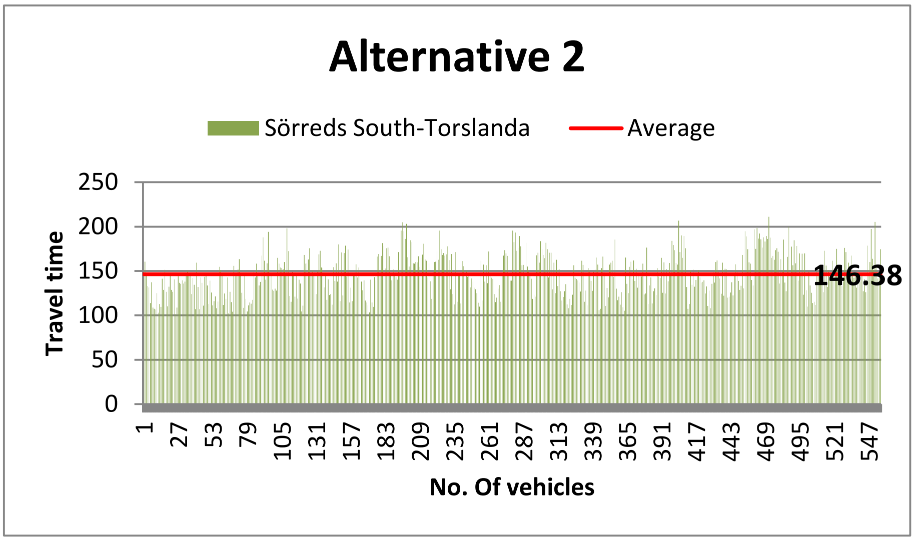


Figure 4.34 *Travel times of vehicles and their average are plotted for Sörreds South to Torslanda route.*

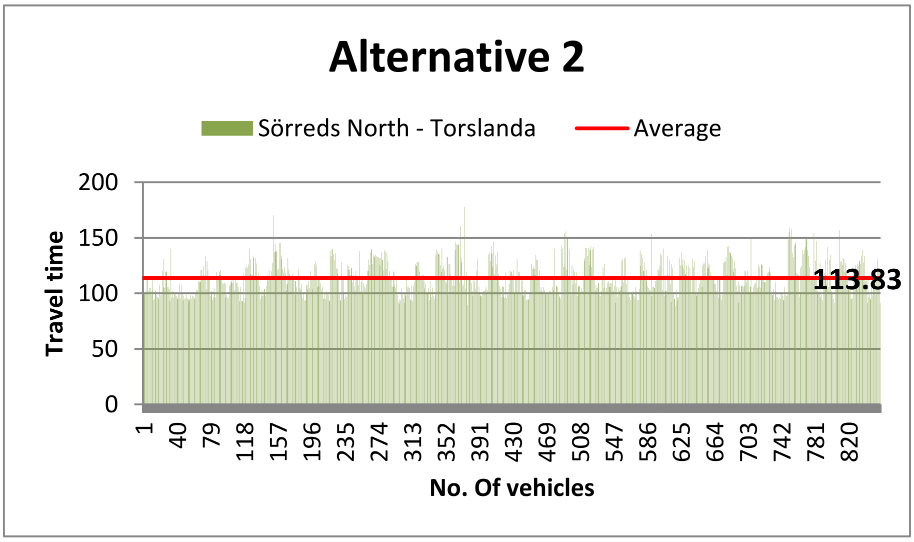


Figure 4.35 *Travel times of vehicles and their average are plotted for Sörreds North to Torslanda route.*

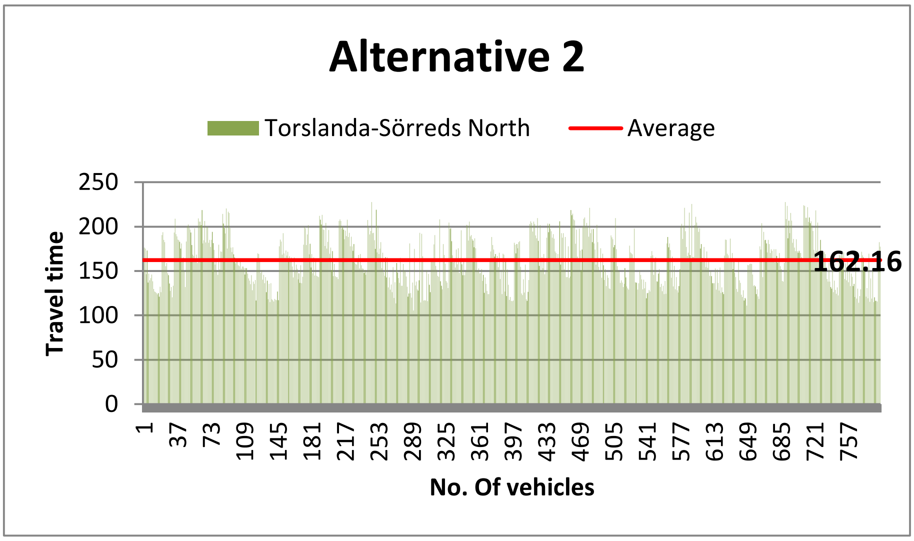


Figure 4.36 Travel times of vehicles and their average are plotted for Torslanda to Sörreds North route.

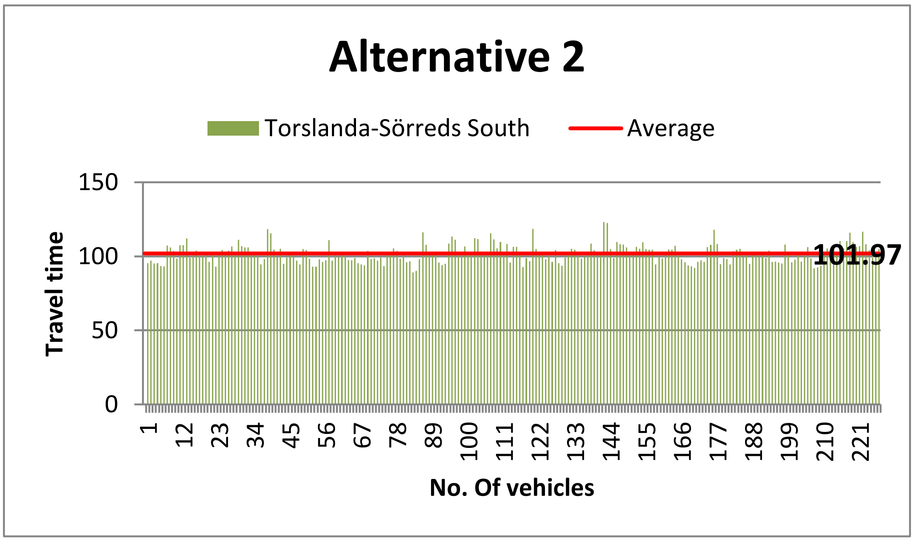


Figure 4.37 Travel times of vehicles and their average are plotted for Torslanda to Sörreds South route.

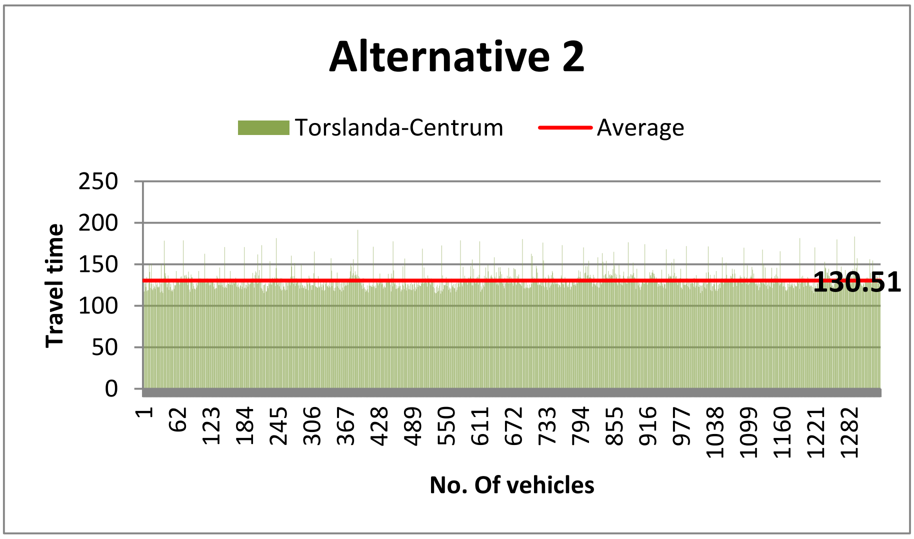


Figure 4.38 Travel times of vehicles and their average are plotted for Torslanda to Centrum route.

4.3.3 Queue record

Average and maximum queue lengths and number of stops against each route of alternative-2 are summarized in Figure 4.39.

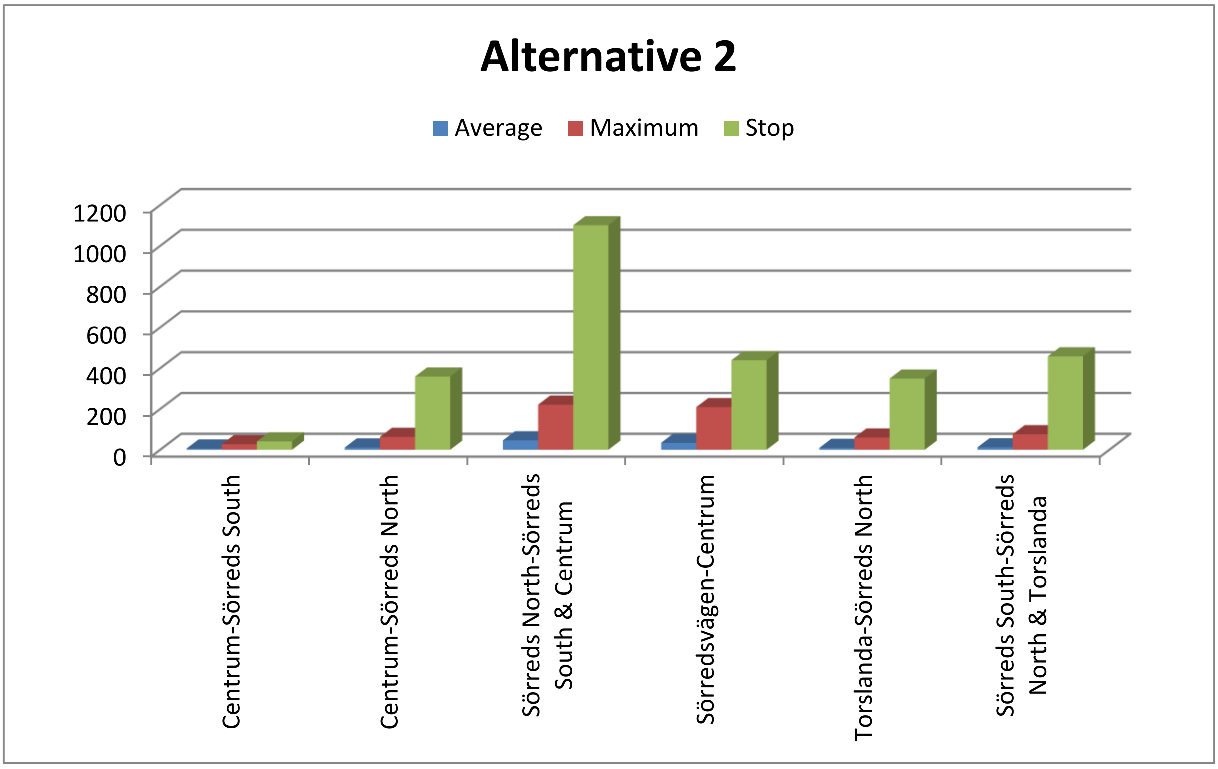


Figure 4.39 Traffic queue values with their respective junction.

4.4 Alternative 3A

Alternative-3A model, having flyover at Torslandavägen was simulated in VISSIM and following parameters for evaluation of results were analyzed.

4.4.1 Delays

Delay in traffic flow for each traffic route that recorded by VISSIM are plotted as illustrate below. A red horizontal line in each illustration showing the average of all delay times

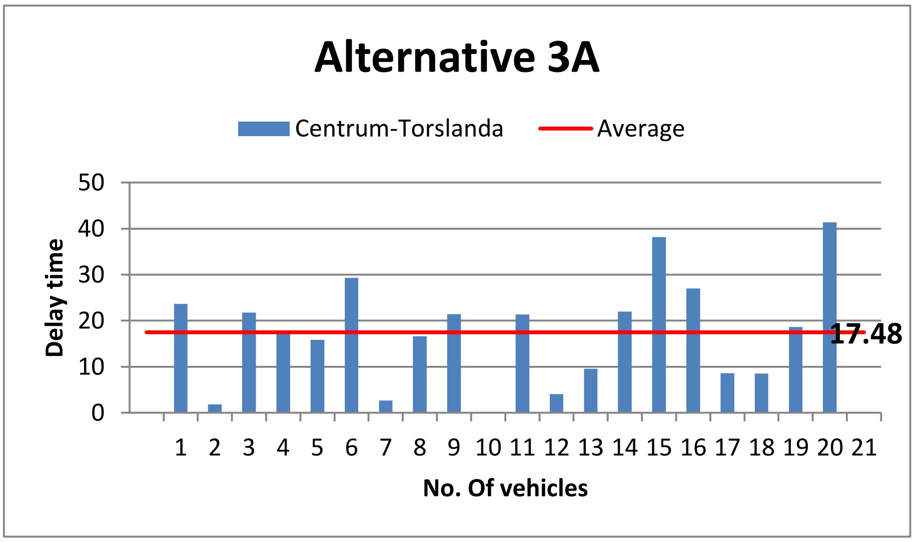


Figure 4.40 Delay times of vehicles and their average are plotted for Centrum to Torslanda route.

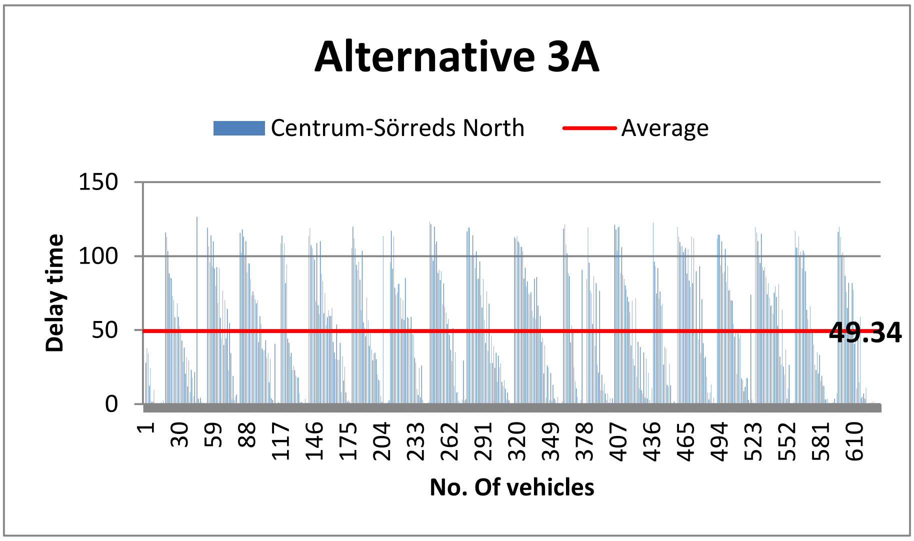


Figure 4.41 Delay times of vehicles and their average are plotted for Centrum to Sörreds North route.

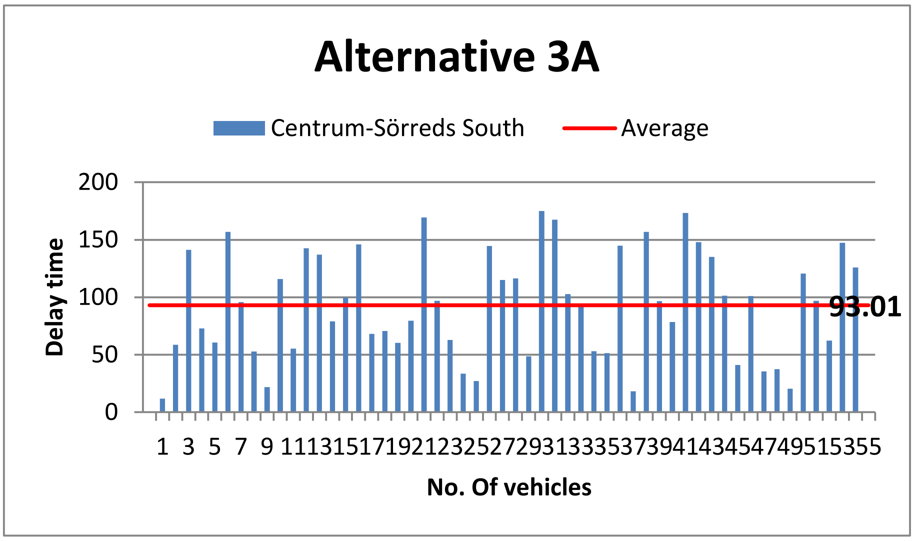


Figure 4.42 Delay times of vehicles and their average are plotted for Centrum to Sörreds South route.

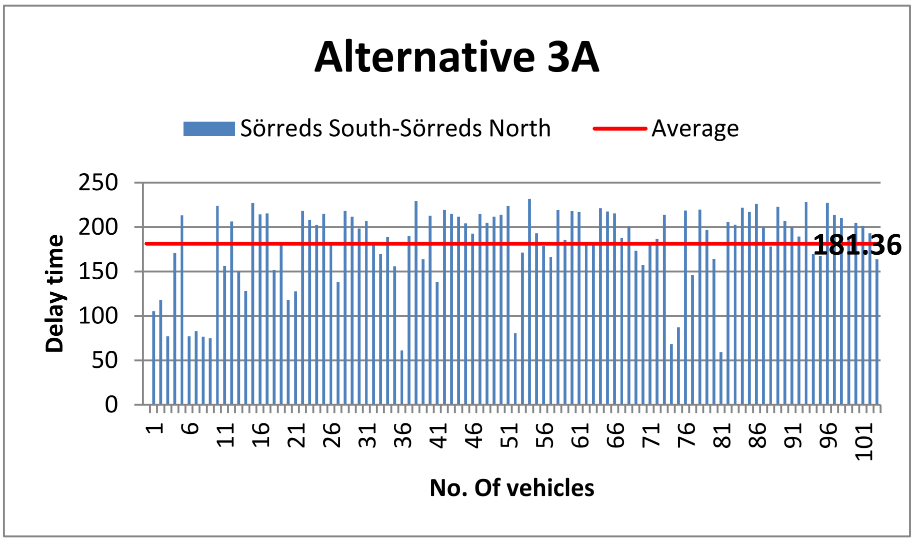


Figure 4.43 Delay times of vehicles and their average are plotted for Sörreds South to Sörreds North route.

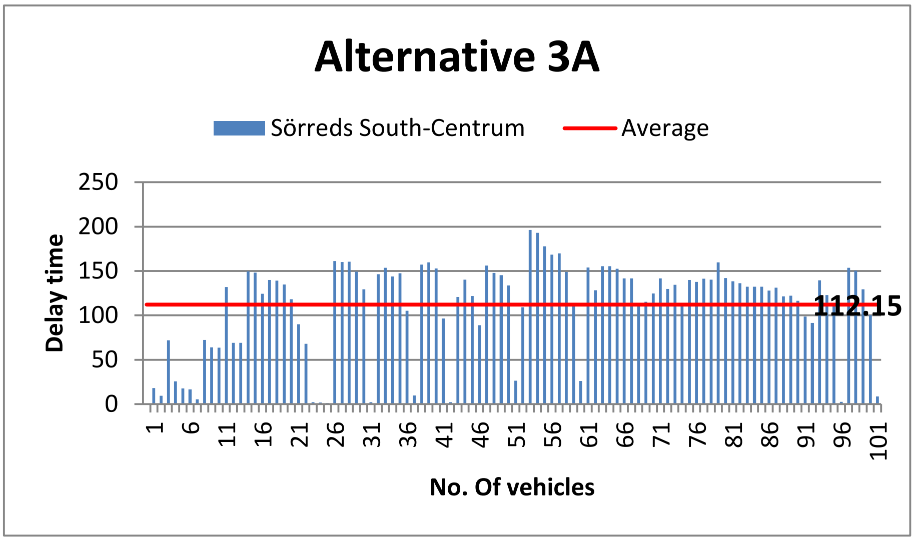


Figure 4.44   Delay times of vehicles and their average are plotted for Sörreds South to Centrum route.

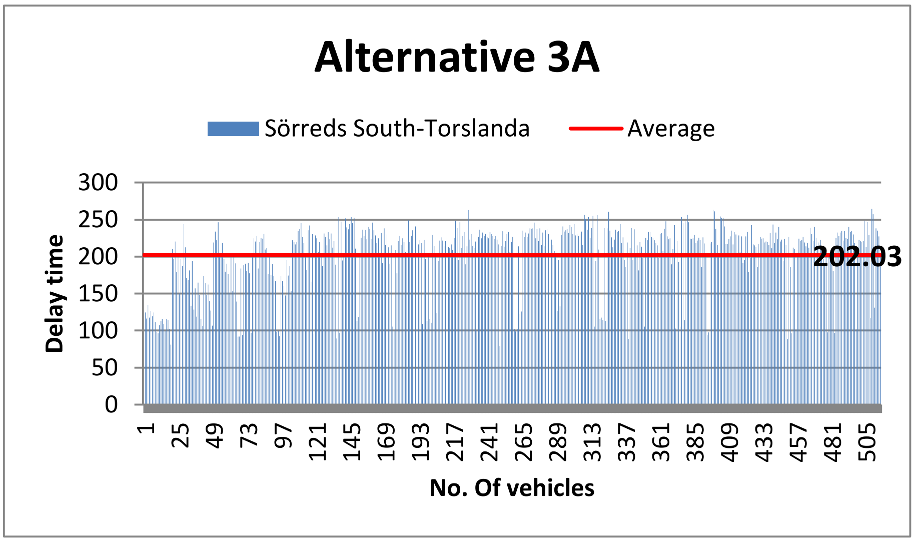


Figure 4.45   Delay times of vehicles and their average are plotted for Sörreds South to Torslanda route.

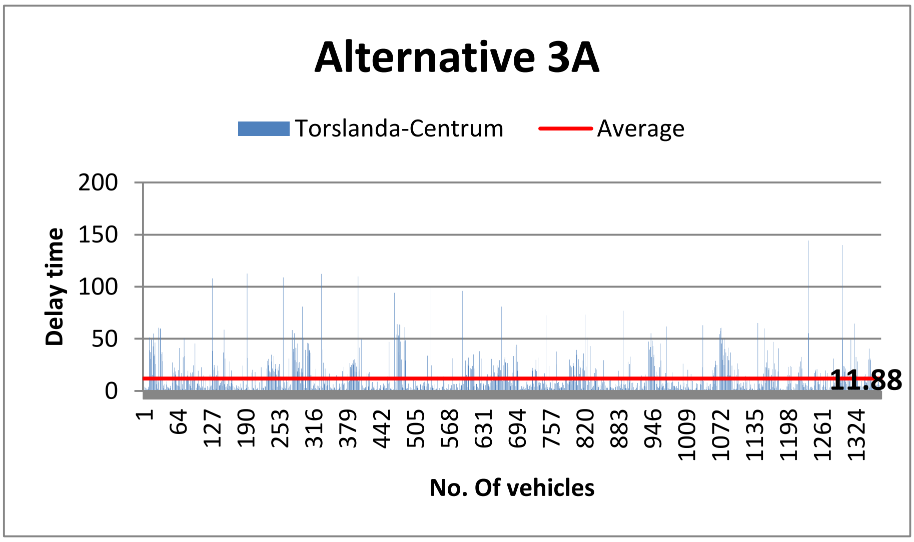


Figure 4.46 Delay times of vehicles and their average are plotted for Torslanda to Centrum route.

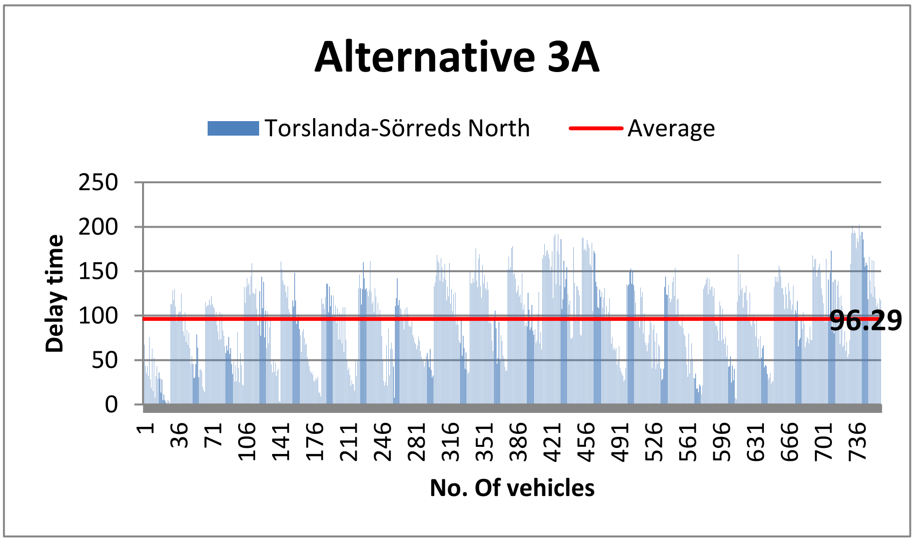


Figure 4.47 Delay times of vehicles and their average are plotted for Torslanda to Sörreds North route.

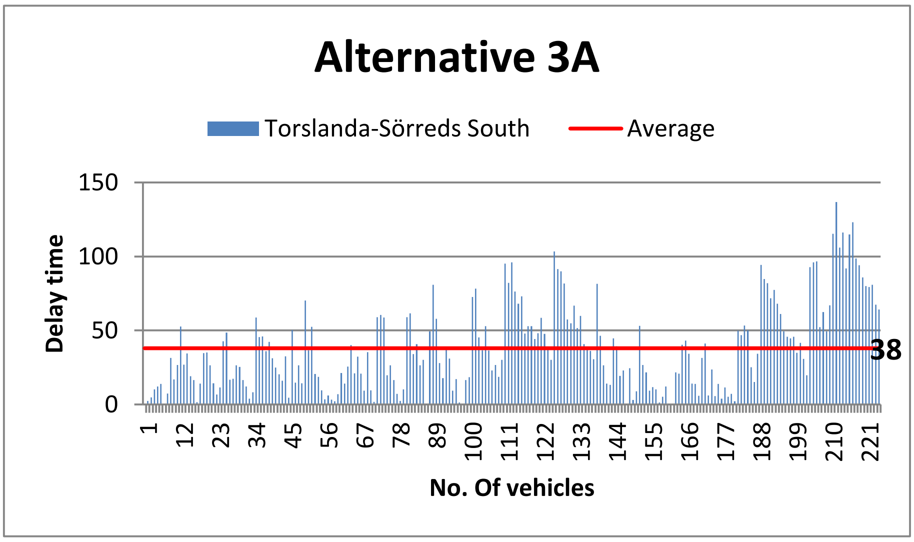


Figure 4.48 Delay times of vehicles and their average are plotted for Torslanda to Sörreds South route.

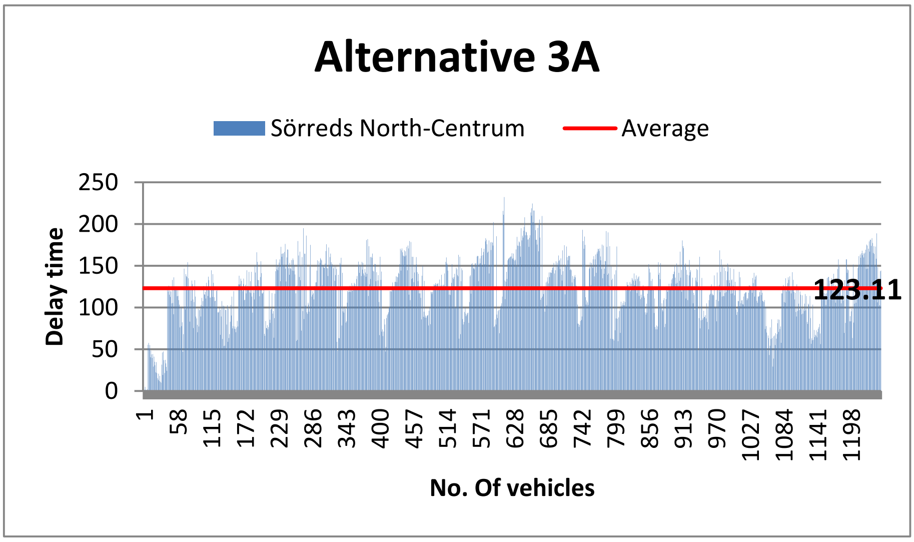


Figure 4.49 Delay times of vehicles and their average are plotted for Sörreds North to Centrum route.

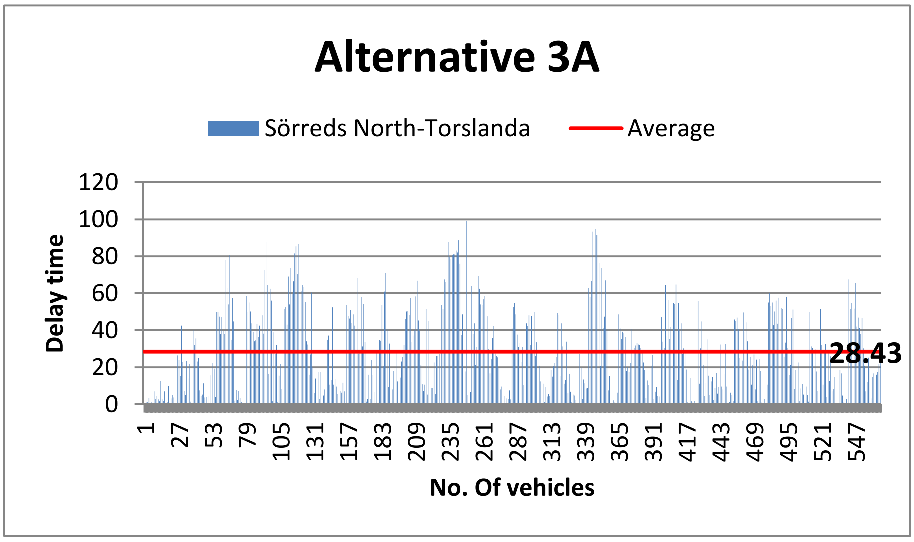


Figure 4.50 Delay times of vehicles and their average are plotted for Sörreds North to Torslanda route.

4.4.2 Travel times

Travel times for each traffic route as recorded by VISSIM are plotted as illustrate below. A red horizontal line in each illustration showing the average of all travel times.

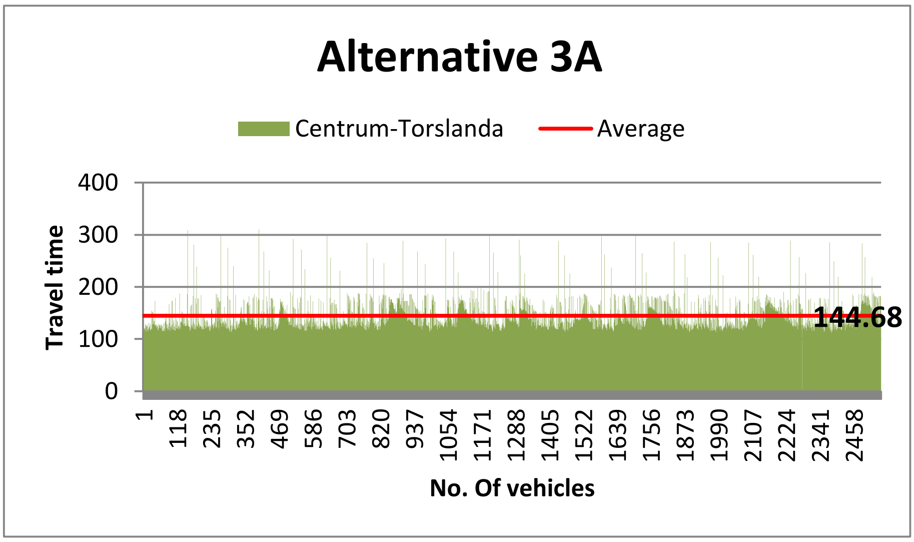


Figure 4.51 Travel times of vehicles and their average are plotted for Centrum to Torslanda route.

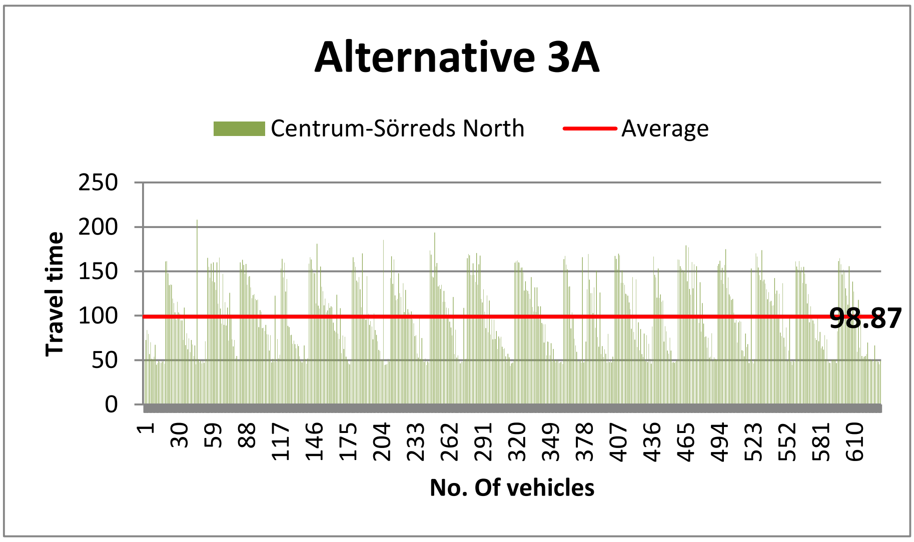


Figure 4.52 Travel times of vehicles and their average are plotted for Centrum to Sörreds North route.

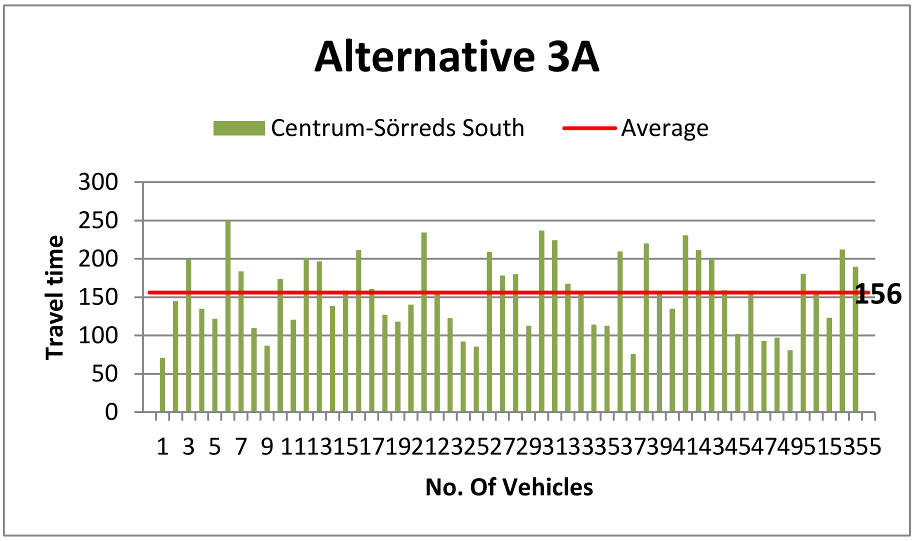


Figure 4.53 Travel times of vehicles and their average are plotted for Centrum to Sörreds South route.

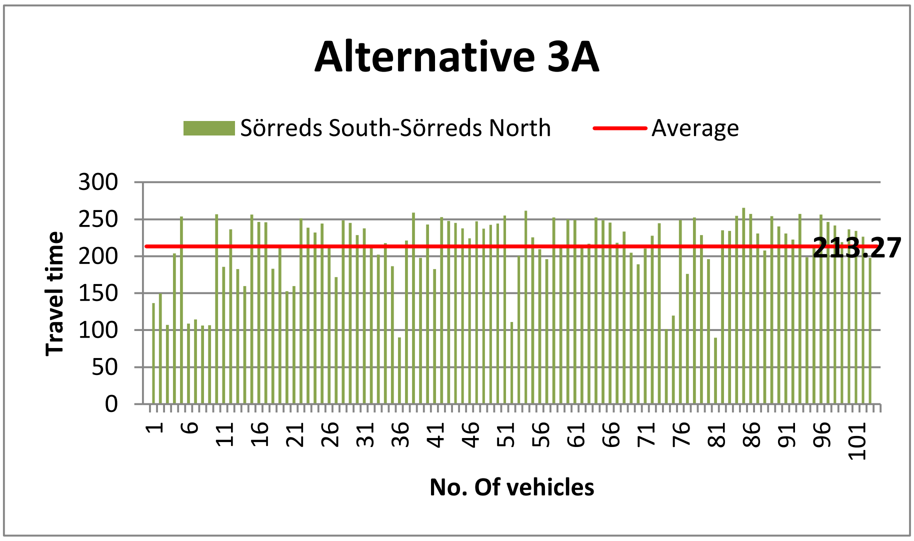


Figure 4.54 Travel times of vehicles and their average are plotted for Sörreds South to Sörreds North route.

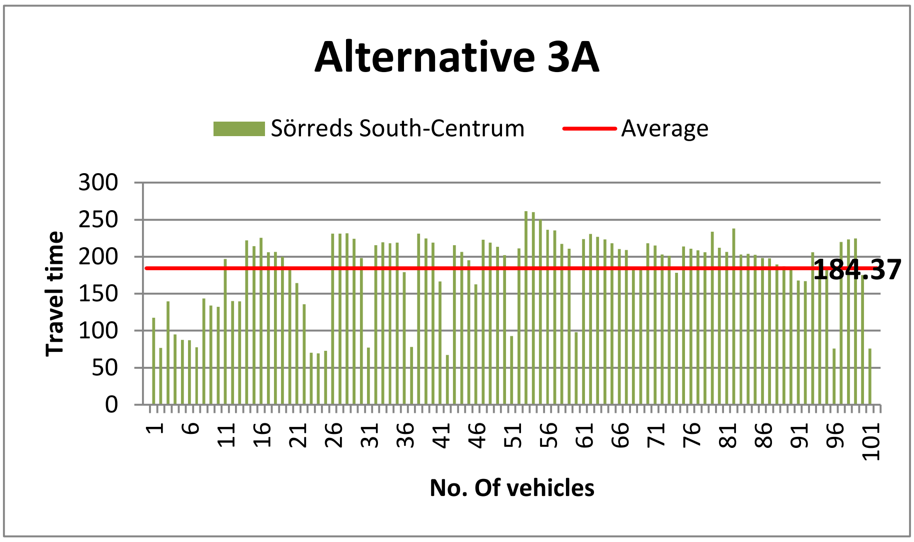


Figure 4.55 Travel times of vehicles and their average are plotted for Sörreds South to Centrum route.

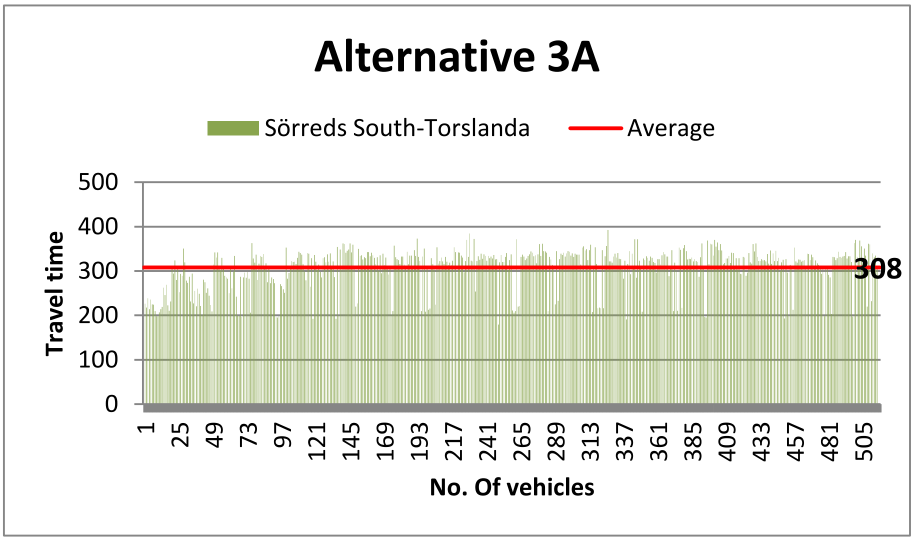


Figure 4.56 Travel times of vehicles and their average are plotted for Sörreds South to Torslanda route.

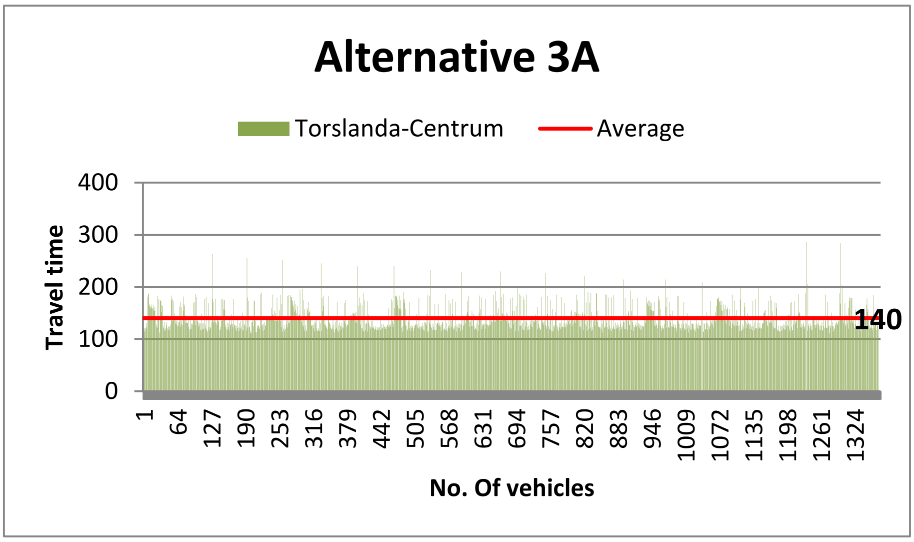


Figure 4.57 Travel times of vehicles and their average are plotted for Torslanda to Centrum route.

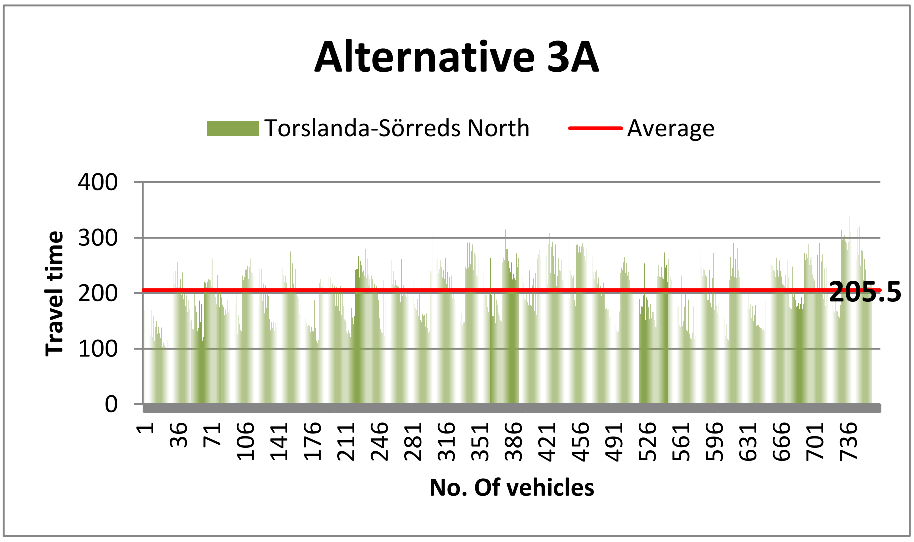


Figure 4.58 Travel times of vehicles and their average are plotted for Torslanda to Sörreds North route.

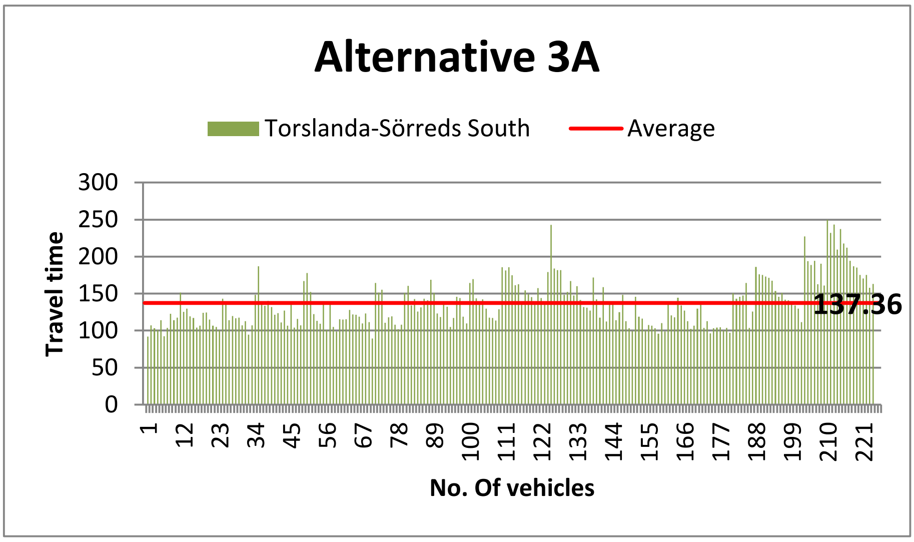


Figure 4.59 Travel times of vehicles and their average are plotted for Torslanda to Sörreds South route.

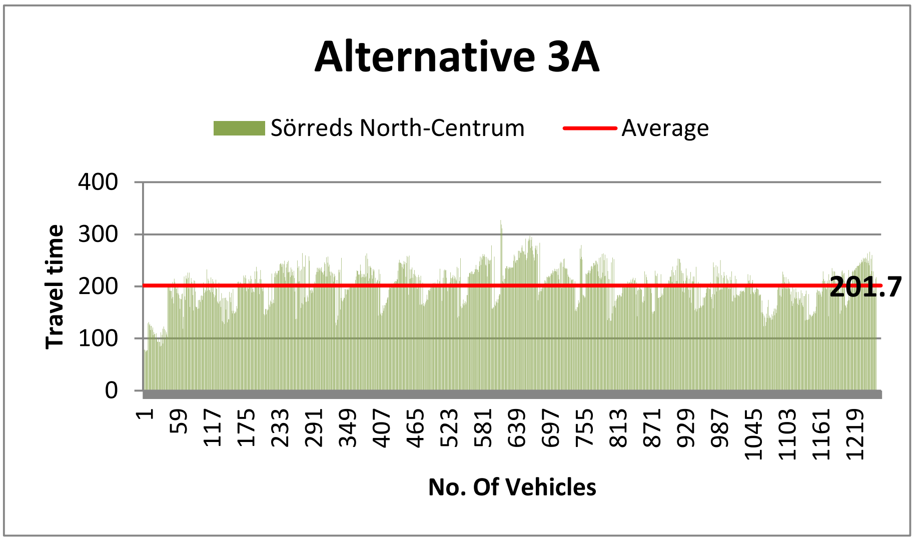


Figure 4.60 Travel times of vehicles and their average are plotted for Sörreds South to Centrum route.

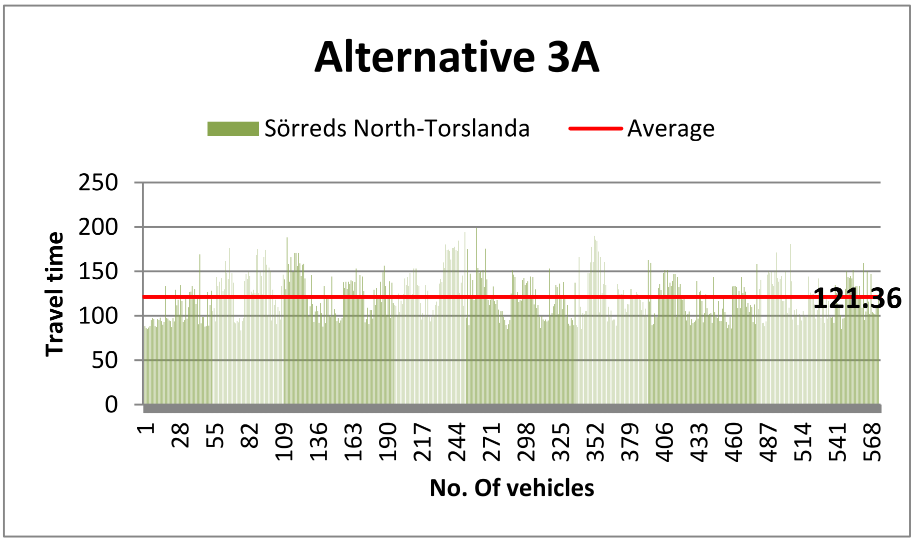


Figure 4.61 Travel times of vehicles and their average are plotted for Sörreds North to Torslanda route.

4.4.3 Queue record

Average and maximum queue lengths and number of stops against each route of alternative-3a are summarized in Figure 4.62.

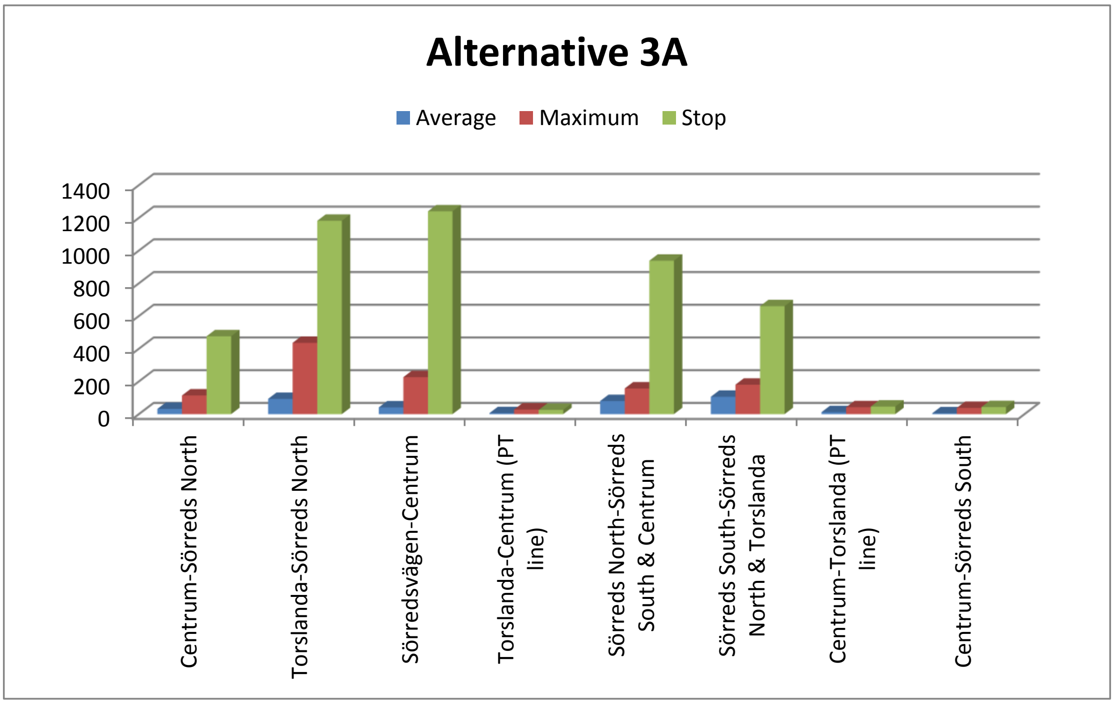


Figure 4.62 Traffic queue values with their respective route.

4.5 Comparative analysis

The results as plotted above can be given a good idea about the better alternative that fulfils the demand in more efficient way. However, in the continuation of results a comparison is made by considering average values of results. The comparisons include both alternatives as well as the present scenario of the intersection with the same amount of traffic as in the alternatives. The purpose to include the present scenario model is to show the necessity of flyover to fulfil the future demand of traffic flow.

4.5.1 Delay time comparison

The comparison as given in Figure 4.63 clearly shows the highest delay time in the present scenario case. However alternative-2 standing with lowest value almost in all routing comparison.

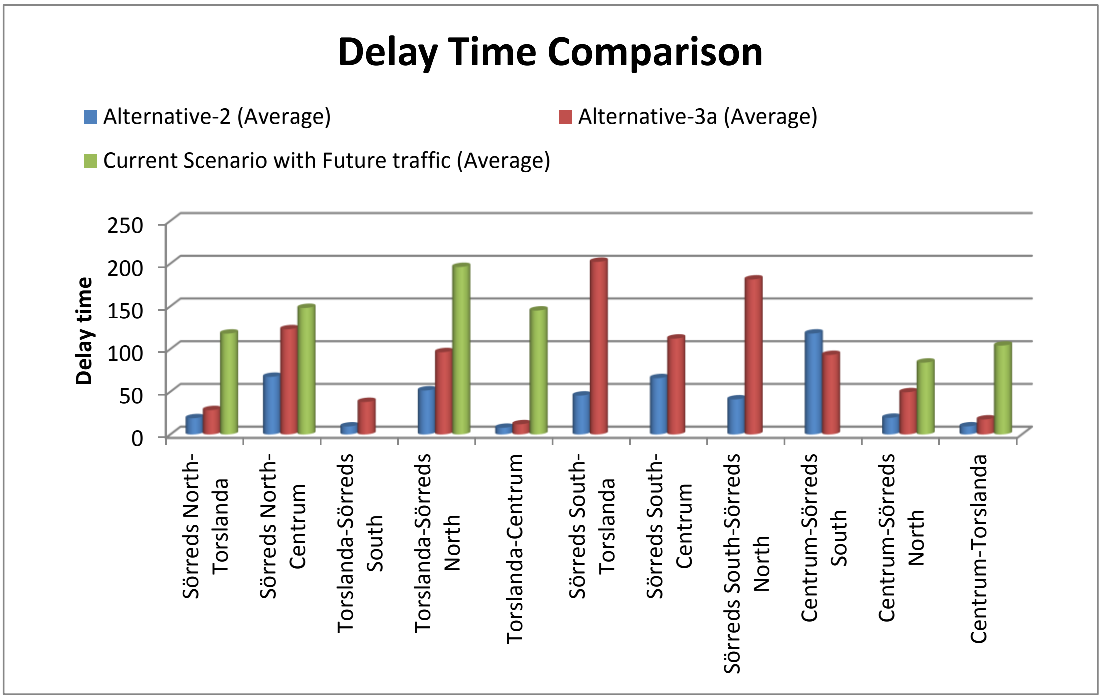


Figure 4.63 Average delay time comparisons between alternatives and present scenario having same amount of traffic.

4.5.2 Travel time comparison

Travel timings for the selected routes are plotted in the same way as did in delay time comparison. The results as illustrates in the Figure 4.64 shows that the lowest travel times belongs to alternative-2 almost in all routing decisions.

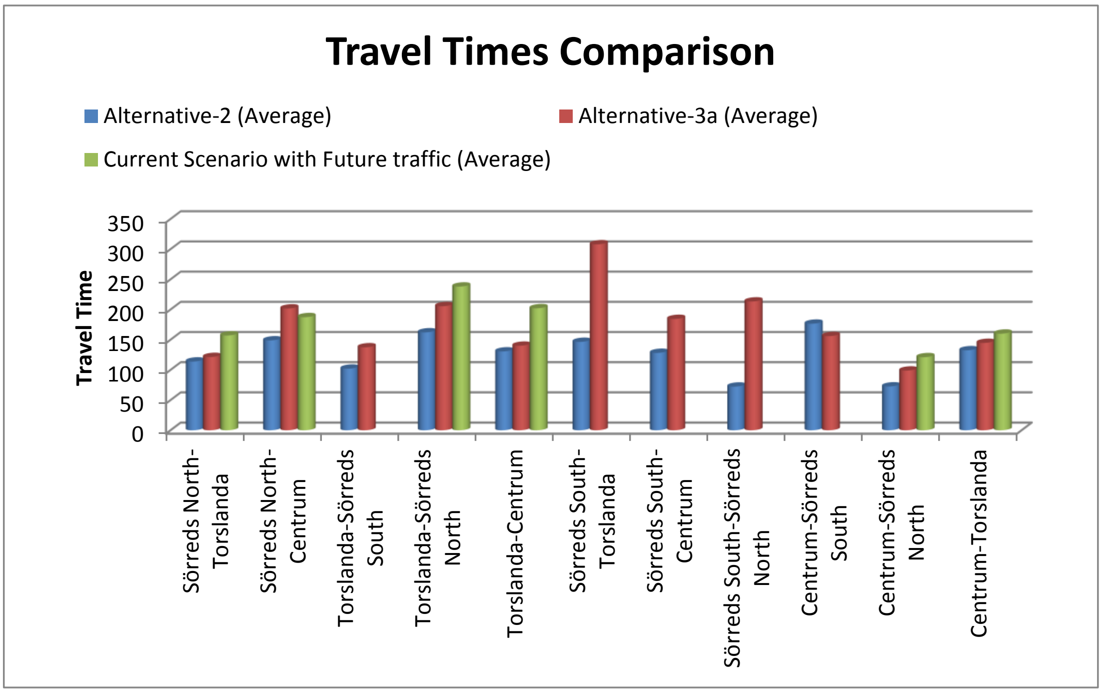


Figure 4.64 Average travel time comparisons between alternatives and present scenario having same amount of traffic.

4.5.3 Queue lengths comparison

Queue lengths are plotted in the Figure 4.65 for all cases. Present scenario having highest queue lengths while alternative-2 existing with lowest values.

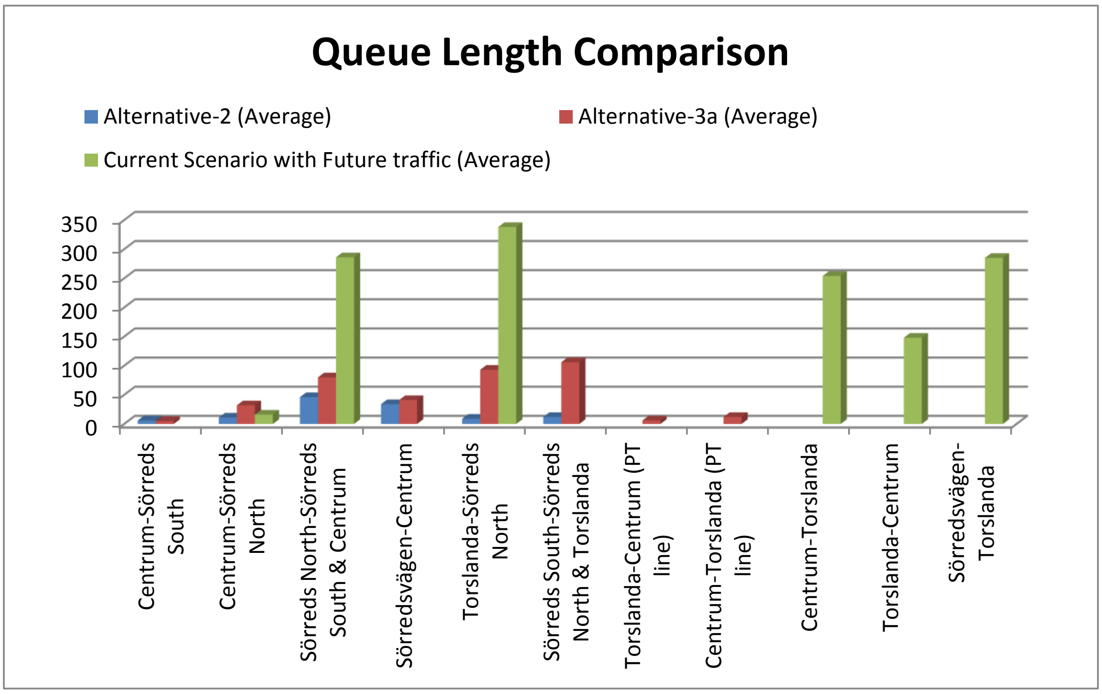


Figure 4.65 Average queue lengths comparison between alternatives and present scenario having same amount of traffic.

4.6 Comparative analysis by SWECO

As discussed earlier, alternative-2 and alternative-3 were analysed by SWECO. The analysis considers some important parameters for comparison which are not included in this research. However, the analyses did by SWECO, by considering following parameters are shown below.

- Environment and safety
- Road safety
- Travel time
- Comparison against established targets

4.6.1 Environment and safety

In point of fact, environmental effects study for two options i.e. alternative-2 andalternative-3 has been made by SWECO. A detailed study of SWECO report has been made to obtain following results to compare both alternatives. Table 4.1 describes the comparison of environment and safety for the two alternatives.

Table 4.1 Environmental safety comparison for both alternatives, i.e. 2 and 3, presented by SWECO (SWECO, 2011 translated version)

	Alt. 2	Comments	Alt. 3	Comments
Environment				
-Exhaust	+	Fewer vehicles affected by the signal. The ramp to the center gives the road extension and increased transport.	-	More vehicles affected by the signal.
-Airborne particles	-	Higher and more irregular rate gives more airborne	+	Lower speeds means less airborne
-CO_2	+	Fewer vehicles affected by the signal. The ramp to the center gives the road extension and increased transport.	-	More vehicles affected by the signal.
-Noise	0	Equivalent	0	Equivalent
Safety				
-Pedestrian	-	HPL during/under the bridge. Precarious.	+	HPL along walkways. Open and bright. More secure.
-Bicycle	-	Cycle path south of the row 155 for passage of the ramps are in the trough. Insecure!	+	Bicycle Trail open and in the plane. More secure!

Environmental comparison for two alternatives shown above in Table 4.1 states that fewer vehicles are affected by signals in alternative-2 as compared to alternative-3 Hence, consequences are more vehicle delays producing more emissions in alternative-3. It means that alternative-2 is more environmental friendly as compared to alternative-3.

4.6.2 Road safety

Table 4.2 gives road safety comparison for both alternatives.

Table 4.2 Road safety comparison between alternative-2 and alternative-3 (SWECO, 2011 translated version)

	Alt. 2	Comments	Alt. 3	Comments
Road Safety				
-Pedestrian	+	1 conflict m ramp from center	-	3 points of conflict. Ramps to / from downtown and Sörredsvägen
-Bicycle	+	1 conflict m ramp from center	-	3 points of conflict. Ramps to / from downtown and Sörredsvägen
-Personal identity (Personb)	+	3 points of conflict north o south signal junction (Volvo) ramp (bus-car)	-	3 points of conflict north o south signal junction (Volvo) Sörredsv / jvgspår
-Car	+	3 points of conflict north o south signal junction (Volvo) ramp (bus-car)	-	3 points of conflict north o south signal junction (Volvo) Sörredsv / jvgspår
-Track/train crossing	+	Multilevel	-	No multilevel.

Considering road safety for both alternatives, it can be seen through Table 4.2 that alternative-3 carries more conflicting points as compared to alternative-2.

As more conflicting points results less sense of security. Thus it can be concluded that alternative-2 is much secured in contrast of alternative-3.

4.6.3 Travel time

Another important parameter to discuss is travel time for both alternatives considering the motorized and non-motorized. Below altered Table 4.3 obtained from SWECO report, provides illustration of travel time required in both alternatives.

Table 4.3 Travel time comparison in both alternative-2 and alternative-3 (SWECO, 2011 translated version)

	Alt. 2	Comments	Alt. 3	Comments
Travel Time				
-Pedestrian	-	Longer paths. Larger differences in height. Fewer conflict points of delay.	+	Short paths. Small differences in height. More points of conflict that gives a delay.
-Bicycle	-	Longer paths. Larger differences in height. Fewer conflict points of delay.	+	Short paths. Small differences in height. More points of conflict that gives a delay.
-Bus travelers, consistently	+		-	
-Bus Passengers, exchange + goals / start journeys	-		+	
- Bus passengers, weighted	+		-	More consistently travelers!
-Car	+	Fewer vehicles affected by the signal. The ramp to the center gives the road extension and increased transport	-	More vehicles affected by the signal. More conflicts and bus priority reduces capacity.
-Truck	+	Fewer vehicles affected by the signal. The ramp to the center gives the road extension and increased transport	-	More vehicles affected by the signal.

For pedestrians, alternative-3 is more suitable considering fact of small height and short paths. Apparently conflicting areas are more in numbers causing delay for pedestrians. Despite of this fact, alternative-3 can be more feasible and convenient for pedestrians to walk through as compared to alternative-2, especially considering fact of long winter and rainy season in Sweden.

On the contrary, from Table 4.3, alternative-2 can be regarded as best option for cars and other heavy traffic by means of less conflicting areas.

4.6.4 Comparison against established targets

Results obtained by SWECO report has been altered and analysed in detail for comparing against established targets stated below in Table 4.4.

Table 4.4 Comparison between alternative-2 andalternative-3 against established targets (SWECO, 2011 translated version)

	Alt.2	Comments	Alt. 3	Comments
-Multilevel rail crossing	Yes	Multilevel	-	No multilevel
-Enhance safety and accessibility on the Road 155	Yes		Fair	
-Attractive cycle path	Fair	Poor alignment but plan separately	Fair	Good alignment but the level crossing
-Attractive public transport services to Torslanda	Yes	Bus Lane	-	Bus lanes but too poor accessibility standard with stops on the ramps
- Attractive exchange item	Fair	It will be better than today. Does not the requirements for "Attractive exchange point" according to VT	Fair	It will be better than today. Does not the requirements for "Attractive exchange point" according to VT
-Coordination with the ongoing expansion work	Fair	equivalent	Fair	equivalent
-Keeping given budget	-		+	

Overall assessment for both alternatives has been presented in Table 4.4. It is quite clear that alternative-3 is not fulfilling project development purposes in terms of following basic objectives:

- One of the purposes to build flyover was to make multilevel rail crossing. In scenario 3 and 3A, there are no multilevel crossing for rail road thus resulting conflicts between road traffic and rail.
- Less safer especially for non-motorized traffic. More chances to conflict with rail road and other traffic.
- Less attractive public transport facility to Torslandavägen with stops located on ramps.

5 Discussion and conclusion

In this thesis, a microscopic simulation software program namely VISSIM has been utilized to study Sörreds Intersection. First use of VISSIM was to display the present working of Sörreds intersection has been made. Later on studies continued on the basis of future increased assumed traffic. It was observed that double volumes in year 2035 will exceed capacity of lanes during peak hours. Thus, two different alternatives proposed by SWECO were analysed by utilizing VISSIM and display of future working of junction has been shown. More congestion situations were experienced in case of implementing alternative 3A more specifically at the start point of Sörreds north entry link. Also, increased green time period for particular link adversely affects other links by increasing queue lengths and delay periods. Furthermore, alternative 3A carries insufficient capacity and will not be able to dismantle the design traffic flows.

Referring from SWECO report, it is clear that growth of traffic is more for Road-155 i.e. Torslandavägen. However the main objective of making flyover was to make traffic more fluent and safer for Sörreds intersection rather than only making Torslandavägen link more fluent. Moreover, another benefit for existence of flyover at Sörreds intersection is provision of multilevel crossing for rail and road users.

6 Recommendations

Overall discussion reflects that the alternative-2 is a better choice while considering the traffic flow and other parameters rather than economic parameter. However it is not an ending document for the research. The real world is full of complexities and the created models can't fully demonstrate that what will happen in future? To get closer picture, continues research should keep in process. There are several aspects and parameters which have been avoided until now, can be helpful to get more accurate findings. Some possible aspects which can consider for the further research are mentioned below.

- Rail road, pedestrians and bicyclists inclusion in both alternatives' model.
- Several kinds of survey from frequent users, public transport drivers and industrial personnel can be helpful to make a good judgment.
- Study of other similar projects that can give assistive information for decision.
- It is observed during both simulation models, that there was a traffic congestion situation occurred at the ring road, when the vehicles going towards centrum from Sörreds north and Sörreds south. The reason is that the ring road which meets Sörredsvägen with Torslandavägen is a combination of a two lane road converting into one lane road. The design can be reviewed by keeping two lanes until it meets Torslandavägen and then can be analyze through simulation.

7 References

Al-Mudhaffar, A., 2006.Impacts of Traffic Signal Control Strategies. Ph.D. Thesis. Traffic and transport planning, infrastructure and planning. Royal Institute of Technology, Stockholm, Sweden

Arvis J-F., et al., 2010. Connecting to Compete- Trade Logistics in the Global Economy [Online] The World Bank. Available at: <http://siteresources.worldbank.org/INTTLF/Resources/LPI2010_for_web.pdf > [Accessed on: 2011-10-30]

Bonneson J.A., McCoy P.T., 2005. Manual of Traffic detector design-Chapter 4 [pdf] Institute of Transportation Engineers (ITE). Available at: http://www.webs1.uidaho.edu/ce572s07/resources/other/manual%20of%20traffic%20detector%20design.pdf [Accessed on: 2011-11-25]

Bonneson J., Sunkari S., & Pratt M., 2009. TRAFFIC SIGNAL OPERATIONS HANDBOOK, TEXAS TRANSPORTATION INSTITUTE

Barceló, J., 2010. Fundamentals of Traffic Simulation. New York: Springer Science+Business Media, LLC.

Federal Highway Administration (FHWA), 2008. Traffic Signal Timing Manual [pdf] US-Department of Transportation. Available at: http://ops.fhwa.dot.gov/publications/fhwahop08024/fhwa_hop_08_024.pdf [Accessed on: 2011-11-25]

Google Earth 6.0. 2008. Sörredsvägen, Gothenburg, Västra Götalands Läan, Sweden 57°42'43.30"N, 11°50'28.92"E, Elevation 31 ft.
Available through: <http://www.google.com/earth/index.html> [Accessed through: 25 September 2011].

Highway Capacity Manual (HCM), 2000.(Fourth edition).TRB, National Research Council, Washington, D.C., 2000.

IIT-Bombay, 200?Transportation engineering. [Online] Available at: http://www.cdeep.iitb.ac.in/nptel/Civil%20Engineering/Transportation%20Engg%20I/72-homes/01-home.html [Accessed on: 2011-11-23]

Kell J.H., Fullerton I.J., 1998. Manual of traffic signal design - Chapter 7. [pdf] Institute of Transportation Engineers. Available at: http://www.webs1.uidaho.edu/ce572s07/resources/other/manual%20of%20traffic%20signal%20design%20-%20ch%207.pdf [Accessed on: 2011-11-25]

Kutz M., 2003. Handbook of Transportation Engineering. [e-book] New York: McGraw-Hill. Available through: Chalmers University Library website <http://www.lib.chalmers.se>[Accessed on: 2011-11-28]

Li M., Wo T., 2011. Prediction and evaluation of traffic quality by static and dynamic simulation; Impact of new bus terminal at Myggenäs intersection, MSc Thesis, Road and Traffic Group, Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden.

PTV, 2011. VISSIM User Manual – Version 5.30-05, PTV Planung Transport Verkehr AG, Karlsruhe, Germany

Roess R.P., et al., 2004. Traffic Engineering.Third Edition. Upper Saddle River, NJ: Pearson Prentice Hall.

Slinn, M., Matthews, P., Guest, P., 2005. Traffic engineering design: principles and practice (second edition). Oxford, UK: Elsevier.

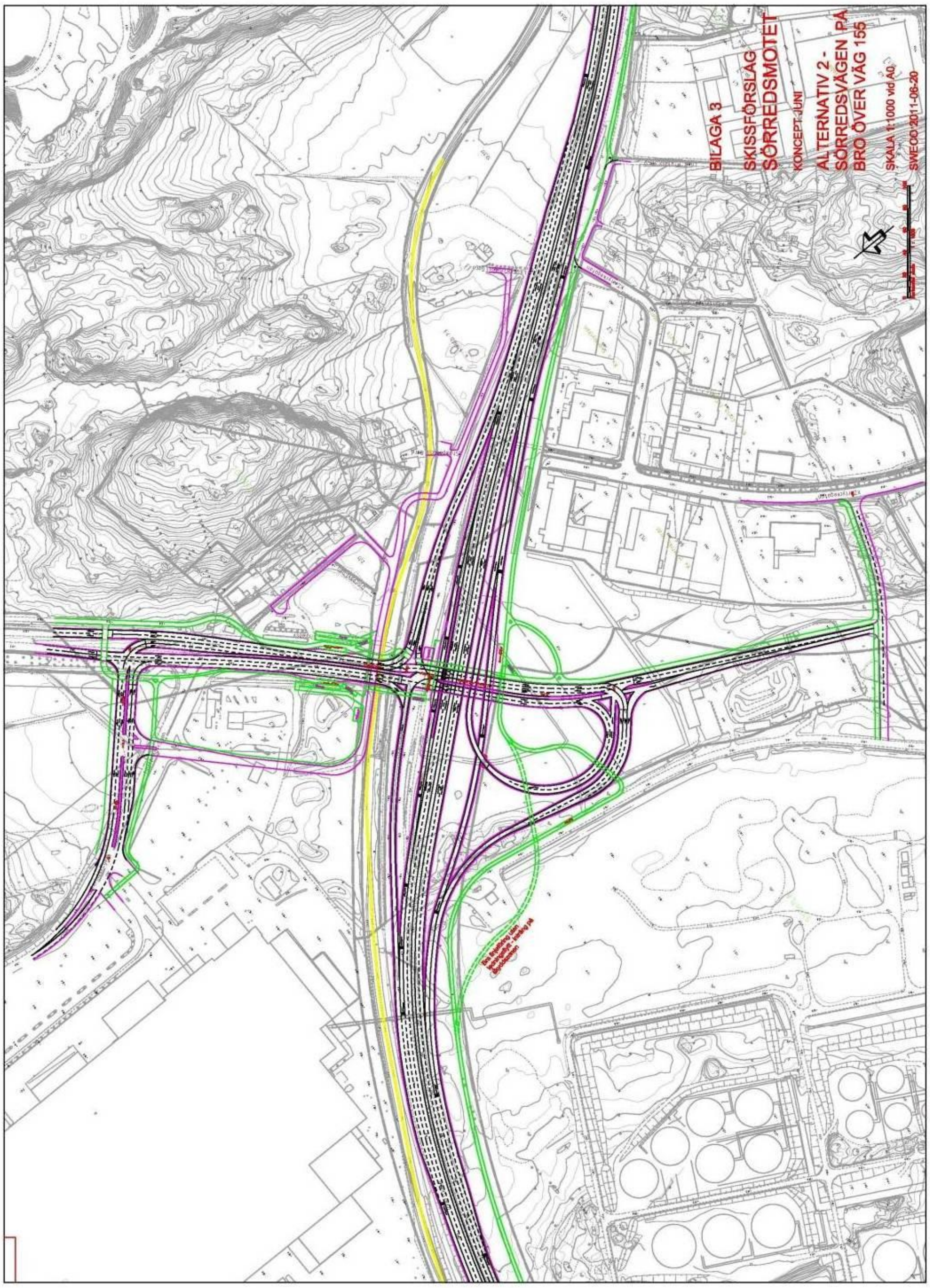
Statistics Sweden, 2011.Population by period. Year 2001-2010 [Online] (Updated on: 2011-02-18 09:40) Available at: http://www.ssd.scb.se/databaser/igraph/MakeGraph.asp?onpx=y&pxfile=tmp2011103117412836BE0101N1.px&PLanguage=2&menu=y&gr_type=1[Accessed on: 2011-10-30]

Statistics Sweden, 2011.Population growth by period. Year 2001-2010 [Online] (Updated on: 2011-02-18 09:40) Available at: http://www.ssd.scb.se/databaser/igraph/MakeGraph.asp?onpx=y&pxfile=tmp201110311743090BE0101N2.px&PLanguage=2&menu=y&gr_type=1[Accessed on: 2011-10-30]

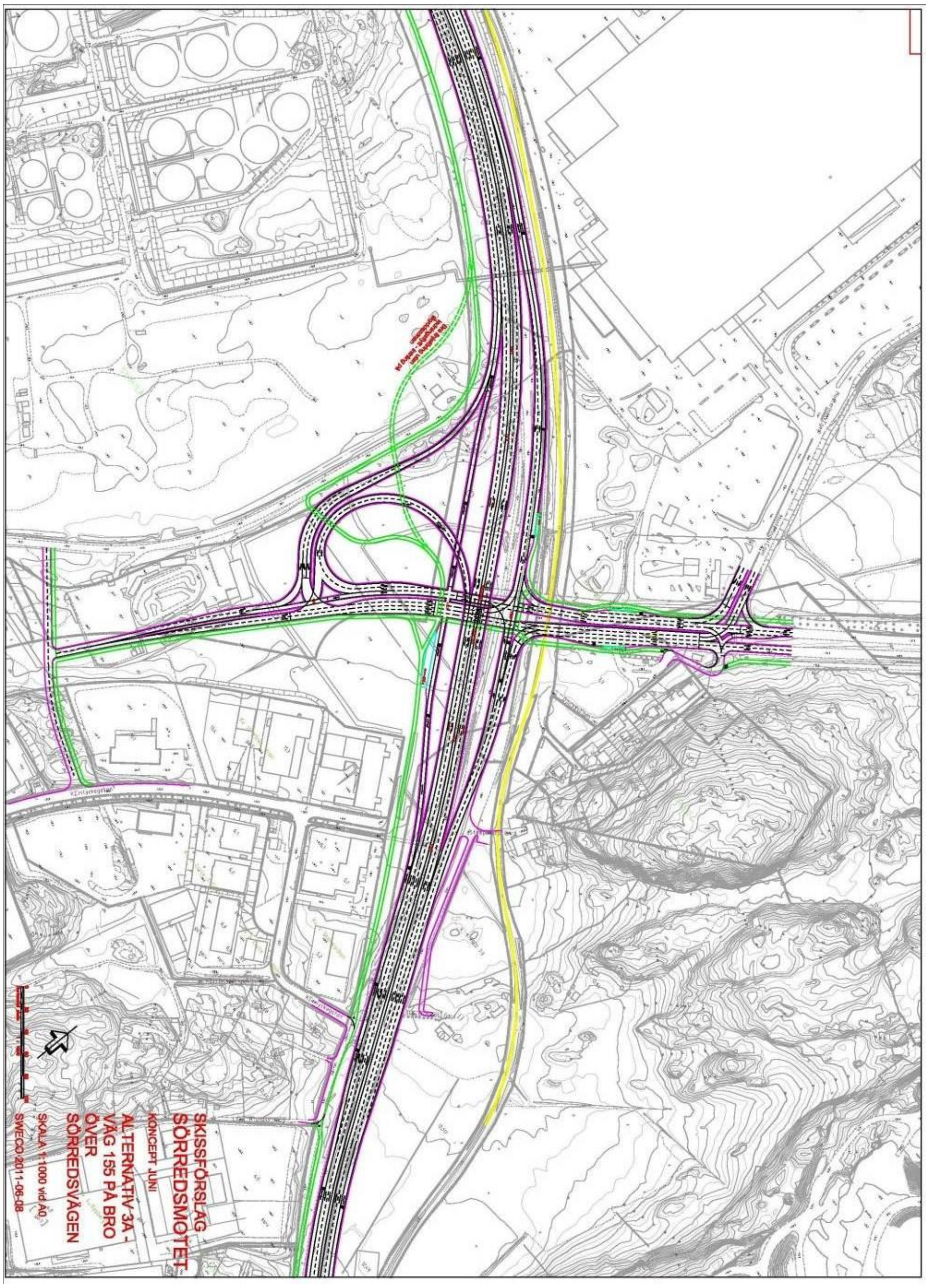
Statistics Sweden, 2011. Fordon enligt bilregistret efter fordonsslag och bestånd. Månad 1975M01-2011M09 [Online] (Updated on: 2011-10-03 09:30) Available at: http://www.ssd.scb.se/databaser/makro/SaveShow.asp [Accessed on: 2011-10-30]

SWECO AB, 2011. Sörredskorsningen-Utformning av trafikplats – jämförande analys av två alternativ, Trafikverket, Gothenburg, Sweden, 2011

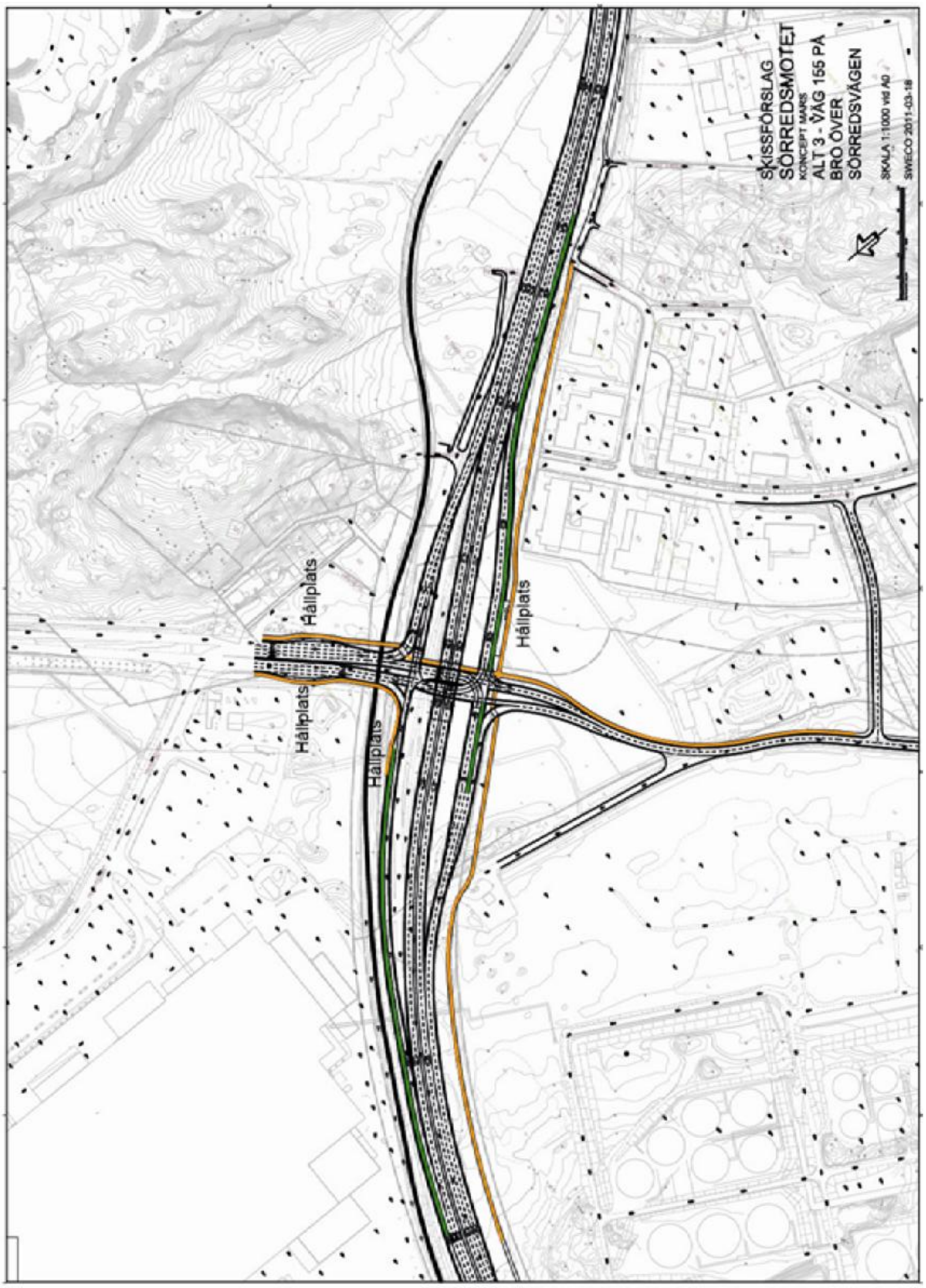
Appendix 1A (Overview of Alternative 2 Design)



Appendix 1B (Overview of Alternative-3A design)



Appendix 1C (Overview of Alternative-3 design)



Appendix 2A (Recorded motorized and non-motorized traffic flow)

TRAFFIC FLOW DATA AT SÖRREDSKORSNINGEN

LAP No.	TIME INTERVAL	WAY 1								WAY 2								WAY 3							
		To Right				To Left				To Right				To Straight				To Left				To Straight			
		LTV		HTV		LTV		HTV		LTV		HTV		LTV		HTV		LTV		HTV		LTV		HTV	
		S	C	B	T	S	C	B	T	S	C	B	T	S	C	B	T	S	C	B	T	S	C	B	T
1	kl 15:59:51	0	17	0	0	0	12	0	0	0	12	0	2	0	29	2	3	0	5	1	0	0	18	1	1
2	kl 16:01:35	0	18	0	0	0	13	0	0	0	4	1	1	2	43	0	1	0	2	0	2	0	19	1	1
3	kl 16:03:09	0	16	0	0	0	13	0	0	0	4	0	0	1	33	0	0	0	10	0	0	0	23	1	1
4	kl 16:04:55	0	8	0	0	1	15	1	0	1	8	2	2	1	36	1	0	0	10	0	1	2	44	0	2
5	kl 16:06:50	0	18	0	0	1	8	2	1	0	1	0	0	1	40	1	0	1	15	0	0	0	41	0	0
6	kl 16:08:51	0	16	0	0	0	25	0	0	0	6	1	0	0	32	2	1	1	8	1	1	0	31	2	0
7	kl 16:10:45	0	8	0	0	0	11	0	0	0	2	0	0	2	25	0	1	0	15	0	0	1	41	0	1
8	kl 16:12:28	0	21	0	1	0	12	1	0	0	3	0	0	0	38	1	0	0	12	0	0	1	38	1	1
9	kl 16:14:18	0	11	0	0	0	13	0	0	0	0	0	0	0	38	1	1	0	12	0	0	1	38	1	1
10	kl 16:15:47	0	10	0	1	0	13	0	0	0	7	0	0	1	43	0	0	1	16	0	0	0	40	1	0
11	kl 16:17:54	0	18	0	1	0	18	2	1	0	6	0	0	0	44	0	0	0	12	0	1	0	34	0	1
12	kl 16:19:50	0	14	0	0	0	19	0	0	0	3	0	0	0	32	2	1	0	7	1	2	0	27	1	0
13	kl 16:21:55	0	9	0	0	1	20	0	0	0	5	0	0	0	42	0	0	0	14	0	0	0	19	1	0
14	kl 16:23:41	0	9	0	1	0	14	1	1	0	6	0	0	0	34	2	1	0	6	1	0	0	26	2	0
15	kl 16:25:25	0	9	0	0	0	14	0	0	0	3	0	0	1	38	1	1	0	6	0	1	0	35	1	0
16	kl 16:27:15	0	11	0	0	0	13	1	1	0	6	2	1	0	41	0	0	1	10	0	0	0	17	1	0
17	kl 16:28:57	0	12	0	0	0	6	0	1	0	3	0	0	0	38	1	0	0	7	0	0	0	17	0	0
18	kl 16:30:41	0	9	0	0	0	9	1	0	0	2	1	0	1	35	2	0	0	4	0	0	0	22	0	0
19	kl 16:32:09	0	16	0	0	1	3	1	0	0	4	1	0	0	39	0	0	0	3	0	0	0	19	0	0
20	kl 16:33:39	0	11	0	0	0	3	0	0	0	4	0	1	0	35	1	0	0	5	0	0	0	16	2	0
21	kl 16:35:12	0	9	0	0	0	6	0	1	0	8	0	0	0	34	1	0	0	9	1	0	0	26	1	0
22	kl 16:36:54	0	12	0	0	0	10	0	0	0	1	0	2	0	41	0	0	1	9	0	0	0	23	0	0
23	kl 16:38:41	0	4	0	0	0	3	1	0	0	6	1	1	0	29	2	0	0	7	0	0	0	12	0	1
24	kl 16:40:07	0	9	0	1	0	5	0	1	0	8	1	1	0	32	2	0	0	2	0	0	0	17	2	1
25	kl 16:41:26	0	7	0	0	0	4	0	0	0	5	0	0	0	33	0	1	0	4	0	0	0	13	1	0
26	kl 16:43:01	0	6	0	0	0	9	0	0	0	2	0	0	1	29	1	0	0	5	0	0	0	15	0	1
27	kl 16:44:29	0	6	0	0	0	3	1	1	0	0	0	0	0	34	0	0	0	2	0	0	0	12	0	0
28	kl 16:45:05	0	12	0	0	0	4	1	0	0	4	2	1	1	36	0	0	0	4	0	0	0	15	0	0
29	kl 16:47:14	0	6	0	0	0	6	0	0	0	0	0	0	1	38	1	0	0	3	0	0	0	17	1	0
30	kl 16:48:39	0	8	0	1	0	3	0	1	0	4	0	3	0	29	0	0	0	5	0	0	1	24	0	1
31	kl 16:50:15	0	10	0	0	0	4	1	0	0	0	0	0	0	13	2	1	0	4	0	0	0	14	0	0
32	kl 16:51:28	0	8	0	0	0	3	0	0	0	4	1	0	0	19	1	1	0	5	0	0	0	6	0	0
33	kl 16:52:46	0	14	1	0	0	4	0	0	0	5	0	0	0	28	0	2	0	1	0	0	0	16	0	3
34	kl 16:54:15	0	9	0	0	0	10	0	0	0	1	0	1	0	16	0	0	0	4	1	0	0	28	0	1
35	kl 16:55:45	0	3	0	0	0	3	1	1	0	2	0	0	1	39	1	0	0	11	1	0	0	19	2	0
36	kl 16:57:25	0	4	0	0	0	6	0	1	0	3	0	0	0	26	1	0	0	6	0	0	0	9	0	1
37	kl 16:59:00	0	7	0	0	0	8	0	0	0	3	1	2	1	33	0	0	0	2	0	0	0	11	1	0
38	kl 17:01:42	0	9	0	0	0	1	0	0	0	2	1	0	2	13	2	0	0	5	0	0	0	17	0	0
TOTAL		0	404	1	6	4	346	15	11	1	147	15	18	17	1257	31	15	5	267	7	8	6	859	24	18

LAP No.	TIME INTERVAL	BI-CYCLER						PEDESTRIAN					
		From Torslanda to Sörredvägen	From Torslanda to Centrum	From Sörredvägen to Torslanda	From Sörredvägen to Centrum	From Centrum to Sörredvägen	From Centrum to Torslanda	From Torslanda to Sörredvägen	From Torslanda to Centrum	From Sörredvägen to Torslanda	From Sörredvägen to Centrum	From Centrum to Sörredvägen	From Centrum to Torslanda
1	kl 15:59:51	2	0	0	0	0	0	0	0	0	0	0	0
2	kl 16:01:35	0	0	0	0	0	0	0	0	0	0	0	0
3	kl 16:03:09	0	1	0	0	0	0	0	1	3	0	0	0
4	kl 16:04:55	0	0	2	0	0	0	0	0	0	0	0	0
5	kl 16:06:50	0	0	3	0	0	0	0	1	0	0	0	2
6	kl 16:08:51	0	1	2	0	0	0	0	0	3	0	0	0
7	kl 16:10:45	0	0	0	0	0	0	1	0	0	0	0	0
8	kl 16:12:28	0	1	1	1	0	0	0	0	0	0	0	0
9	kl 16:14:18	0	0	0	0	0	0	0	0	0	2	0	0
10	kl 16:15:47	0	0	0	0	1	0	0	2	0	0	0	0
11	kl 16:17:54	0	1	0	0	0	0	0	1	0	0	0	0
12	kl 16:19:50	0	0	1	0	0	0	0	0	0	0	0	0
13	kl 16:21:55	0	0	0	0	0	0	0	0	0	0	0	0
14	kl 16:23:41	0	0	0	0	0	0	0	0	0	1	0	0
15	kl 16:25:25	0	0	1	0	0	0	0	1	0	0	0	0
16	kl 16:27:15	0	1	0	0	0	0	0	0	0	1	0	0
17	kl 16:28:57	0	0	1	0	0	0	0	0	1	3	0	0
18	kl 16:30:41	0	0	0	0	0	0	0	1	0	0	0	1
19	kl 16:32:09	0	0	0	0	0	0	0	0	0	0	0	0
20	kl 16:33:39	0	0	2	0	0	0	0	0	1	2	0	0
21	kl 16:35:12	0	0	0	0	0	0	0	1	1	0	0	0
22	kl 16:36:54	0	0	0	0	2	0	0	2	0	0	0	0
23	kl 16:38:41	0	0	0	0	0	1	0	0	0	0	0	0
24	kl 16:40:07	0	0	0	0	0	1	0	0	0	0	0	0
25	kl 16:41:26	0	1	0	0	0	0	0	4	0	2	0	0
26	kl 16:43:01	1	0	0	0	0	0	0	0	0	0	0	0
27	kl 16:44:29	1	1	1	0	0	0	0	1	0	0	0	0
28	kl 16:45:05	0	0	0	0	0	0	0	0	0	0	0	0
29	kl 16:47:14	0	0	0	0	0	0	0	0	0	0	0	0
30	kl 16:48:39	0	0	0	0	0	0	0	0	0	0	0	0
31	kl 16:50:15	0	0	0	0	0	2	0	0	0	0	0	0
32	kl 16:51:28	0	0	0	1	0	1	1	0	0	1	0	0
33	kl 16:52:46	0	0	0	0	0	0	0	0	0	0	0	0
34	kl 16:54:15	0	0	0	1	0	0	0	0	0	1	0	0
35	kl 16:55:45	0	0	0	0	0	0	0	0	0	0	0	1
36	kl 16:57:25	0	0	0	0	0	0	0	0	0	0	0	0
37	kl 16:59:00	0	0	0	0	0	2	0	2	0	0	0	0
38	kl 17:01:42	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		4	7	14	3	3	7	2	17	9	13	0	4

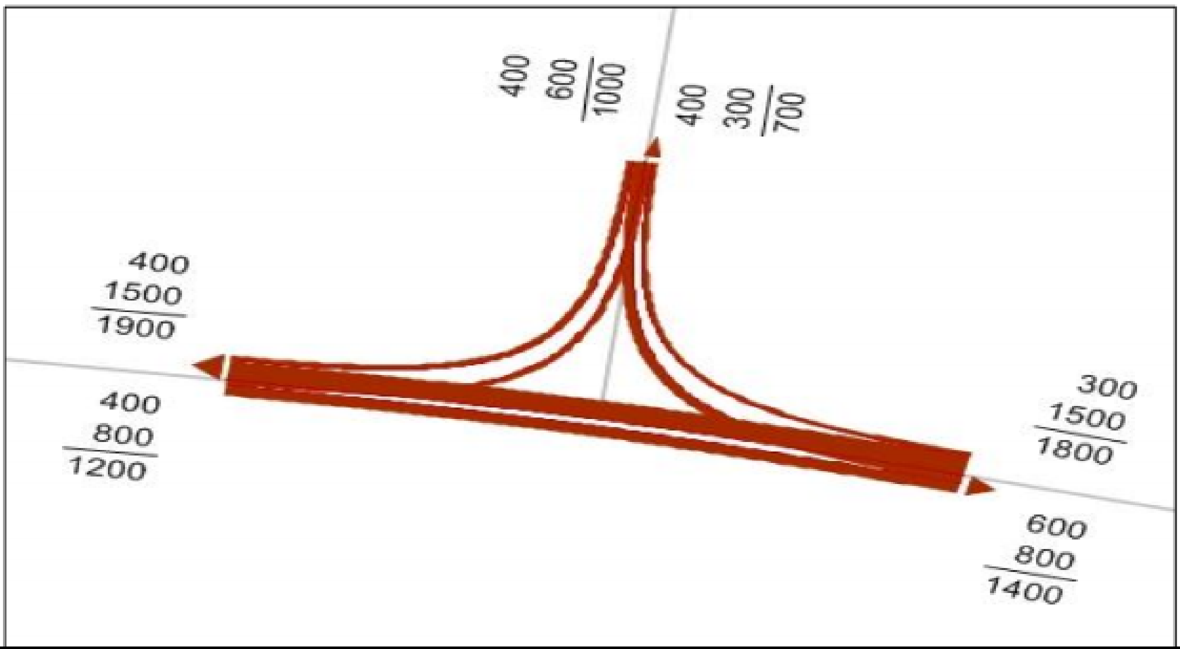
WAY 1 From Sörredsvägen - Torslanda and Centrum
WAY 2 From Centrum - Sörredsvägen and Torslanda
WAY 3 From Torslanda - Sörredsvägen and Centrum

LTV Light vehicles
HTV Heavy vehicles

S Scooter/Motor cycle
C Car
B Bus
T Truck

Date 2011-09-30
Time 16:00 - 17:00

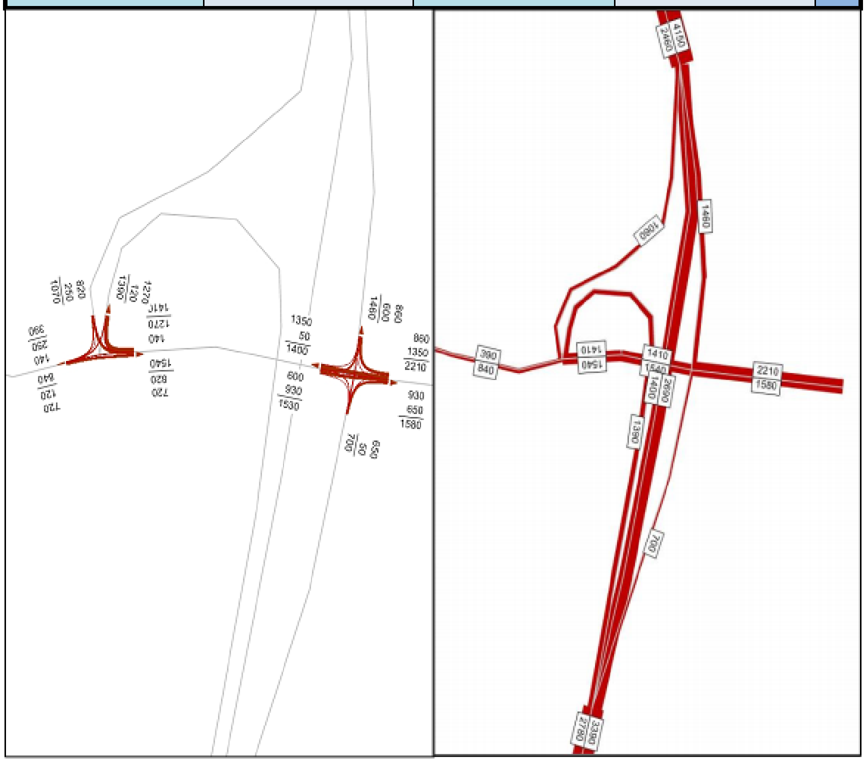
Appendix 2B (Vehicle amounts for present scenario)



Origin	Destination	Vehicles/hour
Centrum		**1800**
	Sörredsvägen	300
	Torslanda	1500
Torslanda		**1200**
	Sörredsvägen	400
	Centrum	800
Sörredsvägen		**1000**
	Torslanda	400
	Centrum	600

Appendix 2C (Vehicle amounts for alternatives)

Origin	Destination	Vehicles/hour
Centrum		**3390**
	Sörreds-North	650
	Sörreds-South	50
	Torslanda	2690
Torslanda		**2470**
	Sörreds-South	250
	Sörreds-North	820
	Centrum	1400
Sörreds-North		**2210**
	Torslanda	860
	Centrum	1350
	Sörreds-South	0
Sörreds-South		**840**
	Centrum	120
	Torslanda	600
	Sörreds-North	120



Appendix 3

(*.pua and *.vap files for Present scenario model)

$SIGNAL_GROUPS

VAP	VISSIM
$	
S1	1
S2	2
S3	3
S4	4
S5	5
S6	6
P1	7
P2	8
P3	9
P4	10

$STAGES

VAP	VISSIM
1	Stage_1
2	Stage_2
3	Stage_3
4	Stage_4

$

STAGE_1	S1 S2 P1
STAGE_2	S3 S4 P2

STAGE_3	S5 S6 P3 P4	

$STARTING_STAGE

$

STAGE_1

$INTERSTAGE1

LENGTH [s]	: 15	
FROM STAGE	: 1	
TO STAGE	: 2	

$

S1	-127	14
S2	-127	0
S3	7	127
S4	7	127
P1	-127	0
P2	4	127

$INTERSTAGE2

LENGTH [s]	: 35	
FROM STAGE	: 1	
TO STAGE	: 3	

$

S1	-127	2
S2	-127	0

S5	0	127
S6	8	127
P1	-127	0
P3	2	127
P4	10	127

$INTERSTAGE3

LENGTH [s] : 35

FROM STAGE : 2

TO STAGE : 3

$

S3	-127	0
S4	-127	10
S5	6	127
S6	6	127
P2	-127	0
P3	7	127
P4	14	127

$INTERSTAGE4

LENGTH [s] : 15

FROM STAGE : 2

TO STAGE : 1

$

S1	3	127
S2	4	127
S3	-127	0

S4	-127	0
P1	4	127
P2	-127	0

$INTERSTAGE5

LENGTH [s] : 18

FROM STAGE : 3

TO STAGE : 1

$		
S	7	127
S2	7	127
S5	-127	10
S6	-127	0
P1	5	127
P3	-127	0
P4	-127	0

$INTERSTAGE6

LENGTH [s] : 15

FROM STAGE : 3

TO STAGE : 2

$		
S3	8	127
S4	7	127
S5	-127	2

S6	-127	0
P2	6	127
P3	-127	0
P4	-127	2

$END

START
Stage_active(1)
StgT(1)<MAX_STG1
Extend_Stg1
O3 OR O4
Interstage(1 , 2)
O5 OR O6
Interstage(1 , 3)
Stage_active(2)
StgT(2)<MAX_STG2
Extend_Stg2
O5 OR O6
Interstage(2 , 3)
O1 OR O2
Interstage(2 , 1)
Stage_active(3)
StgT(3)<MAX_STG3
Extend_Stg3
O1 OR O2
Interstage(3 , 1)
O3 OR O4
Interstage(3 , 2)
END

PARAMETERS	Gen	Comment
MAX_GAP	5	Max. gap time
MAX_STG1	15	Max. duration of stage 1
MAX_STG2	25	Max. duration of stage 2
MAX_STG3	25	Max. duration of stage 3

EXPRESSIONS	Contents
Extend_Stg1	(Headway(1) <= MAX_GAP) OR (Headway(2) <= MAX_GAP)
Extend_Stg2	(Headway(3) <= MAX_GAP) OR (Headway(4) <= MAX_GAP)
Extend_Stg3	(Headway(5) <= MAX_GAP) OR (Headway(6) <= MAX_GAP)
O1	Occupancy(1) > 4
O2	Occupancy(2) > 6
O3	Occupancy(3) > 2
O4	Occupancy(4) > 2
O5	Occupancy(5) > 4
O6	Occupancy(6) > 8

Appendix 4A

(*.pua and *.vap files for Alternative-2 Sörreds North intersection)

$SIGNAL_GROUPS

VAP	VISSIM
$	
S1	1
S2	2
S3	3
S4	4
S5	5

$STAGES

VAP	VISSIM
1	Stage_1
2	Stage_2
3	Stage_3

$

STAGE_1	S1 S5
STAGE_2	S2 S3
STAGE_3	S4

$STARTING_STAGE

$

STAGE_1

$INTERSTAGE1

LENGTH [s]	: 10
FROM STAGE	: 1
TO STAGE	: 2

$

S1	-127	0
S5	-127	5
S2	3	127
S3	8	127

$INTERSTAGE2

LENGTH [s]	: 7
FROM STAGE	: 1
TO STAGE	: 3

$

S1	-127	0
S5	-127	10
S4	2	27

$INTERSTAGE3

LENGTH [s]	: 7
FROM STAGE	: 2
TO STAGE	: 3

$

S2	-127	0

S3 -127 0

S4 3 127

$INTERSTAGE4

LENGTH [s] : 12

FROM STAGE : 2

TO STAGE : 1

$

S1 3 127

S5 5 127

S2 -127 0

S3 -127 0

$INTERSTAGE5

LENGTH [s] : 12

FROM STAGE : 3

TO STAGE : 1

$

S1 5 127

S5 0 127

S4 -127 0

$INTERSTAGE6

LENGTH [s] : 15

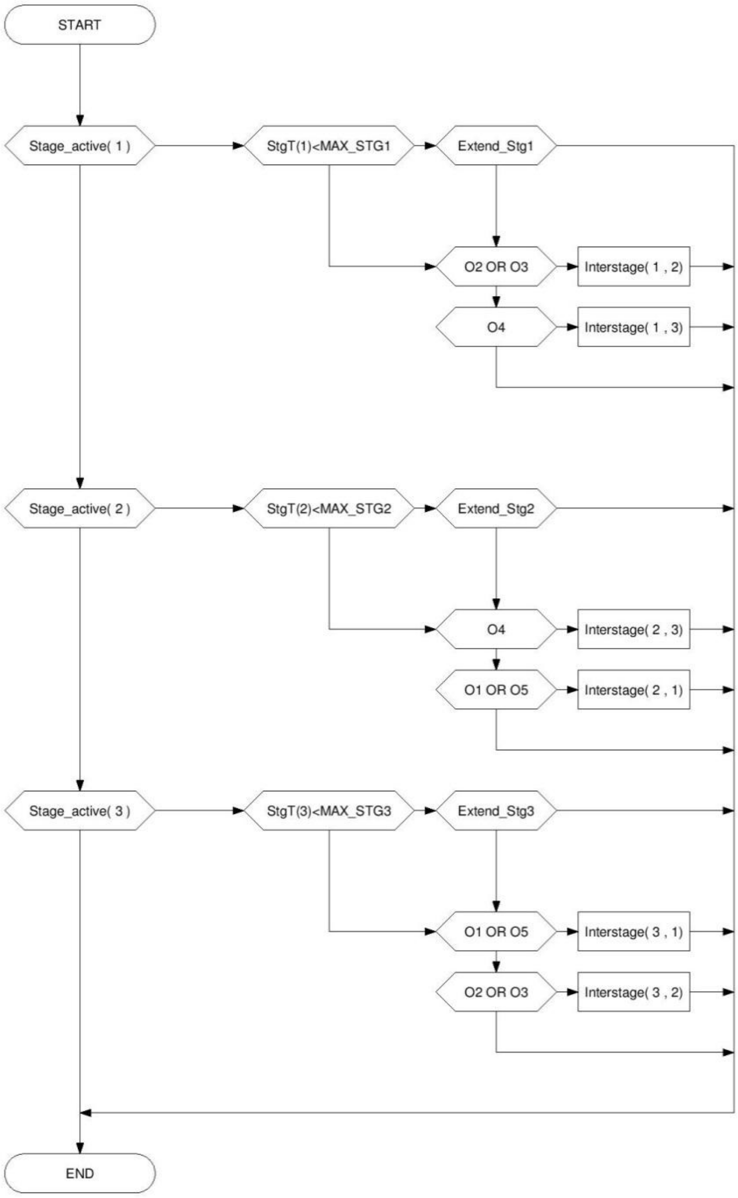
FROM STAGE : 3

TO STAGE : 2

$

S2	5	127
S3	4	127
S4	-127	0

$END


START
Stage_active(1)
StgT(1)<MAX_STG1
Extend_Stg1
O2 OR O3
Interstage(1 , 2)
O4
Interstage(1 , 3)
Stage_active(2)
StgT(2)<MAX_STG2
Extend_Stg2
O4
Interstage(2 , 3)
O1 OR O5
Interstage(2 , 1)
Stage_active(3)
StgT(3)<MAX_STG3
Extend_Stg3
O1 OR O5
Interstage(3 , 1)
O2 OR O3
Interstage(3 , 2)
END

PARAMETERS	**Gen**	**Comment**
MAX_GAP	5	Max. gap time
MAX_STG1	30	Max. duration of stage 1
MAX_STG2	40	Max. duration of stage 2
MAX_STG3	8	Max. duration of stage 3

EXPRESSIONS	**Contents**
Extend_Stg1	(Headway(1) <= MAX_GAP) OR (Headway(5) <= MAX_GAP)
Extend_Stg2	(Headway(2) <= MAX_GAP) OR (Headway(3) <= MAX_GAP)
Extend_Stg3	(Headway(4) <= MAX_GAP)
O1	Occupancy(1) > 4
O2	Occupancy(2) > 6
O3	Occupancy(3) > 8
O4	Occupancy(4) > 0
O5	Occupancy(5) > 4

Appendix 4B

(*.pua and *.vap files for Alternative-2 Sörreds South intersection)

$SIGNAL_GROUPS

VAP	VISSIM
$	
S1	1
S2	2
S3	3
S4	4

$STAGES

VAP	VISSIM
1	Stage_1
2	Stage_2
3	Stage_3

$	
STAGE_1	S1
STAGE_2	S2
STAGE_3	S3 S4

$STARTING_STAGE

$

STAGE_1

$INTERSTAGE1

LENGTH [s]	: 18	
FROM STAGE	: 1	
TO STAGE	: 2	

$

S1	-127	0
S2	3	127

$INTERSTAGE2

LENGTH [s]	: 20	
FROM STAGE	: 1	
TO STAGE	: 3	

$

S1	-127	0
S3	5	127
S4	2	127

$INTERSTAGE3

LENGTH [s]	: 20	
FROM STAGE	: 2	
TO STAGE	: 3	

$

S2	-127	0
S3	4	127
S4	5	127

$INTERSTAGE4

LENGTH [s]	: 10	
FROM STAGE	: 2	
TO STAGE	: 1	
$		
S1	3	127
S2	-127	0

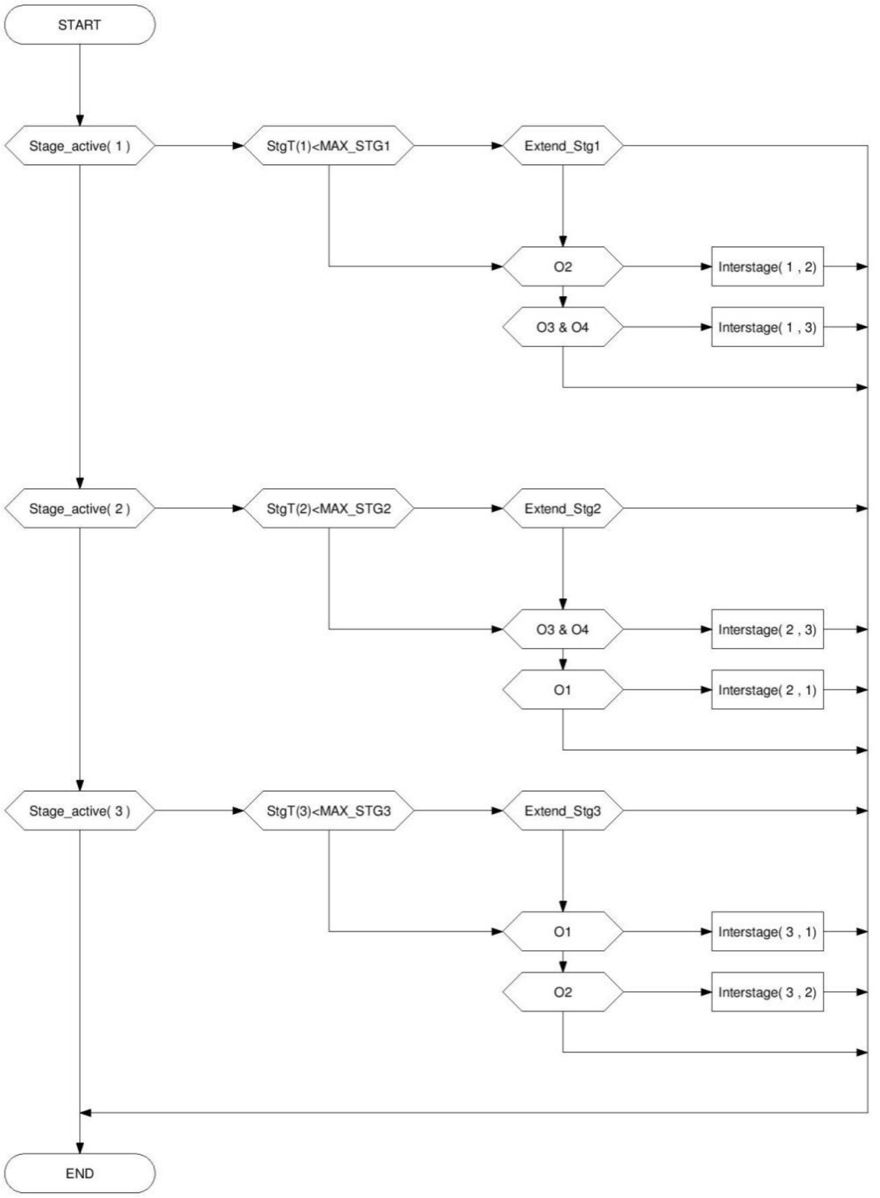
$INTERSTAGE5

LENGTH [s]	: 10	
FROM STAGE	: 3	
TO STAGE	: 1	
$		
S1	5	127
S3	-127	0
S4	-127	8

$INTERSTAGE6

LENGTH [s]	: 20	
FROM STAGE	: 3	
TO STAGE	: 2	
$		
S2	4	127
S3	-127	0
S4	-127	0

$END


START
Stage_active(1)
StgT(1)<MAX_STG1
Extend_Stg1
O2
Interstage(1 , 2)
O3 & O4
Interstage(1 , 3)
Stage_active(2)
StgT(2)<MAX_STG2
Extend_Stg2
O3 & O4
Interstage(2 , 3)
O1
Interstage(2 , 1)
Stage_active(3)
StgT(3)<MAX_STG3
Extend_Stg3
O1
Interstage(3 , 1)
O2
Interstage(3 , 2)
END

PARAMETERS	Gen	Comment
Max_Gap	5	Max. gap time
MAX_STG1	10	Max. duration of stage 1
MAX_STG2	20	Max. duration of stage 2
MAX_STG3	20	Max. duration of stage 3

EXPRESSIONS	Contents
Extend_Stg1	(Headway(1) <= MAX_GAP) OR (Headway(5) <= MAX_GAP)
Extend_Stg2	(Headway(2) <= MAX_GAP) OR (Headway(3) <= MAX_GAP)
Extend_Stg3	(Headway(4) <= MAX_GAP)
O1#	Occupancy(1) > 2
O2#	Occupancy(2) > 6
O3#	Occupancy(3) > 8
O4#	Occupancy(4) > 8

Appendix 5

(*.pua and *.vap files for Alternative-3A)

$SIGNAL_GROUPS

VAP	VISSIM
$	
S1	1
S2	2
S3	3
S4	4
S5	5
S6	6
S7	7
S8	8
S9	9
S10	10
S11	11
S12	12

$STAGES

VAP VISSIM

1 Stage_1

2 Stage_2

3 Stage_3

$

STAGE_1 S1 S2 S9 S11

STAGE_2	S4 S5 S6 S10	
STAGE_3	S3 S8 S7 S12	

$STARTING_STAGE

$

STAGE_1

$INTERSTAGE1

LENGTH [s]:	27	
FROM STAGE :	1	
TO STAGE :	2	

$

S1	-127	0
S2	-127	4
S9	-127	0
S11	-127	0
S4	1	127
S5	6	127
S6	5	127
S10	5	127

$INTERSTAGE2

LENGTH [s] :	18	
FROM STAGE :	1	
TO STAGE :	3	

$

S1	-127	0
S2	-127	0
S9	-127	12
S11	-127	0
S3	5	127
S8	6	127
S7	6	127
S12	4	127

$INTERSTAGE3

LENGTH [s] : 18

FROM STAGE : 2

TO STAGE : 3

$

S4	-127	0
S5	-127	3
S6	-127	3
S10	-127	0
S3	5	127
S8	8	127
S7	8	127
S12	5	127

$INTERSTAGE4

LENGTH [s] : 26

FROM STAGE : 2

TO STAGE : 1

$

S4	-127	3
S5	-127	0
S6	-127	2
S10	-127	3
S1	6	127
S2	0	127
S9	7	127
S11	8	127

$INTERSTAGE5

LENGTH [s] : 27

FROM STAGE : 3

TO STAGE : 2

$

S3	-127	0
S8	-127	0
S7	-127	0
S12	-127	0
S4	2	127
S5	6	127
S6	5	127
S10	5	127

$INTERSTAGE6

LENGTH [s] : 26

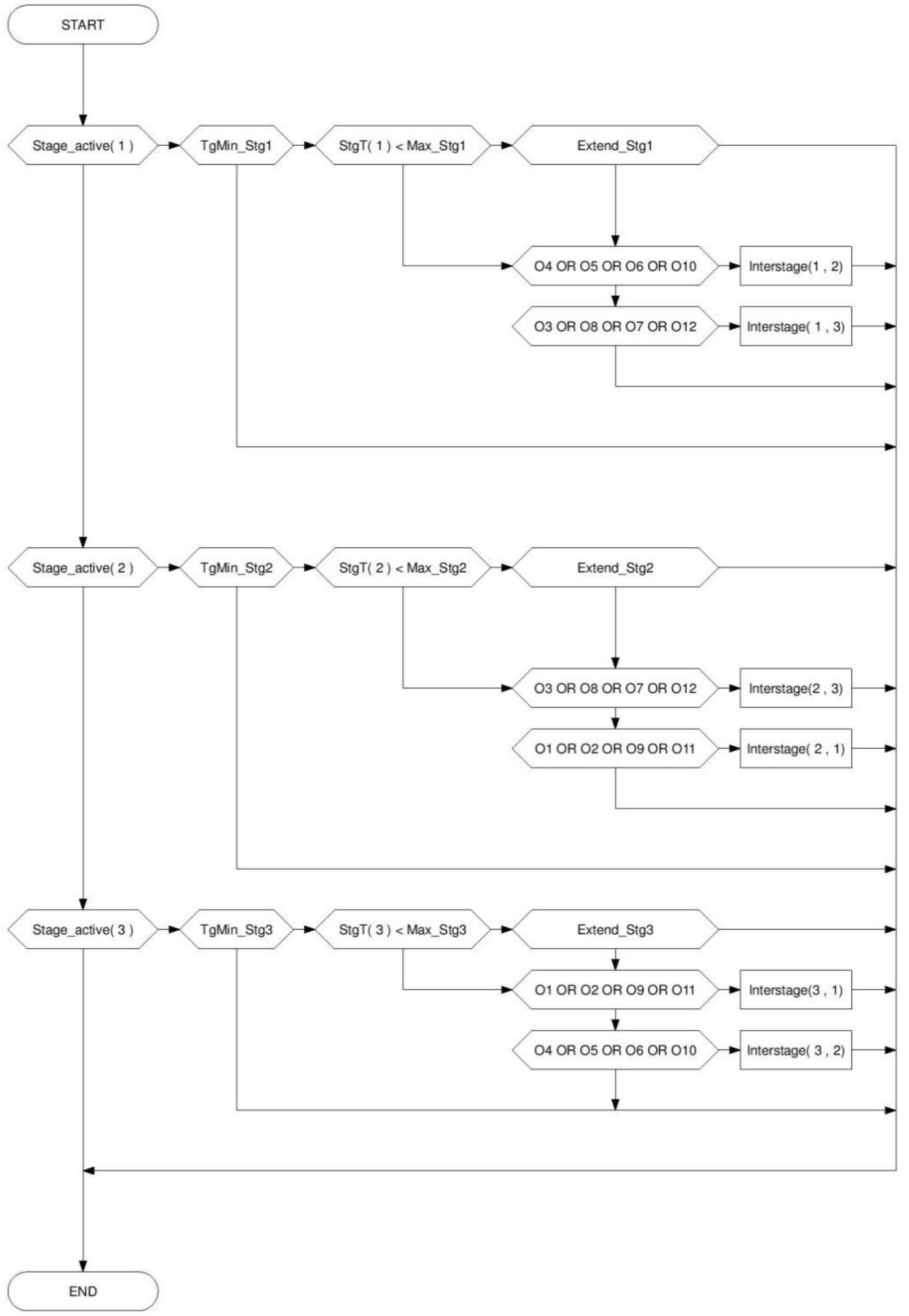
FROM STAGE : 3

TO STAGE : 1

$

S3	-127	0
S8	-127	0
S7	-127	0
S12	-127	8
S1	6	127
S2	2	127
S9	5	127
S11	4	127

$END



ALT_3A.vv

page 1

PARAMETERS	**Gen**	**Comment**
Max_Gap	5	Max. gap time
MAX_STG1	35	Max. duration of stage 1
MAX_STG2	40	Max. duration of stage 2
MAX_STG3	30	Max. duration of stage 3

EXPRESSIONS	**Contents**
TgMin_Stg1	(Tg(S1) >= Tgmin(S1)) & (Tg(S2) >= Tgmin(S2)) & (Tg(S9) >= Tgmin(S9)) & (Tg(S11) >= Tgmin(S11))
Extend_Stg1	(Headway (1) <= Max_Gap) OR (Headway (2) <= Max_Gap) OR (Headway (9) <= Max_Gap) OR (Headway (11) <= Max_Gap)
TgMin_Stg2	(Tg(S4) >= Tgmin(S4)) & (Tg(S5) >= Tgmin(S5)) & (Tg(S6) >= Tgmin(S6)) & (Tg(S10) >= Tgmin(S10))
Extend_Stg2	(Headway (4) <= Max_Gap) OR (Headway (5) <= Max_Gap) OR (Headway (6) <= Max_Gap) OR (Headway (10) <= Max_Gap)
Extend_Stg3	(Headway (3) <= Max_Gap) OR (Headway (8) <= Max_Gap) OR (Headway (7) <= Max_Gap) OR (Headway (12) <= Max_Gap)
TgMin_Stg3	(Tg(S3) >= Tgmin(S3)) & (Tg(S8) >= Tgmin(S8)) & (Tg(S7) >= Tgmin(S7)) & (Tg(S12) >= Tgmin(S12))
O1	Occupancy(1) > 10
O2	Occupancy(2) > 6
O3	Occupancy(3) > 1
O4	Occupancy(4) > 8
O5	Occupancy(5) > 4
O6	Occupancy(6) > 4
O7	Occupancy(7) > 3
O8	Occupancy(8) > 1
O9	Occupancy(9) > 4
O10	Occupancy(10) > 8
O11	Occupancy(11) > 2
O12	Occupancy(12) > 8