CHALMERS

Rerouting of road traffic

A comparison of different rerouting alternatives at unplanned disruptions in road traffic

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

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CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2014

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ABSTRACT

The vision of the Swedish Transport Administration is: *"everyone arrives smoothly, safely and green".* Unplanned disturbances in road traffic have consequences that affect these criteria in a negative way. Rerouting could delimit these consequences but there are few studies performed about rerouting at unplanned incidents. The aim of this thesis is to compare different rerouting alternatives on 2+1 roads at unplanned disruptions in road traffic. The alternatives are investigated considering the accessibility for the road users. The rerouting alternatives are to bypass the traffic past the incident or to redirect the traffic on another road. The alternatives are investigated by simulations in the microsimulation software PTV Vissim. The investigation is performed on the three areas most affected by disruptions in the Western Region: road E45, road 40 and road E20. The conclusions made in this thesis are based on these three areas and might therefore not be applicable in other areas and situations. To evaluate who is responsible for the decision of rerouting, interviews are performed with the operators involved in the clearance of the road. The main issue discovered during the interviews was lack of communication regarding rerouting. In the project *"Hinderfri väg"* the manual *"Vägen fri- snabbt och säkert"* was elaborated by the Swedish Transport Administration. This manual will, when implemented, solve many of the issues discovered. However, one part that should be further developed is how to choose rerouting alternative. The result from the simulations shows that the most appropriate rerouting alternative is dependent on the traffic situation. It is generally advantageous to reroute compared to letting the traffic wait and the best option is to keep one lane in each direction open. Rerouting on another road can be a good option depending on the traffic situation. This result does however not apply if the rerouting route is significantly longer than the original route or if the traffic situation is complicated with high traffic flows. Accessibility is not the only criterion to consider when choosing rerouting alternative, safety and environmental aspects also need to be considered. Before any rerouting can be performed it is important that the safety is ensured.

Key words: Rerouting, Traffic simulation, Unplanned disruptions, Delay, Accessibility, Hinderfri väg, 2+1 roads

Omledning av vägtrafik
En jämförelse av olika omledningsalternativ vid oplanerade störningar i vägtrafiken
Examensarbete inom Infrastructure and Environmental Engineering
ISA APPELQVIST
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Väg och trafik
Chalmers tekniska högskola

SAMMANFATTNING

Trafikverket har visionen: *“alla kommer fram smidigt, grönt och tryggt”.* Oplanerade störningar i vägtrafiken får konsekvenser som påverkar dessa kriterier på ett negativt sätt. Trafikomledning kan begränsa konsekvenserna, men endast få undersökningar är gjorda gällande omledning vid oplanerade händelser i vägtrafiken. Syftet med detta examensarbete är att jämföra olika omledningsalternativ på 2+1 vägar vid oplanerade störningar utifrån framkomligheten för trafikanterna. De omledningsalternativ som undersöks är att leda trafiken förbi olyckan på huvudvägen eller att leda om trafiken på en annan väg. Dessa alternativ jämförs genom att göra simuleringar i mikrosimuleringsprogrammet PTV Vissim. Undersökningarna genomförs för de tre områden i Region väst som är mest drabbade av totalstopp: väg E45, väg 40 och väg E20. Slutsatserna i denna undersökning är baserade på de tre undersökta områdena och kan därför inte anses gälla andra områden och situationer. Intervjuer med de aktörer som är inblandade i arbetet med att få undan stoppet genomförs för att utvärdera vem som är ansvarig för att besluta om omledning. Brister i kommunikationen mellan de olika aktörerna var ett av de största problemen som identifierades i intervjuundersökningen. Manualen *”Vägen fri- snabbt och säkert”,* som tagits fram på uppdrag av Trafikverket i projektet *”Hinderfri väg”,* kommer att lösa många av de problem som upptäckts i undersökning när den implementeras i regionen. En aspekt som dock inte behandlas i manualen är hur man ska välja omledningsalternativ, vilket borde undersökas ytterligare. Resultatet från simuleringarna visar att det mest lämpliga omledningsalternativet beror på varje specifik trafiksituation. Det är generellt fördelaktigt att leda om trafiken jämfört med att låta trafiken vänta och det bästa alternativet är att ha en fil öppen i varje riktning. Omledning på annan väg kan vara ett bra alternativ, beroende på trafiksituationen. Detta resultat gäller dock enbart om omledningsvägen inte är allt för lång jämfört med den ursprungliga vägen eller om trafiksituationen inte är för komplicerad med höga trafikflöden. Framkomlighet är inte det enda kriteriet att ta hänsyn till när beslut om omledningsalternativ ska fattas, säkerhet och miljöaspekter måste också beaktas. Vid omledning måste alltid säkerheten prioriteras, oavsett vilket alternativ man genomför.

Nyckelord: Trafikomledning, Trafiksimulering, Oplanerade störningar, Framkomlighet, Hinderfri väg, 2+1 vägar

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Preface

This Master Thesis has been carried out between January and May 2014 by the authors Isa Appelqvist and Sofia Örngren. The investigation has been conducted at the Department of Civil and Environmental Engineering, Chalmers University of Technology on behalf of the Swedish Transport Administration. Support has been provided by the supervisors Jan Englund at the Road and Traffic Research Group at Chalmers University of Technology and Eva-Marie Mendahl at Business Area Maintenance at the Swedish Transport Administration. Examiner for the thesis is Lars O Ericsson, Professor at the department of GeoEngineering at Chalmers University of Technology.

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Gothenburg May 2014

Isa Appelqvist & Sofia Örngren

Vocabulary

Accessibility	Framkomlighet
Arterial road	Motortrafikled
Business Area Maintenance	Verksamhetsområde Underhåll
Bypassing	Förbiledning eller Överledning
Carriageway	Landsväg
Dual road	Mötesfri väg
Incident leader	Räddningsledare
Load class	Bärighetsklass
Maintenance Entrepreneur	Driftentreprenör
Operation Project Manager	Projektledare på Trafikverket för driftområde
Rerouting	Omledning
Residual Leader	Restvärdesledare
Salvation Operator	Bärgare
Swedish Road Administration	Vägverket, former name of Trafikverket
Swedish Transport Administration	Trafikverket
Traffic Center	Trafikcentralen

Definitions

2+1 road	A road type with two lanes in one direction and one lane in the other direction, alternating. The directions are commonly separated by a guard rail.
AADT	The Average Annual Daily Traffic is the total volume of vehicles over a year divided by 365 days for a certain road.
Accessibility	Capability of reaching a required destination.
ArcGIS	A Geographic Information System software which can be used to collect, analyze and present spatial information.
Bypassing	When traffic is redirected past the incident site either by having one lane open on the two lane road, or by using the one lane road with alternating directions.
Hinderfri Väg	A project initiated by the Swedish Transport Administration where the manual *"Vägen fri- snabbt och säkert"* was elaborated. The project aims at implementing national practices for incidents in road traffic.
Kännbarhet	A measure used by Swedish Transport Administration to evaluated the impact of a disruption in road traffic. In this report called: calculated total vehicle delay.
Läget i trafiken	A webpage handled by the Traffic Center, where private and professional drivers can find information about disturbances in the traffic.
Nationell Vägdatabas (NVDB)	The Swedish Transport Administration's map based database for information, such as speed limits, height, width and weight limitations etc., in the Swedish road network are found.
Rerouting	When the traffic in some way is directed past the incident either by bypassing or by redirecting the traffic on another road.
Vägen fri- snabbt och säkert	A manual that describes how the collaboration between the operators involved in a traffic incident should be performed to make the work more efficient and by that decrease the disturbance in traffic.
Vägtrafikflödeskartan	The Swedish Transport Administration's map based database where information, such as the Average Annual Daily Traffic and average speed, is found.

1 Introduction

The aim of the European Union´s land transport policy is to promote *a mobility that is efficient, safe, secure and environmentally friendly* (European Commission, 2013). In line with this the Swedish Transport Administration has the vision; *everyone arrives smoothly, safely and green* (Trafikverket, 2012a). This means that everyone travels in an easy and efficient way throughout the trip, that the transportation system is sustainable and energy efficient and that it should both be and feel safe in any traffic environment (Tingvall, et al., 2011).

The vision of the Swedish Transport Administration will be achieved both by new investments in the road and rail network and by maintaining the existing network (Trafikverket, 2013a). The maintenance involves planned roadwork but also the management of unplanned disturbances such as traffic accidents and nature related events. Unplanned disturbances that occur on the major road network can cause long interruptions in the traffic resulting in negative consequences for the road users (Trafikverket, 2012b). The consequences of unplanned traffic disruptions can be delayed deliveries, lost work time or missed travel connections. There is also an increased risk for accidents when travelers try to make up for lost time by speeding and increased emissions due to idle running.

1.1 Background

One of the Business Areas within the Swedish Transport Administration is Maintenance. According to the business plan of Maintenance, one of the goals until 2018 is to have a robust, safe and available system that is adjusted to the transportation need (Pettersson, 2013). Within this goal, one part is to increase the accessibility by lowering the number of hours cars are standing still due to various events in the system. The value 2013 was 1 306 000 hours per year and it should be decreased to 1 200 000 hours per year until 2018. This can also be measured as disturbance-hours per vehicle and year. 2013 the disturbance was 19.6 minutes per vehicle and year and it should be decreased to 18 minutes per vehicle and year. The goal will be reached by being better prepared to handle disturbances in the traffic, by better estimating the duration of the disturbance and its effects and by minimizing the consequences of the disturbances.

The Swedish Transport Administration has in the project "*Hinderfri väg"* developed a manual, "*Vägen Fri- Snabbt och säkert"*, to reduce the duration of disturbances by improving the interactions between the operators involved in the rescue operation (Trafikverket, 2012b). When a disruption occurs there are several operators involved such as the Police, the Ambulance Service, the Emergency Service and SOS Alarm. There are also operators which are not involved in the acute rescue work, but play an important role in clearing the road as soon as possible. These are the Salvation Operators, the Maintenance Entrepreneurs and the Swedish Transport Administration's Traffic Center.

Even if the rescue operation is efficient and the road is cleared as fast as possible the disruption can still be comprehensive if the incident is severe. To reduce the consequences of a disturbance, the traffic can be redirected to another road or bypassed on the incident road. The decision if rerouting should be performed and in that case, which of the alternatives to choose, is of great importance to reduce the consequences of disturbances in the road network.

1.2 Purpose

The purpose of this thesis is to investigate the rerouting alternatives at unplanned disruptions in road traffic on 2+1 roads. The thesis aims at comparing the alternatives to redirect traffic to another road and bypass the traffic on the incident road, based on the criterion accessibility. Furthermore, the decision-making process regarding rerouting of traffic is evaluated.

1.3 Limitations

In this study, rerouting alternatives for disruptions on 2+1 roads are evaluated. 2+1 roads are commonly separated by a guard rail which decreases the number of severe accidents (Transek AB, 2005). When an accident occurs however, the traffic situation is more complicated. The disruption leads to worse consequences if it occurs on a narrow road where it is difficult to keep one lane open for traffic. It can also be difficult for the rescue operators to reach the incident area.

The Swedish Transport Administration is divided into six geographical regions. To delimit the project, the Western Region is studied in this project. The Western Region includes the counties of Västra Götaland, Halland and Värmland.

This study evaluates the current situation and therefore no consideration is taken to increased traffic flows in the future. Neither spontaneous rerouting is considered, which means that the road users chose other routes by them self. It is assumed that spontaneous rerouting is more common in cities where there are more alternative routes, while this study is carried out where the rerouting alternatives are limited. Neither decreased traffic flow to the incident road due to traffic information has been considered. The situation with stop in both directions at the same time is not included in this thesis since the only rerouting alternative for this scenario is to redirect the traffic to another road.

1.4 Methodology

In this thesis, three areas with 2+1 roads are investigated and the rerouting alternatives for each area are compared based on the criterion accessibility. The areas are chosen based on statistics of total disruption in road traffic from the Swedish Transport Administration. The three areas with most disruptions are chosen with the help of the Geographic Information System software ArcGIS.

In order to investigate the rerouting alternatives, simulations in the microsimulation software Vissim are performed. Simulations for stop in one, two, four and eight hours are done. From the simulations, the total travel time in the system is evaluated from which a comparison based on accessibility is done. A literature based study of environmental and safety aspects of rerouting is also performed.

The rerouting routes are chosen after consultation with the Operation Project Managers at the Swedish Transport Administration. An ocular inspection, as well as studies in the databases of the Swedish Transport Administration, is performed in each area to gather input data to the simulations.

The Swedish Transport Administration uses a measure of the total vehicle delay to estimate the impact of a disruption in traffic. The total vehicle delay is calculated for the scenarios investigated and compared to the results from the simulations, to see how well the measure represents the simulated delay.

To evaluate the decision-making process for rerouting the manual *“Vägen Fri- snabbt och säkert”*, where the routines elaborated by the Swedish Transport Administration is described, is studied. Interviews with the operators involved in the clearance of the road after a disruption are performed to evaluate how and by who decisions at the site is performed.

2 Rerouting on 2+1 roads

This thesis focuses on investigating rerouting alternatives on 2+1 roads. The possible rerouting alternatives are defined and important factors to consider during rerouting are listed in the chapter below. A study where disturbances on dual roads are investigated is also presented in the following chapter.

2.1 2+1 roads

Dual carriageways and arterial roads are commonly 2+1 roads which have one lane in one direction and two in the other, alternating in sections of 1-2.5 kilometers (Vägverket, 2004). Sections with 1+1 and 2+2 lanes can also occur. The arterial roads have intersections that are separated in level and slow-moving vehicles, cyclists and pedestrians are prohibited. The dual carriageways can have intersections in the same level and slow-moving vehicles, cyclists and pedestrians are allowed.

The dimensions used in the simulation for the lane width is 3.25 meters in the two lane direction and 3.75 meters in the one lane direction (Vägverket, 2004). The dimension of the road side and mid strip is dependent on whether cycling and pedestrian traffic is allowed or not. In the simulation program Vissim, the dimensions of the roadside and the mid strip are not defined. Therefore these measures are irrelevant for the investigation of delays. For the safety on the road and for the possibility to perform rescuing work on the other hand, the width of the roadside and mid strip is of importance.

In the report *"Hur fungerar och upplevs mötesfria vägar?"* written by the consultant company Transek on behalf of the Swedish Road Administration, dual roads have been investigated (Berdica, et al., 2004). According to Transek (2005) dual roads have been proved to have good effects on the safety for the road users, but little is studied how these roads function during disturbances and how the road users perceive dual roads.

In the study, four types of dual roads are compared to each other; highways, multiple lane roads, arterial roads and carriageways (Berdica, et al., 2004). The study concludes that there are small differences in the amount of accidents occurring on the different road types but generally the duration of the incidents is slightly longer on narrow multiple lane roads and the 2+1 roads is more often closed. Disturbances due to maintenance work are more common on 2+1 roads and on narrow multiple lane roads. On 2+1 roads it is common that vehicles drive into the guard rail in the transition from two to one lane which in turn lead to more maintenance work.

The general perception of the dual roads by the road user is investigated based on four aspects; security, accessibility, road safety and space (Berdica, et al., 2004). Highways are graded highest (above 4.5 of 5) for all aspects followed by multiple lane roads (around 4). The 2+1 roads are graded lowest for all aspect, but still around 3 for all but space which is graded 2.67.

2.2 Rerouting alternatives

Due to the nature of 2+1 roads there are a limited number of rerouting alternatives. These are described below.

Rerouting on other road - Rerouting on other road is when the traffic is directed past the incident site on a suitable road in the surrounding road network (Vickberg, 2011). The rerouting begins in an intersection where the rerouting road connects to the main road and ends where the traffic in a suitable intersection can return to the main road.

Bypassing on main road - Bypassing on main road is when the traffic is redirected past the incident site either by having one lane open in each direction, or by using the one lane road with alternating directions (Vickberg, 2011).

> *One lane open in the two-lane direction* - This alternative can be used both for stops in the one-lane direction and for stops in the two-lane direction. For stops in the one-lane direction the traffic is directed to the two-lane direction where on lane is open in each direction (sv. överledning). Either the guard rail is removed or the bypassing begins and ends at suitable openings in the guard rail. For stops in the two-lane direction, one lane is held open if possible (sv. förbiledning).
>
> *Alternating directions in the one-lane direction* - This alternative applies for stops in the two-lane direction when no lane can be held open. The traffic on the two-lane direction is directed past the incident site in the one-lane direction, where the traffic is allowed to pass from each direction alternately. In this alternative signal heads or guards to control the traffic is necessary.

When planning a new 2+1 road, the consequences due to limitations of accessibility must be defined according to guidelines by the Swedish Transport Administration (Vikström, 2011). Rerouting roads should also be planned and signs should be installed at identified critical road sections. When planning a rerouting road network, the following criteria is some of the most important to consider (Vikström, 2011):

- Traffic volume
- Percentage of heavy vehicles
- Public transport
- Suitable start- and stop locations for the rerouting road
- Safety on the rerouting road network, especially considering unprotected road users
- The occurrence of residential buildings, schools and playgrounds along the rerouting road network
- Disturbances due to noise and air pollution
- Accessibility on the rerouting road network
- Limitations for hazardous goods, vehicle length, width and height on the rerouting road network
- Load class on the rerouting road network

3 Effects of disturbances in road traffic

Disturbances in road traffic affect the society in a number of ways where the most predominant for the road user is the time aspect. All kinds of disturbances lead to a loss of time for the road user even if rerouting is performed. Another important factor during disturbances is the safety, both for the road user and the personnel working on clearing the road. When rerouting to another road is performed, also the safety for persons on and near the rerouting road is affected. An aspect that usually not is considered in these situations is the environmental aspect. How the traffic situation is handled leads to different environmental impact which is important if the vision of the Swedish Transport Administration should be fulfilled.

3.1 Time aspects

Increased travel time will most likely occur at unplanned disturbances (Säisä, et al., 2005). Either due to complete stops or decreased speed limits on the primary road or due to longer travel distance on a redirection route. The value of time differs if the delay is expected or not. An unexpected delay is valued higher, so information about disturbances is crucial to decrease the effects of increased travel time.

The Swedish Transport Administration uses a measure, total vehicle delay, to estimate the impact of unplanned events that lead to disruption of traffic flows which is not caused by congestion (Gustafsson, 2013). Since 2012 it is calculated according to Equation 1.

$$Impact = \frac{duration}{2} \cdot AADT \cdot time\ factor \cdot duration \qquad \text{(Eq. 1)}$$

The duration is divided by two since the traffic is assumed to arrive at a constant rate (Cederlöf, 2013). The first car will wait for the entire duration while the last arriving car will not have to wait at all. The Average Annual Daily Traffic is multiplied with a time factor which is divided into three categories; high, medium and low traffic according to the list below.

- High 07-09 and 16-18 13% of AADT/hour (52% in total)
- Medium 09-16 5% of AADT/hour (35% in total)
- Low 18-07 1% of AADT/hour (13% in total)

The impact is not calculated for stops with duration shorter than five minutes (Cederlöf, 2013). The AADT is both for cars and heavy vehicles unless the disruption only applies to heavy vehicles. If the traffic is redirected to another route the impact of the event is regarded to be zero. There is a maximum value for the duration for which the event is still regarded as unplanned. For metropolitan (Stockholm, Gothenburg and Malmö) roads the value is four hours and for other roads it is 12 hours. This model to estimate the impact of unplanned events does not consider the time it takes for any queues to disappear.

The simple model used by the Swedish Transport Administration to estimate the impact of unplanned events that causes disruption of traffic flows was investigated by the consultant company Movea in the study *"Stopp i vägtrafiken"* (2013). The hypothesis was that the model used by the Swedish Transport Administration underestimates the problem in metropolitan cities and overestimates the problem on low traffic roads.

The study shows that the degree of used capacity on the road has great impact on the development and disappearance of the queues (Lind, et al., 2013). At a degree of 0.1 the total time of delay is increased by 22 percent due to delays after the road is open for traffic again. At degrees at 0.6 the delay is increased by 300 percent, see Figure 1.

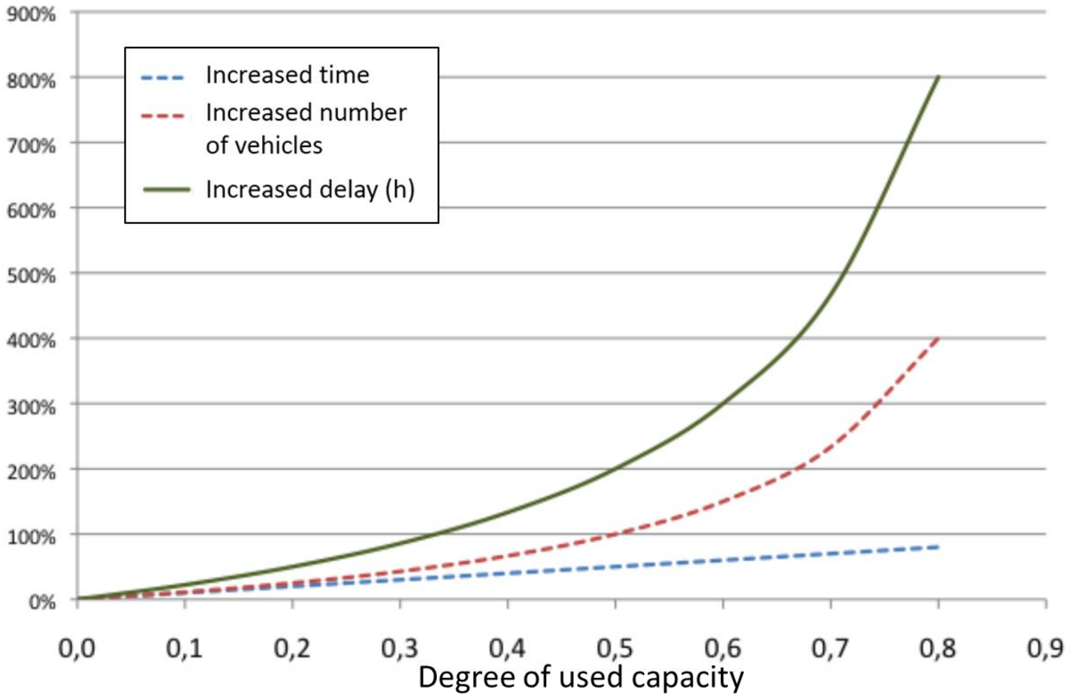

Figure 1 – Increased delays when considering degree of used capacity (Lind, et al., 2013).

By calculating the degree of capacity being used on a redirection rout, it is possible to quickly estimate if the road can handle the increased traffic flow (Lind, et al., 2013). Normally, degrees above 0.9 on the redirection rout should be avoided. Between degrees of 0.7 and 0.9 some delay, normally 10-20 percent, will occur but for degrees lower than 0.7 no delay is usually noticed, except in intersections.

The model used by the Swedish Transport Administration represents the delay quite well for low and medium flows of traffic (<10 000 veh/day in one direction) on highways in rural areas unless the intersections are critical (Lind, et al., 2013). In these cases the model cover around 75-90 percent of the real delays where the difference depends on the delays caused by queues after the road is open again.

The calculation model of the total vehicle delay does however only consider the primary road but in many cases the surrounding network is affected by delays as well, which is called spillback (Lind, et al., 2013). In these cases the model might represent less than 10 percent of the real delays. If the traffic is redirected to another route the impact of the event is regarded to be zero even though the rerouting of traffic also can cause some delays.

3.2 Safety aspects

When it comes to disturbances in traffic, safety is of great importance, both for the personnel working to clear the disturbance but also for the road user and the persons in the area of a possible rerouting road.

According to §81 in the regulation "*AFS 1999:3 Byggnads-och anläggningsarbete*", building- and construction work shall be planned, arranged and conducted so that safety for illness and injury due to passing vehicular traffic is avoided (Arbetsmiljöverket, 2009). Risks connected to passing traffic shall be prevented by the following measures, in the order they are listed:

a) Rerouting of the traffic to another road so that the workplace is not affected.
b) Rerouting so that the traffic passes the workplace within safe distance.
c) The traffic is separated from the work with traffic control devices. To the extent necessary, there shall be protective devices that effectively prevent the traffic from entering the workplace.

Also the following measures shall be considered, either by them self, in combination with each other or together with measure b) or c).

d) Reduce speed past the workplace by signs, road markings or other suitable actions.
e) The traffic is directed past the workplace by a specially appointed person or by a signal head.

One aspect of importance for the safety for the personnel at a road work site, but also for road users and persons at and around the road network, is the velocity. The speed has great impact on the consequences of an accident (Vägverket, 2006). The risk for lethal outcome in an accident between vehicles and pedestrians, two vehicles in a side-on collision and two vehicles in a head-on collision in relation to speed is presented in Figure 2. The risk for lethal outcome of a collision between a pedestrian and a vehicle is 100 percent at speeds over 75 km/h.

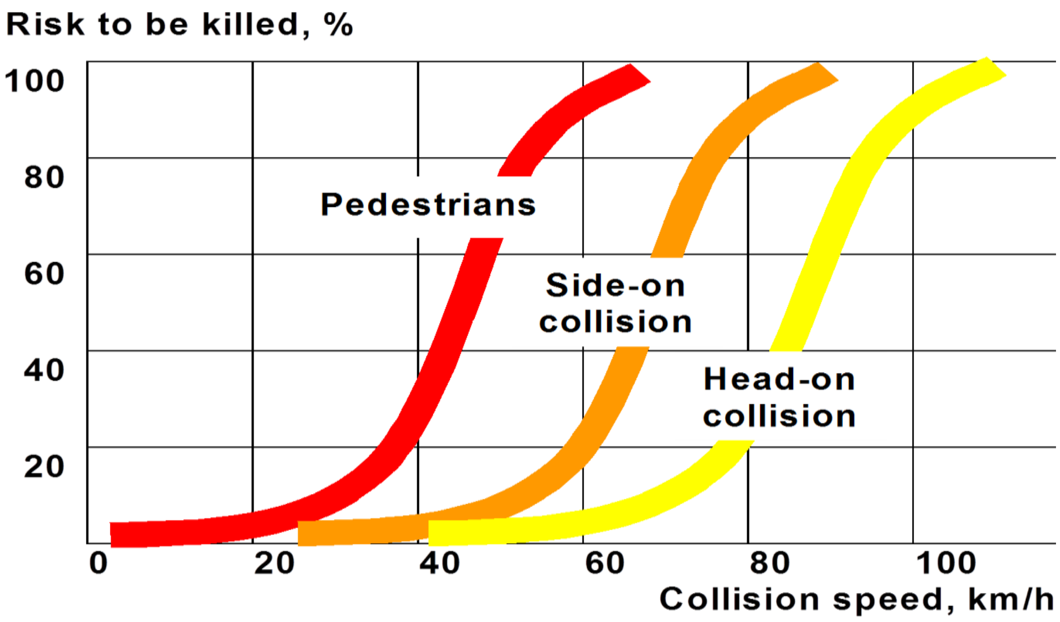

Figure 2 - Risk to be killed in collision with a vehicle at different speeds (Vägverket, 2006).

Accidents connected to decreased speed when passing a disturbance or during rerouting of traffic are hard to evaluate (Säisä, et al., 2005). Decreased speed often lead to increased caution which somewhat prevents accidents. However, passing the disturbance means increased risks for the people working on removing the obstacle. When the traffic is redirected, the risk on the primary road is assumed to be zero since there is no traffic there.

One type of accident connected to disturbances is associated to the loss of time the road users experience (Säisä, et al., 2005). Accidents due to road users trying to recoup the lost time is common in theses situation. This especially applies to professional drivers where the arrival time must be kept. Another phenomenon at road incidents is queues in the opposite direction because people tend to slow down to look at the accident. The temporary inattention also increases the risk for accidents.

When rerouting on another road is performed, the traffic flow on the rerouting road increases considerably compared to the original situation. The increased traffic volume leads to increased risk for accidents (Trafikverket, 2014a). In the diagram below, Figure 3, the number of deaths and seriously injured per AADT for different accident types on rural two-lane roads, are presented. The single accidents decreases with increased AADT while the other types of accidents increases as well as the total number of accidents. Single accidents are more common for low traffic flows simply because there are fewer vehicles in conflict for lower flows (Trafikverket, 2014a).

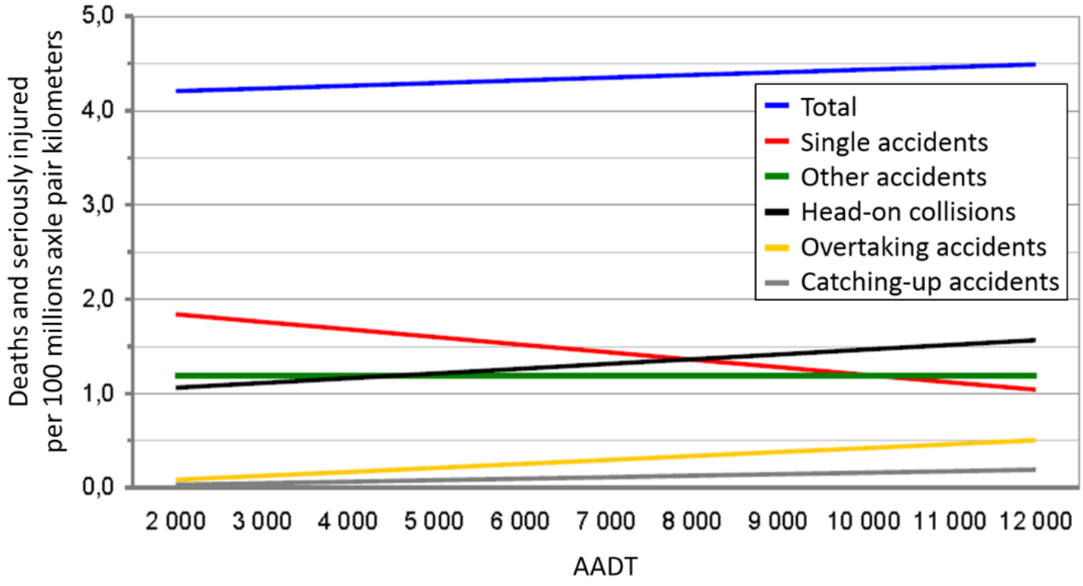

Figure 3 – Theoretically, the number of deaths and seriously injured per AADT for different accident types on rural two-lane roads (Trafikverket, 2014a).

The standard and conditions of the rerouting road also becomes an important factor when it comes to safety during rerouting. The width of the road is one of the factors which have impact on the risk for accidents (Trafikverket, 2014a). In the diagram below, Figure 4, the relative risk of accidents dependent on road width is presented, where index 100 is for road width 5.7-6.6 meters. In the diagram, also other differences in road standard are included. From the diagram it can be seen that a difference in road width from 6.5 to 13 meters gives approximately 25-30 percent decreased risk for accidents.

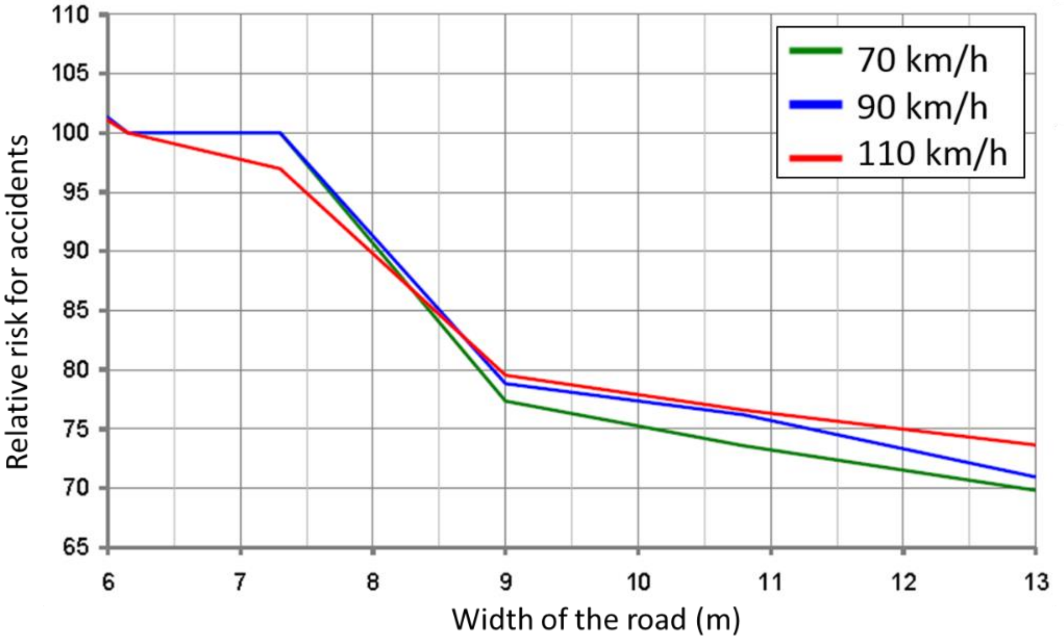

Figure 4 – Relative risk for accidents dependent on width of the road on rural carriageways (Trafikverket, 2014a). Index 100= 5.7-6.6 meter. The calculations are performed based on accidents involving injuries.

3.3 Environmental aspects

Part of the national environmental goals in Sweden until 2020 is to increase the percentage of renewable energy in the transportation sector to ten percent, make the energy usage 20 percent more efficient and reduce the emissions that affects the climate with 40 percent compared to 1990 (Trafikverket, 2014b). The Swedish Transport Administration has together with its partners a goal for 2014 to reduce the emissions of carbon dioxide (CO_2) with 43 000 tones.

The environmental impact of a road can be divided into three phases; the construction of the road, the usage of the road and the demolition of the road (Janhäll, et al., 2013). In this study it is mainly the impact due to the usage of the road that is interesting. The impact during the usage of the road is both from the maintenance of the road and from the traffic. The impact from maintenance includes salting, sanding and dust control which is released to water sources near the road. The impact from traffic is emissions, noise and effects for wildlife. The environmental impact of road traffic is mainly based on speed, type of vehicle, driving pattern, distance and AADT.

Emissions from road traffic mainly consist of carbon dioxide (CO_2), particles (PM_{10}), nitrogen oxides, hydrocarbons and to some extent sulfur dioxide (Janhäll, et al., 2013). These emissions can affect the levels of ozone, sulfate and nitrate in the surrounding area. Carbon dioxide affects the climate while the other emissions affect both the environment and the health of humans, mainly close to the source.

Noise from road traffic is mainly generated by the contact between tires and the road surface and is a growing environmental issue due to increased traffic (Janhäll, et al., 2013). The most common effect of noise is impaired health where high blood pressure and increased risk for cardiovascular diseases have been proven. The effects of both noise and many of the emissions, decrease when the distance to the source decreases, this does however not apply for the emissions that affect the climate.

To understand what type of environmental impacts that are interesting in relation to rerouting of traffic it is essential to understand the effects that rerouting has on the environment (Janhäll, et al., 2013). Rerouting is a short-term event that increases the traffic on another road or lane for a short period of time. Research shows that there are effects on human health if exposed to higher levels of emissions during a limited period of time but this relationship is not completely investigated yet (Janhäll, et al., 2013).

Carbon dioxide cannot be removed compared to many other emissions (Appelgren & Nilsson, 2014). Therefore the emissions of carbon dioxide are directly dependent on the consumption of fossil fuel. One liter of gasoline is equivalent to 2.7 kg of carbon dioxide wherefore it is important to decrease the consumption of fossil fuels. The consumption is directly dependent of the speed, distance and driving pattern.

The result from reducing the delay, which is less queuing and better accessibility, normally also have positive effects on the environmental consequences (Janhäll, et al., 2013). A smooth driving pattern reduces the emissions and fuel consumption wherefore it is important to reduce the number of accelerations and braking (Hadenius, 2001). During constant speed the fuel consumption is lowest at a speed between 50 and 70 km/h (Appelgren & Nilsson, 2014). If the traffic situation causes uneven speed the fuel consumption is decreasing with lower speed. A smooth driving pattern with low speed also reduces noise, other emissions from the engine and particles from tires, road and brakes.

Rerouting on another road can lead to increased need for maintenance on the rerouting road (Janhäll, et al., 2013). It can also increase the risk for accidents with hazardous goods which can have greater impact on the redirection road than the main road. Another risk with rerouting of traffic to another road is the increased risk for accidents with wildlife.

4 The project *"Hinderfri väg"*

There are three primary factors that affect the extent of the delay occurring during an incident; the nature of the incident, the roadway conditions and the execution of the incident clearance (Hall, 2002). The roadway conditions consider both the level of travel demand and the location of the incident within the network, in terms of potential spillback of delay to other parts of the network (Taylor, 2008). The incident clearance process consists of; detection, dispatch, response and service (Hall, 2002). Detection time is the time it takes for the emergency response service (SOS Alarm) to detect the occurrence of the incident. The time from detection until the Emergency Service is dispatched to the incident is called dispatch time and the travel time to the incident site is called response time. Once the Emergency Service has arrived to the incident site, the time required to remove the incident and restore the traffic is called service time.

The Swedish Transport Administration has in the project *"Hinderfri väg"* developed a manual, "*Vägen fri- snabbt och säkert*", to increase the efficiency of the clearance process in order to decrease the disturbances on traffic (Trafikverket, 2012b). The project was performed in the county of Östergötland were the practices now is implemented in the daily work. An implementation project was conducted during the autumn/winter 2013 in Gothenburg and the goal is to implement the project in the entire Western Region in the future (Asp, 2014).

The manual describes how the cooperation of the involved operators can be performed more efficiently which results in decreased delays for the road users. The operators involved after an accident is SOS Alarm, the Ambulance Service, the Emergency Service, the Police, the Maintenance Entrepreneurs, the Salvation Operators, the Swedish Transport Administration's Traffic Center and Residual Leaders (Trafikverket, 2012b). The work process described in the manual is displayed and the task of each operator is described in Appendix A.

When an accident is reported to SOS Alarm it is their responsibility to send Ambulance Service, Emergency Service and Police to the location of the accident (Trafikverket, 2012b). At the same time information is sent to the Swedish Transport Administration Traffic Center and the Swedish Radio (SR). If the accident involves freight transports or hazardous goods SOS Alarm also informs Residual Leaders.

According to the manual *"Vägen fri- snabbt och säkert"* (2012) the operator arriving first to the accident should place his vehicle 20-25 meters in front of the accident to protect the incident site until the other operators arrive (Trafikverket, 2012b). The incident leader makes the decision to close the road for traffic to protect the site and the personnel, to be able to assess the extent of the accident and decide which actions that must be taken in the continued rescue work. The incident leader should thereafter inform SOS Alarm and the Traffic Center about the extent of the accident and give an estimation of the duration of the stop. The Traffic Center should have continuous contact with the Police- and Emergency Service's communication centers, as well as provide information to the public about the accident and if there are any redirection routes.

The Traffic Center should according to the manual "*Vägen Fri- snabbt och säkert"* (2012) inform the Maintenance Entrepreneurs at an early stage so they can be prepared to help out at the site (Trafikverket, 2012b). They can help to protect the site, remediate or remove obstacles from the road and mount signs for the redirection route. The Maintenance Entrepreneurs are also responsible to repair any damage to the road or road elements.

When the Ambulance Service has helped the injured persons and the acute situation is over, the Police or Emergency Service documents the accidents with camera (Trafikverket, 2012b). This is so the Police can investigate the causes of the accident. When the accident is documented the Emergency Service can, when possible, remove the vehicles from the road by placing them in the right lane, the road side or the ditch. In this way the road can be partly opened for traffic.

The Police are responsible to order salvation to the site (Trafikverket, 2012b). The Police should consult the Emergency Service, the Traffic Center, the Salvation Operator and the Maintenance Entrepreneurs to decide if the vehicle should be removed immediately or firstly moved to the side and removed later to decrease the disturbance on the traffic. Factors such as traffic intensity, road conditions, type of vehicle and goods and time of the day must be considered. The Police are responsible to decide about rerouting in consultation with the Maintenance Entrepreneur and the Traffic Center. The Police are also responsible to redirect the traffic but the Emergency Service has the legal authority to help. The Maintenance Entrepreneur is responsible to install the equipment needed to redirect the traffic.

If the accident involves freight transports, the incident leader must request a Residual Leader through SOS Alarm (Trafikverket, 2012b). If hazardous goods is involved an Environmental Residual Leader must be contacted. The Residual Leader is responsible to limit damage and save the goods. The Residual Leader consults the Police and Salvation Operator in the decision of salvation and transshipment. The Salvation Operator should inform the Traffic Center the estimated time for the salvation so that the Traffic Center can keep media informed of the disturbance. The last operator to leave the incident site is responsible to inform the Traffic Center that the road is restored and can be open to traffic again.

In Stockholm and Gothenburg there are a few vehicles circulating on the large roads which can arrive quickly to an incident site by the command of the Traffic Center (Trafikverket, 2012b). These are called VägAssistans and are equipped to assist vehicles with problems, close off lanes or redirect traffic. The purpose of VägAssistans is to remove obstacles in traffic quickly to minimize disturbances on the main road network. In Malmö there is one vehicle operating at two specific road stretches and at certain times of the day when the traffic intensity is high (Trafikverket, 2012c).

5 Vissim

The simulation tool Vissim is a microscopic traffic simulation software developed by the German company PTV AG (Planung Transport und Verkehr AG) (PTV Group, 2014a). Vissim is the world's leading software for microscopic traffic simulation and it is used by state governments, local councils, academic institutions and engineering and planning consultants in over 75 countries (Laufer, 2009). In a microscopic simulation, all vehicles and pedestrians are simulated as individual objects within a system. All modes of transport and their interaction can be simulated in Vissim (PTV Group, 2014b). This includes both motorized traffic such as cars, lorries and buses, rail-based transport such as trams and trains, and non-motorized traffic such as pedestrians and cyclists.

The software uses Wiedemann's car following model, a rule-based lane changing model and the Social Force model for pedestrian dynamics to accurately simulate route choice, lane choice, lane changing and vehicle following behavior (PTV Group, 2014b). Wiedemann's car following model is a psycho-physical model where the driver accelerates or decelerates based on the distance and the difference in speed to the vehicle ahead (PTV Group, 2014c). The rule-based model for lane changing behavior includes parameters such as the gap size required in the adjacent lane which can be configured to suit the local conditions. The Social Force model is based on the idea that the motion of pedestrians can be described as if they are subjected to "social forces" which are a measure of the internal motivations to perform a certain movement (Helbing & Molnár, 1995).

Models in Vissim are created by building the road network that will be simulated and defining input data, applicable traffic rules and desired output. To do this the following functions are used.

Links – Links are the basic elements used to create the road network (PTV AG, 2011). The vehicle flow follows the links in the defined direction. The number of lanes, width of the lanes and the behavior type is chosen for each link.

Connectors – To build a road network, connectors are used to connect the links, see Figure 5 (PTV AG, 2011). Only connected links allow continuing traffic flows. A connector must be created for every route possible in an intersection, lane drop or lane gain.

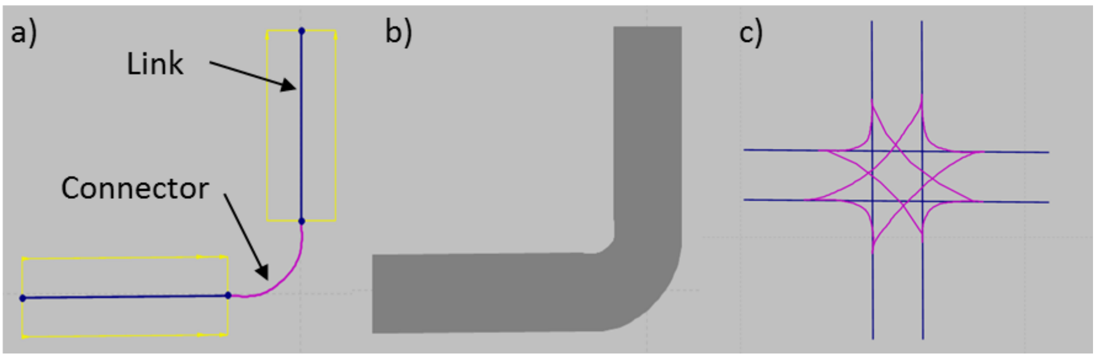

Figure 5 – Description of how links and connectors are used. a) and b) shows a road while c) shows an intersection.

Vehicle input – The vehicle input is defined as the number of vehicles per hour entering the network. The vehicles enter the system according to a Poisson distribution (PTV AG, 2011). The type of vehicles can be chosen and there are no limits of how many vehicle and driver types that can be created (PTV Group, 2014d). However, comprehensive default values are supplied for vehicle types and classes as well as for driving and lane changing behavior. The default vehicle types are car, bus, heavy goods vehicle, tram, pedestrian and bike and the parameters originate from research done by the University of Karlsruhe.

Vehicle routes – A vehicle route is a fixed sequence of links and connectors (PTV AG, 2011). Each routing decision point can have one or multiple destinations, see Figure 6. Each route choice is assigned a percentage of vehicles choosing that particular destination. The percentage of vehicles choosing each route can be changed during the simulation. The vehicles are assigned a route when passing the start of the route choice and will follow this route until they have passed the end of the route choice even if the route choice changes while they are in it. The routing decision can cover any length from turning in an intersection to stretching throughout the whole road network.

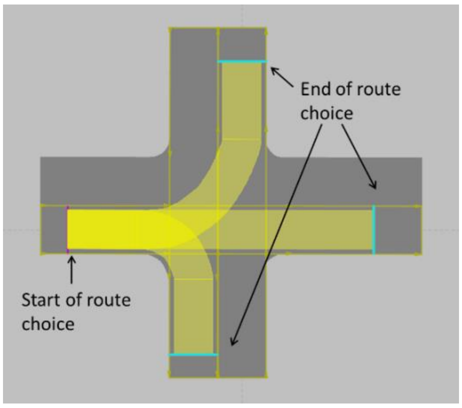

Figure 6 – Vehicle route choice

Desired speed decision – A desired speed decision is placed where a permanent speed change is wanted (PTV AG, 2011). The vehicles get a new speed from the relevant speed distribution when it crosses the desired speed decision. There are default distributions for the desired speed.

Reduced speed area – Reduced speed areas are areas where the speed of the vehicles is changed from the desired speed (PTV AG, 2011). The vehicles decelerate before the defined area so that right speed is kept when entering the area.

Conflict area – In situations where two links or connectors overlap there will be a conflict between vehicles. Conflict areas are used to define the priority rules of the conflict by giving one flow priority over another (PTV Group, 2014e). Conflict areas can be used to model crossing, merging and branching conflicts.

Priority rules – The right of way for non-signalized intersections can be modeled with priority rules (PTV AG, 2011). When using priority rules instead of conflict areas the minimum gap of time and space needed to enter a flow with higher priority can be defined.

Stop signs – Stop signs is used together with priority rules or conflict areas and makes the vehicles stop for at least one time step before entering the priority flow even if it is free to enter (PTV AG, 2011).

Signal controllers – Signalized intersections can be modelled with signal controllers (PTV AG, 2011). Each signal controller can have a number of signal groups or signal phases. In the signal group or phase the time intervals for red, green and amber are defined.

Total travel time – The total travel time is the travel time of all active and arrived vehicles (PTV AG, 2011). This means that the travel time for all vehicles in the system and all vehicles that has left the system is summarized.

6 Method

In this chapter the methodology used for selection of areas, the interview study and the simulations is described. First it is described how the investigated areas were chosen followed by a presentation of the persons included in the interview study. Thereafter the simulation method is described starting with defining which alternatives to model followed by the method to collect and process data used as input to the models. How the different scenarios are modelled is described in detail before the three areas are presented more thoroughly. Also the method for calculating the total vehicle delay is described in this chapter.

6.1 Investigated areas

Both the simulations in Vissim and the evaluation of the decision-making process have been performed for three locations. The three areas with most disruptions in the Western Region have been chosen. To find these areas, statistics over all incidents that led to complete stop in traffic from 2009-2013 were used (Totalstopp Baslista 2009-2013). The events that occurred in the Western Region were sorted out and plotted in ArcGIS using the x and y-coordinates. The x and y-coordinates in the statistic were mixed up according to Gustafsson (2013) and lacked a comma before the last two numbers. This was therefore corrected before the events were plotted in ArcGIS and saved in a shape file. For a description of how the errors were corrected, see Appendix B. To evaluate where the disruptions occurred more densely the GIS-support at the Swedish Transport Administration was consulted. Hansson (2013) at GIS-support used the shape file in the software FME to create a file with larger dots where the events occurred more densely. It was made in a way that if two events were situated less than 500 meters from one another the radius of the dots around them was increased by 25 meters. The more events within 500 meters from an event, the more the area of the dot around the event increased. This gave a visual view of where the events occurred more densely, see Figure 7.

Figure 7 – Example of 2+1-roads in blue with events in red surrounded by pink dots. The two main dots have been more thoroughly investigated by calculating the number of events per meter.

This file was used in ArcGIS together with a layer of 2+1-roads to find the areas where most disruptions occurred. The ten areas that visually had the largest dots were more thoroughly investigated. By measuring the distance over which the events in the dots occurred and counting the number of events in the dots an average value of the number of events per meter was calculated. The three areas with the highest value of events per meter were chosen for the investigation, see Appendix C. These three areas are, see Figure 8:

1. Road E45 north of Trollhättan (Number of events per meter = 0.021)
2. Road 40 east of Ulricehamn (Number of events per meter = 0.015)
3. Road E20 east of Hova (Number of events per meter = 0.012)

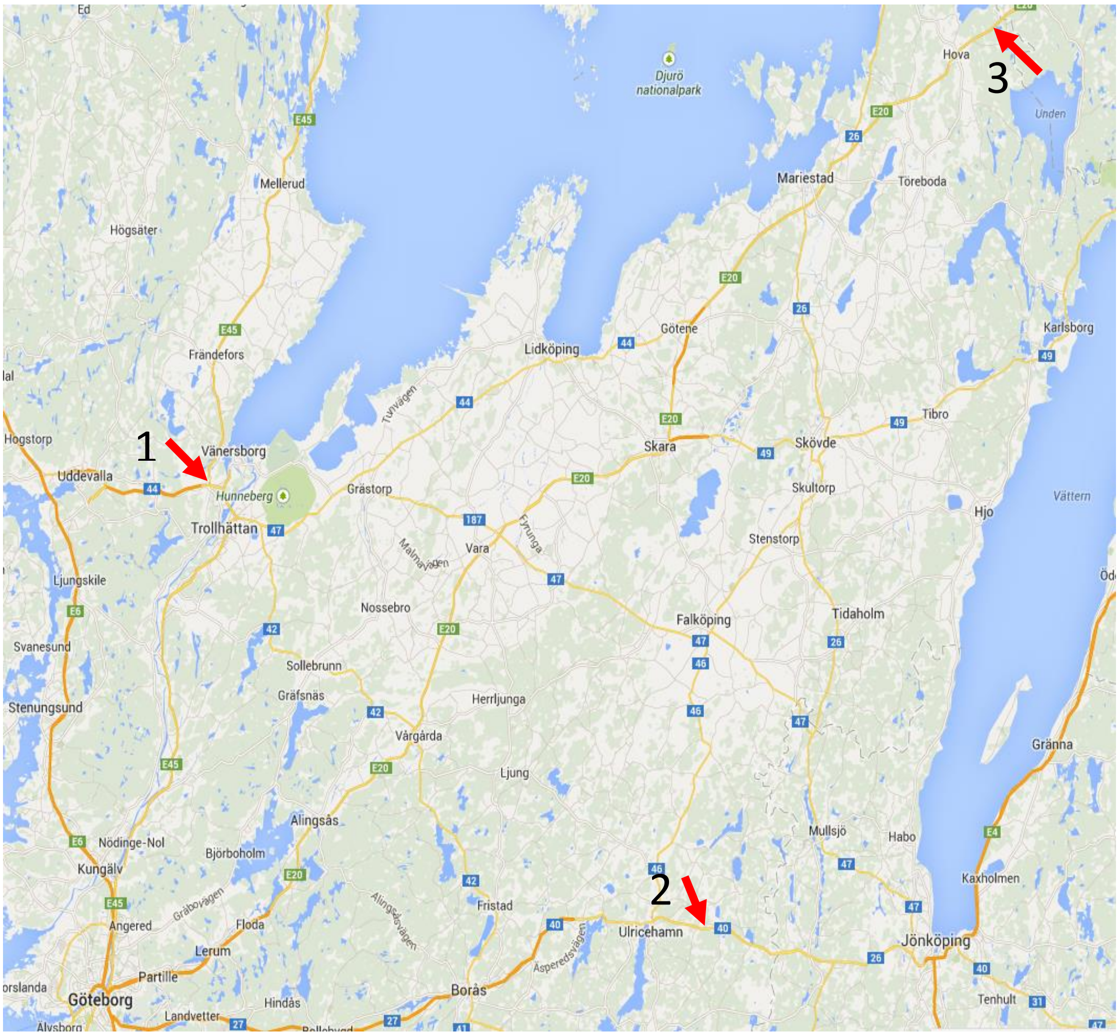

Figure 8 – Map over the three chosen areas. 1: road E45, 2: road 40, 3: road E20.

In the statistics (Totalstopp Baslista 2009-2013) used as input data there are sometimes duplicates of events. This is most likely due to the reporting methods at the Traffic Center where some events sometimes are reported several times (Hovemyr & Weiler, 2014). The events at the three areas were therefore controlled for duplicates. At road E20 duplicates where found and the number of events per meter was recalculated. It did however not change the fact that road E20 is the area third most affected by disruptions. Hereinafter the areas will be referred to as road E45, road 40 and road E20. It was discovered that road E20 have two possible redirection routes that will be referred to as road E20a and road E20b.

6.2 Interviews

In order to investigate the decision process and division of responsibilities during unplanned disturbances a number of interviews with the involved operators were performed. Interviews were conducted with representatives from the Police, the Maintenance Entrepreneurs and Operation Project Manager for each area and the

Traffic Center and Emergency Service in Gothenburg. In an early stage of the study the perception was that the Emergency Service had little to do with the rerouting decision and therefore only one interview with the Emergency Service was conducted. Polices from the Police Communications Center which is located in Gothenburg are also interviewed. The Operation Project Manager in Gothenburg was interviewed to get a first impression of the process before the interview study began.

The interviewees were asked questions about their role and responsibility at an incident site and how they are working with rerouting of traffic. The interviewees were also asked about their opinions of 2+1 roads, the work process at the incident site and who is responsible for managing the traffic situation. All of the questions asked, adjusted to the role of the interviewee, are presented in Appendix D.

The following persons were interviewed:

Traffic Center Gothenburg

- Richard Hovemyr – Traffic leader
- Dennis Weiler – Traffic leader
- Pernilla Fransson – Operations Manager, Traffic Information Railway and Traffic Information Road

Operation Project Managers on the Swedish Transport Administration

- Anders Forsman – Gothenburg
- Ryno Nilsson – Ätradalen (Road 40)
- Niklas Segerström – Mariestad (Road E20)
- Niklas Nilsson – Trollhättan (Road E45)

Maintenance Entrepreneurs

- Vladimir Mausén – Ätradalen (Road 40) Svevia
- Kent Hallén – Mariestad (Road E20) Svevia
- Marcus Molin – Trollhättan (Road E45) Svevia

The Police:

- Patrik Ahlbom – The Communication Center of the County Gothenburg, *Länskommunikationscentralen*
- Susanne Arvidsson – The Communication Center of the County Gothenburg, *Länskommunikationscentralen*
- Mats Berndtzon – Deputy Cheif Traffic Monitoring Gothenburg and Borås (Road 40), *Biträdande chef Trafikövervakning*
- Gunnar Åreng – Site Manager of the Police in Mariestad, Töreboda and Gullspång (Road E20), *Platschef*
- Anders Lindberg – Cheif Superintendent Traffic section Vänersborg (Road E45), *Poliskommisarie Chef Trafiksektionen Vänersborg*

The Emergency Service:

- Peter Volmefjord – Incident leader Emergency Service Mölndal (The Emergency Service in Mölndal are specialists on traffic accidents)

6.3 Simulation

For the three areas studied, a number of simulations were performed in Vissim where some different situations were modelled. For each of the areas the following situations were modelled:

- The situation without stop
- Stop in the one lane direction
    - A: Without rerouting
    - B: With rerouting on other road, with trapped vehicles*
    - C: With rerouting on other road, without trapped vehicles*
    - D: With rerouting in one of the lanes in the two-lane direction
- Stop in the two lane direction
    - E: Without rerouting
    - F: With rerouting on other road, with trapped vehicles*
    - G: With rerouting on other road, without trapped vehicles*
    - H: With one lane open
    - I: With alternately directions in the one-lane direction

**When rerouting on another road is performed some vehicles will reach the incident before the rerouting is opened. These are trapped between the incident and the intersection where the rerouting begins. In model B and F these must wait until the main road is opened and in model C and G all traffic is stopped before the intersection where the rerouting begins. The case in reality is somewhere between the two; some cars are trapped but can with different actions be helped from the site* (Hallén, 2014).

The aim was to perform five simulation runs for each model which turned out to be rather time consuming. Therefore the number of runs was reduced to three simulations in the continued investigation. Each simulation run was performed with different random seed. The random seed allows for stochastic variations of vehicle arrivals. If the same model is run twice with the same random seed the outcome will be the same. If the random seed is varied, the stochastic functions in Vissim are assigned a different value sequence and the traffic flow changes. Therefore the random seed is increased with 1 for each run starting at the default value 42. The average value of the output from the runs is used as result. The output from the model is the total travel time. The total travel time in the basic model, without stop, was subtracted from the travel time in case A to I, with stops, to receive the delay caused by the stop.

6.3.1 Vehicle input and route choices

When creating the model, smaller roads and intersections with low traffic were excluded since they were assumed to have little effect on the result. For the roads included, information about the vehicles route choices was needed. The Average Annual Daily Traffic (AADT) of the road stretches are known from Vägtrafikflödeskartan (Trafikverket, 2014c). For the smaller roads it is a combined AADT for both directions and for the larger roads the AADT of the directions are measured separately. The flow per hour and direction for a specific measuring date is also available. For the roads with AADT combined for both directions the hourly flow were controlled to evaluate if it was reasonable to divide the combined AADT in two, to get the AADT in each direction.

The AADT does however not provide any information about the vehicles route choices in the intersections. Therefore an ocular inspection was performed where turning quotas from each direction were calculated during 30 minutes. This was performed in all of the modelled intersections for each study area. It was assumed that heavy vehicles move in the same pattern as the cars and therefore no consideration was taken to the type of vehicle during the inspection. The ocular inspection resulted in a percentage of cars that turned right, left or went straight ahead from each direction.

The models were created so that the disruption starts at 07.00 in the morning. During the following two hours there is high traffic (13% of AADT) and for the hours after that, medium traffic is simulated (5% of AADT) (Cederlöf, 2013). These times were chosen since they give the worst case scenario of a normal day.

To examine the accuracy of the data collected during the ocular inspection a comparison between the collected AADT and the AADT from the database Vägtrafikflödeskartan was performed. Since the traffic flow vary over the year and over the hours of the day, the collected data must be transformed to a high traffic hour of an average month, to be able to compare it to the AADT from Vägtrafikflödeskartan during high traffic (AADT*0.13). Calculation can be found in Appendix E.

The number of cars turning in to one stretch did not always match the number of cars that was supposed to travel on the stretch according to its AADT. When these cases occurred the AADT was assumed to be more reliable since it has been measured during a longer period of time than the ocular inspection. Therefore the turning percentages were adjusted to better fit the AADT. It is also necessary to have equilibrium in the road system, otherwise there could be cars accumulating. To achieve this, equilibrium over each intersection is necessary. The turning quotas for each area are presented in Appendix F, G, H, and I.

6.3.2 Vissim settings

In the models different time intervals were used in order to simulate the entire situation. For the models without rerouting or bypassing the following time intervals were used:

1. A warm-up period where the model is "filled" with vehicles
2. Stop due to an unplanned event for one, two, four or eight hours when the vehicles remain stationary and queues are formed
3. Opening of the road again where the queues begin to disappear

For the models with rerouting or bypassing these time intervals were used:

1. A warm-up period
2. Stop due to the unplanned event before the rerouting or bypassing begins
3. Stop on the main road with rerouting or bypassing
4. Opening of the main road

The stop durations was chosen based on both the maximum time a stop is called unplanned according to Cederlöf (2013) and the limitations of the program. The maximum duration of an unplanned disruption is 12 hours outside of metropolitan areas. It would however take too long time to simulate durations of this length and it was therefore decided to make simulations with stop up to eight hours. It was also desired to investigate the difference between the rerouting alternatives during both short and medium long durations wherefore also one, two and four hour durations were chosen. The time until rerouting starts was set to one hour according to Mausén (2014). This would however not make sense during stop durations of one hour. According to Volmefjord (2014) the aim is to as soon as possible after a traffic incident start rerouting and sometimes it can be done rather quick. Therefore, the time until rerouting starts was set to 30 minutes when the duration of the stop is one hour.

For all models the default values, including cars and heavy goods vehicles, was used as vehicle input, but the percentage of heavy goods vehicles were adjusted to each area. The percentage of heavy goods vehicles was found in Vägtrafikflödeskartan (Trafikverket, 2014c). The default values are developed based on German traffic but according to Faura (2014) they are a good representation of the Swedish traffic as well. For all three models, freeway behavior was chosen. In the freeway behavior type free lane change are allowed which means that vehicles are allowed to change lane to get more room or higher speed (PTV AG, 2011).

At first, basic models for each area where the total network was built and tested was created. The models needed links for the incoming traffic that were long enough for queues to form when the road was closed. To evaluate the length of these links and the fill up time in the system, the case without rerouting or bypassing was simulated for the longest stop duration.

The basic model was run to get the original travel time in the system. This time was subtracted from the travel time in the models with stop to receive the delay of each scenario. The basic model was used to first create the models with stop, without rerouting, case A and E, from which the rerouting alternatives were created.

To simulate stop for a certain time interval, as needed to simulate the disruption, signal controllers were used. The cycle time for the signal control was set to the total simulation time and two green periods were created. The first green period started at the beginning of the simulation and ran until the stop was supposed to appear. Then the light was switched to red and remained so until the traffic was bypassed or until the stop was cleared, when a new green period started.

At first, conflict areas were used in the smaller intersections on the rerouting road and on the main road priority rules were used to define the priority in the intersections. However, the priority rules turned out to be problematic in some intersections causing undesired traffic jams. Therefore these intersections were modelled with conflict areas instead. When priority rules are used the minimum headway and minimum gap time must be defined. The minimum headway was defined between five and ten meters and the minimum gap time between three and five seconds depending on the distance of the turn. In some scenarios the stops created queues that reached the intersections downstream the incident and hindered other vehicles to cross the road. In these situations it is realistic to believe that vehicles travelling on the main road would stop before the intersection if they could not pass it entirely. Therefore a prohibition to stop in the intersections was modelled, using priority rules. When conflict areas are used prohibition to stop in intersections are included automatically.

When a car have to wait too long to change lane and thereby blocks the traffic, the car is automatically removed from the system. The default time before removal is 60 seconds. Since the cars are queuing and thereby have to wait for very long time before they can change lane, for example when two lanes become one, this time was increased to the simulation time of each model. This means that no cars were removed during even the longest simulations.

6.3.2.1 Description of the cases

Below a general description of how the different cases were modeled follows. Site specific changes are presented in chapter 6.3.3 to 6.3.5.

***Case A and E* -** In the cases without rerouting, the stop was created with a signal head that was red from the warm-up period until the stop was cleared. The time intervals for case A and E for road E45, road 40 and road E20b are presented in Table 1 below.

Table 1 - Time intervals for the models without rerouting (case A and E).

Duration of stop [h]	Warm-up period [s]	Stop due to unplanned event [s]	Main road open again [s]
1	0 – 2000	2000 – 5600	5600 – 9200
2	0 – 2000	2000 – 9200	9200 – 12800
4	0 – 2000	2000 – 16400	16400 – 23600
8	0 – 2000	2000 – 30800	30800 – 41600

Since the model for road E20a is smaller, a shorter warm-up period was needed. Therefore the following time intervals were used instead, see Table 2.

Table 2 – Time intervals for E20a without rerouting (case A and E).

Duration of stop [h]	Warm-up period [s]	Stop due to unplanned event [s]	Main road opened again [s]
1	0 – 1000	1000 – 4600	4600 - 8200
2	0 – 1000	1000 – 8200	8200 – 11800
4	0 – 1000	1000 – 15400	15400 – 22600
8	0 – 1000	1000 – 29800	29800 – 40600

***Case B, C, F and G* -** When the traffic was redirected to another road, the stop was simulated with a signal head that is red during the entire stop. To simulate rerouting the vehicle route choices were changed from the time interval that the rerouting starts. This makes the cars that was supposed to pass the accident, chose the rerouting road instead. When the accident was cleared and the main road could be opened again the route choices on the main road were switched back. The route choices along the redirection road were not switched back since there was redirected traffic from the main road left on the rerouting road a while after the main road was opened again. Since it was difficult to estimate for how long the redirected traffic remains on the rerouting road the route choices were not switched back at all. It was assumed that this simplification will have little influence of the result since the original traffic flow on the rerouting road is low compared to the traffic on the main road.

In cases B and F vehicles were trapped between the accident and the intersection where the rerouting begun. In some cases the queues that these vehicles formed, reached the intersection where the vehicles turned in to the rerouting road. Vehicles that have entered a route choice will not change route even if the route choice changes while the vehicles are in it. These vehicles therefore blocked the rerouting road. To solve this situation a signal head was created just before the route choice in the intersection. The signal head turned red just before the queue reached the intersection so that the vehicles after the intersection could enter the rerouting road.

In case C and G, the signal head before the intersection where the rerouting begun turned red when the stop started. In this way no vehicles entered the road towards the accident so that no vehicles were trapped there. The time intervals for case B, C, D, F, G, H and I for road E45, road 40 and road E20b are presented in Table 3 below. The time until rerouting or bypassing was opened was estimated to 60 minutes (3600 seconds) for the stops in two, four and eight hours based on an interview with Mausén (2014). For the one hour stop the time until rerouting or bypassing was 30 minutes (1800 seconds) based on an interview with Volmefjord (2014). For road E20a the time intervals in Table 4 were used instead.

Table 3 - Time intervals for models with rerouting on other road (B, C, F and G) or on the main road (D, H and I).

Duration of stop [h]	Warm-up period [s]	Stop before rerouting [s]	Rerouting/Bypassing [s]	Main road opened [s]
1	0 – 2000	2000 – 3800	3800 – 5600	5600 – 9200
2	0 – 2000	2000 – 5600	5600 – 9200	9200 – 12800
4	0 – 2000	2000 – 5600	5600 – 16400	16400 – 23600
8	0 – 2000	2000 – 5600	5600 – 30800	30800 – 41600

Table 4 – Time intervals for E20a with rerouting on other road (B, C, F and G) or on the main road (D, H and I).

Duration of stop [h]	Warm-up period [s]	Stop before rerouting [s]	Rerouting/Bypassing [s]	Main road opened [s]
1	0 – 1000	1000 – 2800	2800 – 4600	4600 – 8200
2	0 – 1000	1000 – 5600	5600 – 8200	8200 – 11800
4	0 – 1000	1000 – 5600	5600 – 15400	15400 – 22600
8	0 – 1000	1000 – 5600	5600 – 29800	29800 – 40600

Case D, H and I - These cases were simulated by setting the signal head red from the time of the accident to the time when the bypassing could be opened. Case H, stop in the two lane direction with one lane open, was simulated by creating a new one-lane link after the signal head that were about 100 meters long, see Figure 9. A vehicle route decision was added that made the traffic use this link during the rest of the stop. A reduced speed area was created past the accident. When the stop was cleared the route decision made the traffic take the original two-lane link again. To visualize the scenario the new link was placed on top of the original link so it looked like the cars were driving in one lane.

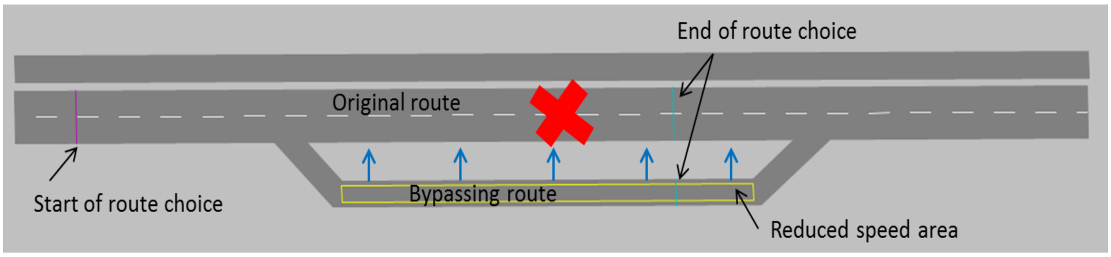

Figure 9 – Schematic picture over case H.

If the two lane road have to be completely closed during the entire stop one option is to bypass the traffic in the direction with one lane, letting the traffic alternate, case I. This option was simulated by creating a one-lane link in the same way as in case H. A signal head was created on the connector to this link to simulate a guard. In the opposite direction a parallel link and a vehicle route decision were created to make the traffic choose this route during the bypassing, see Figure 10. Also on this link a signal head was created. This made the traffic ignore the signal control at all times except during the bypassing. The two new links were put on top of the original one-lane link to visualize the bypassing and reduced speed areas were created. Both signal controllers were set so the traffic from the two-lane direction could pass during two minutes and the traffic from the one-lane direction could pass during one minute, with 20 seconds between. At the end of the bypassing the route decision on the two-lane road was changed back five minutes before the route decision on the one-lane road was changed back. This was because the cars that have already entered the route choice should have time to pass before the traffic runs normally again.

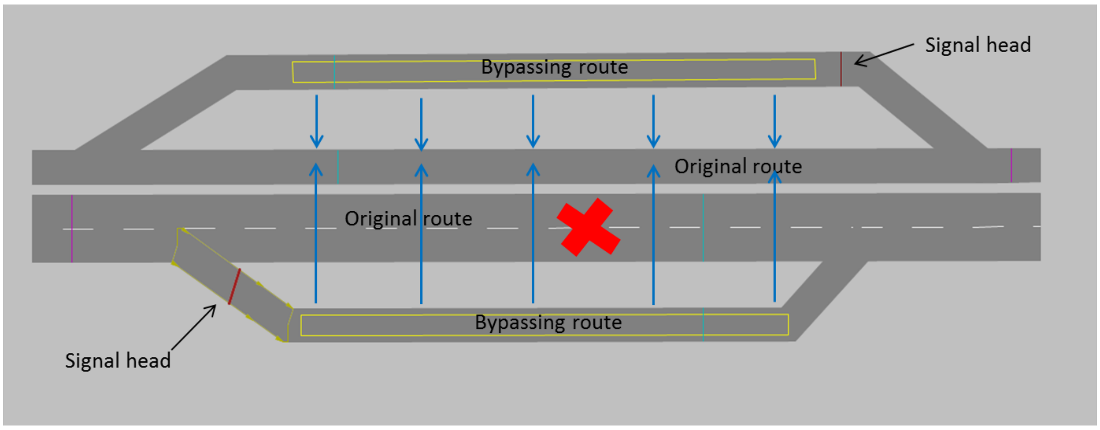

Figure 10 – Schematic picture over case I.

Case D, where the traffic from the one-lane road is bypassed in one of the lanes on the two-lane road, was simulated in a similar way as case I. A new one-lane link was created in each direction with a reduced speed area, see Figure 11. Route decisions made the cars take these routes during the stop. The new link in the one-lane direction was placed on top of the left lane in the two-lane direction and the new link in the two-lane direction was placed on the right lane. In this way it looked like the traffic from both directions was driving in the two-lane road but on one lane each.

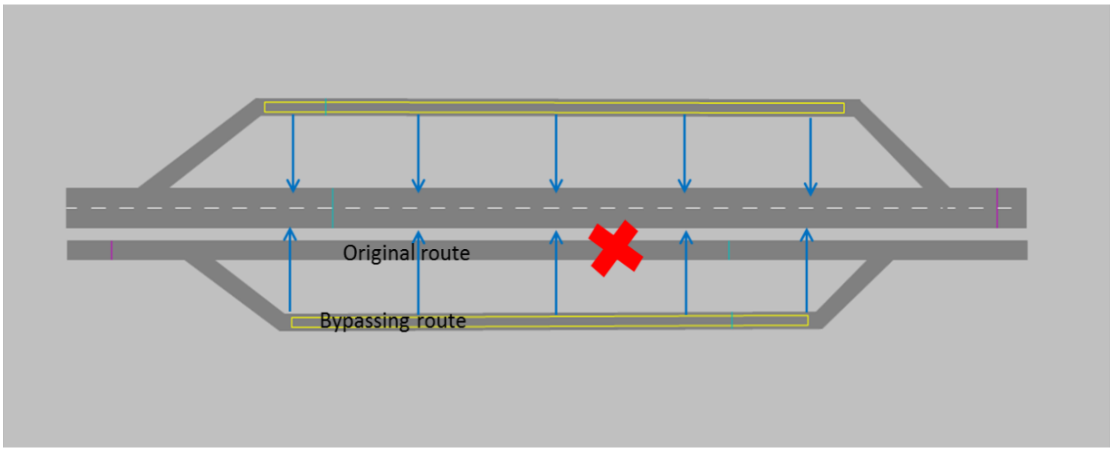

Figure 11 - Schematic picture over case D.

The time intervals for case D, H and I are described in Table 3 and Table 4 above.

6.3.3 Road E45

Road E45 is a European route running from south of Italy, through Austria, Germany, Denmark and Sweden, ending at the border between Sweden and Finland. The area with most disruptions on its 2+1 part in the Western Region is marked with a red cross in Figure 12. The Operation Project Manager Niclas Nilsson (2014) was consulted to evaluate the best redirection route. He recommended that the rerouting should run on road 697 and the municipal roads Borrgatan, Äsperedsvägen and Stampgatan. The suggested roads were investigated in the national road database NVDB (Nationell Vägdatabas, NVDB på webb 2012). The load class was controlled and both the main road and the redirection roads had the highest load class, BK1. Neither the main road nor the redirection road had any restriction concerning gross weight, vehicle width, vehicle length or transportation of hazardous goods. Björn Magnusson (2014), traffic engineer at the municipality of Vänersborg, was consulted to get the Average Annual Daily Traffic (AADT) on the municipal roads. The length of road E45 between intersection 1 and 3 is 1 km and the length of road 44 between intersection 1 and 2 is 1.5 km. The lengths of the rerouting roads are similar the lengths of the main roads.

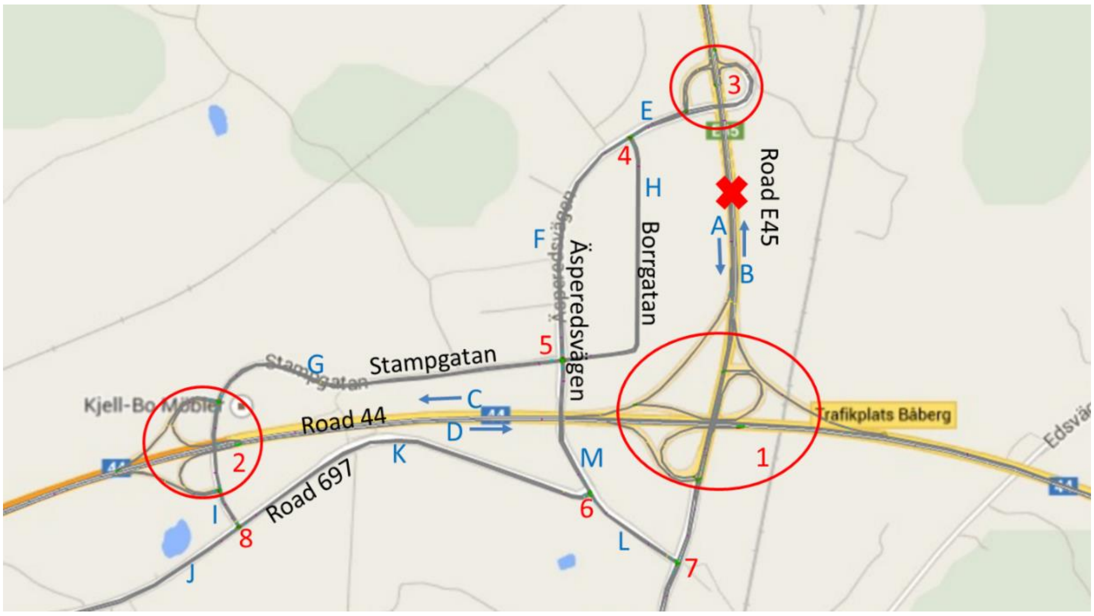

Figure 12 - Map over the investigated area at road E45 with the incident site located at X. The stretches are given letters A-M and the intersections are given numbers 1-8.

In Figure 12, the road stretches are assigned a letter each and the intersections are assigned a number. Road E45 is called A in the north-south direction and B in the south-north direction. The incident causing the stop is located north of intersection 1 where A has one lane and B has two lanes. Road 44 is called C in the east-west direction and D in the west-east direction.

The ocular inspection on road E45 was performed on Monday April 14, 2014. The roads on the rerouting road had a combined AADT for both directions and therefore the hourly flow was controlled to evaluate if it was possible to divide it equally between the directions. Stretch E, F, G and H are municipal roads and therefore it was not possible to control the hourly flow in the database Vägtrafikflödeskartan. Due to an error in Vägtrafikflödeskartan it was not possible to control the hourly flow on stretch K either. Stretch I, J and L were however controlled and the flows were similar in both directions over the day. It was therefore assumed acceptable to divide the AADT in two for all stretches on the rerouting road. The large intersections, 1, 2 and 3 are separated in level but were seen as one intersection when the turning quotas were calculated.

The speed limit on the main road A and B is 100 km/h from intersection 1 and north and 70 km/h over intersection 1 and south (Trafikverket, 2012d). Stretch C and D have a speed limit of 100 km/h. The speed limit on stretch E, F, G, H, M and L are 50 km/h, stretch G changes speed to 70 km/h near intersection 2 and the speed remains 70 km/h over stretch I. Stretch J and K have a speed limit of 80 km/h. There are no stop signs in the system and no intersection where the right hand rule applies. The percentage of heavy goods vehicles on road E45 is 11.4 percent.

The speed the vehicles actually are driving in were controlled in Vägtrafikflödeskartan where measurements of the average speed for passenger cars, passenger cars with trailer, heavy goods vehicles and heavy goods vehicles with trailer are presented. These values can be seen in Table 24 in Appendix F. The municipal roads are not included in the database and can therefore not be controlled. Also the other redirection roads lacked data in the database so it was only possible to control the main roads, stretch A, B, C and D. Here the actual speed was a bit lower than the allowed speed which probably has to do with the many entrances and exits that make the vehicles slow down. The vehicles in the model will by default slow down in turns so it was assumed that the speeds in the model would reflect reality. The speed on road 44, west of intersection 2, is in reality 110 km/h but in the model the allowed speed was set to 100 km/h to better reflect reality.

The intersections that are separated in level, intersection 1, 2 and 3, were simulated by placing all links on the same level and ignoring that vehicles collide in the junctions that in reality are on different levels. Conflict areas were used in all intersections since all the intersections on the main roads are separated in level.

During the stop in the one-lane direction with rerouting on another road a queue was formed on stretch A. This queue reached intersection 3 upstream and therefore a signal head was created before this intersection which hinders the traffic from stopping in the intersection. During stop in the two-lane direction queues were formed that branched out on stretch B, C, L, and D and therefore signal heads were created before intersections 1, 2 and 7.

6.3.4 Road 40

Road 40 is a state road crossing Sweden from west to east. The road is being converted to a highway from Gothenburg to Ulricehamn. The area with most disruptions on its 2+1 part in the Western Region is marked with a cross in Figure 13. The Operation Project Manager Ryno Nilsson (2014) was consulted to evaluate the best redirection route. He recommended the old road 40, now called road 1721, which runs parallel just north of road 40. The suggested road was investigated in the national road database NVDB (Nationell Vägdatabas, NVDB på webb 2012). The load class was controlled and both the main road and the redirection road had the highest load class, BK1. Neither the main road nor the redirection road had any restriction concerning gross weight, vehicle width, vehicle length or transportation of hazardous goods. The stretch between intersection 1 and 2 on road 40 is 3.4 km while the length of the rerouting road between the same intersections is 4.7 km.

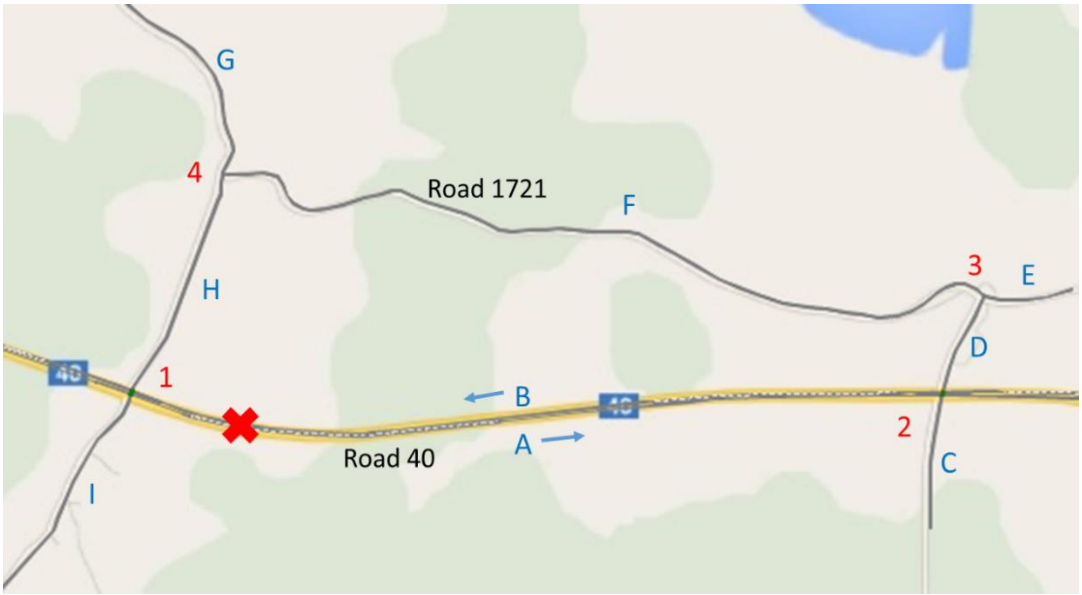

Figure 13 - Map over the investigated area at road 40 with the incident site located at X. The stretches are given letters A-I and the intersections are given numbers 1-4.

In Figure 13 the stretches are assigned a letter each and the intersections are assigned a number. Road 40 is called A in the west-east direction and B in the east-west direction. The incident causing the stop is located east of intersection 1 where A has two lanes and B has one lane.

The ocular inspection on road 40 was performed on Tuesday February 25, 2014. The roads on the rerouting road had a combined AADT for both directions and therefore the hourly flow was controlled to evaluate if it was possible to divide it equally between the directions. For all the roads in the system the flows were similar in both directions over the day and therefore it seemed acceptable to divide the AADT in two.

The speed limit on the main road, A and B, is 100 km/h expect for over the intersections 1 and 2 where the speed limit is 70 km/h (Trafikverket, 2012d). The speed limit on road C, E, F, G, H and I are 70 km/h. In in the small society in intersection 3 and on road D the speed limit is 50 km/h. There are stop signs when entering the main road in intersection 1 and 2 from road C, D, H and I. In intersection 3 and 4 the right hand rule applies. The percentage of heavy goods vehicles on road 40 is 18 percent.

The speeds the vehicles actually are driving in were controlled in Vägtrafikflödeskartan. The values can be seen in Table 29 in Appendix G. Generally in the network, passenger cars are driving a few kilometers per hour too fast and heavy goods vehicles and passenger cars with trailers drive some kilometers per hour slower than the speed limit. These differences were assumed to be within reasonable fluctuation so the speed limits at the roads were used as input in the simulation.

In the simulated cases without rerouting, case A and E, queues were formed on road A and B. These queues reached the intersections downstream, intersection 1 and 2, and hindered other vehicles to cross the road. Signal heads were placed downstream these intersections to avoid that the queue reaches the route decision and hinder the rerouting in the case with rerouting on another road. The stop signs in the intersections between the rerouting road and the main road caused huge delays during rerouting. Therefore they were removed during the simulation of rerouting on other roads to achieve a more realistic behavior. It is not realistic that every vehicle should stop before entering the main road again, and in the reality it is possible that the stop signs are covered in case of rerouting.

6.3.5 Road E20

Road E20 is a European road running from Helsingborg to Stockholm via Gothenburg. The area with most disruptions on its 2+1 part in the Western Region is marked with a red cross in Figure 14. The Operation Project Manager Niklas Segerström (2014) was consulted to evaluate the best redirection route. He recommended that the redirection should run around the lake Skagern using roads 26, 204 and 507. The suggested roads were investigated in the national road database NVDB (Nationell Vägdatabas, NVDB på webb 2012). The load class was controlled and both the main road and the redirection road had the highest load class, BK1. Neither the main road nor the redirection road had any restriction concerning gross weight, vehicle width, vehicle length or transportation of hazardous goods. In the area marked with a red circle a narrow bridge is located. On the bridge two vehicles cannot meet which have been considered in the model.

When interviewing the Entrepreneur responsible for the maintenance area Mariestad, Kent Hallén (2014) another redirection route was suggested. The suggested route was road 3063, see Figure 14. It was decided to also model this route to be able to compare the two alternatives. In the continued report the alternative with rerouting on road 3063 is referred to as road E20a, and the longer route on road 507, 204 and 26 is referred to as road E20b. Also the redirection route for road E20a has the highest load class, BK1. The route has no restrictions concerning gross weight, vehicle width, vehicle length or transportation of hazardous goods. The rerouting road in area E20b runs into the Eastern Region and a maintenance area of which NCC is responsible (Trafikverket, 2013b).

The cases of bypassing the traffic, case D, H and I, or without any rerouting, case A and E, would be the same regardless of redirection road. Since road E20a is a smaller model that is faster to simulate case D, H, I, A and E were simulated in this model and only the basic model and the rerouting cases, B, C, F and G, were modeled in road E20b.

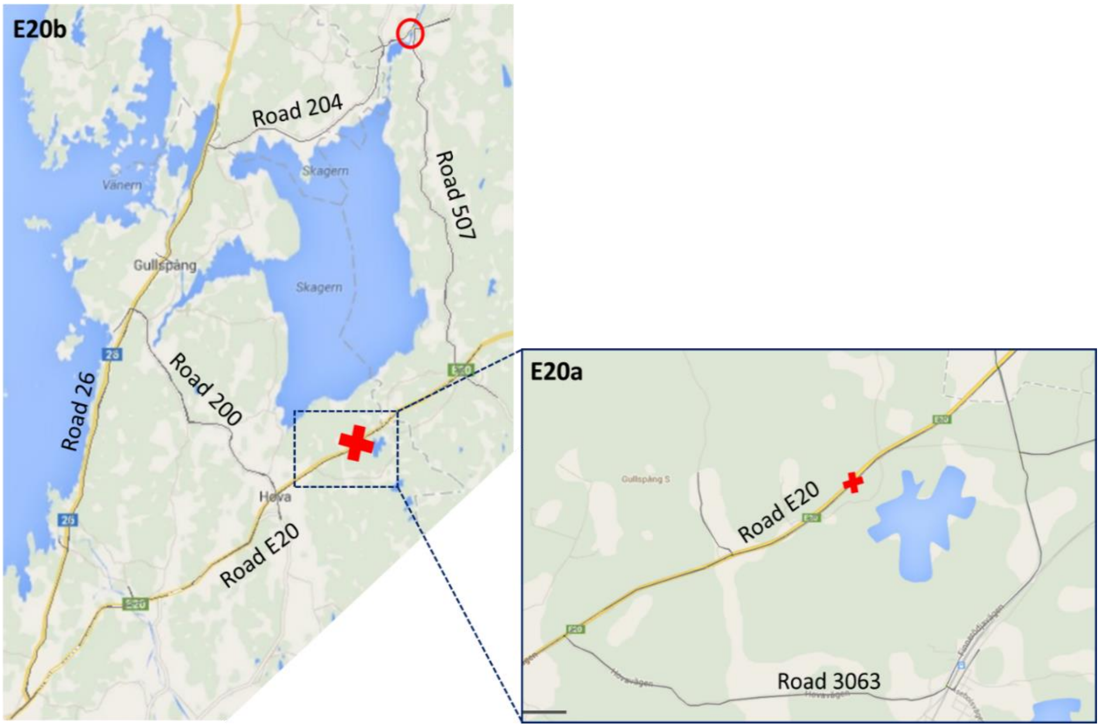

Figure 14 – Investigated areas at road E20 with road E20a to the right and road E20b to the left.

6.3.5.1 Road E20a

The ocular inspection on road E20a was performed on Monday April 7, 2014. The hourly traffic flow was controlled on the rerouting roads since the AADT for these roads were given combined for both directions. For all of the roads in the system the flow were similar in both directions over the day so it was assumed to be acceptable to divide the AADT in two to receive the flow in each direction.

In Figure 15 the stretches are assigned a letter each and the intersections are assigned a number. Road E20 is called A in the west-east direction and B in the east-west direction. The incident causing the stop is located at the red cross where A has two lanes and B has one lane. The stretch between intersection 1 and 3 on road E20 is 5.8 km while the length of the rerouting road between the same intersections is 8.5 km.

Figure 15 - Map over the investigated area at road E20a with the incident site located at X. The stretches are given letters A-I and the intersections are given numbers 1-5.

The speed limit on road A and B is 80 km/h between intersection 1 and 2, 70 km/h when passing intersection 2 and 100 km/h between intersection 2 and 3 (Trafikverket, 2012d). The directions on the road are separated by a guard rail where the speed limit is 100 km/h and not separated where the speed limit is 80 km/h. Where the accident occurs the speed limit is 100 km/h hence the directions are separated. The speed limit on road C, D, E, I, F and G is 70 km/h except for in intersection 5, where the speed limit is decreased to 50 km/h through the a small society. The speed limit on road H is 30 km/h. The percentage of heavy goods vehicles on road E20 is 23.5 percent.

The speeds the vehicles actually are driving in were controlled in Vägtrafikflödeskartan. The values can be seen in Table 35 in Appendix H. On road C and D the average speed of the vehicles varied from 54 km/h up to 68 km/h, depending on vehicle type. The speed limit is 70 km/h and the speed distribution in the model then varies from 68 km/h to 78 km/h. This speed is too high and therefore the speed limit was set to 60 km/h on these two stretches. This distribution varies between 58 km/h and 68 km/h which better reflects the real scenario. For the other roads the vehicles were driving in the speed limit which therefore was used in the models.

In the simulated cases without rerouting, case A and E, queues were formed on road A and B. These queues reached the intersections downstream, intersection 1, 2 and 3, and hindered other vehicles to cross the road. Signal heads were placed downstream intersection 3 in case B to avoid that the queue reaches the route decision and hinder the rerouting. The stop signs in the intersections between the rerouting road and the main road caused additional delays during rerouting. Therefore they were removed during the simulation of rerouting on other roads to achieve a more realistic behavior.

6.3.5.2 Road E20b

The ocular inspection on road E20a was performed on Wednesday Mars 5, 2014. The hourly traffic flow was controlled on the rerouting roads since the AADT for these roads were given combined for both directions. For all of the roads in the system the flow were similar in both directions over the day so it is assumed to be acceptable to divide the AADT in two to receive the flow in each direction.

In Figure 16 the stretches are assigned a letter each and the intersections are assigned a number. Road E20 is called A in the west-east direction and B in the east-west direction. The incident causing the stop is located at the red cross where A has two lanes and B has one lane. The stretch between intersection 1 and 4 on road E20 is 36.1 km while the length of the rerouting road between the same intersections is 77.1 km.

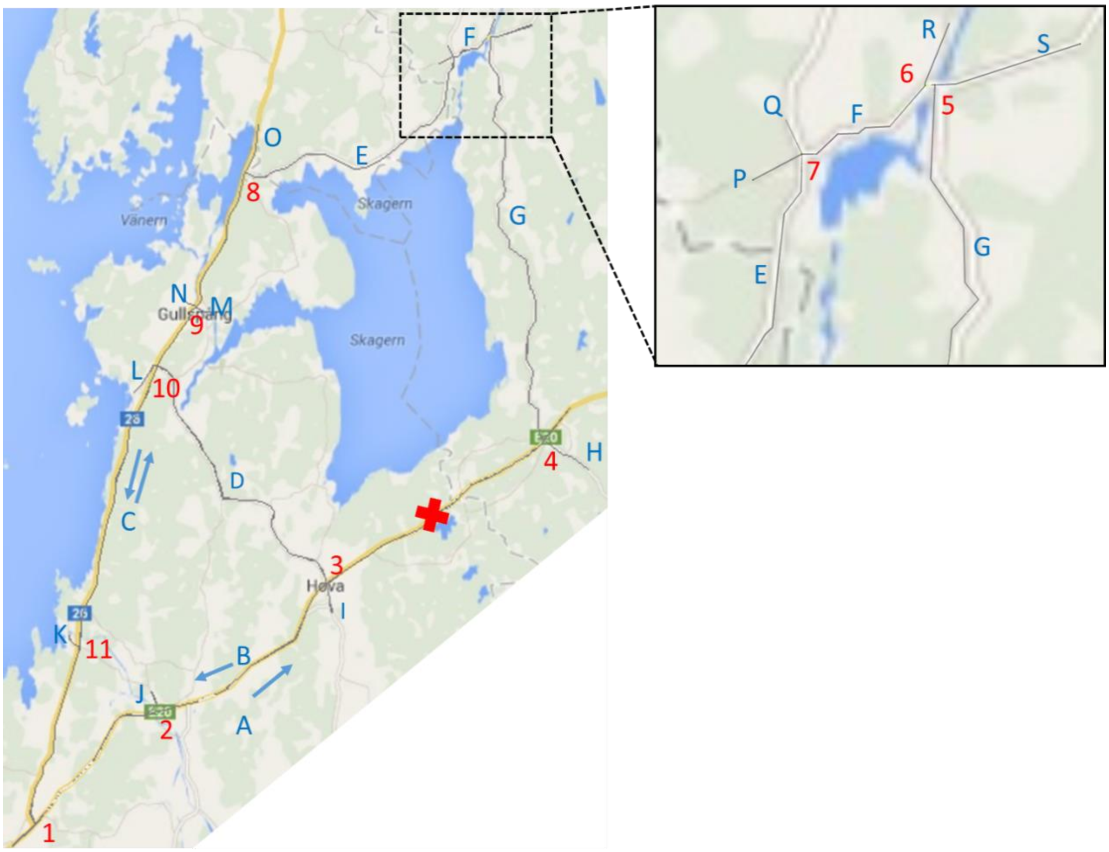

Figure 16 - Map over the investigated area road E20b with the incident site located at X. The stretches are given letters A-O and the intersections are given numbers 1-11.

The speed limit on road A and B is 100 km/h except for a 10 kilometer part over intersection 3 where the speed limit is 80 km/h (Trafikverket, 2012d). The directions on the road are separated by a guard rail where the speed limit is 100 km/h and not separated where the speed limit is 80 km/h. Where the accident occurs the speed limit is 100 km/h hence the directions are separated. The speed limit on road C and O is 90 km/h except for in intersection 9 in Gullspång, where the speed limit is decreased to 70 and 50 km/h through the society. Road E, F, G, I, P and Q have the speed limit 70 km/h with some exceptions in intersections where the speed limit is 50 km/h. Road K, L, M, N, R and S have the speed limit 50 km/h and road D and H have 80 km/h. The percentage of heavy goods vehicles on road E20 is 23.5 percent.

The speeds the vehicles actually are driving in were controlled in Vägtrafikflödeskartan. The values can be seen in Table 47 to Table 49 in Appendix I. The average speed of the vehicles is generally similar to the speed limits which therefore were used in the models.

Between intersection 5 and 6 a narrow bridge is located. The bridge is so narrow that two vehicles cannot meet and the speed here was reduced to 30 km/h. The bridge was simulated in a similar way as the bypassing in case I, where the traffic from each direction was alternating in one lane. One link was created in each direction and a reduced speed area was placed on each link. The links were placed on top of each other and a conflict area was created. The conflict area was set red for both directions, which means that no direction has priority and all vehicles must show consideration to each other. During the scenarios with rerouting however signal heads were placed on each side of the bridge to simulate a guard or a temporary signal head. The signal heads were set green for the redirected traffic for 120 seconds and for the other direction for 30 seconds.

6.3.6 Disturbance per vehicle and year

Within the business plan of the Business Area Maintenance one goal is to decrease the disturbance per vehicle and year in Sweden. The disturbance should be decreased with 1.6 minutes per vehicle and year until 2018. The disturbance time that can be saved on the rerouting alternatives in this investigation has therefore been calculated. The difference in delay between the rerouting alternatives and the case without any rerouting is considered to be the saved disturbance time. For stop in the one-lane direction the delay from case B, C and D have been subtracted from case A for all investigated stop durations. For stop in the two-lane direction the delay from case F, G, H and I have been subtracted from case E. The total number of vehicles in Sweden are considered to be the combined number of cars and heavy vehicles which is about 4 900 000 (Statistiska centralbyrån, 2013).

6.4 Calculated total vehicle delay

The total vehicle delay has been calculated, using the model from the Swedish Transport Administration, for the three areas investigated. The total vehicle delay has been evaluated for both stop in one-lane direction and in the two-lane direction and for stop durations of one, two, four and eight hours each. For stop durations of one and two hours, equation 1 in chapter 3.1 has been used.

For scenarios with stop duration longer than two hours the time factor 0.13 has been used during the two first hours and 0.05 for the rest of the time. The following equation has then been used:

$$Total\ vehicle\ delay = (ADT \cdot 0.13 \cdot duration \cdot average\ waiting\ time) + (ADT \cdot 0.05 \cdot duration \cdot average\ waiting\ time) \quad \text{(Eq. 2)}$$

7 Results

In this chapter the results from the interviews are presented first, followed by the result from the simulations for each area. In the simulation section the delay per vehicle is also presented. Finally the result from the calculations of the total vehicle delay is presented and compared to the simulated delay.

7.1 Interviews

In this section the result from the interviews are presented. The interviewees have answered the questions based on their personal experience which might not represent the view of the respective authority. The interviewees have also answered the question based on their experience from their geographic work area. All of the interviews were conducted in Swedish and are freely translated to English.

The Traffic Center Gothenburg

The Traffic Center receives the alarm of an accident automatically from SOS Alarm (Hovemyr & Weiler, 2014). SOS Alarm also informs all of the "blue light authorities" (Police, Emergency Service and Ambulance Service). The Traffic Center creates an event on the traffic information webpage "*Läget i trafiken"* where private and professional drivers can find information about disturbances in the traffic. At events with large impact the Traffic Center contacts the Maintenance Entrepreneur for the area and when available also VägAssistans. They also contact the radio which informs the public. The Traffic Center can receive information about disturbances from the radio, private persons, The Maintenance Entrepreneurs, the Police or the Emergency Service depending on who is involved in the event (Fransson, 2014).

The Traffic Center is not involved in the work performed at the incidence site or the decision of rerouting. Their main task, according to Hovemyr & Weiler (2014), is to receive and distribute information. It is the Maintenance Entrepreneurs and the Police that are responsible for decision and conduction of rerouting (Fransson, 2014).

Hovemyr & Weiler (2014) says that the manual *"Vägen Fri- snabbt och säkert"* is not implemented in their work, but that most of their work follows the routines described in it. The main difference is that the Traffic Center not is involved in the decision of rerouting roads. According to Hovemyr & Weiler (2014) it is the Maintenance Entrepreneurs that are involved, which can be seen as an extension of the Traffic Center.

The Operation Project Managers

All of the interviewed Operation Project Managers says that they are not involved in the work after an accident (Forsman, 2014; N. Nilsson, 2014; R. Nilsson, 2014; Segerström, 2014). The Operation Project Managers have no responsibilities during an accident and they receive information from the Traffic Center after the incident, if they are informed at all. The Operation Project Managers are mainly responsible for the contract with the Maintenance Entrepreneur (Segerström, 2014).

According to R. Nilsson (2014), N. Nilsson (2014) and Segerström (2014) the Police decides if and on which road rerouting should be performed. As far as R. Nilsson (2014) knows there is no communication with the Traffic Center or the Maintenance Entrepreneur, which sometimes leads to poor decisions of redirection road. The redirection route might be in poor condition and therefore not suitable, or extra maintenance such as snow plowing might be necessary for the increased traffic load

(Segerström, 2014). According to Forsman (2014) the best decision of rerouting can be made if the Traffic Center, the Maintenance Entrepreneurs, the Police and the Emergency Service cooperate.

The Maintenance Entrepreneurs are contacted by the Traffic Center if the Emergency Service needs help to clean the incident site (Segerström, 2014). The Entrepreneurs are also contacted during longer stops to take over the rerouting from the Police. According to Segerström (2014) the Police want the Entrepreneurs to arrive quickly so that they can leave the site. The Entrepreneurs however have two hours to arrive to the site according to their contract with the Swedish Transport Administration. The Entrepreneur does not have the authority to stop or direct the traffic, but sometimes they have to perform the Police's job to do so (Segerström, 2014). It is usually one or two persons from the Entrepreneur coming to the site which complicates the work when they have to redirect the traffic, mount rerouting signs and clean the site at the same time.

According to Forsman (2014) all statistics show that the number of accidents decreases on 2+1 roads. The 2+1 roads are however more difficult to maintain and the guard rails are often run down. Also R. Nilsson (2014) think that 2+1 roads are good from the road users view, but when an accident occurs it is difficult for the rescuing authorities to reach the site. The rescuing work on 2+1 road are difficult and dangerous because of the narrow space and high speed limits (Forsman, 2014; Segerström, 2014). Therefore signs and protection barriers are crucial to maintain the safety at the incident site.

The Maintenance Entrepreneurs

The responsibility of the Maintenance Entrepreneurs is to maintain the serviceability of the roads (Mausén, 2014). During an accident the Maintenance Entrepreneurs assist the Salvation Operator, help to protect the site and inspect rerouting roads (Hallén, 2014). Cleaning the site and repairing damage to road elements are also responsibilities of the Entrepreneur (Molin, 2014). It is the Traffic Center that informs the Maintenance Entrepreneurs of the accident and sends them to the site if necessary (Mausén, 2014; Molin, 2014). According to Hallén (2014) the information of an incident comes from the Police but he also mentions that the Entrepreneurs have some contact with the Traffic Center.

According to Mausén (2014) rerouting is performed in collaboration with the Police and Traffic Center. There are several factors affecting if and how rerouting is performed such as how the accident hinders the traffic. If the Salvation Operator estimates that the clearance will be time consuming, some kind of rerouting is usually performed (Mausén, 2014). Hallén (2014), on the other hand, experience that it is the Police that by them self decides if and how rerouting is performed and it is also the Police that are responsible to redirect the traffic.

The Maintenance Entrepreneurs are however responsible to mount signs for the rerouting road even if it is the Police that decide which road to use (Hallén, 2014). Hallén (2014) believes that there is a difference in how the Police use the experience of the Maintenance Entrepreneurs and he emphasizes the importance of collaboration when choosing a suitable rerouting road. According to Mausén (2014), the rerouting road is chosen by the Maintenance Entrepreneur which has contact with the Traffic Center. How much the Traffic Center is involved in the choice of road is highly dependent on the local knowledge and experience of the specific traffic leader.

Mausén (2014) believes that 2+1 roads are the most dangerous road type to work on which both Hallén (2014) and Molin (2014) agrees with. The road type is narrow and there are often high speed limits which contribute to safety risks for the personnel (Molin, 2014). Mausén (2014) also experience that road users generally have little respect for the personnel at the road work site.

The Police

The Police are most commonly informed last of the blue-light authorities since their responsibility not include lifesaving actions (Ahlbom & Arvidsson, 2014). This means that the Police often arrives to the site last even if the time to arrival practically only depends on the time to drive there (Berndtzon, 2014). It is SOS Alarm that informs the Police through the Police Communication Center which send the Police patrol to the site (Lindberg, 2014). The Police's task at the site is to investigate the cause of the incident and to direct the traffic (Ahlbom & Arvidsson, 2014; Åreng, 2014). The Police is however not involved in all accidents that occurs on the roads. In most cases the parties involved can solve the situation by them self directly at the incident site. The Police are informed when the accident involves injuries, when it occurs on European and state roads or when the accident occurs during high traffic. The traffic Police is only called to the site in case of major accidents or when hazardous goods is involved, otherwise it is an ordinary patrol that is called to the site (Berndtzon, 2014; Åreng, 2014; Lindberg, 2014). Because of lack of resources normally only one Police patrol is sent to an accident. Therefore the Emergency Service often helps the Police to redirect the traffic (Ahlbom & Arvidsson, 2014).

The Police is responsible to order salvation which they do trough SOS Alarm (Ahlbom & Arvidsson, 2014). If the Police are not at the site the Emergency Service must contact the Police which contacts SOS Alarm so that they order salvation to the site.

According to Berndtzon (2014) it is the Police that are responsible for the decision of rerouting in consultation with the incident leader. Lindberg (2014) says that the Police patrol at the site solves the traffic situation together with the Police Communication Center. According to Berndtzon (2014) and Lindberg (2014) there is no contact with the Swedish Transport Administration about neither the accident nor the choice of redirection route. The only contact is in case of longer stops or if remediation of the site is necessary so the Maintenance Entrepreneur must be called to the site (Berndtzon, 2014). The decision on how to redirect the traffic is based on knowledge of the local road network with help from the Police Communication Center (Ahlbom & Arvidsson, 2014; Lindberg, 2014). Åreng (2014) on the other hand emphasizes the importance of communication with the Swedish Transport Administration, or the Maintenance Entrepreneurs ultimately, in order to decide which redirection route that is most suitable. Both Berndtzon (2014) and Lindberg (2014) states that considerations are taken not to send heavy vehicles through a residential area or into roads with height, width or weight limitations, as examples.

It is also the Police that redirect the traffic at the first stage, until the Entrepreneur arrives and mount signs for the new route (Ahlbom & Arvidsson, 2014; Åreng, 2014; Lindberg, 2014). The Police contact the Traffic Center which sends the Maintenance Entrepreneur to the site. According to Ahlbom & Arvidsson (2014) the Police's resources is held on the incident site due to the long arrival time of the Maintenance Entrepreneurs. Åreng (2014) on the other hand have not experienced any problems with that, and thinks that the Entrepreneurs arrive rather quickly. The time until the

Entrepreneurs must arrive is decided by the maintenance contract with the Swedish Transport Administration (Ahlbom & Arvidsson, 2014).

If rerouting is performed depends on the extent of the accident and the situation in general (Berndtzon, 2014). According to Ahlbom & Arvidsson (2014) and Åreng (2014) the safety for the personnel at the site is prioritized in the initial rescuing work. The Police therefore close the lanes necessary to safely perform the rescuing work.

The manual *"Vägen Fri- snabbt och säkert"* is distributed to the Polices concerned with those questions according to Ahlbom & Arvidsson (2014) and all of the operators at the Communication Center are familiar with the project. They believe that the manual is of most importance for the Polices working at the accidents.

Berndtzon (2014) and Åreng (2014) both believe that 2+1 roads are generally good because of the safety for the road users. The road type is however vulnerable when accidents occur and Lindberg (2014) thinks that 2+1 roads lead to an irregular driving behavior. Lindberg (2014), Åreng (2014) and Berndtzon (2014) think that the safety when working on 2+1 road is rather poor. There are usually no or a very narrow roadside which complicates the work (Lindberg, 2014). The guard rail provides some safety according to Åreng (2014) but the road users generally have little respect for blue lights and road barriers.

The Emergency Service

The Emergency Service was only interviewed in the geographical area of Gothenburg which means that the answers reflect the working methods in this area. The Emergency Service arrives first to the site and the Police arrive 10-15 minutes later in the worst cases (Volmefjord, 2014). One member of the Emergency Service crew becomes the incident leader at the site. It is the incident leader together with one leader from the Police and one from the Ambulance Service that are responsible for the work at the site. The main goal of the Emergency Service at an accident is to open the road for traffic as soon as possible without jeopardizing the safety at the incident site. Long stops in traffic cause queues and delays which means large costs for society.

According to Volmefjord (2014) it is the incident leader that, together with the Police decides if the traffic should be redirected. The road is however always closed entirely during the acute rescuing work until the Ambulance has left the site. The Emergency Service has no contact with the Traffic Center considering rerouting. The Traffic Center is contacted first after the rescuing work to inform if there is any damage to the road which the Maintenance Entrepreneurs must restore. According to Volmefjord (2014) rerouting is unusual; instead the focus is on removing the obstacles as quickly as possible and to open the road again. The critical aspect of the work is to get the Salvation Operator to the site quickly.

The ordering of salvation is the responsibility of the Police (Volmefjord, 2014). Since the Police often arrive last to the site there are currently discussions if the Traffic Center should be responsible instead. This is a part of the Swedish Transport Administration's project "*Hinderfri Väg"* which Volmefjord is involved in.

When it comes to 2+1 roads it requires good local knowledge of the road network to reach the incident site (Volmefjord, 2014). It is also a difficult situation to work at the direction with one lane since it is so narrow. The road type is however safe for the road user because of the guard rail.

7.2 Simulations

In the sections below the results from the simulations in Vissim are presented for each area. Results from each of the areas can be seen in Table 50 to Table 53 in Appendix J. The result from the comparison between the AADT counted during the ocular inspection and the AADT from Vägtrafikflödeskartan can be seen in Table 12 to Table 15 in Appendix E. Generally the AADT from the ocular inspection were lower than the AADT from Vägtrafikflödeskartan and the values vary between 20 and 80 percent. There are however a few exceptions where the AADT from the ocular inspection were higher.

7.2.1 Road E45

In Table 5 below, the delay without rerouting is presented for stop in the one-lane and two-lane direction. Note that the delay in the two-lane direction, case E, is greater than in the one-lane direction, case A, due to spillback that blocks both road E45 in the northbound direction and both directions of road 44. Case A only blocks the southbound direction of road E45.

Table 5 – Delay results for case A and E, without rerouting, for road E45 for stop duration of one, two, four and eight hours.

Case	1 hour	2 hours	4 hours	8 hours
A [h]	500	2000	6000	18300
E [h]	900	5500	19100	60700

Below, the delays due to stop in the one-lane direction on road E45 are presented, see Figure 17. Bypassing, case D presented by a grey column, is the option that reduces the delay the most. The delay is similar for the two, four and eight hour durations of the stop which indicates that it is the queue until rerouting starts that mostly affects the delay. Rerouting on another road with (B) and without (C) trapped vehicles are similar for the shorter durations of the stop. When the stop is longer however the delays are smaller without trapped vehicles. Comparing the delay without any rerouting, case A, in Table 5 with the delays in Figure 17 it can be seen that all rerouting options reduce the delay.

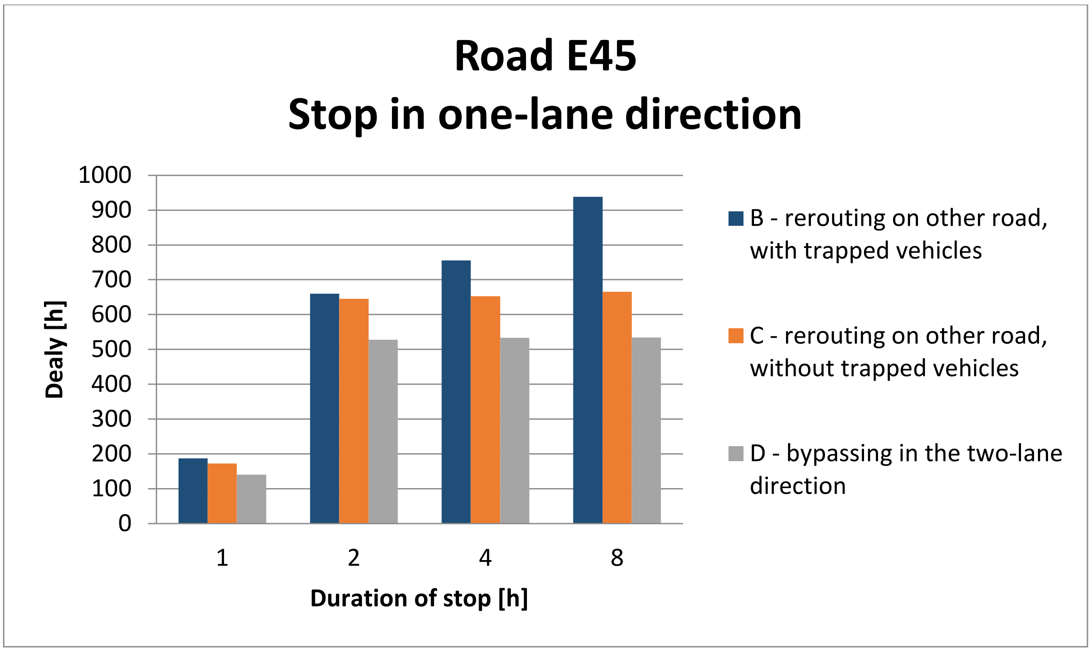

Figure 17 - Delay results for rerouting and bypassing in one-lane direction, case B, C and D, for road E45.

In Figure 18 below, the delays due to stop in the two-lane direction are presented. The option that generally reduces the delay the most is to bypass the traffic in one of the lanes on the two-lane direction if possible, case H. For shorter durations of the stop (1 or 2 hours) rerouting on another road, with trapped vehicles, is the option that gives the second smallest delay and for the longer durations (4 or 8 hours) it is bypassing on the one-lane road, case I. Case G, rerouting on another road without trapped vehicles, causes more delay than when vehicles are trapped. This is because more traffic on road 44 and E45, that was not supposed to turn towards the accident, was hindered. If the delays in Figure 18 are compared to the delays without any rerouting, case E, in Table 5 it can be seen that all rerouting alternatives reduce the delay.

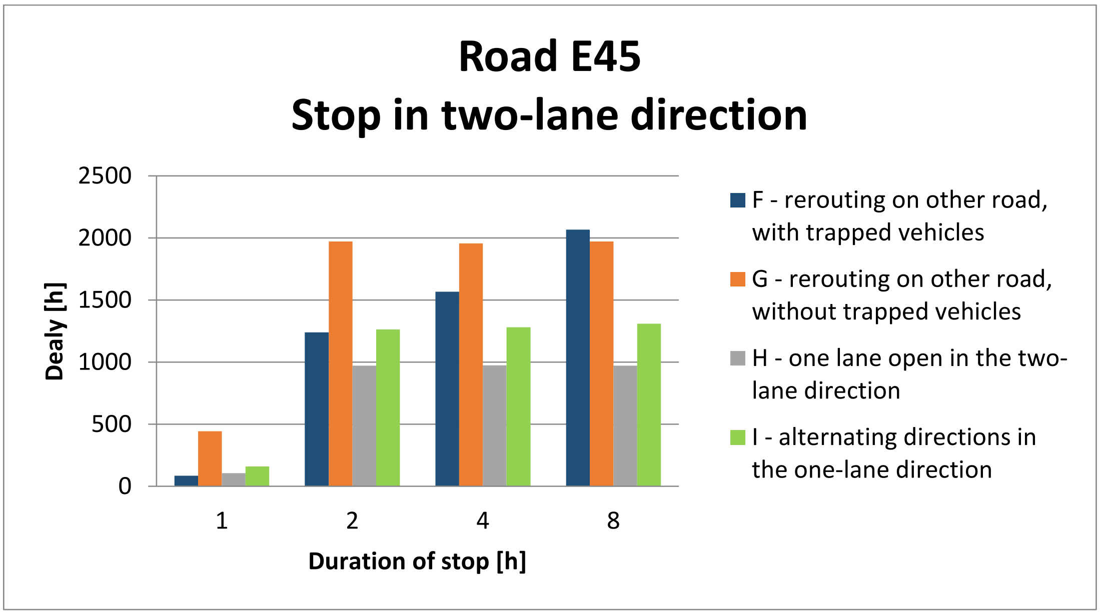

Figure 18 - Delay results for rerouting and bypassing in two-lane direction, case F, G, H and I for road E45.

Generally it can be noted that the delays in the two-lane direction, is greater than the delays in the one-lane direction. This is depending on the spillback from the stop in the two-lane direction which does not occur due to the stop in the one-lane direction.

7.2.2 Road 40

In Table 6 below, the delay without rerouting is presented for stop in the one-lane and two-lane direction. The delay is greater in the two-lane direction than in the one-lane direction.

Table 6 - Delay results for case A and E, without rerouting, for road 40 for stop durations of one, two, four and eight hours.

Case	1 hour	2 hours	4 hours	8 hours
A [h]	300	1400	4400	13700
E [h]	400	1600	5100	15100

Below, the delays due to stop in the one-lane direction on road 40 are presented, see Figure 19. Bypassing, case D presented by a grey column, is the alternative that reduces the delay the most. The delay is similar if the duration of the stop is between two and eight hours which indicate that it is the queue until rerouting starts that mostly affects the delay. When the duration of the stop is one hour the time until rerouting starts is shorter and therefore also the delay. Rerouting on another road without trapped vehicles, case C, reduces the delay more than case B where vehicles are trapped and does almost reduce the delay as much as bypassing the traffic. Comparing the delay without any rerouting, case A, in Table 6 with the delays in Figure 19 it can be seen that all rerouting options reduce the delay.

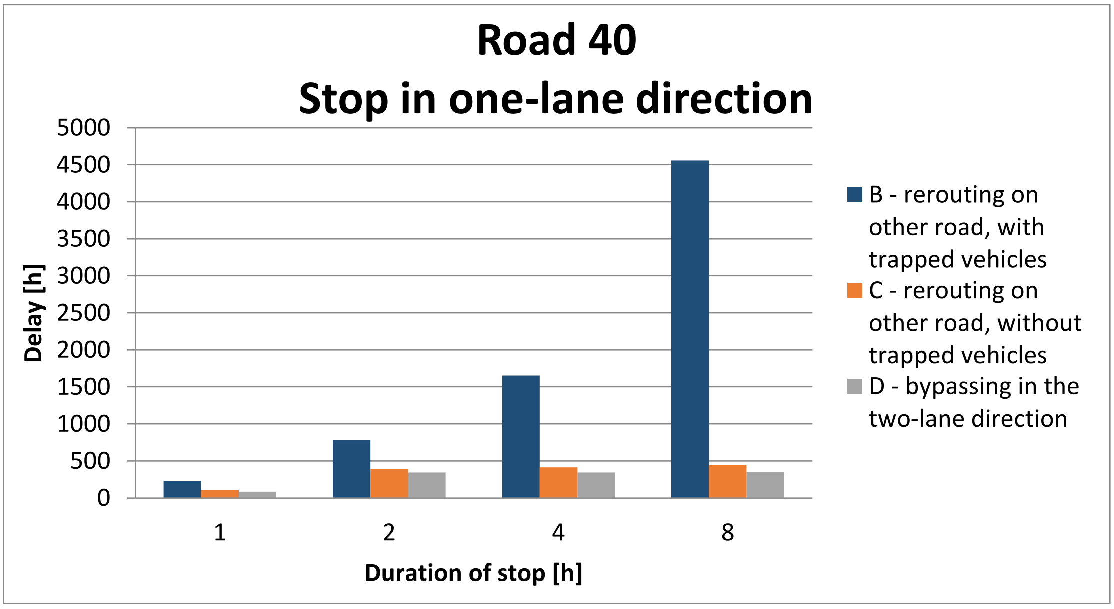

Figure 19 - Delay results for rerouting and bypassing in one-lane direction, case B, C and D for road E40.

In Figure 20 below, the delay due to stop in the two-lane direction is presented. The option that reduces the delay the most is to bypass the traffic in one of the lanes in the two-lane direction if that is possible, case H. Rerouting on another road, case F and G, reduced the delay second most, for shorter durations of the stop (1 or 2 hours). If no vehicles are trapped, case F, the delay is reduced second most for the longer durations of the stop (4 and 8 hours) while if vehicles are trapped, case G, bypassing on the one-lane road, case H, gives the second smallest delay. If the delays in Figure 20 are compared to the delays without any rerouting, case E, in Table 6 it can be seen that all rerouting alternatives reduce the delay.

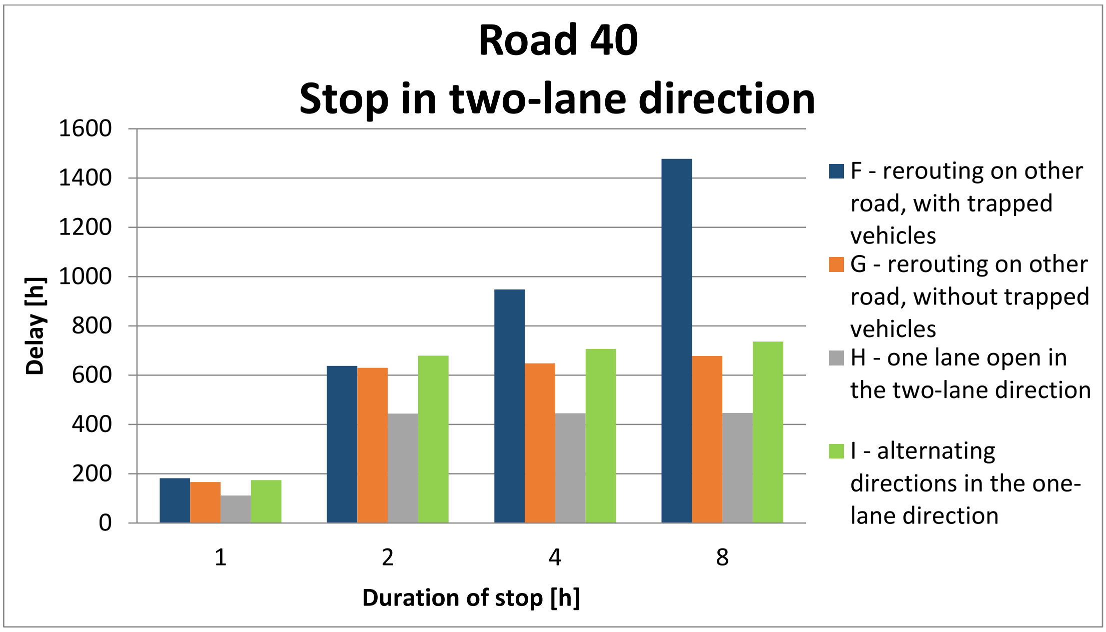

Figure 20 - Delay results for rerouting and bypassing in two-lane direction, case F, G, H and I for road 40.

Generally it can be noted that the delay when rerouting the traffic to another road, case B and F, is greater in the one-lane direction than the two-lane direction due to more cars getting trapped. The delay in the other cases of rerouting and bypassing however is greater in the two-lane direction due to the higher traffic flow in this direction.

7.2.3 Road E20

In Table 7 below, the delay without rerouting is presented for stop in the one-lane and two-lane direction. The delay is equal in the two directions for stop durations for one, two and four hours, and slightly higher for the one-lane direction for the eight hour stop.

Table 7 - Delay results for case A and E, without rerouting, for road E20 for stop durations of one, two, four and eight hours.

Case	1 hour	2 hours	4 hours	8 hours
A [h]	300	1200	4400	10800
E [h]	300	1200	4400	10600

Below the delays due to stop in the one-lane direction on road E20 are presented, see Figure 21. Bypassing, case D presented by a grey column, reduces the delay most. The delay is similar if the duration of the stop is between two and eight hours which indicate that it is the queue until rerouting starts that mostly affects the delay. When the duration of the stop is one hour the time until rerouting starts is shorter and therefore also the delay. For the short rerouting road without trapped vehicles, case Ca, the delay is similar for stop durations of two, four and eight hours. For the longer rerouting road, however, the delay increases with longer stop durations, case Cb.

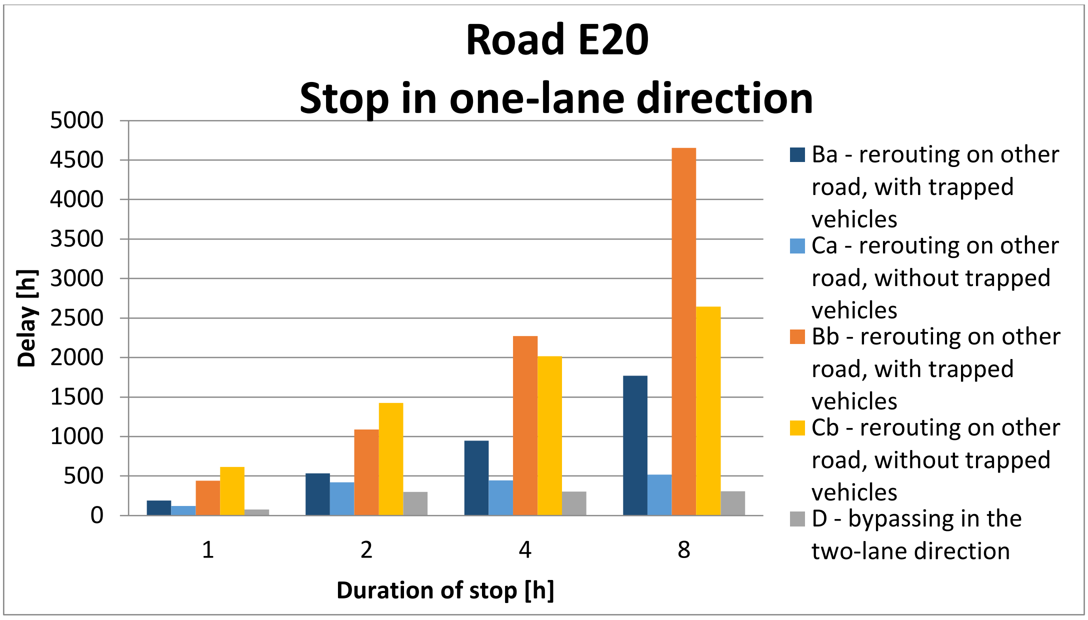

Figure 21 - Delay results for rerouting and bypassing in one-lane direction, case Ba, Ca, Bb, Cb and D, for road E20. Ba and Ca are for the short rerouting road while Bb and Cb is for the longer rerouting road.

In Figure 22 below, the delays due to stop in the two-lane direction are presented. To bypass the traffic in one of the lanes on the two-lane direction leads to the smallest delay, case H presented by a grey column. The shorter rerouting on another road without trapped vehicles, case Ga presented by an grey column, also leads to a small delay as well as bypassing on the one-lane direction, case I presented by a green column. The shorter rerouting option saves time compared to the longer rerouting option. Regarding the longer rerouting option the delay is lower if vehicles are trapped, case F, during shorter durations of the stop (1 and 2 hours). During the longest duration however the delay is smaller if no vehicles are trapped, case G.

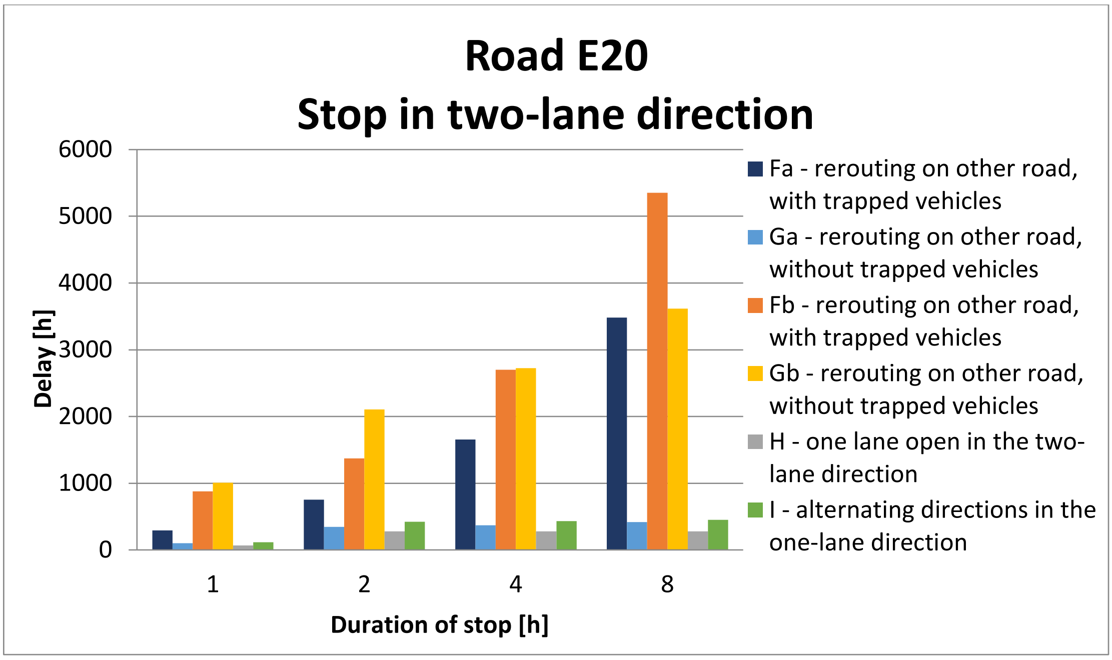

Figure 22 - Delay results for rerouting and bypassing in two-lane direction, case Fa, Ga, Fb, Gb, H and I for road E20. Fa and Ga is for the short rerouting road while Fb and Gb is for the longer rerouting road.

The delay when rerouting to another road, with the short redirection route, is larger in the two-lane direction, case Fa, than in the one-lane direction, case Ba, due to more vehicles getting trapped.

7.2.4 Disturbance per vehicle and year

The complete result from the calculations of reduced disturbance per vehicle in Sweden can be seen in Appendix K. During stop durations of eight hours the disturbance per vehicle can be reduced up to 0.73 minutes compared to case without rerouting, for road E45. The maximum reduction for road 40 is 0.18 minutes, for road E20a it is 0.13 minutes and for road E20b it is 0.10 minutes. This means that the reduction of the disturbance per vehicle and year can be between 6 and 45 percent of the reduction wanted by the Swedish Transport Administration, during an eight hour long incident.

7.3 Total vehicle delay

In the table below, Table 8, the total vehicle delay from the calculations and the delay from the simulations are presented for road E45. The delay from the simulations are from case A and D, without rerouting since the total vehicle delay only is calculated for cases with complete stop. The percentage of the simulated delay that the calculated delay represents can also be seen. The calculated delay covers around 60 to 70 percent of the simulated delay for the one-lane direction. In the two-lane direction the calculated delay is between 22 and 36 percent of the simulated delay.

Table 8 – Comparison of the calculated delay and the delay from the simulations for road E45.

E45		Calculated delay [h]	Simulated delay [h]	Percentage
One-lane direction	1 hour	310	540	57 %
	2 hours	1260	1960	64 %
	4 hours	4260	6040	71 %
	8 hours	12160	18290	66 %
Two-lane direction	1 hour	320	890	36 %
	2 hours	1270	5530	23 %
	4 hours	4290	19090	22 %
	8 hours	13270	60690	22 %

In the table below, Table 9, the total vehicle delay from the calculations and the delay from the simulations are presented for road 40. The percentage of the simulated delay that the calculated delay represents can also be seen. The calculated delay covers around 70 to 80 percent of the simulated delay in both directions.

Table 9 - Comparison of the calculated delay and the delay from the simulations for road 40

Road 40		Calculated delay [h]	Simulated delay [h]	Percentage
One-lane direction	1 hour	270	340	79 %
	2 hours	1070	1400	76 %
	4 hours	3610	4450	81 %
	8 hours	11150	13660	82 %
Two-lane direction	1 hour	300	450	67 %
	2 hours	1180	1630	72 %
	4 hours	4010	5090	79 %
	8 hours	12390	15130	82 %

In the table below, Table 10, the total vehicle delay from the calculations and the delay from the simulations are presented for road E20. The percentage of the simulated delay that the calculated delay represents can also be seen. The calculated delay covers around 70 to 85 percent of the simulated delay in the one-lane direction and 80 to 90 percent of the simulated delay in the two-lane direction.

Table 10 - Comparison of the calculated delay and the delay from the simulations for road E20.

E20		**Calculated delay [h]**	**Simulated delay [h]**	**Percentage**
One-lane direction	1 hour	220	300	73 %
	2 hours	890	1150	77 %
	4 hours	3030	3580	85 %
	8 hours	9250	10780	86 %
Two-lane direction	1 hour	220	270	81 %
	2 hours	880	1100	80 %
	4 hours	2990	3490	86 %
	8 hours	9250	10570	88 %

8 Analysis

In the analysis chapter the result from the interviews are summarized in order to provide a concise overview. The simulations and the total vehicle delay are evaluated in order to explain similarities and differences of the result.

8.1 Interviews

Most of the interviewees agree that it is the Police that make the decision whether to reroute the traffic or not. The Police say that the decision is made in collaboration with the incident leader from the Emergency Service, which the Emergency Service agrees with.

In the choice of rerouting road the Police have no contact with the Traffic Center, neither have the Emergency Service. The Police have contact with their Communication Center which helps in the rerouting decision. Some of the interviewees say that the Maintenance Entrepreneur is involved in the decision of rerouting road. The Entrepreneurs on the other hand have different experiences of their involvement in the decision. Interviewees from the Police, the Operation Project Managers and the Maintenance Entrepreneurs do however emphasize the importance of the involvement of the Entrepreneur due to their knowledge of local conditions. The Operation Project Managers and the Maintenance Entrepreneur believe that the Police in some cases make rather poor choices of rerouting road. Since there in many cases is no contact between the Police and the Maintenance Entrepreneur or the Traffic Center, important information about the rerouting road, such as need of increased snow plowing or ongoing road work, is lost.

It is the Police that redirect the traffic at the first stage and the Maintenance Entrepreneur is responsible to mount signs for rerouting. The Entrepreneurs do not have the authority to stop or direct the traffic but according to the Operation Project Managers the Entrepreneur sometimes has to perform the Police's job. The Police have the perception that the Entrepreneurs arrive late to the site which holds the Police's resources there. The Maintenance Entrepreneur however has two hours to arrive to the site according to the maintenance contract with the Swedish Transport Administration.

The gathered view of all interviewees is that the safety for the personnel on 2+1 roads are quite poor. The narrow space and high speed limits together with little respect from the road users puts the personnel in a vulnerable situation when working on 2+1 roads. The road type is also sensitive to disturbances and when disruptions occur there are usually large consequences. Most of the interviewees do however point out the safety for the road user as a predominantly positive factor with the road type.

8.2 Simulations

In most of the scenarios it is better to do any kind of rerouting compared to letting the traffic wait until the stop is cleared. It can also be noted that the time saved on rerouting increases as the duration of the stop increases. Generally the best rerouting option is to keep one lane open in each direction. If the disruption occurs on the two-lane road the best option is to open one lane and if the disruption occurs on the one-lane road the best option is to bypass in one of the lanes in the two-lane direction. The rerouting alternative that causes most delay is generally to reroute on another road. In case of disruption on the two-lane road, rerouting on another road without any vehicles trapped sometimes is a better option than bypassing on the one-lane road. This does however require that no vehicles get trapped which is not a realistic scenario.

Comparing the delay at the different stop durations it can be seen that the delay during the one-hour stop is generally less than half of the delay during the two-hour stop duration regardless of rerouting alternative. This probably has to do with the longer queue disappearance. The time it takes for a queue that has been formed during one hour to disappear is more than the double compared to one formed during 30 minutes.

Case D, H and I, where one lane is kept open in each direction, have the same delay if the duration of the stop is two, four or eight hours. This implies that the delay is mostly depending on the queue that develops during the stop and the disappearance of the queue. In the one-hour scenario the delay is smaller due to the shorter duration of the stop.

Case B and F, rerouting on another road with trapped vehicles, have an increasing delay when the duration of the stop increases. This most likely depends on the trapped vehicles that have to wait longer if the duration of the stop is longer. If there are no vehicles trapped however, case C and G, the delay is generally similar if the duration of the stop is two, four or eight hours since no cars have to wait until the stop is cleared. Generally the delay is smaller when no vehicles are trapped. At E20b and for stop in the two-lane direction at E45 however the delay is lower if vehicles are trapped, except for during stop duration of eight hours.

The scenarios at road E45 is complex compared to the other areas due to the intersection of two main roads, road E45 and road 44, that creates many enters and exits, but also due to the many smaller roads in the area. This is probably the reason why the delay is lower when vehicles are trapped during rerouting on another road compared to when they are not trapped. If no vehicles were to be trapped, the signal head had to be placed on road 44 which meant that all traffic on this road was blocked; even those who just wanted to go straight ahead on road 44. The traffic flow is high on this road and even if the vehicles only are stopped for one hour it will cause large delays. In the case with trapped vehicles, the trapped queue is rather short and most vehicles will be redirected. This scenario however, lets the traffic on road 44 run for a longer time even if it will be blocked eventually. During the shorter durations of the stop, one, two and four hours, the delay caused by the queuing vehicles on road 44 will exceed the delay caused by the trapped cars at road E45. During the longest duration, eight hours, the delay of the trapped vehicles will instead exceed the delay of the queuing vehicles on road 44.

Regarding area E20b, which is the longer rerouting road for road E20, the reason for the lower delay with trapped vehicles probably is the length and complexity of the redirection road. When no cars are trapped the signal head is placed just before the intersection to the rerouting road. This causes a queue and when the rerouting starts a procession is formed that causes delay in intersections and at the narrow bridge on the redirection route. In the scenario with trapped vehicles there is no procession formed at the redirection road which makes the traffic flow smoother. The redirection road is significantly longer than the main road and traffic jams are created at the bridge. Therefore the vehicles redirected to another road cause more delay than the trapped vehicles, for stop durations of one, two and four hours. When the stop is eight hours however, the delay of the trapped vehicles exceeds the delay due to the long and complex redirection route.

8.3 Total vehicle delay

The calculated total vehicle delay generally covers 60-90 percent of the simulated delay. The calculated delay best corresponds to the simulated delay at road E20 and least at road E45. This probably has to do with the traffic flows. Of the three areas the flows are highest at road E45 and lowest at road E20. According to Lind et al. (2013) the calculated delay covers less of the real delay at higher traffic flows.

At road E45 there is a very low coverage, between 22 and 36 percent, in the two-lane direction. This is most likely due to that the traffic on road 44 also gets blocked in both directions a while after the disruption. This is not considered in the formula for the calculated delay since it only considers the traffic on the road where the disruption occurs.

9 Discussion

The discussion includes thoughts regarding the methodology of the investigation, reflections of the results and speculations regarding other aspects that can affect the choice of rerouting alternative. Finally recommendations for further investigations are suggested.

9.1 Reflections of the method

There is no thoroughly tested method for this type of investigation wherefore the process has been developed during the study. Therefore it is not possible to compare the investigation method with any other study as support.

There are some uncertainties regarding how the three investigated areas were chosen. Ten areas that visually seemed to be most affected by disruption were chosen from the ArcGIS file. From these the three areas with most disruption per meter were chosen. There is a possibility that areas were overlooked in the visual investigation and perhaps all 2+1 roads in the region should have been further investigated. However, the three areas chosen are roads regarded to often be affected by accidents and therefore they are assumed to be suitable areas to examine.

There are always uncertainties when performing an interview-based investigation which must be considered when analyzing the results. The answers of the interviewees are based on personal experience which might not represent the view of the entire authority. The answers can be biased or affected by the way the questions were asked. There is also an uncertainty in the choice of interviewees and for some operators, for example the Emergency Service, more interviews would increase the liability of the result. However there was not room for more interviews within the boundaries of this thesis.

The time until rerouting can start is assumed to be the same for the different alternatives. However, the time until rerouting to another road can be opened is depending on the redirection route and the available resources. When bypassing the traffic in the opposite direction it is rather easy to make an opening in the guard rail. If, however, reversible directions are used signal heads must be installed or guards summoned. If the traffic is bypassed the accident in the same direction additional safety measures to separate the traffic from the accident site have to be taken before the bypassing can be opened. Since the time until a rerouting can be opened is site specific it was decided to use the same time for all alternatives. In reality the personnel working with rerouting must take this aspect into consideration when deciding upon rerouting alternative.

Spillback outside of the areas has not been considered in the simulations. In the models, links for the queues to form on have been made straight and without any intersections. In reality the queues would affect the surrounding road network and cause even more delay in some cases. This does, however, mean that the possibility to reduce the delay is even larger if a suitable rerouting alternative is performed.

It has been visually investigated that the vehicles in the model behave in a desirable way, to confirm the accuracy of the models. It has been controlled that the vehicles travel on the desired routes and that speed decisions, signal heads and priority rules are followed. A calibration of the model could however have been useful to further determine the accuracy. One way could have been to thoroughly investigate the travel time between different locations in the areas simply by driving the stretches several times, different times of the day and on different days. Such an investigation has however not been possible within this thesis.

At first, priority rules were used in all intersections on the main road and conflict areas on the smaller rerouting roads. Priority rules were used since the intersections can be modeled more accurately with defined gap time and gap space. For the relatively large flow on the main road this was considered important to accurately reflect the travel time. However, it was discovered that conflict areas reflect the reality in a good way while the priority rules often led to undesired behavior in some of the intersections. In these intersections the priority rules were changed to conflict areas to receive an accurate result.

In the manual for the simulation software Vissim it is recommended to perform five simulation runs with different random seed. This was done in the beginning of the investigation until it was noticed that the simulations were rather time consuming. Therefore the number of runs in the continued investigation was decreased to three, still with different random seed. The result is more reliable the more runs performed but due to the limitation of time three runs seemed to be a reasonable compromise.

The result from the simulations has been controlled to discover any deviant values. In the cases where the result deviates, the simulations were run again to discover any errors, such as undesired traffic jams. The errors were corrected and the model was run again for all durations of the stop to ensure that there are no errors in the results for that case.

9.2 Reflections of the results

In the sections below the results from the interviews, the simulations and the total vehicle delay are discussed.

9.2.1 Interviews

Most of the interviewees say that the Police, with help from different operators, make the decision about rerouting. This is in agreement with the manual "*Vägen Fri- snabbt och säkert"*, even if it has not yet been implemented in the entire Western Region. The Police are responsible to decide about rerouting, but in consultation with the Traffic Center and the Maintenance Entrepreneur. Some of the interviewees mentions contact with the Maintenance Entrepreneur about rerouting, but most have the perception that the Police makes the decision on their own. The Traffic Center is not involved in the decision of rerouting as it is today, even if "*Vägen Fri- snabbt och säkert"* recently was implemented in Gothenburg.

If the Traffic Center were more involved in the decision of rerouting the collaboration could be enhanced, leading to better decisions. The Traffic Center should have the knowledge of suitable rerouting roads and being able to control the conditions, limitations, level of maintenance and ongoing road works. Much of this information could be obtained by the databases of the Swedish Transport Administration and by having a close contact with the Maintenance Entrepreneur.

Which of the rerouting alternatives to perform, if routing should be performed at all, is not handled particularly in the manual "*Vägen Fri- snabbt och säkert"*. This investigation shows that the choice of rerouting alternative has great impact of the total delay of the disturbance and therefore it is important to reflect on how this choice should be performed. From an accessibility view it is better to perform any kind of rerouting than doing nothing at all in most cases. The decision must however also, if not primarily, consider safety aspects and the environmental impact.

One of the results from the interviews is that there is a slight disagreement about the responsibilities of the Maintenance Entrepreneur and the Police. The Entrepreneurs does in some cases experience that they have to do the Police's job to direct the traffic, while the Police believes that the Entrepreneurs need too long time to arrive to site. The Police think that their resources are being held at the site, directing traffic when they have other important missions. In the manual *"Vägen Fri- snabbt och säkert"* it is stated that it is the Police that is responsible to direct the traffic and that the Emergency Service have the legal authority to help. The Entrepreneur does not have the authority to direct traffic but they are responsible to install equipment to redirect the traffic. The time until the Entrepreneur should arrive to the site is regulated in the contract with the Swedish Transport Administration. The solution to this problem is either to provide the Police with more resources or to shorten the time for the Entrepreneur to reach the site, contracted with the Swedish Transport Administration.

All of the interviewees believe that the safety when working on 2+1 roads is poor and there are mainly two factors that are mentioned: the narrow space and the high speed. To increase the safety for the personnel and the accessibility for the rescue operators on 2+1 roads, the dimensions of the roadside is an important factor to consider when constructing new 2+1 roads. The generally high speed limits on 2+1 roads are experienced as one of the most important aspect when it comes to the feeling of poor safety. It is proved that that the risk of serious injuries and fatalities increase rapidly with increased speed. The perception of poor safety when working 2+1 roads contribute to the fact that rerouting on other road is the best alternative when it comes to safety for the personnel at the site. Rerouting is also the alternative to primarily consider at road works according to guidelines of the Swedish Work Environment Authority (Arbetsmiljöverket, 2009).

9.2.2 Simulations

The result from the simulations are based on the three areas investigated in this thesis and might not be applicable to other road areas. The general conclusions which can be made based on the three areas must be further investigated before applied in other traffic situations. The result can however provide a hint about which rerouting alternatives that might be advantageous.

From an accessibility point of view it is almost always better to reroute the traffic in some way than letting it wait until the road can be opened again. Bypassing is generally a better option than rerouting on another road unless the traffic quickly can be stopped so that no vehicles get trapped, or that the trapped vehicles are helped to pass. This does however not apply for all situations and when working with rerouting one must always consider the specific scenario.

When the traffic situation is complicated, as for road E45, it might be better to focus on a quick opening of the redirection road instead of avoiding vehicles getting trapped or prepare for reversed traffic in the one-lane direction. In these kinds of situations it is important to consider the entire area since spillback is a major issue and can cause more delay than the traffic on the incident road.

When the rerouting road is significantly longer than the incident road or if it contains obstacles, which both was the case at road E20b, it is not always better to reroute the traffic on another road compared to letting it wait. During shorter durations of the stop, one or two hours, it is better to let the traffic wait. It was also better to let vehicles get trapped than to have a procession on the rerouting road that formed even more delay. In these types of situations it is important to know how much longer the redirection route is and to be aware of obstacles along this road.

The general conclusion of what rerouting alternative that is best mainly applies when the main road is straight without any major intersections and the rerouting road is short and with few intersections or other obstacles, like road 40 and road E20a.

Regarding the goal to reduce the disturbance per vehicle and year with 1.6 minutes until 2018, choosing the right rerouting alternative can definitely be a contributing factor. Up to 45 percent of the reduction can be obtained during just one severe event compared to the cases without rerouting.

The traffic flows collected during the ocular inspection was generally lower than the AADT on the roads. Since the AADT is measured during a longer time period it was believed to be more reliable and therefore used when differences occurred. This creates the worst scenario of the two and the aim was to investigate the worst case of a normal day. The differences can depend on a number of factors. First, the indexes used to recalculate the collected data to be able to compare with AADT are general indexes and might not be suitable for the specific road stretches investigated in this study. The recalculation does not consider which day of the week it is. Since the traffic flow vary over the week it might be of importance. All of the ocular inspections were performed between Monday and Thursday so weekend traffic is not represented. The ocular inspections could only be performed once in each area within this study and therefore the result is highly dependent on the traffic situation at that specific day and time. Some of the error can also derive from human errors, which always is a factor during ocular inspection like this.

9.2.3 Total vehicle delay

The calculated total vehicle delay generally represents 60-90 percent of the simulated delay. According to Lind et al. (2013) the calculated total vehicle delay normally covers 75-90 percent of the real delay on highways in rural areas with traffic flows below 10 000 vehicles per day. This is the case for road 40 and road E20 where the calculated delay covers 70-90 percent of the simulated delay. This implies both that the calculated delay is accurate and that the simulated delay reflects reality.

The low coverage for road E45 depends on the effect on road 44 which is not included in the calculated delay. A solution to this problem could be to include the AADT for both directions of road 44 in the AADT for road E45 when calculating the delay. Looking at the traffic situation in the area makes it rather clear that also road 44 will be affected by the disruption. This could however give a too large calculated delay since road 44 is not affected immediately when the disruption occurs.

9.3 Safety and environmental aspects

Safety is the most important criterion regarding all kinds of traffic situations. Rerouting of traffic affects the safety of the road users, the personnel at the incident site and the persons in the area of a possible rerouting road, and none should be disregarded. Safety is one of the criteria in the vision of the Swedish Transport Administration and all the interviewees expressed that the safety is their main concern.

Regarding the safety of those working at the incident site, as well as the ones involved in the accident, the best option is to redirect traffic to another road. This means that the work can be carried out without any worries for accidents with the bypassed traffic or stress over letting the traffic wait if no rerouting is performed. If no rerouting is performed it is not just annoyed drivers that the operators have to worry about but also that the risk for further accidents increase when the drivers later try to make up for lost time. Bypassing the traffic always means an extra risk for the persons working at the accident site. If the traffic is bypassed however, speed is an important factor to consider. Decreased speed can both make the drivers more conscious and reduce the severity of an accident if it happens. Some of the interviewees expressed that drivers sometimes lack respect for the workers and are ruthless when it comes to reducing the speed. Therefore it is important to use proper safety barriers if the traffic should be bypassed. This can however take extra time to install.

If the traffic is rerouted to another road the risk for the ones working with the accident is assumed to be zero. This can however mean an increased risk for all road users as well as for other people in the area of the rerouting road. Figure 3 shows that the number of accidents increases with increased AADT. Even if a temporary rerouting does not change the AADT on the rerouting road there will be a significant increase in traffic while the rerouting occurs. One can imagine that also a temporary increase of traffic increases the risk of accidents in a similar way as the figure shows. Also the standard of the rerouting road affects the safety during rerouting on another road. Often the rerouting road is narrower than the main road which could increase the risk of accidents up to 25 percent. Also on this road the speed is an important factor since the severity of a possible accident could be decreased. It is also important to remember that people staying in the area of the rerouting road may not be used to high traffic and can therefore be inattentive. Especially if there is a school or playground close to the road it is important to make both the drivers and the pedestrians here aware of the new traffic flow.

Regarding safety, there are increased risks with both bypassing, rerouting on another road and also if the traffic is left waiting until the road is cleared. Therefore every situation has to be evaluated individually and the rerouting alternatives assessed. It is however good to be aware of the options and its connected risks so that the evaluation can be performed quickly.

Disruptions in road traffic normally affect the environment in a negative way. If the normal scenario is that the traffic flows smoothly a disruption means increased emissions due to braking, accelerating and also idle running. During complete stop one can however imagine that many drivers turn off their engine after a while.

While the queue is being resolved there can be braking and accelerations, but this happens in all cases of rerouting and also without rerouting. The emissions from bypassing of traffic depend on the type of bypassing. If one lane can be opened in each direction the number of braking and accelerations is lower than if reversible directions is used in one lane. Bypassing means that the source of the emissions is kept on the main road. Even if the levels of emissions are increased during the bypassing it is the same area that gets affected. Bypassing do generally not require any change in maintenance, except if something on the road needs to be repaired.

When rerouting on another road, the emissions are moved from the main road to the rerouting road. It is therefore important to know if there are any particularly sensitive areas along the rerouting road that can get damaged by these emissions. If the rerouting road is a smaller road with more people living close to it, which it have been in some of the investigated areas, the health effects due to emissions and noise are increased. Also if increased maintenance is needed on the rerouting road it can affect sensitive water sources along the road.

It is difficult to say which alternative that produces most emissions or have most effect on the environment when comparing bypassing with rerouting. Regarding carbon dioxide it is only the total emission that is of interest while for other emissions it is also the sensitivity of the recipient that matters.

10 Further investigations

There are some things that were not possible to perform within this thesis but that would have been interesting to further develop. To start with, a more accurate calibration of the models would make the result from the simulations more reliable. Simulations with different traffic flows could be performed to investigate how the choice of rerouting route and how the delay is affected by the traffic volumes. It could also be interesting to simulate shorter durations of the stop to evaluate at what duration it is advantageous to let the traffic wait until the main road is opened.

As described in section *3.1 Time aspects*, the degree of used capacity of the rerouting road is of great importance when choosing route. It would have been interesting to investigate the degree of used capacity of the rerouting roads for the three areas. It has however not been possible to obtain the capacity of these rerouting roads in this thesis.

A comparison of the cost of the time that can be saved on quick opening of rerouting and the resource cost due to the extra personnel it requires could be performed. An evaluation of the safety and environmental aspects in monetary terms could be performed to assess the rerouting alternatives based on these criteria. The Swedish Transport Administration has tools for translating safety risks into monetary costs. The emissions from the different cases could be evaluated in the ad-on modulus to Vissim, called EnViVer, which can calculate the emissions of carbon dioxide, nitrogen and particles. These emissions could also be translated into costs.

To be able to make more general conclusions about which rerouting alternative that is advantageous in a specific situation a more comprehensive investigation is necessary. More areas with differences regarding road type, road conditions and surrounding road network could be investigated.

11 Conclusion

The main issue discovered during the interviews with the different operators was lack of communication regarding rerouting. In the project *"Hinderfri väg"* the manual *"Vägen fri- snabbt och säkert"* was elaborated. When implemented, the manual will solve many of the issues discovered in the working-process after a traffic incident. However, one part that could be further developed is how to choose rerouting alternative. When deciding which rerouting alternative, bypassing or rerouting on another road, to choose it is important to consider safety, accessibility and environmental aspects according to the vision of the Swedish Transport Administration.

Safety should always be prioritized when choosing rerouting alternative. The safety of the road users, the personnel working at the incident site and the people in the area of the rerouting road must all be considered. Every case must therefore be evaluated based on the circumstances in the specific area. To be able to make a good decision of rerouting alternative based on environmental aspects further investigations are needed. It is difficult to differentiate the alternatives based on a literature study. It is suggested that a more comprehensive study in the simulation program EnViVer will be performed.

This study focuses on comparing the alternatives based on the criterion accessibility. Which rerouting alternative that is favorable depends on the traffic situation. The three following conclusions can be made based on the three investigated areas in this thesis:

- In uncomplicated traffic situations with a short rerouting route it is better to reroute the traffic than letting it wait. The best rerouting alternative is generally to keep one lane in each direction open while rerouting on another road is a good option if few vehicles are trapped.
- In situations where the rerouting route is long compared to the original route it is not viable to reroute the traffic during short durations of the stop.
- In complicated traffic situations with high traffic flows the main focus should be to open either a rerouting alternative or the main road as fast as possible.

Choosing the right rerouting alternative can be a contributing factor to reduce the disturbance per vehicle and year in Sweden and thereby reach the goal of the Business Area Maintenance.

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Appendices

Appendix A – "*Hinderfri Väg"*

Appendix B – GIS

Appendix C – Investigated areas

Appendix D – Interview questions

Appendix E – Comparison of measured AADT and AADT from Vägtrafikflödeskartan

Appendix F – Input data road E45

Appendix G – Input data road 40

Appendix H – Input data road E20a

Appendix I – Input data road E20b

Appendix J – Results from the simulations

Appendix K – Results from disturbance per vehicle

Appendix A – “*Hinderfri Väg*”

The figure below, Figure 23, have been elaborated to illustrate the working process at an accident site described in the manual “*Vägen fri- snabbt och säkert*”.

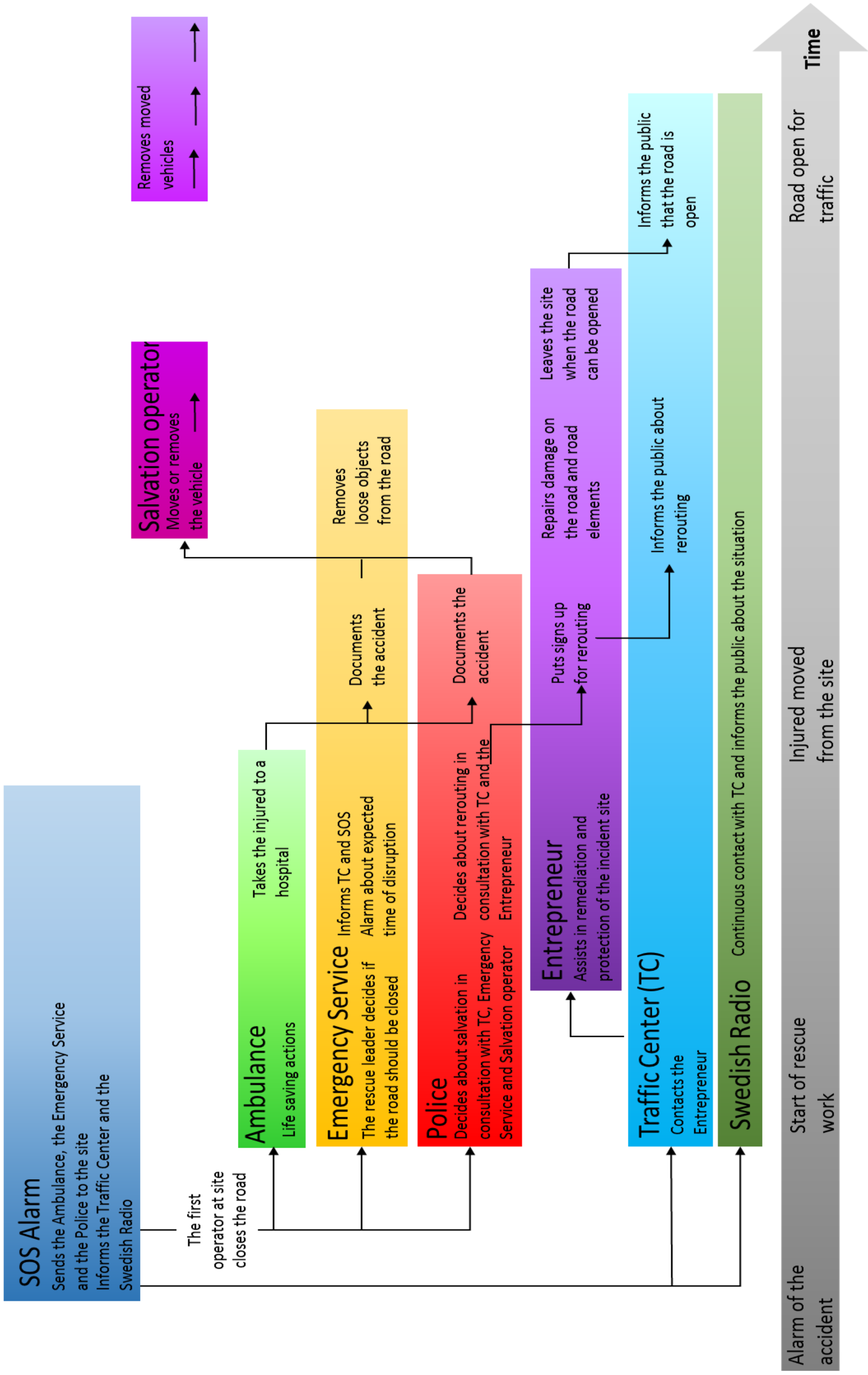

Figure 23 – The working process in the manual “Vägen Fri – Snabbt och säkert”.

Below the responsibility of each operator according to the manual *"Vägen fri- snabbt och säkert"* is described (Trafikverket, 2012b).

SOS Alarm

- is responsible for the emergency call number 112
- alarms the Police and Emergency Service
- prioritizes and directs the missions of the Ambulance Service
- fulfilling commitments at large crisis and extraordinary situations
- runs the SOS-centers which maintains the SOS-service for the emergency call number 112 in Sweden

The Ambulance Service

- cares for injured people
- makes an assessment and priority of injured people
- provides care for injured in the best possible way
- divides the injured to various hospitals

The Emergency Service

- extinguishes fires
- saves lives and hand over injured people to the Ambulance Service
- leads the work at the incident site in the acute state of the rescue
- coordinates different actions and organizations
- protects people, environment and property
- frees people trapped in vehicles
- provides a prognosis of the expected time of stop to the Traffic Center
- remediates the roadway from loose objects
- prevents accidents

The Police

- investigate if and how a crime has been committed
- close off and evacuate the road if needed
- decide about and order salvation of vehicles
- redirect the traffic
- cooperate with the Traffic Center and the Maintenance Entrepreneurs before deciding rerouting
- decide about rerouting
- identify and register the affected in the accident
- lead any search work

The Salvation Operators

- provides salvation of vehicles
- provides helps when stalling and jour reparations
- provides various custom solutions such as obtaining rental cars

Residual Leader

- takes care of insurance- and ownership interests

- saves environment and property (prioritize actions to save the greatest value possible)
- requisitions resources such as remediation- or salvation vehicles if necessary

Among the Residual Leaders there are also a few specially trained Environmental Residual Leaders whom are called to guide and direct especially large remediation actions.

The Traffic Center

- gathers information about traffic accidents and road conditions
- informs the Police about suitable redirection routes
- communicates acute traffic information to SOS Alarm, the Police, the Emergency Service and municipalities
- communicates acute traffic information about queues, acute obstacles, road conditions and roadwork to private motorists and professional drivers through radio, text-TV, GPS and the internet
- guides and directs traffic on state road network with electronic signs and barriers
- sends VägAssistans to an incident site in Stockholm, Malmö and Gothenburg

The Maintenance Entrepreneurs

- is responsible for winter maintenance (snow plowing and deicing)
- maintain and repairs gravel roads, paved roads and bridges
- cuts and removes the vegetation on the road verges
- maintain and repairs the road signs and the guardrails

At traffic accidents the Maintenance Entrepreneurs can assist with both remediation and protection of the site. At longer stops the Entrepreneurs recommends redirection routes and is responsible for putting up signs for the new route.

Appendix B – GIS

Firstly the events in the Western Region were sorted out from the excel file Totalstopp Baslista 2009-2013. The coordinates in the excel file were mixed up so the x-coordinate was written in the y-coordinate column and vice versa (Gustafsson, 2013). There were also too many numbers in the columns to be able to use the coordinates in ArcGIS. Before the coordinates could be used in ArcGIS the new coordinates with two decimals were created. The following formulas were used in excel:

=VÄNSTER(Q1;6)&”,”&HÖGER(Q1;2) for the x-coordinates using the coordinates in the y-column

=VÄSNTER(P1;7)&”,”&HÖGER(P1;2) for the y-coordinates using the coordinates in the x-column

When the coordinates were adjusted a layer with the events could be created using SWEREF 99 TM as coordinate system. A Swedish map, *SverigekartaBakgrund*, was added as background and a layer displaying the road network, *Vägnummer*, was also added. To distinguish the 2+1 road a shape file named *VagInfo* was added and the *2+1 väg* layer was marked. All of these files are found in the folder *GIS_for_alla*, a folder in the Swedish Transport Administrations internal database with GIS files.

Appendix C – Investigated areas

Below, pictures from ArcGIS for the three investigated areas are shown, see Figure 24 to Figure 26. The blue lines are 2+1 roads, the red dots are incidents with disruption in traffic and the pink areas illustrate the density of the disruptions.

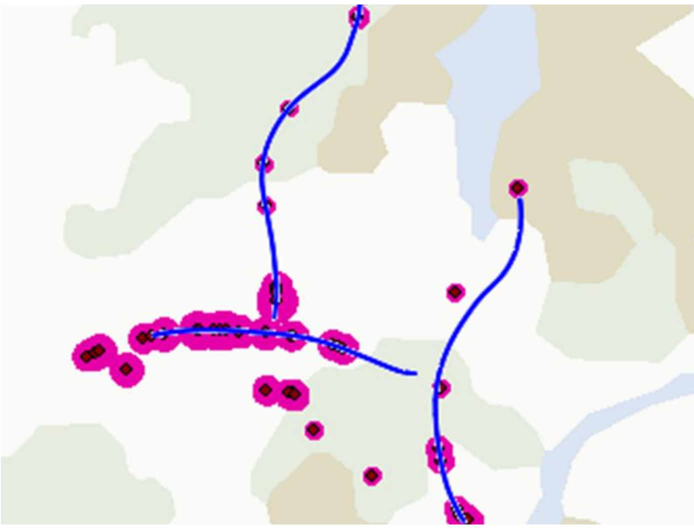

Figure 24 – Road E45.

Figure 25 – Road 40.

Figure 26 – Road E20.

Appendix D – Interview questions

Do we have your permission to refer to this interview in our report?

1. Can you describe your work?
2. What happens when you are alerted about an accident?
   - How does the alarm reach you?
   - Which operators do you cooperate with?
3. What is your view of the total work at an incident site?
   - Which operator is responsible for what?
   - What operator is normally first on site?
4. Which operator do you consider responsible for the decision of rerouting?
   - Which operator do you consider responsible for directing the traffic?
   - Do they cooperate with someone else?
   - Which operator is responsible for mounting signs for redirection?
5. Have you heard about the manual ”*Vägen Fri- snabbt och säkert”*?
   - Do you work according to the practices described in the manual?
6. What is your experience of 2+1-roads?
   - How do you experience the safety for the road users on this road type?
   - How do you experience the accessibility on this road type at an incident?
   - How do you experience your safety while working on the road type at an incident?
7. General questions about the specific area.
   - How long time do you estimate that is takes until you are at the site after receiving an alarm?
   - How long time do you estimate that is takes until the traffic is redirected after the incident?

Appendix E – Comparison of measured AADT and AADT from Vägtrafikflödeskartan

To examine the accuracy of the data collected during this study a comparison between the collected AADT and the AADT from the database Vägtrafikflödeskartan is performed. Since the traffic flows vary over the year and over the hours of the day, the collected data must be transformed to values that can be compared to high traffic; AADT*0.13. Indexes for the variation are found in *Vägars och gators utformning – Dimensioneringsgrunder* (2004) and can be seen in the table below, Table 11.

Table 11 – Indexes for variation in AADT over the year and the day (Vägverket, 2004).

Month	Index for governmental roads	Hour	Index for governmental roads	Hour	Index for governmental roads
1	74	1	16	13	139
2	77	2	10	14	144
3	89	3	7	15	153
4	96	4	7	16	174
5	110	5	15	17	230
6	118	6	34	18	188
7	137	7	120	19	154
8	123	8	137	20	110
9	103	9	129	21	88
10	100	10	120	22	76
11	91	11	127	23	57
12	82	12	133	24	32
∑	1200			∑	2400

The simulations are performed for high traffic in the morning which is between 7 a.m. and 9 a.m. For high traffic the flow is AADT*0.13 according to Cederlöf (2013). The collected data will be transformed to the 8th hour which is between 07.00 and 08.00 and to an average month.

To transform the collected data to hour 8 the following calculations are performed:

$$Q_{hour\ 8} = \frac{Q_{collected}}{\frac{I_{hour}}{2400}} \cdot \frac{I_8}{2400}$$

Where,

$Q_{collected} = Counted\ flow$

$I_{hour} = Index\ for\ hour\ when\ the\ data\ was\ collected$

To transform the traffic flow to a normal month the following calculations are performed:

$$Q = \frac{Q_{hour\ 8}}{\frac{I_{month}}{1200}} \cdot \frac{100}{1200}$$

Where,

$I_{month} = Index\ for\ month\ when\ the\ data\ was\ collected$

Below a comparison between the traffic flow collected during the ocular inspections and the Average Annual Daily Traffic (AADT) for high traffic measured by the Swedish Transport Administration is performed. The AADT for each stretch is in one direction. For the smaller roads where only data in both directions are available it is assumed that AADT in one direction is AADT divided by two. The difference between them is presented as well as the part of AADT which the collected values represent.

Road E45

The data from road E45 was collected April 14, 2014 so the index for month is 96. The result from the comparison is presented in the table below, Table 12.

Table 12 - Comparison of measured AADT and AADT from Vägtrafikflödeskartan for road E45.

Road	$Q_{collected}$	AADT*0.13	Difference	$Q_{collected}$/AADT*0,13
A	294	629	335	0,47
	240	378	138	0,63
	143	633	490	0,23
B	313	629	316	0,50
	216	378	162	0,57
	180	378	198	0,48
C	716	1169	453	0,61
	798	985	187	0,81
D	768	1153	385	0,67
	646	1128	482	0,57
E	59	156	97	0,38
	97	156	59	0,62
F	44	156	112	0,28
	74	156	82	0,47
G	105	150	45	0,70
	48	150	102	0,32
H	40	150	110	0,27
	62	150	88	0,41
I	24	41	17	0,59
	25	41	16	0,61
J	49	69	20	0,71
K	22	45	23	0,49
	36	45	9	0,80
L	106	45	-61	2,36
	101	45	-56	2,24
M	88	137	49	0,64
	72	137	65	0,53

For area E45 all collected values but two are lower than AADT from the Swedish Transport Administration. For road E45 in direction A the measurements vary between 23 and 63 percent of AADT and in direction B it is around half of the AADT. Road 44 (C and D) have measured values between 57 and 81 percent of AADT. The two values with higher measured values compared to AADT is both on road L, and the measured values are more than twice the AADT. According to NVDB the AADT*0,13 is 45, but it is possible that the AADT on road M applies on road L instead. As mentioned previously in the report, road M is a municipal road and the AADT is received from the municipality instead of NVDB. If that is the case the measured values represents 74 to 77 percent of AADT instead which correlates better with the result from the other roads.

Road 40

The data from road 40 was collected February 25, 2014 so the index for month is 77. The result from the comparison is presented in the table below, Table 13.

Table 13 - Comparison of measured AADT and AADT from Vägtrafikflödeskartan for road 40.

Road	$Q_{collected}$	AADT*0.13	Difference	$Q_{collected}$/AADT*0,13
A	267	592	325	0,45
	316	592	276	0,53
	281	592	311	0,47
B	381	530	149	0,72
	330	530	200	0,62
	265	530	265	0,50
C	7	13	6	0,54
D	3	16	13	0,19
	15	16	1	0,94
E	16	12	-4	1,33
F	8	8	0	1,00
	8	8	0	1,00
G	22	19	-2	1,16
	3	19	16	0,16
H	8	16	8	0,50
	16	16	0	1,00
I	2	2	0	1,00

Generally the traffic flow collected during the ocular inspection is lower or equal to the AADT. For road G one measurement is only 16 percent of AADT. For the main road (A and B) the collected flow is around half of AADT. There are two measurements, road E and one on road G where AADT is lower than the collected value.

Road E20a

The data from road E20a was collected April 7, 2014 so the index for month is 96. The result from the comparison is presented in the table below, Table 14.

Table 14 - Comparison of measured AADT and AADT from Vägtrafikflödeskartan for road E20a.

Road	$Q_{collected}$	AADT*0.13	Difference	$Q_{collected}$/AADT*0,13
A	210	442	232	0,48
	217	442	225	0,49
	240	442	202	0,54
B	167	447	280	0,37
	165	447	282	0,37
	166	450	284	0,37
C	14	20	6	0,70
	15	20	5	0,75
D	4	8	4	0,50
	0	8	8	0,00
E	4	10	6	0,40
	2	10	8	0,20
F	4	10	6	0,40
G	6	5	-1	1,20
H	10	6	-4	1,67
I	2	10	8	0,20

Also for road E20a the collected data generally is smaller compared to AADT. For the main road in direction A the collected data is around half of AADT and for direction B the collected data is 37 percent of AADT. The worst case is E where the measured value is only 20 percent of AADT and H where the measured value is 67 percent larger than AADT.

Road E20b

The data from road E20b was collected March 5, 2014 so the index for month is 89. The result from the comparison is presented in the table below, Table 15.

Table 15 - Comparison of measured AADT and AADT from Vägtrafikflödeskartan for road E20b.

Road	$Q_{collected}$	AADT*0.13	Difference	$Q_{collected}$/AADT*0,13
A	266	727	461	0,37
	174	467	293	0,37
	180	423	243	0,43
	159	441	282	0,36
B	204	467	263	0,44
	177	439	262	0,40
	233	447	214	0,52
	211	523	312	0,40
C	122	225	103	0,54
	125	225	100	0,56
	137	295	158	0,46
	139	295	156	0,47
	119	210	91	0,57
	79	210	131	0,38
	76	248	172	0,31
	133	248	115	0,54
D	35	67	32	0,52
	38	79	41	0,48
E	28	57	29	0,49
	22	51	29	0,43
F	36	32	-4	1,13
	19	32	13	0,59
	17	32	15	0,53
G	8	26	18	0,31
	24	10	-14	2,40
H	8	39	31	0,21
I	61	101	40	0,60
J	34	31	-3	1,10
	7	31	24	0,23
K	29	67	38	0,43
L	83	80	-3	1,04
M	76	125	49	0,61
N	14	59	45	0,24
O	84	202	118	0,42
P	9	27	18	0,33
Q	19	50	31	0,38
R	17	58	41	0,29
S	34	32	-2	1,06

Also in area E20b, the collected traffic flow is generally lower than AADT. For the main road in both direction A and B the collected flow is around 40 to 50 percent of AADT. The lowest collected value compared to AADT is around 20 to 30 percent of AADT on road J, N, R, G and C and the highest is 140 percent higher than AADT on road G.

Appendix F – Input data road E45

Below, the input data used in the simulations of road E45 is presented. In Figure 27 the hourly traffic on each road can be seen.

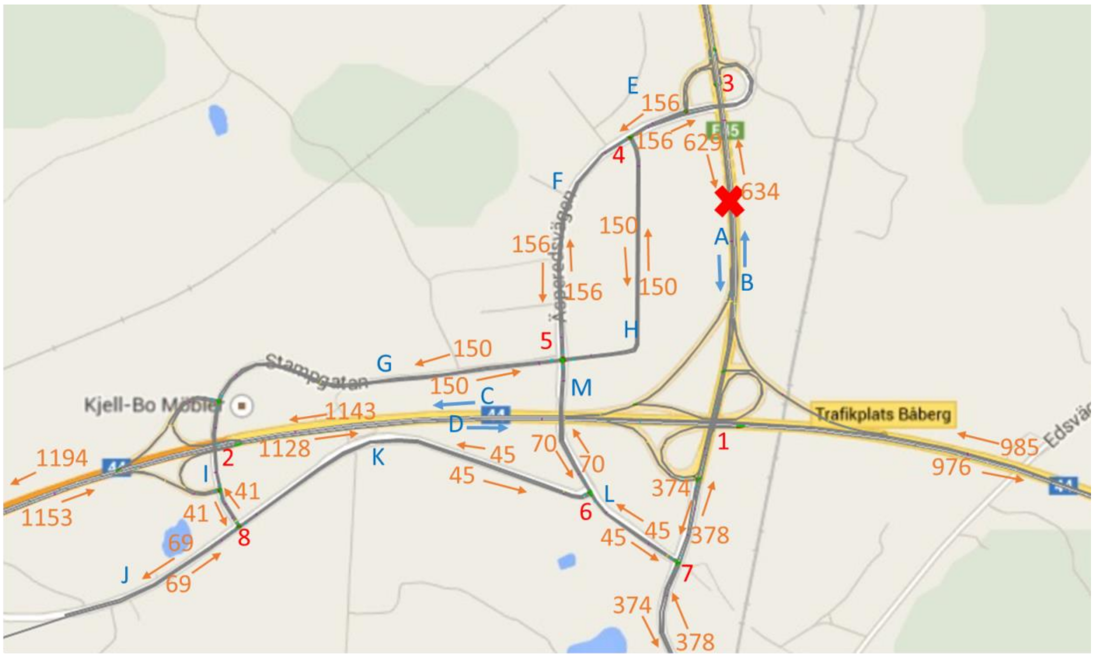

Figure 27 – The traffic flows used as input data in the model for road E45.

In the tables below, Table 16 to Table 23, the turning quotas for each intersection is presented. The "total arriving from" is the number of vehicles arriving to the intersection from each road.

Table 16 - Turning quotas for intersection 1; road A, B, C and D.

Intersection 1	A		B		C		D	
Total arriving from	629	100 %	378	100 %	985	100 %	1128	100 %
Turning right	193	31 %	18	5 %	215	22 %	187	17 %
Turning left	262	42 %	193	51 %	13	1 %	245	22 %
Going straight ahead	174	28 %	167	44 %	757	77 %	696	62 %

Table 17 – Turning quotas for intersection 2; road C, D, G and I.

Intersection 2	C		D		G		I	
Total arriving from	1169	100 %	1153	100 %	150	100 %	41	100 %
Turning right	71	6 %	9	1 %	99	66 %	24	59 %
Turning left	11	1 %	70	6 %	30	20 %	8	20 %
Going straight ahead	1087	93 %	1074	93 %	21	14 %	9	22 %

Table 18 - Turning quotas for intersection 3; road A, B and E.

Intersection 3	A		B		E	
Total arriving from	633	100 %	634	100 %	374	100 %
Turning right	55	9 %	-	-	31	8 %
Turning left	-	-	101	4 %	-	-
Going straight ahead	578	91 %	533	96 %	343	92 %

Table 19 - Turning quotas for intersection 4; road E, F and H.

Intersection 4	E		F		H	
Total arriving from	156	100 %	156	100 %	150	100 %
Turning right	-	-	109	70 %	109	73 %
Turning left	41	26 %	-	-	41	27 %
Going straight ahead	115	74 %	47	30 %	-	-

Table 20 - Turning quotas for intersection 5; road F, G, H and M.

Intersection 5	F		G		H		M	
Total arriving from	156	100 %	150	100 %	150	100 %	70	100 %
Turning right	104	67 %	59	39 %	25	17 %	32	46 %
Turning left	17	11 %	44	29 %	85	57 %	24	34 %
Going straight ahead	35	22 %	47	31 %	40	27 %	14	20 %

Table 21 - Turning quotas for intersection 6; road K, L and M.

Intersection 6	K		L		M	
Total arriving from	45	100 %	45	100 %	70	100 %
Turning right	11	24 %	-	-	36	51 %
Turning left	34	76 %	9	20 %	-	-
Going straight ahead	-	-	36	80 %	34	49 %

Table 22 - Turning quotas for intersection 7; road A, B and L.

Intersection 7	A		B		L	
Total arriving from	374	100 %	378	100 %	45	100 %
Turning right	31	8 %	-	-	31	69 %
Turning left	-	-	14	4 %	14	31 %
Going straight ahead	343	92 %	364	96 %	-	-

Table 23 - Turning quotas for intersection 8; road I, J and K.

Intersection 8	I		J		K	
Total arriving from	41	100 %	69	100 %	45	100 %
Turning right	34	83 %	-	-	10	22 %
Turning left	7	17 %	31	45 %	-	-
Going straight ahead	-	-	38	55 %	35	78 %

The speed the vehicles actually are driving is presented in the table below, Table 24. Only the main road and the rerouting roads are included in this comparison. The comparison is performed to control that the speed limits and speed distributions used in the simulation models are a good representation of the reality.

Table 24 – Speed limit and average speed on road A, B, C and D.

[km/h]	A	B	C	D
Speed limit	100	100	100	100
Passenger cars	82	90	89	98
Passenger cars with trailer	76	80	81	86
Heavy goods vehicles	80	85	86	91
Heavy goods vehicles with trailer	75	75	77	84

Appendix G – Input data road 40

Below, the input data used in the simulations of road 40 is presented. In Figure 28 the hourly traffic on each road can be seen.

Figure 28 – The traffic flows used as input data in the model for road 40.

In the tables below, Table 25 to Table 28, the turning quotas for each intersection is presented. The "total arriving from" is the number of vehicles arriving to the intersection from each road.

Table 25 - Turning quotas for intersection 1; road A, B, H and J.

Intersection 1	A		B		H		I	
Total arriving from	592	100 %	533	100 %	16	100 %	3	100 %
Turning right	7	1 %	5	1 %	4	25 %	1	33 %
Turning left	5	1 %	6	1 %	11	69 %	1	33 %
Going straight ahead	580	98 %	522	98 %	1	6 %	1	33 %

Table 26 - Turning quotas for intersection 2 road A, B, C and D.

Intersection 2	A		B		C		D	
Total arriving from	592	100 %	530	100 %	16	100 %	13	100 %
Turning right	16	3 %	3	1 %	9	56 %	3	23 %
Turning left	6	1 %	4	1 %	6	38 %	1	8 %
Going straight ahead	570	96 %	523	99 %	1	6 %	9	69 %

Table 27 - Turning quotas for intersection 3; road D, E and F.

Intersection 3	D		E		F	
Total arriving from	18	100 %	12	100 %	8	100 %
Turning right	11	61 %	-	-	6	75 %
Turning left	7	39 %	10	83 %	-	-
Going straight ahead	-	-	2	17 %	2	25 %

Table 28 - Turning quotas for intersection 4; road F, G and H.

Intersection 4	F		G		H	
Total arriving from	9	100 %	19	100 %	11	100 %
Turning right	8	89 %	-	-	4	36 %
Turning left	1	11 %	4	21 %	-	-
Going straight ahead	-	-	15	64 %	7	64 %

The speed the vehicles actually are driving is presented in the table below, Table 29. Only the main road and the rerouting roads are included in this comparison. The comparison is performed to control that the speed limits and speed distributions used in the simulation models are a good representation of the reality.

Table 29 – Speed limit and average speed for road A, B, D, F and H.

[km/h]	A	B	D	F	H
Speed limit	100	100	50	70	70
Passenger cars	104	105	50	73	82
Passenger cars with trailer	88	88	51	69	72
Heavy goods vehicles	94	95	47	74	78
Heavy goods vehicles with trailer	80	83	43	66	74

Appendix H – Input data road E20a

Below, the input data used in the simulations of road E20a is presented. In Figure 29 the hourly traffic on each road can be seen.

Figure 29 – Traffic flows used as input data in the model for road E20a.

In the tables below, Table 30 to Table 34, the turning quotas for each intersection is presented.

Table 30 - Turning quotas for intersection 1; road A, B and C.

Intersection 1	A		B		C	
Total arriving from	442	100 %	447	100 %	12	100 %
Turning right	5	1 %	-	-	4	42 %
Turning left	-	-	15	3 %	7	58 %
Going straight ahead	437	99 %	432	97 %	-	-

Table 31 - Turning quotas for intersection 2; road A, B and I.

Intersection 2	A		B		I	
Total arriving from	442	100 %	447	100 %	10	100 %
Turning right	-	-	6	1 %	6	60 %
Turning left	4	1 %	-	-	4	40 %
Going straight ahead	438	99 %	441	99 %	-	

Table 32 - Turning quotas for intersection 3; road A, B, E and F.

Intersection 3	A		B		E		F	
Total arriving from	442	100 %	450	100 %	11	100 %	10	100 %
Turning right	4	1 %	3	1 %	7	64 %	1	10 %
Turning left	8	2 %	2	0 %	3	27 %	5	50 %
Going straight ahead	438	97 %	445	99 %	1	9 %	4	40 %

Table 33 - Turning quotas for intersection 4; road D, E and G.

Intersection 4	D		E		G	
Total arriving from	10	100 %	10	100 %	5	100 %
Turning right	1	10 %	-	-	2	40 %
Turning left	-	-	5	50 %	3	60 %
Going straight ahead	9	90 %	5	50 %	-	-

Table 34 - Turning quotas for intersection 5; road C, D and H.

Intersection 5	C		D		H	
Total arriving from	20	100 %	8	100 %	6	100 %
Turning right	11	55 %	-	-	1	17 %
Turning left	-	-	1	13 %	5	83 %
Going straight ahead	9	45 %	7	88 %	-	-

Below the speed limit on each stretch is presented, see Table 35. Since the actual speed of the vehicles are much below the allowed speed limit on stretch C and D the desired speed decision on these stretches is set to 60 km/h in the simulation model.

Table 35 – Speed limit and average speed for road A, B, C, D and E.

[km/h]	A	B	C	D	E
Speed limit	100	100	70	70	70
Passenger cars	105	93	62	65	77
Passenger cars with trailer	90	83	54	59	53
Heavy goods vehicles	95	90	62	68	76
Heavy goods vehicles with trailer	84	81	56	66	71

Appendix I – Input data road E20b

Below, the input data used in the simulations of road E20b is presented. In Figure 30 the hourly traffic on each road can be seen.

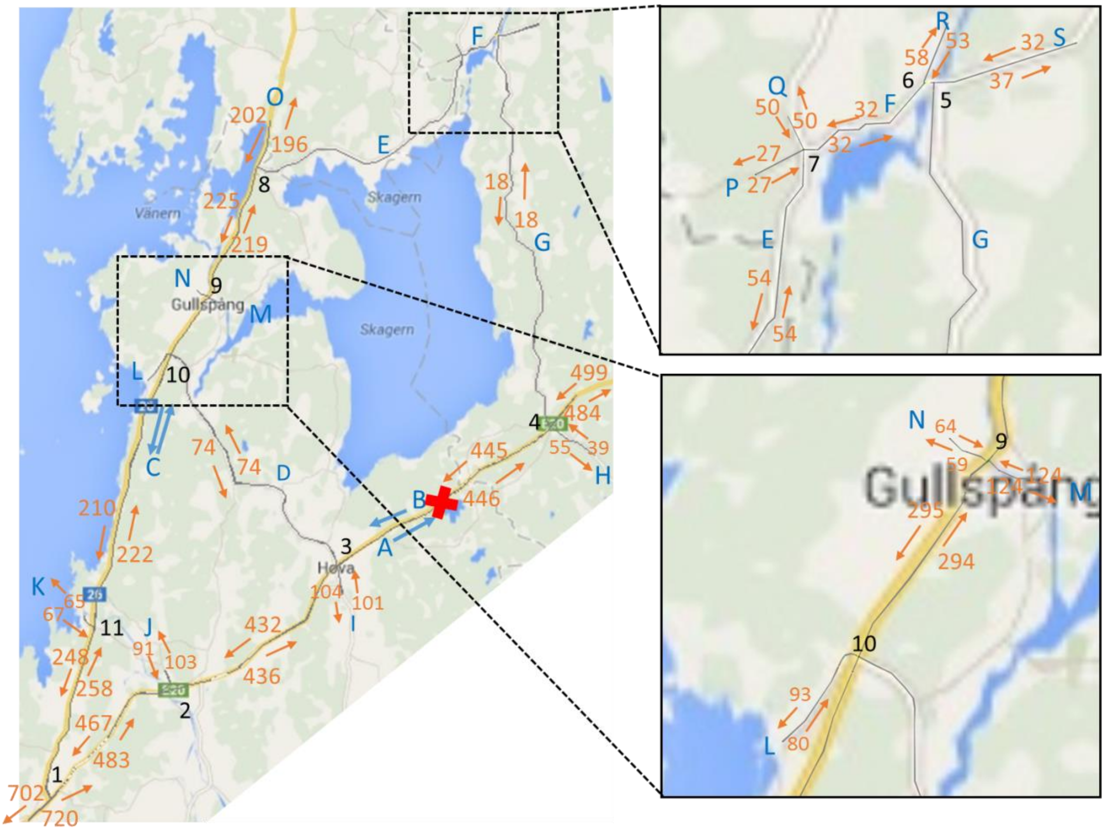

Figure 30 – Traffic flows used as input data in the model for E20b.

In the tables below, Table 36 to Table 46, the turning quotas for each intersection is presented.

Table 36 - Turning quotas for intersection 1; road A, B and C.

Intersection 1	A		B		C	
Total arriving from	728	100 %	467	100 %	248	100 %
Turning right	-	-	10	2 %	245	99 %
Turning left	248	34 %	-	-	3	1 %
Going straight ahead	480	66 %	457	98 %	-	

Table 37 - Turning quotas for intersection 2; road A, B and J.

Intersection 2	A		B		J	
Total arriving from	483	100 %	432	100 %	91	100 %
Turning right	-	-	38	9 %	73	80 %
Turning left	65	13 %	-	-	18	20 %
Going straight ahead	418	87 %	394	91 %	-	

Table 38 - Turning quotas for intersection 3; road A, B, D and I.

Intersection 3	A		B		D		I	
Total arriving from	436	100 %	445	100 %	74	100 %	101	100 %
Turning right	10	2 %	15	3 %	30	41 %	7	7 %
Turning left	10	2 %	73	16 %	23	31 %	45	45 %
Going straight ahead	416	95 %	357	80 %	21	28 %	49	49 %

Table 39 - Turning quotas for intersection 4; road A, B, G and H.

Intersection 4	A		B		G		H	
Total arriving from	446	100 %	499	100 %	18	100 %	39	100 %
Turning right	10	2 %	16	3 %	1	6 %	36	92 %
Turning left	1	0 %	41	18 %	13	72 %	2	5 %
Going straight ahead	435	98 %	442	89 %	4	22 %	1	3 %

Table 40 - Turning quotas for intersection 5; road F, G and S.

Intersection 5	F		G		S	
Total arriving from	37	100 %	18	100 %	32	100 %
Turning right	15	41 %	15	83 %	-	-
Turning left	-	-	3	17 %	3	9 %
Going straight ahead	22	59 %	-	-	29	91 %

Table 41 - Turning quotas for intersection 6; road F_E, F_W and R.

Intersection 6	F_E		F_W		R	
Total arriving from	32	100 %	32	100 %	58	100 %
Turning right	8	25 %	29	91 %	-	-
Turning left	-	-	3	9 %	29	50 %
Going straight ahead	24	75 %	-	-	29	50 %

Table 42 - Turning quotas for intersection 7; road E, F, P and Q.

Intersection 7	E		F		P		Q	
Total arriving from	54	100 %	32	100 %	27	100 %	50	100 %
Turning right	24	44 %	8	25 %	5	19 %	1	2 %
Turning left	3	6 %	1	3 %	15	56 %	1	2 %
Going straight ahead	27	50 %	23	72 %	7	26 %	48	96 %

Table 43 - Turning quotas for intersection 8; road C, E and O.

Intersection 8	C		E		O	
Total arriving from	219	100 %	54	100 %	202	100 %
Turning right	45	21 %	22	41 %	-	-
Turning left	-	-	32	59 %	9	4 %
Going straight ahead	174	79 %	-	-	193	96 %

Table 44 - Turning quotas for intersection 9; road C_N, C_S, M and N.

Intersection 9	C_N		C_S		M		N	
Total arriving from	294	100 %	225	100 %	124	100 %	59	100 %
Turning right	71	24 %	7	3 %	15	12 %	43	73 %
Turning left	20	7 %	38	17 %	72	58 %	1	2 %
Going straight ahead	203	69 %	180	80 %	37	30 %	15	25 %

Table 45 - Turning quotas for intersection 10; road C_N, C_S, D and L.

Intersection 10	C_N		C_S		D		L	
Total arriving from	222	100 %	295	100 %	74	100 %	80	100 %
Turning right	27	12 %	74	25 %	63	85 %	4	5 %
Turning left	13	6 %	20	7 %	5	7 %	49	61 %
Going straight ahead	182	82 %	201	68 %	6	8 %	27	34 %

Table 46 - Turning quotas for intersection 11; road C_N, C_S and K.

Intersection 11	C_N		C_S		K	
Total arriving from	258	100 %	210	100 %	67	100 %
Turning right	-	-	9	4 %	47	70 %
Turning left	56	22 %	-	-	20	30 %
Going straight ahead	202	78 %	201	96 %	-	-

In the following table, Table 47, the average speeds for stretch A and B are presented. Both stretches are divided into five parts in the database Vägtrafikfördeskartan. A1 and B1 is from stretch C to J, A2 and B2 is from stretch J to Hova, A3 and B3 is just north of Hova, A4 and B4 is from Hova to just north of the accident and A5 and B5 is the last stretch to stretch G. Some stretches have varying speed limit. In those cases the dominant speed limit is given in the table below but in the model all changes in speed limit are included.

Table 47 – Speed limit and average speed for road A and B.

[km/h]	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Speed limit	100	100	60	100	100	100	100	60	100	100
Passenger cars	100	102	79	102	97	97	102	79	98	98
Passenger cars with trailer	85	86	75	87	88	84	90	75	88	84
Heavy goods vehicles	95	93	76	93	94	87	95	76	91	91
Heavy goods vehicles with trailer	83	83	74	83	86	80	84	74	83	77

In the following table, Table 48, the average speeds for stretch C are presented. Stretch C is divided into five parts in the database Vägtrafikfördeskartan. C1 is the stretch from stretch O to Gullspång, C2 is the stretch just over Gullspång, C3 is from Gullspång to stretch D and L, C4 is from stretch D and L to K and C5 is from stretch K to road E20.

Table 48 – Speed limit and average speed for road C.

[km/h]	C1	C2	C3	C4	C5
Speed limit	90	90	70	90	90
Passenger cars	95	86	81	91	92
Passenger cars with trailer	88	80	79	84	86
Heavy goods vehicles	91	84	79	89	88
Heavy goods vehicles with trailer	84	81	80	83	83

In the following table, Table 49, the average speeds for stretch D, E, F and G are presented. Stretch E is divided into two parts in the database Vägtrafikfördeskartan. E1 in the table represents the western part of the stretch and E2 the eastern part.

Table 49 – Speed limit and average speed for road D, E, F and G.

[km/h]	D	E1	E2	F	G
Speed limit	80	70	70	70	70
Passenger cars	83	82	82	75	66
Passenger cars with trailer	79	73	76	67	64
Heavy goods vehicles	84	82	80	76	72
Heavy goods vehicles with trailer	78	77	77	66	67

Appendix J – Results from the simulations

Table 50 – Results from the simulation for road E45.

Road E45		Average travel time [s]	Total delay [s]	Total delay [h]
Basic model	1	6 037 296,3		
	2	7 414 275,1		
	4	10 790 512,6		
	8	16 454 650,8		
A	1	7 979 570,8	1 942 274,5	540
	2	14 476 723,4	7 062 448,3	1962
	4	32 516 942,0	21 726 429,4	6035
	8	82 311 630,7	65 856 979,9	18294
B	1	6 711 762,1	674 465,8	187
	2	9 789 119,4	2 374 844,3	660
	4	13 510 758,8	2 720 246,2	756
	8	19 832 239,6	3 377 588,8	938
C	1	6 659 665,5	622 369,2	173
	2	9 738 438,5	2 324 163,4	646
	4	13 140 556,7	2 350 044,1	653
	8	18 851 134,6	2 396 483,8	666
D	1	6 542 812,9	505 516,7	140
	2	9 315 052,4	1 900 777,3	528
	4	12 709 111,6	1 918 599,0	533
	8	18 378 652,0	1 924 001,2	534
E	1	9 252 090,5	3 214 794,3	893
	2	27 320 008,0	19 905 732,9	5529
	4	79 528 312,0	68 737 799,4	19094
	8	234 938 950,4	218 484 299,6	60690
F	1	6 337 730,1	300 433,9	83
	2	11 870 881,0	4 456 605,9	1238
	4	16 430 762,3	5 640 249,7	1567
	8	23 895 705,2	7 441 054,4	2067
G	1	7 634 492,5	1 597 196,3	444
	2	14 507 667,2	7 093 392,1	1970
	4	17 830 473,2	7 039 960,6	1956
	8	23 549 637,3	7 094 986,5	1971
H	1	6415391,6	378 095,3	105
	2	10 908 114,4	3 493 839,3	971
	4	14 292 676,6	3 502 164,0	973
	8	19 948 190,4	3 493 539,6	970
I	1	6 605 467,2	568 170,9	158
	2	11 962 539,8	4 548 264,7	1263
	4	15 399 560,2	4 609 047,6	1280
	8	21 163 164,0	4 708 513,2	1308

Table 51 - Results from the simulation for road 40.

Road 40		Average travel time [s]	Total delay [s]	[h]
Basic model	1	2 698 140,7		
	2	3 381 490,7		
	4	4 909 074,5		
	8	7 500 152,4		
A	1	3 915 668,5	1 217 527,7	338
	2	8 406 480,4	5 024 989,7	1396
	4	20 923 637,1	16 014 562,6	4448
	8	56 689 895,1	49 189 742,7	13664
B	1	3 525 281,4	827 140,7	230
	2	6 199 992,5	2 818 501,8	783
	4	10 858 247,4	5 949 172,9	1653
	8	19 787 367,6	16 405 876,9	4557
C	1	3 092 685,3	394 544,6	110
	2	4 793 002,7	1 411 512,0	392
	4	6 392 274,7	1 483 200,1	412
	8	9 088 398,4	1 588 246,0	441
D	1	3 005 177,7	307 036,9	85
	2	4 616 150,8	1 234 660,1	343
	4	6 148 170,1	1 239 095,6	344
	8	8 746 726,4	1 246 574,0	346
E	1	4 300 644,7	1 602 503,9	445
	2	9 264 276,4	5 882 785,7	1634
	4	23 233 266,0	18 324 191,5	5090
	8	61 960 518,4	54 460 366,0	15128
F	1	3 350 712,1	652 571,4	181
	2	5 675 877,0	2 294 386,3	637
	4	8 320 955,6	3 411 881,0	948
	8	12 821 360,3	5 321 207,9	1478
G	1	3 297 868,1	599 727,4	167
	2	5 650 042,1	2 268 551,4	630
	4	7 240 686,1	2 331 611,6	648
	8	9 940 169,3	2 440 016,9	678
H	1	3 099 112,0	400 971,3	111
	2	4 980 797,2	1 599 306,5	444
	4	6 512 406,5	1 603 332,0	445
	8	9 109 576,0	1 609 423,6	447
I	1	3 325 006,6	626 865,9	174
	2	5 827 226,1	2 445 735,4	679
	4	7 453 319,9	2 544 245,4	707
	8	10 149 076,6	2 648 924,2	736

Table 52 - Results from the simulation for road E20a.

Road E20a		Average travel time [s]	Total delay [s]	Total delay [h]
Basic model	1	965 290,5		
	2	1 165 978,0		
	4	1 727 733,0		
	8	2 644 042,5		
A	1	2 030 507,7	1 065 217,3	296
	2	5 292 356,9	4 126 378,9	1146
	4	14 613 378,2	12 885 645,3	3579
	8	41 467 262,3	38 823 219,8	10784
B	1	1 641 584,8	676 294,3	188
	2	3 094 234,8	1 928 256,9	536
	4	5 136 028,8	3 408 295,9	947
	8	9 017 605,7	6 373 563,1	1770
C	1	1 404 852,3	439 561,9	122
	2	2 681 840,3	1 515 862,4	421
	4	3 333 587,3	1 605 854,3	446
	8	4 508 046,3	1 864 003,8	518
D	1	1 241 934,5	276 644,1	77
	2	2 248 101,8	1 082 123,9	301
	4	2 817 662,5	1 089 929,5	303
	8	3 748 862,9	1 104 820,4	307
E	1	1 937 645,8	972 355,3	270
	2	5 121 845,7	3 955 867,7	1099
	4	14 278 140,6	12 550 407,7	3486
	8	40 711 489,3	38 067 446,8	10574
F	1	2 015 151,1	1 049 860,6	292
	2	3 875 315,8	2 709 337,9	753
	4	7 684 359,8	5 956 626,9	1655
	8	15 171 273,0	12 527 230,5	3480
G	1	1 326 600,4	361 309,9	100
	2	2 414 568,5	1 248 590,5	347
	4	3 053 841,2	1 326 108,2	368
	8	4 140 508,2	1 496 465,7	416
H	1	1213552,6	248 262,2	69
	2	2 165 684,2	999 706,2	278
	4	2 730 249,8	1 002 516,8	278
	8	3 652 307,8	1 008 265,2	280
I	1	1 377 591,1	412 300,6	115
	2	2 690 410,4	1 524 432,5	423
	4	3 283 915,8	1 556 182,8	432
	8	4 262 251,7	1 618 209,1	450

Table 53 - Results from the simulation for road E20b.

Road E20b		Average travel time [s]	Total delay [s]	Total delay [h]
Basic model	1	5 139 421,5		
	2	6 407 989,1		
	4	9 362 462,2		
	8	14 094 148,6		
B	1	6 720 425,4	1 581 003,9	439
	2	10 332 747,0	3 924 757,9	1090
	4	17 546 024,8	8 183 562,6	2273
	8	30 852 299,2	16 758 150,6	4655
C	1	7348060,3	2 208 638,7	614
	2	11 532 985,1	5 124 996,0	1424
	4	16 615 384,1	7 252 921,9	2015
	8	23 613 003,42	9 518 854,8	2644
F	1	8 306 819.9	3 167 398.4	880
	2	11 348 763.4	4 940 774.3	1372
	4	19 077 725.5	9 715 263.3	2699
	8	33 357 080.2	19 262 931.6	5351
G	1	8759558.9	3 620 137.3	1006
	2	13 994 131.3	7 586 142.2	2107
	4	19 169 047.2	9 806 585.0	2724
	8	27114707.1	13 020 558.5	3617

Appendix K – Results from disturbance per vehicle

In Figure 31 the reduced disturbances, compared to the case without rerouting for road E45, can be seen. The reduction is generally larger for stops in the two-lane direction, case F, G, H and I. The reduction also increases with increased stop duration. The time of disturbance can be reduced up to 0.73 minutes per vehicle in Sweden in case H, for an eight hour stop.

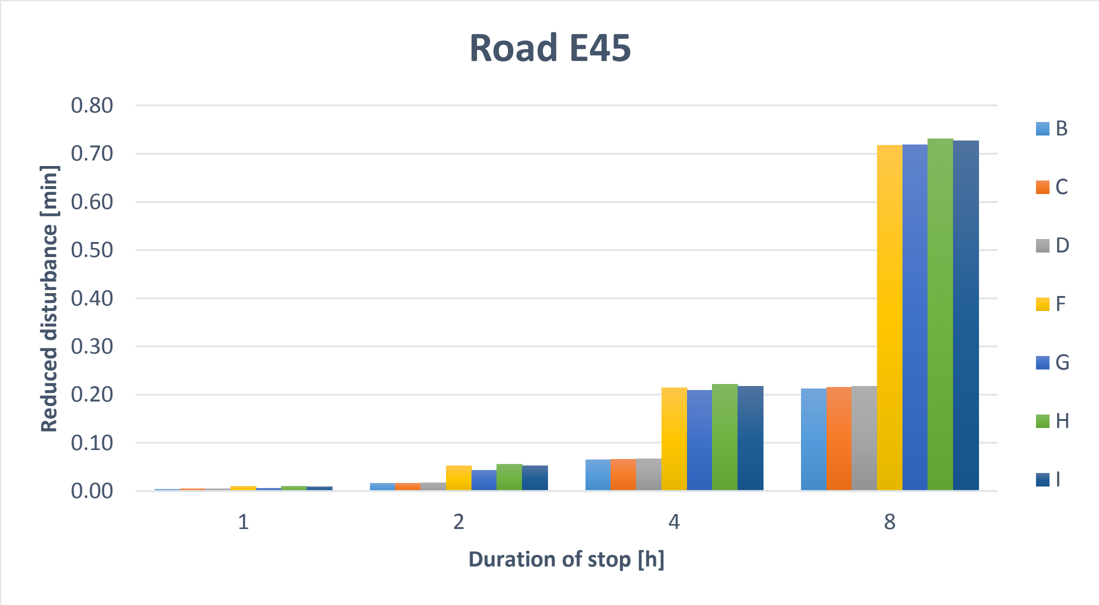

Figure 31 – Reduced disturbance for road E45

In Figure 32 below, the reduced disturbances for road 40 can be seen. The reduction is generally a bit larger with stop in the two-lane direction, case F, G, H and I. The reduction also increases with increased stop duration. The disturbance can be reduced up to 0.18 minutes per vehicle in Sweden in case H, for an eight hour stop.

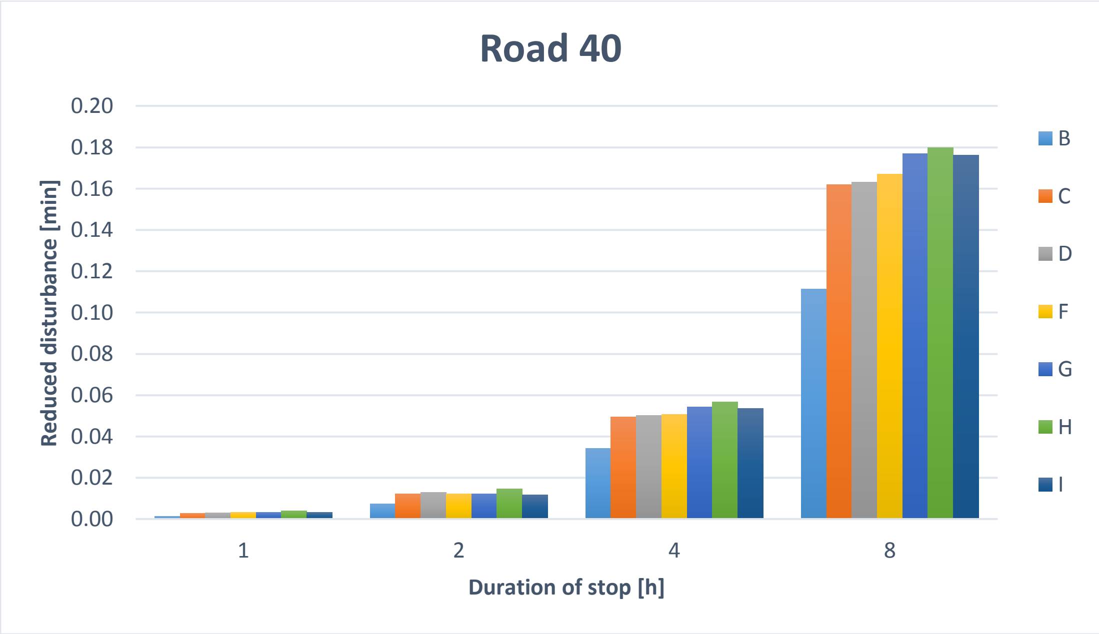

Figure 32 – Reduced disturbance for road 40

In Figure 33 below the reduced disturbances for road E20a can be seen. The reduction increases with increased stop duration. The disturbance can be reduced up to 0.13 minutes per vehicle in Sweden in case D for an eight hour stop.

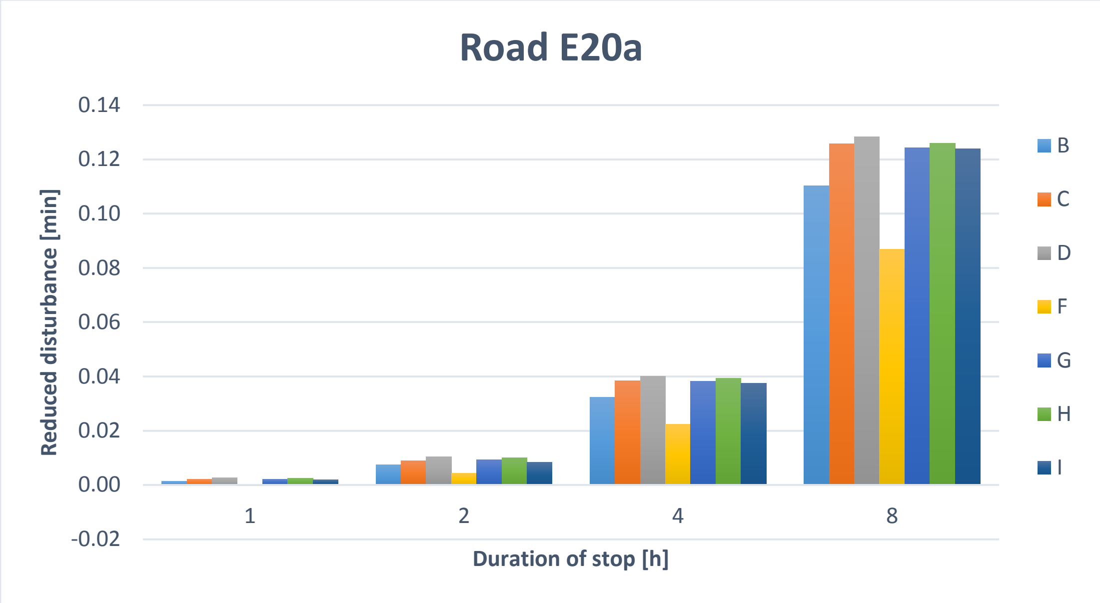

Figure 33 – Reduced disturbance for road E20a

In Figure 34 below the reduced disturbances for road E20b can be seen. The reduction is negative with stop durations of one and two hours. This means that the disturbance increases compared to letting the traffic wait in these scenarios. The reduction increases with increased stop duration. The disturbance can be reduced up to 0.10 minutes per vehicle in Sweden in case C for an eight hour stop.

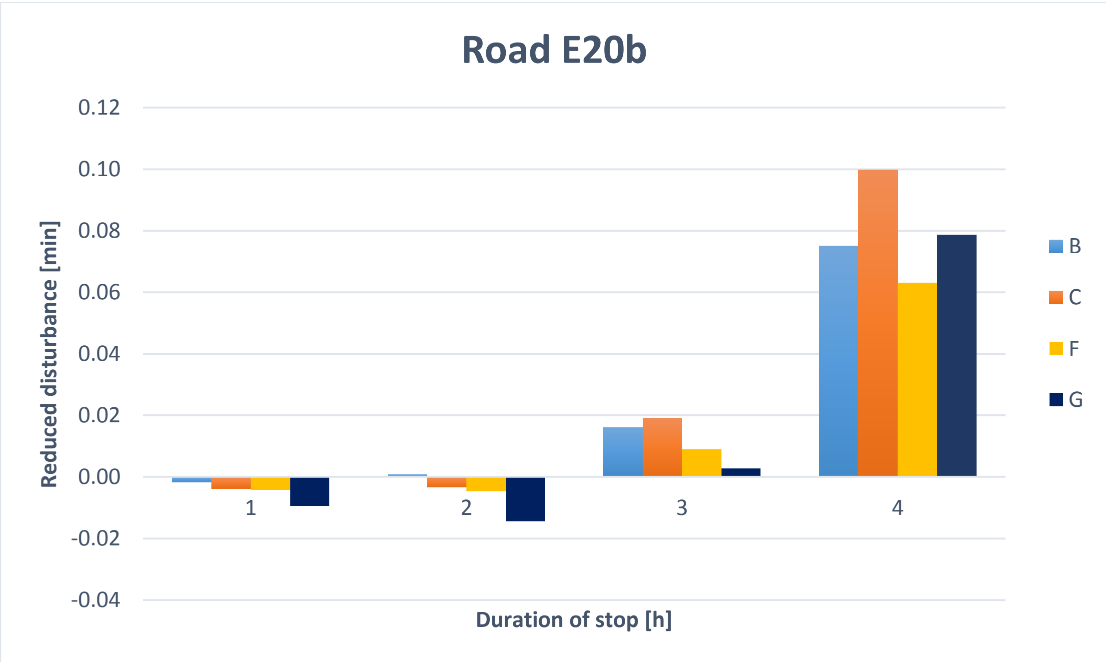

Figure 34 – Reduced disturbance for road E20b