Risk analysis of delay times for goods transport

A study of traffic accidents on the routes Hisingsleden and Lundbyleden in Gothenburg

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

JOHANNA GUSTAVSSON
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Department of Civil and Environmental Engineering
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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

Industrial areas are dependent on goods transports which rely on predictability considering travel time. An industrial area, situated on the South-West part of Hisingen in the city of Gothenburg, will be investigated in this study. There are two different main routes by road to the industrial area, Hisingsleden and Lundbyleden, if travelling into the city from the north. At present, the Swedish Transport Administration desires to reroute traffic from Lundbyleden to Hisingsleden. Additionally, the city of Gothenburg has plans to improve the infrastructure with a project called the West Swedish Package which may affect the traffic system. In this master's thesis Hisingsleden and Lundbyleden are compared in regard to risk of delay for goods transports when considering traffic accidents. Three different scenarios have been created, a scenario of the present, a scenario where the traffic are rerouted from Lundbyleden to Hisingsleden and a scenario with the rerouting of traffic and the construction of the infrastructural improvements. To assess the risk of delay a risk model was created and a risk analysis was performed. There was also a desire to investigate uncertain parameters in the risk model, therefore an uncertainty analysis was performed. The conclusion of the study was that the risk of delay was less on Hisingsleden during the rush hour and day for all scenarios. For the present situation during night both Lundbyleden and Hisingsleden were chosen in regard to lowest type of risk. When rerouting traffic, either with or without the infrastructural improvement, no route could be recommended at night. There are uncertainties in regard to the risk model which connects with the input data. Future improvements of the risk model could be to collect more precise input data to procure a more accurate risk model. The risk model should be possible to apply to similar studies. However, in the future the risk model should focus more on traveling on different time periods rather than choosing between different routes.

Key words: Risk analysis, goods transports, uncertainty analysis, traffic accidents, Hisingsleden, Lundbyleden, traffic rerouting, delay time

Riskanalys med avseende på förseningstid för godstransporter
En studie av trafikolyckor på stråken Hisingsleden och Lundbyleden i Göteborg

Examensarbete inom Infrastructure and Environmental Engineering

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SAMMANFATTNING

Industriområden är beroende av godstransporter vilka i sin tur förlitar sig på pålitlighet med avseende på restid. Det ligger ett industriområde på den sydvästra delen av Hisingen i Göteborg som kommer att studeras i den här studien. För att nå industriområdet norrifrån kan två olika huvudvägstråk väljas, Hisingsleden eller Lundbyleden. Trafikverket vill i dagsläget leda om trafik från Lundbyleden till Hisingsleden. Göteborgs stad har dessutom planer på att förbättra infrastrukturen i staden genom att implementera projektet Västsvenska paketet vilket troligtvis kommer att påverka trafiksystemet. I det här examenarbetet har risken för försening för godstransporter jämförts mellan Hisingsleden och Lundbyleden med hänsyn till trafikolyckor. Tre olika scenarier har skapats: ett scenario för den nuvarande situation, ett scenario där trafikomledning sker från Lundbyleden till Hisingsleden och ett scenario med trafikomledning samt påverkan från förbättringarna av infrastrukturen. Risken för försening togs fram genom att skapa en riskmodell för att utföra en riskanalys. Det var även önskvärt att undersöka osäkra parametrar i riskmodellen, därför utfördes en osäkerhetsanalys. Slutsatsen i studien för den nuvarande situationen var att risken för försening var mindre på Hisingsleden under rusningstid och dagtid för alla scenarier. Under nattetid för den nuvarande situationen kunde antingen Hisingsleden eller Lundbyleden väljas med avseende på den lägsta risken. Ingen rutt kunde väljas under nattetid vid omledning av trafik varken med eller utan infrastrukturförbättringarna. Det finns osäkerheter i riskmodellen vilka beror av indata i riskmodellen. Framtida förbättring av riskmodellen kan vara att samla in mer noggrann indata för att få en mer exakt riskmodell. Det finns möjlighet att riskmodellen kan användas för liknande studier, men i framtiden bör fokus snarare ligga på att färdas en annan tid på dygnet istället för att välja mellan olika stråk.

Nyckelord: Riskanalys, godstransporter, osäkerhetsanalys, trafikolyckor, Hisingsleden, Lundbyleden, trafikomledning, förseningstid

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Preface

This master's thesis was initiated by the Swedish Transport Administration and COWI to investigate the delay time on Hisingsleden and Lundbyleden to justify the desired rerouting of goods transport from Lundbyleden to Hisingsleden. There was also interest to obtain information of how the traffic would be affected by the construction of the West Swedish Package.

The study was carried out at the Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden. The supervisors at Chalmers were Andreas Lindhe and Jan Englund. Pernilla Sott was the supervisor at COWI. We would like to thank the supervisors for their help and support during the master's thesis. We have also received assistance from Susanne Planath (Swedish Transport Administration), Christer Niland (COWI) and Johanna Rödström (COWI) which we are grateful for.

Finally, we want to thank the department of traffic planning at COWI for their technical support during the study.

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Johanna Gustavsson and Lisa Pålsson

1 Introduction

This chapter introduces the topic of the master's thesis including background information, purpose of the thesis and limitations. Furthermore, an outline of the thesis will be presented to guide the reader throughout the report.

1.1 Background

Recently, the South-West region in Sweden decided to expand the infrastructure in the area due to the desire to secure a good transportation system, now as well as in the future (Niland, 2013a). To achieve this goal the region is implementing the West Swedish Package (Swedish Transport Administration, 2013a). The West Swedish Package includes several different projects to improve the communications for public, private vehicle and goods transport in Sweden's South-West region. These infrastructural improvements will mainly be performed within the city of Gothenburg. A few projects have already been finished while other will continue until year 2028. During the construction period several areas in Gothenburg will be obstructed, especially in regard to means of communications, and one aspect with these obstructions will be the necessity of traffic rerouting.

A challenge when rerouting the traffic during the West Swedish Package will be to avoid delays for goods transport since they require accessibility and punctuality (Swedish Road Administration, 2009b). One of the largest industrial areas in Gothenburg, which is dependent on goods transport, is situated on the South-West part of Hisingen where both Gothenburg's Harbour, a large car manufacturer and several refineries are located (Swedish Road Administration, 2009a). The main routes by road for goods transports to and from the South-West part of Hisingen are Hisingsleden/Norrleden, Lundbyleden, Götaleden/Oscarsleden and Söderleden/ Västerleden, see Figure 1.

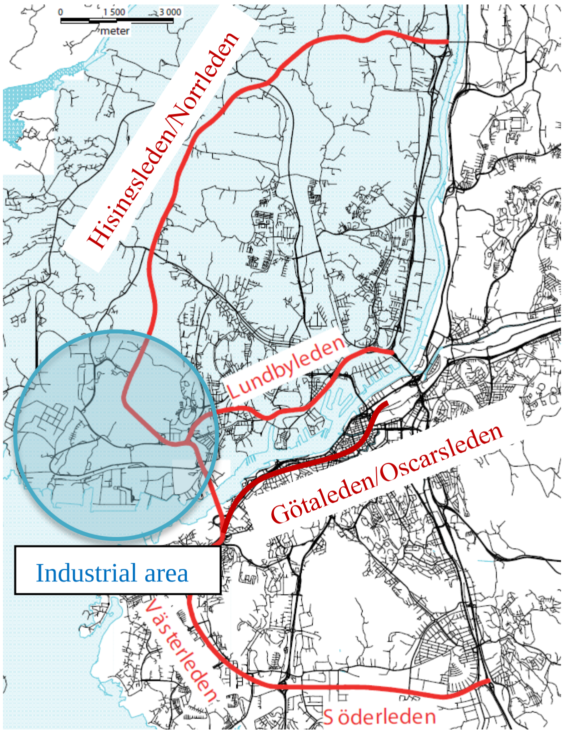


FIGURE 1 MAIN ROUTES TO THE INDUSTRIAL AREA ON HISINGEN (AFTER SWECO SEE SWEDISH ROAD ADMINISTRATION, 2009B).

The Swedish Transport Administration (STA) has an interest in relocating the freight transport in the central parts of Gothenburg to the outer parts of the city on Hisingsleden and Söderleden/Västerleden (Swedish Road Administration, 2008a). In addition, one of the STA long-term goals is to relocate goods transports from Lundbyleden to Hisingsleden/Norrleden (Swedish Road Administration, 2009a). These factors, together with the necessity to divert goods transport during the construction of the West Swedish Package, means it would be of interest to investigate the impact of rerouting the traffic with and without the impact caused by the West Swedish Package. To measure these effects the risk of delay can be assessed using a risk analysis.

1.2 Aim and objectives

The aim of the master's thesis is to assess the risk of delay for goods transports caused by traffic accidents connected with the present and future infrastructural system in Gothenburg. The risk of delay is estimated by creating a risk model and performing a risk analysis. To determine how the traffic situation is at present in regard to the risk of delay due to accidents for goods transport two routes have been chosen, Lundbyleden and Hisingsleden. Furthermore, the possibility of rerouting goods transports from Lundbyleden to Hisingsleden in regard to delay time caused by accidents is assessed. As the final part of the investigation the impact of the West Swedish Package is analysed in regard to delay times. Depending on time of the day a route will be recommended for each alternative in regard to risk of delay.

An uncertainty analysis will be performed to investigate the accuracy and uncertainty of the input parameters and of the result from the risk model. The risk will be displayed in risk time and risk cost, both for the individual goods transport and for all goods transport.

1.3 Limitations

The master's thesis will focus on Lundbyleden and Hisingsleden during the construction of the West Swedish Package. The main projects affecting the accessibility on the two roads to the industrial area on the South-West part of Hisingen will be investigated. Only goods transports will be considered in the thesis since they are sensitive to delays. Furthermore, only goods transports arriving from north to the industrial area will be considered. The thesis will not consider how the goods transports are rerouted to the different roads. Furthermore, delays caused by other incidents than accidents will not be taken into account.

1.4 Outline of the thesis

This master's thesis is structured to begin with the background information regarding the present infrastructure and future infrastructure in Gothenburg with focus on the two routes studied in the report, Hisingsleden and Lundbyleden. This is followed up by the concept of traffic and the concept of risk explaining the necessary theory behind each concept. After the necessary background information is described the risk model is presented with required input parameters. When the procedure of the risk model has been presented the results from the risk model is displayed in the result chapter. Finally, the discussion and conclusion from the master's thesis is presented.

2 Infrastructure and goods transports in Gothenburg

The infrastructure in Gothenburg is important both for industry and private users (Swedish Transport Administration, 2013b). To improve the infrastructure in the city and in the nearby region the West Swedish Package is being implemented (Swedish Transport Administration, 2013a). In this chapter the background of the main routes and goods in general is introduced. Furthermore, major projects from the West Swedish Package and the effect on the goods transports will be presented.

2.1 Main routes by road to the South-West part of Hisingen

Gothenburg is the centre of the Western region of Sweden and requires effective infrastructure to be able to grow (Swedish Transport Administration, 2013b). The harbour on the South-West part of Hisingen has great importance to the West Swedish region with its adjoining industries (Swedish Transport Administration, 2013c). The main routes to the industries on the South-West part of Hisingen are E6, E20, E45, riksväg 40, väg 155, Söderleden/Västerleden, Götaleden/Oscarsleden, Lundbyleden and Hisingsleden/Norrleden, see Figure 2 (WSP, 2012).

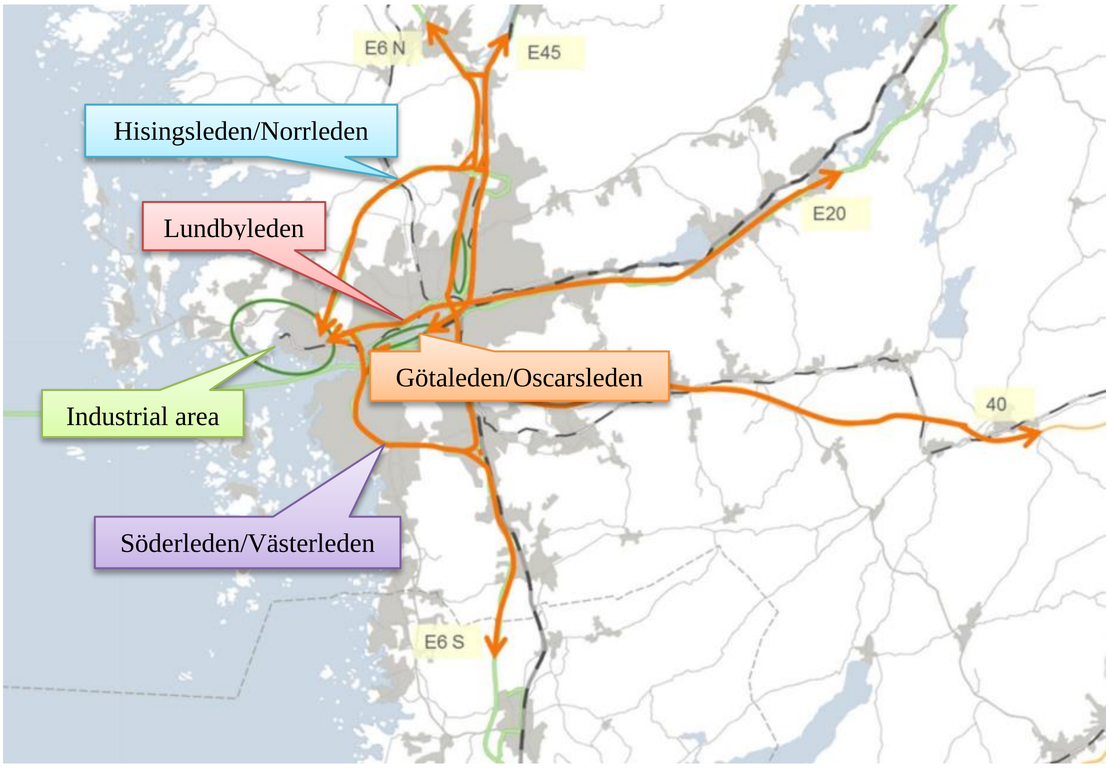


FIGURE 2 MAIN ROUTES FOR GOODS TRANSPORTS (AFTER WSP, 2012)

Söderleden/Västerleden is the main route for goods transports from the South and the East to the industrial area at Hisingen (Swedish Transport Administration, 2011b). Goods transport arriving from the North on E6 and E45 to the South-West part of Hisingen prefer to use Lundbyleden than Hisingsleden/Norrleden because of the poor transport quality on Hisingsleden/Norrleden (Swedish Road Administration, 2009a).

There is a desire to relieve some pressure on Lundbyleden and Götaleden with a ring road, see Figure 3 (Swedish Road Administration, 2008a). Instead of routing the traffic by Lundbyleden and Götaleden the alternatives could be Hisingsleden/Norrleden and Söderleden/Västerleden which would be a part of the ring road around Gothenburg's centre. All four different routes to the industrial area are approximately the same length (Swedish Road Administration, 2009a).

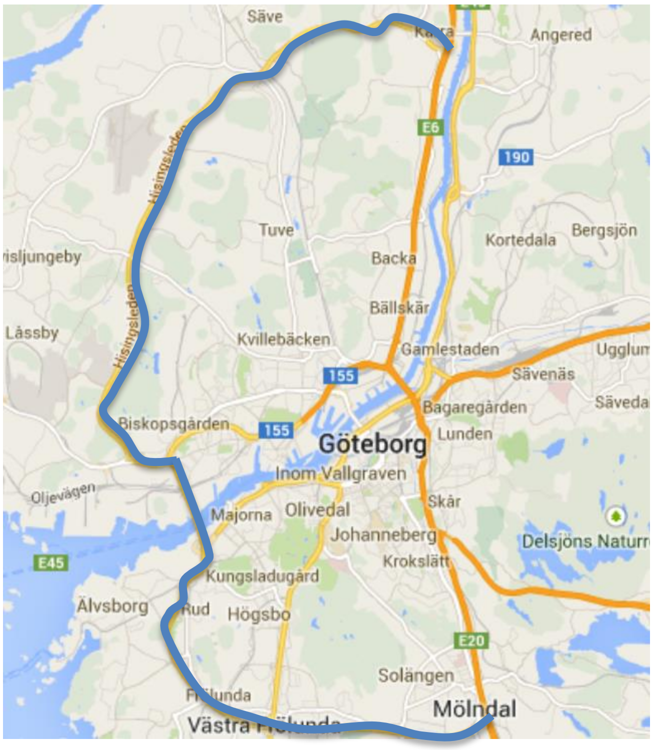


FIGURE 3 DESIRED RING ROAD IN GOTHENBURG IS MARKED IN BLUE (AFTER SWEDISH ROAD ADMINISTRATION, 2008B)

The main focus in the report is goods transports arriving from north to the industrial area, therefore the main routes Lundbyleden and Hisingsleden/Norrleden will be studied in more depth.

2.1.1 Lundbyleden

Lundbyleden, also known as E6.21, is one of the main routes to and from the harbour of Gothenburg and adjoining industries (Swedish Road Administration, 2008a). The road stretches between Bräckemotet and Ringömotet, see Figure 4, and connects with other key roads such as E6, E20 and E45. Lundbyleden has partly freeway standard and is partly a four-lane road which carries between 50 000 – 70 000 vehicles per weekday, of which 7000 – 8000 are heavy vehicles. It is prohibited to transport dangerous goods through Lundbytunneln and there are restrictions on large parts of the route. However, there are dangerous goods transport using the restricted part of the road but the amount is unknown. There are no restrictions between Ringömotet and Brantingmotet, (Swedish Road Administration, 2009a). The public transport on Lundbyleden only consists of a few bus lines (Swedish Road Administration, 2008a).

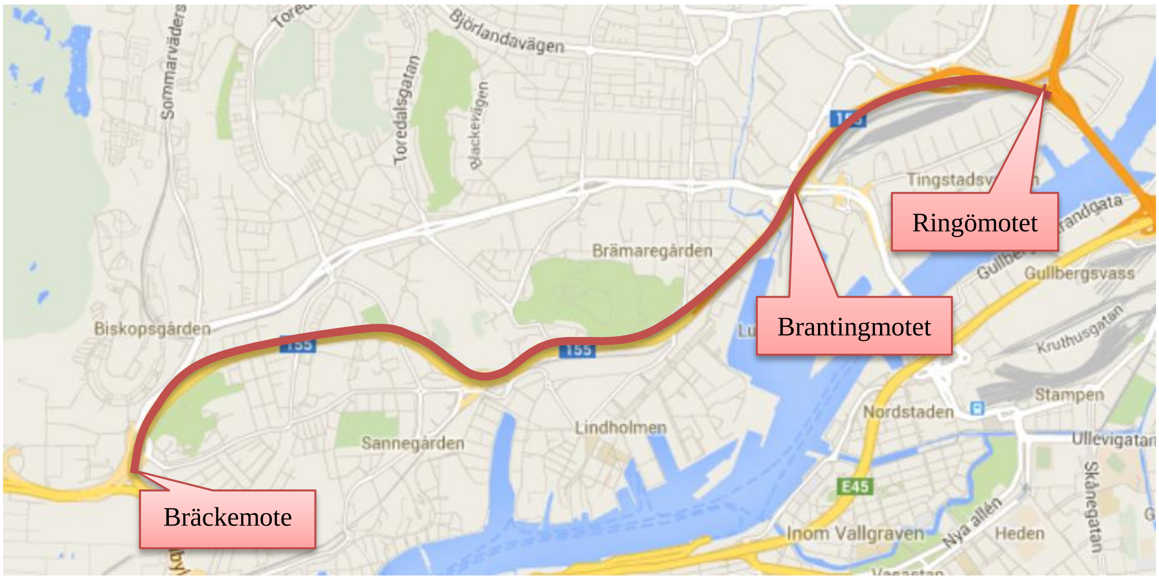


FIGURE 4 MAIN INTERSECTIONS AT LUNDBYLEDEN.

2.1.2 Hisingsleden/Norrleden

Hisingsleden/Norrleden, also known as E6.20, is another route to the industrial area on the South-West part of Hisingen. The road is connected to both E6 in the North-East and Lundbyleden in the South-West (Swedish Road Administration, 2008b). Hisingsleden/Norrleden is divided into two stretches where Hisingsleden is between Älvsborgbron and Tuvevägen and Norrleden is between Tuvevägen and Klarebergsmotet, see Figure 5. The route is mainly a two-lane road, however between Vädermotet and Assar Gabrielssons väg there is a 2+1 road in the North direction. Hisingsleden/Norrleden carries approximately between 13 000 and 21 000 vehicles on an average weekday, of which nine percent are heavy vehicles. The heavy traffic includes both trucks and buses, however the regular bus traffic only consists of a few bus lines and only a few trips per hour during peak traffic time. The public transport in the area is mainly traffic to and from Torslanda and the car manufacturer Volvo (Swedish Transport Administration, 2013c).

The region encourages the traffic, especially heavy vehicles, to choose Hisingsleden/Norrleden instead of Lundbyleden, but has been unable to achieve this goal (Swedish Road Administration, 2008b). One of the main reasons why the traffic prefers to go by Lundbyleden is because Hisingsleden/Norrleden has several traffic lights which interrupt the flow of traffic. Some of these intersections, mainly Assar Gabrielssons väg, Björlandavägen and Klarebergsmotet, see Figure 5, are overburdened during rush hours with traffic interruptions as a result and are the limiting capacity of the road. However, improvements at Hisingsleden are planned and the construction will begin in 2017, see section 2.3.4. Some improvements have already been made on Hisingsleden with the reconstruction of Vädermotet between year 2010-2012 for a better accessibility and a safer traffic environment (Swedish Transport Administration, 2014a). In year 2008, it was suggested to lower the speed limit by 10 km/h from 90 km/h to 80 km/h at Hisingsleden/Norrleden (Göteborgs Stad, 2008).

FIGURE 5 MAIN INTERSECTIONS ON HISINGSLEDEN (BLUE)/NORRLEDEN (RED).

The expected traffic volume in year 2020 is between 18 000 and 29 000 vehicles without any road improvements (Swedish Road Administration, 2008b). If improvements are made the traffic volume in 2020 could increase to between 29 000 and 40 000 vehicles. This increase would be between approximately two to four times as much as the road manages at present.

2.2 Goods transports in general and in Gothenburg

There are different types of goods and different ways of transporting them. There are several aspects that are important for the goods transports. On the South-West part of Hisingen a large industrial area is situated, which is dependent on the goods transports, which will be described more in depth in one of the following sections.

2.2.1 Goods transport modes

Goods can be transported by several different means of transportation but the four main ones are by: road, sea, air and rail (Transport analysis, 2012). There are advantages and disadvantages with the different transport modes. Road transports are flexible but with a higher cost while trains and boats are a better option when the goods are transported a long way or if it is heavy. The major share of goods within Sweden is transported by road (Transport analysis, 2012).

There are restrictions for some goods, like dangerous goods which can cause harm to humans or the environment (Swedish Civil Contingencies Agency, 2014). Dangerous goods is an umbrella term for products that can harm humans, environment and property (Cowi, 2011). Dangerous goods are divided into nine different ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road)-classes depending on its physical and chemical properties. According to a survey performed by Swedish Rescue Services Agency (2006) during a month in 2006, approximately 70 percent of the amount of dangerous goods transported on road in

Sweden was flammable liquids such as gasoline, diesel and petroleum. The second largest share corresponds to caustic compounds (12.5%) and the third to remaining dangerous substances (8.9%). The amount of dangerous goods transported in Sweden is measured on a national level and it is approximately one to ten percent of the heavy goods transports (Swedish Road Administration & Swedish Rescue Service Agency, 1998).

2.2.2 Important factors for goods transport

One of the most important factors regarding goods transports for the industry is predictability considering travel time (Swedish Road Administration, 2008b). Furthermore, flexibility, punctuality and safety are other important factors to consider (Transport analysis, 2012). In addition the trade association for goods transport in Sweden, Sveriges Åkeriföretag, is prioritizing safety and high accessibility (Swedish Road Administration, 2009b). It is estimated that the goods transports can be delayed around 30 minutes without affecting their schedule (Movea, 2013b).

According to STA the cost of one truck to be delayed by an hour is 273 SEK where 228 SEK is the driver salary (Movea, 2013b). However, the traffic consultant company Movea (2013a) has by interviews estimated the cost for a truck to be delayed one hour to be about 700 SEK. Movea also determined the cost of delay to be about 819 SEK per hour during winter time at a completely blocked road event (Movea, 2013a). The extra cost is due to time it takes to close the road and come up with an alternative route.

Since one of the major determining factors for the industry is reliable transportation time, this master's thesis will focus on delay time in regard to goods transports.

2.2.3 Goods transports to parts of Hisingen

Several different operators are located on the South-West part of Hisingen, of which the largest are Gothenburg’s Harbour, a car manufacturer, refineries and a quarry, see Figure 6 for a map of where the operators are situated.

FIGURE 6 INDUSTRIES AT THE SOUTH-WEST PART OF HISINGEN (SWEDISH ROAD ADMINISTRATION, 2009A).

The harbour of Gothenburg is Scandinavia's largest port and manages large amounts of goods (Port of Gothenburg, 2013). To be able to manage these large volumes of goods it is essential that the infrastructure adjoined to the harbour is able to cope with these large traffic flows (Niland, 2013a). The harbour uses routes by road and rail to transport the goods to and from the port. An expansion of the railway has been planned but even if the railway is improved there will still be an increased demand on goods transport by road. The prognosis of the goods flow to and from the harbour predicts a major increase in only a few years, according STA at least 50 percent until 2050 and according to Gothenburg's Harbour as much as 100 percent until 2030 (WSP, 2012).

Vikans Kross och Asfalt AB is a company running a quarry (Swedish Road Administration, 2009a). However, this operator has relatively low amounts of heavy transports compared to the refineries Preem and Shell and the car manufacturer Volvo. Volvo is a big operator in the area and one of the main entrances to Volvo is situated on Hisingsleden, at the intersection at Assar Gabrielssons väg.

Dangerous goods are being handled at some of the industries: the harbour of Gothenburg and the refineries. About two percent of the received containers in the harbour consist of dangerous goods, and of those 50 percent are flammable liquids and caustic compounds (Cowi, 2011). About 15 percent of petroleum transported from Shell's refinery was transported by road in 2007.

2.3 The West Swedish Package and its effects

The West Swedish Package aims to create more predictable travel time for the industries, better public transports and a better environment (Swedish Transport Administration, 2013a). In the West Swedish Package several projects includes improvements for trains, buses, trams, bicycles and cars (Swedish Transport Administration, 2013d). The improvements are financed with funds from the government and nearby regions together with congestion charges (Swedish Transport Administration, 2012a). To fulfil the goal with an attractive goods transport the loss of time as well as the uncertain travel times regarding goods transports have to be decreased (Swedish Transport Administration, 2011a). Furthermore, the vulnerability in the transport system needs to be reduced in order to achieve a properly functioning transportation network. Large interruptions will be caused throughout Gothenburg and traffic strategies are needed to secure a good transportation system.

2.3.1 Major projects

To achieve the West Swedish Packages goals, like more reliable transports for private vehicles and goods transport, the major projects that will be constructed are Hisingsbron, the Marieholm Connection and the West Link (Swedish Transport Administration, 2013d). Hisingsbron will replace the old bridge, the Göta Älv Bridge. The old bridge is the most important link for public transport over the river. To further improve the access across the Göta Älv for goods and private transport the Marieholm Connection will be constructed. The connection consists of a road tunnel beneath the river, Marieholm Tunnel, and a railway bridge across the river, Marieholm Bridge. The West Link is a railway tunnel that is going to be built beneath Gothenburg City to remove the end station by allowing the commuter trains to continue straight on through the central station.

To make public transport better and more reliable, more roads entering Gothenburg will have designated bus lanes (Swedish Transport Administration, 2013d). Also the capacity for commuter trains will be increased by adding carriages and lengthening the platforms. Furthermore, more commuter car parks, bicycle parks and bicycle paths will be built. A new commuter station at Gamlestadstorget will be built to create a new travel centre, both for local and regional passengers.

In this master´s thesis only the major project Marieholm Connection will cause traffic disturbances that affect the risk analysis.

2.3.2 Effects of the adoption of congestion charge in Gothenburg

To improve the infrastructure in Gothenburg and in the nearby regions a congestion charge was implemented in the beginning of 2013 to subsidise these improvements and reduce congestion. The infrastructural improvements are estimated to cost SEK 34 billion, whereas 50 percent comes from congestion charges (SEK 14 billion) together with financing from Region Västra Götaland and Region Halland (SEK 1 billion), Gothenburg City (SEK 1.25 billion) and from the realisation of land values (SEK 0.75 billion) (Swedish Transport Administration, 2012a). The remaining 50 percent is financed by state funding.

Since the establishment of the charge a major reduction in traffic has occurred, however the decrease in traffic was at its peak in the beginning of year 2013 and the reduction decreased somewhat after that (West Swedish Package, 2013a). The changes in traffic in 2013 were also noticed by the truck drivers. Between year 2012 and 2013 the travel time decreased on E6 Norr, however the travel time at Hisingsleden/Norrleden and Lundbyleden increased during the same period (West Swedish Package, 2013b). The increase in travel time on Lundbyleden was due to the reconstruction of Lundbyleden. The traffic amount on Hisingsleden/Norrleden increased with 24-33 percent in 2013 compared to year 2012 and it is probably due to the diversion of traffic because of the congestion charge.

2.3.3 Traffic strategy

There are several projects within the West Swedish Package which will cause traffic disturbances (Niland, 2013a). It is most likely that, the most intense building period for West Swedish Package will occur between year 2016-2020 and coordinated traffic control will be essential. To avoid or at least minimise interruptions on the road network a working procedure called “Trafik 2016” has been initiated. The purpose of this group is to improve the traffic situation during the building period by figuring out and suggesting solutions. "Trafik 2016" has a vision that "It should be as simple and reliable for the road users to reach their destination during the construction period as before the construction period had begun" (Niland, 2013b). The road users may expect to change travel pattern and experience longer travel times. However, the travel times will still be reliable and not vary from one day to another. Regarding goods transports the strategy of “Trafik 2016” is to reroute traffic to the ring road around Gothenburg's centre, which includes Hisingsleden/Norrleden (West Swedish Package, 2014).

2.3.4 Interruptions affecting Hisingsleden/Norrleden and Lundbyleden

Even if the strategy is to reroute traffic from Lundbyleden to Hisingsleden/Norrleden to secure the accessibility of goods transports to the harbour and surrounding industries, there will be interruptions at Hisingsleden due to the West Swedish Package (Swedish Transport Administration, 2014d). Some projects in the West Swedish Package will or have already affected the goods transports on Hisingsleden/Norrleden and Lundbyleden (Swedish Transport Administration, 2013a). These projects are new bus lanes on E6, reconstruction of Lundbyleden (Inlandsgatan-Lindholmsmotet), the Marieholm Tunnel connection at E6, reconstruction of Hisingsleden and construction of Halvors länk and reconstruction of Lundbyleden (Brantingmotet-Ringömotet), see Figure 7. The timeline for each project is found in Figure 8.

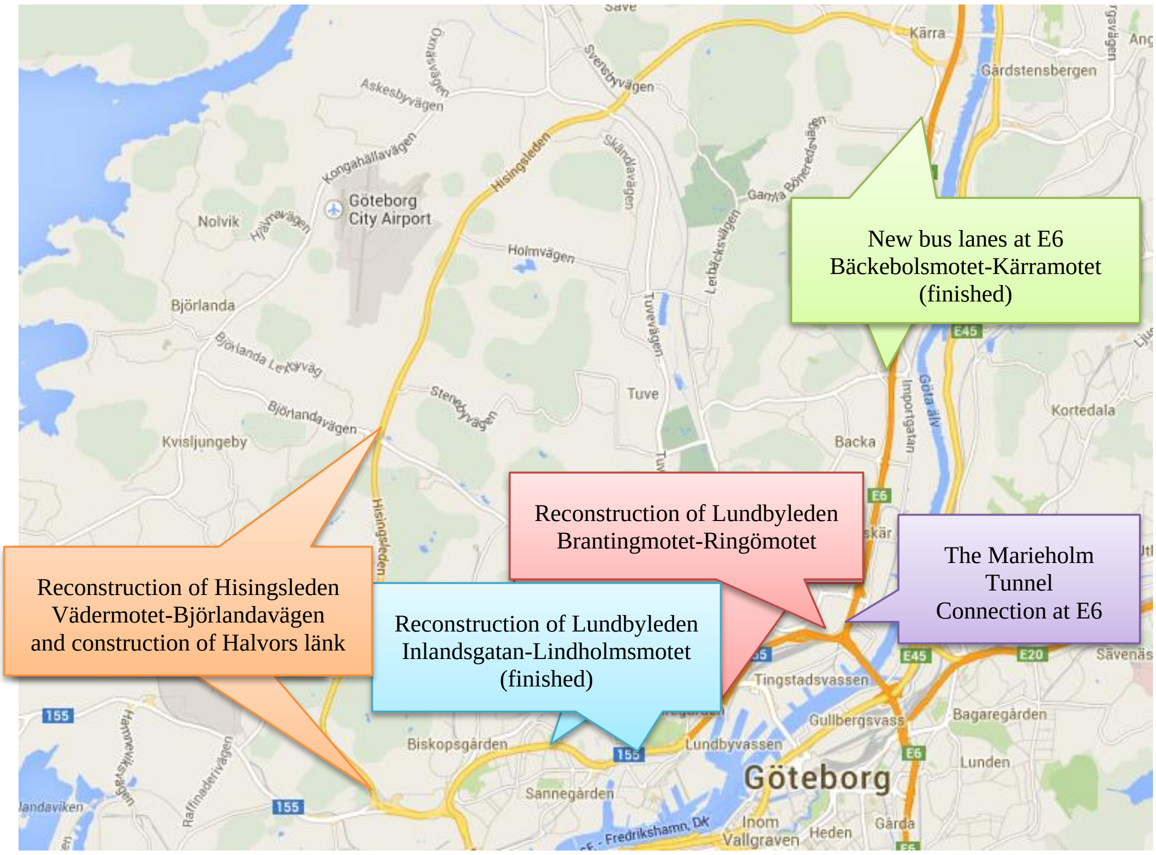


FIGURE 7 INTERRUPTIONS CAUSED BY THE WEST SWEDISH PACKAGE AFFECTING HISINGSLEDEN/NORRLEDEN AND LUNDBYLEDEN.

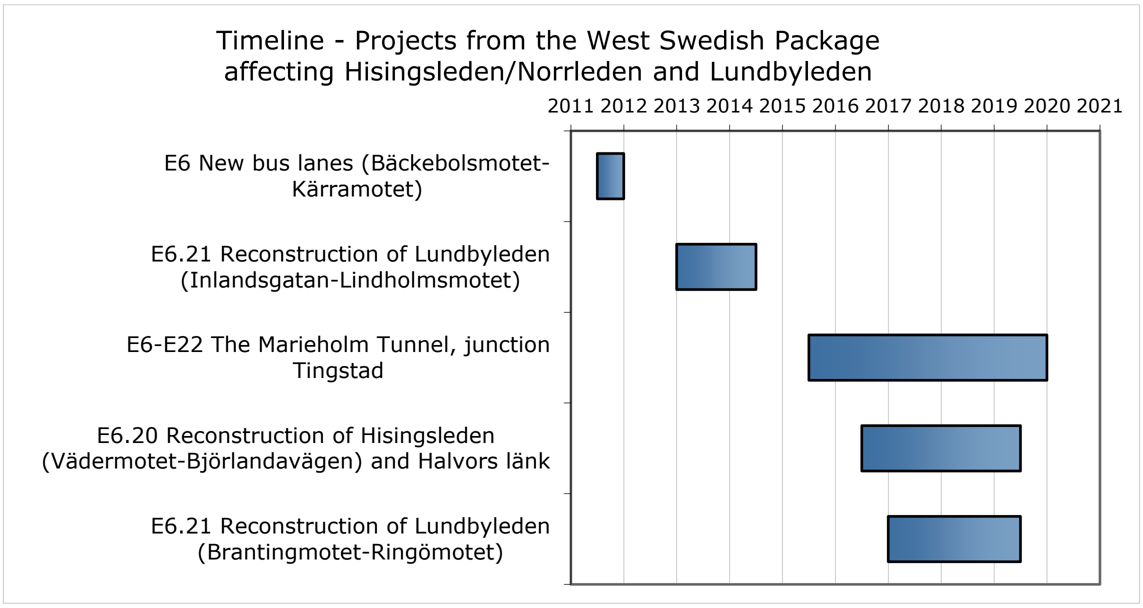


FIGURE 8 TIMELINE: PROJECTS FROM THE WEST SWEDISH PACKAGE AFFECTING HISINGSLEDEN/NORRLEDEN AND LUNDBYLEDEN[1].

[1] Pernilla Sott coordinators for commuters main routes Cowi, mail conversation 2014-02-05

As a part of the West Swedish Package, to increase the accessibility for public transport in the city of Gothenburg, new bus lanes for public transport have been constructed (Swedish Transport Administration, 2012b). The construction of the bus lanes on E6 between Bäckebolsmotet and Kärramotet were finished at the end of 2012, which have resulted in traffic interruptions during the construction period. During the construction time the same number of lanes were open for traffic, however the road was narrowed and the speed limit was lowered from 90 km/h to 70 km/h[2].

One of the main projects that will affect goods transport to and from the South-West part of Hisingen in the future is the Marieholm Tunnel (Swedish Road Administration, 2009c). The tunnel will connect E20, E6, E45 and Lundbyleden and there will be major obstructions at both E45 and E6. The construction of the Marieholm Tunnel starts in 2014 and will be finished by 2021 and will require redirection of the traffic on E6. When the tunnel will be connected to the present infrastructural system at Ringömotet, traffic will be diverted on both sides of the current road and the lanes will be narrowed during the construction period, see Figure 9.

FIGURE 9 TRAFFIC REDIRECTION BETWEEN RINGÖMOTET AND TINGSTADSMOTET (SWEDISH ROAD ADMINISTRATION, 2009C).

Another project which may affect goods transport to the harbour is the reconstruction of Lundbyleden (Swedish Road Administration, 2009b). The road has been altered in stages during the development of the area but has both poor connections to adjoining roads and inadequate traffic safety. To improve Lundbyleden, measures such as safety barriers and grade-separated intersections have and will be implemented, see Figure 10.

[2] Andreas Hellström construction manager ScanAkos Byggledning, mail conversation 2014-03-25

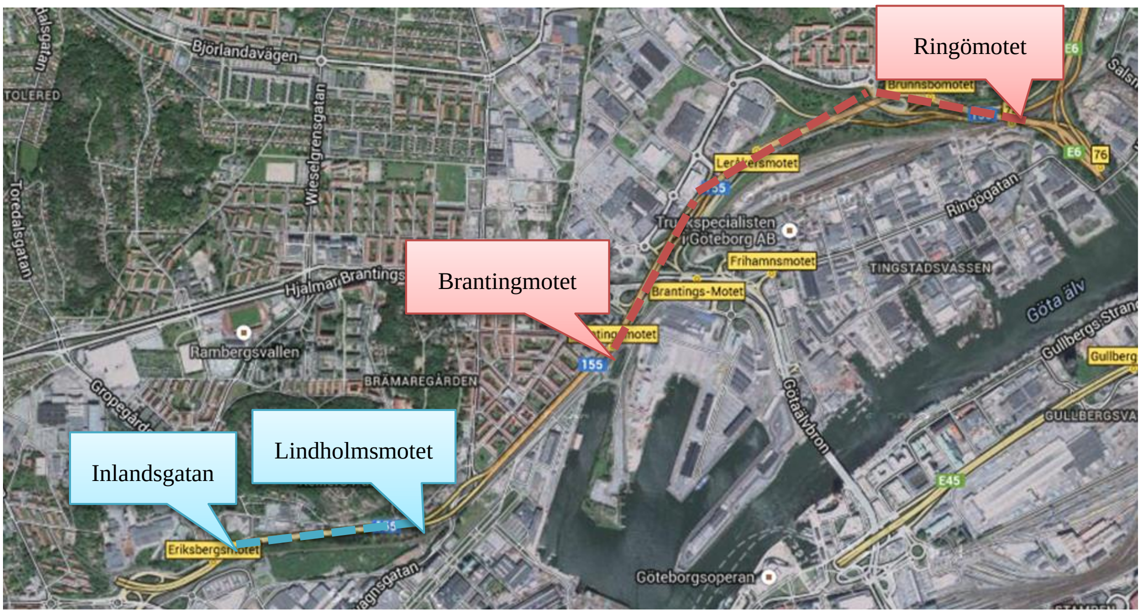


FIGURE 10 ROAD STRETCH IMPROVEMENTS ALONG LUNDBYLEDEN.

Some projects on Lundbyleden are already finished like the safety barriers between Lindholmsmotet and Inlandsgatan (Swedish Transport Administration, 2014b). The grade-separated intersection Lindholmsmotet was constructed during 2012-2014. The stretch between Brantingmotet and Ringömotet will be rebuilt and a new grade-separated intersection Kvillemotet will be made and the construction will begin in 2017 (Swedish Transport Administration, 2014c). According to Christer Claesson, former project leader at STA, Lundbyleden will not be entirely closed during the construction, however the accessibility will be reduced (Christell, 2012).

Included in the West Swedish Package is the reconstruction of Hisingsleden from Björlandavägen to Vädermotet, see Figure 11 (Swedish Transport Administration, 2014d). The road will be rebuilt to a separated four-lane road with three grade-separated intersections. A new road, Halvors länk, will also be included in the project with the purpose to create a route with good accessibility for goods transports to and from Hisingsleden/Norrleden and the harbour of Gothenburg. When Halvors länk is finished a relocation of 2000-3000 trucks per day can be achieved from Lundbyleden and E6 to Hisingsleden/Norrleden (Swedish Road Administration, 2009a). When the infrastructural improvements on Hisingsleden are completed the capacity restrictions will not occur in the intersections. Instead, they will occur at the lanes which will have a capacity of 1500 vehicles per hour and lane.

FIGURE 11 RECONSTRUCTION OF HISINGSLEDEN (BJÖRLANDAVÄGEN-VÄDERMOTET) AND CONSTRUCTION OF HALVORS LÄNK (SWEDISH TRANSPORT ADMINISTRATION, 2014D).

3 The concept of traffic

In this chapter the concept behind traffic flow, road capacity and queuing will be presented to give the background information regarding input parameters needed for the risk model.

3.1 Traffic flow and different relations

In this section the different units in which traffic flow can be measured will be presented. Furthermore, the traffic flow variation during the day will be presented as well as the relationship between flow and accidents, and flow and speed.

3.1.1 Traffic flow

Traffic flow is the amount of vehicles passing one point at a specific time (Hydén, 2008). Traffic flow variations are often different depending on if it is private vehicles, goods transports, which time period it is and different traffic routes. The total traffic flow often varies throughout the day, with rush hour peaks in the morning and afternoon, a lower flow during the day and with the lowest flow during the night, see Figure 12 (West Swedish Package, 2013c). For heavy vehicles there is less variation with slightly higher flows during the day and lower flows during the night.

Usually the weekend flows are quite different from the rest of the week with leisure trips (Hydén, 2008). During the weekdays business trips, goods transport (Hydén, 2008) and dangerous goods transport are conducted (Swedish Rescue Services Agency, 1996). For a short period of time the traffic flow can be larger in one direction, however over a longer period of time the traffic flow often is the same in each direction (Hydén, 2008). The flow also varies within the road, with larger traffic flows on one stretch and lower at another.

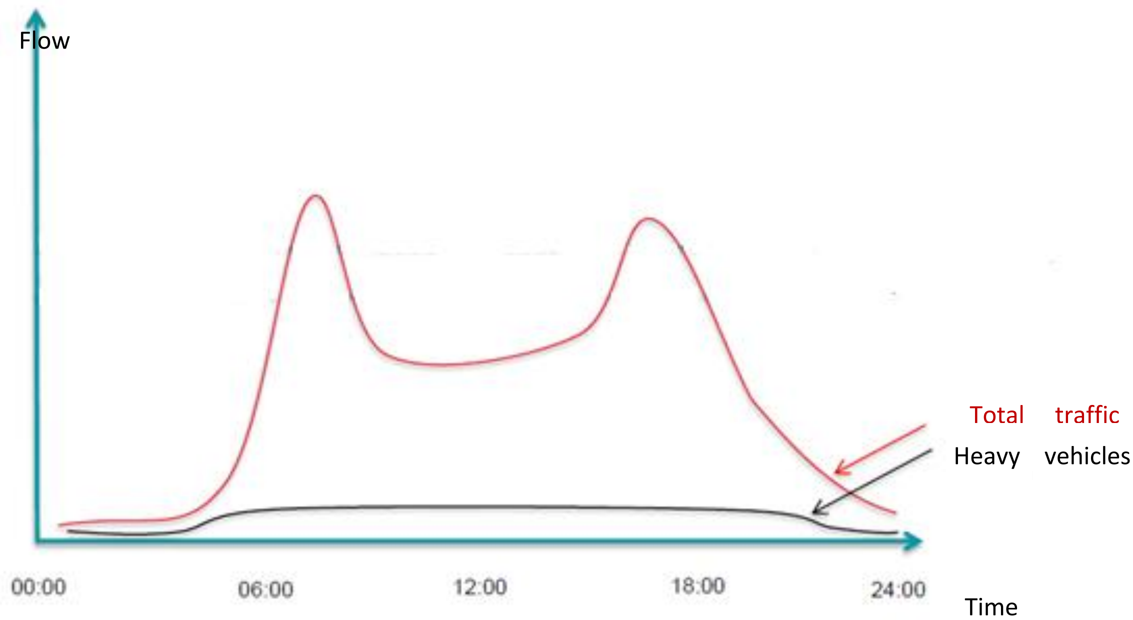


FIGURE 12 TRAFFIC FLOW – DAY VARIATION WHERE THE RED LINE IS THE TOTAL AMOUNT OF TRAFFIC AND THE BLACK LINE IS THE HEAVY TRAFFIC (AFTER WEST SWEDISH PACKAGE, 2013C).

Traffic flow can be measured in several types of units (Kronborg, 1998). The unit can either be in the form of Annual Average Daily Traffic (AADT) or in the form of average weekday. The AADT is the average amount of vehicles per day during a year while the average weekday is the average amount of vehicles on a weekday during one year. The AADT is approximately 90 percent of the traffic flow of an average weekday (Swedish Transport Administration, 2010). Furthermore, it is possible to measure all types of vehicles or only heavy vehicles. Vehicles which are heavier than 3.5 tonnes, which includes heavy trucks and buses, are classified as heavy vehicles (Swedish Transport Administration, 2013e).

3.1.2 Relation between traffic flow and accidents

With an increase of traffic flow, in AADT, there is also an increase of traffic accidents (TÖI, 2014). However, the increase of accidents is not the same as the increase of traffic flow, see Figure 13. If the traffic flow is increased by 10 percent the accident rate will increase by 8.8 percent where the 95 percent confidence interval is between 7.7 percent and 9.85 percent. According to the institute of transport economy in Norway (TÖI) it is not unlikely that this relation between traffic flow, in AADT, and accidents may change with the change in traffic flow.

The fact that the accident rate does not grow with the same percentage as the traffic flow is probably because of that with an increase in the traffic flow drivers lower the speed (TÖI, 2014). Furthermore, the drivers are more aware of the other vehicles and there is a less risk of an accident and the severity of an accident decreases. As a final point the amount of accidents increase less than the increase in traffic flows, hence the risk of an accident decreases with an increase in traffic flow.

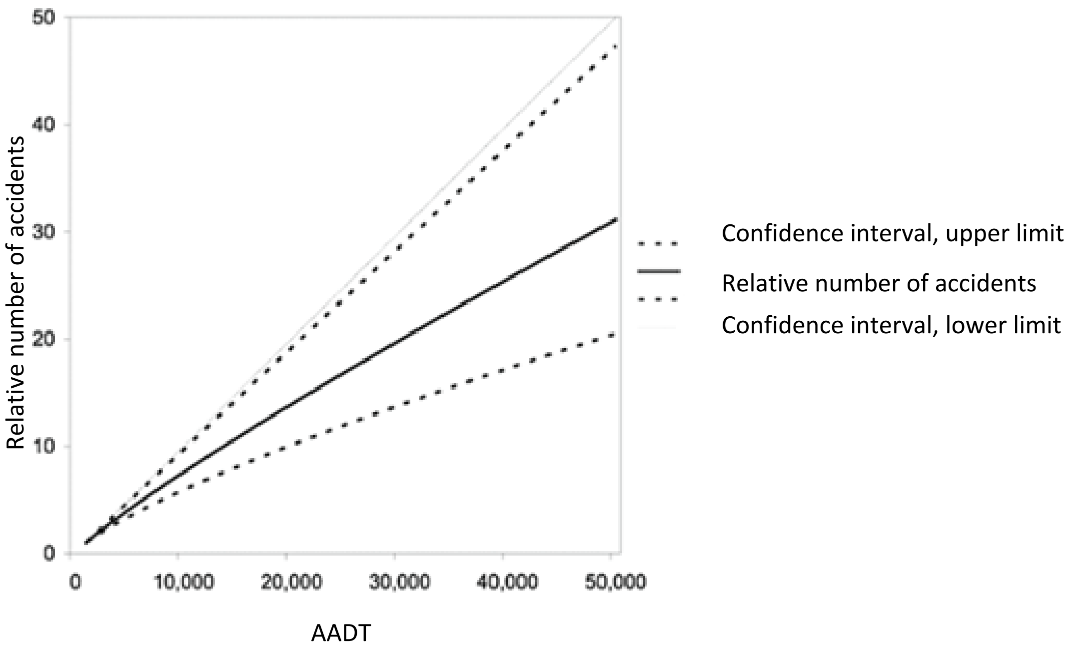


FIGURE 13 RELATION BETWEEN TRAFFIC FLOW AND ACCIDENTS, ACCIDENTS ON Y-AXIS AND TRAFFIC FLOW ON X-AXIS, THE DOTTED LINES ARE THE CONFIDENCE INTERVAL (AFTER TÖI, 2014).

3.1.3 Relation between traffic flow and speed

The STA has relations between traffic flow and speed (Swedish Transport Administration, 2000). From a handbook regarding the relation between traffic flow and speed, Effektkatalog 2000, it is possible to obtain different diagrams depending on road type, area, road width, see Appendix A.

3.2 Road capacity and saturation level

The capacity of a road is measured by how many vehicles that can pass a certain position during a certain period of time (Hydén, 2008). The capacity on a road stretch is affected by several different parameters: heavy traffic, number of lanes, curves, width of the road among others (Kronborg, 1998). It is not only the road itself that may be limiting the traffic amount, it can also be the intersections. The definition of capacity for a traffic intersection is the largest possible outflow at a constant flow (Swedish Road Administration, 2001). A standard value for the capacity of a road is 1800 vehicles per hour and lane (Kronborg, 1998). In an intersection it is possible to calculate the capacity either by hand or in a computer program, for example Capcal (Swedish Road Administration, 2001). There are different types of intersections that can be determining for the capacity of a road. The different intersections are grade-separated intersections, signalized intersections, stop, yield and roundabouts.

The saturation level is the arrival rate divided by the capacity and it should not exceed 0.8 for a well-functioning road (Hydén, 2008). If the saturation level is greater than 1.0 the road is usually unable to cope with the flow and queues will appear. However, it is possible queues appear even if the saturation level is less than 1.0. The Swedish Transport Administration (2012b) regulations state that the saturation level is accepted below 1.0 but the desired saturation level should be lower than 0.8.

3.3 Bottlenecks, completely blocked roads and queuing

Bottlenecks are a section of the road which has lower capacity than the ordinary road (Mannering & Washburn, 2013). A bottleneck can either be caused by an incident or it can be a recurring event. If a bottleneck is caused by an incident the reduction in capacity is due to an accident or the breakdown of a vehicle. A recurring bottleneck is when the road itself causes the bottlenecks, for example a restriction in the number of lanes. The two bottleneck types are separated since they are caused by different events. The induced incident exists for a short period of time and will disappear when the accident is cleared away, while the recurring incident can only be changed by reconstructing the road or choosing another path. When bottlenecks are to be evaluated a deterministic arrival and departure is assumed which means that the arriving vehicles and departure vehicles arrives and departures in an even flow.

Queues appear when the arrival rate is higher than the departure rate (Mannering & Washburn, 2013). If an accident occurs the road can be blocked in a number of ways. In this master's thesis the definition is either that the road can be completely blocked or partly blocked. This affects queuing since with a completely blocked road the departure rate is zero until the lanes are opened again. According to Movea (2013a) a completely blocked road can be defined as when the road is completely blocked in one direction. To estimate the queuing time, the stop time, reduction in capacity and time until the capacity is restored is used for an accident induced incident (Mannering & Washburn, 2013).

4 Risk analysis

In this chapter, background regarding the performed risk analysis is provided. Examples of hazard identification methods will be presented, whereas some of the methods used in the risk analysis will be described in more depth. The risk analysis methods used in this master's thesis are logic models which will also be presented in this chapter. As a final measure in the risk analysis, an uncertainty analysis is performed to investigate the uncertainty of the input data, assumptions and the result from the risk model.

4.1 The concept of risk

A risk is typically described as a combination of two parts, the probability of a hazardous/undesired event and the consequence of the event. The risk can be calculated using for example Equation 1 and thus expressed as the expected consequence (Rosén, et al., 2007). A risk analysis is supposed to identify hazards and evaluate the probability of the hazardous events as well as to estimate the consequences of the events.

$$Risk\ (R) = Probability\ (P)\ x\ Consequence\ (C) \tag{1}$$

A hazardous event is an event that can cause harm and the probability of a hazardous event is the likelihood the event will happen (Rausand, 2011). There are three different approaches how to determine the probability of a hazardous event:

- Classical approach
- Frequency approach
- Bayesian approach

The classical approach can determine the probability of a hazardous event by knowing the finite number of outcomes and the amount of outcomes for the event of interest (Rausand, 2011). This approach is however only appropriate when the likelihood of each outcome is the same. Otherwise the probability of a hazardous event can also be decided with frequency of an event. However, the disadvantage with this method is that each try should be done under the exact same conditions which are difficult in a risk analysis. The third approach is the Bayesian approach which estimates the probability of an event by experience and is a common approach in a risk analysis (Swedish Road Administration & Swedish Rescue Service Agency, 1998).

The consequence of a hazardous event can be described in different terms for example: loss of human life, personal injury, material damage, investigation or cost to clear away an accident (Rausand, 2011). There are other criteria than damage to property and probability of failure which is important when evaluating the risk (Rosén, et al., 2007). An example is for instance delay effects.

4.2 Hazard identification methods

In the beginning of a risk analysis, a hazard identification needs to be performed in order to detect the different potential hazards and hazardous events (Rausand, 2011). There are several different methods which differentiate in regard to available expertise and time, what aspects to consider and amount of perspectives and methods required. Common methods are brainstorming and checklists, hazard matrix, hazard and operability study (HAZOP), failure mode and effects analysis (FMEA), structured brainstorming and change analysis. Some hazard identification methods are more focused on investigating environmental impacts from a hazard, like the hazard matrix. Others are more expensive and focus on more complex systems or a certain kind of system like the HAZOP and FMEA. The structured brainstorming requires certain expertise of the area while others can be used without certain expertise like the brainstorming and checklist and change analysis. A few hazard identification methods have been studied in more depth since these are the ones most applicable for the risk model used in this master's thesis.

4.2.1 Brainstorming and checklists

One of the most practiced methods of identifying hazards or hazardous events is by using brainstorming and checklists (Rausand, 2011). The concept is to come up with possible hazards that may endanger the system or project and organize them in a checklist. The benefits with brainstorming are that it introduces new perspectives and relations between the system and potential hazards. In addition, the most common hazards are easily identified with this method. However, it is common that the method identifies hazards within the participants experience and do not consider new or other possibilities (Burgman, 2005).

Since the brainstorming and checklist method does not require experts or a structured way of organizing the hazards it is possible that the language used may be misinterpreted (Rausand, 2011). Even though brainstorming and checklists is a simple and quick method to identify hazards, it should not be the only method used.

4.2.2 Change analysis

Another method to identify hazards and hazardous events is to use change analysis (Rausand, 2011). With the change analysis it is possible to estimate how hazards or hazardous events differentiates if a change is implemented in a system. To determine these differences the term key differences is used for the change from the old system to the new one. The analysis can be performed in eight different steps shown in Figure 14. The advantages with the change analysis are that it does not require experts, has an efficient way of determine the differences of the systems and is effective for proactive risk assessments. However, the change analysis is much dependent on the experience of the team.

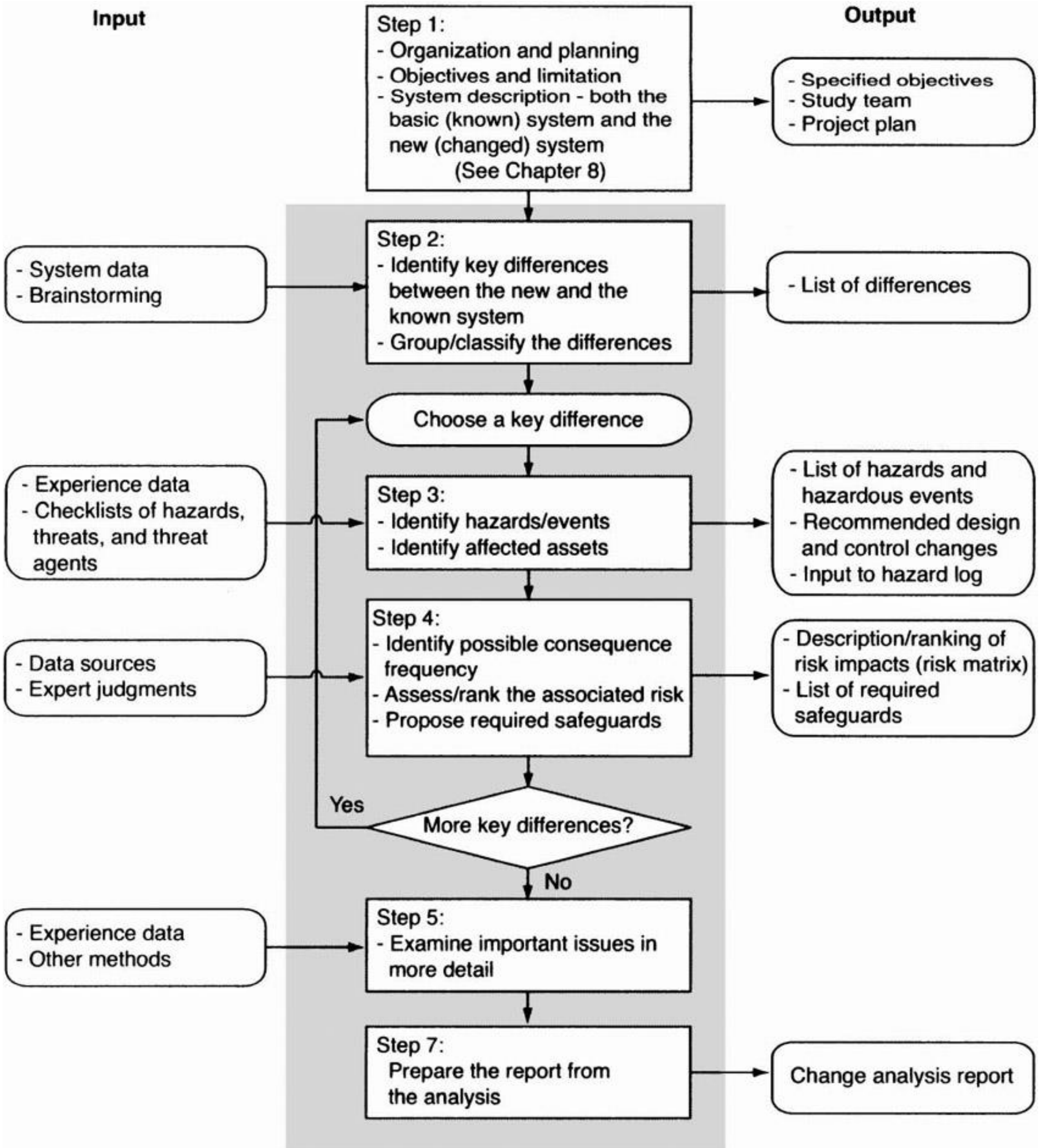


FIGURE 14 THE WORKFLOW OF A CHANGE ANALYSIS (RAUSAND & HØYLAND, 2004A).

4.3 Logic models

Depending on what type of outcome the risk analysis requires there are different methods to procure the different results. Logic models will be used in this master's thesis, which includes fault trees and event trees. The fault tree analysis (FTA) investigates how the event can occur while the event tree analysis (ETA) considers different consequences of the event.

4.3.1 Fault tree analysis

A fault tree is a logic model built from hazard to consequence (Burgman, 2005). The cause of the consequence may be normal events, specific component failures, environmental conditions or human errors (Rausand & Høyland, 2004a). An FTA starts with an accident or specific system failure and addresses the question "How can this event occur?". The accident or specific system failure is called top event, which should give answer to the questions *what*, *where* and *when*. Accordingly, the top event should give answer to what type of critical event, where the critical event occurs and when the critical event occurs. There are also intermediate and basic events, where the basic events are at the lowest level of a fault tree, representing the events that in different combinations may cause the top event to occur.

The relationships of the events are described with logic gates which are AND-gates, where events depend on each other, and OR-gates where the events are independent of each other (Burgman, 2005). Some of the most common symbols used in an FTA are shown in Figure 15.

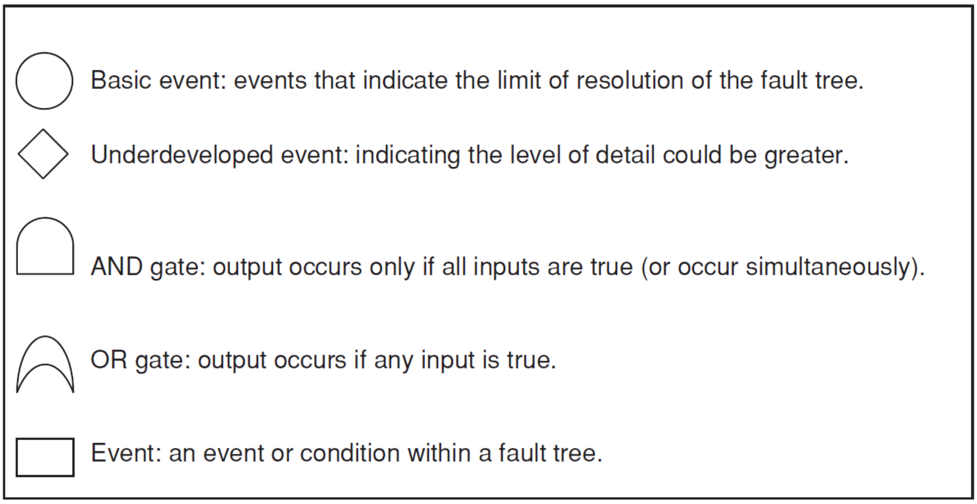


FIGURE 15 SYMBOLS USED IN A FAULT TREE (RAUSAND & HØYLAND, 2004A).

The probability of failure (P_f or P(F)) for the top event is reliant on the probabilities of the intermediate and basic events (P_i or P(i)) (Burgman, 2005). The probability P_f is calculated using different equations dependent on which logic gates that are used. If an AND-gate is used Equation 2 is used and if the gate is an OR-gate Equation 3 is used.

$$P_f = \prod_{i=1}^{n} P_i \qquad (2)$$

$$P_f = 1 - \prod_{i=1}^{n} (1 - P_i) \qquad (3)$$

The potential cause of the system failure is then calculated subtracting the probability of the intermediate events, see Figure 16.

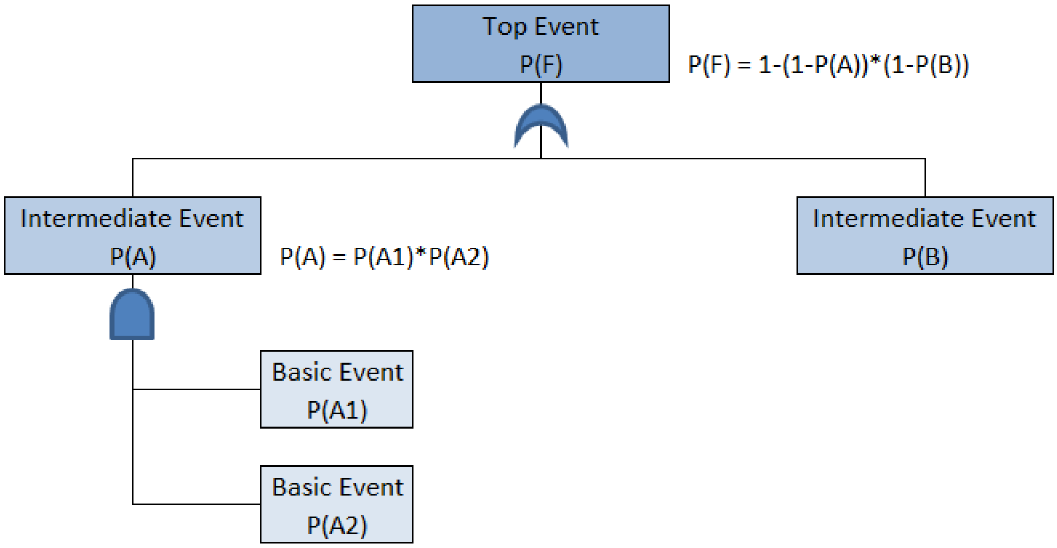


FIGURE 16 EXAMPLE OF A FAULT TREE (AFTER RAUSAND & HØYLAND, 2004A).

4.3.2 Event tree analysis

An event tree is constructed with an initiating event and the outcome of the tree is the possible consequences of this initiating event (Burgman, 2005). With the event tree it is possible to calculate the probability of the sequence of events. The tree is often constructed with binary outcomes (*true* or *false*) but according to Rausand and Hoyland (2004b) it is also possible that it can have multiple outcomes (*yes*, *partly* and *no*). The initiating event begins from the left, the following events builds to the right, see Figure 17. The event tree has a simpler structure than a fault tree and all events happen in a chronological order (Swedish Rescue Services Agency, 2003). It is important to notice that the probability of an event could be altered due to the previous event and the possibility that it may have an effect on other events.

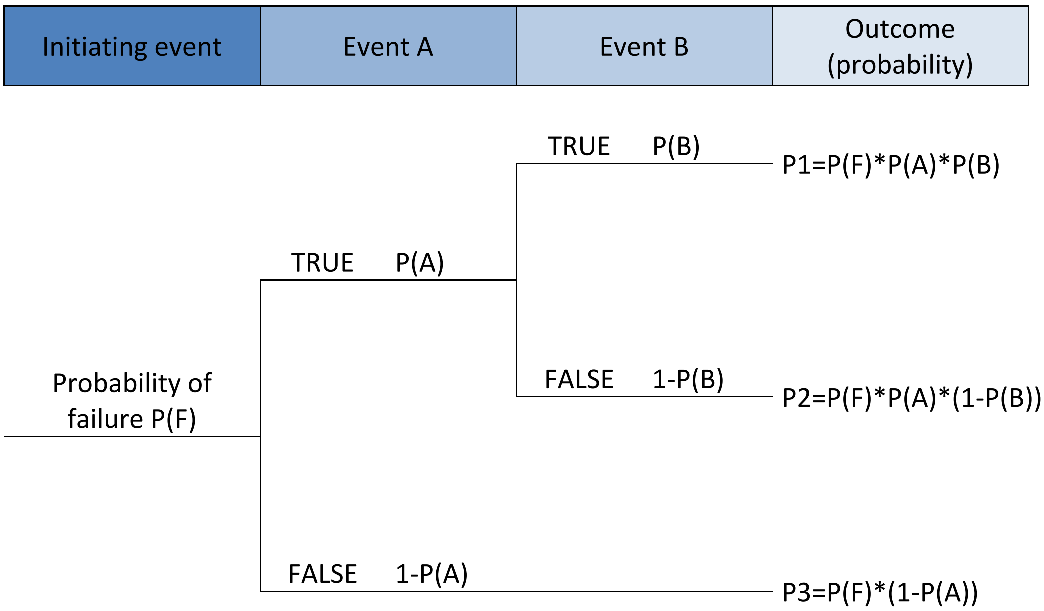


FIGURE 17 EXAMPLE OF AN EVENT TREE (AFTER RAUSAND & HØYLAND, 2004B).

Furthermore, the probability of the chain event can be calculated by multiplying the probability of each event within the sequence with each other (Burgman, 2005). Hence, the probability of the whole sequence of events may be calculated and with this, it is possible to calculate the risk (if expressed as the expected consequence) by multiplying the probability by the consequence.

It is possible to combine the FTA and the ETA in a risk analysis (Swedish Rescue Services Agency, 2003). With the fault tree it is possible to calculate the probability of the initiating event in the event tree model.

4.4 Uncertainty analysis

An uncertainty analysis can be defined as a mean of investigating how limited the available data are and how large the uncertainties are in the input parameters and data (Lopez, et al., 2006). Distributions for the input parameters are created by observing the variation in the data. A Monte Carlo simulation can be used to find random variables of the input data and create a distribution of the output value to find the uncertainty in the result (Burgman, 2005). With the software Oracle Crystal Ball, an add-in to Microsoft Excel, it is possible to estimate the uncertainty for each input value in the spreadsheet (Oracle, 2008). When the assumptions are set, Oracle Crystal Ball performs a Monte Carlo simulation to create a forecast of the results (Oracle, 2014). The software program estimates the uncertainty by assess a rank correlation for every assumption and forecast. If the rank correlation is positive an increase in the assumption returns an increase in the forecast. If the rank correlation is negative an increase in the assumption results in a decrease of the forecast.

5 Risk model

In this chapter the different procedures necessary to procure input data is presented for the risk analysis. The traffic flow, accident statistics and the probability of different events have to be estimated or calculated for the risk model. The procedure for how the risk analysis is performed and necessary input data required is shown in Figure 18 and divided into different steps.

FIGURE 18 SCHEMATIC ILLUSTRATION OF THE STEPS OF CREATING THE RISK MODEL AND PERFOMING THE RISK ANALYSIS.

5.1 Step 1: Choice of method and model

To produce a risk analysis in this master's thesis, a hazard identification method has to be selected together with a risk model.

5.1.1 Hazard identification method

The choice of hazard identification method is dependent on the available expertise in the field, type of field, time and resources. Therefore, methods like structured brainstorming, HAZOP, hazard matrix and FMEA were not possible to select due to lack of one or several of the elements mentioned above. The brainstorming and checklist method is selected in the first phase of the master's thesis to identify different accidents related to hazards and hazardous events which can lead to delay. The change analysis is used when comparing the studied alternatives.

5.1.2 Risk model

The risk models that were chosen to solve the problem are logic models. In order to calculate the probability of an accident, either the frequency approach can be used or the method to calculate the probability of an accident with dangerous goods. The frequency approach was used to calculate the probability of a private vehicle accident or a heavy vehicle accident. This method cannot be applied to accidents with dangerous goods since there are not available accident event data recorded for dangerous goods transports, see section 5.3.3. Hence, the method described in section 5.4 was used to calculate the probability of an accident with dangerous goods.

When applying the method to calculate an accident with dangerous goods, Hisingsleden and Lundbyleden were divided into several stretches. The output value (probability) from this risk model was achieved for each stretch. In order to calculate the probability of a dangerous goods accident for the completely blocked road an FTA was used, see Figure 19.

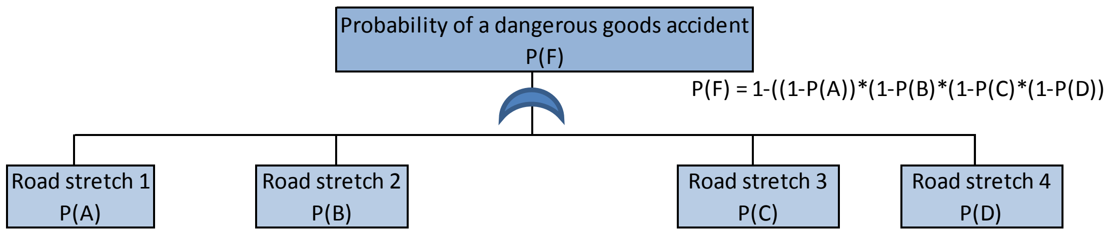


FIGURE 19 FAULT TREE FOR CALCULATION OF THE PROBABILITY OF AN ACCIDENT WITH DANGEROUS GOODS ON A ROAD DIVIDED INTO FOUR STRETCHES.

Once the probabilities are calculated for private vehicle and heavy vehicles as well as dangerous goods, the probabilities can be inserted into an event tree which was chosen as the risk model. The event tree was chosen since it is possible to calculate the probability of the sequence of events, for this problem the probability of delay in terms of time was calculated. In the ETA, the following parameters were considered: time of the day, completely blocked road or not, delay or not and contaminant release or not.

The output of the risk model will be the expected delay in terms of cost and in terms of time. The first output from the model will be in terms of time which is multiplied with a cost factor, 700 SEK, and the risk in terms of expected cost will be achieved. The cost factor is based on previous estimates by Movea (2013b), see section 2.2.2. However, these delay times and delay costs are only expressed for one vehicle. By multiplying with the number of vehicles on the specific road, the total delay time and delay cost for all heavy vehicles can be stated. However, this is not the socio-economic cost since the delay for the receivers are not accounted for.

5.2 Step 2: Limitations and definition

To limit the risk model and to be able to define it, different alternatives together with categories are created to simulate scenarios which are outlined in this chapter.

5.2.1 Definition of Lundbyleden and Hisingsleden

The definition of Hisingsleden and Lundbyleden in this master's thesis can be seen in Figure 20 and is defined as:

- Hisingsleden is located in a rural area between the intersection Kärravägen/Angeredsbron and Vädermotet.
- Lundbyleden is located in an urban area between the west entrance of Lundbytunneln and Ringömotet.

Traffic flows, accidents and completely blocked road accidents outside these stretches are not included in the risk analysis.

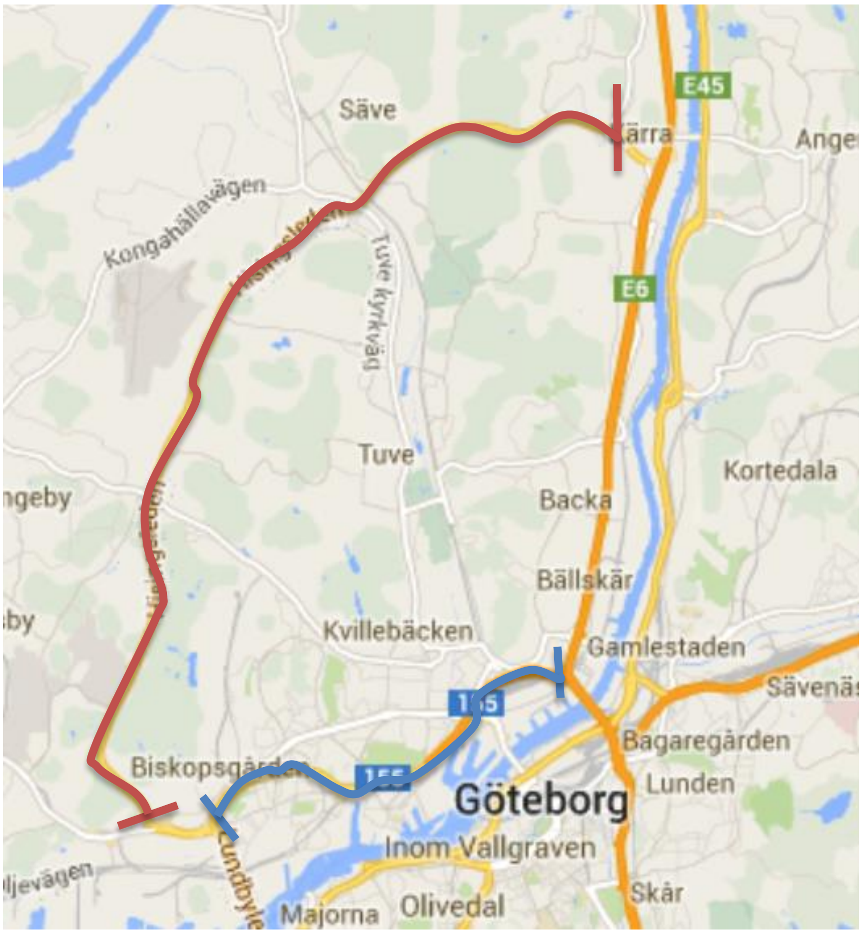


FIGURE 20 DEFINITIONS OF HISINGSLEDEN (RED) AND LUNDBYELDEN (BLUE).

5.2.2 Definition of categories

The risk model will be based on different categories based on different types of accidents and time periods. The time of the day will be divided into different categories depending on the variation in traffic flow. These categories will be described in this chapter.

Vehicles

The accident types are divided into three categories: private vehicles, heavy vehicles and dangerous goods. The three categories were chosen because of their difference in effect on the probability of delay and time it takes to clear away an accident. Some accidents were assessed to have minor impact on the delay time and probability and are therefore not selected as a category. These include accidents involving bicycles and pedestrians. Furthermore, animal accidents have minor impact on the delay times caused by dangerous goods accidents.

Accident event statistics have been divided into private vehicles and heavy traffic since no records of dangerous goods are possible to retrieve. It is assumed that private cars, trucks (light), motorcycles, mopeds, bicycles and all-terrain vehicles are included in private vehicles. Heavy traffic includes vehicles heavier than 3.5 tonnes which is heavy and unknown trucks, buses as well as dangerous goods transports. Furthermore, it is assumed that an accident with a car and a bike is a private vehicle accident and an accident with a car and a truck is a heavy vehicle accident. This assumption is made to be conservative, since it takes a longer period of time to remove an accident that involves a heavy vehicle than a private car. Pedestrians are not included in the model, since it is assumed that an accident with a pedestrian does not lead to any significant delay in terms of time.

The goods transports on the two roads will include buses, since it is not possible to distinguish buses from the goods transports. However there are few bus routes.

In terms of risk time and risk cost the risk can be divided into two categories: one goods transport or all goods transports. However, the risk time for one goods transports can also be applied for any vehicle. The term all goods transports is acquired by multiplying the risk for one goods transport with the number of goods transports on that particular road.

Time of the day

The assumption that the different time periods (rush hour, day and night) begin at certain times is estimated by comparing the mean flow variations in one direction on Hisingsleden and Lundbyleden, see Figure 21. The flow variation on Hisingsleden shows that the peak is at 07.00 in the morning and somewhere between 15.00 and 16.00 in the afternoon. The flow variation for Lundbyleden shows that the peak hour is at 07.00 in the morning and 16.00 in the afternoon. To estimate the different time periods of the day the mean value between the peak hour and the flows during the day and night is assessed. The time periods for both Lundbyleden and Hisingsleden are set to 06.00-08.30 and 14.00-18.00 for rush hour, 08.30-14.00 for day and 18.00-06.00 for night.

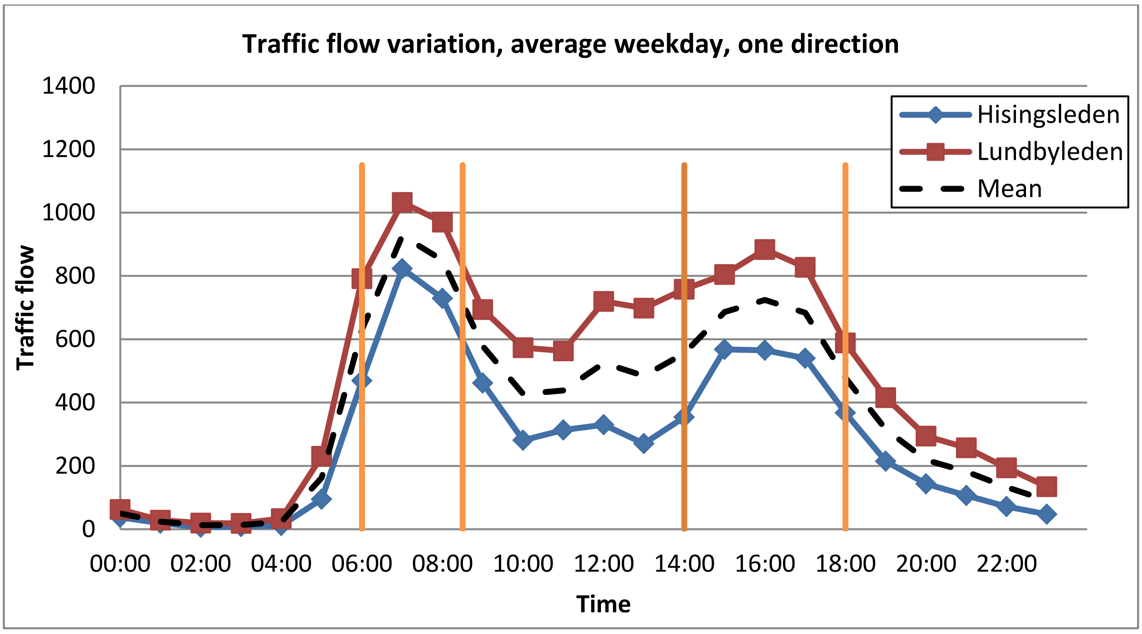


FIGURE 21 MEAN TRAFFIC FLOW VARIATION FOR AN AVERAGE WEEKDAY IN ONE DIRECTION AT HISINGSLEDEN AND LUNDBYLEDEN TO ESTIMATE THE TIME PERIODS, THE ORANGE BARS ARE THE DIVISION BETWEEN THE TIME PERIODS.

5.2.3 Definition of delay time and completely blocked road

A delay for goods transports in this master's thesis is decided to be 30 minutes or more, see section 2.2.2. A delay is always caused by at least one blocked lane in this master's thesis and does not consider partly blocked lanes if traffic accidents and/or completely blocked road accident statistics do not prove otherwise.

At a completely blocked road the road is closed in at least one direction. It is assumed in this master's thesis that there is no possibility to take another route when a completely blocked road event occurs.

5.2.4 Different scenarios

To simulate how the rerouting of traffic from Lundbyleden to Hisingsleden will occur and the impact from the West Swedish Package different scenarios are created.

Alternative 0 - Present situation

Alternative 0 is the present situation on Hisingsleden and Lundbyleden with no modifications. The traffic volumes have not been recalculated to the present year since the impact of the congestion fee in the future is still not completely known.

Alternative 1- Rerouting of traffic from Lundbyleden to Hisingsleden

During the construction of the West Swedish Package the road users will be encouraged to use Hisingsleden instead of Lundbyleden. In Alternative 1 the traffic rerouting will occur without the disturbances from the West Swedish package. The amount of traffic is the maximal number of vehicles that can be rerouted to Hisingsleden from Lundbyleden without exceeding the saturation level of 0.8 in the intersections, since these are limiting the capacity.

For Alternative 1, the volume of traffic being diverted is estimated from capacity calculations. Together with an expert[3] from STA reasonable scenarios for rerouting of

[3] Bertil Hallman long-term traffic planner and traffic analytic STA, meeting 2014-03-17

goods transport have been discussed. However, the rerouting of traffic is difficult to predict and hence the estimate from the capacity calculations is used.

The key difference between Alternative 0 and Alternative 1 is the change in traffic flow, which would have the largest influence on the delay.

Alternative 2 – Rerouting of traffic and disturbances from projects during the construction of the West Swedish Package

For Alternative 2 the traffic rerouting from Alternative 1 occurs and the disturbances from the projects during the West Swedish Package are applied. In order to evaluate how the traffic will be affected for Alternative 2 during the construction of the projects within the West Swedish Package, experience from similar completed construction projects will be used. The three projects are: new additional bus lanes on E6, additional lanes on Söderleden/Västerleden and the reconstruction on Lindholmsmotet.

During the construction of the additional bus lanes on E6 the speed was lowered by 20 km/h from 90 km/h to 70 km/h and the existing lanes were narrowed down[4]. When the additional lanes on Söderleden/Västerleden were constructed the speed was lowered by 10 km/h from 80 km/h to 70 km/h[5]. Furthermore, during the reconstruction of Lindholmsmotet the speed was lowered by 20 km/h from 70 km/h to 50 km/h[6]. A temporary signalized intersection was used during the construction of Lindholmsmotet which caused some queues during rush hour.

Based on the previous projects mentioned above, engineering judgements with experts[7] have been done to estimate the possible effect the different projects will have on Hisingsleden and Lundbyleden. The speed varies on Hisingsleden but the primary speed limit is 80 km/h with parts where the speed limit is lower than 80 km/h. However, the speed limit is assumed to be 80 km/h on the entire stretch as a simplification. The assessed speed on Hisingsleden and Lundbyleden, based on engineering judgement during the construction of the West Swedish package projects is shown in Figure 22.

[4] Andreas Hellström construction manager ScanAkos Byggledning, mail conversation 2014-03-25
[5] Per Eriksson senior project manager at the Swedish Transport Administration, mail conversation 2014-05-09
[6] Johan Edin coordinating construction manager at the Swedish Transport Administration, mail conversation 2014-04-09
[7] Pernilla Sott and Johanna Rödström coordinators for commuters main routes Cowi, meeting 2014-04-07

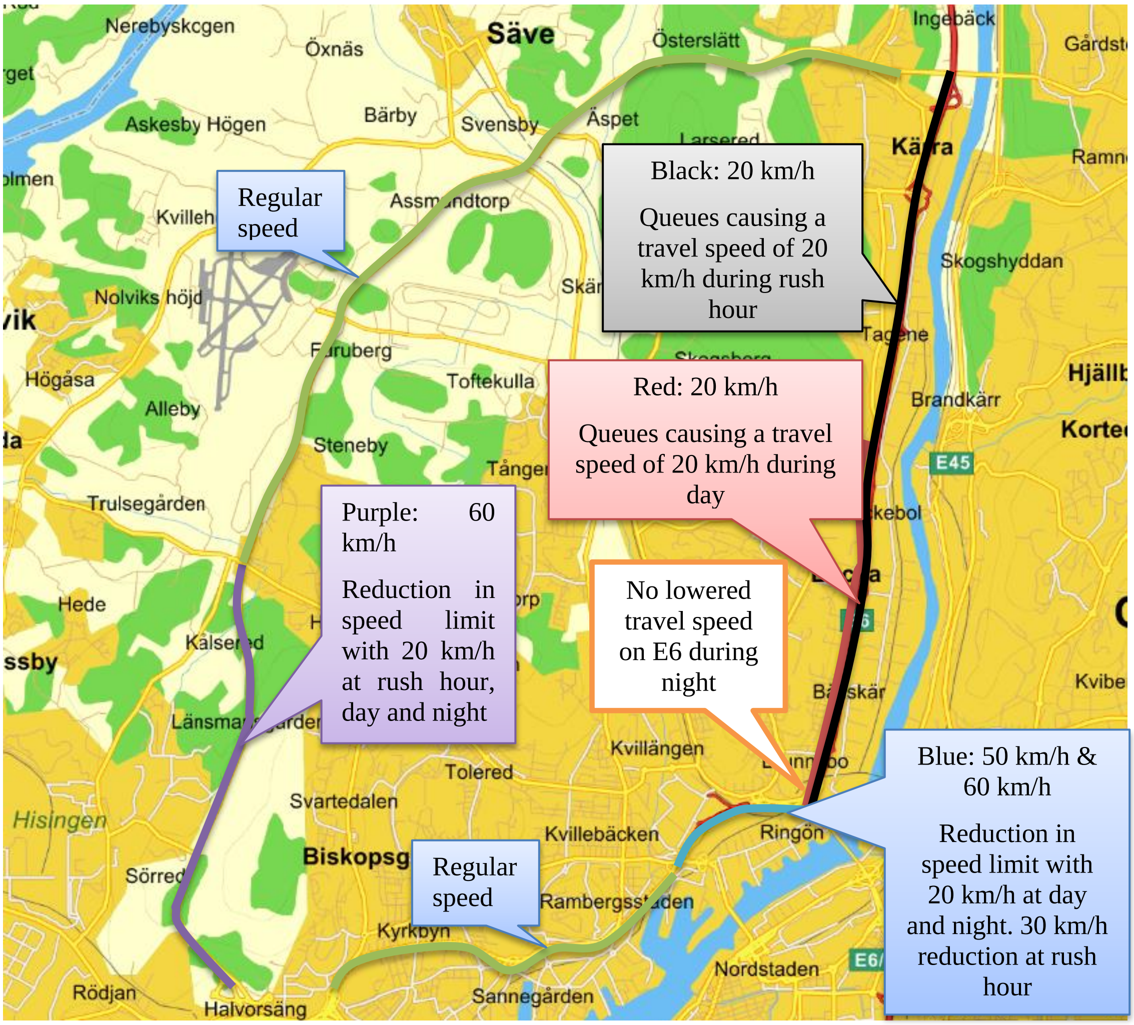


FIGURE 22 SPEED ON HISINGSLEDEN AND LUNDBYLEDEN, BASED ON ENGINEERING JUDGEMENT WHEN APPLYING PREVIOUS CONSTRUCTION PROJECTS IN THE AREA.

On Hisingsleden it is estimated that the speed will be lowered by 20 km/h from 80 km/h to 60 km/h between Björlandavägen and Vädermotet due to the construction of grade-separated intersections and additional lanes. Since the speed was lowered between 10-20 km/h on Söderleden/Västerleden, Lindholmsmotet and E6 it is a reasonable assumption that the speed will be lowered by 20 km/h on Hisingsleden. This assessment is viable since the reconstruction of Hisingsleden will be similar to both the additional bus lanes at E6 and the grade-separated intersection at Lindholmsmotet. However, the lanes at Söderleden/Västerleden were only reduced by 10 km/h but to be conservative the reduction of 20 km/h is used for Hisingsleden.

Lundbyleden will have more extensive construction projects affecting the travel time than Hisingsleden with the connection of the Marieholm Tunnel and the construction of the new road junction at Brantingsmotet. The Marieholm Tunnel will be a point obstruction which will cause queues for an unknown distance on E6 Norr which may cause delays when driving towards Lundbyleden. The new road junction Brantingmotet has a certain stretch with a lower speed limit which also may cause delay.

The speed limit is assessed to be lowered by 20 km/h from 70 km/h to 50 km/h between Ringömotet and Brantingmotet where the new road junction is constructed. However, during rush hour the travel speed is assessed to be lowered by 30 km/h since during rush hour, queues will probably form and it will not be possible to travel in the designated speed. Between Brantingmotet and the west entrance of the Lundbytunnel regular speed will be applied.

When the Marieholm Tunnel is to be connected, large obstructions will be present at E6. No similar project within the area has been investigated in regard to travel speed, therefore an assessment of the travel speed for the Marieholm Tunnel is done. The point obstruction of the connection of the Marieholm Tunnel will cause a point delay at Ringömotet. This delay is estimated to be caused by queues causing lowered speed from Ringömotet to Klarebergsmotet. The assessment is that the travel speed will be 20 km/h between Klarebergsmotet and Ringömotet during rush hour. The distance with the lower speed is halved during the day while during the night the speed is assumed to be the regular travel speed.

A lowered speed can affect the flow and therefore the probabilities in the event tree. According to diagrams from STA, see Appendix A, the flow will not change dependent on speed if the flow is lower than 2000 veh/hr in both directions for a four-lane road like Lundbyleden (Swedish Transport Administration, 2000). For Hisingsleden a linear relation exist and it is possible to calculate the new flow with this relation. In the master's thesis curve S3 has been used and since the speed limit on Hisingsleden is 80 km/h an interpolation has been performed between the diagrams of 70 km/h and 90 km/h for a two-lane road.

The key difference between Alternative 2 and Alternative 0 is the traffic flow, which would have the largest influence on the risk of delay.

5.3 Step 3: Compilation of statistical input data

The input data for the risk model is retrieved and/or calculated by different means and are described in this chapter.

5.3.1 Road information - NVDB

To determine the road standard it is possible to use NVDB, the national road database (NVDB, 2014). The database is designed like a map where it is possible to retrieve information about road classification, speed limits, safety barriers, amounts of lanes etc.

According to NVDB Hisingsleden is an ordinary road with a total road width between 10 m and 22 m. The speed limit varies between 70 km/h and 80 km/h for Hisingsleden and on Lundbyleden the speed limit is constant of 70 km/h, see Figure 23. Lundbyleden on the other hand has freeway standard with a total road width between 17 m and 25 m.

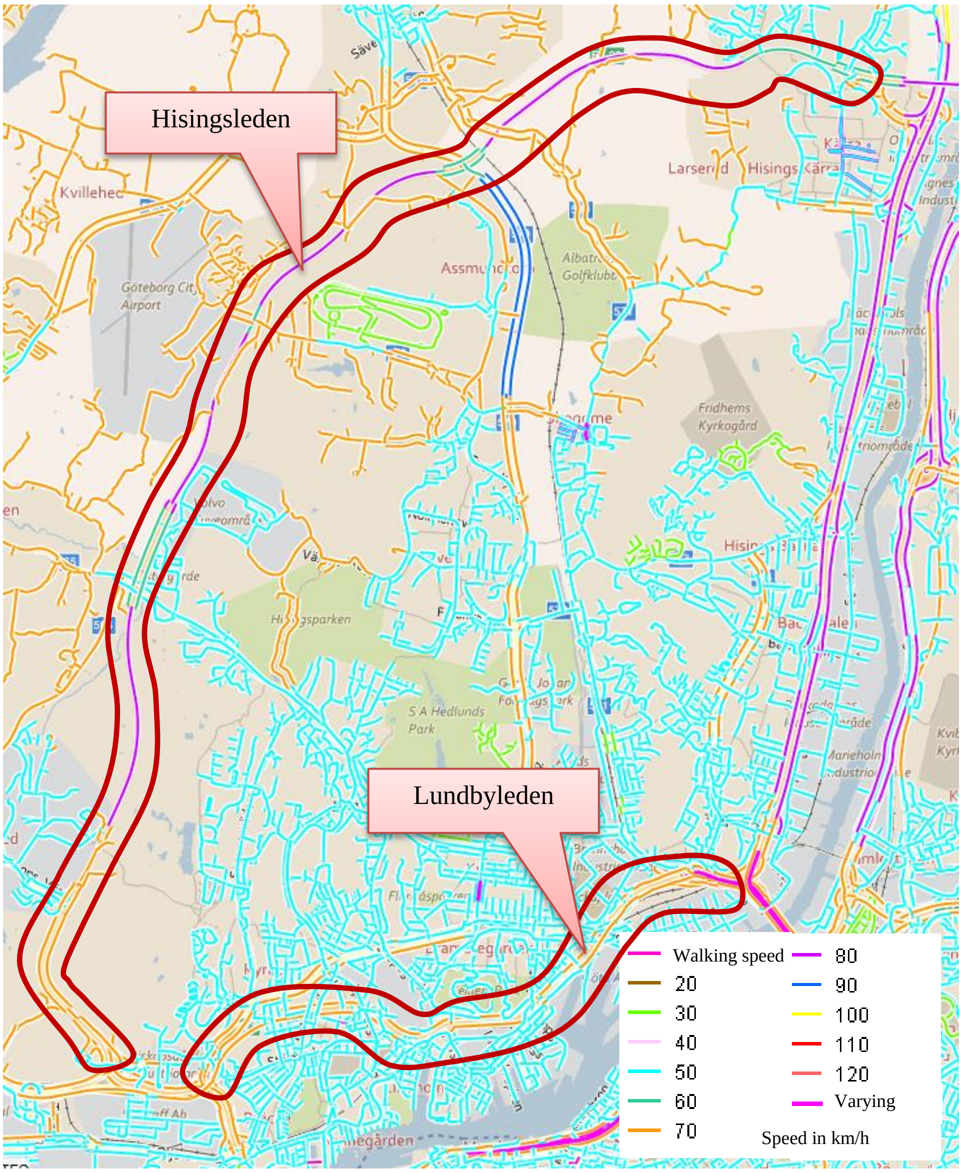


FIGURE 23 SPEED LIMIT FOR HISNGSLEDEN AND LUNDBYLEDEN (NVDB, 2014).

5.3.2 Traffic flows on Hisingsleden and Lundbyleden

On the STA website it is possible to retrieve information regarding the traffic flow on the public road network in Sweden (Swedish Transport Administration, 2013e). There are two different types of maps that display the flows in different ways, the TIKK and the TFK. The TIKK map shows the type of traffic flow and the actual flow with different types of symbols and tables. The TFK map on the other hand presents the measurements directly in the map with bars of different size which displays the amount of traffic.

Trafikkontoret also measures traffic flows on different roads in Gothenburg city (Trafikkontoret, 2013a). The flows are presented in a table where the traffic is divided into different groups such as the total amounts of traffic and the heavy traffic.

The TIKK and TFK traffic flows are stated in AADT (Trafikkontoret, 2013a) while the flows from Trafikkontoret are presented in average weekday (Swedish Transport Administration, 2013e). Both the values from STA and Trafikkontoret are based on only a few measurements and it is important to notice that this creates an uncertainty with the values. If the traffic flows from STA are recalculated into average weekday the flows from Trafikkontoret are generally higher, see Appendix B.

The traffic flows in the risk model are separated in to measurements from Lundbyleden and Hisingsleden. The flows are mean values for average weekday, therefore data during weekends or holidays are not accounted for. The data is compiled from TIKK and is based on flow variation during different days of the year. The flow variation is used since variation will be required for the risk model instead of mean values for one day which is also possible to retrieve from TIKK.

Traffic flows compiled from the STA website are from year 2010 and 2011 for Hisingsleden and Lundbyleden respectively. Measurements are made approximately every fourth year and more recent measurements are hence not available. Congestion charges were implemented in Gothenburg in 2013 and the traffic flows decreased at first, however the reduction was not permanent. Therefore, it is difficult to predict traffic flows in the future due to the implementation of congestion charges. For this reason the most recent measurements available are used in the risk model.

Mean values for traffic flows in the North-South direction on Hisingsleden and the East-West direction on Lundbyleden are used since the master's thesis only focus on goods transports to the industrial area in the western part of Gothenburg. The traffic flows to the industrial area are chosen due to the assumption that the reliability in time is more important to the industries than from. To be conservative the model uses average weekday traffic flows since these flows are higher and more accurate to the modelled situation than the AADT. The AADT flow includes weekends, which has significantly lower traffic flows, both regarding private transports and heavy transports, than the weekdays.

Since the rerouting only is in theory the assumption is that the share of heavy goods transports will be exactly the same for Alternative 1 and 2 as for Alternative 0.

Hisingsleden

The average weekday flows for Hisingsleden is presented in Table 1 with the mean values of total flow and the heavy vehicle flow separated into rush hour, day and night.

TABLE 1 AVERAGE WEEKDAY TRAFFIC FLOW FOR HISINGSLEDEN FROM THE NORTH TO THE SOUTH.

	Average weekday traffic flow (N-S)	
Time of the day	Total traffic, mean	Heavy traffic, mean
Rush hour	15028	1541
Day	9798	1627
Night	2673	297

From the traffic flow variation on Hisingsleden it is possible to separate total flow and the flows in the north-south and south-north directions. Since this master's thesis only considers traffic to the industrial area the traffic variation from the North to the South will be considered. The mean traffic flow variation during one day from the North to the South at Hisingsleden year 2010 indicates high peaks in the morning and in the afternoon, see Figure 24.

The traffic flows were measured at five different points at between three to eight times during the year depending on measuring point and type of measurement.

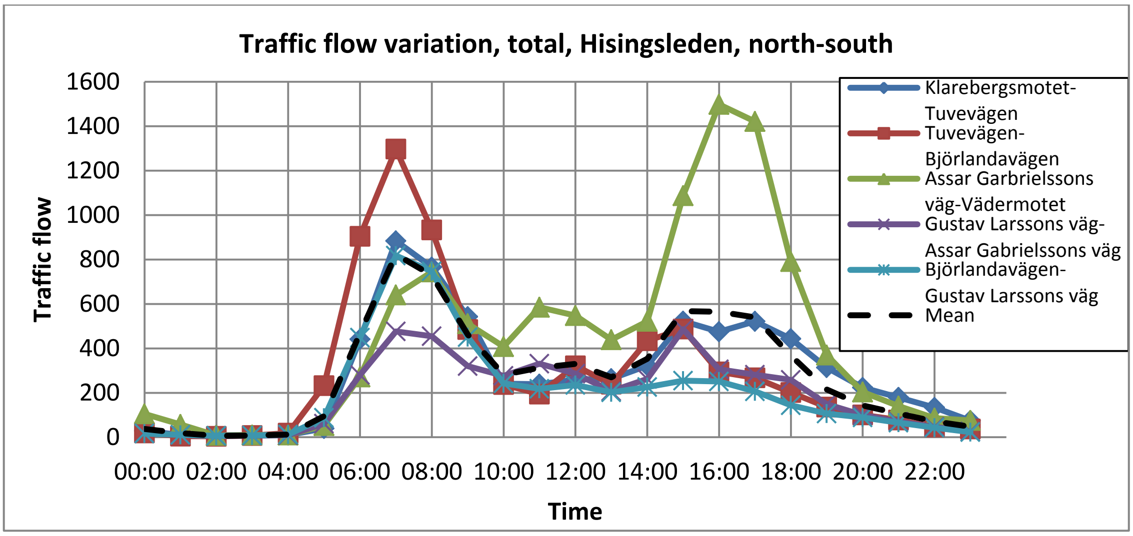


FIGURE 24 THE MEAN TRAFFIC FLOW VARIATION FOR AN AVERAGE WEEKDAY IN THE NORTH-SOUTH DIRECTION ON HISINGSLEDEN, DIVIDED INTO DIFFERENT STRETCHES.

Lundbyleden

The traffic flow measured at Lundbyleden only has values in both directions and it is not possible to distinguish the flow in only one direction. The mean average flow in the East-West direction on Lundbyleden was estimated by dividing the total traffic flow with number of directions, see Table 2 and Figure 25. The traffic flows are retrieved from three different measuring points at six to seven different times during 2011 depending on measuring point and type of measurement.

TABLE 2 AVERAGE WEEKDAY TRAFFIC FLOW FOR LUNDBYLEDEN IN ONE DIRECTION.

Time of the day	Average weekday traffic flow (E-W)	
	Total traffic, mean	Heavy traffic, mean
Rush hour	22901	2519
Day	18100	3066
Night	12879	458

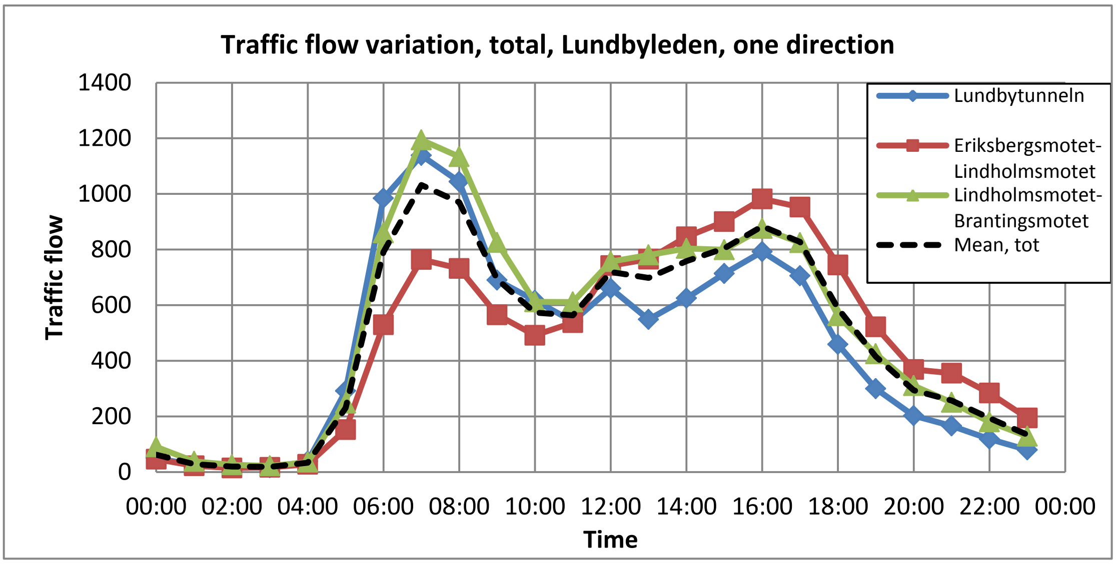


FIGURE 25 THE TRAFFIC FLOW VARIATION FOR AN AVERAGE WEEKDAY IN BOTH DIRECTIONS ON LUNDBYLEDEN, DIVIDED INTO DIFFERENT STRETCHES IN ONE DIRECTION.

5.3.3 Road accident event statistics – STRADA and NTIS

In this master's thesis the accidents are divided into two groups, accidents causing a narrower road and accidents causing a completely blocked road in traffic. There are two different databases to compile relevant accident data from: The Swedish Traffic Accident Data Acquisition (STRADA) and the NTIS. STRADA includes all types of accidents while the NTIS database only considers completely blocked road accidents.

STRADA is a GIS-based system to store information about traffic accidents and the type of injury in Sweden (Swedish Transport Agency, 2012). The accident event statistics include information about type of accident, degree of damage, position, numbers and types of vehicles involved etc. The different types of accidents are private cars, trucks (heavy, light and unknown), buses, motorcycles, mopeds, bicycles, pedestrians and all-terrain vehicles. The accident data is retrieved between year 2009 and 2013 along with the completely blocked road accident data.

STRADA compiles input information from the police and most of the emergency hospitals (Swedish Transport Agency, 2012). To be able to separate if accidents reported from the police and the hospitals are the same a quality measure has been implemented (VTI, 2005). The values in the quality measure range between 0-100 and if the value is 70 and above it is assumed the police reported accident and the hospital accident is the same. However, emergency hospitals do not collect information about type of involved vehicles and number of vehicles. STRADA does not take into account accidents which are not reported to the police and/or the hospitals.

In this master's thesis only accident event statistics from the police are used since emergency hospitals does not collect information about type of involved and number of vehicles (Swedish Transport Agency, 2012). On Hisingsleden approximately 32 percent of the accidents are input information from the emergency hospitals. Similarly the share of emergency hospitals reports on Lundbyleden is 20 percent. There are also accidents which there are no records of, and since the accidents are not reported to either the hospital or police it is assumed that the delay time caused by them are less than 30 minutes and hence not affecting the input data for the risk model.

Information about traffic accidents for the stretches Hisingsleden and Lundbyleden are retrieved during 2009-01-01 – 2013-12-31 from STRADA. To be able to assess the amount of accidents each weekday, an assumption is made that the same number of accidents occurs each year and in each direction.

From the NTIS database it is possible to extract completely blocked road statistics in regard to accidents. The statistics are from year 2009-01-01 – 2013-12-31 for Hisingsleden and Lundbyleden. The data is based only on incidents caused by accidents and where there is no chance of diverting the traffic to take another route (Movea, 2013a).

It is assumed that an accident causing a delay of less than 30 minutes does not affect the result in the master's thesis. Therefore, the completely blocked road accidents causing a delay less than 30 minutes are not included in the input data. The duration of a completely blocked road accident is assumed to be the same regardless of the change in traffic flow.

An assumption has been made that the increase of weekday traffic accidents increase with the weekday flow with the same relation as the AADT accidents increase with the AADT flow. Furthermore, it is assumed that the increase in completely blocked road accidents have the same relation as the AADT accidents.

5.4 Step 4: Calculation and retrieval of probability and consequence

The procedure how to obtain probability for certain events and the consequence for the events is described in the following chapter.

5.4.1 Probability of different events

The probabilities for different events are divided into five parts in the master's thesis: transports during different time periods of the day, accidents, contaminant release, completely blocked road and delay time which is presented in the section below.

Probability of a transport during different time periods of the day

To estimate the probability of a transport happening at a certain time of the day the frequency approach is used. By dividing the number of transport occurring during the specific time period with the total number of transport the probability of a transport is achieved.

Probability of a private vehicle accident and a heavy vehicle accident

In order to assess the probability of a private vehicle accident and a heavy vehicle accident per day, accident event statistics are used with the frequency approach. The approach is used to calculate the probability of a specific accident by dividing the number of accidents with the total number of accidents. In the case with a completely blocked road the number of completely blocked road accidents is divided with the total number of accidents.

Probability of an accident with dangerous goods and the probability of contaminant release

A transport with dangerous goods are often transported with heavy trucks and the probability of contaminant release due to an accident with a pedestrian, bicycle or an animal is low (Swedish Rescue Services Agency, 1996). However, the probability of an accident with dangerous goods is higher if there is a collision or if the truck is pulling of the road. Therefore, the probability of an accident with dangerous goods often neglects accidents with low probabilities. A dangerous goods accident is defined as an accident with dangerous goods where the contaminants from the goods are released.

To calculate the probability of an accident with dangerous goods the road is usually divided into sections with similar road standard, road type etc. (Swedish Rescue Services Agency, 1996). These sections are often separated by larger intersections. If accident statistics are not available for each section, the accident ratio from the matrix in Appendix C is used.

There are three main steps in calculating the probability of an accident with dangerous goods (Swedish Rescue Services Agency, 1996):

1. Assess the AADT
2. Assess the number of single-car and collision accidents during one year
3. Assess the number of signposted dangerous goods transports per day

Step 1 includes identifying the average amount of vehicles passing the road on a weekday during a year (Swedish Rescue Services Agency, 1996).

To assess the number of single-car and collision accidents in step 2 there are two alternatives (Swedish Rescue Services Agency, 1996). The first alternative considers available accident statistics during several years, for example from STRADA. To secure an accurate result, the total number of accidents should be at least 30 and preferable more than 50. The second alternative considers an accident ratio retrieved from a matrix for accidents with dangerous goods depending on type of area, road standard and road type, see Appendix C. If the difference in result between alternative 1 and alternative 2 is large, alternative 2 should be chosen if accident statistics is insufficient and alternative 1 should be chosen if accident statistics is sufficient and available from several years.

Step 3 includes specifying the number of signposted dangerous goods transports passing the road every day. The amount of signposted vehicles is often based on field studies or information from the conveyors.

To calculate the number of vehicles signposted with dangerous goods in an accident per year Equation 4 is used.

$$\begin{aligned} &Number\ of\ vehicles\ signposted\ with\ dangerous\ goods\ in\ accidents\ per\ year \\ &= O((Y * X) + (1 - Y)(2X - X^2)) \end{aligned} \tag{4}$$

Where
O = number of accidents on the road per year (excluding accidents involving pedestrians, cyclists and animals)
Y = Share of single-car accidents
X = Share of transports signposted with dangerous goods

To achieve the number of dangerous goods accidents per year, the number of vehicles signposted with dangerous goods in accidents per year is multiplied with the probability (index) of contaminant release, see Appendix C.

The model for calculating the probability of a dangerous goods accident do not take into consideration the type of the dangerous goods being transporter or the amount of dangerous goods (Swedish Rescue Services Agency, 1996).

It is possible to modify the model only to consider weekdays by only using the traffic flows and accidents for weekdays (Swedish Rescue Services Agency, 1996). The traffic work (vehicle kilometres a year) is multiplied by 5/7 to represent the traffic work for a weekday while the accidents will only consider accident during weekdays. If the matrix approach is used the values are not affected.

The probability of contaminant release due to an accident with a pedestrian, bicycle or an animal is low, therefore these types of accidents are not included when calculating the probability of an accident with dangerous goods.

<u>Dangerous goods on Hisingsleden and Lundbyleden</u>

Hisingsleden is divided into four parts, each part characterised by a the difference in speed limit. The speed limit on Hisingsleden varies between 60 and 80 km/h. However, the matrix used when achieving the probability for contaminant release and the accident ratio for each stretch only considers speed limits that vary between 70 and 90 km/h. Therefore, depending on the length of the speed limits stretches, they have different weight when interpolating the accident ratio and the probability of contaminant release.

The computational matrix also considers whether the road is situated in a rural or urban area. It is assumed that Hisingsleden is situated in a rural area. Furthermore, the roads are characterised as ordinary roads either wider than 8 meters or narrower than 8 meters. When calculating the accident ratio, it is important to distinguish between wider or narrower roads than 8 meters. However, when calculating the probability of contaminant release the probability is the same regardless of if the road is wider or narrower than 8 meters.

On Lundbyleden dangerous goods are only allowed to travel between Ringömotet and Brantingmotet. The road between the two grade-separated intersections has a speed limit of 70 km/h and is defined as a freeway with urban area surrounding it.

The number of signposted dangerous goods transports per day must be known in order to proceed with the calculations. However, to spend time on this by doing a field study is too extensive. Instead, a recently made risk analysis for dangerous goods on Hisingsleden is used for accurate values on Hisingsleden (Cowi, 2011). In the report from the technical consultant Cowi it is assumed, based on statistics and assumptions, that the share of dangerous goods transports at Hisingsleden is four percent of the AADT. However, the traffic flow in the risk model is based on the average weekday flows but the same assumption of four percentages will be made for these flows. No information for Lundbyleden is accessible and therefore the value of three percent based on the information from Swedish Rescue Services Agency (1996) is applied.

In this master's thesis the computational matrix for dangerous goods accidents is used instead of the accident statistics since the numbers of accidents are less than 30 in most cases. The probability of a completely blocked road at a dangerous goods accident is assumed to be 100 percent if contaminants are released while if there is no contaminant release the probability is the same as the private and heavy vehicle accidents.

Probability of a completely blocked road

To estimate the probability of a completely blocked road the frequency approach is applied for all events expects when there is a contaminant release with dangerous goods transport. In this case the Bayesian approach is used where it is assessed that there will always be a completely blocked road if these chain of events occur.

Probability of delay

The probability of delay is based on the Bayesian approach where the probability is estimated by an expert[8].

5.4.2 Consequence of different accident events

The consequence can either be based on completely blocked road accidents or non-completely blocked road accidents. The consequence for a completely blocked road accident is based on the time it takes to clear away an accident and to dissolve a queue. For a non-completely blocked road accident it depends on the arrival and departure rate. The two different types of consequences will be presented below.

To be able to assess the risk of delay in regard to time, the time to clear away an accident has to be estimated. An expert in risk in regard to delay time has assisted to estimate the time it takes to clear away an accident. These numbers are approximate and are based on experience. The time to clear away an accident with dangerous goods, both with and without contaminant release, only considers a transport with petroleum.

[8] Håkan Alexandersson former worker at Swedish Rescue Agency Services, telephone interview 2014-02-25.

Completely blocked road

To estimate the consequence for a completely blocked road, the duration of a completely blocked road accident is required and is retrieved from the NTIS database and then the total queue time is procured by calculation. When calculating the queue time the capacity of the road or limiting intersections is required.

<u>Calculation of capacity in intersections</u>

Capcal is a computer program where it is possible to calculate the capacity and accessibility in intersections (Trivector, 2013a). The Capcal version (v.3.3.0.4) used in this master's thesis is not the recent one, since there is a bug in the latest version when applying the program at the intersections in the master's thesis. The result from Capcal includes capacity, saturation level, delay times and queue lengths. The input data is divided into different sheets: geometry, traffic flows and traffic signals.

The geometry sheet includes information about type of intersection, speed limit, number of lanes, lane width and restricted lane length, allowed turn directions, distance to stop line, left turn queue without blocking and right/left turn queue after stop line (Trivector, 2013a). Furthermore information about the crossings can be put into the geometry sheet. In the traffic sheet the traffic volume is specified with number of heavy vehicles, pedestrian volume among others (Trivector, 2013b). To produce an accurate intersection the different signal times are inserted into the traffic signal sheet where green time, safety time and such are defined. In some cases if input data is unavailable it is possible to use standard values in the traffic signal sheet which are described in the Capcal user manual from Trivector (2013b).

To be able to decide upon different scenarios the capacity on Hisingsleden has to be estimated in order to assess the amount of vehicles that can be transferred to the road. A risk analysis, *Genomförbarhetsstudie, södra Hisingsleden*, has been performed on Hisingsleden, in order to investigate the capacity (Swedish Transport Administration, 2013c). Two intersections with lower capacity were investigated in depth: the intersections at Assar Gabrielssons väg/Hisingsleden and Björlandavägen/Hisingsleden. According to the risk analysis performed by STA these intersections will limit the capacity on Hisingsleden, therefore these will be further investigated in Capcal. In this master's thesis input data required for each intersection in Capcal are based on values from the same report. The used traffic flows from *Genomförbarhetsstudie, södra Hisingsleden* range somewhere between the mean value for the rush hour from STA and the maximum value for the rush hour from STA. Therefore it seems reasonable to use these values.

The national road database, NVDB, is used to compile information about speed limit. To retrieve remaining information in the geometry sheet, satellite maps from the websites Eniro and Google are used.

In the traffic flow sheet information about traffic flows in each lane and direction needs to be inserted. Traffic flows from one hour in the morning (07:00-08:00) and one in the afternoon (16:00-17:00) during October 2012 are used for the intersection at Björlandavägen/Hisingsleden, see Figure 26 (Swedish Transport Administration, 2013c).

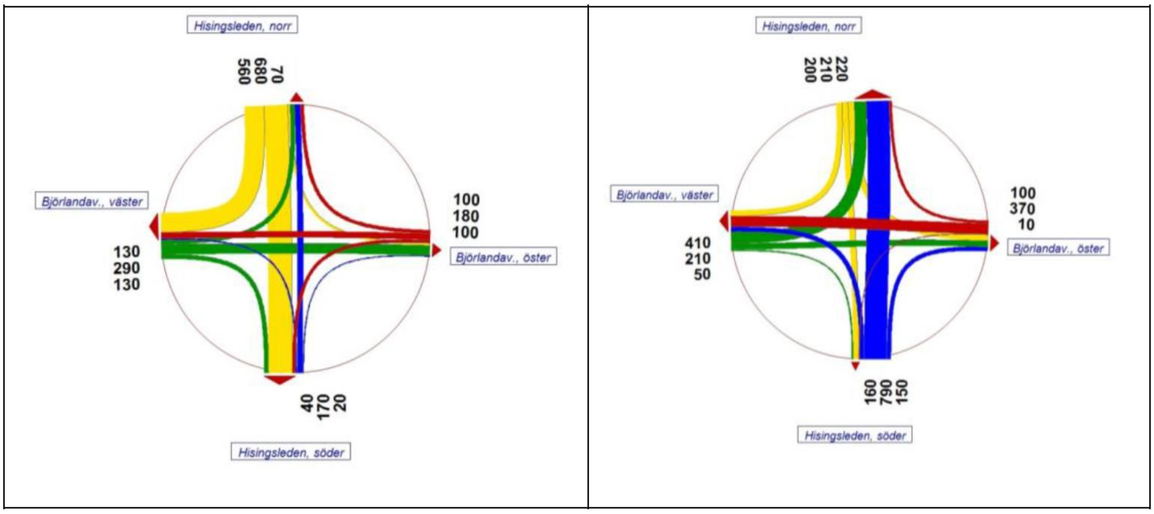


FIGURE 26 TRAFFIC FLOWS FROM ONE HOUR IN THE MORNING (07:00-08:00 TO THE LEFT) AND ONE HOUR IN THE AFTERNOON (16:00-17:00 TO THE RIGHT) DURING OCTOBER 2012 (SWEDISH TRANSPORT ADMINISTRATION, 2013C).

At the intersection at Assar Gabrielssons väg/Hisingsleden traffic flows from 2010 in the afternoon (16:00-17:00) are used (Swedish Transport Administration, 2013c). However, the traffic flows at the intersection Assar Gabrielssons väg/Hisingsleden are not diverted on different lanes and turning directions, therefore an engineering judgement of the traffic flows together with experts[9] within the field is made, see Figure 27, original flows in Appendix D.

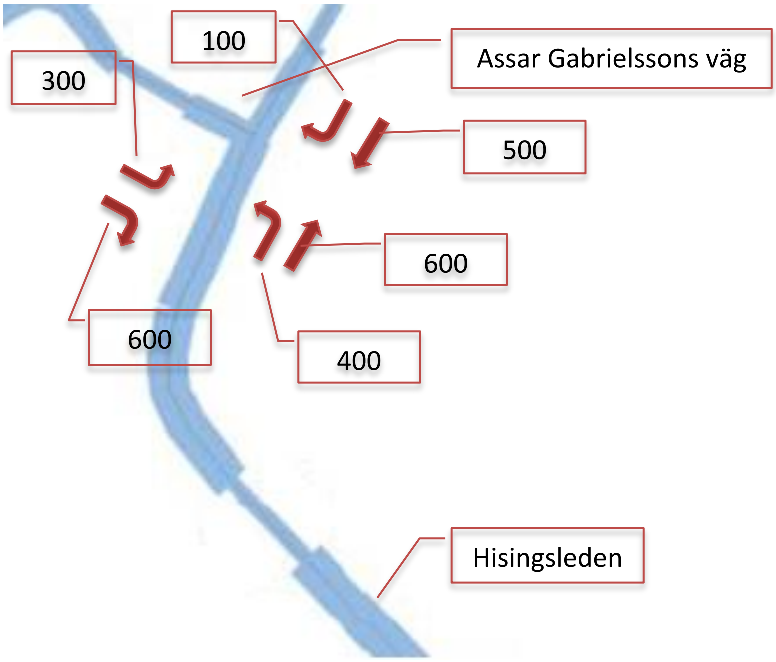


FIGURE 27 THE INTERSECTION AT ASSAR GABRIELSSONS VÄG/HISINGSLEDEN WITH TURNING FLOWS IN VEHICLES PER HOUR (AFTER THE SWEDISH TRANSPORT ADMINISTRATION, 2013C)

The percentage of heavy traffic is also included in the traffic flows sheet, which are retrieved from TIKK. An assumption is made that the percentage of heavy traffic is the mean value of the stretches south and north of the intersection. The same percentage of heavy traffic from each direction is assumed in Capcal.

[9] Pernilla Sott and Johanna Rödström coordinators for commuters main routes Cowi, meeting 2014-03-14

Input data in the traffic signals sheet includes information about the traffic phases where all times were standard values since this data was unavailable.

The result from Capcal in the form of capacity is based on several assumed input values, therefore the capacity from Capcal should be rounded off. It is common to round off to closest ten, 50 or 100.

The results from the capacity calculation in the intersections Assar Gabrielssons väg/Hisingsleden and Björlandavägen/Hisingsleden from Capcal can be found in Appendix E. The capacity calculations for the two intersections are performed at two different time periods. The time periods are selected when the highest flow is occurring.

Queue growth and time to dissolve a queue

The queuing time at a completely blocked road can according to Movea (2013b) be assessed by knowing the traffic flow (q), capacity (cap), saturation level (B), queue time (t) and duration of a completely blocked road accident (A). To determine the time it takes for the queue to assemble and dissipate for completely blocked road accidents Equation 5 and 6**(6** is used.

$$B = \frac{q}{cap} \tag{5}$$

$$t = \frac{A}{2} \times (1 + B) \tag{6}$$

For private and heavy traffic during a completely blocked road, statistics of the duration of a completely blocked road is used. However, for dangerous goods no statistics are available and therefore the same situation is applied as for a non-completely blocked road accident. Hence, the assessment by experts is used.

Non-completely blocked road

If the queue is caused by an incident that creates a partly blocked road it is possible to determine the queuing time by estimating the arrival and departure rate (Mannering & Washburn, 2013). If a queue forms the dissipation of a queue occur when the arrival and departure curve intersects.

5.5 Step 5: Logic model

In order to perform a risk analysis a logic model, in the form of an event tree is developed. The logic model is made in Microsoft Excel and an example of the event tree is shown in Figure 28.

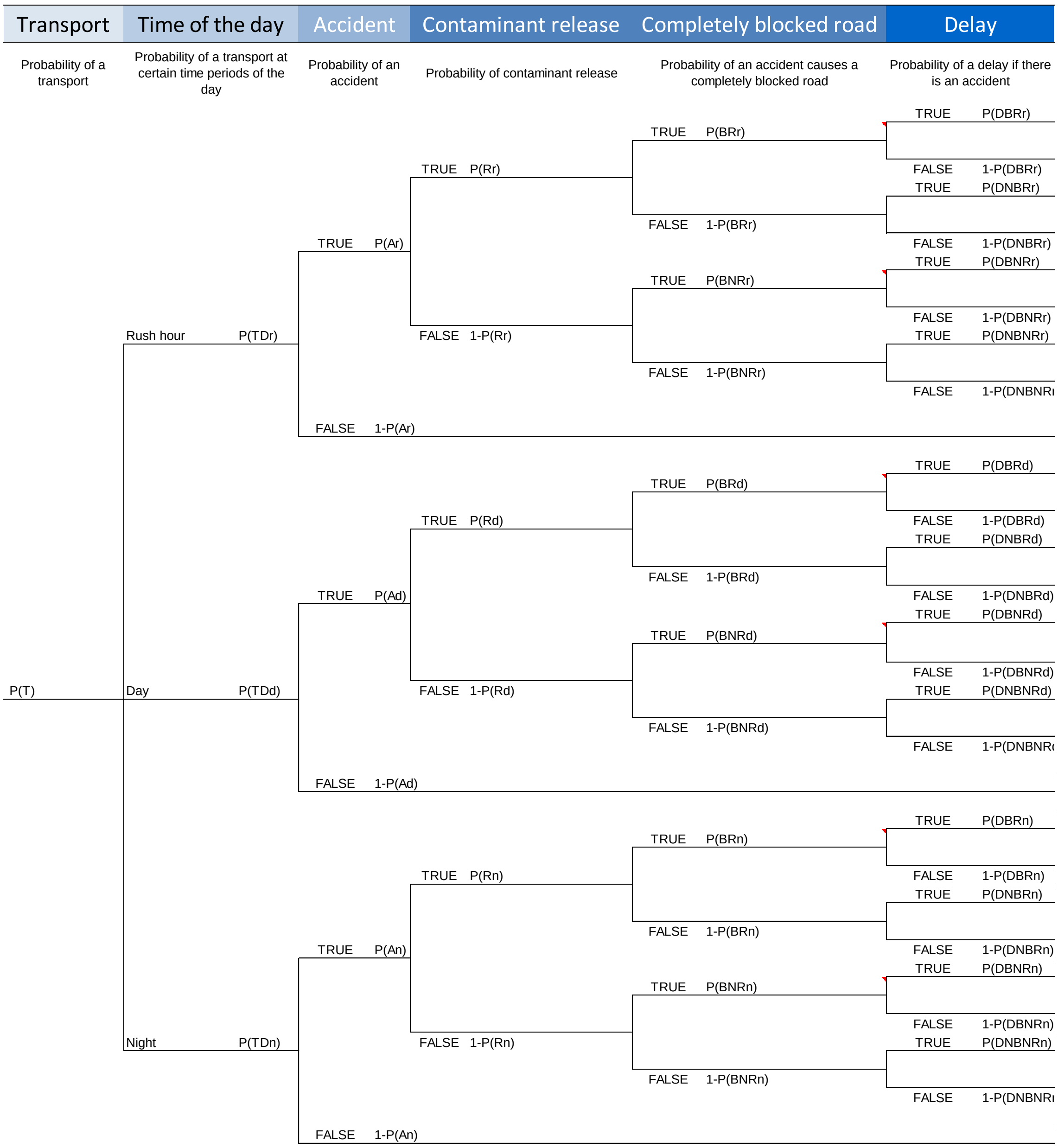


FIGURE 28 SCHEMTATIC PICTURE OF THE EVENT TREE USED IN THE RISK ANALYSIS.

There are abbreviations in Figure 28 where Table 3 shows the explanations of the abbreviations.

TABLE 3 ABBREVIATIONS AND THEIR EXPLANATIONS.

Abbreviation	Explanation	Abbreviation	Explanation
T	Transport	D	Delay
TD	Time of the day	r	Rush hour
A	Accident	d	Day
R	Contaminant release	n	Night
B	Completely blocked road	N	None

The event tree is developed from the left to the right and the first step is to determine the probability of a transport, which always is 1. Hence, the probability of a transport is 100 percent. The risk model is divided into different time periods of the day and the share of transports during different time periods is then determined from statistics of the flow variation. The probability of an accident during the time periods is calculated from statistical data by dividing the number of accident during the specific time period with the total number of accidents during one day. When performing a risk model considering accidents with dangerous goods, whether a contaminant release occurs or not are considered. An accident can either cause a completely blocked road or not. Finally, the event tree considers if there will be delay or not.

5.6 Step 6: Uncertainty analysis

In order to perform an uncertainty analysis an assessment of the distribution and variation of the specific input parameter needs to be executed. A triangular distribution is chosen for all cases except for the relation between traffic flow and accidents where a normal distribution is used. A triangular distribution is used both in order to make a simple model but also since the input data are limited and the maximum and minimum values can be compiled from available statistics (Swedish Road Administration & Swedish Rescue Service Agency, 1998). In the Monte Carlo simulations, 10 000 trials have been performed in order to represent uncertainties in input parameters.

Assumptions for the input parameters for the uncertainty analysis are described below.

<u>Traffic flow:</u> A triangular distribution is used for the traffic flow. The maximum and minimum values were retrieved from the data acquired, see Appendix F for actual values. The most extreme values from each stretch are used as maximum and minimum values.

<u>Accidents:</u> A triangular distribution is used for the number of accidents. The maximum and minimum values were retrieved from the data acquired, see Appendix F for actual values. The most extreme values from one year in the specific time period are used as maximum and minimum values.

<u>Completely blocked road accident:</u> A triangular distribution is used for the number of completely blocked road accidents. The maximum and minimum values were retrieved from the data acquired see Appendix F for actual values. The most extreme values from one year in the accurate time period are used as maximum and minimum values.

Triangular distribution for the duration of the accidents will be used.

A triangular distribution is used for the probability of a completely blocked road accident for dangerous goods when there is a contaminant release. The range is between 0.9 and 1.0 and a mean value of 1.0 is assumed. The maximum value cannot exceed 1.0 therefore the mean value and maximum value is the same.

<u>Probability of delay:</u> The probability distribution for the delay during rush hour has a range between 0.9 and 1.0 with a triangular distribution. The maximum value cannot exceed 1.0 therefore the mean value and maximum value is the same.

For the probability of delay for day and night the values range between 0.6-0.8 and 0.4-0.6 in a triangular distribution.

<u>Probability of contaminant release:</u> A triangular distribution is used for the probability of contaminant release with a range between 0.15 and 0.215 for Hisingsleden and a range between 0.08 and 0.18 for Lundbyleden.

Consequence: The private vehicle accidents have a triangular distribution with a range of 0.75-2 hours with a mean of 1 hour according to an expert[10] while the heavy vehicle accidents has a triangular distribution with a range of 2-4 hours with a mean of 3 hours according to the same expert.

The consequences of restoring a dangerous goods accident have triangular distributions with an assumed range of 6-10 hours with no contaminant release and a range of 13-19 hours with contaminant release. The range increases with the severity of the consequence since this pattern appear between the private and heavy vehicle accidents.

Cost: The cost is assumed to have a triangular distribution with the mean value as 700 SEK and minimum and maximum values to be 273 SEK and 819 SEK.

Share of dangerous goods transports: A triangular distribution is used for the share of dangerous goods transports with a range between 0.01 and 0.10.

Reduced speed: The reduced speed will have a triangular distribution with a range of 15-25 km/h with 20 km/h as mean for Hisingsleden. On Lundbyleden a triangular distribution is also assumed with a range of 15-25 km/h with 20 km/h as mean during day and night, while during rush hour a range of 20-40 km/h with a mean value of 30 km/h is assumed.

Relation between traffic flow and accidents: A normal distribution is used for this parameter since the confidence intervals for the relation was possible to obtain.

[10] Håkan Alexandersson former worker at Swedish Rescue Agency Services, telephone interview 2014-02-25.

6 Input data for the risk model

In this section the input data for the risk model for Alternative 0, 1 and 2 will be presented. For a description of the three alternatives see section **Error! Reference source not found.**.

6.1 General input data

The general input data that is valid for all alternatives and are shown in Table 4, Table 5 and Table 6.

TABLE 4 SHARE OF DANGEROUS GOODS TRANSPORTS, PROBABILITY OF CONTAMINANT RELEASE AND COST FOR A TRUCK TO BE DELAYED.

	Hisingsleden	Lundbyleden
Share of dangerous goods transports	4%	3%
Probability of contaminant release	0.199	0.130
Cost for a goods transport to be delayed [SEK]	700	700

TABLE 5 PROBABILITY OF DELAY FOR A NON-COMPLETELY BLOCKED ROAD DURING RUSH HOUR, DAY AND NIGHT FOR PRIVATE VEHICLES, HEAVY VEHICLES AND DANGEROUS GOODS[11].

Time of the day	Probability of delay
Rush hour	1.0
Day	0.7
Night	0.5

TABLE 6 TIME TO CLEAR AWAY AN ACCIDENT DEPENDENT ON TYPE OF ACCIDENT[12].

Type of accident	Time to clear away an accident [hrs]
Private vehicle	1.0 (0.75-2.0)
Heavy vehicle	2.0-4.0
Dangerous goods, no contaminant release	8.0
Dangerous goods, contaminant release	16.0

The time to clear away a private vehicle accident can range between 0.75-2.0 hours, however the mean value is one hour. For heavy vehicles the mean value ranges between two to four hours.

The probability of contaminant release for a dangerous goods transport on Hisingsleden will be an average value of the different road stretches of 0.2. On Lundbyleden an average value of the different road sections of 0.13 is used. Average values are used since the risk model is not divided into different road stretches.

[11] Håkan Alexandersson former worker at Swedish Rescue Agency Services, telephone interview 2014-02-25.
[12] Håkan Alexandersson former worker at Swedish Rescue Agency Services, telephone interview 2014-02-25.

The non-completely blocked road events only appear at Lundbyleden, according to the completely blocked road definition, since there are two lanes in each direction which enables a partly blocked road. Hisingsleden consists only of one lane in each direction, which would always result in a completely blocked road according to the definition in this master's thesis. However, the statistics indicates that there are accidents where there are partly blocked road which should be considered. It is assumed that the expert assessments regarding probability of delay also corresponds to this scenario.

Both at Hisingsleden and Lundbyleden the arrival rate is lower than the departure rate, hence there will not appear any queues during a non-completely blocked road event.

6.2 Alternative 0 - Present situation

The input data for Alternative 0, for both Hisingsleden and Lundbyleden is presented in this section.

Hisingsleden

The traffic flow, the number of accidents and completely blocked road accidents for Hisingsleden are shown in Table 7.

TABLE 7 THE TRAFFIC FLOW, THE NUMBER OF ACCIDENTS AND COMPLETELY BLOCKED ROAD ACCIDENTS IS OF AN AVERAGE WEEKDAY IN ONE DIRECTION FOR HISINGSLEDEN.

Time of the day	Traffic flow		Number of accidents		
	Total	Heavy traffic	Private vehicle	Heavy traffic	Completely
Rush hour	15 028	1 541	0.0085	0.0008	0.0023
Day	9 798	1 627	0.0023	0.0019	0.0039
Night	2 673	297	0.0035	0.0004	0.0008

The probabilities of a private vehicle, heavy vehicle and dangerous goods accident, and the probability of a completely blocked road for Hisingsleden are shown in Table 8.

TABLE 8 PROBABILITIES OF A PRIVATE VEHICLE, HEAVY VEHICLE AND DANGEROUS GOODS ACCIDENT, AND THE PROBABILITY OF A COMPLETELY BLOCKED ROAD ACCIDENTS FOR HISINGSLEDEN.

	Probability of a transport			Probability of an accident			
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Completely blocked road*
Rush hour	0.56	0.44	0.44	0.56	0.25	0.0014	0.25
Day	0.34	0.47	0.47	0.34	0.625	0.0016	0.91
Night	0.10	0.09	0.09	0.10	0.125	0.0009	0.2

* When a contaminant release occur the probability of a completely blocked road is 1 during rush hour, day and night.

The duration, queue time and total duration at a completely blocked road event without contaminant release and with contaminant release on Hisingsleden is shown in Table 9 and Table 10 respectively.

TABLE 9 DURATION, QUEUE TIME AND TOTAL DURATION AT A COMPLETELY BLOCKED ROAD WITHOUT CONTAMINANT RELEASE ON HISINGSLEDEN.

	Completely blocked road accident without contaminant release								
Time of the day	Duration			Queue time			Total delay		
	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods
Rush	1.05	1.05	8	1.1	1.1	8.44	2.15	2.15	16
Day	1.05	1.05	8	0.9	0.9	6.9	1.95	1.95	15
Night	1.75	1.75	8	1.05	1.05	4.71	2.8	2.8	13

TABLE 10 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT WITH CONTAMINANT RELEASE FOR A DANGEROUS GOODS TRANSPORT ON HISINGSLEDEN.

	Completely blocked road accident with contaminant release		
Time of the day	Duration	Queue time	Total delay
Rush hour	16	17	33
Day	16	14	30
Night	16	10	26

Lundbyleden

The traffic flow, the number of accidents and completely blocked road accidents for Lundbyleden are shown in Table 11.

TABLE 11 THE TRAFFIC FLOW, THE NUMBER OF ACCIDENTS AND COMPLETELY BLOCKED ROAD ACCIDENTS IS OF AN AVERAGE WEEKDAY IN ONE DIRECTION FOR LUNDBYLEDEN.

Time of the day	Traffic flow		Number of accidents		
	Total	Heavy traffic	Private vehicle	Heavy traffic	Completely blocked road
Rush hour	22 901	2 519	0.014	0.0065	0.0031
Day	18 100	3 066	0.005	0.0039	0.0015
Night	12 879	458	0.003	0.0015	0.0008

The probabilities of a private vehicle, heavy vehicle and dangerous goods accident, and the probability of a completely blocked road for Lundbyleden are shown in Table 12.

TABLE 12 PROBABILITIES OF A PRIVATE VEHICLE, HEAVY VEHICLE AND DANGEROUS GOODS ACCIDENT, AND THE PROBABILITY OF A COMPLETELY BLOCKED ROAD ACCIDENT FOR LUNDBYLEDEN.

	Probability of a transport			Probability of an accident			
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Completely blocked road*
Rush hour	0.43	0.42	0.42	0.64	0.55	0.00025	0.15
Day	0.31	0.51	0.51	0.22	0.32	0.00031	0.18
Night	0.26	0.08	0.08	0.15	0.13	0.00016	0.17

The duration, queue time and total duration at a completely blocked road event without contaminant release and with contaminant release on Lundbyleden is shown in Table 13 and Table 14 respectively.

TABLE 13 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT WITHOUT CONTAMINANT RELEASE ON LUNDBYLEDEN.

	Completely blocked road accident without contaminant release								
Time of the day	Duration			Queue time			Total delay		
	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods
Rush	1.31	1.31	8	0.83	0.83	5.06	2.14	2.14	13
Day	2.35	2.35	8	1.42	1.42	4.84	3.77	3.77	13
Night	2.50	2.50	8	1.44	1.44	4.6	3.94	3.94	13

TABLE 14 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT FOR DANGEROUS GOODS TRANSPORTS WITH CONTAMINANT RELEASE ON LUNDBYLEDEN.

	Completely blocked road accident with contaminant release		
Time of the day	Duration	Queue time	Total delay
Rush hour	16	10	26
Day	16	10	26
Night	16	9	25

6.3 Alternative 1 - Rerouting of traffic from Lundbyleden to Hisingsleden

The input data for Alternative 1, for both Hisingsleden and Lundbyleden are presented in this section.

The amounts of total traffic and heavy traffic that can be transferred from Lundbyleden to Hisingsleden are shown in Table 15.

TABLE 15 THE AMOUNTS OF TOTAL TRAFFIC AND HEAVY TRAFFIC THAT CAN BE TRANSFERRED FROM LUNDBYLEDEN TO HISINGSLEDEN.

	Rush hour, per hour	Day, per hour	Night, per hour	Total traffic flow per day
Change in total traffic	0	43	340	4 314
Change in heavy traffic	0	7	19	268

Hisingsleden

The traffic flow, the number of accidents and completely blocked road accidents for Hisingsleden are shown in Table 16.

TABLE 16 THE TRAFFIC FLOW, THE NUMBER OF ACCIDENTS AND COMPLETELY BLOCKED ROAD ACIDENTS IS OF AN AVERAGE WEEKDAY IN ONE DIRECTION FOR HISINGSLEDEN.

Time of the day	Traffic flow		Number of accidents		
	Total	Heavy traffic	Private vehicle	Heavy traffic	Completely blocked road
Rush hour	15 028	1 541	0.0085	0.0008	0.0023
Day	10 829	1 798	0.0025	0.0021	0.0042
Night	10 829	1 203	0.0133	0.0009	0.0028

The probabilities of a private vehicle, heavy vehicle and dangerous goods accident, and the probability of a completely blocked road for Hisingsleden are shown in Table 17.

TABLE 17 PROBABILITIES OF A PRIVATE VEHICLE, HEAVY VEHICLE AND DANGEROUS GOODS ACCIDENT, AND PROBABILITY OF A COMPLETELY BLOCKED ROAD FOR HISINGSLEDEN.

	Probability of a transport			Probability of an accident			
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Completely blocked road*
Rush hour	0.42	0.34	0.34	0.35	0.2	0.0014	0.25
Day	0.28	0.4	0.4	0.10	0.56	0.0016	0.91
Night	0.3	0.26	0.26	0.55	0.24	0.0009	0.20

The duration, queue time and total duration at a completely blocked road event without contaminant release and with contaminant release on Hisingsleden is shown in Table 18 and Table 19 respectively.

TABLE 18 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT WITHOUT CONTAMINANT RELEASE ON HISINGSLEDEN.

	Completely blocked road accident without contaminant release								
Time of the day	Duration			Queue time			Total delay		
	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerou s goods
Rush	1.05	1.05	8	1.1	1.1	8.4	2	2	16
Day	1.05	1.05	8	0.9	0.9	7.2	2	2	15
Night	1.75	1.75	8	1.05	1.05	7.2	3	3	13

TABLE 19 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT FOR DANGEROUS GOODS TRANSPORTS WITH CONTAMINANT RELEASE ON HISINGSLEDEN.

	Completely blocked road accident with contaminant release		
Time of the day	Duration	Queue time	Total delay
Rush hour	16	17	33
Day	16	14	30
Night	16	14	30

Lundbyleden

The traffic flow, the number of accidents and completely blocked road accidents for Lundbyleden are shown in Table 20.

TABLE 20 THE TRAFFIC FLOW, THE NUMBER OF ACCIDENTS AND COMPLETELY BLOCKED ROAD ACCIDENTS IS OF AN AVERAGE WEEKDAY IN ONE DIRECTION FOR LUNDBYELDEN.

Time of the day	Traffic flow		Number of accidents		
	Total	Heavy traffic	Private vehicle	Heavy traffic	Completely blocked road
Rush hour	22 901	2 519	0.014	0.0066	0.0031
Day	17 069	2 895	0.004	0.0037	0.0014
Night	4 723	0	0.001	0.0002	0.0003

The probabilities of a private vehicle, heavy vehicle and dangerous goods accident, and the probability of a completely blocked road for Lundbyleden are shown in Table 21.

TABLE 21 PROBABILITIES OF A PRIVATE VEHICLE, HEAVY VEHICLE AND DANGEROUS GOODS ACCIDENT, AND PROBABILITY OF A COMPLETELY BLOCKED ROAD FOR LUNDBYLEDEN.

	Probability of a transport			Probability of an accident			
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Completely blocked road*
Rush hour	0.52	0.47	0.47	0.7	0.63	0.00025	0.15
Day	0.36	0.53	0.53	0.23	0.35	0.00029	0.18
Night	0.12	0.00	0.00	0.07	0.02	0	0.21

The duration, queue time and total delay at a completely blocked road event without contaminant release and with contaminant release on Lundbyleden is shown in Table 22 and Table 23 respectively.

TABLE 22 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT WITHOUT CONTAMINANT RELEASE ON LUNDBYLEDEN.

	Completely blocked road accident without contaminant release								
	Duration			Queue time			Total delay		
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangero us goods	Private vehicle	Heavy vehicle	Dangero us goods
Rush	1.31	1.31	8	0.83	0.83	5.06	2.14	2.14	13
Day	2.35	2.35	8	1.42	1.42	4.84	3.76	3.76	13
Night	2.50	2.50	8	1.44	1.44	4.6	3.82	3.82	12

TABLE 23 DURATION, QUEUE TIME AND TOTAL DURATION AT A COMPLETELY BLOCKED ROAD EVENT FOR A DANGEROUS GOODS TRANSPORT WITH CONTAMINANT RELEASE ON LUNDBYLEDEN.

	Completely blocked road accident with contaminant release		
Time of the day	Duration	Queue time	Total delay
Rush hour	16	10	26
Day	16	10	26
Night	16	8	24

6.4 Alternative 2 - Rerouting of traffic and disturbances from projects during the construction of the West Swedish Package

The input data for Alternative 2, for both Hisingsleden and Lundbyleden is presented in this section.

Hisingsleden

The traffic flow, the number of accidents and completely blocked road accidents for Hisingsleden are shown in Table 24.

TABLE 24 THE TRAFFIC FLOW, THE NUMBER OF ACCIDENTS AND COMPLETELY BLOCKED ROAD ACCIDENTS IS OF AN AVERAGE WEEKDAY IN ONE DIRECTION FOR HISINGSLEDEN.

Time of the day	Traffic flow		Number of accidents		
	Total	Heavy traffic	Private vehicle	Heavy traffic	Completely blocked road
Rush hour	13 351	1 369	0.008	0.0069	0.0021
Day	9 152	1 520	0.002	0.0018	0.0036
Night	9 152	1 017	0.012	0.0008	0.0025

The probabilities of a private vehicle, heavy vehicle and dangerous goods accident, and the probability of a completely blocked road for Hisingsleden are shown in Table 25.

TABLE 25 PROBABILITIES OF A PRIVATE VEHICLE, HEAVY VEHICLE AND DANGEROUS GOODS ACCIDENT, AND PROBABILITY OF A COMPLETELY BLOCKED ROAD FOR HISINGSLEDEN.

	Probability of a transport			Probability of an accident			
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Completely blocked road*
Rush hour	0.43	0.35	0.35	0.36	0.21	0.0013	0.25
Day	0.28	0.39	0.39	0.10	0.55	0.0014	0.91
Night	0.29	0.26	0.26	0.54	0.24	0.0008	0.20

The duration, queue time and total delay at a completely blocked road event without contaminant release and with contaminant release on Hisingsleden is shown in Table 26 and Table 27 respectively.

TABLE 26 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT WITHOUT CONTAMINANT RELEASE ON HISINGSLEDEN.

	Completely blocked road accident without contaminant release								
Time of the day	Duration			Queue time			Total delay		
	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods
Rush	1.05	1.05	8	1.04	1.04	7.95	2.08	2.08	16
Day	1.05	1.05	8	0.88	0.88	6.7	1.92	1.92	15
Night	1.75	1.75	8	1.47	1.47	6.7	3.22	3.22	15

TABLE 27 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD EVENT FOR DANGEROUS GOODS TRANSPORTS WITH CONTAMINANT RELEASE ON HISINGSLEDEN.

	Completely blocked road accident with contaminant release		
Time of the day	Duration	Queue time	Total delay
Rush hour	16	15.89	32
Day	16	13.41	29
Night	16	13.41	29

Lundbyleden

The traffic flow, the number of accidents and completely blocked road accidents for Lundbyleden are shown in Table 28.

TABLE 28 THE TRAFFIC FLOW, THE NUMBER OF ACCIDENTS AND COMPLETELY BLOCKED ROAD ACCIDENTS IS OF AN AVERAGE WEEKDAY IN ONE DIRECTION FOR LUNDBYELDEN.

Time of the day	Traffic flow		Number of accidents		
	Total	Heavy traffic	Private vehicle	Heavy traffic	Completly blocked road
Rush hour	22 901	2 519	0.014	0.0065	0.0031
Day	17 069	2 895	0.004	0.0037	0.0014
Night	4 723	0	0.001	0.0002	0.0003

The probabilities of a private vehicle, heavy vehicle and dangerous goods accident, and the probability of a completely blocked road for Lundbyleden are shown in Table 29.

TABLE 29 PROBABILITIES OF A PRIVATE VEHICLE, HEAVY VEHICLE AND DANGEROUS GOODS ACCIDENT, AND PROBABILITY OF A COMPLETELY BLOCKED ROAD FOR LUNDBYLEDEN.

	Probability of a transport			Probability of an accident			
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Completely blocked road*
Rush	0.52	0.47	0.47	0,7	0.63	0.00025	0.15
Day	0.36	0.53	0.53	0.23	0.35	0.00029	0.18
Night	0.12	0.00	0.00	0.07	0.018	0	0.21

The duration, queue time and total delay at a completely blocked road event without contaminant release and with contaminant release on Lundbyleden is shown in Table 30 and Table 31 respectively.

TABLE 30 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD WITHOUT CONTAMINANT RELEASE ON LUNDBYLEDEN.

	Completely blocked road accident without contaminant release								
	Duration			Queue time			Total delay		
Time of the day	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerous goods	Private vehicle	Heavy vehicle	Dangerou s goods
Rush	1.31	1.31	8	0.83	0.83	5.06	2.14	2.14	13
Day	2.35	2.35	8	1.41	1.41	4.79	3.76	3.76	13
Night	2.50	2.50	8	1.32	1.32	4.22	3.82	3.82	12

TABLE 31 DURATION, QUEUE TIME AND TOTAL DELAY AT A COMPLETELY BLOCKED ROAD FOR DANGEROUS GOODS TRANSPORTS WITH CONTAMINANT RELEASE ON LUNDBYLEDEN.

	Completely blocked road accident with contaminant release		
Time of the day	Duration	Queue time	Total delay
Rush hour	16	10.12	26
Day	16	9.58	26
Night	16	8.44	24

6.5 Uncertainty analysis

The input parameters modelled using uncertainties are presented in Table 32 together with the type of probability distribution and parameters used to define the distribution.

TABLE 32 DIFFERENT DISTRIBUTIONS AND MIN,MEAN, MAX/ 2.5 PERECENTILE ; 97.5 PERCENTILE.

Parameter	Distribution	Min ; Mean ; Max
Probability of delay (rush hour)	Triangular	0.9 ; 1.0 ; 1.0
Probability of delay (day)	Triangular	0.6 ; 0.7 ; 0.8
Probability of delay (night)	Triangular	0.4 ; 0.5 ; 0.6
Probability of a completely blocked road	Triangular	0.9 ; 1.0 ; 1.0
Probability of contaminant release, Hisingsleden	Triangular	0.15 ; 0.199 ; 0.215
Probability of contaminant release, Lundbyleden	Triangular	0.08; 0.13 ; 0.18
Consequence (restore private vehicle accident)	Triangular	0.75 ; 1.0 ; 2.0
Consequence (restore heavy vehicle accident)	Triangular	2 ; 3 ; 4
Consequence (restore dangerous goods accident, without	Triangular	6 ; 8 ; 10
Consequence (restore dangerous goods accident, with	Triangular	13 ; 16 ; 19
Cost	Triangular	273 ; 700 ; 819
Share of dangerous goods transports	Triangular	0.01 ; 0.03 ; 0.10
Alternative 2: Reduced speed, Hisingsleden	Triangular	15 ; 20 ; 25
Alternative 2: Reduced speed, Lundbyleden	Triangular	25 ; 30 ; 35

Parameter	Distribution	2.5 percentile; 97.5
Relation between traffic flow and accidents	Normal	7.7; 9.9

7 Results

In this chapter the results from the risk model and results from the uncertainty analysis are presented. The result is divided into two types: risk time and risk cost. The risk cost is achieved by multiplying the risk time with a cost factor. Both types of result can either be presented for one goods transport or for all goods transports on Hisingsleden or Lundbyleden. Note that the risk cost only includes the consequence for the individual driver and is therefore not a socio-economic cost, since costs may also arise from others.

The results are either based on point estimates or mean values from the uncertainty analysis. Results from the uncertainty analysis are based on the point values together with distributions for all input parameters which create distributions of the risk and therefore also mean values.

In section 7.1-7.3 the results from the point estimates are presented, while in section 0 the results from the point estimates and the uncertainty analysis are compared and evaluated.

7.1 Alternative 0 - Present situation

The risk model for Alternative 0 is found in Appendix G. The results from the risk model are shown in Table 33 and Table 34.

TABLE 33 RESULTS FOR ALTERNATIVE 0 AT HISINGSLEDEN (CALCULATIONS BASED ON POINT ESTIMATES).

Hisingsleden Alternative 0	Risk time for one goods transport [hrs]	Risk cost for one goods transport [SEK]	Risk time for all goods transports [hrs]	Risk cost for all goods transports [SEK]
Rush hour	0.73	524	45.2	32 302
Day	0.66	483	43.0	31 419
Night	0.04	30	0.5	355

TABLE 34 RESULTS FOR ALTERNATIVE 0 AT LUNDBYLEDEN (CALCULATIONS BASED ON POINT ESTIMATES).

Lundbyleden Alternative 0	Risk time for one goods transport [hrs]	Risk cost for one goods transport [SEK]	Risk time for all goods transports [hrs]	Risk cost for all goods transports [SEK]
Rush hour	0.98	683	99	69 489
Day	0.48	337	60	40 405
Night	0.06	41	1	3 130

7.2 Alternative 1 - Rerouting of traffic from Lundbyleden to Hisingsleden

The risk model for Alternative 1 is found in Appendix G. The results from the risk model are shown in Table 35 and Table 36.

TABLE 35 RESULTS FOR ALTERNATIVE 1 AT HISINGSLEDEN (CALCULATIONS BASED ON POINT ESTIMATES).

Hisingsleden Alternative 1	Risk time for one goods transport [hrs]	Risk cost for one goods transport [SEK]	Risk time for all goods transports [hrs]	Risk cost for all goods transports [SEK]
Rush hour	0.39	271	24	16 710
Day	0.51	354	36	25 485
Night	0.30	85	14	4 076

TABLE 36 RESULTS FOR ALTERNATIVE 1 AT LUNDBYLEDEN (CALCULATIONS BASED ON POINT ESTIMATES).

Lundbyleden Alternative 1	Risk time for one goods transport [hrs]	Risk cost for one goods transport [SEK]	Risk time for all goods transports [hrs]	Risk cost for all goods transports [SEK]
Rush hour	1.27	888	129	90 366
Day	0.56	390	65	45 621
Night	0.01	7	0	0

7.3 Alternative 2 - Rerouting of traffic and disturbances from projects during the construction of the West Swedish Package

The risk model for Alternative 2 is found in Appendix G. The results from the risk model are shown in Table 37 and Table 38.

TABLE 37 RESULTS FOR ALTERNATIVE 2 AT HISINGSLEDEN (CALCULATIONS BASED ON POINT ESTIMATES).

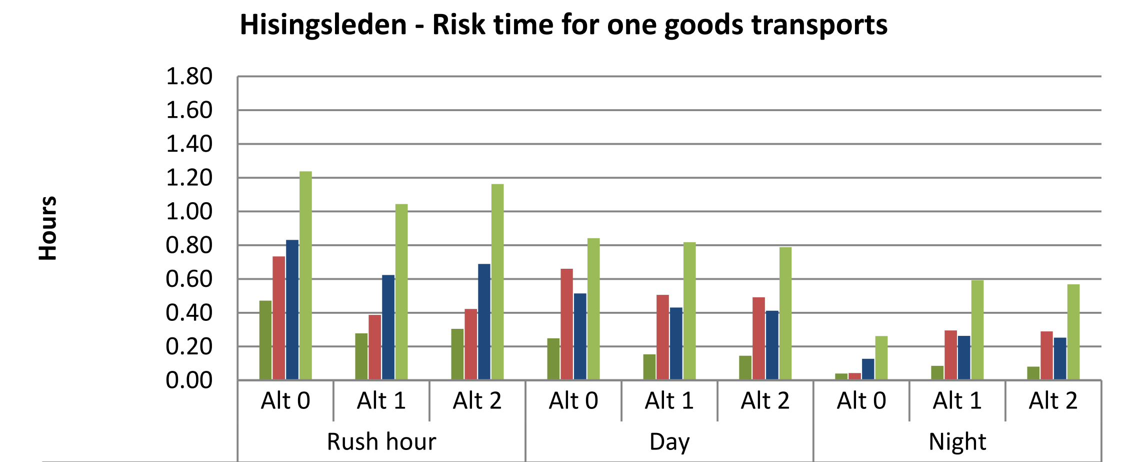
Hisingsleden Alternative 2	Risk time for one goods transport [hrs]	Risk cost for one goods transport [SEK]	Risk time for all goods transports [hrs]	Risk cost for all goods transports [SEK]
Rush hour	0.42	296	23	16 205
Day	0.49	345	30	20 943
Night	0.29	83	12	3 375

TABLE 38 RESULTS FOR ALTERNATIVE 2 AT LUNDBYLEDEN (CALCULATIONS BASED ON POINT ESTIMATES).

Lundbyleden Alternative 2	Risk time for one goods transport [hrs]	Risk cost for one goods transport [SEK]	Risk time for goods transports [hrs]	Risk cost for goods transports SEK]
Rush hour	1.27	982	129	99 959
Day	0.52	398	61	46 576
Night	0.01	8	0	0

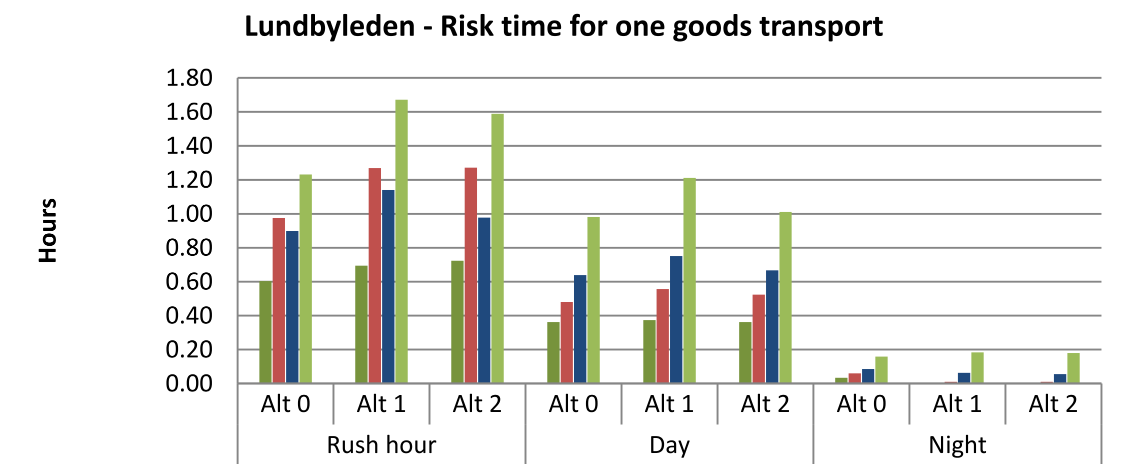
7.4 Uncertainty analysis

The results from the uncertainty analysis along with the results from the point estimates are shown in Figure 29 to Figure 36. The point estimates are presented in order to be evaluated and compared with the mean values from the Monte Carlo simulation. It is also possible to see the uncertainty in the Monte Carlo simulation by displaying the 95th percentile and 5th percentile. The uncertain parameters affecting the results, which were found in the uncertainty analysis, can be seen in Appendix H. Altogether there are about 140 parameters affecting the results. In the charts in the appendix there are only the top ten parameters for the risk cost for all goods transports presented. Only the risk cost for all goods transports are presented since the risk time and the number of goods transports will be included in the risk cost for all goods transports.



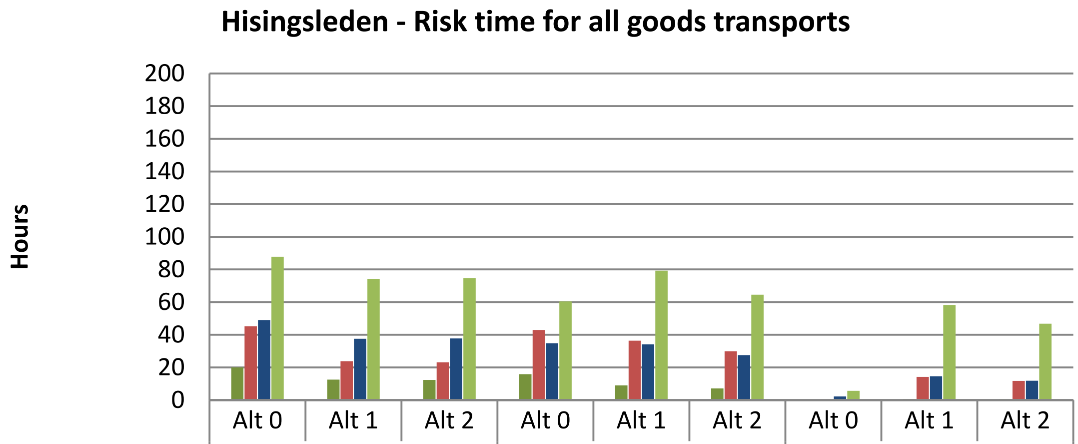
	Rush hour Alt 0	Rush hour Alt 1	Rush hour Alt 2	Day Alt 0	Day Alt 1	Day Alt 2	Night Alt 0	Night Alt 1	Night Alt 2
5 percentile	0.47	0.28	0.31	0.25	0.15	0.15	0.04	0.09	0.08
Point estimate	0.73	0.39	0.42	0.66	0.51	0.49	0.04	0.30	0.29
Mean	0.83	0.62	0.69	0.51	0.43	0.41	0.13	0.26	0.25
95 percentile	1.24	1.04	1.16	0.84	0.82	0.79	0.26	0.59	0.57

FIGURE 29 HISINGSLEDEN - RISK TIME FOR ONE GOODS TRANSPORT.



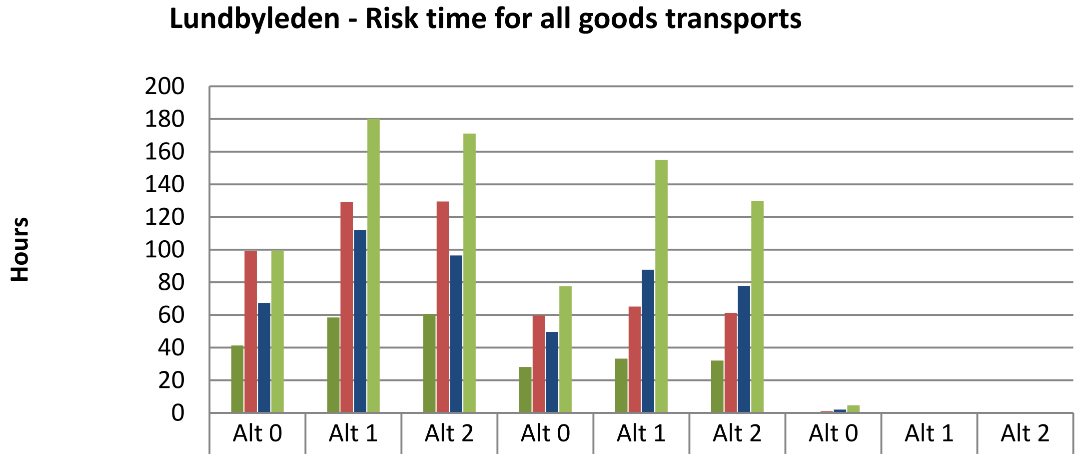
	Rush hour Alt 0	Rush hour Alt 1	Rush hour Alt 2	Day Alt 0	Day Alt 1	Day Alt 2	Night Alt 0	Night Alt 1	Night Alt 2
5 percentile	0.60	0.69	0.72	0.36	0.37	0.36	0.03	0.00	0.00
Point estimate	0.98	1.27	1.27	0.48	0.56	0.52	0.06	0.01	0.01
Mean	0.90	1.14	0.98	0.64	0.75	0.67	0.09	0.06	0.06
95 percentile	1.23	1.67	1.59	0.98	1.21	1.01	0.16	0.18	0.18

FIGURE 30 LUNDBYLEDEN - RISK TIME FOR ONE GOODS TRANSPORT.



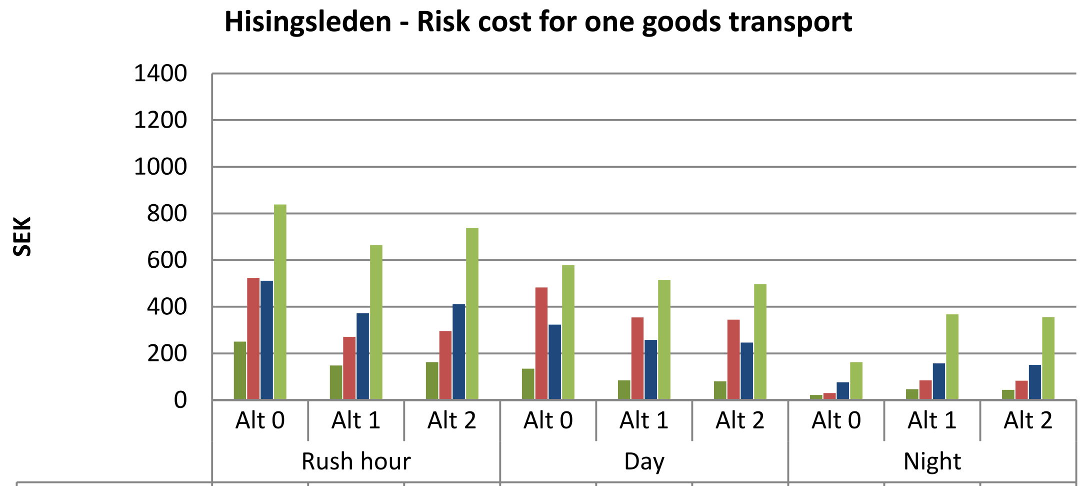
	Rush hour			Day			Night		
	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2
5 percentile	20.0	12.6	12.4	15.8	9.1	7.2	0.4	0.7	0.5
Point estimate	45.2	23.9	23.1	43.0	36.4	29.9	0.5	14.2	11.8
Mean	49.1	37.6	37.7	34.9	34.1	27.5	2.2	14.6	11.8
95 percentile	87.7	74.2	74.7	60.5	79.3	64.5	5.7	58.3	46.8

FIGURE 31 HISINGSLEDEN - RISK TIME FOR ALL GOODS TRANSPORTS.



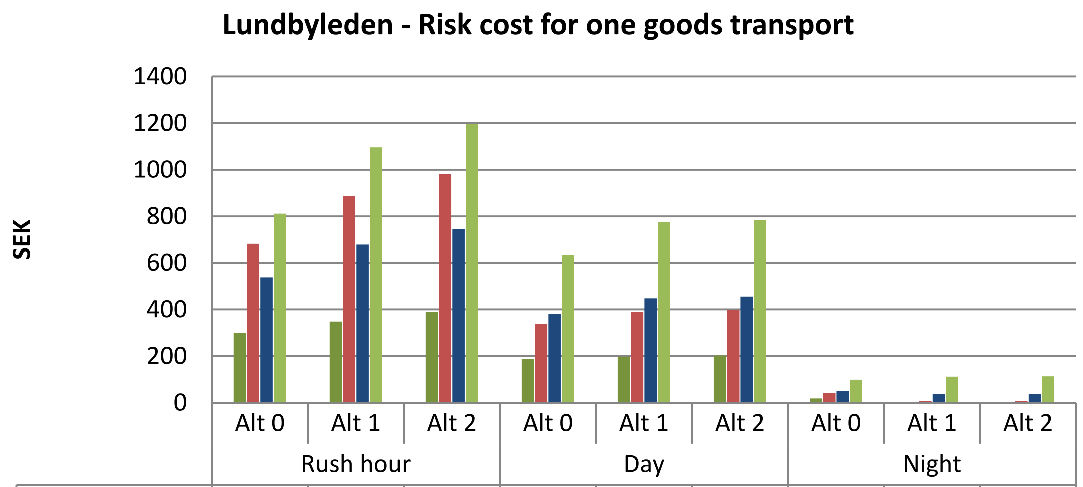
	Rush hour			Day			Night		
	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2
5 percentile	41.3	58.5	60.6	28.2	33.2	32.1	0.5	0.0	0.0
Point estimate	99.3	129.1	129.5	59.6	65.2	61.3	1.1	0.0	0.0
Mean	67.3	112.0	96.4	49.6	87.7	77.8	2.0	0.0	0.0
95 percentile	99.5	180.2	171.1	77.5	154.9	129.7	4.7	0.0	0.0

FIGURE 32 LUNDBYLEDEN - RISK TIME FOR ALL GOODS TRANSPORTS.



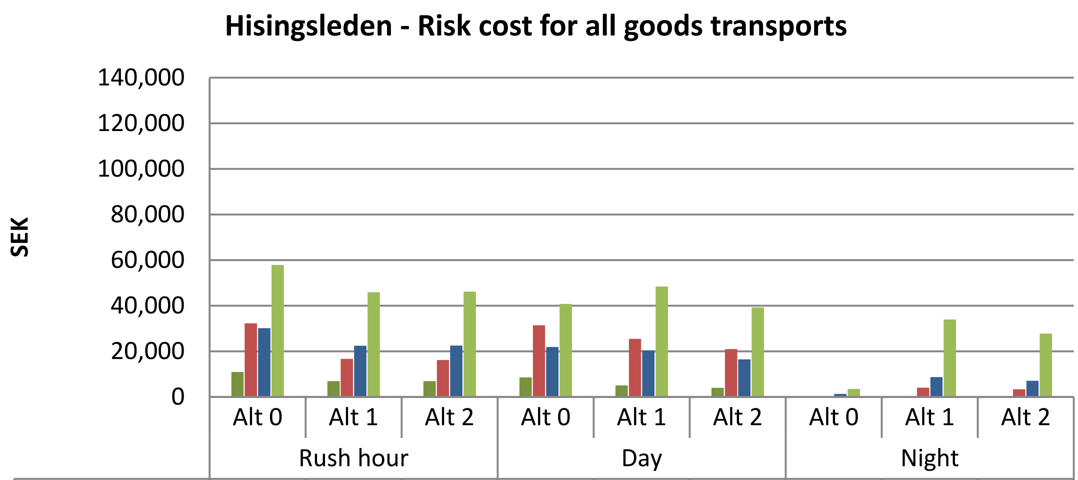
	Rush hour Alt 0	Rush hour Alt 1	Rush hour Alt 2	Day Alt 0	Day Alt 1	Day Alt 2	Night Alt 0	Night Alt 1	Night Alt 2
5 percentile	250	148	163	135	85	80	22	46	44
Point estimate	524	271	296	483	354	345	30	85	83
Mean	511	372	411	323	258	246	76	158	151
95 percentile	839	665	738	578	516	496	163	367	355

FIGURE 33 HISINGSLEDEN - RISK COST FOR ONE GOODS TRANSPORT.



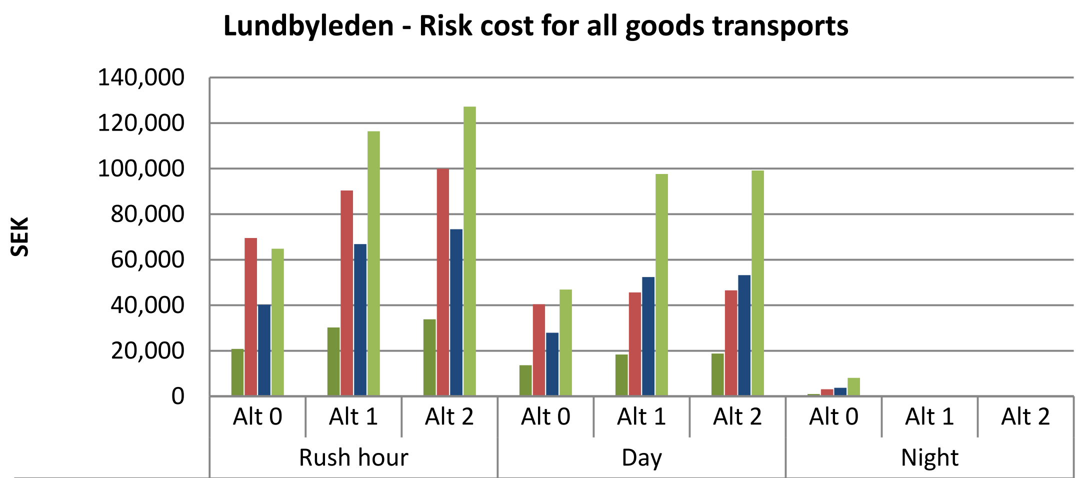
	Rush hour Alt 0	Rush hour Alt 1	Rush hour Alt 2	Day Alt 0	Day Alt 1	Day Alt 2	Night Alt 0	Night Alt 1	Night Alt 2
5 percentile	300	348	389	187	198	203	18	0	0
Point estimate	683	888	982	337	390	398	41	7	8
Mean	538	679	747	381	448	455	51	37	38
95 percentile	812	1096	1195	633	774	784	99	112	113

FIGURE 34 LUNDBYLEDEN - RISK COST FOR ONE GOODS TRANSPORT.



	Rush hour			Day			Night		
	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2
5 percentile	10,925	6,908	6,899	8,564	5,029	3,999	210	376	300
Point estimate	32,303	16,710	16,205	31,419	25,485	20,943	355	4,076	3,375
Mean	30,190	22,416	22,497	21,893	20,383	16,449	1,326	8,692	7,049
95 percentile	57,923	45,875	46,188	40,753	48,414	39,207	3,508	33,948	27,787

FIGURE 35 HISINGSLEDEN - RISK COST FOR ALL GOODS TRANSPORTS.



	Rush hour			Day			Night		
	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2	Alt 0	Alt 1	Alt 2
5 percentile	20,840	30,271	33,817	13,681	18,349	18,775	971	0	0
Point estimate	69,489	90,366	99,959	40,405	45,621	46,576	3,130	0	0
Mean	40,248	66,821	73,407	27,942	52,349	53,194	3,744	0	0
95 percentile	64,788	116,409	127,201	46,911	97,655	99,193	8,076	0	0

FIGURE 36 LUNDBYLEDEN - RISK COST FOR ALL GOODS TRANSPORTS.

8 Discussion

In this chapter a thorough discussion of the results will be presented together with uncertainties in the input parameters and the risk model. To be able to obtain the recommended route in regard to risk time and risk cost the risks at Hisingsleden and Lundbyleden will be compared between the different routes and for the different alternatives. Future infrastructural improvements that may affect the risk model at Hisingsleden and Lundbyleden will also be considered. The risk model is based on present input values and a discussion of the feasibility of the risk model for the future and possible improvements will be made. Whether the risk model can be used in other application areas will also be discussed.

8.1 Discussion of the uncertain parameters and comparison of the point estimates and the mean values

The result will include both a comparison between the routes and a comparison between the different scenarios in order to suggest a route recommendation, see section 8.1.4. Furthermore, uncertain parameters affecting the result will be discussed.

8.1.1 Lundbyleden and Hisingsleden

In this section the results from the point estimates will be compared between Lundbyleden and Hisingsleden.

The risk cost for one goods transport will have the exact same relation as the risk time for one vehicle for the different times of the day. Since the risk cost follows the same pattern as the risk time, the same relation as the risk time is attained for all goods transports. Therefore, the risk time and risk cost will be denoted risk in this section.

General discussion

In general the risk for both one goods transport as well as for all goods transports is higher at Lundbyleden compared to Hisingsleden. There are a few cases where the risk is lower at Lundbyleden which will be presented in the sections below and the causes of the divergence.

Alternative 0 – Present situation

<u>One goods transport:</u> At Alternative 0 during the day the risk is lower at Lundbyleden than Hisingsleden. The cause of the higher risk at Hisingsleden is due to a high probability of completely blocked road events. The probability of a completely blocked road accident on Hisingsleden is high while on Lundbyleden the probability is quite low. Other probabilities stay the same.

<u>All goods transports:</u> The risk for all goods transports during the day on Lundbyleden is lower than on Hisingsleden due to the same reasons as for one goods transport.

Alternative 1 – Rerouting of traffic from Lundbyleden to Hisingsleden

<u>One goods transport:</u> During the night on Lundbyleden a lower risk is achieved due to that all goods transports have been transferred to Hisingsleden. This causes the share of transports at night to be zero for heavy traffic which makes the total risk for the three different vehicle categories to be low. The risk at night for private vehicles at Hisingsleden is also high and this is caused by the fact that the share of transports at

night is higher due to the rerouting. Furthermore, the probability of an accident is also greater at Hisingsleden than Lundbyleden during the night for a private vehicle which causes the risk to increase.

<u>All goods transports:</u> The risk for all goods transports during night is zero since there are no goods transports on Lundbyleden.

Alternative 2 – Rerouting of traffic and disturbances from projects during the construction of the West Swedish Package

<u>One goods transport:</u> Alternative 2 follows the same pattern as Alternative 1 with a lower risk during the night for Lundbyleden than for Hisingsleden. The causes for this are due to the same reasons as for Alternative 1.

<u>All goods transports:</u> Alternative 2 follows the same pattern as Alternative 1 with a risk of zero during the night on Lundbyleden.

8.1.2 Different scenarios

In this section the results from the alternatives will be compared and the values are based on results from the point estimate.

The risk cost for one goods transport will have the exact same relation as the risk time for one vehicle for the different times of the day. Since the risk cost follows the same pattern as the risk time, the same relation as the risk time is attained for all goods transports. Therefore, the risk time and risk cost will be denoted risk in this section.

Hisingsleden – For one goods transport and for all goods transports

For Alternative 0 at Hisingsleden there is a higher risk at rush hour and day compared to night. The high risk is due to a higher share of transports, accidents and completely blocked road accidents during the rush hour and day. The number of transports is significantly higher at rush hour and day compared to night which results in high risk for all goods transports.

There is a much lower risk at rush hour and a lower risk at day for Alternative 1 compared to Alternative 0 for Hisingsleden. The reason for this is that the traffic amount is higher at night and that the accident rate increases at night. The increase of transports at night causes that the share of transports during rush hour and day to be lowered. Since there is a great increase of transports during the night the risk increases significantly during this time of the day.

A lower probability of an accident, which also causes a lower risk, occurs for Alternative 1 during rush hour due to that the total amount of accident increases while accidents occurring during rush hour stay the same. During the day the probability of an accident decreases and the amount of accidents increases, however the total amount of accidents increases with a larger rate. At night, the probability of an accident increases significantly due to the large increase of traffic flow which increases the amount of accidents.

The completely blocked road accident has almost the same probability in Alternative 0 and Alternative 1 at Hisingsleden. The traffic flow changes during day and night, however it causes only minor changes to the probability of an accident which does not affect the risk significantly.

In Alternative 2 the risk stays almost the same compared to Alternative 1 with minor changes. The risk is still lower during rush hour and day compared to Alternative 0 and with a higher risk during the night. The percentage of heavy transports during rush hour, day and night differs which effects the risk for all goods transports. The percentage of goods transports are higher during the day and night compared to rush hour.

Lundbyleden – For one goods transport and for all goods transports

For Alternative 0 at Lundbyleden there is a higher risk at rush hour and day compared to night. The high risk is due to a higher share of transports and accidents during the rush hour and day. The number of transports is significantly higher at rush hour and day compared to night which results in high risk for all goods transports.

A higher probability of an accident, which also causes a higher risk, occurs for Alternative 1 during rush hour due to that the total amount of accident decreases while accidents occurring during rush hour stay the same. During the day the probability of an accident increases and the amount of accidents decreases, however the total amount of accidents decreases with a larger rate. At night, the probability of an accident decreases significantly due to the large decrease of traffic flow which decreases the amount of accidents.

The completely blocked road accidents have almost the same probability in Alternative 0 and Alternative 1. The traffic flow changes during day, however it causes only minor changes to the probability of an accident with a completely blocked road which does not affect the risk significantly. Furthermore, the traffic flow during night changes more for heavy and dangerous vehicles than the private vehicles. Therefore, the probability of a completely blocked road accident increases during night.

In Alternative 2 the risk stays almost the same compared to Alternative 1 with only minor changes. The risk is still higher during rush hour and day compared to Alternative 0 and with a lower risk during the night. The percentage of heavy transports during rush hour, day and night differs which effects the risk for all goods transports. The percentage of goods transports are higher during the day compared to rush hour.

8.1.3 Point estimates and uncertainty analysis

In this section the results from the point estimate and the uncertainty analysis will be compared.

The analyses methods for the risk model are either based on the point estimates or the uncertainty analysis. The point estimates are based on point values where the distribution is unknown and may contain extreme values. The uncertainty analysis on the other hand is originated from distributions and most likely value where the likeliest value is based on the point values from the point estimate. Therefore, the mean value from the uncertainty analysis may be different from the point estimate.

The two percentiles, the 5th and the 95th, provide information how the result can vary and what types of extreme values that can be expected. A large difference between the 5th and 95th percentile means larger uncertainties, while a smaller difference means less uncertainties. If only point estimates were used it would not have been possible to retrieve this information.

The results from the point estimate are compared with the mean values from the uncertainty analysis. In most cases the values are quite close to each other. Occasionally, the values from the point estimate are below the mean values from the uncertainty analysis and in some cases the values from the point estimate are above. Furthermore, the values from the point estimate mainly range between the 5th percentile and the 95th percentile. However, there is one exception where the point estimate exceeds the 95th percentile from the uncertainty analysis. The exception is during rush hour for Lundbyleden for Alternative 0 when considering risk cost for all goods transports.

The exception is close to the maximum value of the risk cost probably since the distribution for the cost is skewed. A test was performed with a lower risk cost and a more symmetric distribution. In this case the risk cost for all goods transports at Lundbyleden for Alternative 0 was below the 95th percentile and was very close to the mean value of the uncertainty analysis. Hence, this indicates that the value from the point estimate is higher than the mean values from the uncertainty analysis in the risk model. This event does not appear for only one goods transport. The reason for this could be that when multiplying the amount of vehicles the effect amplifies.

8.1.4 Recommended route

Depending on the risk time and risk cost, different routes may be suggested to avoid the highest predicted risk. The risk time and risk cost based on results from the uncertainty analysis will be compared between Lundbyleden and Hisingsleden to decide which route to choose. The results from the point estimate will however be considered.

Alternative 0

The recommended route for Alternative 0 is presented in Table 39.

TABLE 39 RECOMMENDED ROUTES DEPENDING ON TIME OF THE DAY AND RISK TYPES FOR ALTERNATIVE 0.

	Rush hour	Day	Night
Risk time, one	Hisingsleden	Hisingsleden	Lundbyleden*
Risk time, all	Hisingsleden	Hisingsleden	Lundbyleden*
Risk cost, one	Hisingsleden	Hisingsleden	Lundbyleden*
Risk cost, all	Hisingsleden	Hisingsleden	Hisingsleden

* The recommended route to achieve a lower risk is Lundbyleden from the mean values of the uncertainty analysis. However, the result from the point estimate indicates that the lowest risk is achieved if Hisingsleden is chosen instead.

For Alternative 0 Hisingsleden is recommended during the rush hour and day. However, during the night the recommendation depends on if it is risk time or risk cost that is governing. Since the risk time is multiplied with the cost factor the risk time and risk cost should have the same pattern in the results. However, this does not apply for this case when there are different recommendations depending on risk time and risk cost. The reason for this abnormality could be caused by the random values from the distributions that Oracle Crystal Ball uses.

Alternative 1 and Alternative 2

The recommended route for Alternative 1 and Alternative 2 is presented in Table 40

TABLE 40 RECOMMENDED ROUTES DEPENDING ON TIME OF THE DAY AND RISK TYPES FOR ALTERNATIVE 1 AND ALTERNATIVE 2.

	Rush hour	Day	Night
Risk time, one	Hisingsleden	Hisingsleden	Lundbyleden
Risk time, all	Hisingsleden	Hisingsleden	- **
Risk cost, one	Hisingsleden	Hisingsleden	Lundbyleden
Risk cost, all	Hisingsleden	Hisingsleden	- **

** No route is recommended.

As for Alternative 0 the recommended route during the rush hour and day is Hisingsleden. However, for Alternative 1 and Alternative 2 all goods transports are rerouted from Lundbyleden to Hisingsleden during night, this means that the risk time for all goods transports is zero for Lundbyleden at night. The risk time for one goods transport on Lundbyleden during night is less than the risk time for one goods transport on Hisingsleden. This indicates that there is no need to transfer goods transports from Lundbyleden to Hisingsleden. Since there is no real risk rime or risk cost at Lundbyleden for all goods transports at night no route is recommended. However, there is a possibility that Lundbyleden would have a lower risk time if any goods transports were conducted during the night.

8.1.5 Uncertain input parameters

In this section the input parameters in regard to the effects on the results will be presented and discussed. The uncertainty charts from Appendix I is used when assessing these parameters. The uncertainty charts will only include results based on the risk cost for all goods transports, since the risk cost for one goods transport and the risk time for one/all goods transport will be included in the risk cost for all goods transports. The parameters will be evaluated with and according to the rank correlation from the uncertainty charts.

Alternative 0

The time of the day of the parameter have significant impact on the result. For example during rush hour, almost all input parameters refer to rush hour.

Hisingsleden

The parameters affecting the result are the traffic flow, number of accidents, the cost for a goods transport to be delayed and the duration of a completely blocked road accident.

Lundbyleden

The parameters affecting the result are the traffic flow, number of accidents and the cost for a goods transport to be delayed.

During night the traffic flow has greater impact than during rush hour and day.

The numbers of completely blocked road accidents have large influence during day and night. However, during rush hour the parameter is not included within the ten parameters that have the largest impact on the result.

The duration of a completely blocked road accident has some influence on the result during rush hour and day. However, during night the parameter is not included within the ten parameters that have the largest impact on the result.

Alternative 1 and Alternative 2

The uncertain input parameters for Alternative 1 and Alternative 2 are almost identical, therefore the result from the two alternatives will be discussed at the same time. The time of the day of the parameter have significant impact on the result as it was in Alternative 0. For example during rush hour, almost all input parameters refer to rush hour.

Hisingsleden

The parameters affecting the result are the traffic flow, number of accidents and the cost for a goods transport to be delayed.

The number of accidents with a completely blocked road has large influence during night. However, during rush hour and day the parameter is not included within the ten parameters that have the largest impact on the result.

The duration of a completely blocked road accident has some influence on the result during day. However, during rush hour and night the parameter is not included within the ten parameters that have the largest impact on the result.

Lundbyleden

The parameters affecting the result are traffic flow, number of accidents and the cost for a goods transport to be delayed.

The duration of a completely blocked road accident has some influence on the result during day and night. However, during rush hour the parameter is not included within the ten parameters that have the largest impact on the result.

Conclusion

There are several parameters from the uncertainty analysis which has great impact on the results from the risk model. However, many parameters are the same independent of route or alternative. The uncertainty analysis indicates that three parameters have large impact for all alternatives and on both routes. These parameters are traffic flow, number of accidents and cost for a goods transports to be delayed. Hence, these parameters are important to study further and if possible obtain larger amounts of statistic data to optimize the risk model and obtain as accurate results as possible.

There are more parameters that have influence on the results, the number of completely blocked road accidents and the duration of completely blocked road accidents. These could also be investigated further to improve the risk model and the accuracy of the result.

8.2 Uncertainty in the risk model

In the risk model several input parameters are used based on both statistics and assumptions. The input data based on statistical data are compiled from different databases during the same period of time, however it is unknown how the data varies before and after this time period. External factors such as road work, weather conditions etc., may have an impact on the accidents and the traffic flow on the routes. The assessed values are only based on one source and therefore large uncertainties lies within those parameters and hence they will be discussed.

8.2.1 Uncertainties in the statistical data

A large amount of data was procured by statistical data. The purpose of this section is to discuss how accurate this data is.

The traffic flow in the risk model is based on statistics and might have been impacted by external factors. At Hisingsleden the intersection at Vädermotet was reconstructed during year 2010-2012 which could have had an impact on the traffic flow during these years which is something the risk model does not consider. Furthermore, the grade-separated intersection Lindholmsmotet at Lundbyleden was constructed during 2012-2014, which also could have had an impact on the traffic flow during these years by causing obstructions on the road.

The traffic flows used in the risk model is based on values from the database TIKK. There was also a possibility to use values from Trafikkontoret which was generally higher than the values from TIKK. If these values had been implemented in the model a higher flow would have been procured and fewer vehicles would have been possible to reroute from Lundbyleden to Hisingsleden because of the capacity. However, the values from Trafikkontoret are based on fewer measurements than the values from STA and therefore re more uncertain.

The risk model is based on data between 2009 and 2013 and no prognosis of the traffic flow was performed in this master's thesis since the impact of the congestion fee is still unknown. If an increase of traffic flow is uniform between the two routes the relation between the risk time and the risk cost would be the same and would not affect the result. However, if a non-uniform increase would happen, depending on where, either more or less vehicles could be transferred from Lundbyleden to Hisingsleden.

Some accident data from STRADA is unaccounted for, since not all hospital data is specified to what kind of vehicle data the accidents was involved in. Furthermore, not all accidents are reported to either the hospital or police, however in this master's thesis it is assumed that these accidents are not so severe in those cases and therefore will not affect the results to a large extent. Since some of the data from STRADA are not accounted for, the accident statistics used in the risk model are limited and may not be utterly accurate and not entirely reflect the reality.

Another factor that may have affected the accident data on Hisingsleden is the change in speed limit, where the speed was lowered 10 km/h during 2012. A lowered speed limit results in a higher traffic flow. According to the relation between traffic flow and accidents, the accident rate will increase with higher traffic flow. However, the severity of an accident decreases with an increase of traffic flow and could affect the duration of an accident.

According to statistics the percentage of heavy vehicles vary between the different time periods of the day and at the different routes. This assessment that the percentages stay the same throughout the different alternatives may not be entirely correct. However, it is difficult to prove otherwise.

It is assumed in the risk model that buses are included in the category heavy vehicles. According to this assumption the number of goods transport are higher than in reality. However, there are few buses and it is presumed these will not affect the results significantly.

8.2.2 Uncertainties in the assessments

Some data has been assessed since no statistical data was available. These data is discussed in this section regarding uncertainties.

The maximal increase in traffic flow between Alternative 0 and Alternative 1 is assessed by using a saturation level of 0.8. This might not be reasonable as the maximal amount of traffic rerouted for example during the night. At certain times the goods transports being rerouted are less on Lundbyleden than the capacity on Hisingsleden can handle. In the risk model the amount of goods transports being rerouted never exceeds the available goods transports on Lundbyleden. However, in some cases the rerouted traffic redistributes all traffic from Lundbyleden to Hisingsleden which does not seem reasonable. For a future risk model a more accurate assumption regarding the traffic rerouted should be made. Since no data or expertise was available an assumption had to be made in regard to the capacity calculations. To reroute the maximal traffic is an extreme case and is probably not reasonable to conduct and therefore it is suggested to investigate this further to obtain a more reasonable number.

In regard to the calculation of the probability of an accident with dangerous goods the estimation with the computational matrix was chosen since the amount of accident data were lacking. If the probability rather had been calculated with accident statistics the probability would have been less. Therefore the computational matrix is on the conservative side.

As has been mentioned earlier a relation between accidents and traffic flow has been applied. However, there are uncertainties in the relation and there is a possibility that the relation changes with the change of traffic flow. This provides uncertainty when recalculating the traffic accidents and completely blocked road accidents and may be difficult to change. The relation also considers AADT rather than average weekday which has been used in this risk analysis. This also provides uncertainty to the risk model. Nonetheless, these changes are minor and should be possible to disregard.

To estimate the probability of delay and time to clear away an accident an expert from the Swedish Rescue Service Agency were consulted with. However these values were only based on one experts experience and no data were available for these assumptions. Because of this, these values are quite uncertain and if possible more accurate values would be appropriate. The duration to clear away an accident was also estimated by the help of the same expert and can be compared to the duration of the completely blocked road accidents. However, since the completely blocked road accidents only consider the completely blocked road accidents they will not consider accidents where the road only gets narrowed. The completely blocked road statistics also only considers a shorter time period, an expert can have experience from a longer time span.

In regard to the cost for a goods transport to be delayed it is based on studies and calculated values from the traffic consultant company Movea. The value chosen for this study was an estimated value by the drivers and lies between two extreme values. However, this value is skewed to the maximum value and may be too high compared to the real cost. Further investigations of what the real cost is could be performed to obtain a more accurate value.

In the future a reconstruction of Hisingsleden will be made along with a completely new road to the industries (Halvorslänk). When these improvements are performed the capacity will increase to the road capacity itself and thus more vehicles could be transferred from Lundbyleden to Hisingsleden if desirable. However, it is difficult to predict if it will be required since it depends on the amount of traffic.

To calculate the capacity the computer program Capcal was used. However, the software used was not of the latest version which could affect the capacity from the calculations. If another capacity would be achieved with a newer version of Capcal a different consequence could be attained. On the other hand the output values from the Capcal simulation should be addressed in rounded off values and therefore changes in the model should not be so severe. However, rounded off values have not been applied in this master's thesis and thus could affect the results. Therefore, the capacity used are not conservative and could be a flaw regarding the input values.

In Alternative 2 the effects from the projects on Hisingsleden and Lundbyleden are a major assessment. The assessments are based on experience and compared to similar projects in the area which gives credibility. The connection of the Marieholm Tunnel is only based on expert judgements and therefore the elicitation is highly uncertain. However, the output from this assumption only contributes with a small consequence and therefore has little impact on the result.

8.3 Uncertainties regarding the uncertainty analysis

The distribution chosen for the uncertainty analysis is a triangular distribution. However, since the triangular distribution only consider maximum and minimum values, the extreme values are not accounted for. In order to account for the extreme values more detailed statistics are required to be able to use another distribution, for example a normal or lognormal distribution.

As mentioned above maximum and minimum values are possible to acquire in several cases. However, there are instances where only the mean value is obtained. In these cases the maximum and minimum values are assessed and could be an uncertainty in the risk model. Regardless of this, these values create a distribution and the likeliest value already is obtained these assessments should not generate a too great uncertainty in the risk model.

In a few cases in the uncertainty charts from the uncertainty analysis Hisingsleden affects Lundbyleden and vice versa. This could be caused by that Oracle Crystal Ball changes all input parameters at the same time and evaluates the results and decides which parameters affect the results the most. However, Oracle Crystal Ball does not take into account how the parameters are connected to the output values. Therefore, it is possible that Oracle Crystal Ball assesses input parameters that have no connection with the specific output values to have an impact on these output values.

8.4 Future infrastructural improvements on Hisingsleden and Lundbyleden affecting the risk model

The future infrastructure in Gothenburg will probably be rather different from the infrastructure existing at present. The changes to infrastructure will probably alter many of the input values for the risk model, for example the different traffic flows and capacity for the routes.

At Hisingsleden the new bypass Halvorslänk and the new grade-separated intersections together with the expansion to a four-lane road will increase the attractiveness and have the possibility to reroute up to 2000-3000 heavy transports from Lundbyleden and E6 to Hisingsleden. In the risk analysis the total amount of vehicles that can be transferred during one day is approximately 4300 vehicles, whereas 270 are heavy traffic. This indicates that a greater amount of vehicles could be transferred in the future from Lundbyleden to Hisingsleden. Since the risk model transfers all heavy traffic from Lundbyleden during the night in Alternative 1 a larger transfer would probably not be necessary. However, during the day and especially during the rush hour a greater rerouting possibility would be required.

Hisingsleden will probably attract more vehicles in the future, especially between Vädermotet and Assar Gabrielssons väg for the commuters to and from Volvo. The reconstruction of Lundbyleden will probably cause a higher attractiveness and a safer road. However, it is difficult to predict which road that will increase the most in traffic flow.

8.5 Improvements of the risk model, areas of use and future application

In this section the risk model will be discussed in terms of improvements and areas of use today as well as in the future.

8.5.1 Input data and definitions

There are several possible ways to improve the risk model. The input data in the risk model has several flaws with old traffic flow data and few measurements. If more and newer measurements of traffic flows were to be obtained and a traffic prognosis for future traffic flows is performed, a more accurate risk model could be acquired. On Lundbyleden it was only possible to acquire traffic flows for both directions. For a more accurate risk model traffic flows in the desired direction would be of great use.

Several values are assessed with experts, among others, the delay time and the travel speed during the construction of the West Swedish Package. A possibility would be to confirm these values by other experts to ensure their accuracy. A further step would be to obtain statistics regarding these values.

In the present risk model the length of the two routes are only considered in regard to dangerous goods transports. To correct this flaw the length of the road should be considered. One way to do this could be to add E6 between Klarebergsmotet and Ringömotet to Lundbyleden into the risk model. It was not possible to execute this with the present risk model since the data available have no record of how many vehicles that chooses different routes at large intersections like Ringömotet. If E6 would have been included in the risk model the results would probably be more precise and better suited to compare with Hisingsleden.

Another improvement of the input data of the risk model could be to count cars for the capacity calculations in both the intersections were values already was obtained to procure present values. The values used are a few years old and a newer count would give more accurate traffic flows.

The completely blocked road accidents assume that there is no possibility to take another route if the vehicle travels on the road that the accident has occurred. In reality it is could be possible to divert the traffic from the location where the accident is situated or earlier to choose an entirely different route to avoid as much delay as possible. Since the model does not consider this it might be a flaw in the model. For example when dealing with a heavy vehicle accident it can prolong for several hours, it is possible a large amount of the traffic has been diverted to a different route and therefore barely have been affected. Therefore, to enhance the risk models accuracy this case should be included in the risk model.

According to accident statistics on Hisingsleden there are accidents were non-completely blocked road accidents occurs. The definition of completely blocked road accidents is that the road should be completely closed in at least one direction. The definition of a delay states that there is no delay if not at least one lane is completely blocked. In the master's thesis the lanes are either blocked or not blocked. Therefore, all accidents on Hisingsleden should be completely blocked road accidents since there is only one lane in each direction. However, this is not the case according to accident statistics. In the risk analysis the case of completely blocked road accidents are based on the statistics and it is assumed that there may be accidents were the lane is only partly blocked. Therefore the assumption of the expert is altered by using it for partly blocked lanes. However, since these values are only an elicitation from one expert this assumption should not cause to great impact on the results but should be improved in further studies.

8.5.2 Risk model

The risk model is based on two hazard identification methods and a logic model. There are several different and more extensive hazard identification methods which may improve the risk model further with a more comprehensive investigation in regard to hazardous events.

The risk model is created in the software program Excel which has been applicable to achieve a functioning risk model and procure reasonable results. It is possible that a different software program could have simplified the creation of the model and also facilitates changes in the risk model.

Another possibility could have been to have gone more in depth in some hazardous events. The accidents could have been divided into different severity classes which could have had different consequence depending on the time to clear away an accident. A similar division could have been achieved with the contaminant release, depending on the type of release.

In the master's thesis only accidents are considered as a cause of delay. The choice to use accidents was because maintenance is often planned and can be prepared for and also has a similar time period between the roads. Since Lundbyleden has a higher flow the wear might be larger and the maintenance could have a higher frequency. Weather conditions are the same on both routes and therefore this kind of interruption on the road was not considered. In further studies other causes like maintenance, queues and environmental impacts, such as flooding and landslides, could be included in the risk model to evaluate all types of reasons for delay.

The share of transports has great impact on the results especially when rerouting traffic from one route to another. Since the traffic flow, number of accidents and number of completely blocked road accidents are connected to each other the share of transports can have unexpected consequences in the results. One of these unexpected abnormalities is the increase of risk time at Lundbyleden for Alternative 1 during rush hour when no traffic is transferred from the road. The expected result would have been the same risk time as in Alternative 0. However, since the share of transport also affect the unchanged variables the risk time changes and causes this abnormality. This causes also similar effects in other results in the risk model.

8.5.3 Areas of use and future application

The risk model was created for three different scenarios with two specific roads. The two roads are quite similar in location and use. However, since the model is primarily based on statistics of traffic flows, number of accidents and number of completely blocked roads for these two roads it should be possible to use the risk model for other cases. The probability of delay is mainly based on these types of roads with these traffic flows and could need to be changed for another road type. Otherwise the risk model should be applicable for most types of roads.

Furthermore, it is possible to obtain the risk of delay for other types of vehicles than goods transports. The risk time for all private vehicles can for example be obtained by multiplying the risk time for one vehicle with the number of private vehicle transports on the road. The risk cost for other types of vehicles can be achieved if another cost for a vehicle to be delayed is applied. Moreover, the socio-economic cost should be possible to obtain if the proper cost factor is applied. In this study only the delay for the individual goods transport is included. The socio-economic cost could include the recipients cost for the delay, the impact it has on the consumers and other steps in the transport chain.

The probability of an accident with dangerous goods is based on a model designed for the Swedish road network and it is uncertain how this would affect the use of the risk model elsewhere. However, the probability of a dangerous goods accident only contributes to a minor part of the risk, therefore the usage elsewhere than in Sweden could be feasible.

In the model the dominating amounts of transfer of traffic can be performed during the night and some at the day while none at the rush hour. This indicates that in the future a large challenge will probably be to encourage the traffic to choose other time periods of the day to travel rather than choosing between different routes. Therefore, the risk model should probably focus more on time periods rather than possible routes.

Finally, the risk model could be used to direct traffic to the most optimal travel route regarding risk of delays in the future by using the output from the risk model in interactive road signs.

9 Conclusions

The main conclusions of this master's thesis are:

- The recommended route for Alternative 0, considering risk time and risk cost for all goods transport is Hisingsleden at rush hour and day. At night the goods transports should be recommended to travel at Hisingsleden when considering risk cost while on Lundbyleden when considering risk time.
- The recommended route for Alternative 1 and Alternative 2 is Hisingsleden during the rush hour and during day. At night no route has been recommended since no goods transports are conducted at Lundbyleden.
- The most uncertain parameters retrieved from the uncertainty analysis include traffic flow, number of accidents and cost for goods transport to be delayed. More data regarding these input data should be obtained to procure a more accurate risk model.
- Other uncertainties in the risk model are input data collected from statistics, assessment based on expert judgements and distributions in the uncertainty analysis.
- It is possible to improve the risk model by obtaining more accurate input data and reconsider the definition and limitations of the risk model.
- Future applications of the risk model is to use it to compare time periods of the day rather than different routes since this will have greatest impact on the risk.
- Finally, the risk model is a powerful tool to assess the risk of delay and could be used to direct traffic to the most optimal travel route in the future.

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Appendices

Appendix A – Effektkatalog 2000

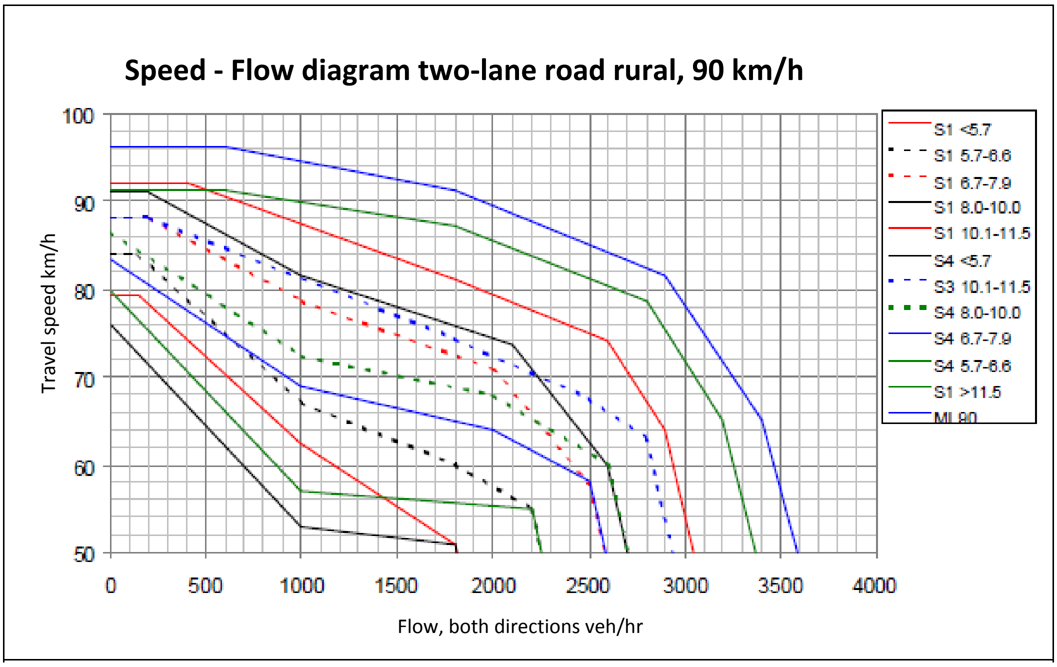


FIGURE A.1 RELATIONS BETWEEN TRAFFIC FLOW AND SPEED ON A TWO-LANE ROAD WITH A SPEED LIMIT OF 90 KM/H (AFTER SWEDISH TRANSPORT ADMINISTRATION, 2000).

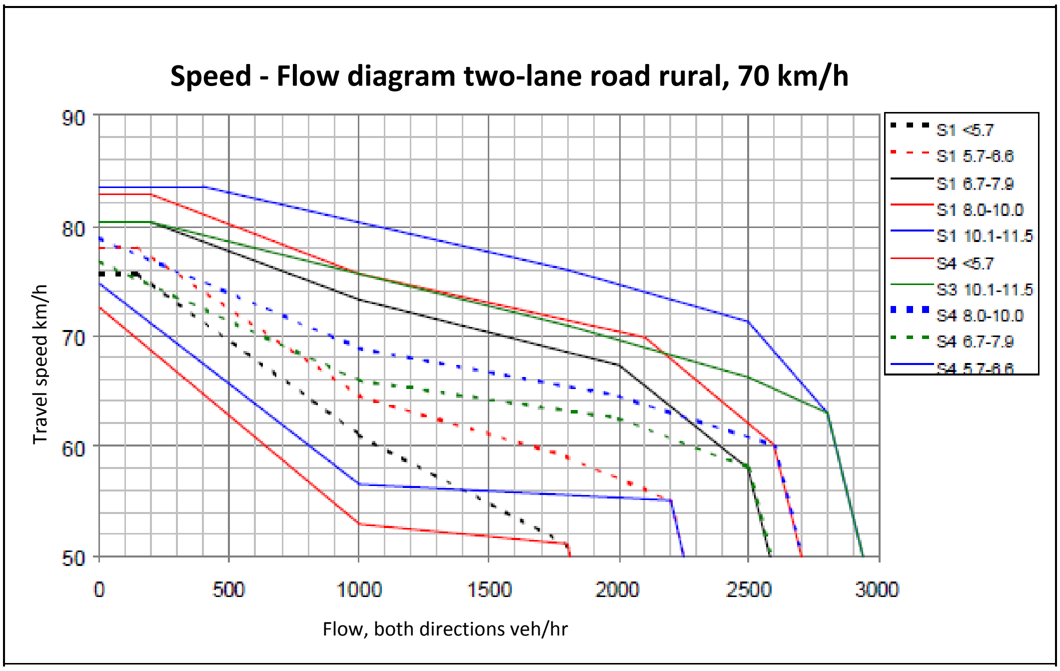


FIGURE A.2 RELATIONS BETWEEN TRAFFIC FLOW AND SPEED ON A TWO-LANE ROAD WITH A SPEED LIMIT OF 70 KM/H (AFTER SWEDISH TRANSPORT ADMINISTRATION, 2000).

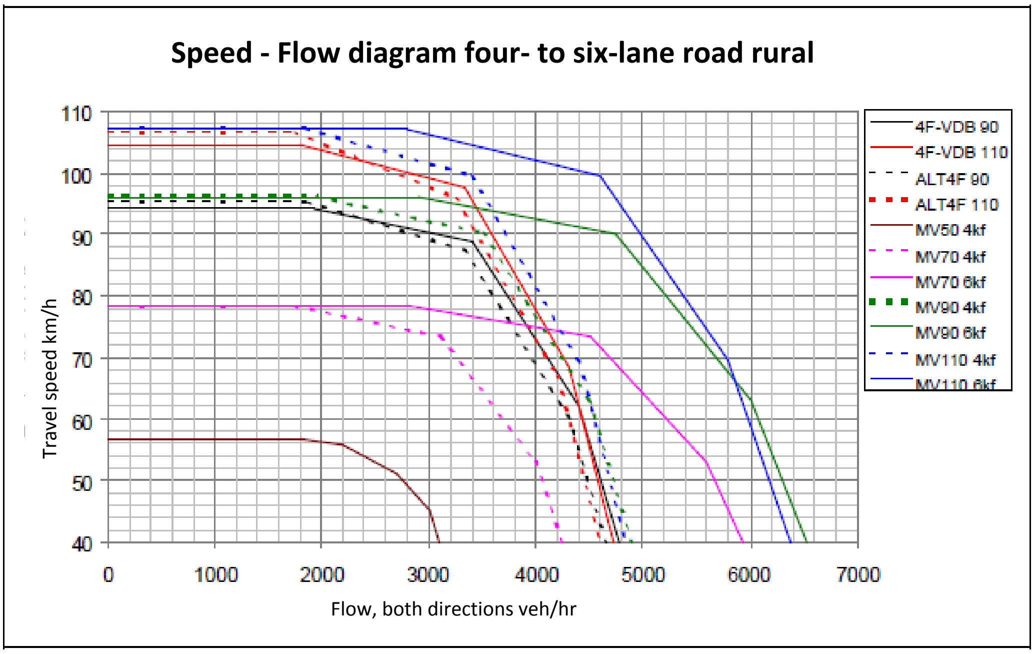


FIGURE A.3 RELATIONS BETWEEN TRAFFIC FLOW AND SPEED ON A FOUR- TO SIX- LANE ROAD (AFTER SWEDISH TRANSPORT ADMINISTRATION, 2000).

Appendix B –Traffic flow from Trafikkontoret and STA

TABLE B.1 COMPRAISON BETWEEN THE TRAFFIC FLOW FROM TRAFIKKONTORET AND STA.

Hisingsleden		Lundbyleden	
Total traffic	Amount of vehicles	Total traffic	Amount of vehicles
STA	12 962	STA	48 728
TK	16 500	TK	44 700
Heavy vehicles		Heavy vehicles	
STA	1 219	STA	5 242
TK	1 267	TK	7 460

Appendix C - Computational matrix for dangerous goods accidents

BEBYGGELSE MILJÖ	Olycks-kvot	Andel singel-olyckor	Index för farligtgods-olycka	HASTIGHETS-GRÄNS	Olycks kvot	Andel singel olyckor	Index för farligtgods-olycka	GATU/ VÄGTYP	Olycks-kvot	Andel singel olyckor	Index för farligtgods-olycka
TÄTORT (STAD)	1.20	0.15	0.05	30	1.50	0.05	0.01	Område	1.00	0.10	0.01
								Gata/väg	2.00	0.05	0.01
				50	1.20	0.15	0.03	Område	1.00	0.15	0.03
								Gata/väg	1.20	0.15	0.03
								Trafikled	1.50	0.10	0.02
				70	0.80	0.30	0.12	Gata/väg	0.65	0.25	0.11
								Trafikled	0.80	0.25	0.11
								Ringled	0.90	0.25	0.11
								Flerfältsväg	0.60	0.30	0.13
								Motorväg	0.60	0.30	0.13
LANDSBYGD	0.40	0.45	0.30	70	0.70	0.30	0.15	Grusväg	0.70	0.35	0.18
								Tvåfältsväg	0.80	0.30	0.15
								Flerfältsväg	0.60	0.30	0.15
				90	0.40	0.45	0.28	Grusväg	0.70	0.40	0.25
								<5 m bred	0.45	0.45	0.28
								5 - 5.9 m	0.42	0.45	0.28
								6 - 11 m	0.40	0.45	0.28
								11 - 13 m	0.35	0.45	0.28
								ML	0.37	0.40	0.25
								Flerfältsväg	0.40	0.35	0.22
								Motorväg	0.32	0.50	0.34
				110	0.28	0.55	0.40	<8 m Norrland	0.21	0.60	0.41
								11 - 13 m	0.30	0.50	0.34
								ML el flerfältsväg	0.28	0.50	0.34
								Motorväg	0.26	0.60	0.42

Olyckskvot = Det förväntade antalet singelolyckor och kollisionsolyckor med enbart bilar inblandade per miljon fordonskilometer.
Andel singelolyckor = Andelen singelolyckor av antalat singelolyckor och kollisionsolyckor med enbart bilar inblandade.
Index för farligtgodsolycka = Sannolikheten att ett fordon skyltat med farligt gods i en trafikolycka orsakar en farligtgodsolycka
Gatu/vägtyp definierad som område kan avse bostadsområde, militäranläggning, sjukhusområde eller motsvarande, där förekomsten av genomfartstrafik är ringa.

FIGURE C.1 COMPUTATIONAL MATRIX FOR THE PROBABILITY OF A DANGEROUS GOODS ACCIDENT.

Appendix D – Traffic flow on Hisingen

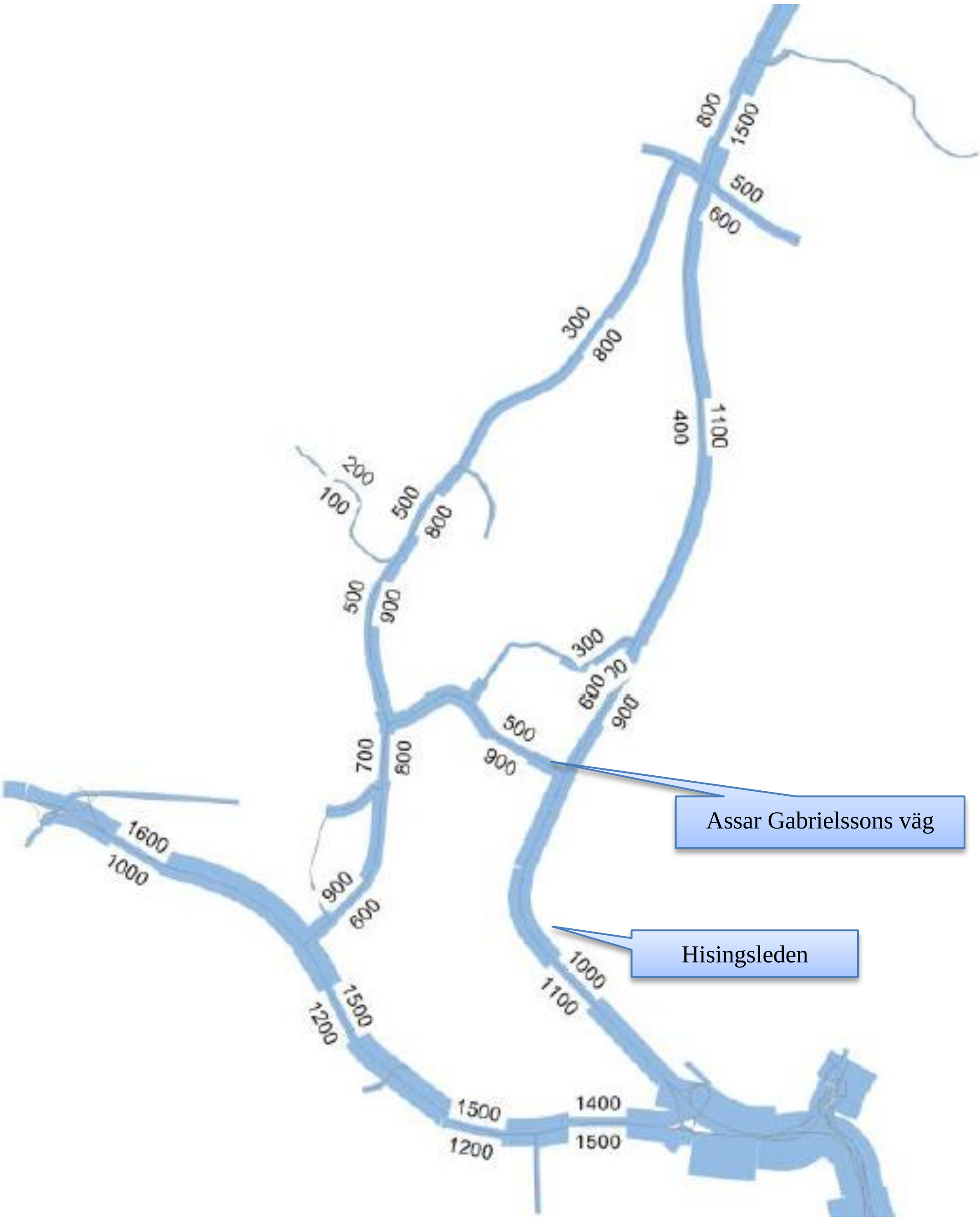


FIGURE D.1 TRAFFIC FLOW ON HISINGEN (AFTER SWEDISH TRANSPORT ADMINISTRATION, 2013C)

Appendix E – Capacity calculations from Capcal

Björlandavägen/Hisingsleden 07-08

Björlandavägen/Hisingsleden kl.07-08
Korsningstyp: Trafiksignal

Körfältsuppgifter

Tillfart	Körfält	Riktning	Kort körfält (m)	Bredd (m)
Björlanda, west	1	HR		3.5
	2	RV		3.5
	3	V	40	3.5
Björlanda, north	1	H		3.5
	2	R		3.5
	3	R		3.5
	4	V		3.5
Björlanda, east	1	HR		3.5
	2	R		3.5
	3	V	60	3.5
Björlanda, south	1	H	55	3.5
	2	R		3.5
	3	R		3.5
	4	V	75	3.5

Geometri

Tillfart	Stopplinje	Radie hsv	Vinkel	Lutning %
Björlanda, west	13	20		0
Björlanda, north	14	15		0
Björlanda, east	20	20		0
Björlanda, south	16	15		0

Frånfarter och refuger

Tillfart	Frånfartsbredd (m)	Refugbredd (m)
Björlanda, west	7.0	0.0
Björlanda, north	7.0	0.0
Björlanda, east	7.0	0.0
Björlanda, south	7.0	0.0

Hastigheter

Tillfart	Led	Lokal
Björlanda, west	70	50
Björlanda, north	80	60
Björlanda, east	50	50
Björlanda, south	80	60

Flöden per riktning

Tillfart	Höger	Rakt fram	Vänster
Björlanda, west	65	210	275
Björlanda, north	560	680	70
Björlanda, east	50	230	100
Björlanda, south	20	170	40

Flöden per fordonstyp

Tillfart	Tunga fordon (%)	Cyklar/h	Fotgängare/h
Björlanda, west	11	0	0
Björlanda, north	11	0	0
Björlanda, east	11	0	0
Björlanda, south	11	0	0

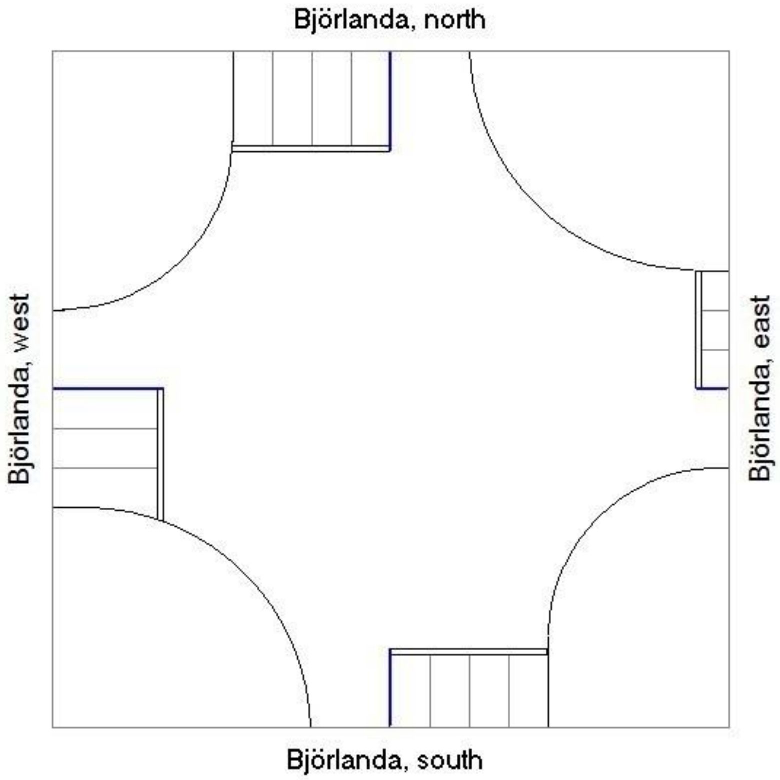
Flöden per körfält

Tillfart	Körfält	Höger	Rakt fram	Vänster
Björlanda, west	1	65	65	
	2		145	145
	3			130
Björlanda, east	1	50	50	
	2		180	
	3			100

Flöden per tillfart

Tillfart	Flöde
Björlanda, west	550
Björlanda, north	1310
Björlanda, east	380
Björlanda, south	230
Summa	2470

Korsningsbild



Resultat, en timme.
Kapacitet och kölängder per körfält

Tillfart	Körfält	Riktning	Flöde (f/t)	Kapacitet	Belastningsgrad	Kölängd Medel	90-percentil
Björlanda, west	1	HR	130	569	0.23	1.1	3.6
	2	RV	290	465	0.62	3.2	8.5
	3	V	130	360	0.36	1.3	4.1
Björlanda, north	1	H	560	747	0.75	5.1	12.8
	2	R	340	811	0.42	2.6	7.0
	3	R	340	811	0.42	2.6	7.0
	4	V	70	598	0.12	0.5	2.2
Björlanda, east	1	HR	100	559	0.18	0.9	3.0
	2	R	180	589	0.31	1.6	4.7

	3	V	100	450	0.22	1.0	3.2
Björlanda,	1	H	20	360	0.06	0.1	1.1
	2	R	85	810	0.10	0.6	2.4
	3	R	85	810	0.10	0.6	2.4
	4	V	40	360	0.11	0.3	1.7

Assar Gabrielssons väg/Hisingsleden 16-17

Assar gabrielssons väg/Hisingsleden kl.16-17
Korsningstyp: Trafiksignal

Körfältsuppgifter

Tillfart	Körfält	Riktning	Kort körfält (m)	Bredd (m)
Assar gabrielsson, west	1	H		3.5
	2	V		3.5
Assar gabrielsson, north	1	H		3.5
	2	R		3.5
Assar gabrielsson, south	1	R		3.5
	2	V		3.5
	3	V		3.5

Geometri

Tillfart	Stopplinje	Radie hsv	Vinkel	Lutning %
Assar gabrielsson, west	8	30		0
Assar gabrielsson, north	15	40		0
Assar gabrielsson, south	6	5		0

Frånfarter och refuger

Tillfart	Frånfartsbredd (m)	Refugbredd (m)
Assar gabrielsson, west	7.0	0.0
Assar gabrielsson, north	5.0	0.0
Assar gabrielsson, south	5.0	0.0

Hastigheter

Tillfart	Led	Lokal
Assar gabrielsson, west	50	50
Assar gabrielsson, north	70	70
Assar gabrielsson, south	70	70

Flöden per riktning

Tillfart	Höger	Rakt fram	Vänster
Assar gabrielsson, west	600		300
Assar gabrielsson, north	100	500	
Assar gabrielsson, south		600	400

Flöden per fordonstyp

Tillfart	Tunga fordon (%)	Cyklar/h	Fotgängare/h
Assar gabrielsson, west	10	0	0
Assar gabrielsson, north	10	0	0
Assar gabrielsson, south	10	0	0

Flöden per körfält

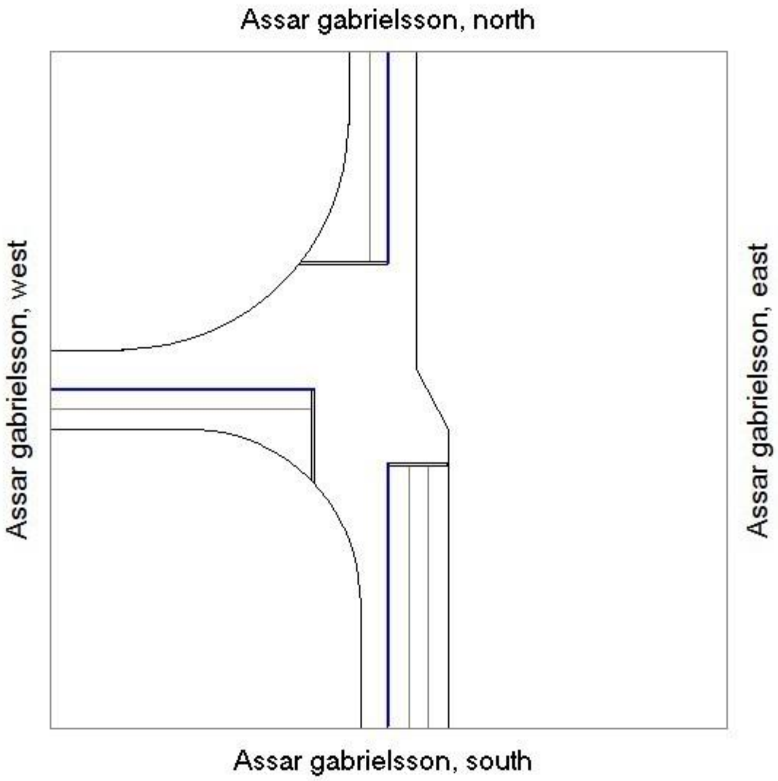
Tillfart	Körfält	Höger	Rakt fram	Vänster
Assar gabrielsson, south	1		600	

2	200
3	200

Flöden per tillfart

Tillfart	Flöde
Assar gabrielsson, west	900
Assar gabrielsson, north	600
Assar gabrielsson, south	1000
Summa	2500

Korsningsbild



Resultat, en timme.

Kapacitet och kölängder per körfält

						Kölängd	
Tillfart	Körfält	Riktning	Flöde	Kap	Belastningsgr	Medel	90-percentil
Assar gabrielsson, west	1	H	60	664	0.90	0.0	0.0
	2	V	30	615	0.49	0.0	0.0
Assar gabrielsson, north	1	H	10	561	0.18	0.0	0.0
	2	R	50	564	0.89	0.0	0.0
Assar gabrielsson, south	1	R	60	918	0.65	0.0	0.0
	2	V	20	254	0.79	0.0	0.0
	3	V	20 0	254	0.79	0.0	0.0

Appendix F – Input values for the distributions

TABLE F.1 AVERAGE WEEKDAY TRAFFIC FLOW FOR HISINGSLEDEN FROM THE NORTH TO THE SOUTH.

Time of the day	Hisingsleden: Average weekday traffic flow (N-S)					
	Total traffic, mean	Heavy traffic, mean	Total traffic, max	Heavy traffic, max	Total traffic, min	Heavy traffic, min
Rush	15 028	1 541	39 968	2 340	5 504	507
Day	9 798	1 627	15 600	2 240	5 173	1 227
Night	2 673	297	21 088	907	107	44

TABLE F.2 AVERAGE WEEKDAY TRAFFIC FLOWS FOR LUNDBYLEDEN IN ONE DIRECTION.

Time of the day	Lundbyleden: Average weekday traffic flow (One direction)					
	Total traffic, mean	Heavy traffic, mean	Total traffic, max	Heavy traffic, max	Total traffic, min	Heavy traffic, min
Rush	22 901	25 19	31 840	3 408	14 123	1 502
Day	18 100	30 66	22 004	3 413	13 109	2 738
Night	12 879	458	19 856	1 523	392	80

TABLE F.3 NUMBER OF ACCIDENTS ON HISINGSLEDEN.

Time of the day	Hisingsleden: Number of accidents								
	Total traffic			Private vehicles			Heavy vehicles		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Rush hour	0.009	0.013	0.006	0.008	0.013	0.006	0.0008	0.0039	0.000
Day	0.004	0.006	0.000	0.002	0.004	0.000	0.0019	0.0039	0.000
Night	0.004	0.008	0.002	0.003	0.008	0.002	0.0004	0.0019	0.000

TABLE F.4 NUMBER OF ACCIDENTS ON LUNDBYLEDEN.

Time of the day	Lundbyleden: Number of accidents								
	Total traffic			Private vehicles			Heavy vehicles		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Rush hour	0.020	0.027	0.010	0.013	0.015	0.008	0.007	0.015	0.002
Day	0.008	0.015	0.004	0.005	0.010	0.000	0.004	0.006	0.002
Night	0.005	0.012	0.002	0.003	0.008	0.000	0.002	0.004	0.000

TABLE F.5 NUMBER OF ACCIDENTS WITH A COMPLETELY BLOCKED ROAD ON HISINGSLEDEN.

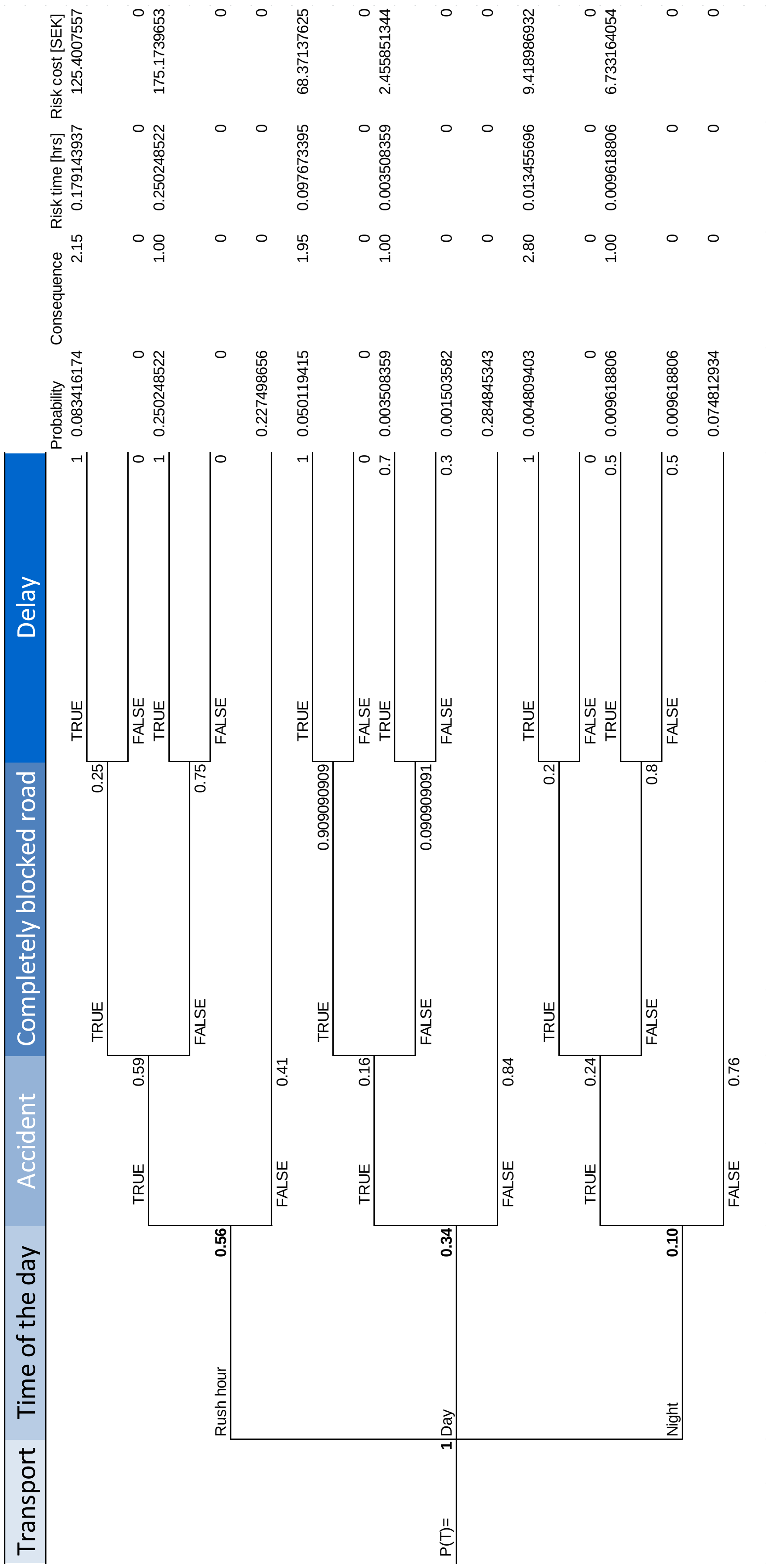
Time of the day	Hisingsleden: Number of accidents with a completely blocked road		
	Mean	Max	Min
Rush hour	0.0023	0.0039	0.000
Day	0.0039	0.0077	0.000
Night	0.0008	0.0039	0.000

TABLE F.6 NUMBER OF ACCIDENTS WITH A COMPLETELY BLOCKED ROAD ON LUNDBYLEDEN.

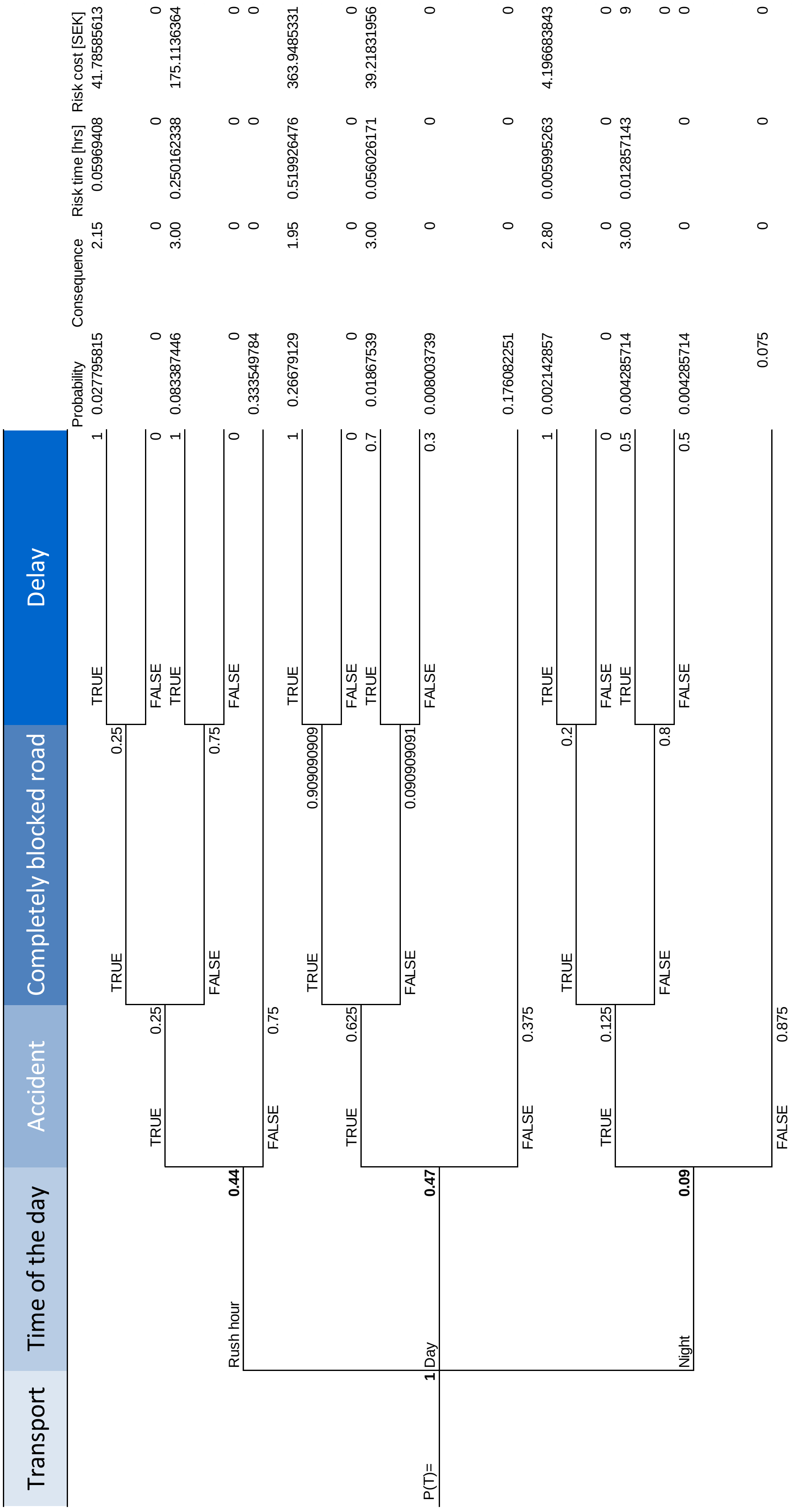
Time of the day	Lundbyleden: Number of accidents with a completely blocked road		
	Mean	Max	Min
Rush hour	0.0031	0.0077	0.000
Day	0.0015	0.0077	0.000
Night	0.0008	0.0039	0.000

Appendix G – Risk model

Alternative 0 Hisingsleden – Private vehicles



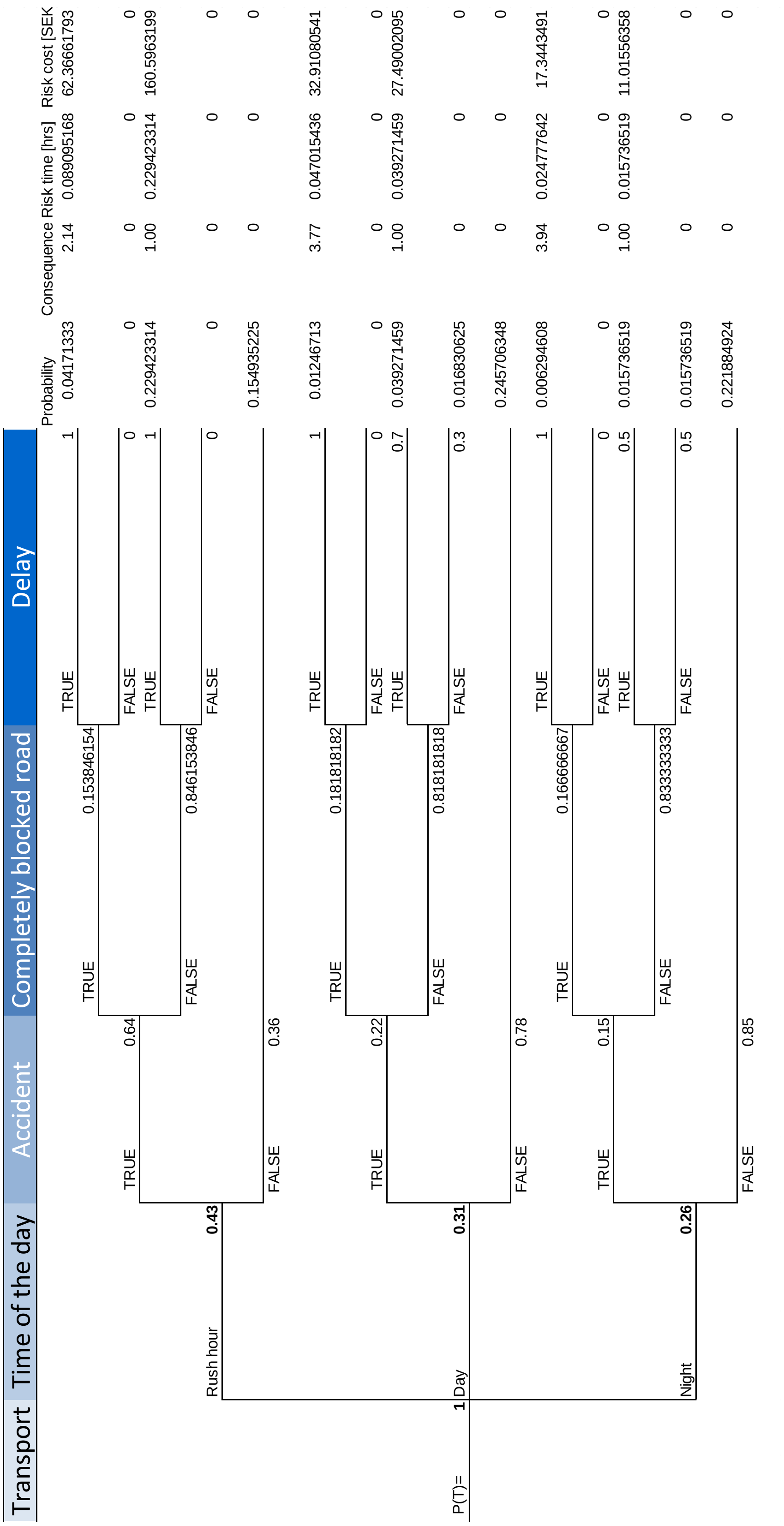
Alternative 0 Hisingsleden – Heavy vehicles



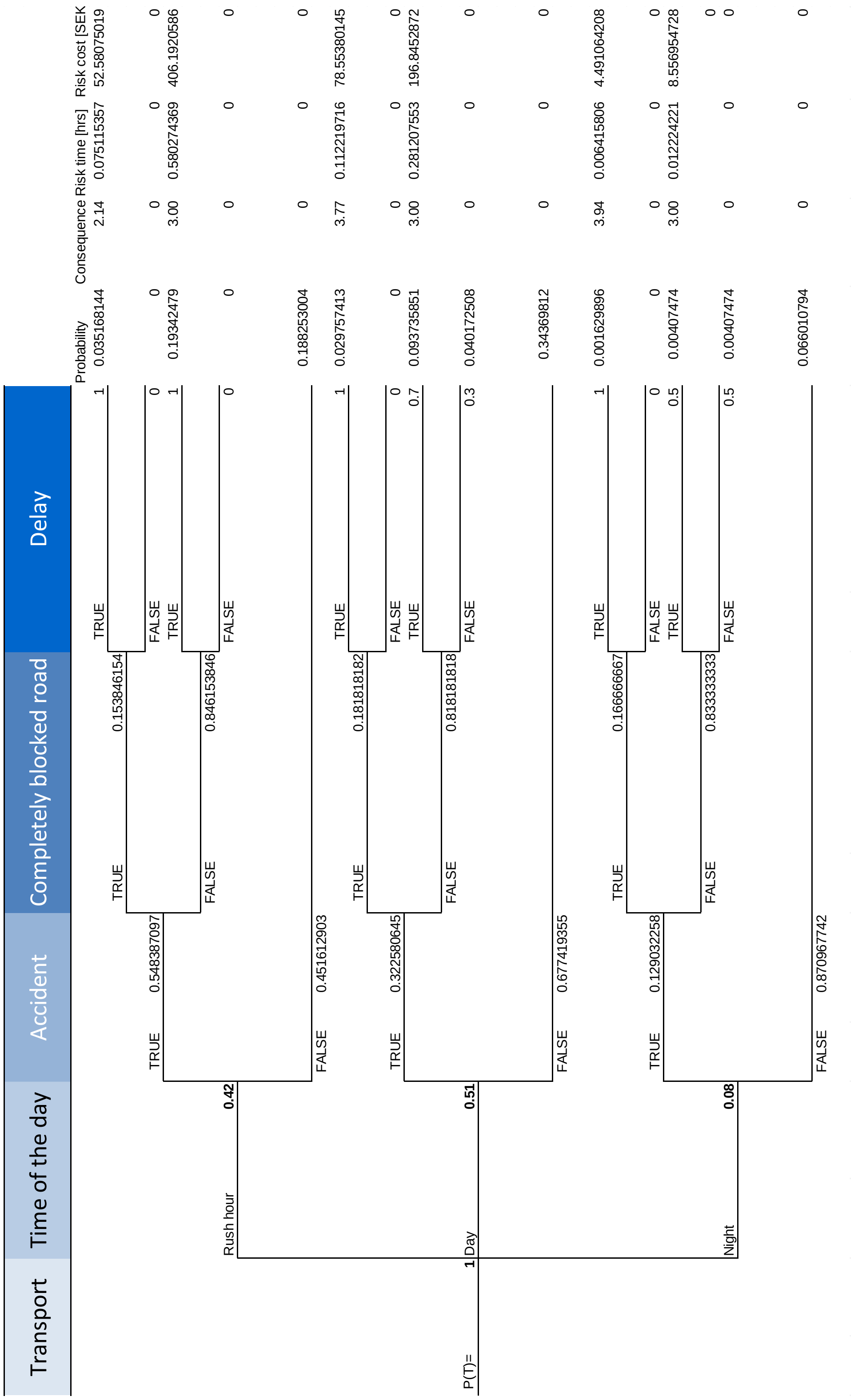
Alternative 0 Hisingsleden – Dangerous goods

The event tree for Alternative 0 Hisingsleden – Dangerous goods are found at page 117.

Alternative 0 Lundbyleden – Private vehicles



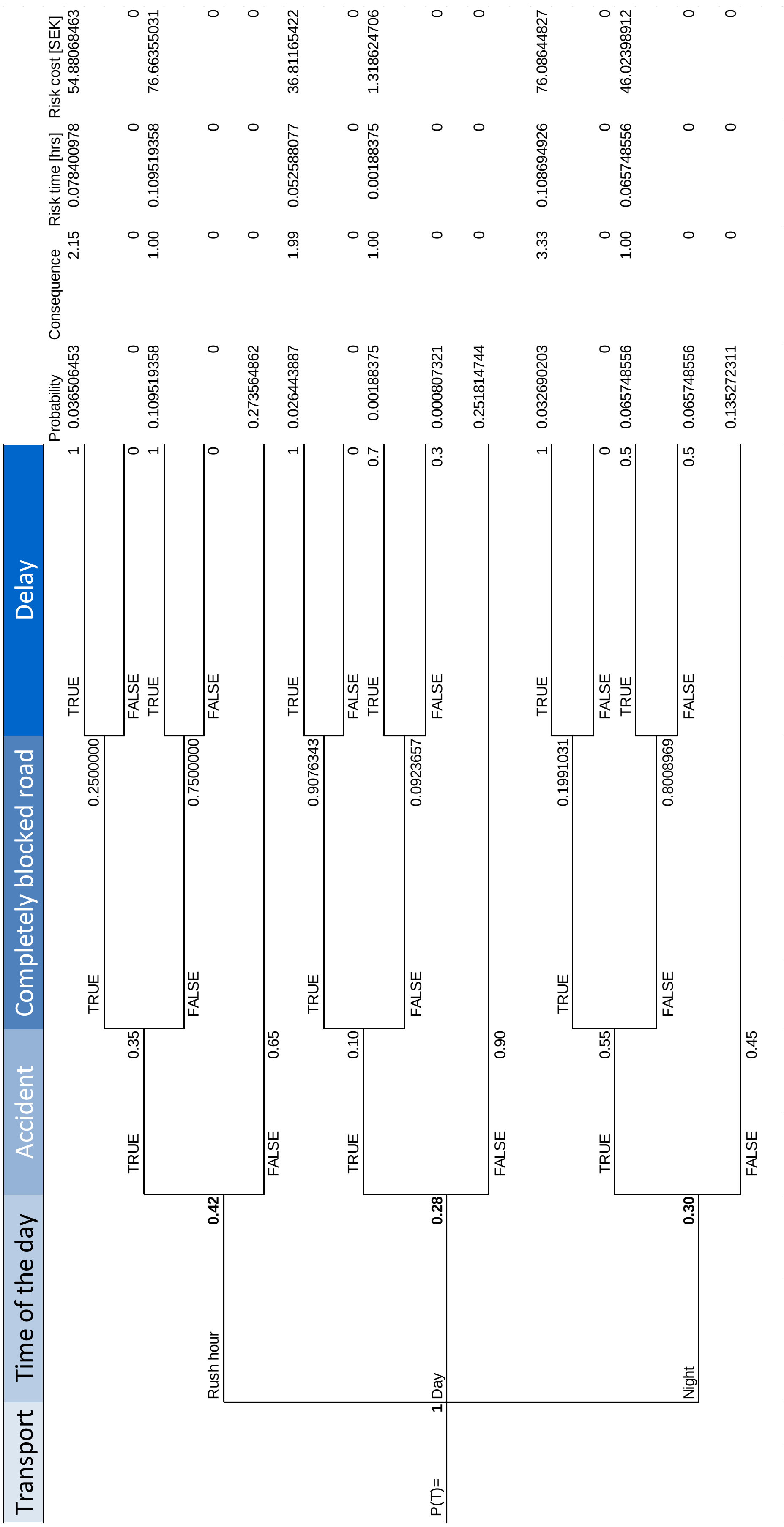
Alternative 0 Lundbyleden – Heavy vehicles



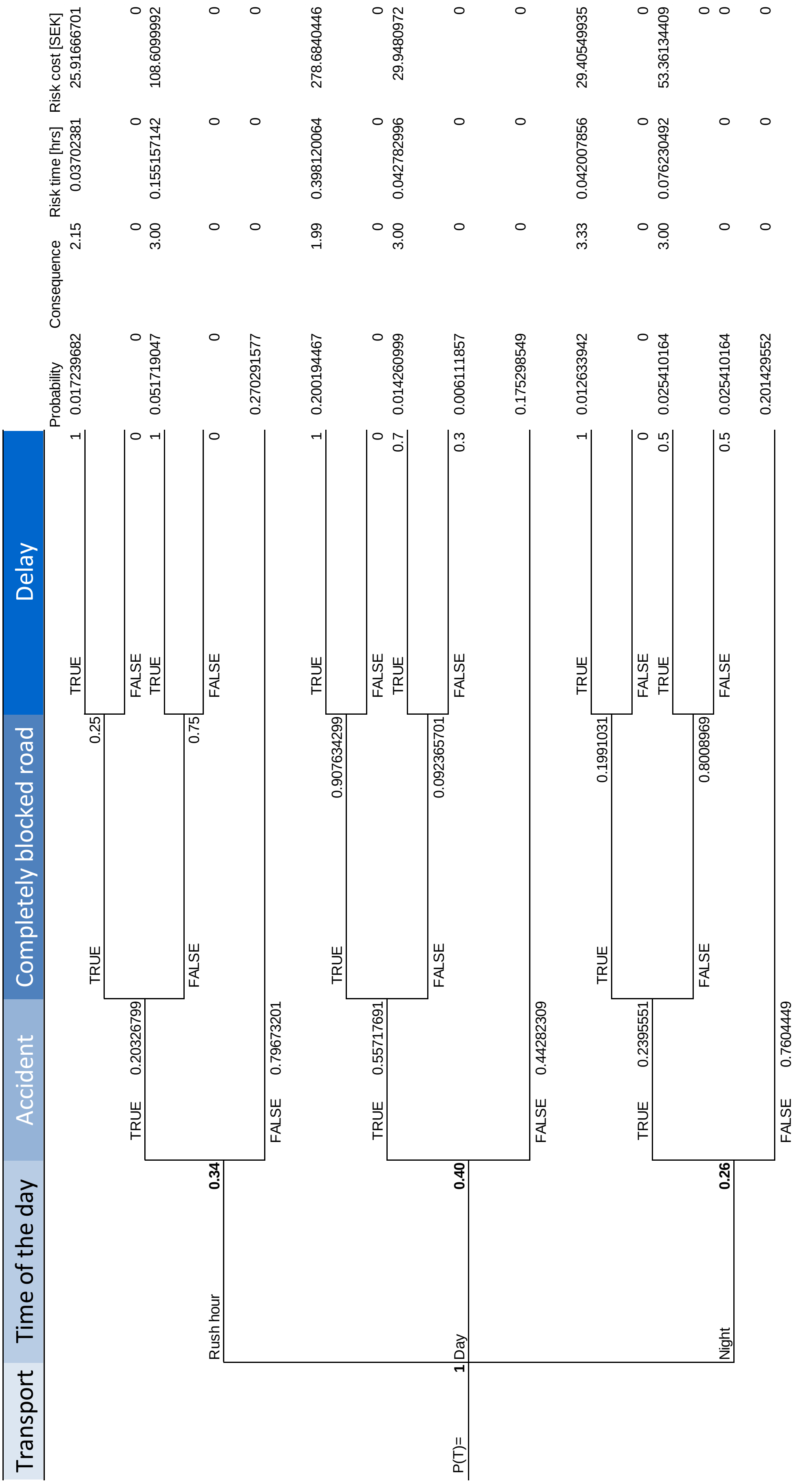
Alternative 0 Lundbyleden – Dangerous goods

The event tree for Alternative 0 Lundbyleden – Dangerous goods are found at page 119.

Alternative 1 Hisingsleden – Private vehicles



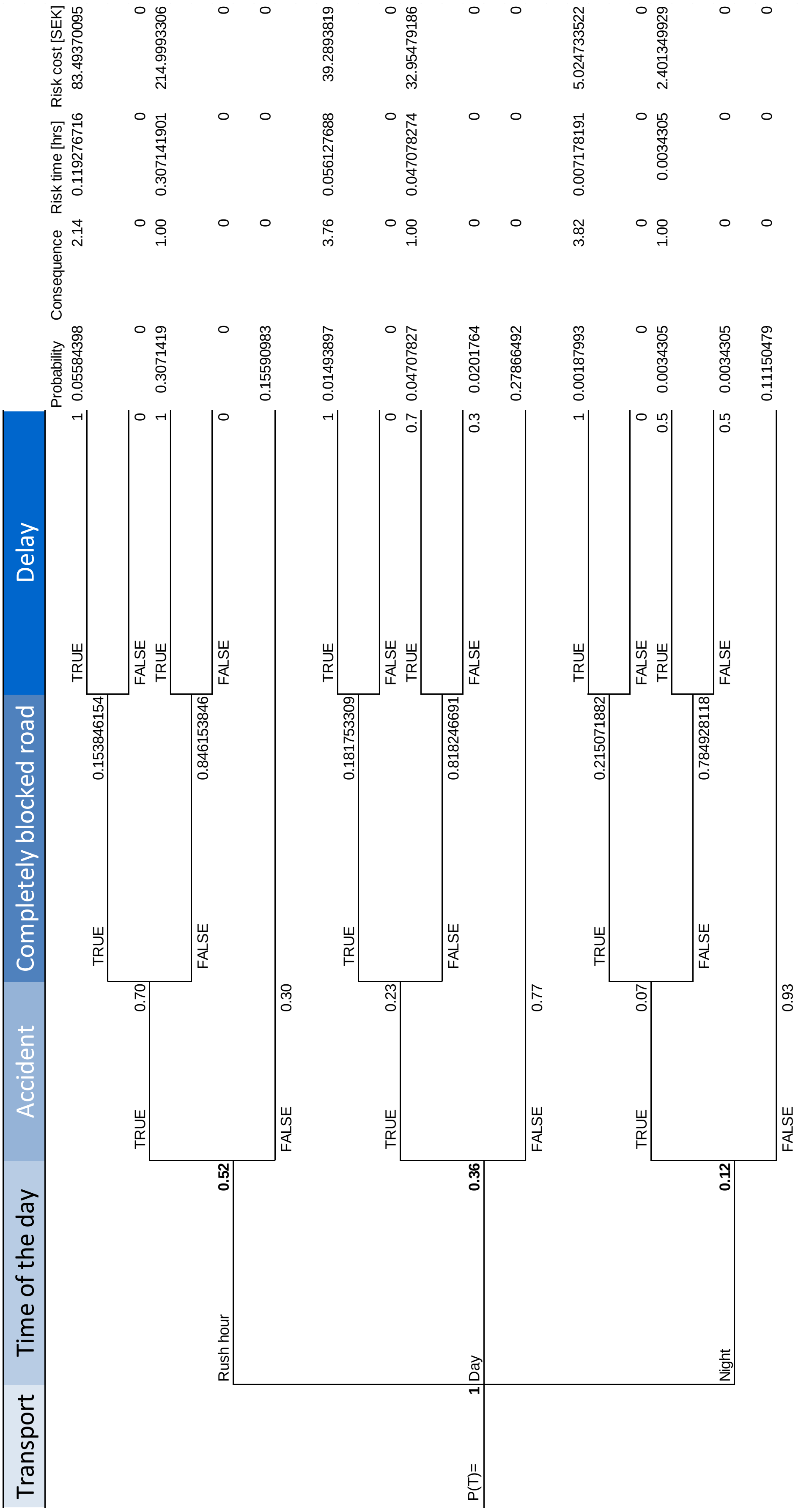
Alternative 1 Hisingsleden – Heavy vehicles



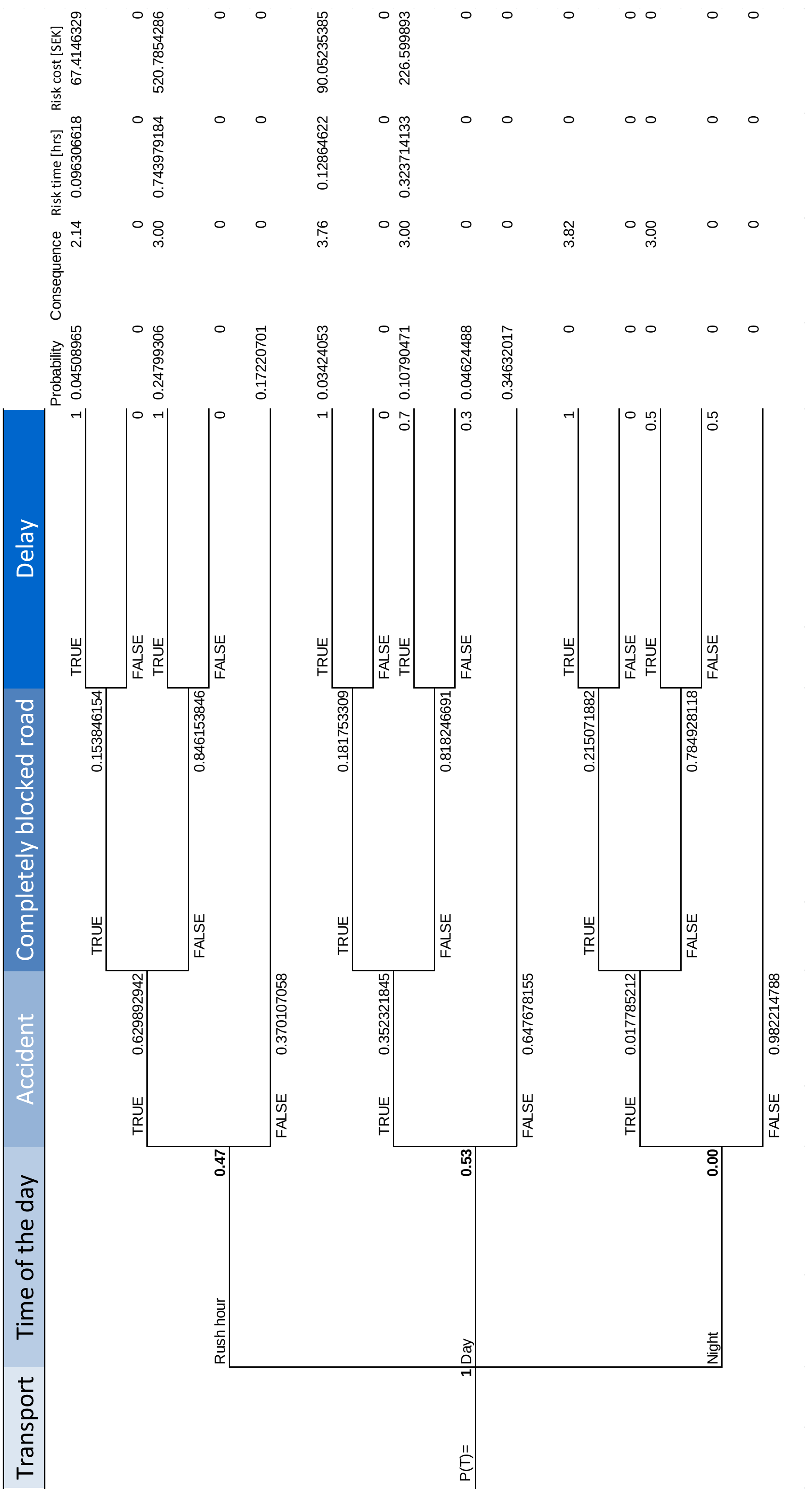
Alternative 1 Hisingsleden – Dangerous goods

The event tree for Alternative 1 Hisingsleden – Dangerous goods are found at page 121.

Alternative 1 Lundbyleden – Private vehicles



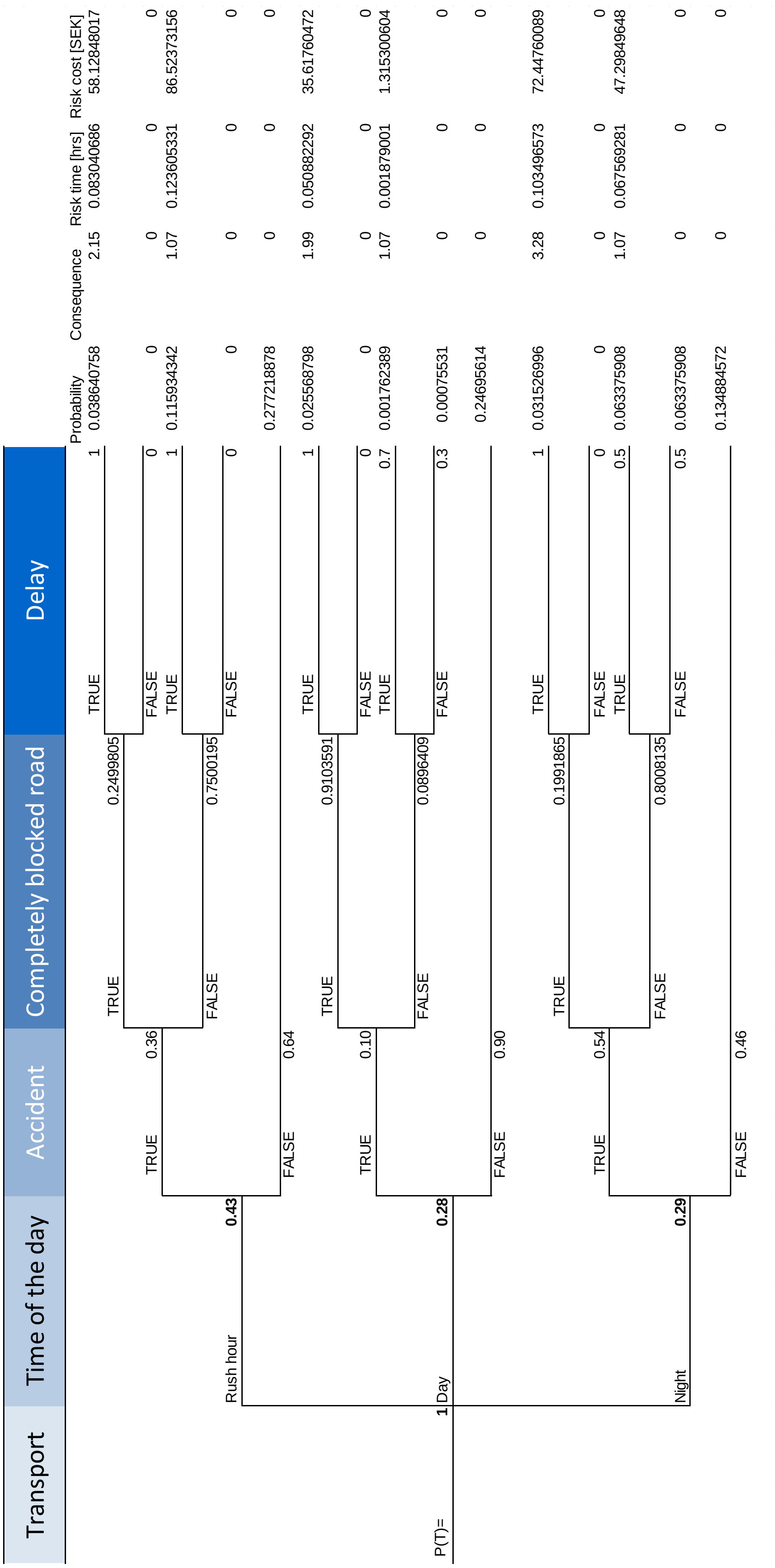
Alternative 1 Lundbyleden – Heavy vehicles



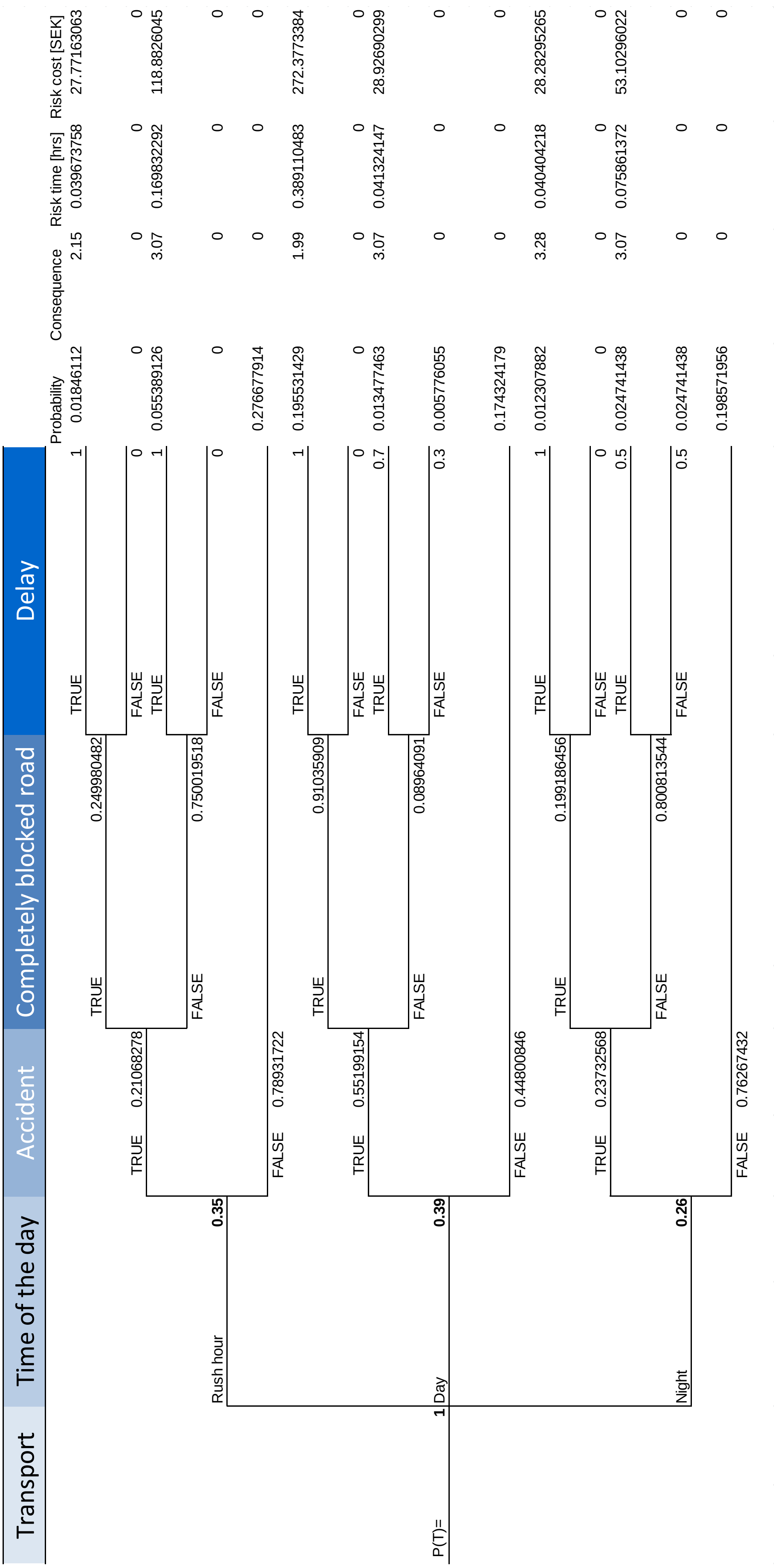
Alternative 1 Lundbyleden – Dangerous good

The event tree for Alternative 1 Lundbyleden – Dangerous goods are found at page 123.

Alternative 2 Hisingsleden – Private vehicles



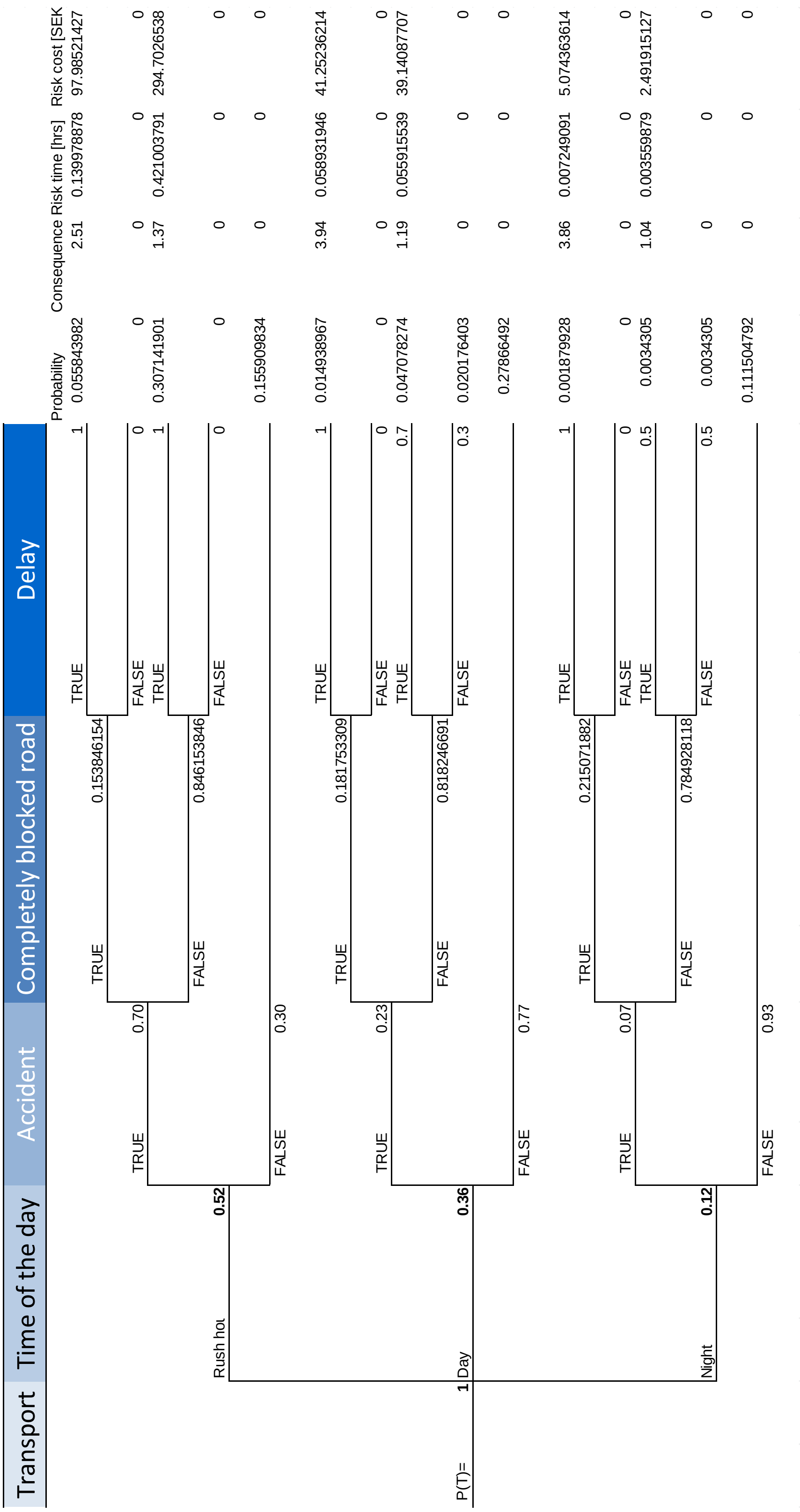
Alternative 2 Hisingsleden – Heavy vehicles



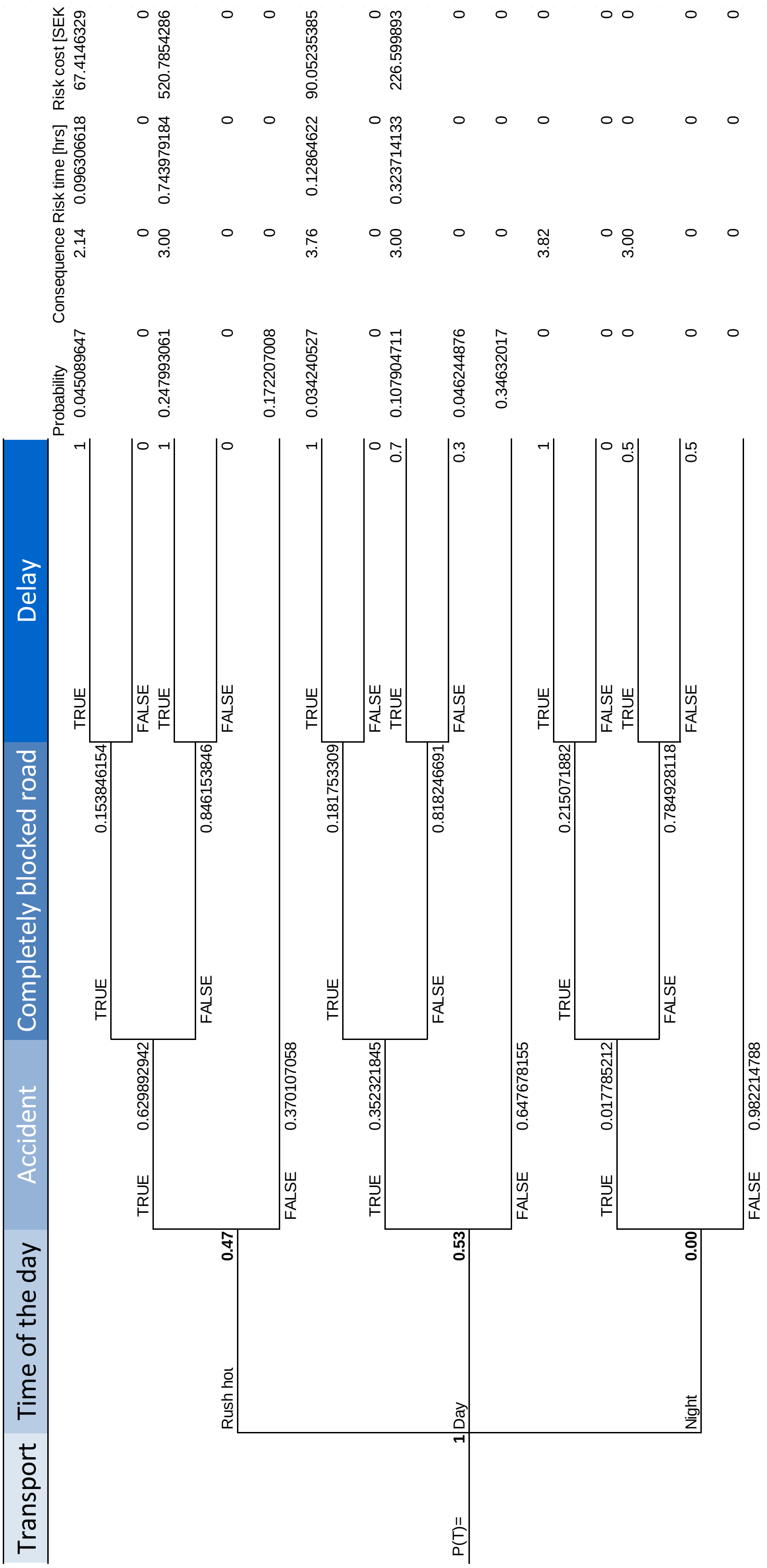
Alternative 2 Hisingsleden – Dangerous goods

The event tree for Alternative 2 Hisingsleden – Dangerous goods are found at page 125.

Alternative 2 Lundbyleden – Private vehicles



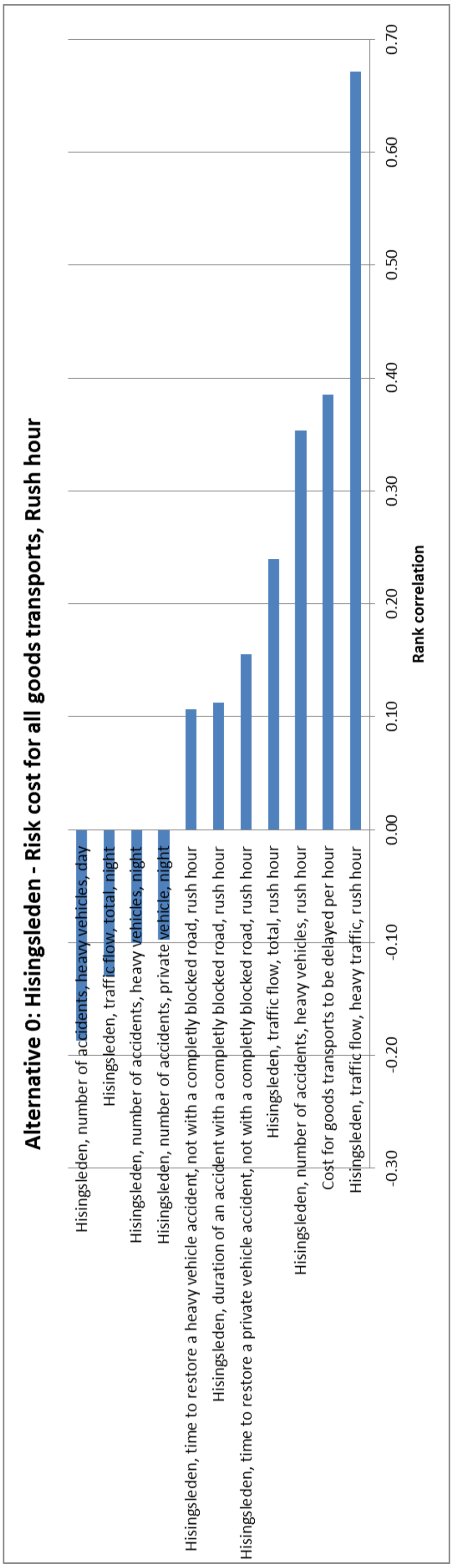
Alternative 2 Lundbyleden – Heavy vehicles

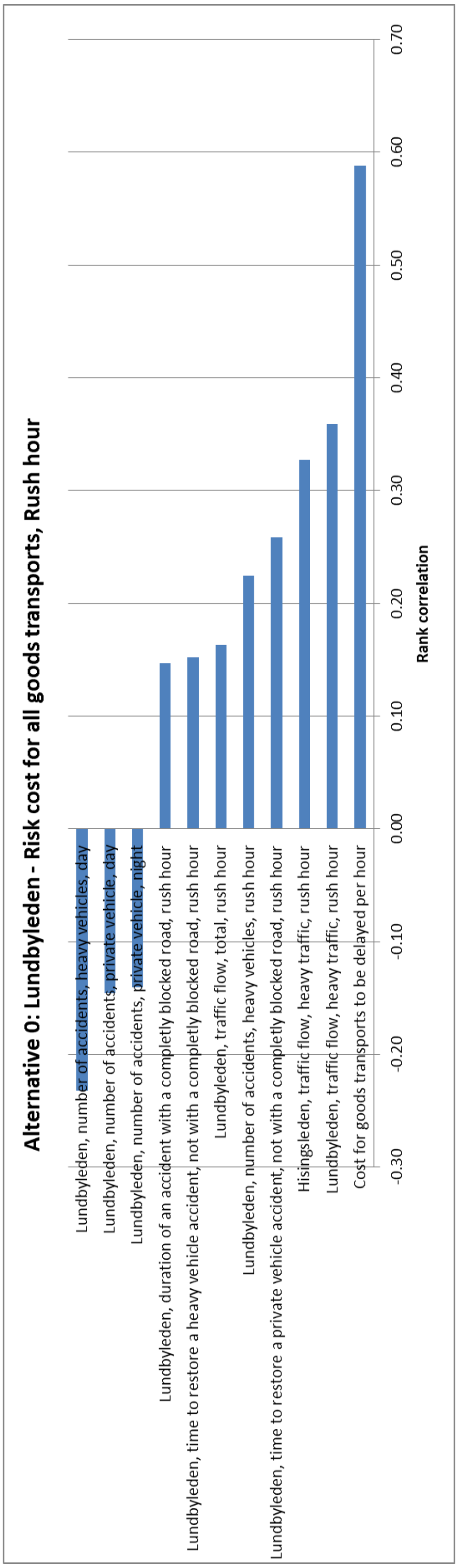


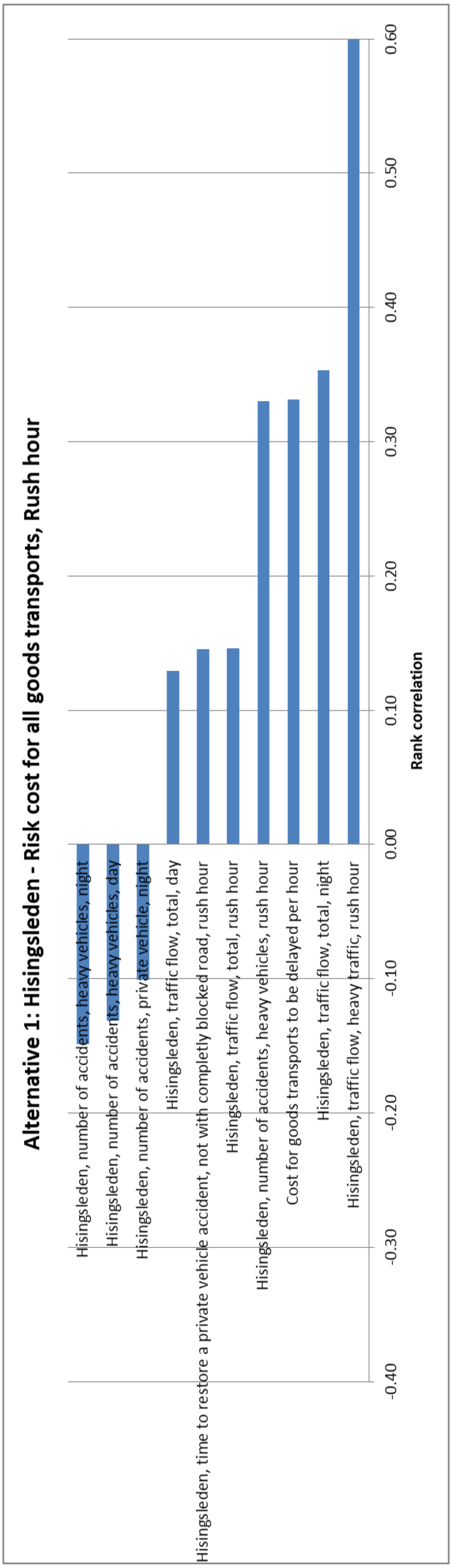
Alternative 2 Lundbyleden – Dangerous good

The event tree for Alternative 2 Lundbyleden – Dangerous goods are found at page 127.

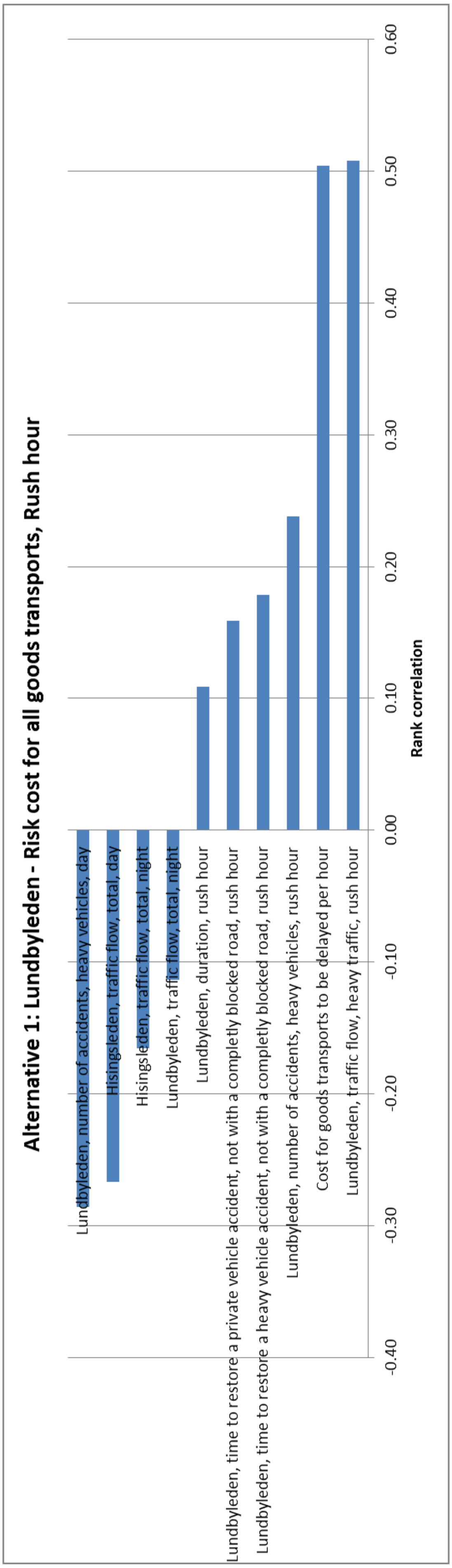
Appendix H – Uncertainty analysis



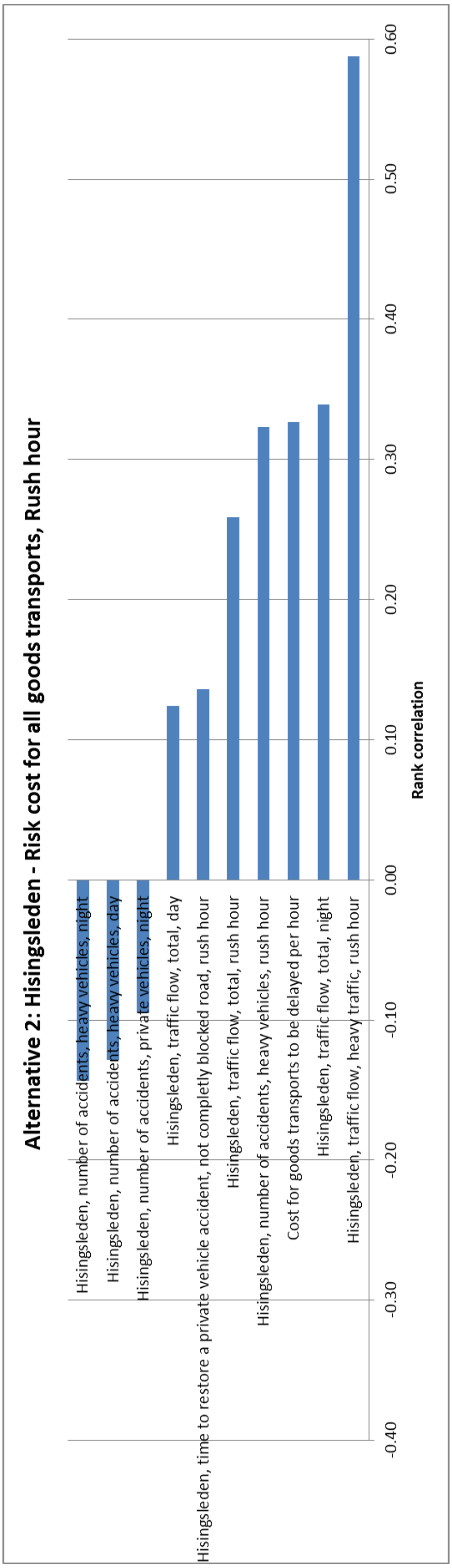


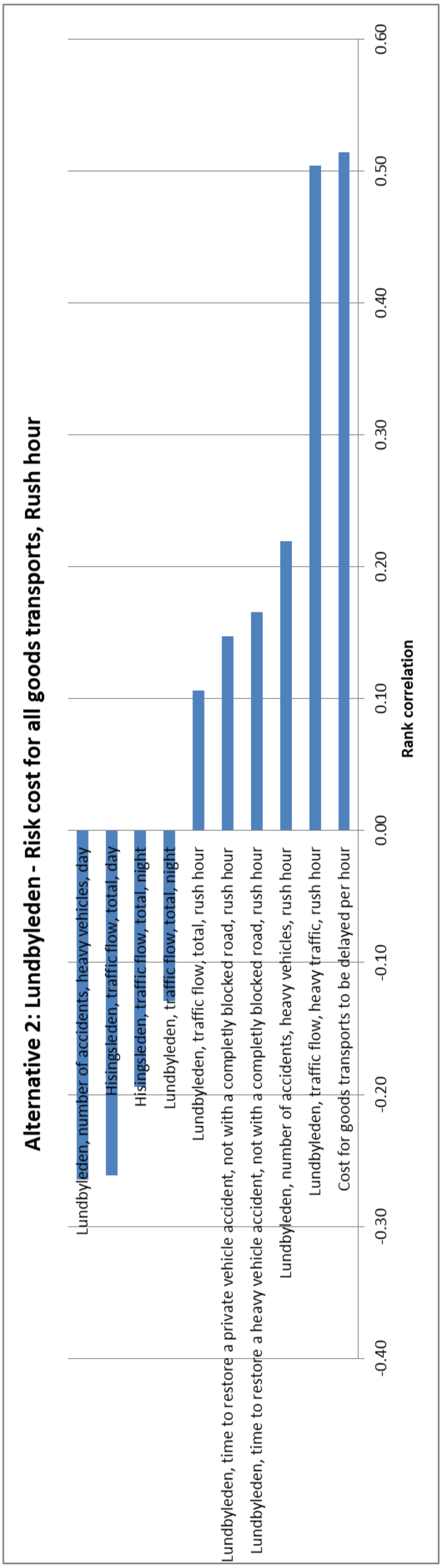


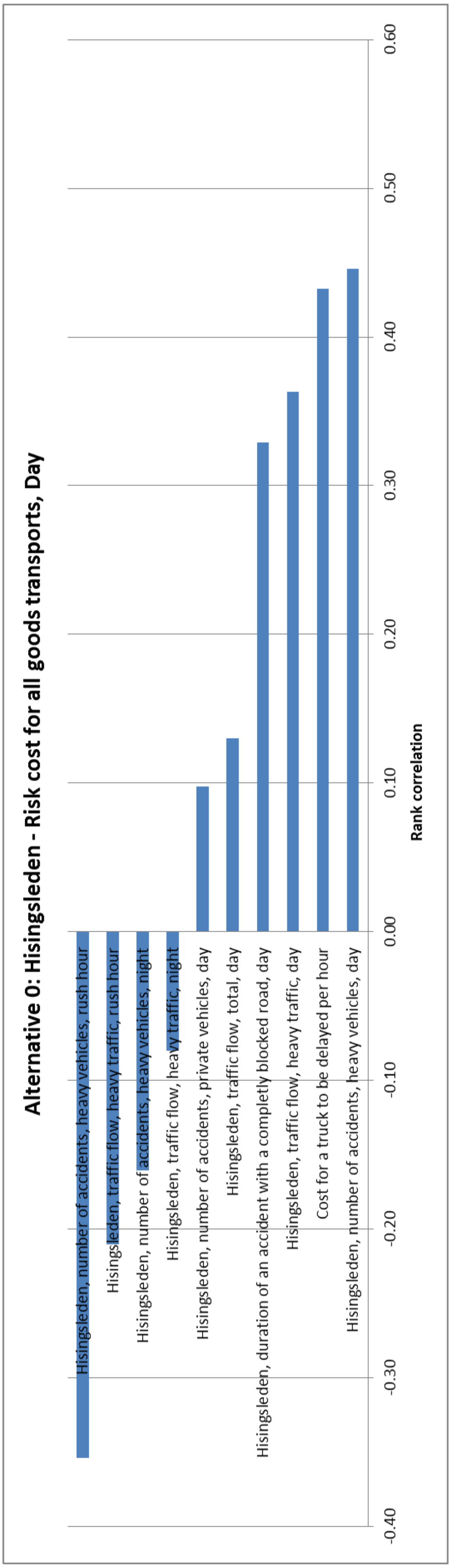
Alternative 1: Hisingsleden - Risk cost for all goods transports, Rush hour
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, number of accidents, heavy vehicles, day
Hisingsleden, number of accidents, private vehicle, night
Hisingsleden, traffic flow, total, day
Hisingsleden, time to restore a private vehicle accident, not with completly blocked road, rush hour
Hisingsleden, traffic flow, total, rush hour
Hisingsleden, number of accidents, heavy vehicles, rush hour
Cost for goods transports to be delayed per hour
Hisingsleden, traffic flow, total, night
Hisingsleden, traffic flow, heavy traffic, rush hour
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Rank correlation

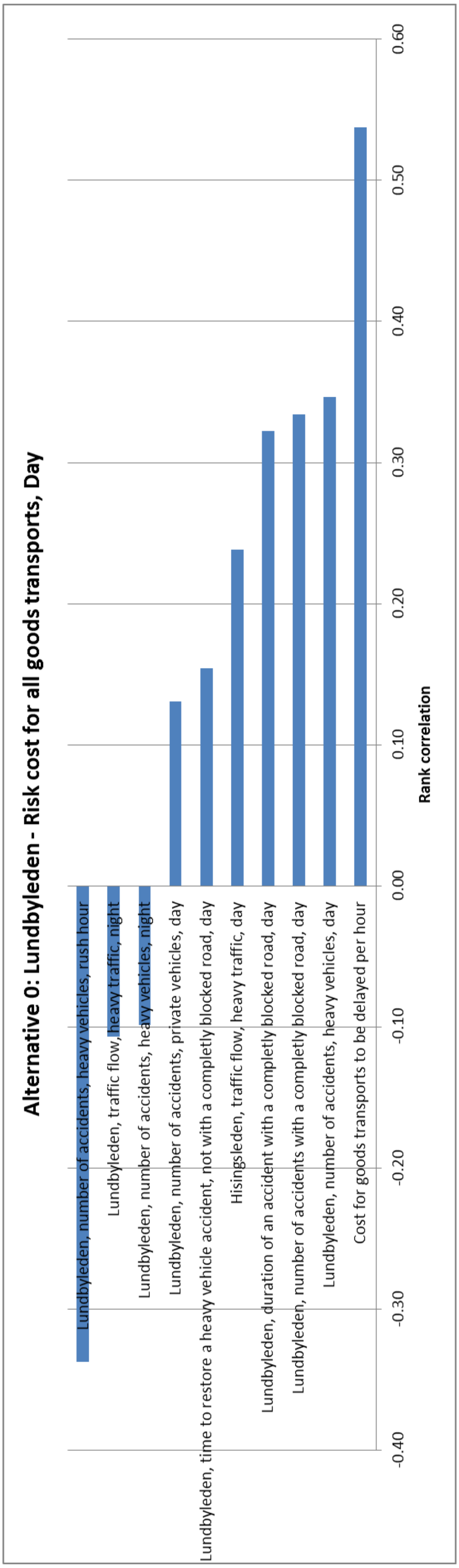


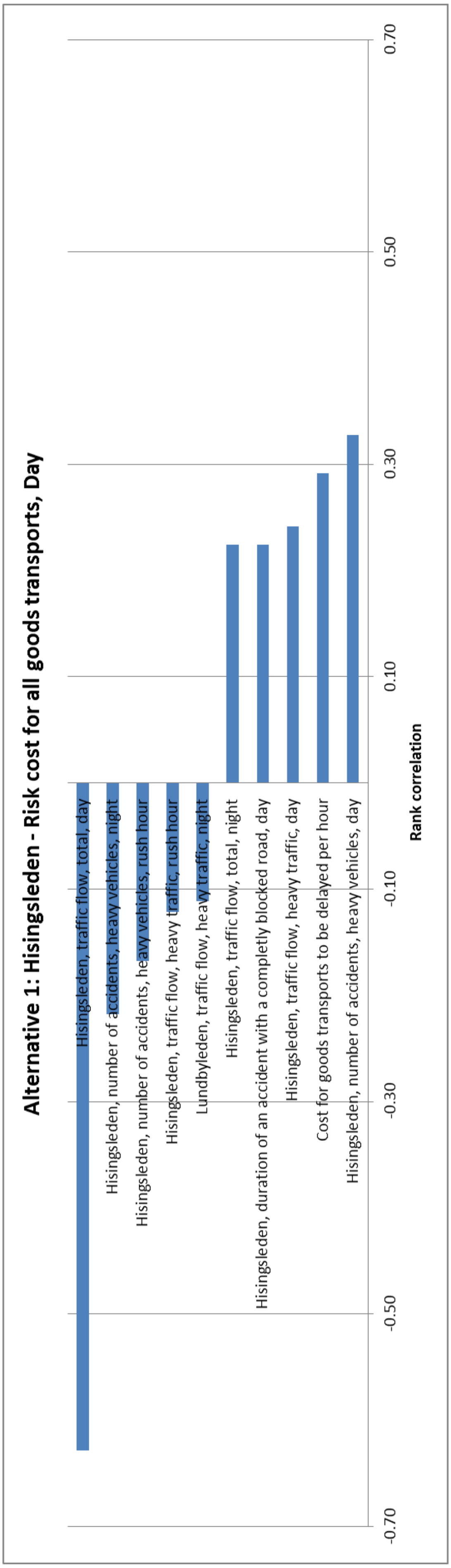
Alternative 1: Lundbyleden - Risk cost for all goods transports, Rush hour
Lundbyleden, number of accidents, heavy vehicles, day
Hisingsleden, traffic flow, total, day
Hisingsleden, traffic flow, total, night
Lundbyleden, traffic flow, total, night
Lundbyleden, duration, rush hour
Lundbyleden, time to restore a private vehicle accident, not with a completly blocked road, rush hour
Lundbyleden, time to restore a heavy vehicle accident, not with a completly blocked road, rush hour
Lundbyleden, number of accidents, heavy vehicles, rush hour
Cost for goods transports to be delayed per hour
Lundbyleden, traffic flow, heavy traffic, rush hour
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Rank correlation

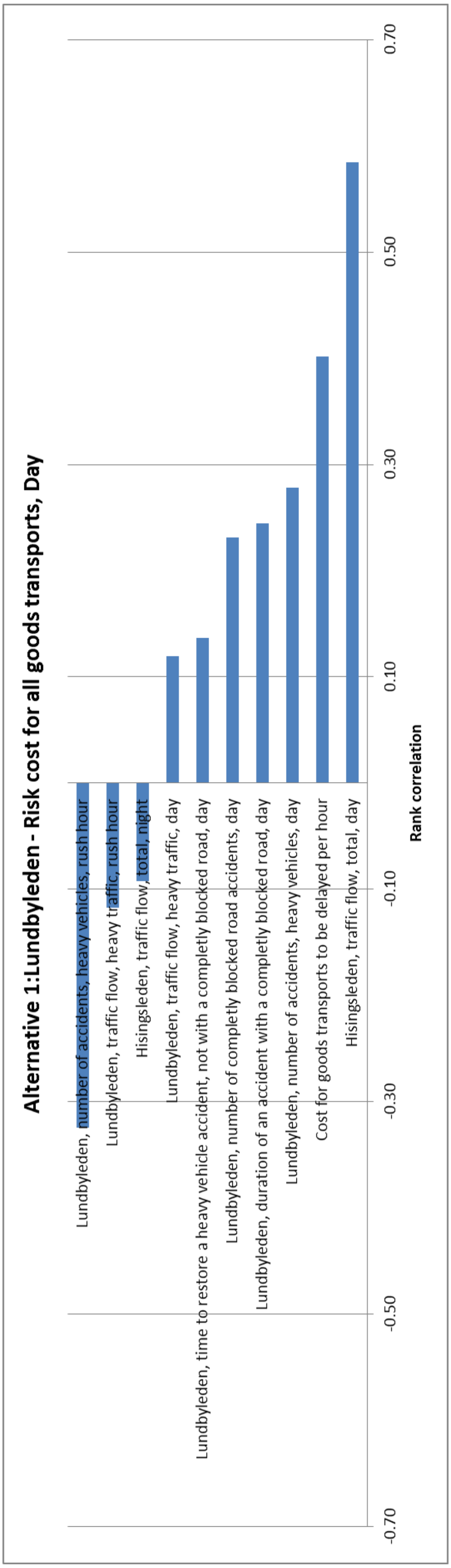

Alternative 2: Hisingsleden - Risk cost for all goods transports, Rush hour
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, number of accidents, heavy vehicles, day
Hisingsleden, number of accidents, private vehicles, night
Hisingsleden, traffic flow, total, day
Hisingsleden, time to restore a private vehicle accident, not completly blocked road, rush hour
Hisingsleden, traffic flow, total, rush hour
Hisingsleden, number of accidents, heavy vehicles, rush hour
Cost for goods transports to be delayed per hour
Hisingsleden, traffic flow, total, night
Hisingsleden, traffic flow, heavy traffic, rush hour
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Rank correlation

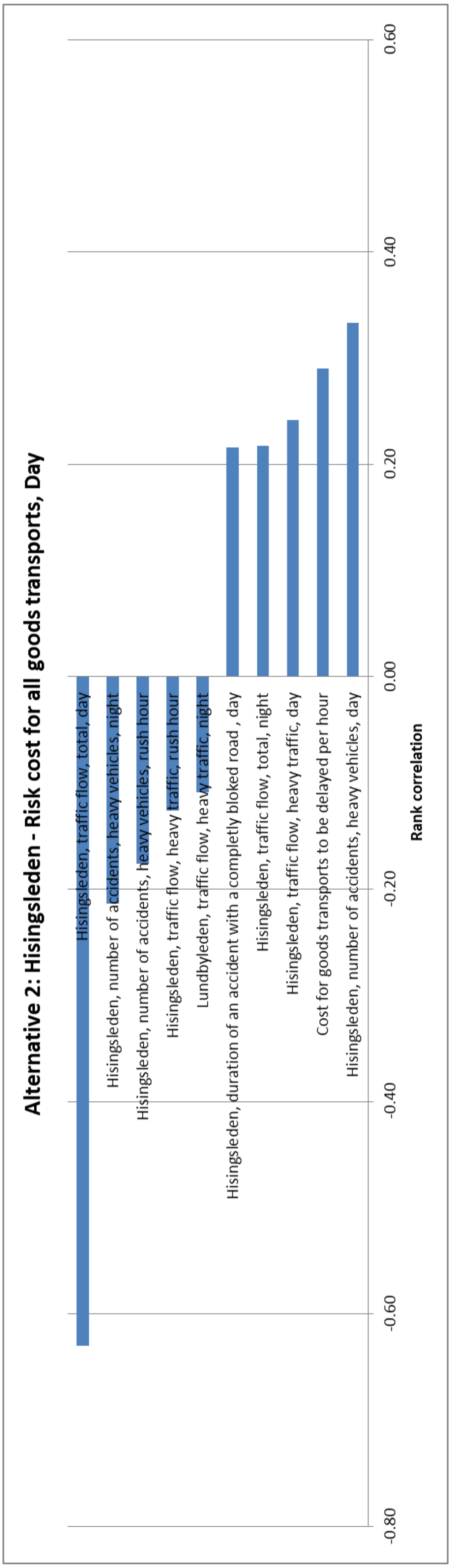

Alternative 2: Lundbyleden - Risk cost for all goods transports, Rush hour
Lundbyleden, number of accidents, heavy vehicles, day
Hisingsleden, traffic flow, total, day
Hisingsleden, traffic flow, total, night
Lundbyleden, traffic flow, total, night
Lundbyleden, traffic flow, total, rush hour
Lundbyleden, time to restore a private vehicle accident, not with a completly blocked road, rush hour
Lundbyleden, time to restore a heavy vehicle accident, not with a completly blocked road, rush hour
Lundbyleden, number of accidents, heavy vehicles, rush hour
Lundbyleden, traffic flow, heavy traffic, rush hour
Cost for goods transports to be delayed per hour
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Rank correlation

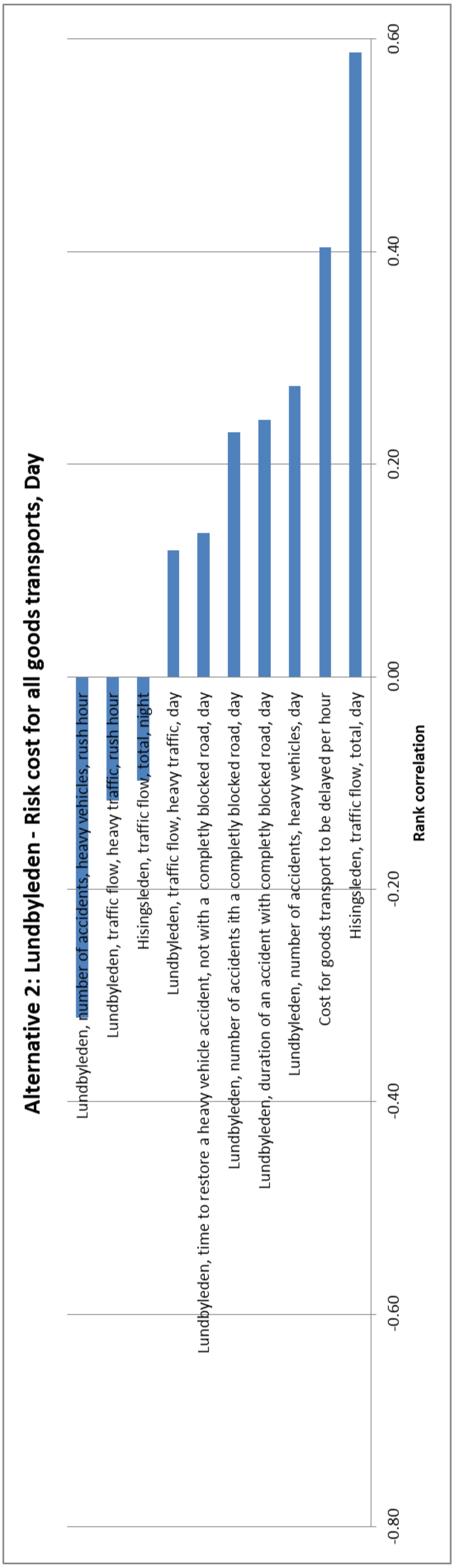

Alternative 0: Hisingsleden - Risk cost for all goods transports, Day
Hisingsleden, number of accidents, heavy vehicles, rush hour
Hisingsleden, traffic flow, heavy traffic, rush hour
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, traffic flow, heavy traffic, night
Hisingsleden, number of accidents, private vehicles, day
Hisingsleden, traffic flow, total, day
Hisingsleden, duration of an accident with a completly blocked road, day
Hisingsleden, traffic flow, heavy traffic, day
Cost for a truck to be delayed per hour
Hisingsleden, number of accidents, heavy vehicles, day
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Rank correlation

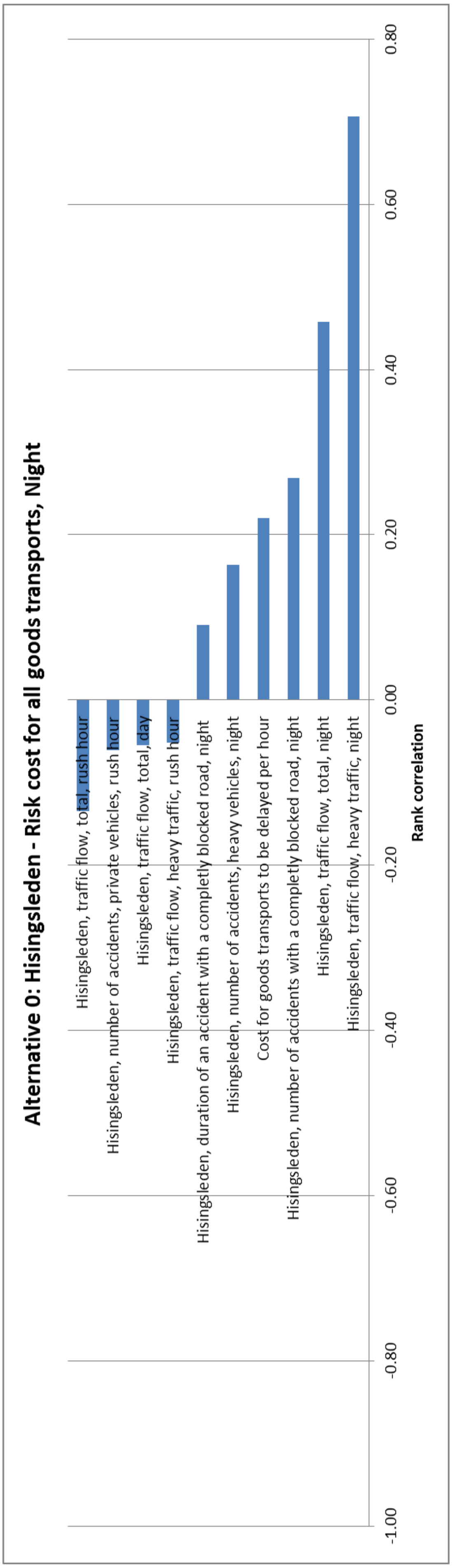

Alternative 0: Lundbyleden - Risk cost for all goods transports, Day
Lundbyleden, number of accidents, heavy vehicles, rush hour
Lundbyleden, traffic flow, heavy traffic, night
Lundbyleden, number of accidents, heavy vehicles, night
Lundbyleden, number of accidents, private vehicles, day
Lundbyleden, time to restore a heavy vehicle accident, not with a completly blocked road, day
Hisingsleden, traffic flow, heavy traffic, day
Lundbyleden, duration of an accident with a completly blocked road, day
Lundbyleden, number of accidents with a completly blocked road, day
Lundbyleden, number of accidents, heavy vehicles, day
Cost for goods transports to be delayed per hour
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Rank correlation

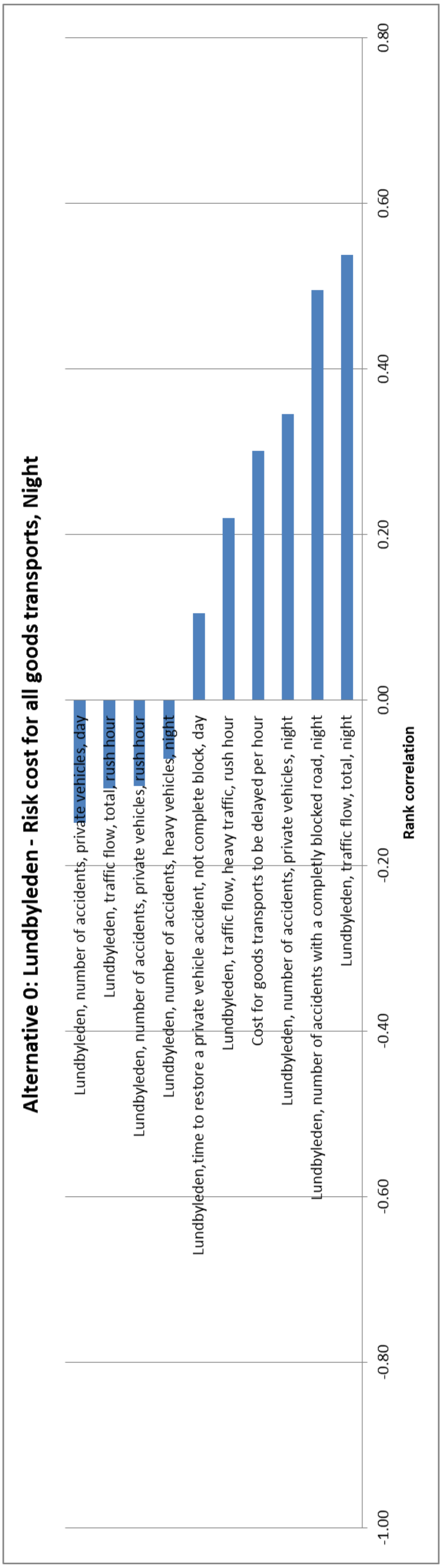

Alternative 1: Hisingsleden - Risk cost for all goods transports, Day
Hisingsleden, traffic flow, total, day
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, number of accidents, heavy vehicles, rush hour
Hisingsleden, traffic flow, heavy traffic, rush hour
Lundbyleden, traffic flow, heavy traffic, night
Hisingsleden, traffic flow, total, night
Hisingsleden, duration of an accident with a completly blocked road, day
Hisingsleden, traffic flow, heavy traffic, day
Cost for goods transports to be delayed per hour
Hisingsleden, number of accidents, heavy vehicles, day
-0.70
-0.50
-0.30
-0.10
0.10
0.30
0.50
0.70
Rank correlation

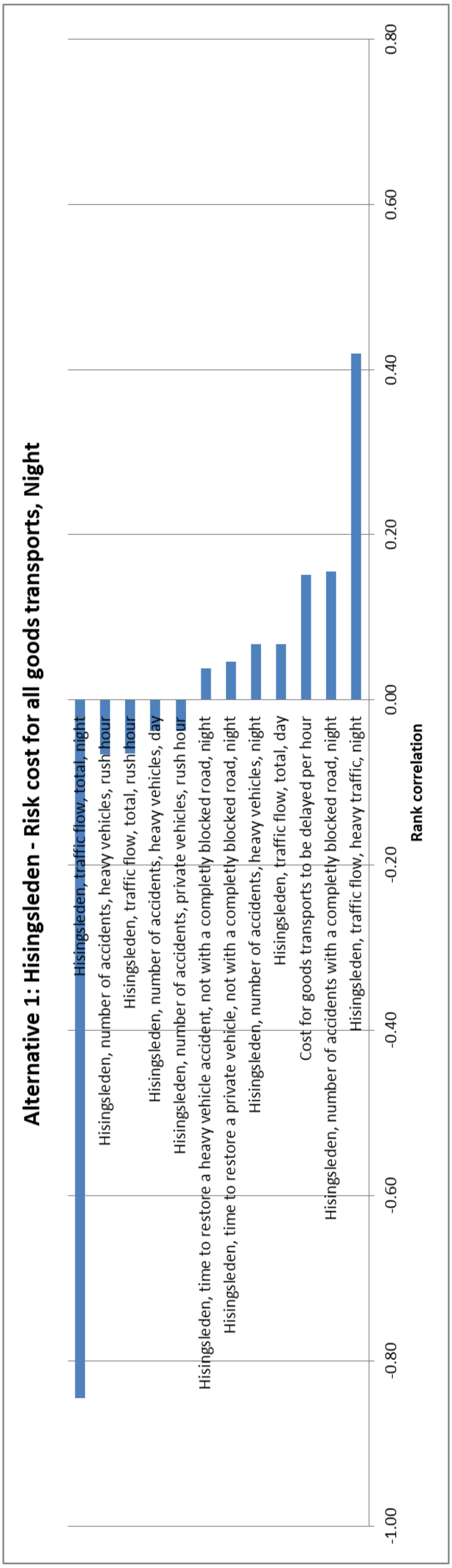

Alternative 1:Lundbyleden - Risk cost for all goods transports, Day
Lundbyleden, number of accidents, heavy vehicles, rush hour
Lundbyleden, traffic flow, heavy traffic, rush hour
Hisingsleden, traffic flow, total, night
Lundbyleden, traffic flow, heavy traffic, day
Lundbyleden, time to restore a heavy vehicle accident, not with a completly blocked road, day
Lundbyleden, number of completly blocked road accidents, day
Lundbyleden, duration of an accident with a completly blocked road, day
Lundbyleden, number of accidents, heavy vehicles, day
Cost for goods transports to be delayed per hour
Hisingsleden, traffic flow, total, day
-0.70
-0.50
-0.30
-0.10
0.10
0.30
0.50
0.70
Rank correlation

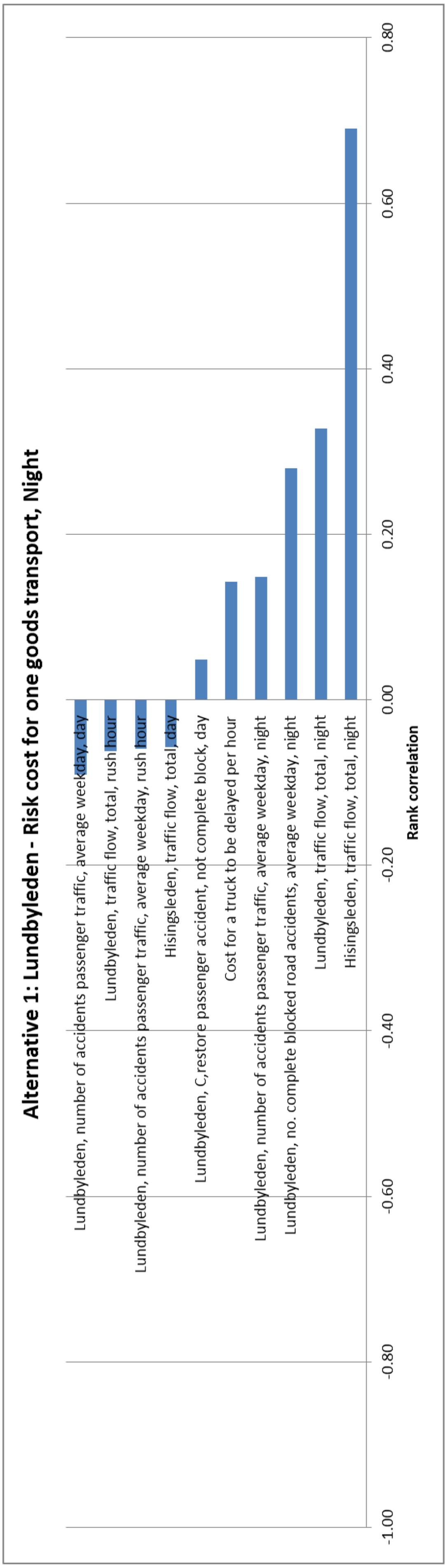

Alternative 2: Hisingsleden - Risk cost for all goods transports, Day
Hisingsleden, traffic flow, total, day
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, number of accidents, heavy vehicles, rush hour
Hisingsleden, traffic flow, heavy traffic, rush hour
Lundbyleden, traffic flow, heavy traffic, night
Hisingsleden, duration of an accident with a completly bloked road , day
Hisingsleden, traffic flow, total, night
Hisingsleden, traffic flow, heavy traffic, day
Cost for goods transports to be delayed per hour
Hisingsleden, number of accidents, heavy vehicles, day
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
Rank correlation

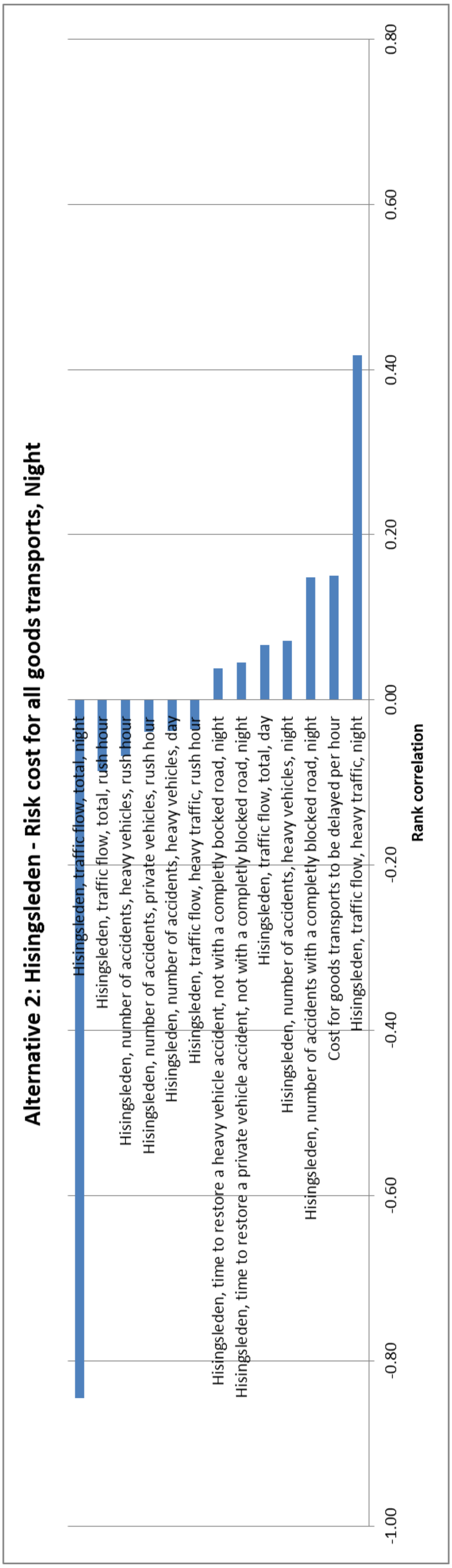

Alternative 2: Lundbyleden - Risk cost for all goods transports, Day
Lundbyleden, number of accidents, heavy vehicles, rush hour
Lundbyleden, traffic flow, heavy traffic, rush hour
Hisingsleden, traffic flow, total, night
Lundbyleden, traffic flow, heavy traffic, day
Lundbyleden, time to restore a heavy vehicle accident, not with a completly blocked road, day
Lundbyleden, number of accidents ith a completly blocked road, day
Lundbyleden, duration of an accident with completly blocked road, day
Lundbyleden, number of accidents, heavy vehicles, day
Cost for goods transport to be delayed per hour
Hisingsleden, traffic flow, total, day
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
Rank correlation

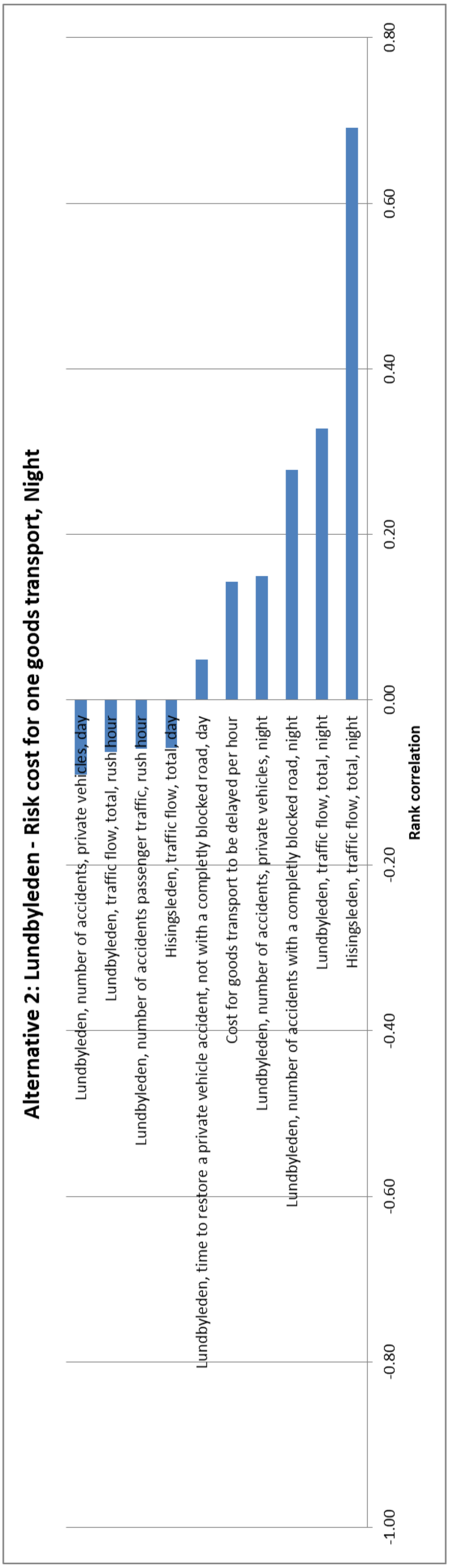

Alternative 0: Hisingsleden - Risk cost for all goods transports, Night
Hisingsleden, traffic flow, total, rush hour
Hisingsleden, number of accidents, private vehicles, rush hour
Hisingsleden, traffic flow, total, day
Hisingsleden, traffic flow, heavy traffic, rush hour
Hisingsleden, duration of an accident with a completly blocked road, night
Hisingsleden, number of accidents, heavy vehicles, night
Cost for goods transports to be delayed per hour
Hisingsleden, number of accidents with a completly blocked road, night
Hisingsleden, traffic flow, total, night
Hisingsleden, traffic flow, heavy traffic, night
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
Rank correlation


Alternative 0: Lundbyleden - Risk cost for all goods transports, Night
Lundbyleden, number of accidents, private vehicles, day
Lundbyleden, traffic flow, total, rush hour
Lundbyleden, number of accidents, private vehicles, rush hour
Lundbyleden, number of accidents, heavy vehicles, night
Lundbyleden,time to restore a private vehicle accident, not complete block, day
Lundbyleden, traffic flow, heavy traffic, rush hour
Cost for goods transports to be delayed per hour
Lundbyleden, number of accidents, private vehicles, night
Lundbyleden, number of accidents with a completly blocked road, night
Lundbyleden, traffic flow, total, night
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
Rank correlation

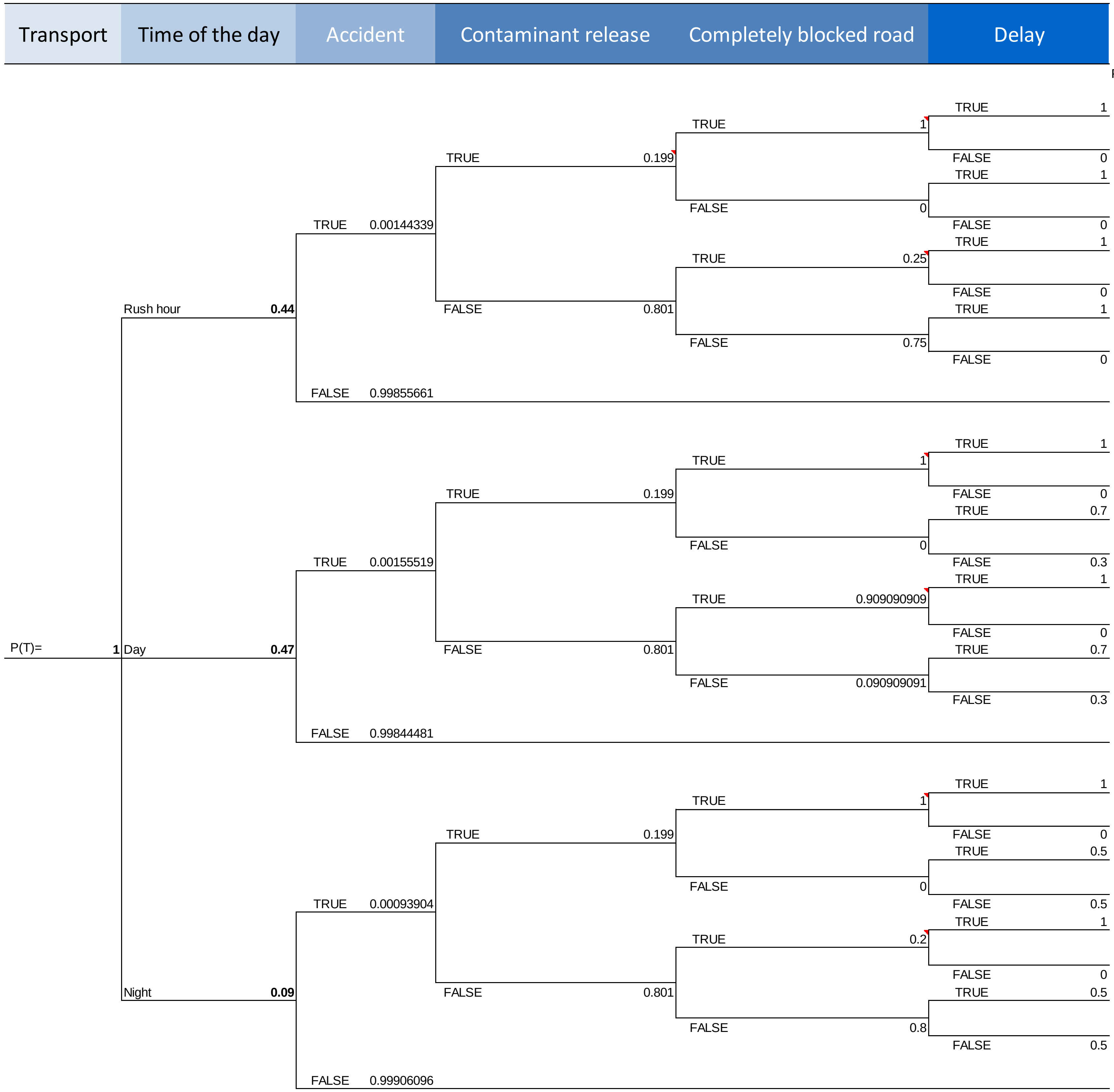

Alternative 1: Hisingsleden - Risk cost for all goods transports, Night
Hisingsleden, traffic flow, total, night
Hisingsleden, number of accidents, heavy vehicles, rush hour
Hisingsleden, traffic flow, total, rush hour
Hisingsleden, number of accidents, heavy vehicles, day
Hisingsleden, number of accidents, private vehicles, rush hour
Hisingsleden, time to restore a heavy vehicle accident, not with a completly blocked road, night
Hisingsleden, time to restore a private vehicle, not with a completly blocked road, night
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, traffic flow, total, day
Cost for goods transports to be delayed per hour
Hisingsleden, number of accidents with a completly blocked road, night
Hisingsleden, traffic flow, heavy traffic, night
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
Rank correlation


Alternative 1: Lundbyleden - Risk cost for one goods transport, Night
Lundbyleden, number of accidents passenger traffic, average weekday, day
Lundbyleden, traffic flow, total, rush hour
Lundbyleden, number of accidents passenger traffic, average weekday, rush hour
Hisingsleden, traffic flow, total, day
Lundbyleden, C,restore passenger accident, not complete block, day
Cost for a truck to be delayed per hour
Lundbyleden, number of accidents passenger traffic, average weekday, night
Lundbyleden, no. complete blocked road accidents, average weekday, night
Lundbyleden, traffic flow, total, night
Hisingsleden, traffic flow, total, night
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
Rank correlation


Alternative 2: Hisingsleden - Risk cost for all goods transports, Night
Hisingsleden, traffic flow, total, night
Hisingsleden, traffic flow, total, rush hour
Hisingsleden, number of accidents, heavy vehicles, rush hour
Hisingsleden, number of accidents, private vehicles, rush hour
Hisingsleden, number of accidents, heavy vehicles, day
Hisingsleden, traffic flow, heavy traffic, rush hour
Hisingsleden, time to restore a heavy vehicle accident, not with a completly bocked road, night
Hisingsleden, time to restore a private vehicle accident, not with a completly blocked road, night
Hisingsleden, traffic flow, total, day
Hisingsleden, number of accidents, heavy vehicles, night
Hisingsleden, number of accidents with a completly blocked road, night
Cost for goods transports to be delayed per hour
Hisingsleden, traffic flow, heavy traffic, night
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
Rank correlation

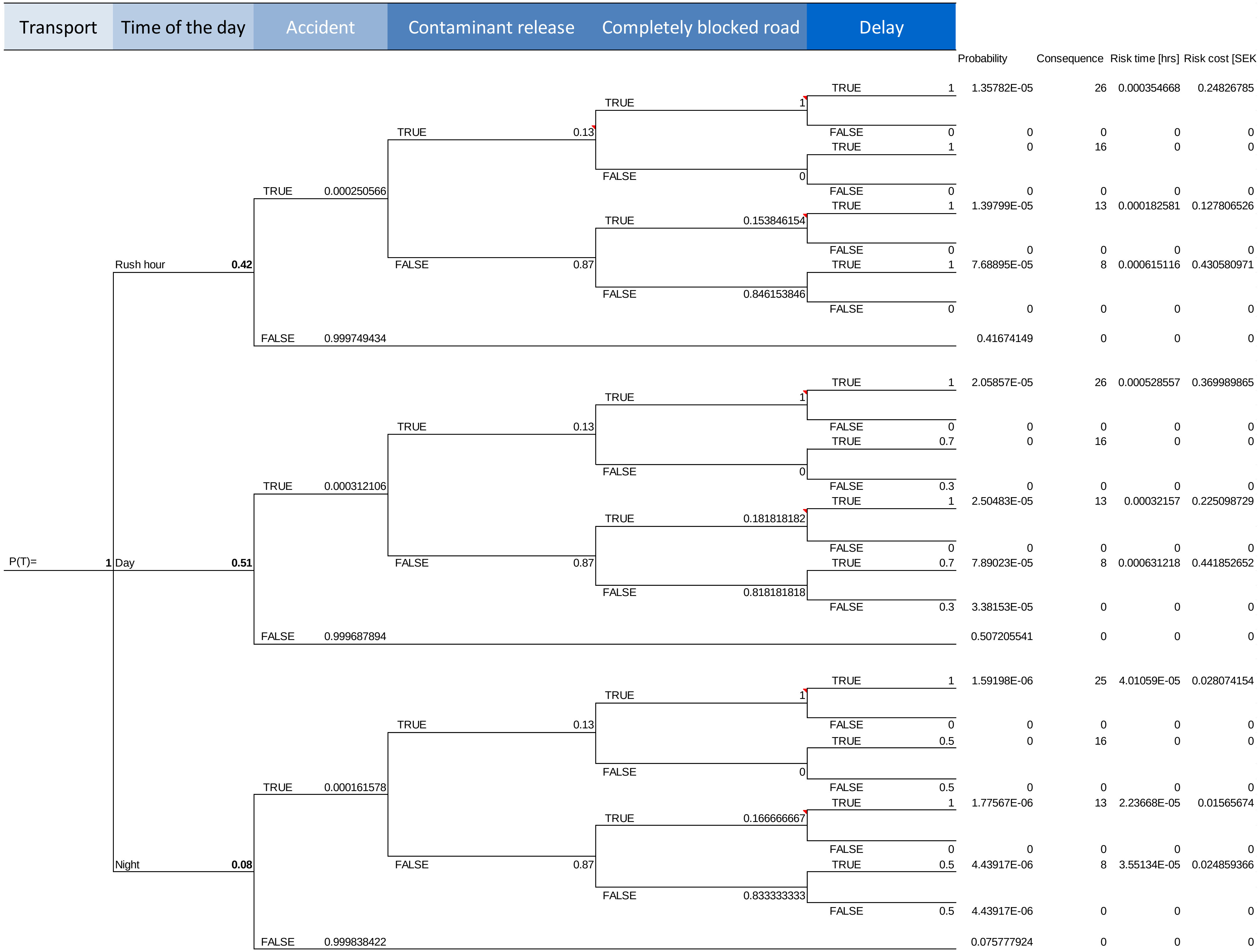

Alternative 2: Lundbyleden - Risk cost for one goods transport, Night
Lundbyleden, number of accidents, private vehicles, day
Lundbyleden, traffic flow, total, rush hour
Lundbyleden, number of accidents passenger traffic, rush hour
Hisingsleden, traffic flow, total, day
Lundbyleden, time to restore a private vehicle accident, not with a completly blocked road, day
Cost for goods transport to be delayed per hour
Lundbyleden, number of accidents, private vehicles, night
Lundbyleden, number of accidents with a completly blocked road, night
Lundbyleden, traffic flow, total, night
Hisingsleden, traffic flow, total, night
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
Rank correlation

Alternative 0 Hisingsleden – Dangerous goods

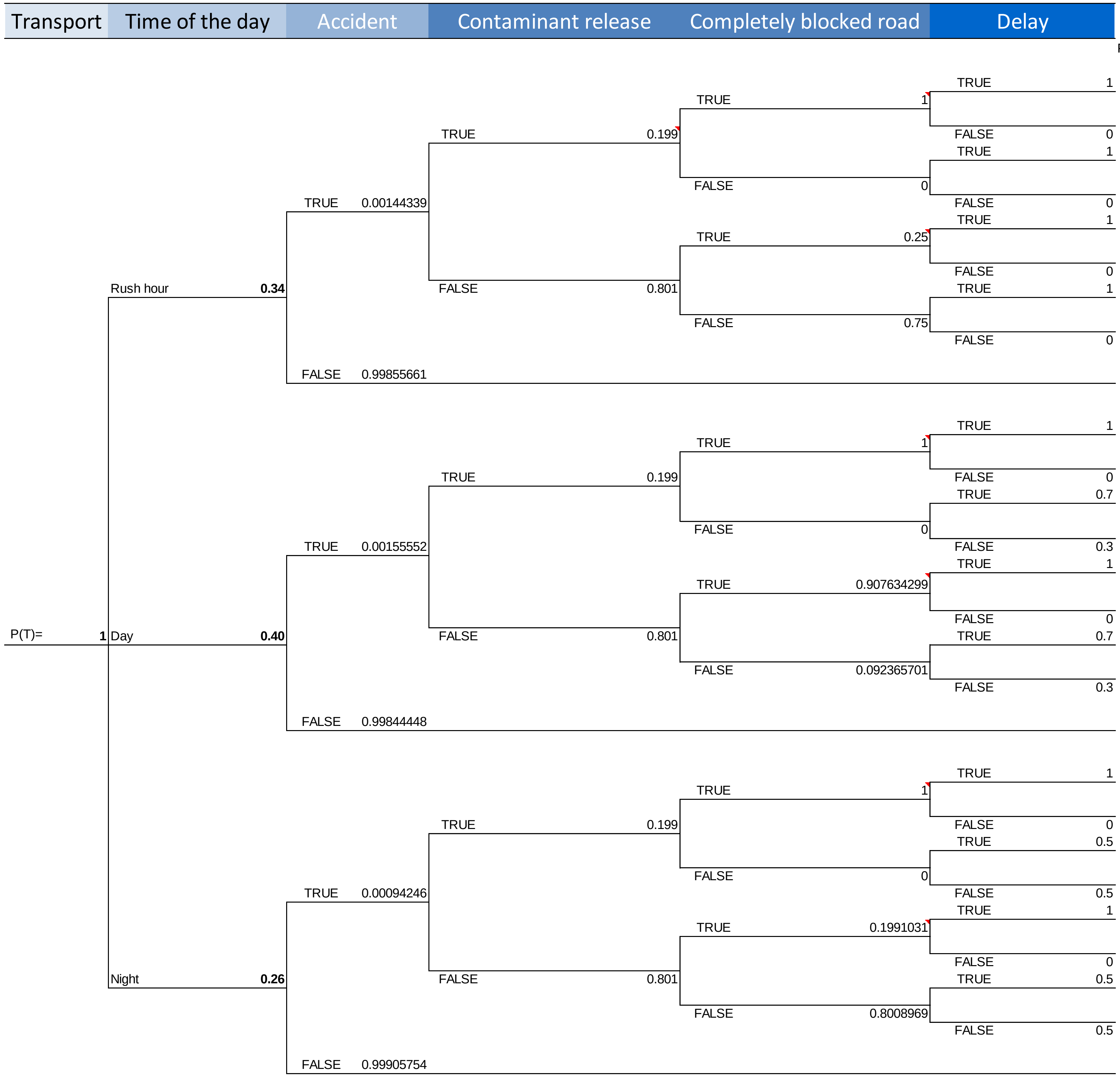


Probability	Consequence	Risk time [hrs]	Risk cost [SEK]
0.000127743	33	0.004200414	2.940289828
0	0	0	0
0	16	0	0
0	0	0	0
0.000128545	16	0.002113399	1.479379493
0	0	0	0
0.000385636	8	0.003085086	2.159560085
0	0	0	0
0.444091121	0	0	0
0.000145319	30	0.004329164	3.030414907
0	0	0	0
0	16	0	0
0	0	0	0
0.000531752	15	0.00792065	5.544454866
0	0	0	0
3.72226E-05	8	0.000297781	0.208446688
1.59526E-05	0	0	0
0.468822424	0	0	0
1.60173E-05	26	0.00040972	0.286804181
0	0	0	0
0	16	0	0
0	0	0	0
1.28944E-05	13	0.000164918	0.115442286
0	0	0	0
2.57887E-05	8	0.00020631	0.144416883
2.57887E-05	0	0	0
0.085633797	0	0	0

Alternative 0 Lundbyleden – Dangerous goods

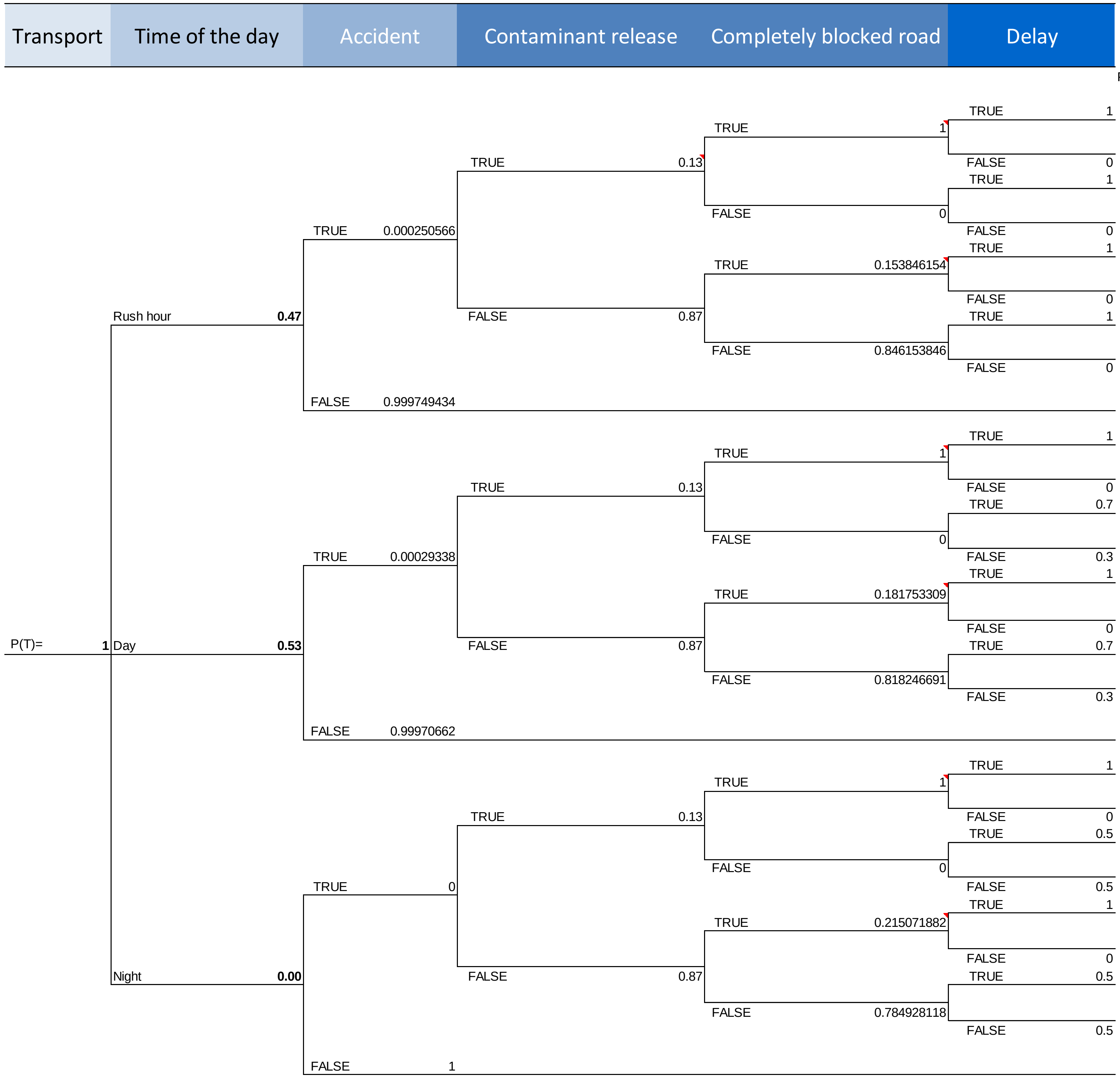


Alternative 1 Hisingsleden– Dangerous goods



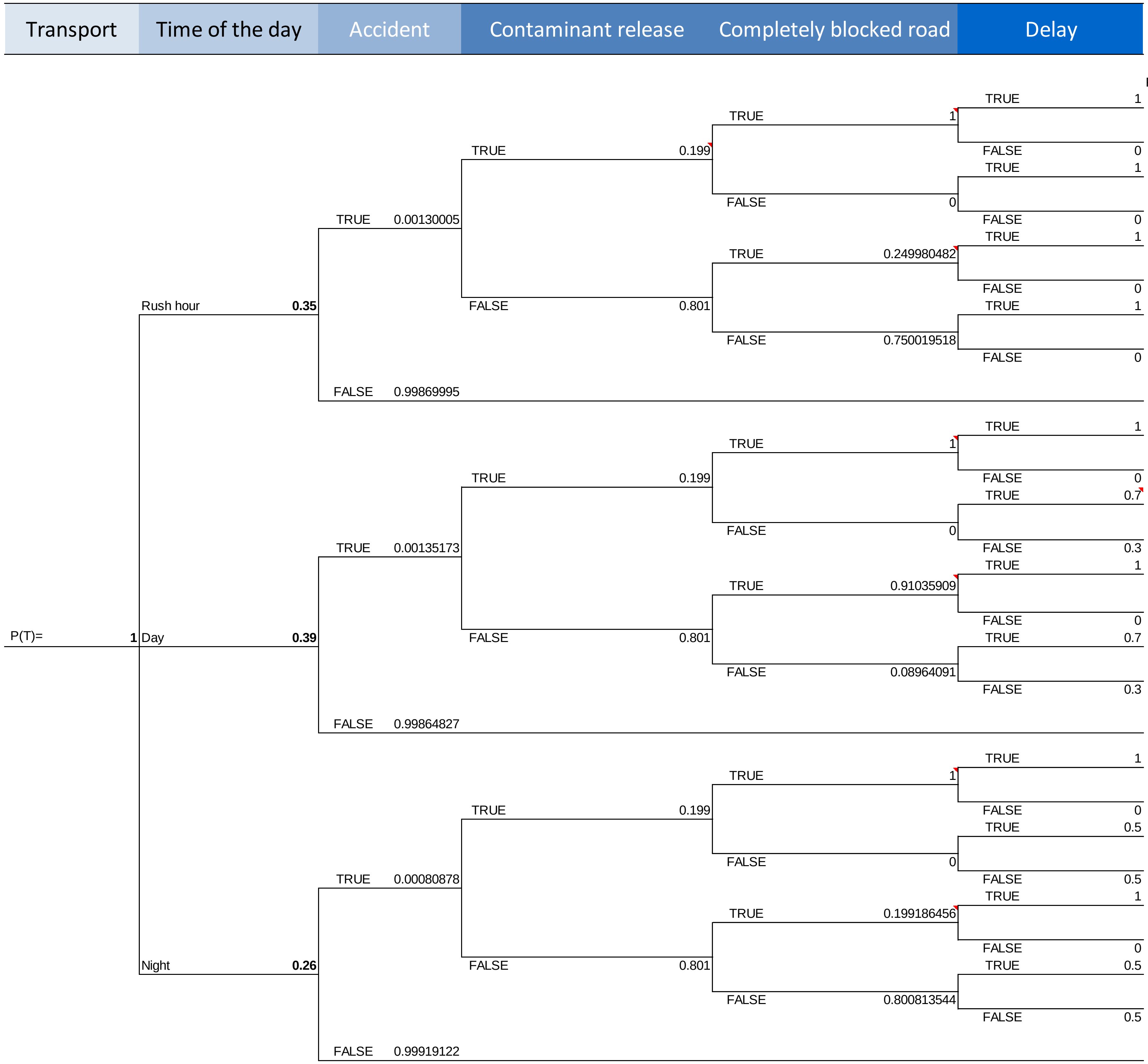
Delay		Probability	Consequence	Risk time [hrs]	Risk cost [SEK]
TRUE	1	9.74445E-05	33	0.003204151	2.242905579
FALSE	0	0	0	0	0
TRUE	1	0	16	0	0
FALSE	0	0	0	0	0
TRUE	1	9.80566E-05	16	0.001612139	1.128497091
FALSE	0	0	0	0	0
TRUE	1	0.00029417	8	0.002353359	1.647350991
FALSE	0	0	0	0	0
		0.338760636	0	0	0
TRUE	1	0.00012254	30	0.003725206	2.607644491
FALSE	0	0	0	0	0
TRUE	0.7	0	16	0	0
FALSE	0.3	0	0	0	0
TRUE	1	0.000447679	15	0.006804727	4.763308673
FALSE	0	0	0	0	0
TRUE	0.7	3.18908E-05	8	0.000255126	0.178588296
FALSE	0.3	1.36675E-05	0	0	0
		0.395250094	0	0	0
TRUE	1	4.9679E-05	30	0.001510241	1.057168734
FALSE	0	0	0	0	0
TRUE	0.5	0	16	0	0
FALSE	0.5	0	0	0	0
TRUE	1	3.98135E-05	15	0.000605165	0.423615435
FALSE	0	0	0	0	0
TRUE	0.5	8.00753E-05	8	0.000640603	0.448421855
FALSE	0.5	8.00753E-05	0	0	0
		0.264634179	0	0	0

Alternative 1 Lundbyleden – Dangerous goods



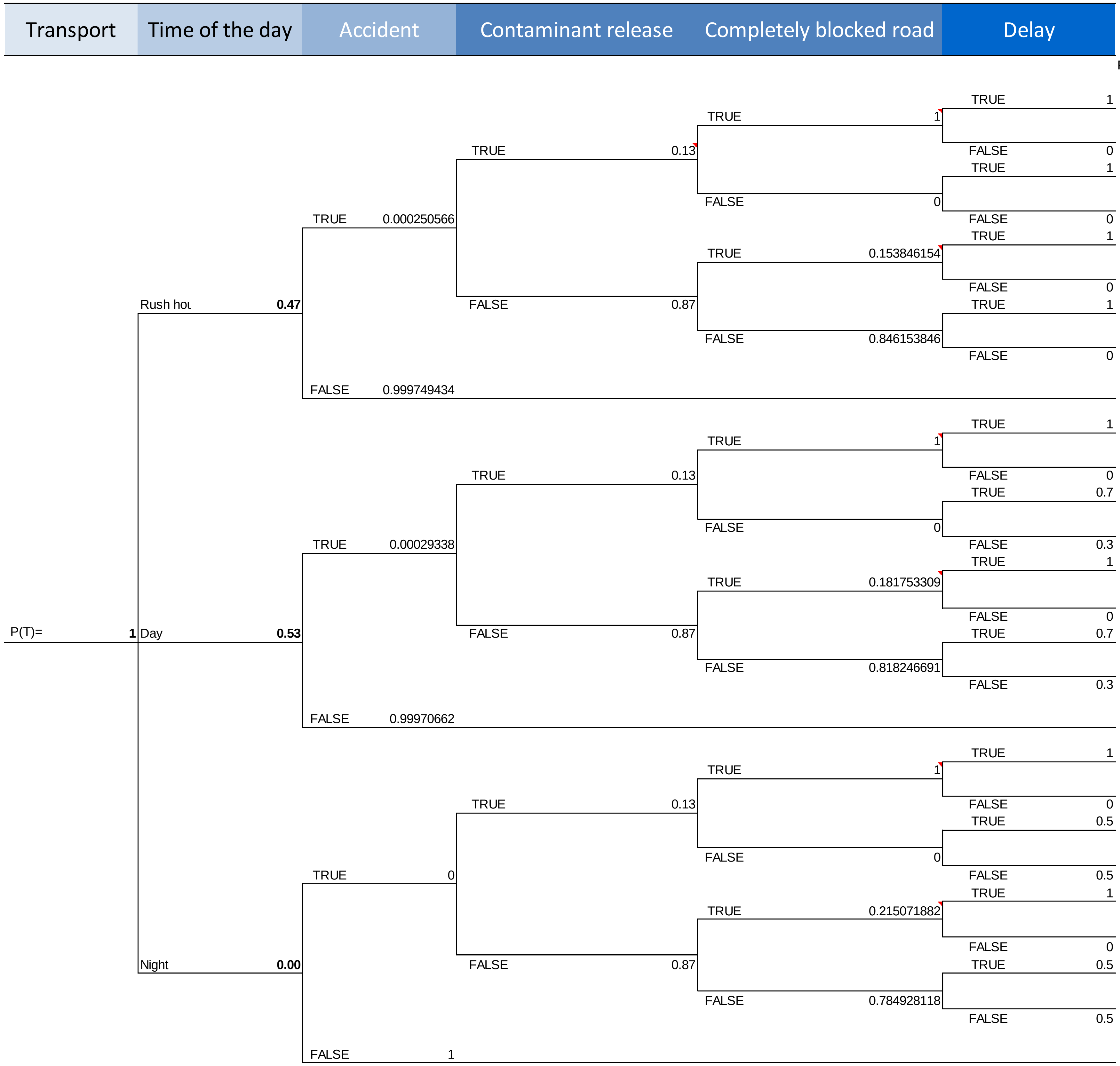
Probability	Consequence	Risk time [hrs]	Risk cost [SEK
1.51562E-05	26	0.000395886	0.277120315
0	0	0	0
0	16	0	0
0	0	0	0
1.56046E-05	13	0.000203799	0.14265957
0	0	0	0
8.58252E-05	8	0.000686601	0.480620968
0	0	0	0
0.465173131	0	0	0
2.03935E-05	26	0.000521676	0.365173506
0	0	0	0
0	16	0	0
0	0	0	0
2.48057E-05	13	0.00031727	0.222089227
0	0	0	0
7.81719E-05	8	0.000625375	0.437762677
3.35022E-05	0	0	0
0.53455341	0	0	0
0	24	0	0
0	0	0	0
0	16	0	0
0	0	0	0
0	12	0	0
0	0	0	0
0	8	0	0
0	0	0	0
0	0	0	0

Alternative 2 Hisingsleden – Dangerous goods



Probability	Consequence	Risk time [hrs]	Risk cost [SEK]
9.06854E-05	32	0.002898043	2.028629908
0	0	0	0
0	16	0	0
0	0	0	0
9.12479E-05	16	0.001461028	1.02271974
0	0	0	0
0.000273772	8	0.002208292	1.545804328
0	0	0	0
0.350072454	0	0	0
0.000104668	29	0.003085123	2.15958609
0	0	0	0
0	16	0	0
0	0	0	0
0.000383536	15	0.005665112	3.965578187
0	0	0	0
2.64361E-05	8	0.000213238	0.149266729
1.13298E-05	0	0	0
0.388583156	0	0	0
4.19044E-05	29	0.001235146	0.864602442
0	0	0	0
0	16	0	0
0	0	0	0
3.35969E-05	15	0.000496251	0.347375773
0	0	0	0
6.75369E-05	8	0.000544764	0.381334473
6.75369E-05	0	0	0
0.260152139	0	0	0

Alternative 2 Lundbyleden – Dangerous goods



Delay		Probability	Consequence	Risk time [hrs	Risk cost [SEI
TRUE	1	1.51562E-05	26	0.000401505	0.281053326
FALSE	0	0	0	0	0
TRUE	1	0	16	0	0
FALSE	0	0	0	0	0
TRUE	1	1.56046E-05	13	0.000209584	0.14670895
FALSE	0	0	0	0	0
TRUE	1	8.58252E-05	8	0.000718418	0.502892574
FALSE	0	0	0	0	0
		0.465173131	0	0	0
TRUE	1	2.03935E-05	26	0.000525505	0.367853217
FALSE	0	0	0	0	0
TRUE	0.7	0	16	0	0
FALSE	0.3	0	0	0	0
TRUE	1	2.48057E-05	13	0.000321927	0.225348691
FALSE	0	0	0	0	0
TRUE	0.7	7.81719E-05	8	0.000640049	0.448034466
FALSE	0.3	3.35022E-05	0	0	0
		0.53455341	0	0	0
TRUE	1	0	24	0	0
FALSE	0	0	0	0	0
TRUE	0.5	0	16	0	0
FALSE	0.5	0	0	0	0
TRUE	1	0	12	0	0
FALSE	0	0	0	0	0
TRUE	0.5	0	8	0	0
FALSE	0.5	0	0	0	0
		0	0	0	0