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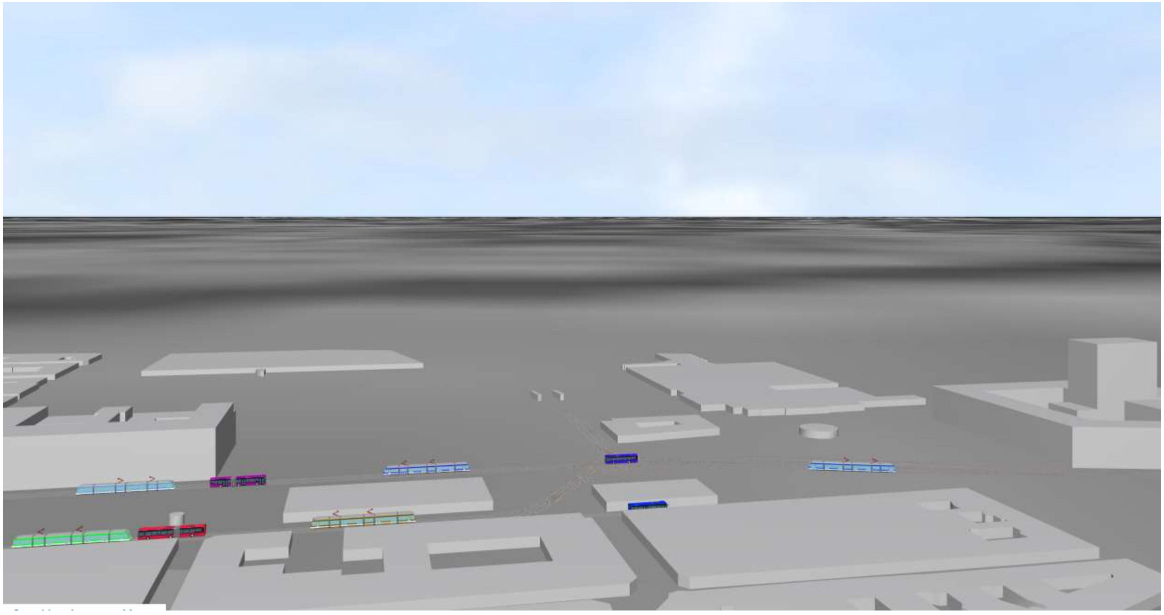

Congestion in public transport system

A micro-simulation analysis of congestion in public transport in Brunnsparken and Centralstationen by using software PTV Vissim

Master's thesis within Infrastructure and Environmental Engineering MCS Program

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Abstract

This report describes an analysis of a highly congested public transport area, which is located in the center of the city of Gothenburg. A microscopic model is created in order to analyse the congestion in the area and investigate the effect of potential implementation of stop-skipping solutions, in which some stop points are removed. A literature review was conducted regarding congestion in public transport and how different types of stop-skipping have been applied previously. Further, the process of the creation of the model and the used simulation tool PTV Vissim is explained. The data, which form the basis of the simulation imput, are obtained from Västtrafik AB. Further, to validate the results of the model, the desired speed of the model has been calibrared by conducting fiel study measurements.

The delay and the average speed of the vehicles are compared for the current situation and the stop-skipping scenarios. Moreover, the saved time for all passengers, which might need to walk between the transport hubs Brunnsparken and Centralstationen are estimated. The desirability of the solutions is analysed by comparing the lost time for travelers having to walk between these hubs for different proportions of alighting passengers. In addition to that, the implementation of stop-skipping entails, to some extent, less travel time and increased average speed for public transport vehicles serving the hubs. The reducation of travel times and an increased speed, could be used to increase the frequency of the lines and thereby the capacity of public transpor lines in service. This could contributes to achieve the goal of the municipality to increase the number of trips by public transport to 55% by 2035. This is especially important though demands are expected to increase due to the expected population growth of the city of Gothenburg. Finally, the consequences of the implementation of the stop-skipping solutions are discussed and a recommendation for further studies is been suggested.

Keywords: *Congestion, public transport lines, stop-skipping, delay, speed, microscopic traffic simulation, PTV Vissim*

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1. Introduction

Urban developments and climate change raise numerous challenges related to the sustainability of cities and regions around the world, including transport systems. Public transport systems (PTS) are characterized by their importance for the quality and the stability of any socio-economic system. Furthermore, PTS contributes to a large extent to the mobility of people and sustainable developments. Thus, planning, design, and operations of a PTS play a significant role in the equilibrium and sustainable evolution of any region (Rosello et al., 2016).

Public transport (PT) plays a central role in sustainable developments, by contributing to the sustainability of cities, including a reduced negative impact on the environment, in comparison with other transportation modes, and enhanced accessibility by a faster and more reliable transportation system. Moreover, PTS also contributes to greener and more energy-efficient vehicles and has other indirect impacts on societies in terms of social justice and creation of new employment. Public transport also improves the mobility and accessibility of residents, which is important in order to enable urban developments, as well as to achieve environmental goals and decreasing their energy consumption. To underline the importance of the usage of public transport, Roselló et al. (2016) compared the benefits of using PT to other modes of transport in terms of energy consumption, greenhouse gas emissions, other pollutants, safety, and security. In order to make PT more attractive and thus reducing CO_2 emissions, it is important to increase the efficiency of PT in terms of comfort, frequency, travel time, and fare levels (Roselló et al, 2016). The difficulties of the traffic management on public transport systems are, however, often related to various factors such as arrival and departure times, the passengers' waiting time and vehicle operation (Nguyen and Descotes-Genon, 2007).

This thesis provides a solution to mitigate the problems, regarding the congestion at the current bottleneck of the PT system in Gothenburg, Brunnsparken. For this purpose, the software PTV Vissim is used, and different simulations are performed with relevant parameters for the current situation (se chapter 3.2). Further, the efficiency of the solution for improving the current system and the related challenges are discussed.

1.1 Background

Here, the background of the thesis, including the public transport system of Gothenburg with its challenges and the main connection point of the PT system: Brunnsparken, are described.

1.1.1 Public transport in Gothenburg

The population of the city of Gothenburg is growing rapidly. The city is estimated to grow with approximately 150 000 inhabitants to the year 2035 (Trafikkontoret, 2017). A rapid growth of population and an expansion of the city entail a variety of challenges, related to mobility and transport. As the population grows, more and more people need to travel, and a significant proportion of these are expected to use PT as their preferred mode of transport.

In 2011 the city of Gothenburg formulated a transport strategy document. It is a governing document which guides how the transport system of the city shall be developed in order to meet the challenges related to sustainable transport, which the city is facing for the nearest decades. The objective is to make Gothenburg an easily accessible regional center, by creating an attractive, efficient, and sustainable transport system (Trafikkontoret, 2017).

Furthermore, according to the transport strategy, the municipality aims to increase the number of trips by PT to 55% by 2035 (Trafikkontoret, 2017). The current public transport modes are bus, boat, and tram. However, the use of PT has increased by 27 % between 2011 and 2018, as seen in Figure 1, corresponding to an average yearly increase of 3.4 % (Trafikkontoret, 2017). Hence, PT is one of the few transport modes for which the number of trips per year are in line with the transport strategic goal of the municipality. According to Trafikkontoret (2017), the overall demand for public transport is expected to increase by 27 % between 2011 and 2035, which corresponds to an average annual increase by 1 %, indicating a movement to a situation where PT is the main mode of transportation.

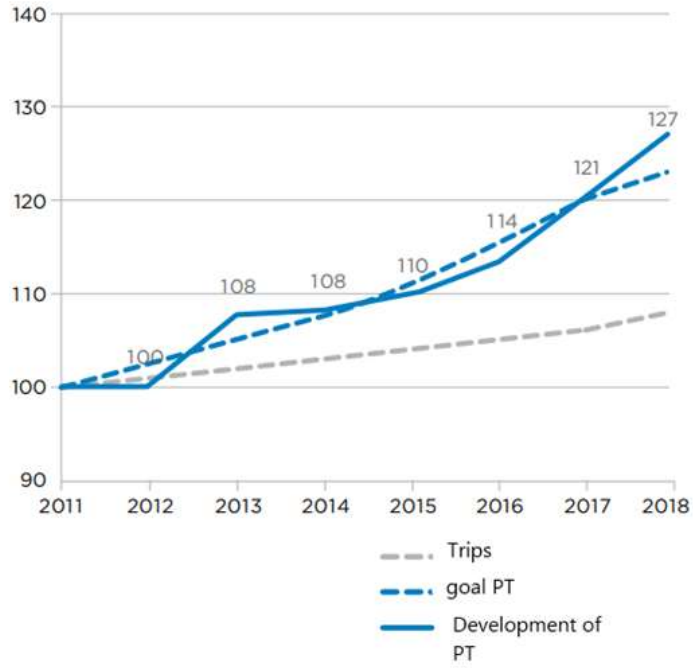

Figure 1: Development, goals and estimated need of increased travel by PT 2011–2018, index 100, from Trafikkontoret 2018 (Göteborgs Stad, 2018)

An increased use of PT gives rise to numerous benefits, including better air quality in the city, less greenhouse gas emission and less congestion. This requires, however, improvements of the public transport system, since an increased number of PT trips might result in higher demands in terms of service level, travel times, and traffic regularity.

1.1.2 Brunnsparken

During the 16th and 17th century the area, which today is called Brunnsparken was a place for an iron wave and was called the home of the iron wave (Ljung, 2013). However, it was later moved to Järntorget, and the last remains of the iron wave at Brunnsparken was burned down. In 1822, the area was transformed into parking and trees were planted on the site in order to create a walking space. Over time, the function of Brunnsparken and the walking area has changed gradually, and today the place is primarily an essential hub of the public transport, a development that has started with the first horse-drawn trams, which had Brunnsparken as their starting point. The first line, to Johanneberg, was introduced in 1789 and was thereafter followed by lines to Getebergsäng, Redbergslid, and Slottsskogen (Ljung, 2013).

Brunnsparken is located in the city centre of Gothenburg, as seen in Figure 2. It is the main transit point of the local public transport network and almost all tram lines and many bus lines pass through it and stop there. Furthermore, at Brunnsparken, the shared tram and bus stop points at Södra Hamngatan, and Norra Hamngatan are heavily loaded and the capacities of departures during peak hours are reached.

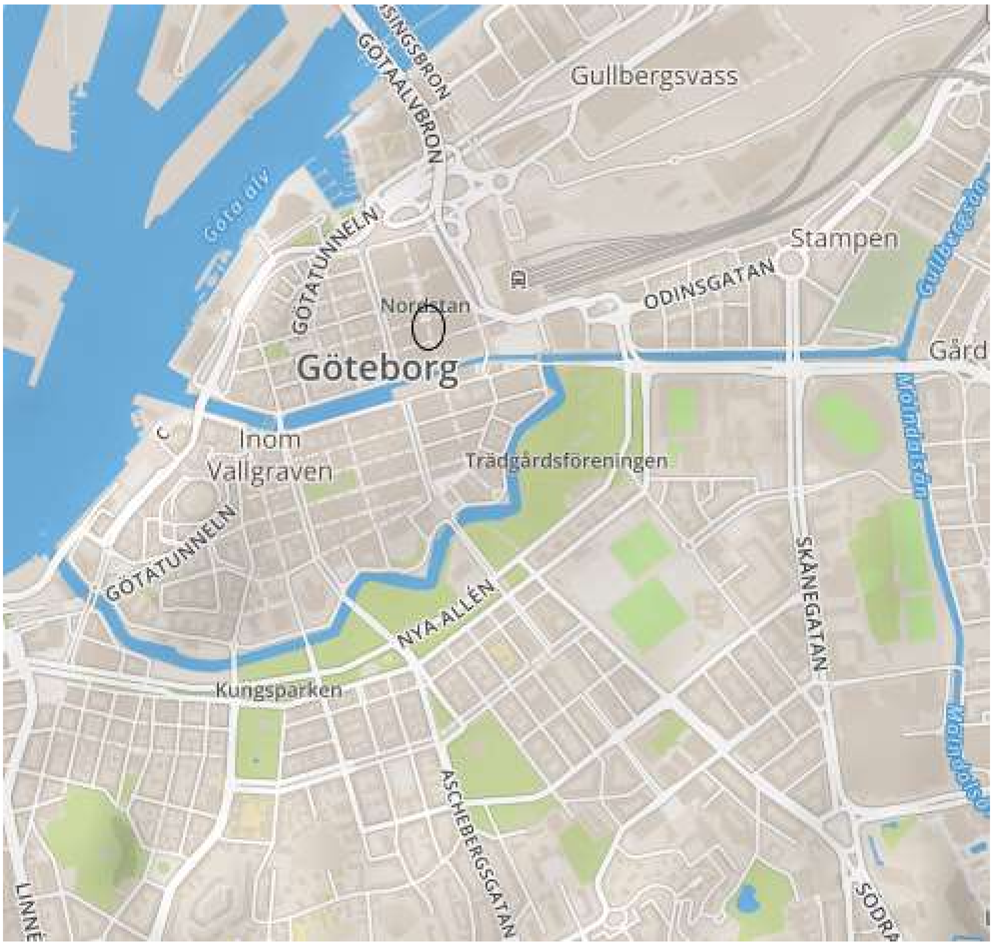

Figure 2 A map illustrating the location of the case study area (from setallitkarta.se, copyright: Open street map).

The average speed of a tram through the centre of the city is approximately 17.6 km/h, which could be explained by the short distances between the hubs Brunnsparken, Centralstationen and Nordstan. The network also contains cross turns, entailing a low average speed through the city center (Blomquist, 2013).

1.2 Scope of the problem

The scope of the problem is to analyse congestion in a PT network for central transit points. Further, the possibility to let some lines pass through without stopping at a connection point should be analysed. The analysis should be performed with a simulation tool, which considers the complexity of the problem. Moreover, an analysis which compares the time for all passengers for the current and modified scenarios should be performed.

1.3 Aim and objectives

In this master thesis the delay at the shared tram and bus stop points at the hub Brunnsparken and the speed of the trams through it, should be estimated. This should be done with the software PTV Vissim, based on realistic parameters, valid for the current situation.

Furthermore, a cost-effective possible improvement to the system should be proposed and simulated. More precisely, a stop-skipping solution should be proposed, in which two of the stop points in the hub Brunnsparken (one in the eastbound and the other one in the westbound direction), and two in the hub Centralstationen are removed, in order to increase the speed through the area and to decrease the delay of the trams. Thus, dwell times, as well as acceleration and deceleration times of these stop points are saved. Furthermore, the time lost by passengers having to walk between the nearby hubs should be estimated. The total travel times for the new system should be calculated for different proportions of people having to walk between the hubs. The critical proportion could be found for which the total saved time equals to the total lost time. The possibility to only let a part of the lines stop at Brunnsparken, as well as at Centralstationen is based upon the fact that both hubs have two parallel tracks, heading in the eastbound and westbound direction.

The objectives regarding the simulations are to estimate the net difference in total travel time for all travelers and to construct a cost benefit analysis in order to evaluate the differences in the generalized cost times between the current and modified scenarios. This might provide a support to the decision makers, in determining whether these modifications are desirable.

1.4 Limitations

The simulation considers the area of Brunnsparken east of Östra hamngatan including Norra hamngatan, Södra hamngatan, Kvarnbron, Drottningtorget and a part of Stampgatan and Nils Ericsonnsgatan (see chapter 3). The main reason why the public transport stop Nordstan is not included is that no modifications are suggested regarding this hub. Another reason is that it has only one tram stop point in each direction, making stop-skipping for only a part of the tram lines impossible, without building more tracks. Furthermore, only public transport vehicles have been regarded in the simulation model of the network since the number of other vehicles within the area has been observed to be so few that they are assessed not to have a significant impact on the system. The analysis is limited to simulations performed in PTV Vissim. These analyses are highly relevant for the public transport planning process and could consider more parameters than an analytical solution within the format of the project and are therefore considered as suitable for this project.

2. Literature review

In order to gain better knowledge about the problems related to congestion in public transport in general and in the specific case study area of the thesis, a literature review was conducted. Facts related to the background and the characteristics of the study area in terms of public transport system have been analysed. To get a comprehensive understanding of the current public transport system of the city and future developments, reports from the traffic office of the city have been studied. Multiple sources as books, scientific articles and research publications form the basis of this thesis.

2.1 Public transport planning

Public transport planning aims to change the existing state of a network to an improved target state, by implementing one or several measures. The planning should be a support for the decision makers (Friedrich et al., 2016). It is, however, difficult to achieve or even define an optimal solution since objectives of different nature are competing. Further, the pre-conditions are often so that it is impossible to increase the welfare for all individuals without decreasing the welfare for some (Varian, 2010).

A solution that is optimized for a population as a whole, is called pareto optimal and accordingly, the process is called pareto optimization (Friedrich et al., 2016). For the proposed measure within this report, this is the case, since some passengers would have longer travel time with the proposed solution. Whether the measure should be implemented could be determined by Kilder Hicks criterion: "A measure should be implemented if, from the gains of the winners all losses of the losers could be compensated for, leaving a surplus". Regarding this, the evaluation could be made by a multi criteria analysis, in which several properties of different kinds are assigned a value. A benefit with this is that several values which are of importance for passengers are taken into consideration. The drawback is, however, its subjectivity, since the assessor must decide how the different values should be evaluated. To instead restrict the analysis to travel time or cost is more precise but leaves other values without consideration.

When considering implementing a measure, the current state must first be evaluated. Transport supply data and data on mobility behaviour should be considered. The deficiencies and their causes should be identified with respect to the objective (e.g. minimizing travel time). Moreover, a new scenario is proposed and the possible ways it could impact the evaluation function is considered. Further, its impact should be estimated, and the proposed scenario direct compared to the current one (Friedrich et al., 2016).

Public transport planning in Sweden is made by the national, regional and municipal authorities. The local and regional public transport services are since 2012 mainly controlled by the regional governments, but in many cases the planning is shared with the municipalities (Paulsson et al, 2017). The public transport authority of Västra Götaland was earlier to 50% owned by the Västra Götaland Region (VGR) and to 50% by the municipalities but is today entirely owned by the former entailing more power to the regional level. Further, in Gothenburg the buses are driven by different operators based on procurements. With the approach of Västtrafik, these also have an influence on how a bus line is served and could however make larger changes, for example adding or removing a stop point, more complicated (Hägglund, 2020). All trams and tracks are owned by the municipality of Gothenburg and driven by the municipality owned company Göteborgs Spårvägar AB, through Västtrafik (Göteborgs Stad, n.d.). Thus, the removal of stop points must be accepted by the municipality.

2.2 Stop-spacing and stop-skipping problem

The planning of all public transport lines must consider the stop-spacing and stop-skipping problem. On a public transport line, the denser distributed the stops are, the shorter is the average way for the passengers to reach their nearest bus stop, but the longer time does the actual public transport trip take, resulting in a trade-off with an optimal spacing to minimize the total transport time. This optimal spacing depends on steady running speed, acceleration and deceleration rates, feeder mode speed, and dwell time (White p.136, 2017). If vehicles for instance have high accelaration rate and the dwell times are short a stop does not increase the travel time for the vehicle as much as if the dwell times are long and the acceleration rate is low.

Chen et al. (2017) describes the stop spacing problem as a trade-off between access coverage and mobility. By setting accessibility as an upper threshold and focusing on mobility, the study analysis suggested reducing the bus network in Yangcheng in China by 28 stops.

In addition to that, from an economic and environmental perspective, there are benefits of having more sparsely distributed stops. More acceleration and deceleration, and longer dwelling times entail a higher number of required vehicles and drivers and higher emissions. The optimal distance from an economic and environmental perspective is, therefore, higher than the distance which minimizes the average total travel time (White p.137, 2017).

Furtermore, Li & Bertini (2008) states that bus stop spacing generally is too small on many routes. Peter G. Furth and Adab B. Rahbee (2000) used a discrete approach to model the impact of moving the location of bus stops along the routes in Boston. By letting every intersection be a possible location for a bus stop, the optimal stop-spacing distance was found to be 400 m instead of 200 m, which was the current average. Considered impacts were operational costs due to the stopping delays, delays to throughgoing passengers, and distance to the nearest stop for the passengers. Moreover, if the walking distance is too far from people's destination or origin, it might entail that potential passengers select other modes of transport. The transport authorities are, therefore, usually constructing lines which do not have a significant loss of passengers due to sparsely distributed stops, and therefore this was considered as a constraint in the analysis. They further argue that the effects of having a nearby stop is apparent, while the impacts on other passengers are more diffuse, entailing a tendency for cities to have denser stop spacing than what is optimal. This could, however, be counteracted by stop-spacing guidelines (Peter G. Furth and Adab B. Rahbee, 2000).

In an existing network, some stops could be considered being removed entirely or being skipped by some lines or only some vehicles, making a stop-skipping problem.

Stop-skipping is a well-known solution that has been studied and analysed by many researchers using various assumptions (Liu et al., 2013). It is a solution that can be studied at different levels as planning level and real-time operation level (Sun & Hickman, 2007). Stop-skipping has impact on passengers' waiting time, entailing that some passengers have to wait for at least one or more headways to be served, if stop-skipped is applied. The total trip time of other buses is also affected by stop-skipping, which in turn influences the operating cost of the bus company (Liu et al., 2013).

According to Chen et al. (2014) stop skipping can either be dynamic or pre-set, whereas the former is implemented based on the current traffic situation. They analysed pre-set stop skipping in a Bus rapid transit system, (which is an innovative high effective bus system) in Beijing. Stop skipping was possible since buses there are driving on bus lanes that are adjacent to general lanes. Their standpoint was that stop-skipping preferably is used in the direction with lowest demand. They found that the total costs decreased by 22.6 %, with the implementation of stop skipping but that the operational costs were increased by 10.2 %. They also write that the system must be properly designed in order to not cause frustration among passengers.

A study conducted by Nguyen and Descotes-Genon (2007) in which real-time stop-skipping was applied in an urban network, claims that, stop-skipping strategy can reduce passengers' waiting time, leading to improved transit service quality and operating efficiency. It is, however, most effective on lines with short headways and high passenger demand.

2.3 Congestion and crowding effects in public transport systems

Congestion in public transport is described by the phenomena that are caused by high density of passengers or vehicles and might result in decreased service performance. Crowding is one of the effects of congestion in public transport and refers to lower on-board comfort due to increment of on-board load (Cats et al., 2016).

The main impacts of the congestion of public transport are on-board discomfort, denied boarding and irregular vehicle arrivals. On-board discomfort is caused by the crowding in the vehicles and might increase the time value of the passengers and their travel costs. Denied boarding might occur when vehicles have no residual capacity, entailing that passengers must wait for the next vehicle. The presence of irregular vehicle times depends on dwell times, the boarding and alighting passenger flows as well as the on-board passenger load (Cats et al., 2016).

Crowding has an impact on vehicle dwell times at stops as well as passenger waiting times, which in its turn increases the variability of headways and reduces reliability (Zhang et al., 2016). A study performed by Kim et al. (2015) shows that the dwell time delay affects the path choice of passengers. The transfer delay was, however, found to be insignificant. There are two reasons for this, firstly the transfer delay is smaller than the dwell time delay and secondly, passengers tend to perceive dwell time delay worse than the transit delay, for which passengers can move. Bordagaray et al. (2013) conducted a study which showed that the factor passengers value highest is reliability followed by travel time.

Wardman and Whelan (2010) found that congested transit does not only decrease the disutility of the standing passengers but also of the seated passengers. Further this could be expressed by disutility ratio by a travel time multiplicative factor of 2.7 for the standing passengers and 1.7 for the seated passengers in very congested conditions. Furthermore, the travel time increases with congestion and must be considered in generalized time (Li & Hensher, 2011).

2.4 Generalized travel time

How to value travel time spent in different modes is a concern under debate due to its subjectivity. On the one hand, Small (2012) states three arguments why the valuation of travel time is important. Firstly, it is important for decision making for transport authorities. Secondly, it gives insight in human behaviour, which is of interest within economic theory and thirdly it is essential for travel time modelling. Further, Horowitz (1981) introduces a non-linear model for generalised travel time in which the total public transport travel time for a trip is valued differently, depending on how much of it that is bus-in vehicle time, waiting time, transfer time and how the environmental conditions during the trip are. Pratt (2000) instead uses a linear model with value of travel times shown in Table 1.

Tabel 1 Valuation of time spent in different modes. (Transport capacity and Service Manual, second edition, 2003)

	In-Vehicle Time	Walk Time	Initial Wait time	Transfer Time
Average	1.0	2.2	2.1	2.5
Range	1.0	0.8-4.4	0.8-5.1	1.1-4.4

Cesario (1976) however, states that the valuation of travel time is very subjective since it differs between different individuals and situations. An example regarding individuals is that someone with a full-time job probably values the travel time higher than someone with more spare time. Example of different valuation of time between different situations could be that someone who is on the way to work in the morning probably would value the time higher than someone who takes a trip to go shopping since the former will experience an impact on her daily routines and needs to get up earlier in the morning. Furthermore, Cherlow (1981) writes that there is a dispute about travel time saving and whether a specified valuation of time is applicable in a wide range of situations at all. One reason for this is that the valuation of time generally has begun with the assumption that it is related to the wage of the travellers, which makes it difficult to make a general valuation. Liu et al. (2013) uses a linear model for the valuation of time in order to evaluate the impacts of implementation of stop-skipping with coefficients for in-vehicle time, waiting time and trip time for buses. These factors are however set to 1.

2.5 Calibration of parameters

All microsimulation models include several input-parameters which must be calibrated in order to find relevant results. There has however, not yet been developed any general calibration principles (Hollander & Liu, 2008). The performer of the simulation must calibrate the model through available data, performing measurements in order to retrieve the data or making realistic assumptions.

Input-data in the microsimulation program PTV Vissim regarding public transport is such as entry time distribution of vehicles into the system, dwell time distribution and speed distribution of the vehicles. Siddharth & Rammadurai (2013) made a study about calibration of a Vissim model for Indian conditions and writes that the most sensitive parameters are the most important to calibrate. They found that the most sensitive parameters and thereby the most important to calibrate, were speed distribution and gap time. Micro simulation models use random seeds. It is therefore preferable to run simulations with plenty of different random seeds in order to retrieve a result which is valid for several random procedures.

3. Site Description

The studied area, which is shown in Figure 3, is limited by the streets Södra hamngatan and Norra Hamngatan with the starting point at the junction Fontänbron at Östra hamngatan (west) and ending point Stampgatan (east). Hence, the junction at Fontänbron in Östra Hamngatan is not included in the study area due to its traffic complexities.

The area is characterrised by its location in the centre of the city and has high frequent public transport. The two main hubs of the public transport system in Gothenburg, Brunnsparken and Centralstationen, are located in the area. Approximately nine tram lines and two bus lines operate these hubs daily. The number of departures from Norra Hamngatan during peak hours is close to 40 vehicles per hour, which entails a reached limit capacity and the capacity at Södra Hamngatan is also used (Blomquist, 2013).

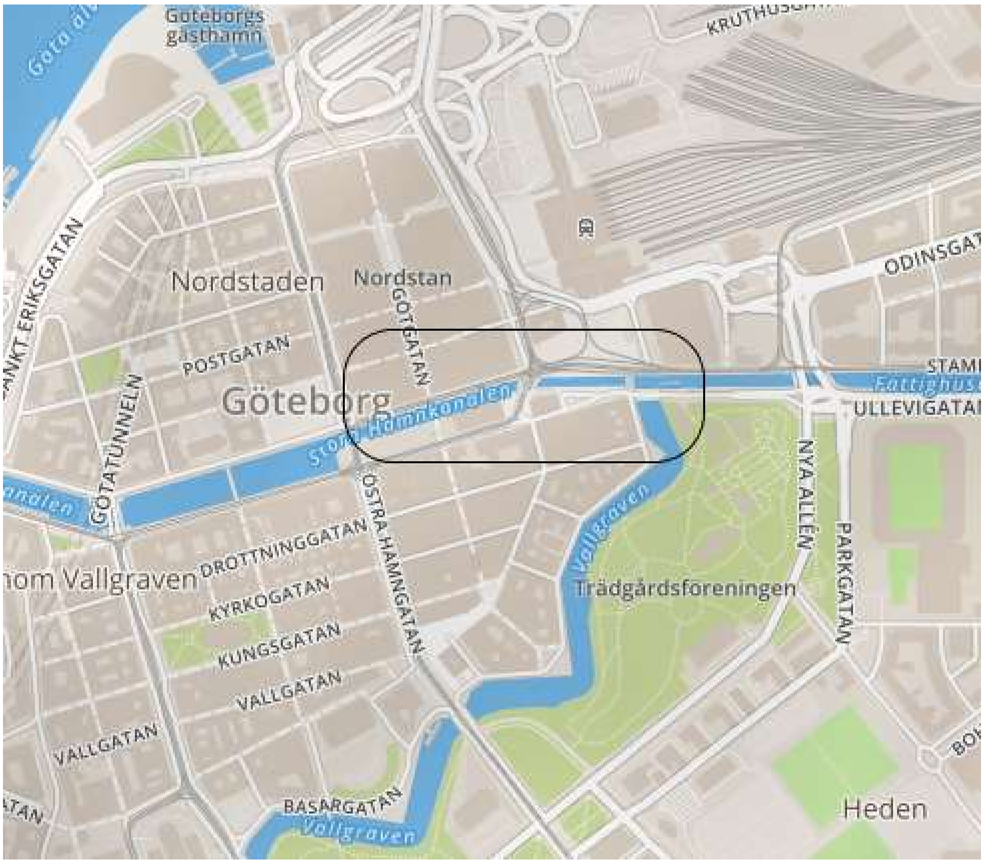

Figure 3 The map illustrates the case study area included in simulation of PTV Vissim analysis, located in the center of the city of Gothenburg (satellitkarta.se, 2020, copyright:opem street map)

Brunnsparken is referred to as the bottleneck of the city, due to the high capacities of public transport lines passing through the area as seen in Figure 4 (Sahlberg, 2016). Sahlberg further writes that it is urgent to improve and increase the speed of the public transport lines passing through the center of the city as Gothenburg is growing rapidly, and car traffic should be reduced by 25% (Sahlberg, 2016). However, according to the reports from Trafikkontoret, (Blomquist, 2013), there are plans to improve the current system in order to meet the demands of an increased use of public transport since it is important to find alternative routes for tram traffic through the centre of the city, in order to enable extended tram traffic and increase the accessibility. Engström also states that new tracks will be built in both directions in Parkgatan, outside of Allén, where car traffic today goes in the eastern direction (Sahlberg, 2016).

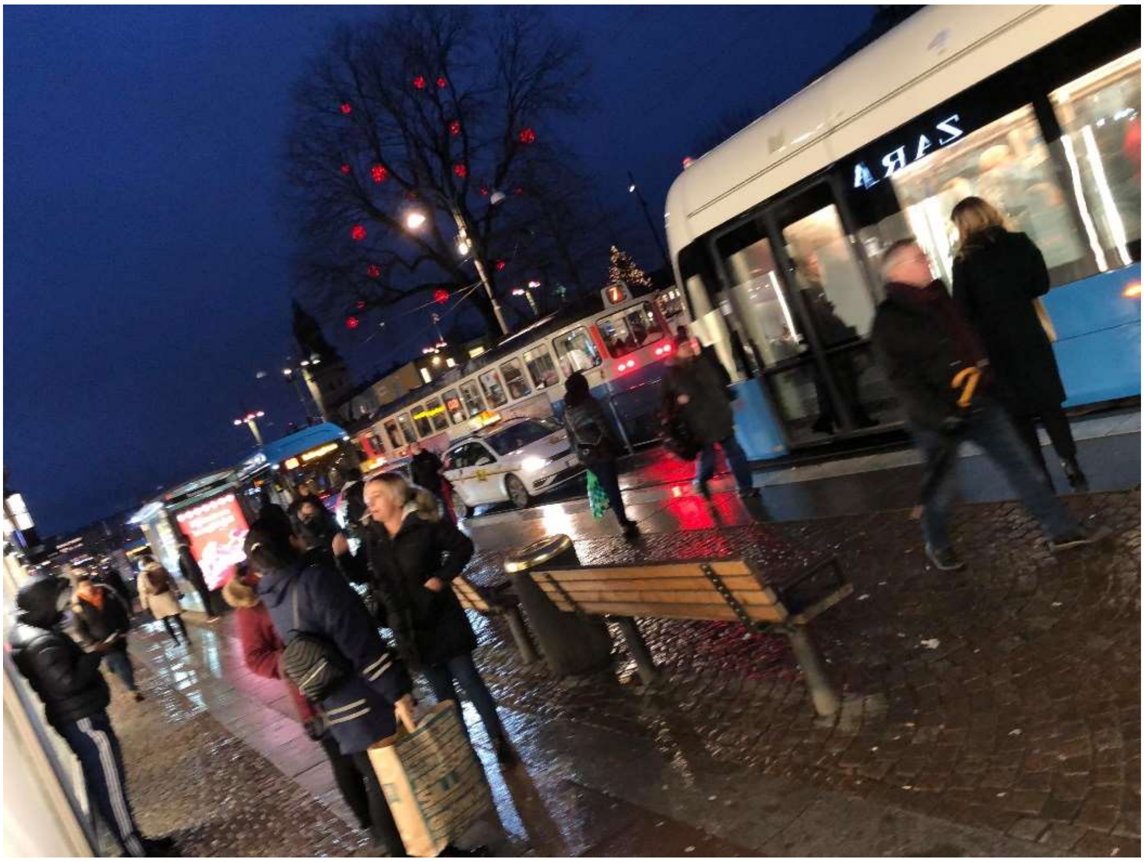

Figure 4 An illustration of bottlenecks at Södra Hamngatan during peak hours (Botan, 2019).

Most (9 different tram lines and two bus lines) of the public transport lines that operate in the city of Gothenburg passes through Brunnsparken and Centralstationen. At Brunnsparken, there are 4 shared public transport stop points for trams and buses and cars share, to some extent, the lanes with the public transport line in the eastbound lane of Södra Hamngatan. At the Centralstationen, for the considered area there are 3 shared stop points for bus and tram lines and 3 stop points only for tram lines. More detailed information for all public transport lines and their respective stops, in both hubs, are presented in Table 2.

Tabel 2 All considered lines and their respective stop points at Brunnsparken and Centralstation.

Lines	**Brunnsparken**	**Centralstationen**
Tram 1	C1,B2	B,C
Tram 2	C1,C2	A,C
Tram 3	B1,B2	B,D
Tram 4	C1, C2	A,C
Tram 6	B2, C1	
Tram 7	C1,C2	A,C
Tram 9	B1,C2	A,D
Tram 11	B1,C2	A,D
Tram 13		B,D
Bus 16	C1,B2	
Bus 60	B1,C2	D, L

Nordstan (as could be seen in Figure 5), which is one of the largest shopping centers of Sweden, is situated adjecent to Brunnsparken and has a total area of 317 000 $m^2$of which 70 000 m^2 are for resturants and shops. It has approximately 30 million visitors per year, making it one of the most prominent trip attractions in Sweden. Beseides the visitors, around 6000 people work in Nordstan every day, altogether making it a destination for numerous passenger of which a big share are traveling with different public transport lines passing through Brunnsparken and Centralstationen (Nordstan, 2020).

The size and position of Nordstan, the Central station and the adjacent regional bus hub Nils Ericssonsterminalen, contributes in making Brunnsparken and Centralstationen the main public transport hubs of Gothenburg.

Figure 5 The shopping centre Nordstan (From Wikimedia Commons)

4. Methodology and simulation model

This chapter comprises the methodology that has been used for the performance of the simulations. The chapter also describes the literature review methodology and data collection. Data regarding the public transport lines, stop times and timetables have been collected. The results are generated from the software PTV Vissim, where the current situation and the proposed solutions are compared.

4.1 Data collection

Relevant data, such as stop time for public transport lines and the designed timetables in the study area, have been collected from Västtrafik AB. All public transport lines which operate in the area are managed by them. Västtrafik is responsible for the public transport system, including buses, trains, trams, and boats functioning in western Sweden and they execute multiple measurements to develop and offer smart services, as well as sustainable trips for people living and working in the region (Västtrafik AB, n.d.).

By registering the operation of every tram during service, an empirical distribution for the stop times of vehicles had previously been derived by Västtrafik. The stop times are the times a vehicle is at rest on the platform. In practice a tram sometimes stops twice at a stop for boarding passengers. This is however not possible to model in Vissim. Therefore, the trams were only simulated to stop once for boarding and alighting passengers and the stop time distribution was used as dwell time distribution. The compiled data for alighting and boarding passengers obtained from Västtrafik were collected in December 2019 between Monday-Thursday during the peak hours, from 6.00 am to 8.30 am (Hägglund, 2020). The dwell time and entry time distributions are found in Appendix III.

4.2 PTV Vissim simulation and modelling performance

PTV Vissim is a traffic and transport planning tool developed by the German company PTV AG and is used worldwide. It is a time step, behavior-based and microscopic simulation program used to model multimodal transport operations (PTV Group user manual, 2020). It is the world's leading program for the simulation of traffic and transport and has more than 12 000 users, including public authorities, consulting firms, and universities (PTV group b, 2020). It is useful for the evaluation of various alternatives for transportation planning measures of effectiveness (Vissim 5.40 User Manual, 2011). The simulation performance of the software generates realistic and detailed information and therby allows to simulate the interactions between pedestrian streams and public transport as well as private transport (PTV Group, 2020).

PTV Vissim uses a psycho-physical perception model, created by Wiedemann (1974). In this a vehicle driving with higher speed moves with its desired speed until it attains the driver's specific threshold distance to the preceding vehicle and the driver will then start to decelerate.

The Wiedemann (1974) model is based on four phases which defines the driving behaviour during different traffic conditions. The four different phases driving states, which are the bases of PTV Vissim, are *free driving*, *approaching*, *following* and *braking*. *Free driving* is when the driver has sufficiently long distance to the preceding vehicle that he accelerates in order to hold his desired speed. There will however always be oscillations around this. *Approaching* defines when the driver is sufficiently close to the preceding vehicle that he adjusts his acceleration dependent on it. The speed will then be an interpolation between the speed of the preceding vehicle and his desired speed. Moreover, *following* is when the driver has come so close to the preceding vehicle that he keeps the distance to it rather constant. The distance between the vehicles will however, to some extent oscillate. *Braking* is when the distance between the vehicles falls between the safety distance, which could occur if the preceding vehicle brakes quickly.

PTV Vissim was chosen to perform as simulation tool of this project due to the size of the simulated area, which requires an enhanced microscopic analysis which supports the simulation of public transport. The program is also very user-friendly and suitable for the problem.

The following subsections present how the traffic network was set up in PTV Vissim. Essential functions such as links, connectors, conflicts, public transport stops, and public transport lines are explained. The guideline network setup which has been used in the case study of this thesis was released in 2020.

4.2.1 Links, connectors and conflicting areas

One of the initial steps to perform when setting up a network is to create links and connectors; which vehicles and pedestrians move on. Different attributes such as lane widths, link behaviour types, vehicle types, and displayed types are included in links characteristics (PTV, User Manuals 2020). Urban motorized is chosen as link type whereas railroad is chosen for the display type. Vehicle modes which have been allocated to use the links in the network are bus and tram traffic. In order to connect links, connectors were inserted, and for these, intermediate spline points were generated in order to make the transition between the links smooth.

When links are merged together, the program generates conflict areas for which the priority could be set. The priory of these define which links that have the right of way when two road users arrive at the same time. The status of the conflict areas and priority is decided by the model creator, dependent on the priority rules. Regarding the creation of this model, the conflict area of the junction by Kvarnbron, shown in Figure 6, is very complicated due to the unique unofficial praxis among the drivers, which gives the lines with the lowest line number highest priority. This is not possible to implement in PTV Vissim, so therefore high priority was set to an approach with generally low line numbers and vice verse. Figure 6 shows different conflict area status by the intersection adjecent to Kvarnbron. The status marked as green illustrates right of way, red illustrates yield and yellow undetermined.

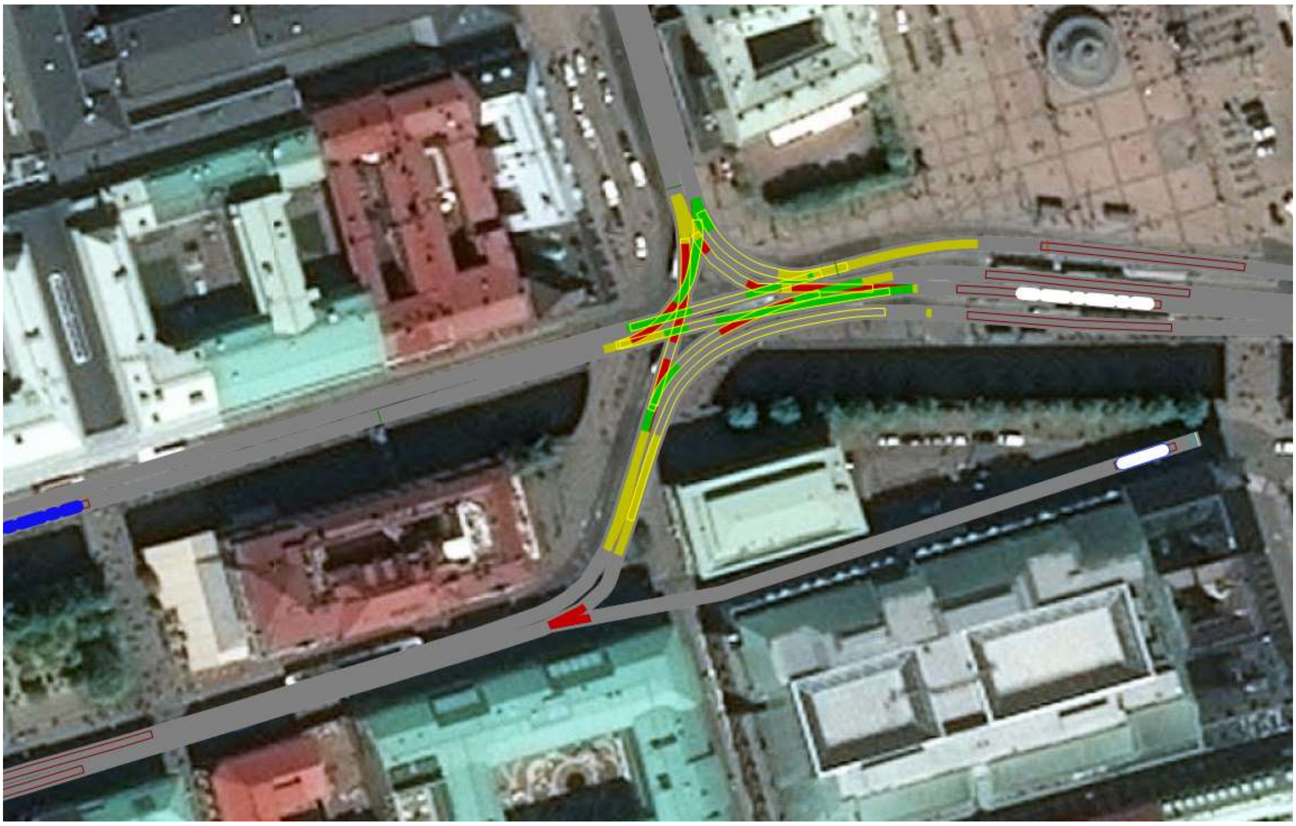

Figure 6: An illustration of the status of the conflicting area in Kvarnbron from Vissim simulation.

4.2.2 Public transport lines and Public transport stops

Public transport lines and the allocations of corresponding timetables and line routes which serve fixed public transport stops were defined according to the existing public transport system. Furthermore, stop point locations, are shown in Figure 7. Regarding Brunnsparken, the stop points B1 and B2 are situated at Norra Hamngatan and the stop points C1 and C1 at Södra Hamngatan. At Centralstationen all stop points (A, B, C, D) are situated at the same spot and are found next to each other as seen in Figure 7. Moreover, bus 60 stops at stop point C2, which is located at Södra hamngatan in Brunnsparken and continue on Södra Hamngatan instead of following the routes of the tram lines and further stops at Slussplatsen south of Centralstationen. In the opposite direction the line does, however, follow the same route as the trams.

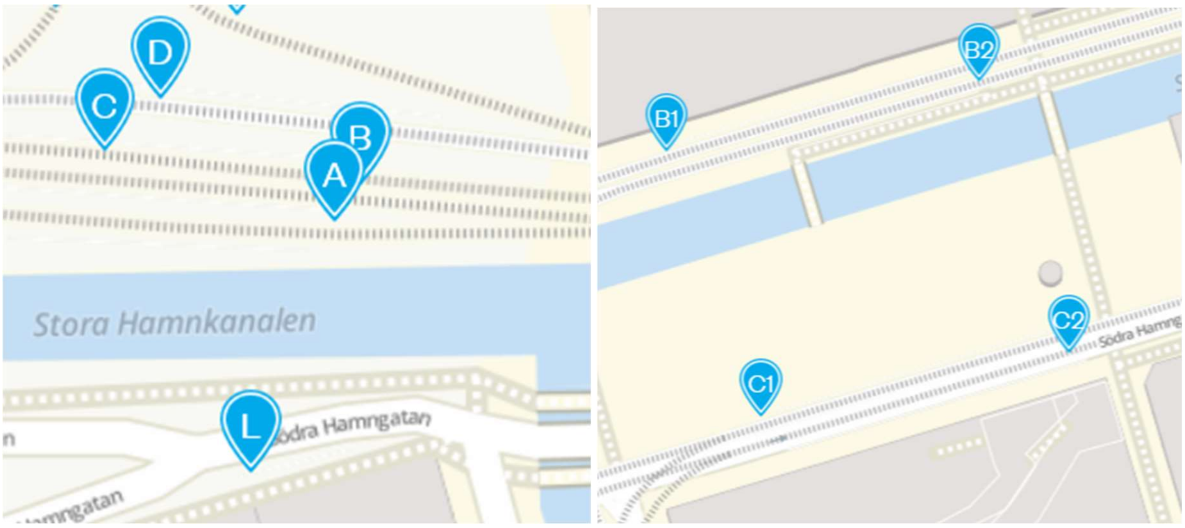

Figure 7 The location of stop points, Centralstationen (left) and Brunnsparken (right) (Västtrafik AB,2020) Open Street map.

Furthermore, the timetables for the first public transport stop and the dwell times for the stops, were set according to data provided by Västtrafik (see appendices II & III). Since it takes some time from when the vehicles enter the network until they depart from their first stops a time offset was used so the vehicles should depart from their first stops at appropriate times. Route decisions of each public transport line were created by drawing their routes along the links. In PTV Vissim, a public transport line always has a fixed route (PTV Vissim, 2020). Further relevant attributes, such as vehicle type were set for the lines. The average speed for all lines during the peak hours is approximately 17.6 km/h in the city centre (Blomquist, 2013), leading to the initial assumption of an average linear speed distribution between 15 km/h and 20 km/h, for all lines in the network.

Additionally, the length of each tram was modified to adjust the capacities and the length of the lines in service. Today, Göteborgs spårvägar uses four different models, named M28, M29, M31 and M32, of which the oldest model was manufactured in 1960 (Göteborgs spårvägar, n.d.). The length of the models in service varies from 14.2 to 306 meters. For practical reasons all lines operating in the system were assumed to have the same length, since only one vehicle type can be selected for a line. The length 30.6 meters, since most of vehicles in service have approximately this length. Moreover, buses were also adjusted to have appropriate length considering the buses in service.

4.2.3 Method for determining public transport dwell times

To be able to determine the vehicle dwell times at stops, PTV Vissim differentiates between three variable modelling approaches, where various input data are required based on the chosen model type. In this thesis, a dwell time distribution is given as an input in the program. This could be given as either a normal or an empirical distribution, depending on the available data (PTV Group, 2020). Normal distribution describes how values between the lower limit and upper limit are distributed, with mean and standard deviation, while empirical distribution defines the upper and lower limits with intermediate points in the curve (PTV Vissim, User manual, 2020). In this thesis, an empirical time distribution is used. Individual data point values of each station obtained from Västtrafik are inserted. The data with the intermediate points (limits between intervals of time) in their proportion is found in Figure 14 in appendix III.

4.2.4 Simulation running and travel time measurements

The input data for the simulation is based on real-time information as dwell time distribution. The duration of the used simulation is 2 hours, corresponding to the morning peak hours of public transport lines which use the current network, from 6.30 am to 8.30 am. In the simulation 15 minutes of the warm-up period is included, so the actual simulation start time is 6.15 am, but the warm-up time is not considered in the result. Simulation parameters as variation of a random seed, iterations of dynamic assignments and simulation speed were set. In order to find a representative result for the whole network, 10 simulation runs were performed with different random seeds and the average of these runs was thereafter used. The main objective of the simulation performance is to measure the total travel time for each public transport line in the network. To measure the total travel time origin and destination markings were set for each route. Figure 8 illustrates a 3D image of the real road network created in PTV Vissim, including surrounding areas. Other output data as averege travel time, speed, delay, etc. of all vehicles are calculated automaticly by the program.

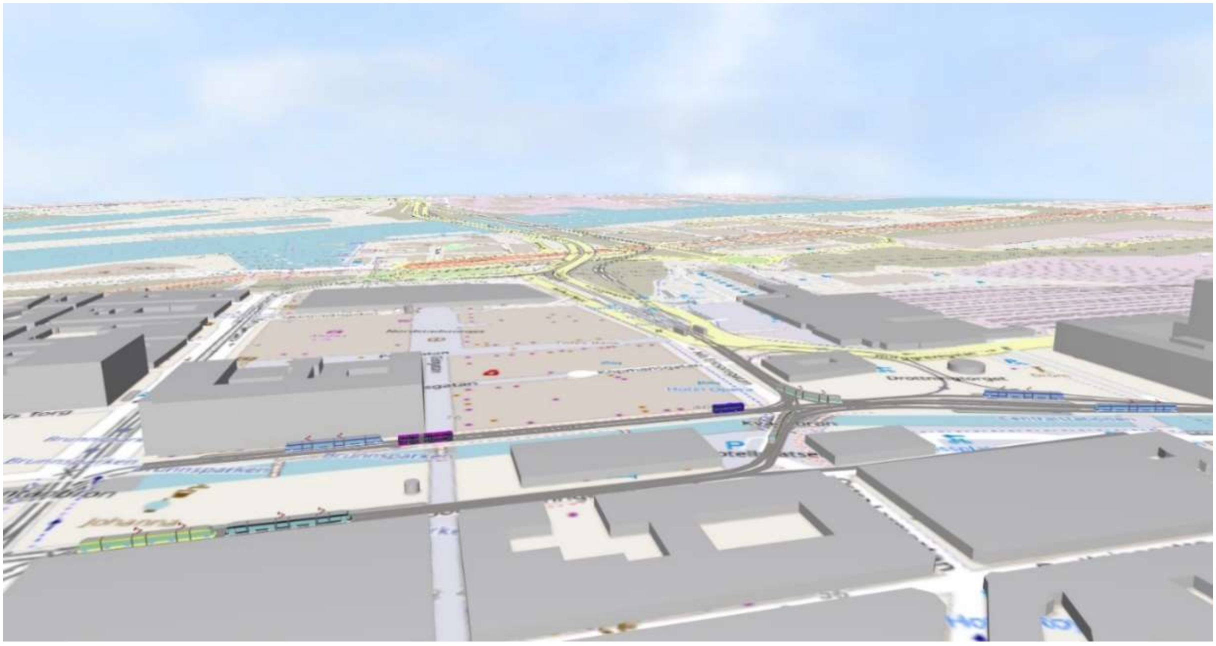

Figure 8 A 3D view of the simulated area (from the simulation model PTV Vissim, 2020).

4.2.5 Calibration of the model

To be able to confirm that the simulation model was representative, a calibration of the model was performed. Most of the input parameters, such as dwell time distribution and entry time distribution were obtained from Västtrafik, and were therby not calibrated. The desired speed distribution, however, was important to calibrate due to its importance for the simulation and thereby for the results. The validation was done by performing a field study measurement which lasted two consecutive days. The route which was selected to be observed is the one which starts at Södra Hamngatan, stops at stop point C2, turns right by Kvarnbron, stops at stop point A at the Centralstationen and continue onto Stampgatan. It is the route where most of the public transport lines pass through (lines as 2, 7,4 11 and 9). The field study was performed, by letting two observers stand at two different points (one in the beginning and one in the end of the route) and documenting the coordinates of the spots in order to find the distance between them and registering the time points when the vehicles were passing respective spot. The first point was at Stampgatan and the second point was at the corner of the intersection on Södra Hamngatan. By comparing the passing times at the two points with the result given by the Vissim model, the speed distribution could be validated. In Vissim 10 simulations of vehicle travel time, with different random seeds were performed for this. A desired linear speed distribution of 15km/h as lower bound and 20km/h as higher bound, was used as input for the simulation of the network. At the junction by Kvarnbron reduced speed areas were however used since the speed through an intersection was expected to be low. The results from the field measurements are found in appendix III. The results from the field measurements are found in Appendix III.

4.2.6 Stop-skipping scenarios

For the stop skipping solution, 3 different scenarios were chosen, by using the scenario management function in PTV Vissim. The scenario management is based on the base scenario which includes all stop points and from this modifications were made.

The first scenario was to skip the stop points A and D at Centralstationen. The second scenario was to remove stop points B2 and C1 at Centralstationen. The reason that these stop points were selected is that the removal of stop points leads to higher speed which is not desirable close to shopping centers, which is the case for stop B1, which is adjacent to the shopping center Nordstan and C2 which is adjacent to the shopping center Arkaden. At the stop points B2 and C1 the sight is much better for the pedestrians. The third scenario is to remove all four of the mentioned stop points B2, C1, A and D. This entails that for all scenarios, all lines stop at least at one of the hubs Nordstan, Brunnsparken and Centralstationen.

4.3 Comparisons of saved and lost times for passengers

In order to give an indication about the desirability of the project, the total saved time of passengers going through the area was compared to the possible lost time of passengers having to walk between Brunnsparken and Centralstationen. The saved time was estimated by using data from Västtrafik about number of passengers onboard on the vehicles during the considered time. Since the provided data is for whole hours (6-7, 7-8, and so forth), the onboard load for the time from 6 to 9, was used. The number of passengers traveling on each route was multiplied with the saved time for each route and mode of transport (bus or tram). Further the sum of the values for all routs was taken to calculate the total saved time.

In order to estimate the total lost time of people having to walk between the stops Brunnsparken and Centralstationen for the different scenarios, the proportion of alighting passengers who would have to walk between the connection points should be estimated. This is, however, a complex problem that is outside of the scope of this thesis. Some of the passengers could make their transit at other stops in the system and so not having to walk the distance that all and therefore a analysis of the entire system with a macroscopic tool like PTV Visum would be required for this. Therefore, the lost times for all (integer percentage) proportions were calculated. Further the proportion of passengers having to walk between the stops for the lost time to equal the saved time, was calculated for the different scenarios, in order to give decision makers a support regarding the desirability of the project. The calculations of lost time were based on Google maps estimation of 3 minutes walking time between the hubs.

5. Results

In the following section, an analyse of the results obtained from PTV Vissim simulations, as speed, delay, travel times and the calculations of saved and lost times, are presented.

5.1 Speed and delay

The delay of the vehicles is an essential result, when studying the effect of the different stops-skipping scenarios. As seen in Figure 9, the average delays of the vehicles are found for the base (current) case and the 3 different stop-skipping scenarios. However, it is important to mind that the delay is the difference between the desired speed and the actual speed of a vehicle, i.e. the difference between the time for a vehicle to go through the area and the time that would be needed if there were no other vehicles in the system. The time needed to stop at a public transport stop is thus not considered as delay time. As expected, scenario 3 is the one with lowest delay; 10.21 s. This corresponds to less than half of the delays for the base case (39 %). When the stops are removed the vehicles can drive with a higher and more even speed and so the following vehicle does not have to adjust its speed to the same extent.

The removal of the stop points A and D at Centralstationen is clearly more effective in decreasing the delay (48 % of the base case delay) than the removal of stops B2 and C2 in Brunnsparken (88 % of the base case delay). This indicates that scenario 1 is relatively beneficial to implement. One reason for this is however, that the results are dependent on how long time the trams spend on the stops since the PT stops can give rise to queueing. During the simulated peak hours, stop points A and D have 107 and 148 alighting passengers per hour, between 6 and 8.30 whereas stop B2 and C1 have 64 and 104 alighting passengers per hour, respectively. Moreover, stop A and D have 168 and 187 boarding passengers per hour, respectively, whereas stop B2 and C1 have 73 and 54 boarding passengers per hour.

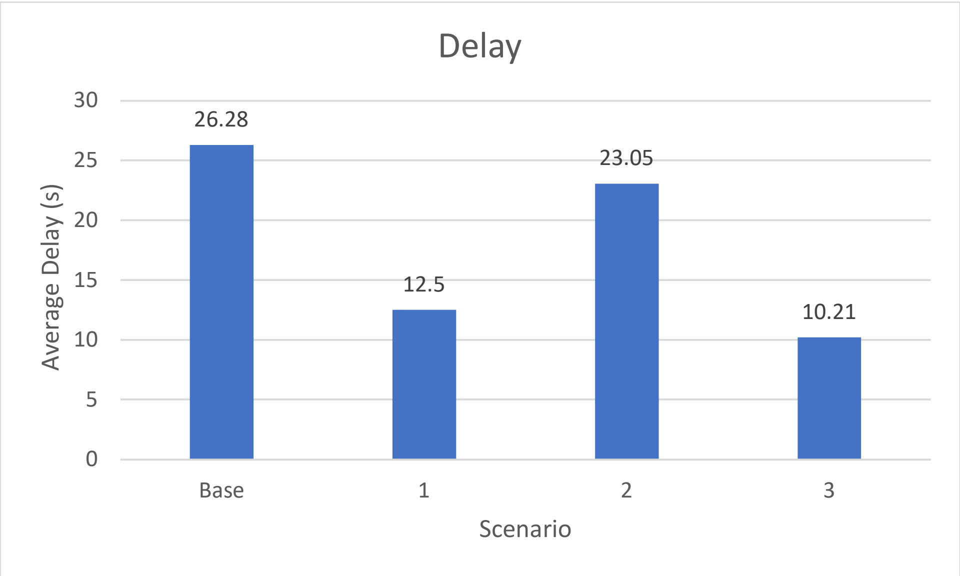

Figure 9 The average delay per vehicle for the different scenarios.

Further, the average speed of the different vehicles, for the different scenarios, is shown in Figure 10. The result for the base case shows that the speed through the area is remarkably low, 9 km/h, which is lower than many people can walk (Minetti, 2000). For stop-skipping solution, the highest speed is, as expected for Scenario 3 (32 % higher). Scenario 1 has 18 % higher speed than the base case whearas scenario 2 has 11 % higher speed than the base case. Scenario 1 and 2 do thereby not differ as much regarding speed as regarding delay. This is since the increament of speed for scenario 2, to a large extent is a consequence of saved dwell time whereas scenario 1 also, to a large extent, decreases the (non-dwell-time) delay.

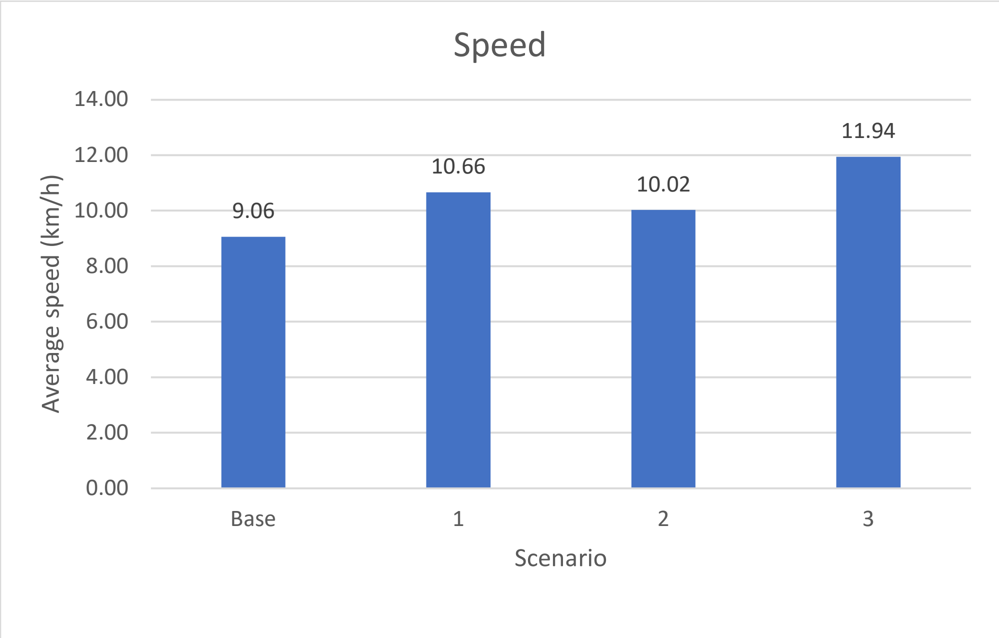

Figure 10 The average speed for all vehicles in the network for the different scenarios

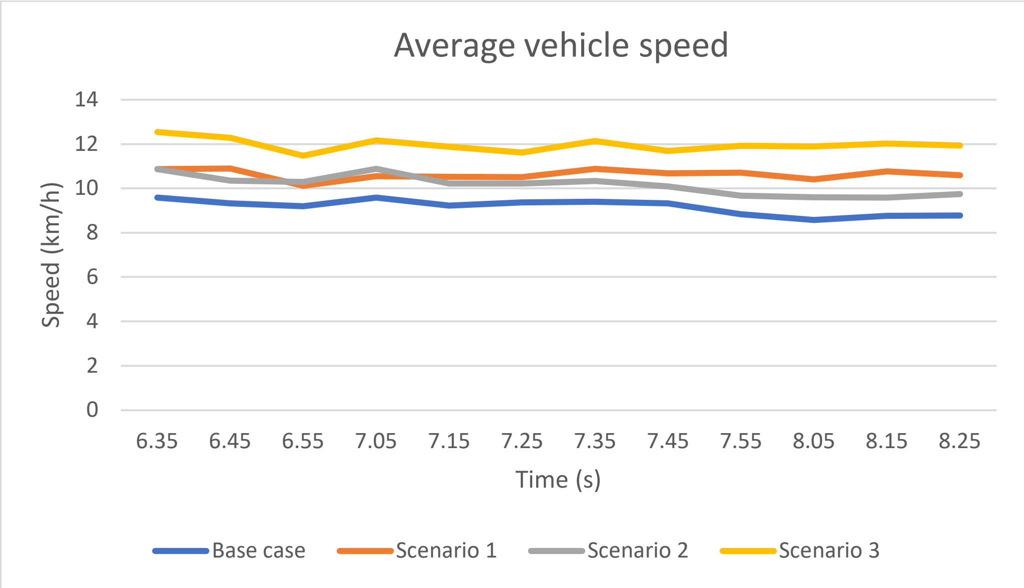

Figure 11 The time variation of the speed for the different scenarios. The value for 6.35 is the average between 6.30-6.40 amd so forth.

The time variation of the speed is shown in Figure 11. Here the average speed of every 10 minutes interval during the simulation period is presented. As expected the base case has the lowest speed during the entire simulated period whearas Scenario 3 has the highest speed during the entire period. However, in the beginning of the period the scenarios 1 and 2 have rather similar speed but in the end of the period scenario 1 has clearly higher speed. The good performance of scenario 3 is remarkable during the entire simulation and the very low speed of the base case, in particular about 8.05 am (8.58 km/h).

In Figure 12, the corresponding travel times for all scenarios are presented. This is of high importance to analyse the advantages of each scenario in terms of saved time. Scenario 1 and 2 where either stop points A and D or B2 and C1 are removed, have a decrease in average travel time of 19 s and 17 s, respectively, for each line which passes through the existing network, due to an increased speed and decreased delay for lines passing through the route where these stops are located. Moreover, Scenario 3, which is the max scenario, for which each line skips either Brunnsparken or Centralstationen, decreases the average travel time by 44 s, leading to an improved speed and delays of all lines serving the network.

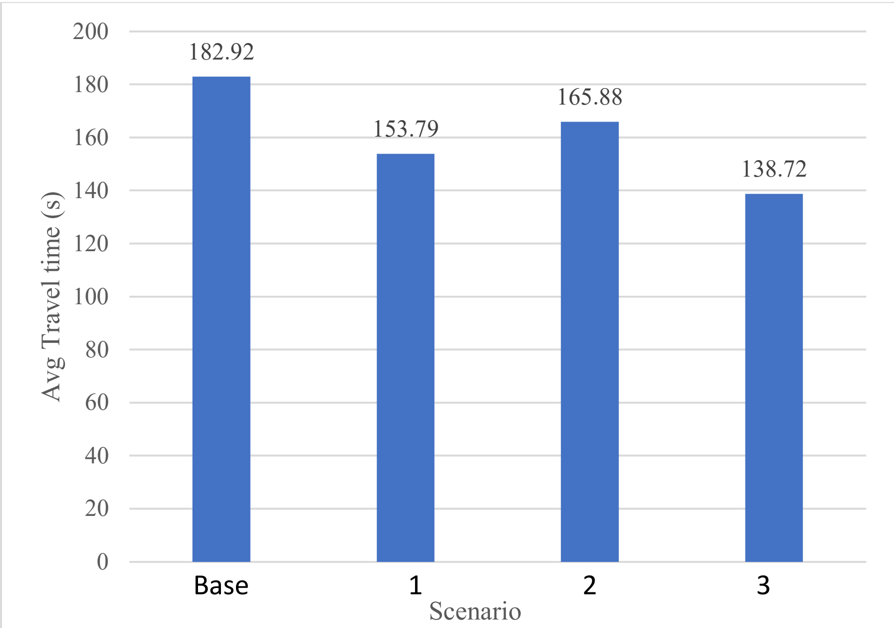

Figure 12 The average travel time per vehicle for the different scenarios.

Table 3 shows a complete results where the base Case and the other scenarios for stop-skipping are compared regarding several parameters. All values are the average from the 10 simulation runs performed in the PTV Vissim model. Parameters of special interest to observe are as Delaystopsaverage and StopsTotAvg, where the former describes the average time every vehicle is at rest and the latter, the average number of stops which vehicles make due to interaction with other vehicles. Remarkably, is that the Delaystopavg, for all vehicles, is 16.6 s for the base case, meaning that the vehicles are at rest during, on average, 16.6 s without being at a public transport stop point. Further, in comparison with the Base Case, it is found that the delaystopsavg (for all vehicles) is 68 % lower for Scenario 1 and 72 % lower for scenario 3. This reduction leads to an increased speed for these scenarios.

Moreover, StopsTotAvg indicates the number of times the vehicles are at rest in the system (except for stops at public transport stop points). For the base case, there are, on average, 0.49 stops, so about every other vehicle has to make an undesirable stop in the system. In this respect, both scenarios 1 and 3 are useful since they decrease the number of delay stops by 41% and 45%, respectively. However, Scenario 2 only decreases the number by 14%.

Table 3: Average values for the different scenarios for the 10 simulation runs. The categories delayavg, delaytot, stopsavg, stopstot and delaystopavg only consider the stops and delay due to other vehicles and do neither include nor consider the stops at public transport stop points.

Scenario	Base Case	Scenario 1	Scenario 2	Scenario3
DELAYAVG(ALL) (s)	26.28	12.5	23.05	10.21
DELAYAVG(BUS) (s)	22.47	9.98	20.62	9.6
DELAYAVG(TRAM) (s)	27.68	13.42	23.95	10.43
STOPSAVG(ALL) (-)	0.49	0.29	0.42	0.27
STOPSAVG(BUS) (-)	0.32	0.1	0.23	0.12
STOPSAVG(TRAM) (-)	0.55	0.36	0.49	0.33
SPEEDAVG(ALL) (km/h)	9.06	10.66	10.02	11.94
SPEEDAVG(BUS) (km/h)	8.7	10.17	9.43	11.05
SPEEDAVG(TRAM) (km/h)	9.17	10.82	10.22	12.23
DELAYSTOPAVG(ALL) (s)	16.6	5.38	15.37	4.8
DELAYSTOPAVG(BUS) (s)	10.93	1.3	10.73	2.11
DELAYSTOPAVGTRAM (s)	18.68	6.86	17.08	5.78
DISTTOT(ALL) (km)	128.59	131.21	128.75	131.15
DISTTOT(BUS) (km)	29.19	30	29.27	29.83
DISTTOT(TRAM) (km)	99.4	101.21	99.49	101.33
TRAVTMTOT(ALL) (s)	51400.51	44292.6	46612.48	39534.23
TRAVTMTOT(BUS) (s)	12155.73	10616.6	11258.45	9714.11
TRAVTMTOT(TRAM) (s)	39244.78	33676	35354.03	29820.11
DELAYTOT(ALL) (s)	7086.79	3600.81	6168.14	2906.63
DELAYTOT(BUS) (s)	1633.4	768.53	1492.32	729.31
DELAYTOT(TRAM) (s)	5453.39	2832.28	4675.82	2177.32
STOPSTOT(ALL) (-)	138	84	119	77
STOPSTOT(BUS) (-)	24	8	18	9
STOPSTOT(TRAM) (-)	114	76	101	68

5.2 Passengers lost and saved times for stop-skipping solution

The total saved time that all passengers traveling between Brunnsparken and Centralstationen would experience going through the system per hour was calculated to be 39.4 h with scenario 1, 20.6 h with scenario 2 and 60.3 h with scenario 3. There is, however, no available data from Västtrafik regarding the alighting passengers for line 60. For the comparison with the lost time, the saved time for line 60 should thereby not be considered. Further, the saved time that all passengers going through Brunnsparken and Centralstationen, except those traveling with line 60 would experience, was calculated to be 34.3 h for scenario 1, 20.6 h for scenario 2 and 55.1 h for scenario 3.

In Figure 13 these values of saved time are presented for the different scenarios by the constant value lines. The blue line represents how the lost time vary linear with the proportion pf passengers having to walk between Brunnsparken and Centralststionen with the proposed scenarios. The intersection points represents the proportions corresponding to equaly how much saved and lost time. For scenario 1 this proportion is 10.3 %, for scenario 2 this is 12.2 % and for scenario 3 this is 32.7 %, which, as expected, is close to the sum of the proportions for scenario 1 and scenario 2.

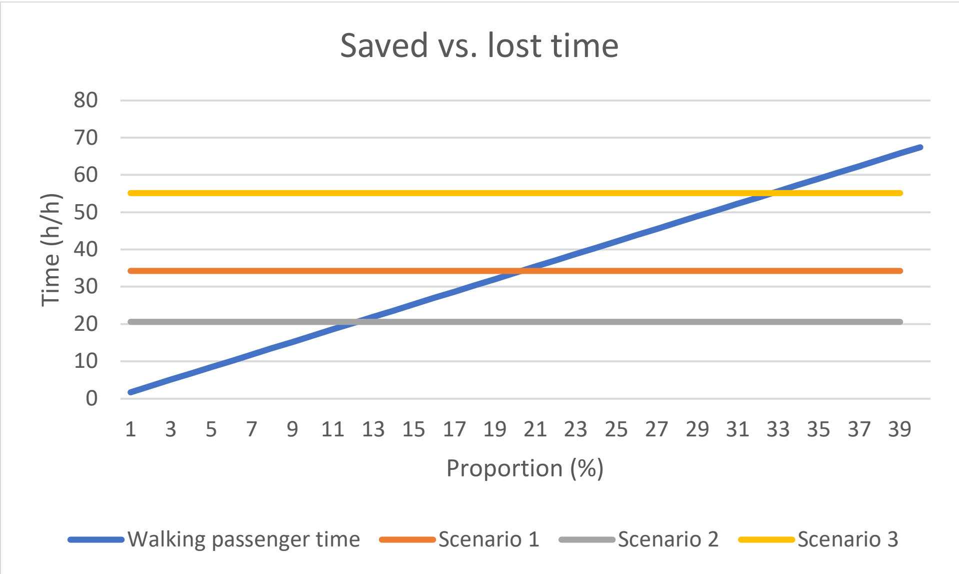

Figure 13 The estimated saved travel times for the 3 stop-skipping scenarios plotted against the estimated walking time between Brunnsparken and Centralstationen for different proportions of alighting passengers.

6. Discussion & Validation

The fact that the dwell time and entry time data are empirical, strengthens the reliability of the result and decreases the number of assumptions in the model. Further, links representing roads and tracks have been drawn very close to the actual routes. The calibration control of the speed supports the choice of desired speed distribution. For the stop-skipping scenarios the same dwell time distribution was, however used, due to the scope. This entails, to some extent, an overestimation of the speed for the stop skipping scenarios since the dwell-times probably will be higher for these scenarios. Further, there are, properties that were assessed not being reasonable to include, as simulation of pedestrians. The presence of pedestrians does likely impact the speed of the trams, to some extent, but since the trams have right of way this was not assessed to be large enough to be considered. Furthermore, a simple observance of the area has been done at the calibration occasion. This showed that the public transport lines leaving the network towards east sometimes formed queues, due to the traffic signal at Stampgatan. Such queuing as well as other, periodical and occasional, events taking place outside of the simulated area, which are a result of many different events in the entire system, cause variations in the system performance but these are considered by the used entry time distribution. Moreover, unpredictable events, occuring within the system, like broken trams and errors with switches could also have major impacts on the delays and the travel times in the network, but the approach of this thesis is, however, to simulate a day without these types of events.

Due to the scope of the project, which focus on whether its desirable to implement the analysed specific stop-skipping that all, rather than exactly what stop points that should be skipped, all simulations have been done only for morning peak hours. An analysis of the afternoon could give a slightly different result regarding which of the stop-skipping solutions that would be most effective but since all solutions include skipping of stop points in both directions, this is not expected to be very different.

During the field study for the calibration of the model, it was observed that the number of non-public transport vehicles used in the network were few and did not affect the public transport significantly. They were therefore not included in the model. The observance of non-public transport should however be interpreted with caution, as observance of these has been carried out only for two occasions during the morning rush hour. On the other hand, inclusion of these vehicles is expected to give a, if significant, even lower speed through the area, showing even clearer the need of improvements.

7. Conclusion and Recommendations

For the current situation, the average travel times per vehicle is influenced by factors as the speed of the vehicles in the network, the distance between the routes measured for vehicle travel times, and the frequency of vehicles in the network. For the implementation of stop-skipping, the result shows that Scenario 3, for which, each line that passes through the network skips at least one stop in either of these two hubs, would reduce the average travel times through the network by 24 %. As mentioned in literature review, a previous study conducted by Nguyen and Descotes-Genon (2007) states that stop-skipping improves transit service quality and operating efficiency. In this case, the implementation of stop-skipping entails, to some extent, less travel time and delay for the public transport lines which pass through the hubs. The reduction of travel times could be used to increase, for instance, the frequency and thereby the capacity of the public transport lines in the system. This is of great importance since demands are expected to increase due to the expected population growth of the city of Gothenburg and this could contribute to achieve the goal of the municipality to increase the number of trips by public transport to 55% by 2035.

The analysis about how much lost and saved time the passengers would have with the proposed stop-skipping scenarios shows that even if a large proportion of the passengers (up to 32.7 % for scenario 3) would have to walk between the connection points Brunnsparken and Centralstation, the saved time would still exceed the lost time. However, it is difficult to make valid conclusions about exactly how much time the travellers would save and lose, due to the complexity of determining the lost times of passengers needing to walk between the stations to make their desired interchange. Such analysis might require more extensive data, as number of passenger interchanges between lines operating in the system. The used micro model, performed with PTV Vissim, should also be combined with a macroscopic model , e.g. made with PTV Visum, for which a larger and more complex network can be created and other relevant parameters are taken into consideration. The micro model performs however well, in analysing local effects of the stop skipping scenarios, such as comparing their speed, delays and the total travel times within the analysed area. This is important to be able to improve these properties for the public transport lines which pass through the area. Micro and macro models should therefore rather be seen as complements than alternatives. The suggesed stop-skipping solutions can also be modified in order to further optimize the system performance. Implementing time variating stop skippping for which different stop points are skiped during different time intervall could also be benefecial, particularly during an epidemy as the current outbreak of COVID-19, when distance between pedestrians is desirable.

Finally, implementing a stop-skipping can be a very cost-effective solution, as it does not require any new constructions and drastic changes and since it leads to an increased supply and a system efficiency enhancement. However, further studies, like a macro model, are recommended in order to estimate more precisely how the different solutions would affect the passengers saved and lost times and further exactly how a stop-skipping scenario should be implemented to have as high system performance as possible.

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Appendices

Appendix I

In the following table average values from different scenarios obtained from Vissim simulations are presented.

1.Standard deviations values

Table 4: Standard deviation values for the different scenarios for the 10 simulation runs.

Scenario	Base Case	Skip A and D	Skip B2 and C1	Skip A, D, B2 and C1
DELAYAVG(ALL)	25.07	1.05	25.38	0.75
DELAYAVG(30)	22.24	1.17	22.08	0.96
DELAYAVG(40)	26.18	1.27	26.66	0.82
STOPSAVG(ALL)	0.16	0.03	0.15	0.03
STOPSAVG(30)	0.43	0.03	0.2	0.03
STOPSAVG(40)	0.08	0.04	0.14	0.04
SPEEDAVG(ALL)	0.95	0.07	1.15	0.08
SPEEDAVG(30)	0.93	0.07	1.05	0.13
SPEEDAVG(40)	0.96	0.09	1.18	0.09
DELAYSTOPAVG(ALL)	25.23	0.9	25.46	0.64
DELAYSTOPAVG(30)	22.44	1.04	22.36	0.87
DELAYSTOPAVG(40)	26.32	1.1	26.67	0.68
DISTTOT(ALL)	7.59	0.33	7.58	0.39
DISTTOT(30)	1.71	0.14	1.69	0.14
DISTTOT(40)	5.88	0.34	5.89	0.37
TRAVTMTOT(ALL)	3257.9	357.11	3666.76	334.58
TRAVTMTOT(30)	809.55	58.63	845.13	110.36
TRAVTMTOT(40)	2470.87	360.8	2834.24	295.25
DELAYTOT(ALL)	5850.55	296.97	5973.83	216.28
DELAYTOT(30)	1445.76	85.88	1441.69	72.24
DELAYTOT(40)	4408.57	266.07	4534.82	175.06
STOPSTOT(ALL)	48	10	44	9
STOPSTOT(30)	33	2	15	2
STOPSTOT(40)	19	9	29	8

2. Saved and lost time

The departure load data from all passengers together with the calculated saved travel time for all lines are shown in table 5.

Table 5 an Excel sheet for the estimation of saved time

Line	Hour	DepartureLoad	Pax/veh	S1 TS/pax (s)	S2 TS/pax (s)	S3 TS/pax (s)	S1 TS (s/h)	S2 TS (s/h)	S3 TS (s/h)
1	6	143.5	43.1828	0.02	35.23	35.14	5.2	9128.0	9104.7
1	7	371.93							
1	8	261.86							
1	9	190							
2	6	215	40.3576	46.49	-0.13	46.45	11257.3	-31.5	11247.7
2	7	233.8							
2	8	277.64							
2	9	148.5							
3	6	83.2	19.6389	0.02	35.23	35.14	2.4	4151.3	4140.7
3	7	101.6							
3	8	168.7							
3	9	99.34							
4	6	160.63	30.8212	46.49	-0.13	46.45	8597.3	-24.0	8589.9
4	7	213.3							
4	8	180.86							
4	9	163.06							
7	6	157.6	37.5233	46.49	-0.13	46.45	12211.2	-34.1	12200.7
7	7	288.17							
7	8	342.22							
7	9	217.78							
9	6	187.03	43.0953	46.49	-0.13	46.45	13022.8	-36.4	13011.6
9	7	327.33							
9	8	326							
9	9	198.33							
11	6	187.86	38.4357	46.49	-0.13	46.45	14295.0	-40.0	14282.7
11	7	309							
11	8	425.6							
11	9	203							
60	6	144.71	25.7099	-0.030	0	-0.02	-10	0	-7
60	7	446.69							

60	8	411.29								
60	9	189.16								
1	6	231.33	65.4356	-0.45	40.29	39.75	-162.0	14500.2	14305.9
1	7	412.15								
1	8	436.2								
1	9	521.1								
2	6	30	35.5617	-0.45	40.29	39.75	-112.0	10029.5	9895.0
2	7	374.25								
2	8	342.55								
2	9	388.94								
3	6	112.89	51.5401	53.04	-0.46	53.35	16402.1	-142.3	16498.0
3	7	301.5								
3	8	513.33								
3	9	462.57								
4	6	262.47	57.5873	-0.45	40.29	39.75	-168.4	15081.2	14879.1
4	7	424.15								
4	8	436.33								
4	9	350.25								
7	6	257.33	83.7765	-0.45	40.29	39.75	-245.0	21939.8	21645.7
7	7	668.31								
7	8	708								
7	9	520								
9	6	175.59	66.8298	53.04	-0.46	53.35	21267.9	-184.5	21392.2
9	7	464.4								
9	8	562.95								
9	9	376.11								
10	6	6	68.2741	53.04	-0.46	53.35	27159.4	-235.5	27318.2
11	7	603.17								
11	8	927								
11	9	476								
60	6	141.07	27.7658	50.89	-0.13	51.29	18369.0	-46.9	18513.4
60	7	484.31								
60	8	457.49								
60	9	227.52								
						Total (s/h)	141892.1	74054.7	217018.6

						Total (h/h)	27.8	14.5	42.6

Table 6 Data for vehicles and travel times for each route in the network for the base case

Route	Lines	VEHS(BUS)	VEHS(TRAM)	TRAVTM(BUS)	TRAVTM(TRAM)	DISTTRAV(BUS)	DISTTRAV(TRAM)
1 Södra hamngatan-Centralen	2,4,7,9,11	0	67		205.53		525.77
2Centralen-Norra hamngatan	3,9,11,60	24	21	202.6	209.26	514.74	514.74
3 Södra hamngatan-Slussplatsen	60	26	0	158.45		333.85	
4 Nordstan-Södra hamngatan	6,16	7	14	109.31	117.16	336.29	336.29
5 Centralen-Södra hamngatan	1,2,4,7	0	49		207.01		530.63
6 Norra hamngatan Centralen	1,3	0	23		189.64		509.21
7 Norra hamngatan Nordstan	6,16	17	13	105.84	102.87	313.24	313.24
8 Centralen-Nordstan	13	0	6		154.75		376.85
9 Nordstan-Centralen	13	0	7		98.21		377.97

Table 7 Data for vehicles and travel times for each route in the network for Scenario 1

Route	Lines	VEHS(BUS)	VEHS(TRAM)	TRAVTM(BUS)	TRAVTM(TRAM)	DISTTRAV(BUS)	DISTTRAV(TRAM)
1 Södra hamngatan-Centralen	2,4,7,9,11	0	68		159.04		525.77
2Centralen-Norra hamngatan	3,9,11,60	25	22	151.71	156.22	514.74	514.74
3 Södra hamngatan-Slussplatsen	60	26	0	158.48		333.85	
4 Nordstan-Södra hamngatan	6,16	7	14	109.31	117.42	336.29	336.29
5 Centralen-Södra hamngatan	1,2,4,7	0	51		207.46		530.63
6 Norra hamngatan Centralen	1,3	0	23		189.62		509.21
7 Norra hamngatan Nordstan	6,16	17	13	105.55	102.87	313.24	313.24
8 Centralen-Nordstan	13	0	6		88.12		376.85
9 Nordstan-Centralen	13	0	7		97.93		377.97

Table 8 Data for vehicles and travel times for each route in the network for Scenario 2

Route	Lines	VEHS(BUS)	VEHS(TRAM)	TRAVTM(BUS)	TRAVTM(TRAM)	DISTTRAV(BUS)	DISTTRAV(TRAM)
1 Södra hamngatan-Centralen	2,4,7,9,11	0	68		205.66		525.77
2Centralen-Norra hamngatan	3,9,11,60	24	21	202.73	209.72	514.74	514.74
3 Södra hamngatan-Slussplatsen	60	26	0	158.45		333.85	
4 Nordstan-Södra hamngatan	6,16	6	14	72.76	74.55	336.29	336.29
5 Centralen-Södra hamngatan	1,2,4,7	0	49		166.72		530.63
6 Norra hamngatan Centralen	1,3	0	23		154.41		509.21
7 Norra hamngatan Nordstan	6,16	18	13	68.75	68.22	313.24	313.24

8 Centralen-Nordstan	13	0	6		152.02		376.85
9 Nordstan-Centralen	13	0	7		95.38		377.97

Table 9 Data for vehicles and travel times for each route in the network for Scenario 3

Route	Lines	VEHS(BUS)	VEHS(TRAM)	TRAVTM(BUS)	TRAVTM(TRAM)	DISTTRAV(BUS)	DISTTRAV(TRAM)
1 Södra hamngatan-Centralen	2,4,7,9,11	0	68		159.08		525.77
2Centralen-Norra hamngatan	3,9,11,60	25	22	151.31	155.91	514.74	514.74
3 Södra hamngatan-Slussplatsen	60	26	0	158.47		333.85	
4 Nordstan-Södra hamngatan	6,16	6	14	72.76	74.55	336.29	336.29
5 Centralen-Södra hamngatan	1,2,4,7	0	51		167.26		530.63
6 Norra hamngatan Centralen	1,3	0	23		154.5		509.21
7 Norra hamngatan Nordstan	6,16	18	13	68.74	68.27	313.24	313.24
8 Centralen-Nordstan	13	0	6		86.73		376.85
9 Nordstan-Centralen	13	0	7		95.14		377.97

Appendix II

Timetable data obtained from Västtrafik

1 Brunnsparken_West bound

Tabell 10 Timetable for bus 60 at stop B1 during the peak hours (6.30am-8.30am), recalculated to seconds.

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:12:00.000	06:12:00.000	22320	-180	60	B1
2020-01-27 06:22:00.000	06:22:00.000	22920	420	60	B1
2020-01-27 06:31:00.000	06:31:00.000	23460	960	60	B1
2020-01-27 06:39:00.000	06:39:00.000	23940	1440	60	B1
2020-01-27 06:45:00.000	06:45:00.000	24300	1800	60	B1
2020-01-27 06:51:00.000	06:51:00.000	24660	2160	60	B1
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	60	B1
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	60	B1
2020-01-27 07:10:00.000	07:10:00.000	25800	3300	60	B1
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	60	B1
2020-01-27 07:20:00.000	07:20:00.000	26400	3900	60	B1
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	60	B1
2020-01-27 07:28:00.000	07:28:00.000	26880	4380	60	B1
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	60	B1
2020-01-27 07:36:00.000	07:36:00.000	27360	4860	60	B1
2020-01-27 07:40:00.000	07:40:00.000	27600	5100	60	B1
2020-01-27 07:44:00.000	07:44:00.000	27840	5340	60	B1
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	60	B1
2020-01-27 07:52:00.000	07:52:00.000	28320	5820	60	B1
2020-01-27 07:56:00.000	07:56:00.000	28560	6060	60	B1
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	60	B1
2020-01-27 08:04:00.000	08:04:00.000	29040	6540	60	B1
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	60	B1
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	60	B1
2020-01-27 08:16:00.000	08:16:00.000	29760	7260	60	B1
2020-01-27 08:20:00.000	08:20:00.000	30000	7500	60	B1
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	60	B1
2020-01-27 08:28:00.000	08:28:00.000	30480	7980	60	B1

Tabell 11 Timetable for line 9 at stop B1 during the peak hours (6.30am-8.30am), recalculated to seconds.

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:17:00.000	06:17:00.000	22620	120	9	B1
2020-01-27 06:33:00.000	06:33:00.000	23580	1080	9	B1
2020-01-27 06:49:00.000	06:49:00.000	24540	2040	9	B1
2020-01-27 07:02:00.000	07:02:00.000	25320	2820	9	B1
2020-01-27 07:15:00.000	07:15:00.000	26100	3600	9	B1
2020-01-27 07:26:00.000	07:26:00.000	26760	4260	9	B1
2020-01-27 07:37:00.000	07:37:00.000	27420	4920	9	B1
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	9	B1
2020-01-27 07:56:00.000	07:56:00.000	28560	6060	9	B1
2020-01-27 08:05:00.000	08:05:00.000	29100	6600	9	B1
2020-01-27 08:14:00.000	08:14:00.000	29640	7140	9	B1
2020-01-27 08:23:00.000	08:23:00.000	30180	7680	9	B1

Table 12 Timetable for line 3 at stop B1 during the peak hours (6.30am-8.30am), recalculated to seconds.

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:21:00.000	06:21:00.000	22860	360	3	B1
2020-01-27 06:36:00.000	06:36:00.000	23760	1260	3	B1
2020-01-27 06:51:00.000	06:51:00.000	24660	2160	3	B1
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	3	B1
2020-01-27 07:15:00.000	07:15:00.000	26100	3600	3	B1
2020-01-27 07:26:00.000	07:26:00.000	26760	4260	3	B1
2020-01-27 07:37:00.000	07:37:00.000	27420	4920	3	B1
2020-01-27 07:46:00.000	07:46:00.000	27960	5460	3	B1
2020-01-27 07:55:00.000	07:55:00.000	28500	6000	3	B1
2020-01-27 08:04:00.000	08:04:00.000	29040	6540	3	B1
2020-01-27 08:14:00.000	08:14:00.000	29640	7140	3	B1
2020-01-27 08:23:00.000	08:23:00.000	30180	7680	3	B1

Tabell 13 Timetable for line 4 stop C1 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:20:00.000	06:20:00.000	22800	300	4	C1
2020-01-27 06:26:00.000	06:26:00.000	23160	660	4	C1
2020-01-27 06:40:00.000	06:40:00.000	24000	1500	4	C1
2020-01-27 06:52:00.000	06:52:00.000	24720	2220	4	C1
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	4	C1
2020-01-27 07:04:00.000	07:04:00.000	25440	2940	4	C1
2020-01-27 07:10:00.000	07:10:00.000	25800	3300	4	C1
2020-01-27 07:22:00.000	07:22:00.000	26520	4020	4	C1
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	4	C1
2020-01-27 07:44:00.000	07:44:00.000	27840	5340	4	C1
2020-01-27 07:53:00.000	07:53:00.000	28380	5880	4	C1
2020-01-27 08:02:00.000	08:02:00.000	28920	6420	4	C1
2020-01-27 08:10:00.000	08:10:00.000	29400	6900	4	C1
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	4	C1
2020-01-27 08:28:00.000	08:28:00.000	30480	7980	4	C1

Table 14 Timetable for line 6 at stop C1 during the peak hours (6.30am-8.30am), recalculated to seconds.

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:20:00.000	06:20:00.000	22800	300	6	C1
2020-01-27 06:31:00.000	06:31:00.000	23460	960	6	C1
2020-01-27 06:41:00.000	06:41:00.000	24060	1560	6	C1
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	6	C1
2020-01-27 07:00:00.000	07:00:00.000	25200	2700	6	C1
2020-01-27 07:08:00.000	07:08:00.000	25680	3180	6	C1
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	6	C1
2020-01-27 07:23:00.000	07:23:00.000	26580	4080	6	C1
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	6	C1
2020-01-27 07:42:00.000	07:42:00.000	27720	5220	6	C1
2020-01-27 07:51:00.000	07:51:00.000	28260	5760	6	C1
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	6	C1
2020-01-27 08:09:00.000	08:09:00.000	29340	6840	6	C1
2020-01-27 08:18:00.000	08:18:00.000	29880	7380	6	C1

2020-01-27 08:28:00.000	08:28:00.000	30480	7980	6	C1

Tabell 15 Timetable for line 1 stop C1 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:29:00.000	06:29:00.000	23340	840	1	C1
2020-01-27 06:43:00.000	06:43:00.000	24180	1680	1	C1
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	1	C1
2020-01-27 07:09:00.000	07:09:00.000	25740	3240	1	C1
2020-01-27 07:21:00.000	07:21:00.000	26460	3960	1	C1
2020-01-27 07:31:00.000	07:31:00.000	27060	4560	1	C1
2020-01-27 07:40:00.000	07:40:00.000	27600	5100	1	C1
2020-01-27 07:49:00.000	07:49:00.000	28140	5640	1	C1
2020-01-27 07:58:00.000	07:58:00.000	28680	6180	1	C1
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	1	C1
2020-01-27 08:17:00.000	08:17:00.000	29820	7320	1	C1
2020-01-27 08:26:00.000	08:26:00.000	30360	7860	1	C1

Tabell 16 Timetable for line 2 at stop C1 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:17:00.000	06:17:00.000	22620	120	2	C1
2020-01-27 06:37:00.000	06:37:00.000	23820	1320	2	C1
2020-01-27 06:51:00.000	06:51:00.000	24660	2160	2	C1
2020-01-27 07:05:00.000	07:05:00.000	25500	3000	2	C1
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	2	C1
2020-01-27 07:26:00.000	07:26:00.000	26760	4260	2	C1
2020-01-27 07:36:00.000	07:36:00.000	27360	4860	2	C1
2020-01-27 07:45:00.000	07:45:00.000	27900	5400	2	C1
2020-01-27 07:54:00.000	07:54:00.000	28440	5940	2	C1
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	2	C1
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	2	C1
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	2	C1

Tabell 17 Timetable for line at stop B1 during the peak hours (6.30am-8.30am), recalculated to seconds.

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:20:00.000	06:20:00.000	22800	300	11	B1
2020-01-27 06:32:00.000	06:32:00.000	23520	1020	11	B1
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	11	B1
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	11	B1
2020-01-27 07:09:00.000	07:09:00.000	25740	3240	11	B1
2020-01-27 07:21:00.000	07:21:00.000	26460	3960	11	B1
2020-01-27 07:29:00.000	07:29:00.000	26940	4440	11	B1
2020-01-27 07:37:00.000	07:37:00.000	27420	4920	11	B1
2020-01-27 07:45:00.000	07:45:00.000	27900	5400	11	B1
2020-01-27 07:51:00.000	07:51:00.000	28260	5760	11	B1
2020-01-27 07:57:00.000	07:57:00.000	28620	6120	11	B1
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	11	B1
2020-01-27 08:09:00.000	08:09:00.000	29340	6840	11	B1
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	11	B1
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	11	B1
2020-01-27 08:27:00.000	08:27:00.000	30420	7920	11	B1

Table 18 Timetable for line 16 at stop C1 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:24:00.000	06:24:00.000	23040	540	16	C1
2020-01-27 06:34:00.000	06:34:00.000	23640	1140	16	C1
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	16	C1
2020-01-27 06:54:00.000	06:54:00.000	24840	2340	16	C1
2020-01-27 06:59:00.000	06:59:00.000	25140	2640	16	C1
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	16	C1
2020-01-27 07:08:00.000	07:08:00.000	25680	3180	16	C1
2020-01-27 07:13:00.000	07:13:00.000	25980	3480	16	C1
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	16	C1
2020-01-27 07:23:00.000	07:23:00.000	26580	4080	16	C1
2020-01-27 07:28:00.000	07:28:00.000	26880	4380	16	C1
2020-01-27 07:33:00.000	07:33:00.000	27180	4680	16	C1
2020-01-27 07:38:00.000	07:38:00.000	27480	4980	16	C1
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	16	C1
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	16	C1
2020-01-27 07:53:00.000	07:53:00.000	28380	5880	16	C1
2020-01-27 07:58:00.000	07:58:00.000	28680	6180	16	C1
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	16	C1
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	16	C1
2020-01-27 08:13:00.000	08:13:00.000	29580	7080	16	C1
2020-01-27 08:18:00.000	08:18:00.000	29880	7380	16	C1
2020-01-27 08:23:00.000	08:23:00.000	30180	7680	16	C1
2020-01-27 08:28:00.000	08:28:00.000	30480	7980	16	C1

Tabell 19 Timetable for line 7 at stop C1 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:27:00.000	06:27:00.000	23220	720	7	C1
2020-01-27 06:39:00.000	06:39:00.000	23940	1440	7	C1
2020-01-27 06:52:00.000	06:52:00.000	24720	2220	7	C1
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	7	C1
2020-01-27 07:15:00.000	07:15:00.000	26100	3600	7	C1
2020-01-27 07:25:00.000	07:25:00.000	26700	4200	7	C1
2020-01-27 07:34:00.000	07:34:00.000	27240	4740	7	C1
2020-01-27 07:42:00.000	07:42:00.000	27720	5220	7	C1
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	7	C1
2020-01-27 07:54:00.000	07:54:00.000	28440	5940	7	C1
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	7	C1
2020-01-27 08:06:00.000	08:06:00.000	29160	6660	7	C1
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	7	C1
2020-01-27 08:18:00.000	08:18:00.000	29880	7380	7	C1
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	7	C1
2020-01-27 08:30:00.000	08:30:00.000	30600	8100	7	C1

2 Brunnsparken-East bound

Tabell 20 Timetable for line 1 at stop B2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	**clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:03:00.000	06:03:00.000	21780	-720	1	B2
2020-01-27 06:23:00.000	06:23:00.000	22980	480	1	B2
2020-01-27 06:36:00.000	06:36:00.000	23760	1260	1	B2
2020-01-27 06:49:00.000	06:49:00.000	24540	2040	1	B2
2020-01-27 07:00:00.000	07:00:00.000	25200	2700	1	B2
2020-01-27 07:09:00.000	07:09:00.000	25740	3240	1	B2
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	1	B2
2020-01-27 07:27:00.000	07:27:00.000	26820	4320	1	B2
2020-01-27 07:39:00.000	07:39:00.000	27540	5040	1	B2
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	1	B2
2020-01-27 07:57:00.000	07:57:00.000	28620	6120	1	B2

2020-01-27 08:06:00.000	08:06:00.000	29160	6660	1	B2
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	1	B2
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	1	B2

Tabell 21 Timetable for line 2 at stop C2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	**clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:16:00.000	06:16:00.000	22560	60	2	C2
2020-01-27 06:29:00.000	06:29:00.000	23340	840	2	C2
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	2	C2
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	2	C2
2020-01-27 07:06:00.000	07:06:00.000	25560	3060	2	C2
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	2	C2
2020-01-27 07:22:00.000	07:22:00.000	26520	4020	2	C2
2020-01-27 07:33:00.000	07:33:00.000	27180	4680	2	C2
2020-01-27 07:41:00.000	07:41:00.000	27660	5160	2	C2
2020-01-27 07:45:00.000	07:45:00.000	27900	5400	2	C2
2020-01-27 07:54:00.000	07:54:00.000	28440	5940	2	C2
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	2	C2
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	2	C2
2020-01-27 08:22:00.000	08:22:00.000	30120	7620	2	C2

Tabell 22 Timetable for line 3 at stop B2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	**clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:13:00.000	06:13:00.000	22380	-120	3	B2
2020-01-27 06:24:00.000	06:24:00.000	23040	540	3	B2
2020-01-27 06:35:00.000	06:35:00.000	23700	1200	3	B2
2020-01-27 06:48:00.000	06:48:00.000	24480	1980	3	B2
2020-01-27 07:00:00.000	07:00:00.000	25200	2700	3	B2
2020-01-27 07:12:00.000	07:12:00.000	25920	3420	3	B2
2020-01-27 07:22:00.000	07:22:00.000	26520	4020	3	B2
2020-01-27 07:33:00.000	07:33:00.000	27180	4680	3	B2
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	3	B2

2020-01-27 07:52:00.000	07:52:00.000	28320	5820	3	B2
2020-01-27 08:01:00.000	08:01:00.000	28860	6360	3	B2
2020-01-27 08:10:00.000	08:10:00.000	29400	6900	3	B2
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	3	B2
2020-01-27 08:29:00.000	08:29:00.000	30540	8040	3	B2

Tabell 23 Timetable for line 4 at stop C2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	**Clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:20:00.000	06:20:00.000	22800	300	4	C2
2020-01-27 06:32:00.000	06:32:00.000	23520	1020	4	C2
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	4	C2
2020-01-27 06:56:00.000	06:56:00.000	24960	2460	4	C2
2020-01-27 07:08:00.000	07:08:00.000	25680	3180	4	C2
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	4	C2
2020-01-27 07:30:00.000	07:30:00.000	27000	4500	4	C2
2020-01-27 07:40:00.000	07:40:00.000	27600	5100	4	C2
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	4	C2
2020-01-27 07:57:00.000	07:57:00.000	28620	6120	4	C2
2020-01-27 08:06:00.000	08:06:00.000	29160	6660	4	C2
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	4	C2
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	4	C2

Tabell 24 Timetable for line 6 at stop B2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	**Clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:20:00.000	06:20:00.000	22800	300	6	B2
2020-01-27 06:32:00.000	06:32:00.000	23520	1020	6	B2
2020-01-27 06:37:00.000	06:37:00.000	23820	1320	6	B2
2020-01-27 06:52:00.000	06:52:00.000	24720	2220	6	B2
2020-01-27 07:05:00.000	07:05:00.000	25500	3000	6	B2
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	6	B2
2020-01-27 07:18:00.000	07:18:00.000	26280	3780	6	B2
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	6	B2
2020-01-27 07:46:00.000	07:46:00.000	27960	5460	6	B2

2020-01-27 07:56:00.000	07:56:00.000	28560	6060	6	B2
2020-01-27 08:04:00.000	08:04:00.000	29040	6540	6	B2
2020-01-27 08:11:00.000	08:11:00.000	29460	6960	6	B2
2020-01-27 08:18:00.000	08:18:00.000	29880	7380	6	B2
2020-01-27 08:25:00.000	08:25:00.000	30300	7800	6	B2

Tabell 25 Timetable for line 7 at stop C2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	**Clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:16:00.000	06:16:00.000	22560	60	7	C2
2020-01-27 06:33:00.000	06:33:00.000	23580	1080	7	C2
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	7	C2
2020-01-27 06:55:00.000	06:55:00.000	24900	2400	7	C2
2020-01-27 07:05:00.000	07:05:00.000	25500	3000	7	C2
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	7	C2
2020-01-27 07:25:00.000	07:25:00.000	26700	4200	7	C2
2020-01-27 07:33:00.000	07:33:00.000	27180	4680	7	C2
2020-01-27 07:41:00.000	07:41:00.000	27660	5160	7	C2
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	7	C2
2020-01-27 07:58:00.000	07:58:00.000	28680	6180	7	C2
2020-01-27 08:06:00.000	08:06:00.000	29160	6660	7	C2
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	7	C2
2020-01-27 08:22:00.000	08:22:00.000	30120	7620	7	C2
2020-01-27 08:30:00.000	08:30:00.000	30600	8100	7	C2

Tabell 26 Timetable for line 9 at stop C2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:15:00.000	06:15:00.000	22500	0	9	C2
2020-01-27 06:27:00.000	06:27:00.000	23220	720	9	C2
2020-01-27 06:38:00.000	06:38:00.000	23880	1380	9	C2
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	9	C2
2020-01-27 07:01:00.000	07:01:00.000	25260	2760	9	C2
2020-01-27 07:12:00.000	07:12:00.000	25920	3420	9	C2
2020-01-27 07:20:00.000	07:20:00.000	26400	3900	9	C2
2020-01-27 07:26:00.000	07:26:00.000	26760	4260	9	C2
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	9	C2
2020-01-27 07:44:00.000	07:44:00.000	27840	5340	9	C2
2020-01-27 07:52:00.000	07:52:00.000	28320	5820	9	C2
2020-01-27 08:01:00.000	08:01:00.000	28860	6360	9	C2
2020-01-27 08:10:00.000	08:10:00.000	29400	6900	9	C2
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	9	C2
2020-01-27 08:28:00.000	08:28:00.000	30480	7980	9	C2

Tabell 27 Timetable for line 11 at stop C2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:20:00.000	06:20:00.000	22800	300	11	C2
2020-01-27 06:27:00.000	06:27:00.000	23220	720	11	C2
2020-01-27 06:36:00.000	06:36:00.000	23760	1260	11	C2
2020-01-27 06:46:00.000	06:46:00.000	24360	1860	11	C2
2020-01-27 06:56:00.000	06:56:00.000	24960	2460	11	C2
2020-01-27 07:07:00.000	07:07:00.000	25620	3120	11	C2
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	11	C2
2020-01-27 07:22:00.000	07:22:00.000	26520	4020	11	C2
2020-01-27 07:29:00.000	07:29:00.000	26940	4440	11	C2
2020-01-27 07:36:00.000	07:36:00.000	27360	4860	11	C2
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	11	C2
2020-01-27 07:50:00.000	07:50:00.000	28200	5700	11	C2
2020-01-27 07:55:00.000	07:55:00.000	28500	6000	11	C2
2020-01-27 08:01:00.000	08:01:00.000	28860	6360	11	C2

2020-01-27 08:07:00.000	08:07:00.000	29220	6720	11	C2
2020-01-27 08:13:00.000	08:13:00.000	29580	7080	11	C2
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	11	C2
2020-01-27 08:26:00.000	08:26:00.000	30360	7860	11	C2

Tabell 28 Timetable for line 16 at stop B2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	**clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:27:00.000	06:27:00.000	23220	720	16	B2
2020-01-27 06:37:00.000	06:37:00.000	23820	1320	16	B2
2020-01-27 06:47:00.000	06:47:00.000	24420	1920	16	B2
2020-01-27 06:52:00.000	06:52:00.000	24720	2220	16	B2
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	16	B2
2020-01-27 07:02:00.000	07:02:00.000	25320	2820	16	B2
2020-01-27 07:07:00.000	07:07:00.000	25620	3120	16	B2
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	16	B2
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	16	B2
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	16	B2
2020-01-27 07:29:00.000	07:29:00.000	26940	4440	16	B2
2020-01-27 07:33:00.000	07:33:00.000	27180	4680	16	B2
2020-01-27 07:39:00.000	07:39:00.000	27540	5040	16	B2
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	16	B2
2020-01-27 07:49:00.000	07:49:00.000	28140	5640	16	B2
2020-01-27 07:53:00.000	07:53:00.000	28380	5880	16	B2
2020-01-27 07:59:00.000	07:59:00.000	28740	6240	16	B2
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	16	B2
2020-01-27 08:09:00.000	08:09:00.000	29340	6840	16	B2
2020-01-27 08:13:00.000	08:13:00.000	29580	7080	16	B2
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	16	B2
2020-01-27 08:23:00.000	08:23:00.000	30180	7680	16	B2
2020-01-27 08:29:00.000	08:29:00.000	30540	8040	16	B2

Tabell 29 Timetable for line 60 at stop C2 during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	**Clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:22:00.000	06:22:00.000	22920	420	60	C2
2020-01-27 06:32:00.000	06:32:00.000	23520	1020	60	C2
2020-01-27 06:38:00.000	06:38:00.000	23880	1380	60	C2
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	60	C2
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	60	C2
2020-01-27 06:56:00.000	06:56:00.000	24960	2460	60	C2
2020-01-27 07:02:00.000	07:02:00.000	25320	2820	60	C2
2020-01-27 07:08:00.000	07:08:00.000	25680	3180	60	C2
2020-01-27 07:15:00.000	07:15:00.000	26100	3600	60	C2
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	60	C2
2020-01-27 07:23:00.000	07:23:00.000	26580	4080	60	C2
2020-01-27 07:27:00.000	07:27:00.000	26820	4320	60	C2
2020-01-27 07:31:00.000	07:31:00.000	27060	4560	60	C2
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	60	C2
2020-01-27 07:39:00.000	07:39:00.000	27540	5040	60	C2
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	60	C2
2020-01-27 07:47:00.000	07:47:00.000	28020	5520	60	C2
2020-01-27 07:51:00.000	07:51:00.000	28260	5760	60	C2
2020-01-27 07:55:00.000	07:55:00.000	28500	6000	60	C2
2020-01-27 07:59:00.000	07:59:00.000	28740	6240	60	C2
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	60	C2
2020-01-27 08:07:00.000	08:07:00.000	29220	6720	60	C2
2020-01-27 08:11:00.000	08:11:00.000	29460	6960	60	C2
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	60	C2
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	60	C2
2020-01-27 08:23:00.000	08:23:00.000	30180	7680	60	C2
2020-01-27 08:27:00.000	08:27:00.000	30420	7920	60	C2

3 Centralstationen_West bound

Tabell 30 Timetable for line 1 at stop C during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:27:00.000	06:27:00.000	23220	720	1	C
2020-01-27 06:41:00.000	06:41:00.000	24060	1560	1	C
2020-01-27 06:55:00.000	06:55:00.000	24900	2400	1	C
2020-01-27 07:07:00.000	07:07:00.000	25620	3120	1	C
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	1	C
2020-01-27 07:29:00.000	07:29:00.000	26940	4440	1	C
2020-01-27 07:38:00.000	07:38:00.000	27480	4980	1	C
2020-01-27 07:47:00.000	07:47:00.000	28020	5520	1	C
2020-01-27 07:56:00.000	07:56:00.000	28560	6060	1	C
2020-01-27 08:06:00.000	08:06:00.000	29160	6660	1	C
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	1	C
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	1	C

Tabell 31 Timetable for line 2 at stop C during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:15:00.000	06:15:00.000	22500	0	2	C
2020-01-27 06:35:00.000	06:35:00.000	23700	1200	2	C
2020-01-27 06:49:00.000	06:49:00.000	24540	2040	2	C
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	2	C
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	2	C
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	2	C
2020-01-27 07:34:00.000	07:34:00.000	27240	4740	2	C
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	2	C
2020-01-27 07:52:00.000	07:52:00.000	28320	5820	2	C
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	2	F
2020-01-27 08:01:00.000	08:01:00.000	28860	6360	2	C
2020-01-27 08:10:00.000	08:10:00.000	29400	6900	2	C
2020-01-27 08:18:00.000	08:18:00.000	29880	7380	2	F
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	2	C
2020-01-27 08:29:00.000	08:29:00.000	30540	8040	2	C

Tabell 32 Timetable for line 3 at stop D during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:19:00.000	06:19:00.000	22740	240	3	D
2020-01-27 06:34:00.000	06:34:00.000	23640	1140	3	D
2020-01-27 06:49:00.000	06:49:00.000	24540	2040	3	D
2020-01-27 07:01:00.000	07:01:00.000	25260	2760	3	D
2020-01-27 07:13:00.000	07:13:00.000	25980	3480	3	D
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	3	D
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	3	D
2020-01-27 07:44:00.000	07:44:00.000	27840	5340	3	D
2020-01-27 07:53:00.000	07:53:00.000	28380	5880	3	D
2020-01-27 08:02:00.000	08:02:00.000	28920	6420	3	D
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	3	D
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	3	D
2020-01-27 08:30:00.000	08:30:00.000	30600	8100	3	D

Tabell 33 Timetable for line 4 at stop C during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:18:00.000	06:18:00.000	22680	180	4	C
2020-01-27 06:24:00.000	06:24:00.000	23040	540	4	C
2020-01-27 06:38:00.000	06:38:00.000	23880	1380	4	C
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	4	C
2020-01-27 06:55:00.000	06:55:00.000	24900	2400	4	C
2020-01-27 07:02:00.000	07:02:00.000	25320	2820	4	C
2020-01-27 07:08:00.000	07:08:00.000	25680	3180	4	C
2020-01-27 07:20:00.000	07:20:00.000	26400	3900	4	C
2020-01-27 07:30:00.000	07:30:00.000	27000	4500	4	C
2020-01-27 07:42:00.000	07:42:00.000	27720	5220	4	C
2020-01-27 07:51:00.000	07:51:00.000	28260	5760	4	C
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	4	C
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	4	C

2020-01-27 08:17:00.000	08:17:00.000	29820	7320	4	C
2020-01-27 08:26:00.000	08:26:00.000	30360	7860	4	C

Tabell 34 Timetable for line 7 at stop C during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:25:00.000	06:25:00.000	23100	600	7	C
2020-01-27 06:37:00.000	06:37:00.000	23820	1320	7	C
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	7	C
2020-01-27 07:01:00.000	07:01:00.000	25260	2760	7	C
2020-01-27 07:13:00.000	07:13:00.000	25980	3480	7	C
2020-01-27 07:23:00.000	07:23:00.000	26580	4080	7	C
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	7	C
2020-01-27 07:40:00.000	07:40:00.000	27600	5100	7	C
2020-01-27 07:46:00.000	07:46:00.000	27960	5460	7	C
2020-01-27 07:52:00.000	07:52:00.000	28320	5820	7	C
2020-01-27 07:58:00.000	07:58:00.000	28680	6180	7	C
2020-01-27 08:04:00.000	08:04:00.000	29040	6540	7	C
2020-01-27 08:10:00.000	08:10:00.000	29400	6900	7	C
2020-01-27 08:16:00.000	08:16:00.000	29760	7260	7	C
2020-01-27 08:22:00.000	08:22:00.000	30120	7620	7	C
2020-01-27 08:28:00.000	08:28:00.000	30480	7980	7	C

Tabell 35 Timetable for line 9 at stop D during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:15:00.000	06:15:00.000	22500	0	9	D
2020-01-27 06:31:00.000	06:31:00.000	23460	960	9	D
2020-01-27 06:47:00.000	06:47:00.000	24420	1920	9	D
2020-01-27 07:00:00.000	07:00:00.000	25200	2700	9	D
2020-01-27 07:13:00.000	07:13:00.000	25980	3480	9	D
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	9	D

2020-01-27 07:35:00.000	07:35:00.000	27300	4800	9	D
2020-01-27 07:46:00.000	07:46:00.000	27960	5460	9	D
2020-01-27 07:54:00.000	07:54:00.000	28440	5940	9	D
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	9	D
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	9	D
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	9	D
2020-01-27 08:30:00.000	08:30:00.000	30600	8100	9	D

Tabell 36 Timetable for line 11 at stop D during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	**clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:18:00.000	06:18:00.000	22680	180	11	D
2020-01-27 06:30:00.000	06:30:00.000	23400	900	11	D
2020-01-27 06:42:00.000	06:42:00.000	24120	1620	11	D
2020-01-27 06:55:00.000	06:55:00.000	24900	2400	11	D
2020-01-27 07:07:00.000	07:07:00.000	25620	3120	11	D
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	11	D
2020-01-27 07:27:00.000	07:27:00.000	26820	4320	11	D
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	11	D
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	11	D
2020-01-27 07:49:00.000	07:49:00.000	28140	5640	11	D
2020-01-27 07:55:00.000	07:55:00.000	28500	6000	11	D
2020-01-27 08:01:00.000	08:01:00.000	28860	6360	11	D
2020-01-27 08:07:00.000	08:07:00.000	29220	6720	11	D
2020-01-27 08:13:00.000	08:13:00.000	29580	7080	11	D
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	11	D
2020-01-27 08:25:00.000	08:25:00.000	30300	7800	11	D

Table 37 Timetable for line 13 at stop D during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	13	D
2020-01-27 07:47:00.000	07:47:00.000	28020	5520	13	D
2020-01-27 07:56:00.000	07:56:00.000	28560	6060	13	D
2020-01-27 08:04:00.000	08:04:00.000	29040	6540	13	D
2020-01-27 08:13:00.000	08:13:00.000	29580	7080	13	D
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	13	D

Table 38 Timetable for line 60 at stop D during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:21:00.000	06:21:00.000	22860	360	60	D
2020-01-27 06:30:00.000	06:30:00.000	23400	900	60	D
2020-01-27 06:38:00.000	06:38:00.000	23880	1380	60	D
2020-01-27 06:44:00.000	06:44:00.000	24240	1740	60	D
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	60	D
2020-01-27 06:56:00.000	06:56:00.000	24960	2460	60	D
2020-01-27 07:02:00.000	07:02:00.000	25320	2820	60	D
2020-01-27 07:09:00.000	07:09:00.000	25740	3240	60	D
2020-01-27 07:15:00.000	07:15:00.000	26100	3600	60	D
2020-01-27 07:19:00.000	07:19:00.000	26340	3840	60	D
2020-01-27 07:23:00.000	07:23:00.000	26580	4080	60	D
2020-01-27 07:27:00.000	07:27:00.000	26820	4320	60	D
2020-01-27 07:31:00.000	07:31:00.000	27060	4560	60	D
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	60	D
2020-01-27 07:39:00.000	07:39:00.000	27540	5040	60	D
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	60	D
2020-01-27 07:47:00.000	07:47:00.000	28020	5520	60	D
2020-01-27 07:51:00.000	07:51:00.000	28260	5760	60	D
2020-01-27 07:55:00.000	07:55:00.000	28500	6000	60	D
2020-01-27 07:59:00.000	07:59:00.000	28740	6240	60	D

2020-01-27 08:03:00.000	08:03:00.000	28980	6480	60	D
2020-01-27 08:07:00.000	08:07:00.000	29220	6720	60	D
2020-01-27 08:11:00.000	08:11:00.000	29460	6960	60	D
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	60	D
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	60	D
2020-01-27 08:23:00.000	08:23:00.000	30180	7680	60	D
2020-01-27 08:27:00.000	08:27:00.000	30420	7920	60	D

4 Centralstationen_East bound

Table 39 Timetable for line 60 at stop L during the peak hours (6.30am-8.30am), recalculated to seconds

2020-01-27 06:23:00.000	06:23:00.000	22980	480	60	L
2020-01-27 06:33:00.000	06:33:00.000	23580	1080	60	L
2020-01-27 06:39:00.000	06:39:00.000	23940	1440	60	L
2020-01-27 06:45:00.000	06:45:00.000	24300	1800	60	L
2020-01-27 06:51:00.000	06:51:00.000	24660	2160	60	L
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	60	L
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	60	L
2020-01-27 07:09:00.000	07:09:00.000	25740	3240	60	L
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	60	L
2020-01-27 07:20:00.000	07:20:00.000	26400	3900	60	L
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	60	L
2020-01-27 07:28:00.000	07:28:00.000	26880	4380	60	L
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	60	L
2020-01-27 07:36:00.000	07:36:00.000	27360	4860	60	L
2020-01-27 07:40:00.000	07:40:00.000	27600	5100	60	L
2020-01-27 07:44:00.000	07:44:00.000	27840	5340	60	L
2020-01-27 07:48:00.000	07:48:00.000	28080	5580	60	L
2020-01-27 07:52:00.000	07:52:00.000	28320	5820	60	L
2020-01-27 07:56:00.000	07:56:00.000	28560	6060	60	L
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	60	L
2020-01-27 08:04:00.000	08:04:00.000	29040	6540	60	L
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	60	L
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	60	L

2020-01-27 08:16:00.000	08:16:00.000	29760	7260	60	L
2020-01-27 08:20:00.000	08:20:00.000	30000	7500	60	L
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	60	L
2020-01-27 08:28:00.000	08:28:00.000	30480	7980	60	L

Table 40 Timetable for line 13 at stop B during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	**Clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 07:20:00.000	07:20:00.000	26400	3900	13	B
2020-01-27 07:31:00.000	07:31:00.000	27060	4560	13	B
2020-01-27 07:40:00.000	07:40:00.000	27600	5100	13	B
2020-01-27 07:50:00.000	07:50:00.000	28200	5700	13	B
2020-01-27 07:59:00.000	07:59:00.000	28740	6240	13	B
2020-01-27 08:10:00.000	08:10:00.000	29400	6900	13	B
2020-01-27 08:19:00.000	08:19:00.000	29940	7440	13	B
2020-01-27 08:29:00.000	08:29:00.000	30540	8040	13	B

Table 41 Timetable for line 3 at stop B during the peak hours (6.30am-8.30am), recalculated to seconds

2020-01-27 06:25:00.000	06:25:00.000	23100	600	3	B
2020-01-27 06:37:00.000	06:37:00.000	23820	1320	3	B
2020-01-27 06:50:00.000	06:50:00.000	24600	2100	3	B
2020-01-27 07:02:00.000	07:02:00.000	25320	2820	3	B
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	3	B
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	3	B
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	3	B
2020-01-27 07:45:00.000	07:45:00.000	27900	5400	3	B
2020-01-27 07:54:00.000	07:54:00.000	28440	5940	3	B
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	3	B
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	3	B
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	3	B

Table 42 Timetable for line 11 at stop A during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	Clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:21:00.000	06:21:00.000	22860	360	11	A
2020-01-27 06:38:00.000	06:38:00.000	23880	1380	11	A
2020-01-27 06:48:00.000	06:48:00.000	24480	1980	11	A
2020-01-27 06:55:00.000	06:55:00.000	24900	2400	11	A
2020-01-27 06:58:00.000	06:58:00.000	25080	2580	11	A
2020-01-27 07:09:00.000	07:09:00.000	25740	3240	11	A
2020-01-27 07:18:00.000	07:18:00.000	26280	3780	11	A
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	11	A
2020-01-27 07:31:00.000	07:31:00.000	27060	4560	11	A
2020-01-27 07:38:00.000	07:38:00.000	27480	4980	11	A
2020-01-27 07:45:00.000	07:45:00.000	27900	5400	11	A
2020-01-27 07:52:00.000	07:52:00.000	28320	5820	11	A
2020-01-27 07:57:00.000	07:57:00.000	28620	6120	11	A
2020-01-27 08:03:00.000	08:03:00.000	28980	6480	11	A
2020-01-27 08:09:00.000	08:09:00.000	29340	6840	11	A
2020-01-27 08:15:00.000	08:15:00.000	29700	7200	11	A
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	11	A
2020-01-27 08:26:00.000	08:26:00.000	30360	7860	11	A

Table 43 Timetable for line 9 at stop A during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:16:00.000	06:16:00.000	22560	60	9	A
2020-01-27 06:28:00.000	06:28:00.000	23280	780	9	A
2020-01-27 06:40:00.000	06:40:00.000	24000	1500	9	A
2020-01-27 06:52:00.000	06:52:00.000	24720	2220	9	A
2020-01-27 07:03:00.000	07:03:00.000	25380	2880	9	A
2020-01-27 07:14:00.000	07:14:00.000	26040	3540	9	A
2020-01-27 07:22:00.000	07:22:00.000	26520	4020	9	A
2020-01-27 07:26:00.000	07:26:00.000	26760	4260	9	A
2020-01-27 07:37:00.000	07:37:00.000	27420	4920	9	A
2020-01-27 07:46:00.000	07:46:00.000	27960	5460	9	A
2020-01-27 07:54:00.000	07:54:00.000	28440	5940	9	A

2020-01-27 08:03:00.000	08:03:00.000	28980	6480	9	A
2020-01-27 08:12:00.000	08:12:00.000	29520	7020	9	A
2020-01-27 08:21:00.000	08:21:00.000	30060	7560	9	A
2020-01-27 08:30:00.000	08:30:00.000	30600	8100	9	A

Table 44 Timetable for line 7 at stop A during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:17:00.000	06:17:00.000	22620	120	7	A
2020-01-27 06:35:00.000	06:35:00.000	23700	1200	7	A
2020-01-27 06:46:00.000	06:46:00.000	24360	1860	7	A
2020-01-27 06:57:00.000	06:57:00.000	25020	2520	7	A
2020-01-27 07:07:00.000	07:07:00.000	25620	3120	7	A
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	7	A
2020-01-27 07:27:00.000	07:27:00.000	26820	4320	7	A
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	7	A
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	7	A
2020-01-27 07:50:00.000	07:50:00.000	28200	5700	7	A
2020-01-27 08:00:00.000	08:00:00.000	28800	6300	7	A
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	7	A
2020-01-27 08:17:00.000	08:17:00.000	29820	7320	7	A
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	7	A

Table 45 Timetable for line 4 at stop A during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	clock	Time from midnight (s)	Time from 6.15 (s)	Line	Stop
2020-01-27 06:21:00.000	06:21:00.000	22860	360	4	A
2020-01-27 06:34:00.000	06:34:00.000	23640	1140	4	A
2020-01-27 06:46:00.000	06:46:00.000	24360	1860	4	A
2020-01-27 06:58:00.000	06:58:00.000	25080	2580	4	A
2020-01-27 07:10:00.000	07:10:00.000	25800	3300	4	A
2020-01-27 07:21:00.000	07:21:00.000	26460	3960	4	A
2020-01-27 07:32:00.000	07:32:00.000	27120	4620	4	A
2020-01-27 07:42:00.000	07:42:00.000	27720	5220	4	A

2020-01-27 07:50:00.000	07:50:00.000	28200	5700	4	A
2020-01-27 07:59:00.000	07:59:00.000	28740	6240	4	A
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	4	A
2020-01-27 08:17:00.000	08:17:00.000	29820	7320	4	A
2020-01-27 08:26:00.000	08:26:00.000	30360	7860	4	A

Table 46 Timetable for line 2 at stop A during the peak hours (6.30am-8.30am), recalculated to seconds

Date and clock	**clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:17:00.000	06:17:00.000	22620	120	2	A
2020-01-27 06:30:00.000	06:30:00.000	23400	900	2	A
2020-01-27 06:46:00.000	06:46:00.000	24360	1860	2	A
2020-01-27 06:59:00.000	06:59:00.000	25140	2640	2	A
2020-01-27 07:08:00.000	07:08:00.000	25680	3180	2	A
2020-01-27 07:16:00.000	07:16:00.000	26160	3660	2	A
2020-01-27 07:24:00.000	07:24:00.000	26640	4140	2	A
2020-01-27 07:28:00.000	07:28:00.000	26880	4380	2	A
2020-01-27 07:35:00.000	07:35:00.000	27300	4800	2	A
2020-01-27 07:43:00.000	07:43:00.000	27780	5280	2	A
2020-01-27 07:47:00.000	07:47:00.000	28020	5520	2	A
2020-01-27 07:56:00.000	07:56:00.000	28560	6060	2	A
2020-01-27 08:05:00.000	08:05:00.000	29100	6600	2	A
2020-01-27 08:14:00.000	08:14:00.000	29640	7140	2	A
2020-01-27 08:24:00.000	08:24:00.000	30240	7740	2	A

Table 47 Timetable for line 1 at stop B during the peak hours (6.30am-8.30am), recalculated to seconds

Date and Clock	**Clock**	**Time from midnight (s)**	**Time from 6.15 (s)**	**Line**	**Stop**
2020-01-27 06:20:00.000	06:20:00.000	22800	300	1	B
2020-01-27 06:24:00.000	06:24:00.000	23040	540	1	B
2020-01-27 06:38:00.000	06:38:00.000	23880	1380	1	B
2020-01-27 06:51:00.000	06:51:00.000	24660	2160	1	B
2020-01-27 07:11:00.000	07:11:00.000	25860	3360	1	B
2020-01-27 07:21:00.000	07:21:00.000	26460	3960	1	B
2020-01-27 07:29:00.000	07:29:00.000	26940	4440	1	B
2020-01-27 07:41:00.000	07:41:00.000	27660	5160	1	B
2020-01-27 07:50:00.000	07:50:00.000	28200	5700	1	B

2020-01-27 07:59:00.000	07:59:00.000	28740	6240	1	B
2020-01-27 08:08:00.000	08:08:00.000	29280	6780	1	B
2020-01-27 08:17:00.000	08:17:00.000	29820	7320	1	B
2020-01-27 08:26:00.000	08:26:00.000	30360	7860	1	B

Appendix III

1 Dwell times distribution (From Västtrafik)

Table 48 Average stop times for PT lines at Brunnsparken and Centralstation respectively.

Stopp Times (s)	Brunnsparken	Centralstation
0–10	1	1
11–20	13	7
21–30	44	30
31–40	23	27
41–50	9	16
51–60	5	9
61–70	3	5
71–80	1	3
81–90	1	2
91–100	0	1

The empirical input data for stop times were inserted into a time distribution in Vissim for the calculation of dwell times for each public transport line which operated the network. This empirical time distribution defines the likelihood for a vehicle to have a specific dwell time at a specific stop. Figures 14 show graphs of the stop time distribution curves from the two hubs Brunnsparken and the Centralstationen The inserted data points are displayed in as intermediate points in the curves.

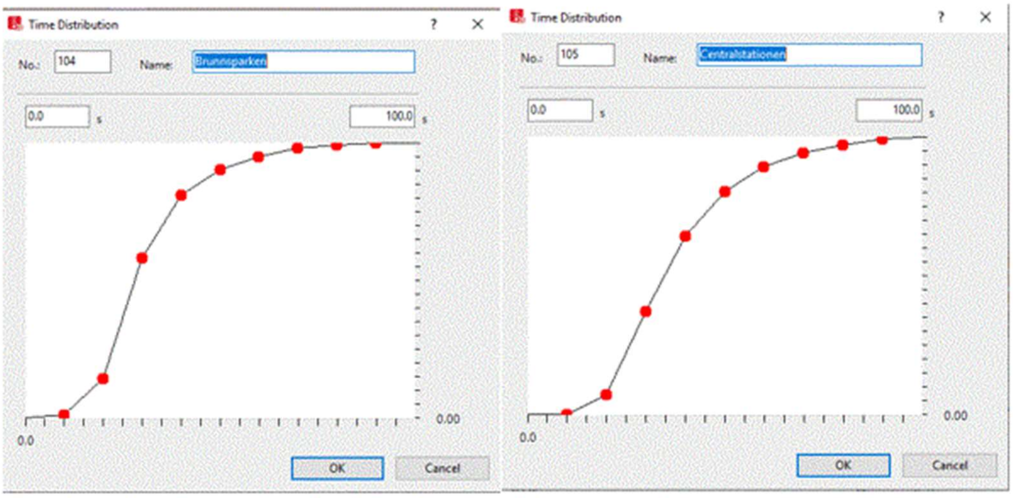

Figure 14 Cumulative dwell time distribution curves for the public transport through Brunnsparken (right) and Centralstationen (left) created in Vissim

2. Actual and planned times distribution

The empirical data for the difference between the actual departure times and the planned departure times is presented in the following graphs. The data was inserted into Vissim for the calculation of entry time distribution for each public transport which operates in the network. Figure 15 show graphs of the entry time distribution. Data is obtained from Västtrafik AB (Häggstöm, 2019).

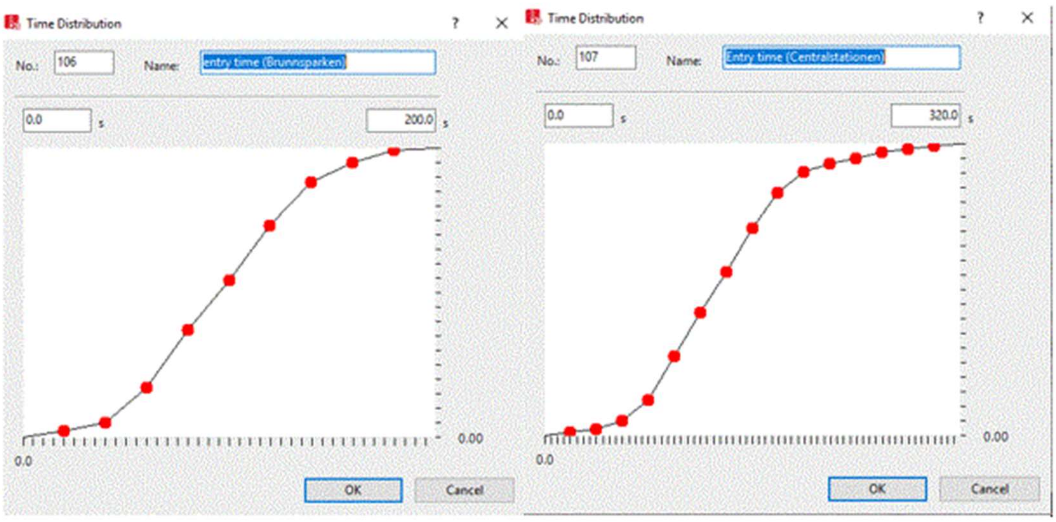

Figure 15 Actual and planned time distribution (from Västtrafik)

3. Departure loads for each line (From Västtrafik)

Tabell 49 The number of passengers onboard when lines entering the network

Line	linje	Hour	StopArea	NextStop	StopAreaName	DepartureLoad
5001	1	6	1760	1950	Brunnsparken	143,5
5001	1	7	1760	1950	Brunnsparken	371,93
5001	1	8	1760	1950	Brunnsparken	261,86
5001	1	9	1760	1950	Brunnsparken	190
5002	2	6	1760	1950	Brunnsparken	215
5002	2	7	1760	1950	Brunnsparken	233,8
5002	2	8	1760	1950	Brunnsparken	277,64
5002	2	9	1760	1950	Brunnsparken	148,5
5003	3	6	1760	1950	Brunnsparken	83,2
5003	3	7	1760	1950	Brunnsparken	101,6
5003	3	8	1760	1950	Brunnsparken	168,7
5003	3	9	1760	1950	Brunnsparken	99,34
5004	4	6	1760	1950	Brunnsparken	160,63
5004	4	7	1760	1950	Brunnsparken	213,3
5004	4	8	1760	1950	Brunnsparken	180,86
5004	4	9	1760	1950	Brunnsparken	163,06
5007	7	6	1760	1950	Brunnsparken	157,6
5007	7	7	1760	1950	Brunnsparken	288,17
5007	7	8	1760	1950	Brunnsparken	342,22
5007	7	9	1760	1950	Brunnsparken	217,78
5009	9	6	1760	1950	Brunnsparken	187,03
5009	9	7	1760	1950	Brunnsparken	327,33
5009	9	8	1760	1950	Brunnsparken	326
5009	9	9	1760	1950	Brunnsparken	198,33
5011	11	6	1760	1950	Brunnsparken	187,86
5011	11	7	1760	1950	Brunnsparken	309
5011	11	8	1760	1950	Brunnsparken	425,6
5011	11	9	1760	1950	Brunnsparken	203
5060	60	6	1760	1950	Brunnsparken	144,71
5060	60	7	1760	1950	Brunnsparken	446,69
5060	60	8	1760	1950	Brunnsparken	411,29
5060	60	9	1760	1950	Brunnsparken	189,16

5001	1	6	1950	1760	Centralstationen	231,33
5001	1	7	1950	1760	Centralstationen	412,15
5001	1	8	1950	1760	Centralstationen	436,2
5001	1	9	1950	1760	Centralstationen	521,1
5002	2	6	1950	1760	Centralstationen	30
5002	2	7	1950	1760	Centralstationen	374,25
5002	2	8	1950	1760	Centralstationen	342,55
5002	2	9	1950	1760	Centralstationen	388,94
5003	3	6	1950	1760	Centralstationen	112,89
5003	3	7	1950	1760	Centralstationen	301,5
5003	3	8	1950	1760	Centralstationen	513,33
5003	3	9	1950	1760	Centralstationen	462,57
5004	4	6	1950	1760	Centralstationen	262,47
5004	4	7	1950	1760	Centralstationen	424,15
5004	4	8	1950	1760	Centralstationen	436,33
5004	4	9	1950	1760	Centralstationen	350,25
5007	7	6	1950	1760	Centralstationen	257,33
5007	7	7	1950	1760	Centralstationen	668,31
5007	7	8	1950	1760	Centralstationen	708
5007	7	9	1950	1760	Centralstationen	520
5009	9	6	1950	1760	Centralstationen	175,59
5009	9	7	1950	1760	Centralstationen	464,4
5009	9	8	1950	1760	Centralstationen	562,95
5009	9	9	1950	1760	Centralstationen	376,11
5010	10	6	1950	1760	Centralstationen	6
5011	11	7	1950	1760	Centralstationen	603,17
5011	11	8	1950	1760	Centralstationen	927
5011	11	9	1950	1760	Centralstationen	476
5060	60	6	1950	1760	Centralstationen	141,07
5060	60	7	1950	1760	Centralstationen	484,31
5060	60	8	1950	1760	Centralstationen	457,49
5060	60	9	1950	1760	Centralstationen	227,52

4. Results from the model calibration

Tabell 50 The results from the model used to calibrate the desired speed distribution

TIMEINT	Route	VEHS(ALL)	TRAVTM(ALL)	DISTTRAV(ALL)
900-4500	1	30	194.78	470.4
900-4500	2	10	188.33	455.96
900-4500	3	11	152.49	328.34
900-4500	4	14	105.74	297.21
900-4500	5	21	198.08	469.18
900-4500	6	10	189.94	509.21
900-4500	7	11	94.53	277.29
900-4500	8	0		
900-4500	9	1	86.41	339.89