Traffic Flow Variation in Central Gothenburg

A study of how the traffic situation is affected by nearby construction works

Master's thesis in Architecture and Civil Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

During the spring of 2017 several maintenance works and construction projects were carried out in central Gothenburg. This affected the capacity of nearby roads and the traffic flow. The aim of this study was to investigate how the traffic flow has changed as a response to the ongoing construction works. This understanding would be of benefit for traffic planning during construction works in this area in the future. Both roads affected by the construction works along with alternative roads bypassing the affected area, has been identified through studying different maps e.g. construction activity maps. Traffic flow and travel time data have been obtained for these roads and analyzed in order to identify the changes. A decline in number of vehicles was observed in the affected area. Some of the missing traffic rerouted as a response to the alternative roads, but also to other roads within the affected area. A increase in travel time could be seen as well in this area, which probably contributed towards the decline in traffic flow. Some major activities of the ongoing construction works could be linked to changes in traffic flow and travel time changes.

Keywords: Traffic flow, Travel time, Peak hour, road work, construction work, E45, Hisingsbron, Road capacity, Gothenburg

Preface

This thesis concludes my studies at the Master of Science program of Infrastructure and Environmental Engineering at Chalmers University of Technology.

I would like to acknowledge some people that have help me along the way of this thesis. First of all I would like to thank my two supervisors Claes Johansson and Gunnar Lannér, which have constantly given me support along the way. The original idea for the thesis was presented by Anders Sjöholm. Joachim Karlgren and Ingela Lundgren Sandberg from the Traffic and Public Transport Authority have helped me a lot with the gathering of the data needed to make this thesis possible. The knowledge of the different ongoing construction events was acquired through Christina Lundqvist and Viveka Karlsson. A reference group consisting of Svante Möller, Magnus Lorentzon and Mats Tjernkvist gave me some valuable input along the way. I would also like to thank my Examiner Anders Markstedt, which have also given me some valuable input. Finally i would like to thank Erik and Petter for constant companionship during the process.

Thank you

Carl-Johan Schultze Gothenburg, December 2017

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1
Introduction

During the spring of 2017 several maintenance works and construction projects that are affecting the capacity of roads were carried out in central Gothenburg. This could ultimately lead to traffic jams and delays for the road users. However, as a consequence of the increased travel time and complex situation on certain roads, some road users probably selected different routs towards their destination, bypassing the affected roads. For some the public transport system or cycling will be a better option for getting towards their destination and by doing so leaving their car behind.

If these changes in traffic flow could be predicted accurately, the maintenance and construction projects affecting the travel time on roads could be planned more carefully and precise. This would be of benefit for the client, contractor and the road user resulting in increased benefits for the society.

1.1 Aim

The aim of this study is to obtain a greater understanding of how traffic flow in central Gothenburg change with construction works affecting the nearby roads. Furthermore, to investigate where the traffic transfers.

1.2 Objectives

The following questions are to be answered:

- *How does the traffic flow change with the construction works?*
- *If the traffic decreased, where does it transfer?*
- *Has the travel time been affected?*

1.3 Limitations

The project is limited to the area around the central station, Centralstationen, in the central parts of Gothenburg and to cars as the mean of transportation. Furthermore, some roads bypassing this area will be studied in order identify possible movement in traffic flow. Construction work outside the decided area will in some cases be acknowledged but not considered for the project. The effect the construction works around Centralstationen have on the traffic flow in the area will be limited in this study to the period of January to June, 2017.

2

Theoretical Background

To understand the report some basic key concepts has to be explained.

Traffic flow is the number of vehicles that passes through a section during a specific time (Trafikverket, 2014).

Travel time is defined as the time it takes to travel a certain stretch, from start to finish (Elefteriadou, 2013). This concept can be expressed as follows:

$$TT(h) = \frac{d}{V_{avg}} \tag{2.1}$$

where,

TT is the travel time [hours]
d is the distance traveled [km]
V_{avg} is the average speed [km/h]

Travel time is especially a useful expression as it is relatable and travelers are able to plan there trip and choice of route when the travel time is known. However, as the travel time might be easy for the individual to measure it is hard to measure in a larger context, with a large group of vehicles. This because every car has to be measured as individuals, which means that the same vehicle has to be identified both at a starting point and its specific destination. This gets more complex as there are several starting points and destinations.

When the known ideal travel time is exceeded, the excess time is called *delay* (Elefteriadou, 2013). The same measuring problems for travel time also apply to delays, as the route of each individual vehicle has to be known.

Peak hours or *rush hours* is referring to the hours, usually in the morning and afternoon, when the roads have most users (Downs, 2003). This occurs because most people need to travel for the same few hours a day.

The *vehicle capacity* of a road or the *Road Capacity* is defined by the Highway Capacity Manual (HCM2000) as "the maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions" (TRB, 2000). This capacity can be used to measure the usage of a road.

The ratio between the traffic flow and the capacity of the road is called the *degree of saturation* (Trafikverket, 2014).

And shows how much percentage of the road capacity that is used with a given traffic flow.

2.1 What Happens when Road Capacity is Reduced?

When the capacity of a road is reduced the theory is that this affects the travel time, which will ultimate lead to a reduced traffic flow. *The Greenshield's model* tries to establish a connection between key traffic parameters (Elefteriadou, 2013). The model consists of three relationships, flow-speed, flow-density and speed-density, seen in Figure 2.1.

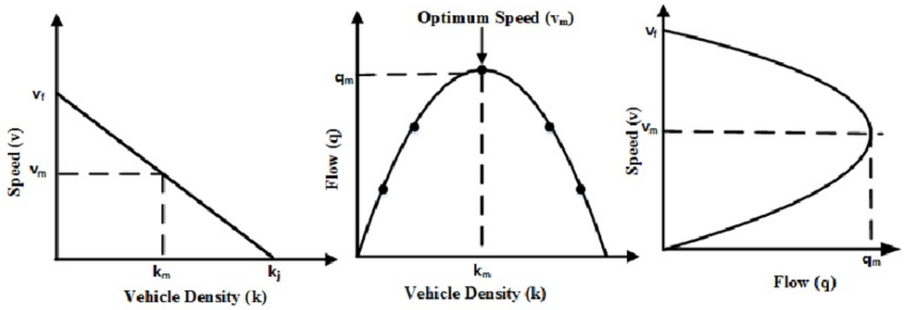


Figure 2.1: Greenshield's Fundamental Diagrams (a) Speed-Vehicle Density, (b) Flow-Vehicle Density, (c) Speed-Flow (Zaidi et al., 2015)

As seen in the relationship of flow-vehicle and density, Figure 2.1 (b) at the road capacity the optimum speed is achieved, this is the point where the maximum flow occurs. If the vehicle density where to increase from this point the flow would decrees and so would the speed as well. The far right end of this diagram would represent severe congestion when both flow and speed would be close to zero. More congested conditions would lead to reduced speed and flow, this will ultimately lead to longer travel times for the individual. However, the delays caused by the congestion often discourage people from using the road during certain peak hours, which will balance the level of congestion (Litman, 2017).

Intersections with a high degree of saturation is the main governing factor for the capacity of a stretch of road (Trafikkontoret, 2013). A high degree of saturation would imminently lead to congestion and delays. The public transport system are to be prioritized in intersections, reducing the capacity for other vehicles even further. Although by increasing the capacity of a road does not necessarily lead to less congestion. The Standing Advisory Committee on Trunk Road Assessment (SACTRA) concluded in their report that it could rather attract even more traffic and the congested situation could reappear (Wood et al., 1994). This phenomenon is called *induced traffic*. If a road would have a decreased capacity instead, this could by symmetry lead to a reduction in traffic, according to Goodwin et al. (1998). When a congested situation develops some traffic will relocate to alternative routes.

However, the roads that the traffic redirects to might also experience congested conditions from the additional traffic. This could then lead to the overall reduction of traffic in the area. Long-term traffic chaos followed by a reduced capacity is not that common, since road users tend to adapt within the first few days. Congested situations tend to make people postpone, avoid unnecessary trips or even change their destination (Litman, 2017).

Goodwin et al. (1998) have analyzed the result from over 100 case-studies on the subject of reduced overall traffic due to reduced capacity. The result of the case-studies, where complete information was available, showed that roads with reduced capacity experienced a unweighted average reduction in traffic levels of 41 %. Some of the traffic relocated to other alternative roads but a overall reduction in the surrounding area of 25 % could be observed (Goodwin et al., 1998). The median result of the same studies showed that 50 % of the cases had a overall reduction in traffic of more than 14 %. However, when conducting these kind of studies some problems always arise. The confined area of the case-study might be too small and by so missing other longer alternative routes, where traffic might have transferred. Another problem is when the capacity reduction is implemented other means of transport is often improved as a response. This will encourage an additional shift away from the use of a car as the mean of transport. Goodwin et al. (1998) also identified three further problems, the day to day variability in traffic, traffic growth due to other factors (long term) and partial sampling.

The case-studies analyzed could further be categorized into three different set of cases according to Goodwin et al. (1998). The first case, were studies where no or a small reduction in traffic levels, congestion and offset traffic were observed. In these cases it was likely that there had been no change in effective capacity on the affected road. But increased capacity on other roads initiated the change in traffic flows. The second category were cases which experienced a reduction in traffic on the affected road, but good capacity on alternative routes or at other times during day existed. This was not enough to discourage people from using their car, but rather making them avoid the unacceptable congestion by choosing other routes or rescheduling their trip. The last set of cases experience a severe reduction of capacity on the affected road and the alternative routes cannot handle the extra amount of traffic. In these cases traffic is moved to alternative routes as well as there are a overall reduction in traffic due to behavioural changes of individuals. This overall reduction in traffic may as well be due to that road users change their destination avoiding the area entirely. This leads to a reduction of traffic flow in the confined study-area, but a increase somewhere else.

2.2 The Effect of Construction Work on Road Capacity

During a construction work it is common that the number of lanes are reduced or at least narrowed (Strömgren and Olstam, 2016). This will reduce the pace and speed of the traffic, which could result in a bottleneck situation and ultimately queues and congestion. This in addition to that slow moving vehicles often will occupy a part of the road during this time. As stated in the report by Strömgren and Olstam (2016) narrower lanes gives fewer overtakings, indicating that the spacing between the cars increases and fill up less quickly. This reduces the capacity of the road due to lower vehicle density. Strömgren and Olstam (2016) identified different affecting variables and recommend that the proportion of heavy vehicles, width of open lanes and proportion of commuter traffic among others should be considered when studying the capacity of a road affected by a construction site.

2.3 The Behaviour of Drivers

The behaviour of drivers while doing traffic forecasts is often assumed, but these changes in behaviour will affect the end result quite heavily (Goodwin et al., 1998). When the capacity of a road changes there are a set of people who are bound by habit. Minor changes in time and small detours is acceptable travel changes in order to avoid congestion. However, changes that requires larger responses is usually done slowly. While some of the people make detours to avoid the delays, other people, that does not usually take this route, replaces them on the affected road. These people are fast to respond to changes and can make use of the new circumstances. When delays are known road users are likely to change their time of departure in order to avoid a possible late arrival (Noland and Polak, 2002).

The behaviour of drivers is not constant and is likely to be different over time (Goodwin et al., 1998). In the beginning of capacity reduction commuters and people who uses the affected road regularly does not respond instantly. It usually takes a few days for the regular road users to adjust their route or time of departure in order to compensate for the time lost. This could result in heavy congestion and more queues than usual. However, this might not always be the case, this is often depending on the amount of information and warnings issued about congestion to the public in advance. In which case the traffic flows without any difficulty. Within the first year, when road users have had the time to adapt to the new conditions, the rapid changes of the first days rather transfers into a steady flow.

If the capacity of a road is likely to be reduced some changes in behaviour could be expected (Goodwin et al., 1998). Some people will choose other routes, bypassing the congested area and some will change their time of departure and by doing so avoiding the most congested times of the day. If these changes are not possible or if congested conditions could not be avoided, then it is likely that the total amount of traffic will reduce.

2.4 Examples of Reduced Capacity on Roads

In Oslo, 2009, the road of E18 underwent maintenance work and were studied. During this time the number of lanes was reduced with one in each direction down from three leading to a capacity reduction (Tennøy et al., 2016). Due to this capacity reduction it was expected to be a congested situation on the road, but thanks to information shared with the public beforehand no delays were observed. The traffic was reduced by 13 % and by 5 % on the alternative routes. This indicates that traffic problems and predicted congested situations often is exaggerated.

A similar case has been studied in 2015, when the 500 m long Smestads tunnel in Oslo was reduced down from four to two lanes due to construction work (Tennøy et al., 2016). A normal day about 50 000 vehicles uses the Smestads tunnel, which serves as an important link bypassing Oslo. In addition to the closing of two lanes, reducing the capacity by 50 %, the speed was also reduced to 50 km/h down from 70 km/h. Countermeasures were also introduced as a part of the change. A bus lane was built temporally, simultaneously as the authorities ran a large information campaign in order to influence road users choice of route and mean of transport. The traffic flow in the tunnels during peak hours was quite stable, but when the capacity reduction was introduced the flow decreased by 25 % (morning peak) and 23 % (evening peak). In this situation there were no problems with congestion despite the predictions. When this was discovered by the road users the traffic flow started to increase again. Tennøy et al. (2016) calculated the delays for vehicles using the tunnel. The most amount of delay was about 1.8 minutes, which was not enough to discourage people from using the road, re-routing or choosing other means of transportation. Although the construction work did not affect the traffic in a major way, the risk of a congested situation increased.

A survey was also conducted by Tennøy et al. (2016), which aimed to investigate how many of the drivers who would actively change their traveling pattern due to the construction work. The finding of the survey was that only about 6 % of the drivers aimed to chose another route bypassing the capacity reduction.

2.5 Predicting the Road Capacity

To be able to plan road works correct and precise it is important to know the roads capacity at the site of the construction (Strömgren and Olstam, 2016). This capacity must be known to be able to predict the possible delay caused. If the predicted delays are deemed unacceptable, extra measures to ease the traffic flow can be made, such as restricting work hours to off-peak hours or night time (Weng and Yan, 2016).

2.5.1 The Example of The Göta Tunnel

The following section is a summary of the report *Systemanalys* by Sjöholm (2017).

A example of trying to predict the effect of a maintenance work on the traffic flow is the work carried out in the Göta Tunnel in Gothenburg, 2018 (Sjöholm, 2017). The study aimed to identify the current traffic condition and the movement of traffic flow due to the disturbance caused by the maintenance work. In this instance three different cases were simulated, if the tunnel was open during the maintenance work, if the eastbound traffic in the tunnel was closed for traffic, and the case where one lane was open in each direction.

First of all, other construction sites that could affect the result and the current traffic situation were identified. These other construction sites could have had an effect on the result and are therefore acknowledged. The current traffic flows (2017-01-16) during the morning and evening hours are displayed in Figure 2.2 and 2.3. These numbers were later compared to the different scenarios in order to evaluate the result.

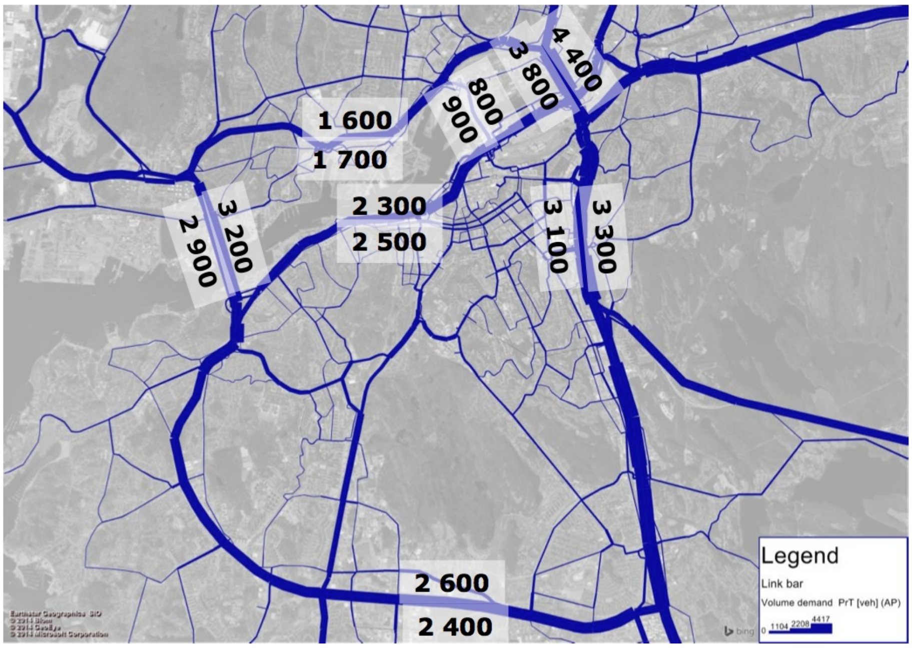


Figure 2.2: Current traffic flow in vehicles per hour on roads around Gothenburg during the morning hours (Sjöholm, 2017).

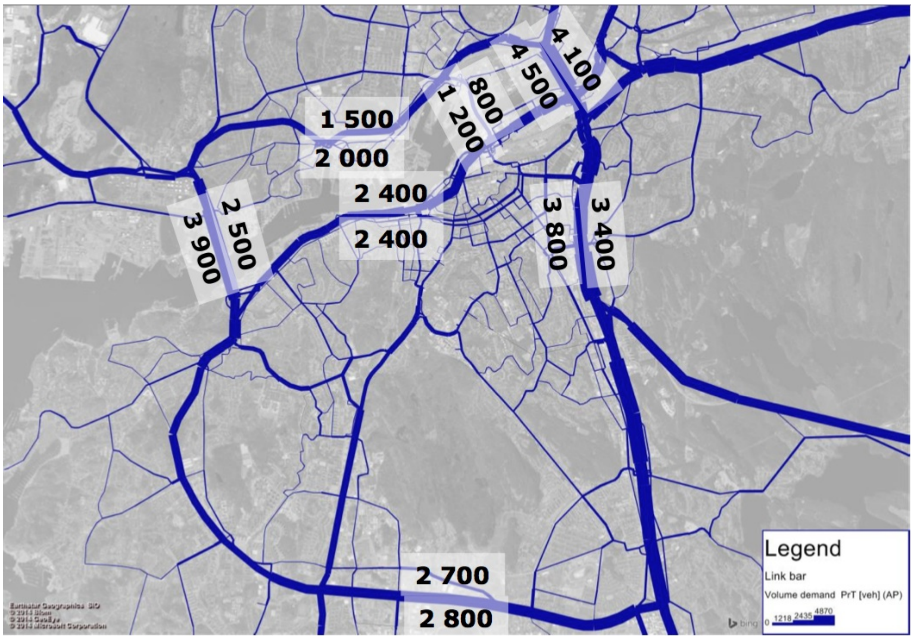


Figure 2.3: Current traffic flow in vehicles per hour on roads around Gothenburg during the evening hours (Sjöholm, 2017).

The case with the tunnel open in both directions during the maintenance work resulted in some movement in traffic flows. Some areas experienced a decrease in traffic due to limited mobility. The decreased traffic seemed to reappear in other areas around Gothenburg. This could indicate that these areas are connected and changes are corresponding to each other. The mobility would become worse both on the roads that are affected directly by construction works, but also the roads where the traffic diverts to. This because the increased amount of traffic results in a worsened condition compared to the current situation. In conclusion for the case where no directions in the tunnel were closed, the areas in Table 2.1, displayed below, were deemed worse compared to the current situation. See Figure 2.4 for a overview of the predicted situation.

Table 2.1: Areas and with a change in number of vehicles and traffic flow due to the construction work in the Göta Tunnel.

Areas with limited availability and decreased traffic	**Areas with increased traffic**	**Areas deemed worse compared to the current situation**
The central station	The Tingstad Tunnel	The central station.
Korsvägen	The Älvsborg Bridge	The Älvsborg Bridge.
Haga	Ullevigatan	The Götaälv Bridge.
The link E45/Marieholm	Alléstråket	Alléstråket.
	Söderleden	Korsvägen.
		The Tingstad Tunnel.
		Ullevigatan.

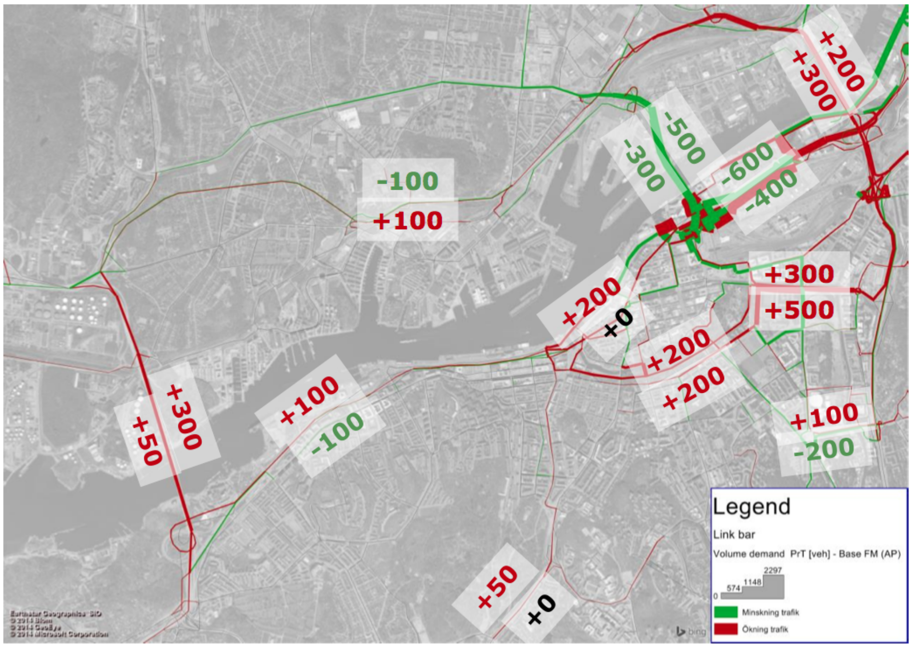


Figure 2.4: Predicted traffic situation in 2018 with the Göta Tunnel open compared to the current situation (Sjöholm, 2017).

In the case where the Göta Tunnel is closed in the eastbound direction the main limitation in traffic flow is in the tunnel itself. It is estimated to be reduced by 2 500 veh/h (vehicles per hour). Some of the missing traffic is predicted to move to the following roads:

- Lundbyleden/ The Älvsborg Bridge (+ 900 veh/h eastbound)
- Söderleden (+ 400 veh/h eastbound)
- Västra Sjöfarten/Skeppsbron (+ 300 veh/h eastbound)
- Alléstråket/ Ullevigatan (+ 600 veh/h eastbound)

This resulted in a worsened condition on the same roads excluding Söderleden, see Figure 2.5.

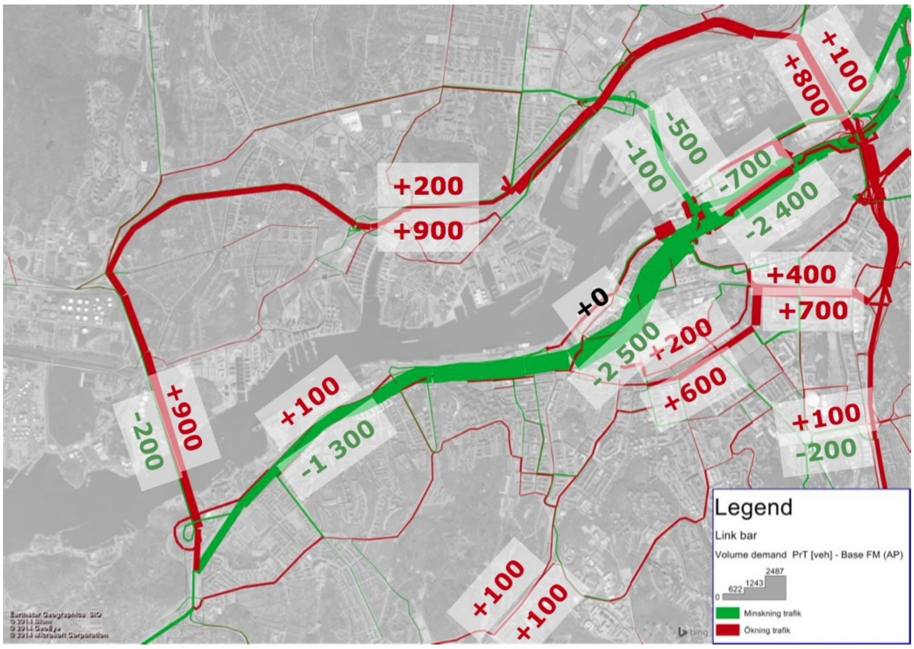


Figure 2.5: Predicted traffic situation, 2018 in the morning hours compared to today's situation. Case with the Göta Tunnel closed down in the eastbound direction (Sjöholm, 2017).

The last case, where one lane in each direction remained open in the tunnel, resulted in almost the same situation as the one above. The big difference is that this case affects both the east- and westbound directions. The number of vehicles declined by 2 600 veh/h in the tunnel itself and the increase in vehicles occurred on the same roads as motioned above, roughly in the same numbers. See Figure 2.6 below.

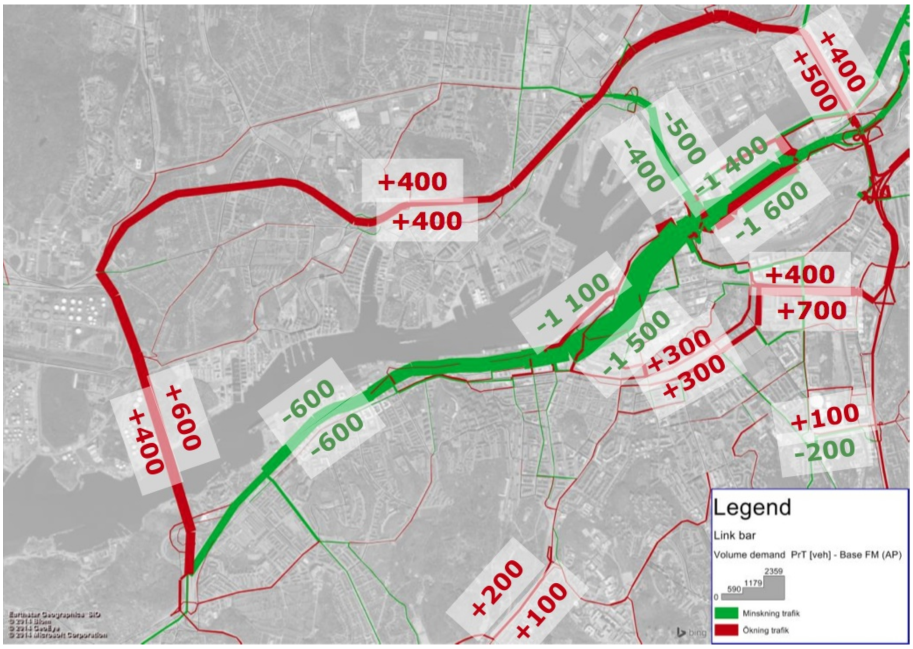


Figure 2.6: Predicted traffic situation in 2018 compared to today's situation. Case with one lane open in each direction in the Göta Tunnel (Sjöholm, 2017).

The conclusion in the report by Sjöholm (2017) was that traffic in the first case needs to decrease by 10 % in order to reduce the pressure on the roads. In the two other cases the risk for heavy congestion were great. Therefore the traffic in these cases need to be reduced by 20 % or maybe more in order to reduce the risk to acceptable levels.

2.5.2 The Example of the Tingstad Tunnel

The following section is a summary of some key points in the report *Trafikanalys Tingstadstunneln* by Sjöholm (2015). The report concerns the traffic situation during a maintenance work conducted in the Tingstad Tunnel in central Gothenburg.

The data used in the report was gathered from the congestion fee system in Gothenburg.

The Predicted Effect on Traffic Flow and Travel Time

Over a weekend in October, 2015, a maintenance work was carried out in the Tingstad Tunnel in Gothenburg (Sjöholm, 2015). During the work the western tunnel was closed and traffic was directed to the the eastern tunnel. Two lanes was dedicated to northbound traffic and one lane to southbound traffic. This changed the capacity of the tunnel dramatically. It was estimated that the traffic flow would decrees from 5 000 veh/h to 1 400 veh/h in the south direction and to 3 400 veh/h in the north direction.

Two different models were used to estimate the traffic flow. To analyze the traffic flows and how the traffic redirects around Gothenburg the VISUM model was used. To study the capacity of the Tingstad Tunnel during the maintenance work the VISSIM model was used. The travel time and queue length were also analyzed with this model.

Three different scenarios were simulated:

- No redirection of traffic during the maintenance work (worst-case scenario)
- Some redirection of traffic during the maintenance work
- Full redirection of traffic during the maintenance work

In the worst case scenario queues will increase in length with the pace of 10 km/h during the rush hours. This would mean that the traffic system will collapse. The travel time in this situation will be several hours.

In the second case some of the traffic is redirected over two bridges in Gothenburg going over the river, the Älvsborg Bridge and Götaälv Bridge. The VISUM model showed that the risk of exceeding the capacity of these two bridges were low. Even with some traffic redirecting over the bridges the more detailed VISSIM model showed that the queues will still be extensive in the Tingstad Tunnel during the rush hours of the day.

In the last scenario a large part of the traffic selects other routes. This was simulated through that everyone that were able to select another route did so, or selects other means of transport. Even though a big part of the vehicles were reduced in the tunnel there were still some risk for queues during the maintenance work.

To be able to achieve the desired conditions in the Tingstad tunnel the traffic need to be reduced by 2 500 veh/h in the southern direction and 500 veh/h traveling north. To reach these numbers, proper information needs to be issued so that the road users can plan their trip in advance. The alternative routes offers good options for redirected traffic, they have the spare capacity and the traveling time dose not increase too much compared to the original route through the tunnel.

Review of the prediction

Sjöholm (2016) followed up on the predictions made in the report, *Trafikanalys Tingstadstunneln*, to see how well the they fitted reality.

To follow up on how well the models predicted the real situation, the following aspects were analyzed:

- Traffic flows on the Götaälv Bridge and the Älvsborg Bridge
- The redirection of traffic
- The capacity in the Tingstad tunnel
- How traffic varied during the day
- If there had been a increase in other means of transport

The data used were collected from the congestion fee system and the Traffic Administrations regional database (Sjöholm, 2016).

The total amount of traffic had, according to the study, decreased by 19 500 vehicles. This decrease in traffic was not likely according to Sjöholm (2016). Some sources of error were identified and the large decrease could partially be due to some missing data. The missing data included traffic counts on the bridges of *Jordfallsbron* and *Angeredsbron*, which serves as passages between the two big links of the E6 and E45. However, it could be established that the traffic did increase on the bridges Götaälv Bridge and the Älvsborg Bridge, while reducing in the tunnel, see Table 2.2.

Table 2.2: Traffic change on the Götaälv Bridge, the Älvsborg Bridge and the Tingstad Tunnel during the maintenance work. The changes is displayed in percentage compared to other weekends in October, 2015.

	Change in southbound traffic	Change in northbound traffic
The Götaälv Bridge	79 %	67 %
The Älvsborg Bridge	37 %	28 %
The Tingstads Tunnel	-52 %	-42 %

The measurements also points to that between 6 000 and 9 000 vehicles traveling south on the E6 redirected to the E45. The traffic moving north on the same stretch were lacking the same type of data, but a traffic count on the E45 indicates that around 4 000 vehicles moved from the E6 to the E45 in this direction.

A traffic increase has also been identified on other roads around Gothenburg. One change in traffic was that traffic moved from the E6 to the road *Lundbyleden*, but there was no increase in traffic observed west of the junction of *Brantingsmotet*. This indicates that the Götaälv Bridge has been used more frequently than the Tingstad tunnel as a response to the maintenance work.

The traffic flow variation in the tunnel seems to have decreased not only during the rush hours, but the whole day, see Figure 2.7. This while the opposite was observed for the other passing's over the river see Figure 2.8 and 2.9. The blue line indicates normal traffic conditions and the red line is the measured traffic during the maintenance work.

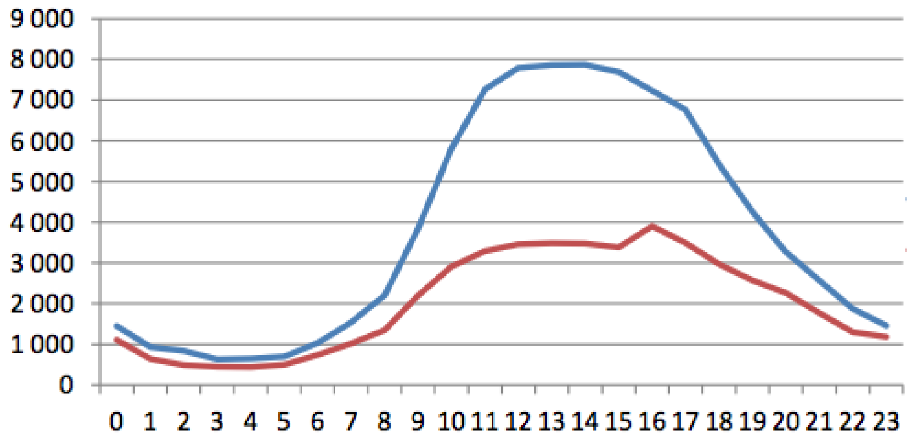


Figure 2.7: Difference in traffic flow in the Tingstad Tunnel for both directions during the maintenance work, displayed in vehicles per hour. (Sjöholm, 2016).

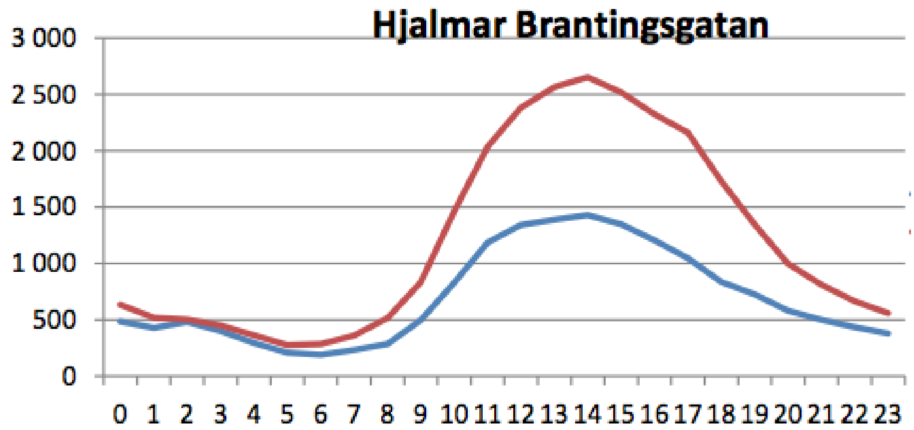


Figure 2.8: Difference in traffic flow on the road *Hjalmar Brantingsgatan*, leading up to the Götaälv Bridge, for both directions displayed in vehicles per hour. (Sjöholm, 2016).

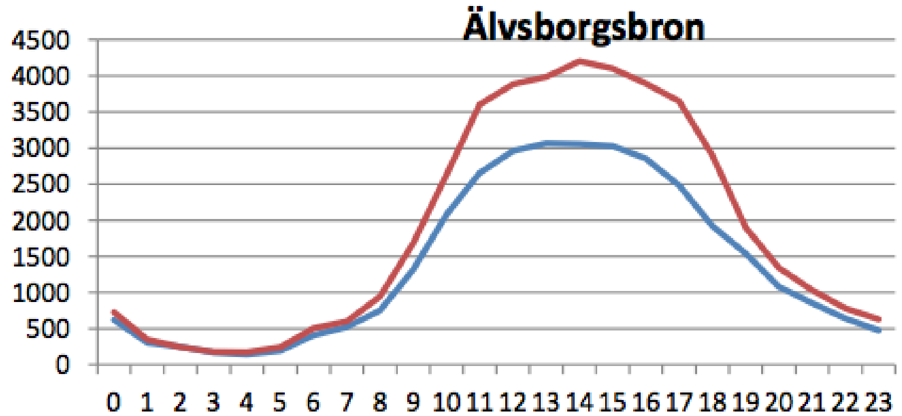


Figure 2.9: Difference in traffic flow on the Älvsborg Bridge for both directions, displayed in vehicles per hour. (Sjöholm, 2016).

During the time of the maintenance work it is probable that the Tingstad Tunnel reached it's capacity of 1 400 veh/h in the southbound direction. This can be seen in Figure 2.7 above. The red line, which represents the traffic flow during the capacity reduction, flattens during the peak hours of the day, indicating that maximum has been reached. It was estimated that 1 600 vehicles was still going to use the tunnel. This prediction seems to have been credible.

It was also investigated if road users switched from using their car in favour of the public transport instead as a response to the disturbance. The amount of passengers of the public transport system increased during this weekend. The real number can have been even larger because tickets purchased with the phone application and through text messages have not been recorded. The estimation is that around 5 000 more trips have been made with the public transport system.

In conclusion the traffic flow seems to have decreased by between 5 000 - 10 000 vehicles and the information campaign seems to have given a desired effect on traffic.

3
Method

This chapter describes the methods used obtaining and analyzing the data needed for the study. The data obtained have been analyzed in Microsoft Excel.

3.1 The Selection of Roads

The construction works around Centralstationen are predicted to affect the capacity of roads in the area. Maps have been studied to be able to identify roads, which could possibly be affected and that goes through the area and not only within the area itself, see Figure 3.1. Roads with its destination within the area are not likely to be as affected. This because road users will not have the possibility to change their choice of route towards their destination. The maps have been obtain from the Traffic and Public Transport Authority.

Figure 3.1: Map of roads going through the Centralstationen area in Gothenburg. ©Lantmäteriet with own symbols.

The alternative roads, which the traffic may divert to, have to be identified as well. This in order to investigate how a change in traffic in around Centralstationen affect other roads in the Gothenburg area. Data received by Mats Tjernkvist shows how the traffic changed in Gothenburg in the beginning of 2017 compered to 2016[1]. During this time some of the construction works around Centralstationen had started and was ongoing. Some roads with identified changes have been evaluated and considered for this study.

All the roads will be analyzed in both directions, city center and away from city center. The city center is defined as a point at Gustaf Adolfs torg in central Gothenburg, see Figure 3.2. The direction pointing to or leading towards this point is defined as direction city center.

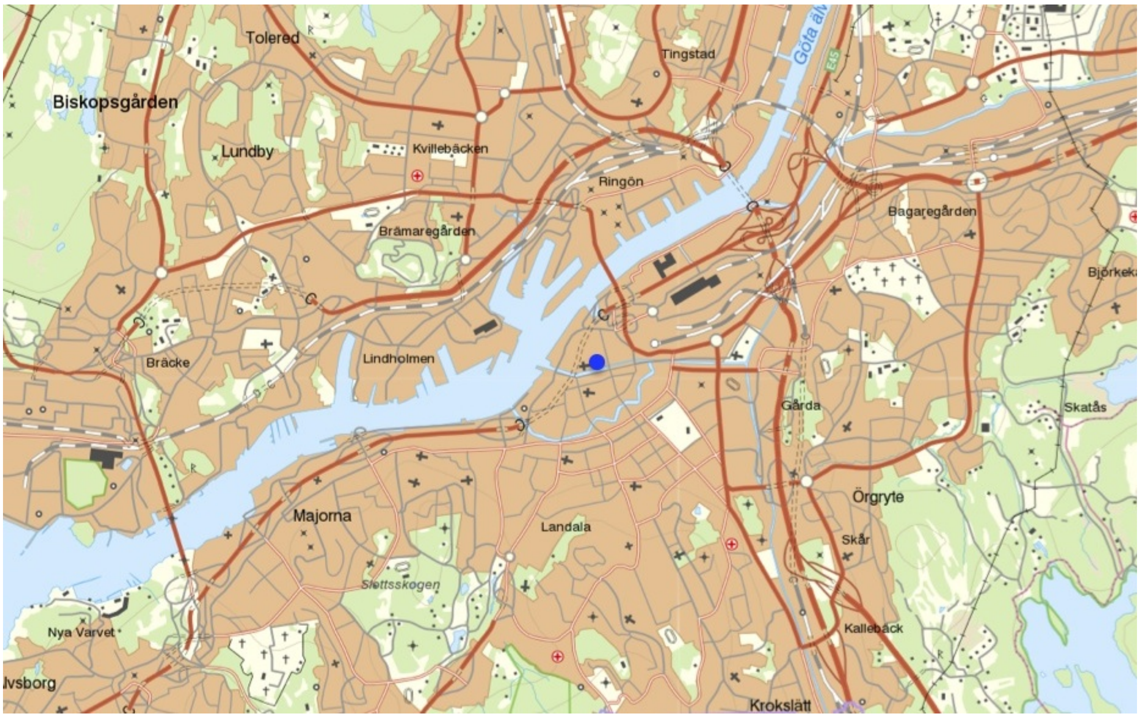


Figure 3.2: Gustaf Adolfs torg, Gothenburg. ©Lantmäteriet with own symbols.

The number of roads analyzed have later been reduced due to lack of sufficient data.

3.2 How to Measure the Traffic Flow and Traveling time

To be able to acquire the traffic flow data, the number of vehicles has to be measured and identified. This is done through the fixed measurement points around Gothenburg. There are five different sections in Gothenburg where traffic flow are measured. These sections will later be described in Section 4.1.

[1]Mats Tjernkvist, M4Traffic, 2017-09-05

The travel time has in previous years been measured with a fixed camera measurement system. However, in 2016 this system was replaced with the *floating car data system* (Trafikkontoret, 2016). This new system uses mobile phones and technical equipment in cars in order to calculate the travel time on certain roads.

As mentioned in Section 2.2 the amount of heavy traffic might affect the capacity of the roads. However, according to the Traffic and Public Transport Authority the amount of heavy traffic does not seem to increase nor decrease with seasonal changes or between the years. (Trafikkontoret, 2016). And will therefore be unaccounted for in this report.

3.3 The Traffic Flow Data

The traffic flow data is obtained from the Traffic and Public Transport Authority. This data has been collected by fixed measurement systems around Gothenburg, see Appendix A Figure A.2 and A.3 for the locations of the measurements. Three locations cannot be seen on the map, The Angereds Bridge, Kungälvsleden and Säröleden. The traffic flow is divided into 15 minutes intervals each day to be able to identify the peak hours and how they change over time. The traffic flow data is obtained for the roads described in Section 3.1. The data analyzed were collected between January and June for the years 2015, 2016 and 2017.

The traffic flow has been measured each 15 minutes for the whole period for each analyzed road. This traffic flow is converted into vehicles per hour and a average traffic flow is calculated for each 15-minute interval of a day for each month. This gives the average daily traffic flow variation for each month, which can be compared between the years. This will enable peak hours for the different years to be identified. The traffic flow for a average day representing the whole period will be compared between the years as well. This in order to easily see how much the traffic have changed. A average day is used instead of the total sum of the period due to lack of data during some weeks and months for some roads. In addition to this the average-day of every week is calculated and displayed in a graph for the whole period. This is done in order to see if there have been any major changes in traffic flow over time. Some of the weeks which completely lacks data will be displayed as a gap in the graph. Weekends, the February holiday and Easter have been excluded in this study. The traffic during these times are not deemed representative for the period and a comparison between the years would be difficult. This because the holidays occurs on different weeks and dates between the years. The weekends are excluded as well because the traffic flow have a different characteristics compared to the weekdays and changes between the years would be more difficult to identify.

3.4 The Travel Time Data

The travel time data was obtained through the Traffic and Public Transport Authority. The data was extracted from the application *Geoservicio*. The median travel time during weekdays for each month (January - June) will be obtained, which will be used to compare the travel time between the years. Only weekdays (Monday-Friday) have been analyzed and holidays such as Easter have been excluded, see list below for excluded dates. This in order to be able to compare the months between the years. The years available were 2016 and 2017, therefore 2015 is not analyzed in a travel time aspect.

- **New years eave** 1/1
- **Epiphany** 6/1
- **February holiday** 15/2 - 19/2 2016 & 13/2 - 17/2 2017
- **Easter** 21/3 - 28/3 2016 & 10/4 - 17/4 2017
- **First of May**
- **Feast of the Ascension** 5/5 2016 & 25/5 2017
- **National Day of Sweden** 6/6

When extracting the data from the database, a stretch has to be defined in order to collect the travel time. This stretch will be as long as possible and will include the point where the traffic flow have been measured. However, it can not be affected by the capacity of other intersecting roads. It will be mentioned between which points the stretch is drawn, if it has been shortened. In the database you have the possibility to chose to gather data from common vehicles (Passenger), logistical vehicles (Telematics) or both. In this study both the common and logistical vehicles will be used.

The travel time is going to be represented as a median for each month, so extreme values will not affect the result. In addition to this the 15th and 85th percentile will be displayed. This in order to see if the span of the travel time have changed, which could say something about the security in travel time of the stretch. The percentiles could also indicate if there are big differences during the day.

4
The Construction Works and their Impact on Traffic

The construction works in central Gothenburg by the central station, Centralstationen, see Figure 4.1, are most likely going to affect the capacity of the nearby roads. This chapter will describe the current situation, the type of work carried out and the potential effect it will have on the nearby roads. See Appendix B for the activities carried out.

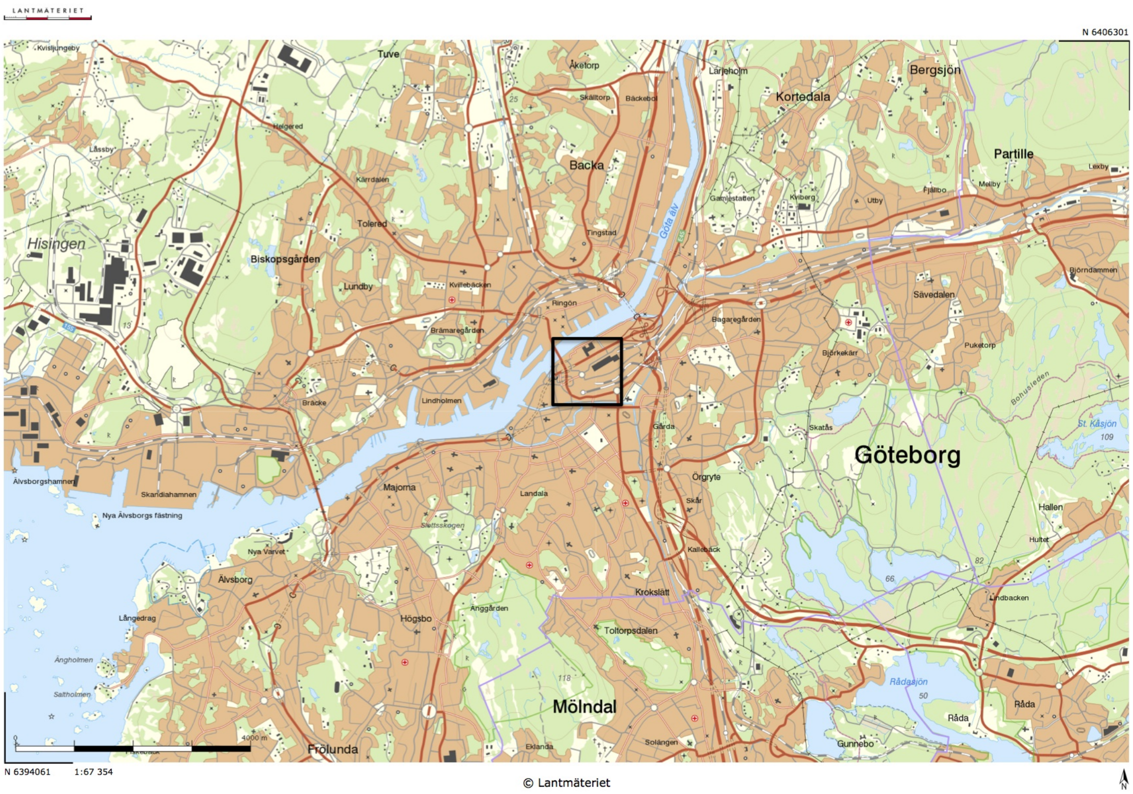


Figure 4.1: Location of the area of Centralstationen in Gothenburg. ©Lantmäteriet with own symbols.

4.1 The current situation

The aim of the city of Gothenburg is to increase the sustainable ways of travel while decreasing the unsustainable, mainly motorized vehicles (Trafikkontoret, 2016). One specific goal is that transportation with bicycles and walking will make up at least 35 % of all travels within the city by 2035. Another goal is that the public transport will make up 55 % of all motorized travels in Gothenburg by the same year. This ultimately means that the travels with cars has to decrees by 23 % or 1.1 % per year.

The development and change in the traffic situation around Gothenburg has been monitored and analyzed. Since the year 2011, when the goals mentioned above were implemented, the number of cars in the city have increased by 0.9 %.

The measurements are done in five different strategic sections around Gothenburg:

- The 28 fixed measurement points
- The border of the municipality
- The passing over the river Göta älv
- The central parts of the city
- The City-section

The 28 fixed measurement points is evenly spread out in Gothenburg on both large and small roads. These points is used to monitor the general development of traffic within the city. The recent development identified by the measurement points is displayed in Table 4.1.

The measurement points by the border of the municipality are able to monitor key passages between Gothenburg and neighboring municipalities. These points are able to identify changes in commuter traffic from other municipalities.

The monitored passings over Göta älv includes the Götaälv Bridge, the Älvsborg Bridge, the Tingstad Tunnel and the Angereds Bridge. As seen in Table 4.1, this section experienced a increase as well. However, both the Götaälv and the Älvsborg Bridge experienced a decrease in passed vehicles. The reduction in traffic on the Älvsborg Bridge can be explained with the ongoing maintenance work, reducing the number of lanes (Trafikkontoret, 2016), see Section 4.4. The Götaälv Bridge leading to the area of Centralstationen, might have been affected due to the planned construction work in this area during the fall (Trafikkontoret, 2016). It is also noticeable that the Tingstad Tunnel handles about half of the traffic flow monitored in this section.

The measurement points making up the central parts of the city includes locations as; Haga, Vasastaden, Landala, Lorensberg, Johanneberg, Heden, Gårda, Nordstaden and Vallgraven. This section is one of the few where traffic actually has decreased. The biggest change in this section can been seen on the roads of Norra Hamngatan and Södra Hamngatan. On Norra Hamngatan the traffic was reduced by 3 000 vehicles while increasing on Södra Hamngatan by 1 500 compared with 2015. The reason for this change was probably different construction works that was ongoing in the area at the time.

The city-section measures the traffic flows within the moat of Gothenburg. This section has experienced a decrease in traffic since 1988. Some construction works have also been ongoing within this area, which might have affected the traffic flow.

Table 4.1: Change in traffic in the different sections.

	Change in traffic between 2015 & 2016	**Average number of passings per weekday in 2016**
The 28 fixed measurement points	+ 0,3 %	1 302 900 veh/day
The municipality boarder points	+ 0,9 %	445 600 veh/day
Passings over Göta älv	+ 1,1 %	236 400 veh/day
The central parts	- 1,1 %	-
The city-section	- 1,1 %	34 700 veh/day

4.2 Traffic investigation - Trivector, 2014

Brogren and Sjöstrand (2016) conducted a investigation of the traffic situation in the area of Centralstationen. The area is defined in Figure 4.2.

Figure 4.2: Overview of the defined area of the central station (Brogren and Sjöstrand, 2016).

Eleven thousand people work within the area displayed above and 220 000 people passes through it every day (Brogren and Sjöstrand, 2016). This number can be further divided into the groups displayed in the list below. Note that vehicles and the public transport can transport more than one person.

- Vehicles (62 000)
- Trams and buses (4 000)
- Pedestrians and cyclists (50 000)

In a study done as preparatory work for *Bangårdsviadukten* it was concluded that the traffic numbers have been declining for the last 25 years, from 96 200 vehicles per day to 39 800. This reduction is manly due to a change in policy over several decades. The biggest change in traffic numbers was in 2012-2013, when traffic was reduced by 19 % in the central parts of Gothenburg. During this time the congestion fee was introduced, more public transport was implemented and several constructions around the city was ongoing.

In a survey conducted by Brogren and Sjöstrand (2016) it was found that over half of the vehicles that used the Götaälv Bridge also used the road of Nils Ericsonsgatan. When the road experienced disturbance in traffic flow only 28 % of the vehicles decided to stay on the route. Most of the vehicles chose to use the Tingstad Tunnel instead, bypassing the area.

4.3 The Construction Works around Centralstationen

In the area around Centralstationen in Gothenburg three main construction works are carried out between 2016 and 2021; The Hising Bridge, E45 Lilla Bommen - Marieholm and The West Link Project, henceforth referred to as Västlänken, (Trafikverket, 2016). The area around Centralstationen is not only the biggest public transport location, it is also the number one destination in the city. This means that the traffic situation is very complex and deemed vital. Due to this collaboration between the different construction projects within this area is necessary.

During the planing of the traffic situation in the area it was decided that pedestrians, cyclists, public transport and delivery to various businesses will be prioritized during the projects.

The following sections will describe the different projects briefly and their activities between January 2017 and June 2017. The following map, Figure 4.3, is a overview of the area with key locations marked.

Figure 4.3: Overview of the area around Centralstationen with key locations marked. ©Lantmäteriet with own symbols.

1. The Hising Bridge
2. Bananbron
3. Stadstjänarebron
4. Norra Sjöfarten
5. Shelltomten
6. Hamntorgsgatan
7. Hamntorget
8. Nils Ericsons Terminalen
9. Drottningtorget
10. Nils Ericsonsgatan
11. Falutorget
12. Stadstjänaregatan
13. Gullbergs Strandgata
14. Partihandelsgatan
15. Södra Sjöfarten
16. Åkareplatsen
17. Västra Sjöfarten
18. Bergslagsgatan
19. Odinsgatan
20. Friggagatan

4.3.1 The Hising Bridge

The Hising Bridge will replace the current Götaälv Bridge over the river Göta älv in the central parts of Gothenburg (Göteborgs Stad, 2017*a*). The bridge itself will be lower than the current bridge and make it easier for pedestrians, cyclist, public transport and cars to get across. The new bridge will also free space, which can be used for apartments and office buildings. The bridge will have one bridge abutment in the area around Centralstationen and one between *Ringön* and *Frihamnen* on the island of Hisingen. The bridge is planned to be completed in 2021. The construction site is displayed in Figure 4.4.

Figure 4.4: Overview of the work area of the Hising Bridge. ©Lantmäteriet with own symbols.

In January 2017 the project started with the reconstruction of one of the bridges, the so called "*Bananbron*", going over the E45, see Figure 4.3 (Trafikverket, 2016). This in order to handle the extra traffic going over the E45, when the nearby bridge, *Stadstjänarebron*, was demolished in the next step of the project. This was done because the new bridge abutment is going to be constructed in this area (Göteborgs Stad, 2017*b*). It was expected that this demolition would have a big impact on traffic. During the reconstruction of Bananbron, the road *Norra Sjöfarten* between Bananbron and Stadstjänarebron was closed. A new connection to Bananbron was built on the so called "*Shelltomten*".

A new connection between the roads of *Hamntorgsgatan*, *Hamntorget* and Norra Sjöfarten was built as a countermeasure for the rerouted traffic from the closed bridge and the affected roads.

In February, 2017, the construction of a new access ramp to the Hising Bridge from *Nils Ericsons Terminalen* started. However, this have been been pushed forward due to lack of space. During this time the current ramp leading from the road *Bergslagsgatan* up to the Götaälv Bridge was closed. The only access to the bridge was now via the road *Drottningtorget*. The traffic traveling west on the E45 towards the Götaälv Bridge is redirected through the Tingstad Tunnel instead (Trafikverket, n.d.).

During June, 2017 the Götaälv Bridge was closed for trams. This because the construction of a new ramp for trams leading up to the bridge started. During this time more buses used the bridge more frequently as a replacement, possibly competing with the same space as the cars.

4.3.2 E45 Lilla Bommen - Marieholm

The highway of E45, which passes through central Gothenburg, has to be rebuilt to be adapted to other development projects in the area (Trafikverket, 2017*a*). To enable this, the highway will be lowered 6 m between the road *Falutorget* and Stadstjänarebron. This is a stretch of about 800 m, half of which will be constructed as a tunnel. In addition to this the intersection by Falutorget, which today is governed by traffic signals, will be replaced by a separated intersection. The main part of the construction is planned to take place between the summer of 2016 and December of 2020. The work area is displayed roughly in Figure 4.5.

Figure 4.5: Overview of the work area of the E45 project. ©Lantmäteriet with own symbols.

The access to the E45 heading east from *Stadstjänaregatan* was closed starting November, 2016 (Trafikverket, 2016). This meant that the number of lanes was reduced from four to two between The Göta Tunnel and Falutorget[1]. During this time the eastbound traffic is rerouted to alternative roads (Trafikverket, 2016). Traffic that want to access the E45 heading east are redirected to the rebuilt Partihandelsgatan and Falutorget (Trafikverket, n.d.). Partihandelsgatan was a one way

[1] Christina Lundqvist, Atkins, 2017-11-29

street towards the east during this time. In February, when Stadstjänarebron was demolished, as mentioned in Section 4.3.1, the exit from the E45 by *Norra Sjöfarten* closed. This meant that the westbound lanes were reduced from three lanes to two and narrowed down[2]. Traffic going west on the E45 are redirected to the exits by Falutorget or Järntorget instead. Road users that want to access the area of Centralstationen may do this via Partihandelsgatan, which now no longer is a one way street, and Falutorget (Trafikverket, n.d.). It was predicted that the traffic would increase in the intersection of Falutorget-Gullbergs Strandgata during this time as well (Trafikverket, 2016). To be able to handle this increase in the intersection a temporary roundabout was constructed during January, 2017. The road *Gullbergs Strandgata* might have had reduced capacity as well during this time due to a construction site east of Stadstjänaregatan.

In February, 2017 the traffic lanes heading in a eastbound direction on the E45 was temporarily pushed somewhat to the south and narrowed down, running parallel to Partihandelsgatan. This to enable the construction of the northern tunnel, which started in April, 2017 and will be ongoing until October, 2019.

The speed limit on the E45 by Centralstationen have also been reduced from 70 km/h to 50 km/h during the time of the construction work[2].

4.3.3 Västlänken

To be able to develop the Gothenburg region and stimulate growth the public transport system needs to be improved (Trafikverket, 2017*b*). Today the central station in Gothenburg serves as the only train station in Gothenburg. Both departing and arriving trains need to use the same set of tracks, which means that a train need to depart the same way as it arrived. This reduces the capacity of the station. Västlänken includes 8 kilometers double track of railway, that will run through a tunnel for 6 kilometers in central Gothenburg. In addition to this, two new stations will be constructed and the current central station will be rebuilt. This will enable trains to run through the city, increasing capacity. The additional stations will reduce the pressure on the only current station and the public transport system in the city as a whole.

The part of the project that will affect the area around Centralstationen is a stretch of 1 800 m, from the tracks by *Olskroken* to Centralstationen and *Lilla Bommen* (Trafikverket, 2017*c*). This includes the construction of the new central station. The new station will consist of two platforms, four tracks and entrances by *Gullbergsvass*, the Nils Ericson Terminal and one where the Götaälv Bridge is located today. This project will start 2018, but preparatory work will be ongoing during 2017 (Trafikverket, 2016). See Figure 4.6 for the extent of the construction site for the new central station.

[2] Christina Lundqvist, Atkins, 2017-11-29

Figure 4.6: Overview of the work area for the new central station. ©Lantmäteriet with own symbols.

The preparatory work during the period concerning this report consist mainly of archaeological surveys. Although the road of Norra Sjöfarten might have been affected in January 2017, due to installation of district heating. During this time only one lane was open on the stretch between Hamntorget and *Västra Sjöfarten*.

4.3.4 Smaller Ongoing Projects in the Area

The three main projects mentioned above are not the only projects that are ongoing in the area. There are some smaller active projects within the area around Centralstationen which could be of interest. Two carparks in the area was demolished, one by *Åkareplatsen* in January, 2017 and one by Hamntorgsgatan, which was suppose to start in May but got heavily delayed (Trafikverket, 2016). Due to issues by the Nils Ericson Terminal some bus stops will move to Åkareplatsen. The preparatory work for the new bus stops will start in February, 2017, during this time a bus lane was closed in this area (Göteborgs Stad, 2017*a*). This means that buses and other vehicles had to share the remaining lanes. The construction of the new bus stops started in April, 2017. This affected the current pick up point for taxis, which moved to Odinsgatan (Göteborgs Stad, 2017*b*). During this time the construction of a new roundabout in the area also started. It was predicted that this would reduce the capacity of the nearby roads somewhat more.

4.3.5 The Predicted Effects on Traffic

In the report by the Swedish Transport Administration and the Traffic and Public Transport Authority some possible problems concerning the traffic in the area have been identified (Trafikverket, 2016).

When the access to the E45 from Stadstjänaregatan was closed, see Section 4.3.2, Bergslagsgatan was predicted to handle more of the public transport, which could cause problems and delays. The two intersections Stadstjänaregatan-Bergslagsgatan and Kruthusgatan-Bergslagsgatan would therefore be more strained.

When the roundabout was constructed in the intersection Falutorget-Gullbergs Strandgata, see Section 4.3.2, traffic could have been affected. In the end only a temporary roundabout was constructed, however a final solution for this intersection are constructed during the fall of 2017.

The demolition of the carpark by Åkareplatsen, see Section 4.3.4, would not itself lead to a big change in traffic numbers, but it could lead to more vehicles searching for parking spots in the area the first few days. This was probably not the case when the carpark by Hamntorgsgatan was removed. The vehicles with the carpark as its destination would probably just use the carpark right next to it instead. However, this demolition also made it possible to increase the work area by the Hising Bridge, which in its turn can cause disturbance on Gullbergs Strandgata.

The relocation of the eastbound lanes of the E45 to the south, see Section 4.3.2, probably increased the number of vehicles on Norra Sjöfarten and Södra Sjöfarten. This due to that these two roads will serve as a possible exit from the E45 instead of Stadstjänarebron.

Concerns was also raised for the traffic situation on Gullbergs Strandgata and Hamntorgsgatan in April, 2017. These two roads was predicted handle a large amount of traffic compared to the current situation.

4.4 Constructions Works Outside the Specified Area

Other construction works carried out in Gothenburg outside the area around Centralstationen could affect the roads analyzed and therefore the result of this study.

Maintenance of the Vasa Bridge

The Vasa Bridge in central Gothenburg will undergo heavy maintenance work with start of 19th of June, 2017 (Göteborgs Stad, 2017*c*). The bridge was demolished during the work and traffic was therefore rerouted to the nearby Viktoria Bridge. The trams and buses that uses the bridge are rerouted both over Kungsportsplatsen and over the Viktoria Bridge. The maintenance work is planned to last 10 months.

Maintenance of the Älvsborg Bridge

The maintenance of the Älvsborg Bridge started on April 1, 2016 with the east side of the bridge. This affected the direction from Frölunda towards Hisingen (Trafiken.nu, 2017). This first part of the project lasted until November, 2016. During the time of the maintenance one lane was closed down. As a countermeasure a reversible traffic lane was introduced. This means that three lanes was open towards Hisingen in the morning and three lanes towards Frölunda in the afternoon. At least one lane was the same size as before, but the others were narrowed down. The work zone was active between 07-19 every weekday. The same type of work was carried out during the same time in 2017, but concerning the west side of the bridge (the direction of Hisingen towards Frölunda).

5
Result

The data have been analyzed in different aspects in order to see what changed during 2017 compared to the reference years of 2015 and 2016. The selected roads in the area of Centralstationen can be seen in Appendix A Table A.1 and Table A.2 for roads identified as possible alternative routes where traffic might have transferred. See Figure A.1 in Appendix A for map over alternative routes. The road of Engelbrektsgatan have been divided into two parts, 149 and 150 (names of the measurement points), this due to two different measurement points on the same stretch of road. The same is true for Kungsbackaleden.

5.1 Change in Peak Hours

The peak hours for the area generally occur in the morning around 8 am, with the exceptions of Gullbergs Strandgata (away from city center) and Partihandelsgatan. The afternoon peak in the area usually occurs between 4 and 5 pm. On the Götaälv Bridge and Drottningtorget this peak occurs somewhat earlier. Gullbergs Strandgata (city center) have three peak hours during a day in the morning, the middle of the day and in the afternoon.

For most of the roads the time when the peak hours occur did not change drastically for 2017 compared to the reference years of 2015 and 2016. However, some of the peaks changed somewhat and become wider. This can be seen for Drottningtorget in the direction towards the city center, see Figure 5.1. For this road the peaks seems to occur a bit earlier compared to 2015 and 2016 as well. For some roads the peaks almost disappeared and the curve had become more smooth throughout the day. This can be seen for Odinsgatan in the direction away from the city center especially the morning peak, see Figure 5.2.

Drottningtorget - City center

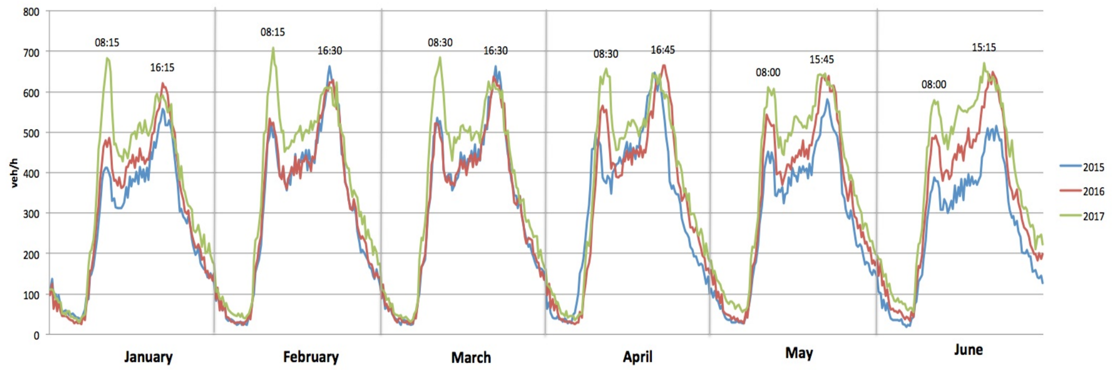


Figure 5.1: Average daily traffic flow variation each month for the years 2015, 2016 and 2017, for Drottningtorget in the direction towards the city center. The X-axis shows 24 hours for each month.

Odinsgatan - Away from city center

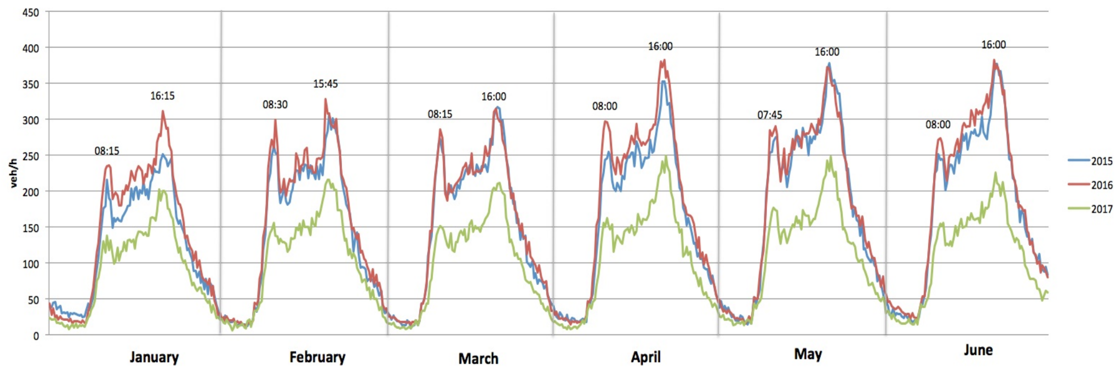


Figure 5.2: Average daily traffic flow variation each month for the years 2015, 2016 and 2017, for Odinsgatan in the direction away from the city center. The X-axis shows 24 hours for each month.

There are no major changes in peak hours between the months of the same year.

For the analyzed alternative roads the peak hours are unchanged with some exceptions. Järntorget in the direction away from city center it seams that during 2016 and 2017 more distinct peak hours emerged (especially March-June), see Figure 5.3. The peak hours for the road Lundbyleden also changed in both directions. The peaks are not as distinct as before and they occurred a bit earlier during 2017 compared to the reference years. See Figure 5.4.

Järntorget - Away from city center

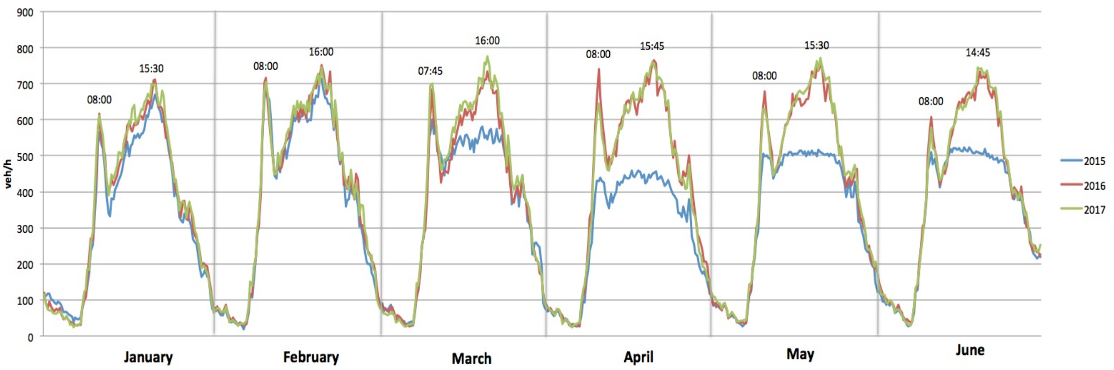


Figure 5.3: Average daily traffic flow variation each month for the years 2015, 2016 and 2017, for Järntorget in the direction away from the city center. The X-axis shows 24 hours for each month.

Lundbyleden - Away from city center

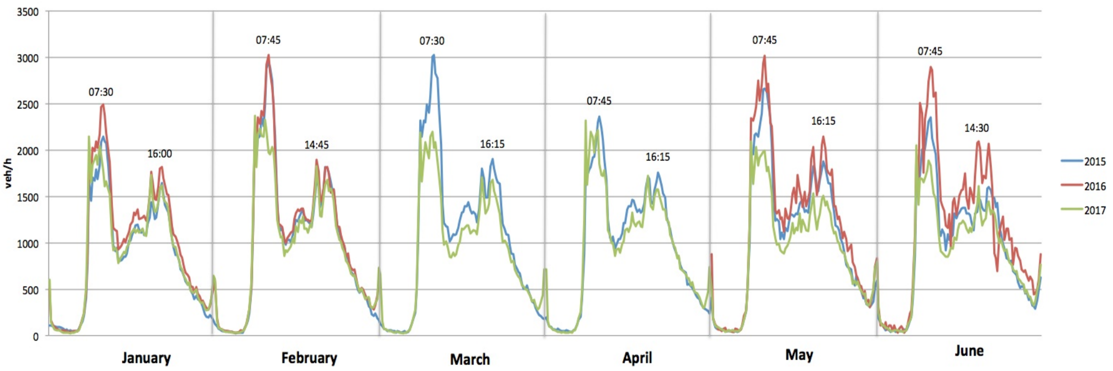


Figure 5.4: Average daily traffic flow variation each month for the years 2015, 2016 and 2017, for Lundbyleden in the direction away from the city center. The X-axis shows 24 hours for each month.

The average day variation for all the analyzed roads, including the alternative roads, displayed for each month, can be seen in Appendix C. The numbers are an average for each 15 minutes during a day for a month, see Section 3.3. The peak hours for the roads in the area of Centralstationen are displayed in Table 5.1 on page 36. The table display the estimated time for when the peak hours occurred during 2015, 2016 and 2017 between January and June on each road.

Table 5.1: Peak hours for roads in the area of Centralstationen during the years 2015, 2016 and 2016. The peak hours are separated with a slash "/". The peak hours are a rough estimation for all of the months during the period.

	2015	**2016**	**2017**
Drottningtorget (city center)	08:00/16:30	07:45/16:15-16:45	08:00-08:30/ 15:15-17:30
Drottningtorget (away from city center)	07:45-08:00/15.45-16:00	07:45-08:00/15:30-15:45	08:00/15:45-16:00
Friggagatan (city center)	08:00/16:15-17:00	08:00/16:15-17:00	08:00/16:45
Friggagatan (away from city center)	08:00/16:00-16:15	08:00/16:15	08:00/16:00
The Götaälv Bridge (city center)	07:45/16:00	08:00/15:45-16:00	08:00/16:00
The Götaälv Bridge (away from city center)	07:45-08:00/15:45-16:00	07:45-08:00/15:30-15:45	08:00/15:45-16:00
Gullbergs Strandgata (city center)	07:15/12:00/16:00	07:15/12:00/16:00	07:15/12:00/16:00
Gullbergs Strandgata (away from city center)	06:45	06:45	06:45
Marieholmsleden/E45 (city center)	06:45-07:15/16:00-16:15	06:30-07:30/16:00	06:30-07:30/16:00-16:15
Marieholmsleden/E45 (away from city center)	07:30-07:45/16:00	07:30-07:45/16:00	07:30-07:45/16:00
Nils Ericsonsgatan (city center)	08:00/16:15-17:15	07:45-08:15/16:00-17:00	08:15/16:00-16:45
Nils Ericsonsgatan (away from city center)	07:45-08:00/16:00	08:00/15:30-16:30	08:00-08:30/15:30-17:00
Odinsgatan (city center)	08:00-08:15/16:15	08:00-08:15/16:15	08:15
Odinsgatan (away from city center)	08:00-08:30/16:15	08:00-08:30/16:00	08:15/16:00-16:45
Partihandelsgatan (city center)	08:00-08:30	08:00	08:00
Partihandelsgatan (away from city center)	08:45-09:15	08:45-09:15	08:45-09:15
Polhemsplatsen (city center)	07:45-08:15/16.00-16:45	08:00-08:45/16:00-16:30	08:30-08:45/16:00-16:45
Polhemsplatsen (away from city center)	08:00-08:30/16:15-16:45	07:45-08:30/16:00-17:00	07:45-08:30/16:15-17:00

5.2 Change in Traffic Flow

The traffic flow for each road each year are displayed in Table C.1 and C.2 in average vehicles per day in Appendix C. The Table 5.2 below shows the difference in traffic flow between the 2017 and the reference years of 2015 and 2016.

Table 5.2: Difference in traffic flow for a average day each year for the roads within the area of Centralstationen. CC = City center, ACC = Away from city center.

	Difference 2015-2017		**Difference 2016-2017**	
Direction	**CC**	**ACC**	**CC**	**ACC**
Drottningtorget	26 %	-19 %	16 %	-20 %
Friggagatan	65 %	-14 %	56 %	-22 %
The Götaälv Bridge	-23 %	-22 %	-22 %	-23 %
Gullbergs Strandgata	4 %	3 %	-6 %	-6 %
Nils Ericsonsgatan	-4 %	-8 %	-7 %	-12 %
Marieholmsleden/E45	-4 %	2 %	-13 %	-6 %
Odinsgatan	66 %	-35 %	62 %	-39 %
Partihandelsgatan	22 %	2 %	25 %	3 %
Polhemsplatsen	-3 %	-1 %	-2 %	-4 %

In the area of Centralstationen the E45 handles the most amount of traffic by far. The Götaälv Bridge, which handles the second most traffic, has about half the traffic flow of the E45.

In total for the analyzed roads in the area of Centralstationen a decline of 2 % (2015 and 2017) and 7 % (2016 and 2017) has been observed. However, there is a big variation between the roads and especially the direction. In the direction towards the city center a much smaller decrease of traffic has been observed (-2 %) while there is a clear decline in the direction of away from the city center (-7 %) (2016-2017). On some roads a significant increase in traffic have been observed. This can be seen clearly on the roads of Odinsgatan and Friggagatan in the direction towards the city center. The large increase on these two roads, roughly 60 %, will be discussed later in Section 6.2. The Götaälv Bridge had a significant decrease in traffic flow of about 22 % in both directions.

Of all the roads analyzed the Tingstad Tunnel handles the most amount of traffic. Other roads that had a large amount of traffic flow are; Kungsbackaleden, Kungälvsleden, Lundbyleden, Oscarsleden and the Älvsborg Bridge.

Table 5.3 on the next page shows the difference in traffic flow between the 2017 and the reference years of 2015 and 2016 for the identified alternative roads. For most of the alternative roads only slight changes between 2017 and the reference years was observed with some exceptions. Roads with significant changes are Engelbrektsgatan (150), Emigrantvägen, Första Långgatan, Hjalmar Brantingsgatan, Oscarsleden, Södra Vägen and the Älvsborg Bridge. In total a 2 % increase between

2017 and 2015 and a 2 % decrease between 2017 and 2016 are observed for both directions for the alternative roads.

Table 5.3: Difference in traffic flow for a average day each year for the alternative routes. CC = City center, ACC = Away from city center.

	Difference 2015-2017		**Difference 2016-2017**	
Direction	**CC**	**ACC**	**CC**	**ACC**
The Angereds Bridge	6 %	9 %	5 %	5 %
Dag Hammarskjöldsleden	1 %	-4 %	-1 %	-3 %
Kungsbackaleden (1608)	1 %	7 %	-2 %	0 %
Kungsbackaleden (1609)	6 %	7 %	-2 %	-2 %
Emigrantvägen	21 %	-16 %	30 %	4 %
Engelbrektsgatan (149)	-4 %	-9 %	-4 %	-6 %
Engelbrektsgatan (150)	-24 %	-10 %	-26 %	-14 %
Första Långgatan	-10 %	-8 %	-11 %	-8 %
Hjalmar Brantingsgatan	-10 %	-4 %	-11 %	-7 %
Järntorget	1 %	17 %	4 %	2 %
Kungälvsleden	-5 %	-4 %	-7 %	-5 %
Lundbyleden	7 %	-8 %	4 %	-9 %
Nya Allén		2 %		1 %
Olskroksmotet	9 %	7 %	7 %	1 %
Oscarsleden	-11 %	-8 %	-12 %	-11 %
Parkgatan	8 %		6 %	
Redbergsvägen	4 %	0 %	-8 %	-3 %
Skånegatan	-6 %	4 %	-4 %	2 %
Slussgatan	7 %	0 %	7 %	-1 %
Stigbergsliden	-8 %	2 %	-2 %	2 %
Säröleden	4 %	1 %	4 %	1 %
Södravägen	18 %	2 %	-7 %	-11 %
The Tingstad Tunnel	8 %	6 %	1 %	0 %
Ullevigatan	8 %	6 %	8 %	3 %
Willinsbron	1 %	2 %	-4 %	2 %
The Älvsborg Bridge	-1 %	21 %	-16 %	20 %
Örgrytevägen	-6 %	1 %	0 %	0 %

5.3 Change in Travel Time

For travel time only the years of 2016 and 2017 have been analyzed, as mentioned in Section 3.4. See Appendix D for the travel time for the analyzed roads.

During the reference year of 2016 the travel time in the area of Centralstationen is quite constant between the months, with the Götaälv Bridge as an exception, which has had a declining trend during this time. The 15th and 85th percentile has a quite large span for the roads, where the 85th percentile in some cases are more than twice the travel time compared to the median travel time.

The travel time did in general increased in both directions between 2016 and 2017 in the area of Centralstationen. The Götaälv Bridge had a quite large increase in travel time compared to 2016 in both directions, see Figure 5.5. However, in the direction towards the city center the median travel time during January actually decreased. In addition to a overall increase in median travel time the travel time span also increased. On the E45 in the area of Centralstationen the travel time and travel time span also increased significantly, see Figure 5.6. Only one road in the area experienced a decrease in travel time, Polhemsplatsen in the direction away from the city center. However, the travel time span did not decrease and during some months it actually increased, see Figure 5.7. Another road that stands out is Odinsgatan in the direction towards the city center, which has had a slight increase in travel time between the years. However in June, 2017, the travel time span increases dramatically. Partihandelsgatan has had a huge increase in travel time starting from March 2017.

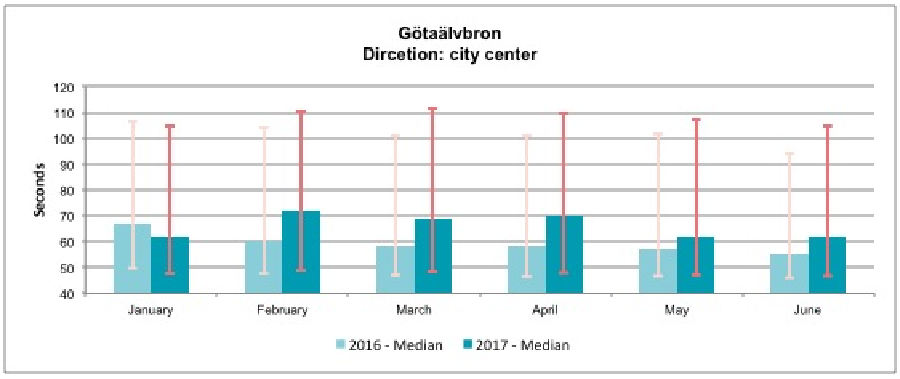


Figure 5.5: Median travel time, with 15th and 85th percentile for the Götaälv Bridge in the direction towards the city center. For other direction see Appendix D.

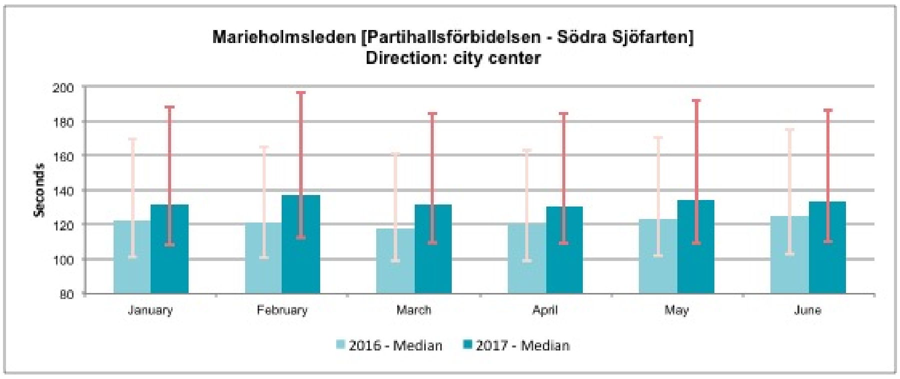


Figure 5.6: Median travel time, with 15th and 85th percentile for Marieholmsleden/E45 in the direction towards the city center. For other direction see Appendix D.

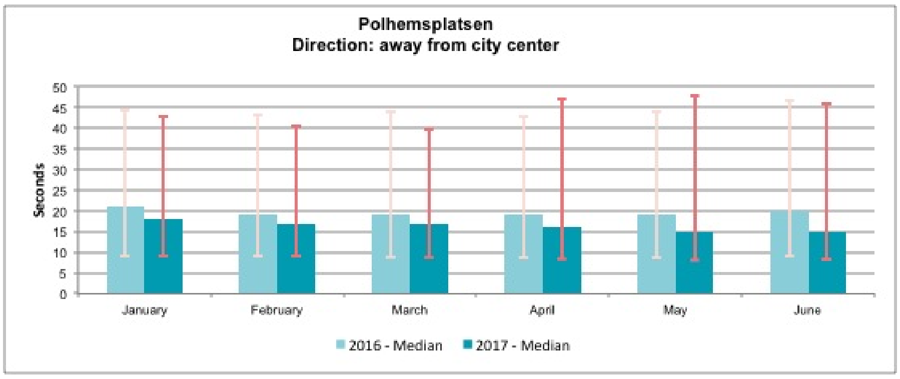


Figure 5.7: Median travel time, with 15th and 85th percentile for Polhemsplatsen in the direction away from the city center. For other direction see Appendix D.

The median travel time for the alternative roads are quite even throughout 2016. An exception is the Älvsborg Bridge in the direction away from the city center, where the median travel time during March, May and June are somewhat longer than during January, February and April. Another exception is the Tingstad Tunnel, which seems to have had a increasing trend during 2016 in the direction away from the city center. The travel time span, between the percentiles, is very mixed. Some roads like the Angereds Bridge and Oscarsleden had a more narrow travel time span while the 85th percentile almost doubled in travel time for Ullevigatan and Engelbrektsgatan (150).

The travel times on the alternative roads did not change between the years significantly with some exceptions. On the road of Engelbrektsgatan (149) travel time increased slightly in both directions, but the travel time span increased more distinct. This especially during April, see Figure 5.8. Like for Engelbrektsgatan some months stand out for other roads as well. In February on Hjalmar Brantingsgatan in the direction away from the city center the median travel time increased by almost a minute compared to 2016, see Figure 5.9. The other months does not show any signs of a significant difference. Another month that stands out is June on Ullevigatan towards the city center, where the median travel time increased fourfold. On the Älvsborg Bridge in the direction away from the city center experienced a significant decrease in median travel time during March 2017 compared to 2016, but a increase in April. The following roads had a unrealistically high increase in traveling time for all or some months of 2017; Kungsbackaleden, Olskroksmotet (City center), Oscarsleden and the Älvsborg Bridge (City Center).

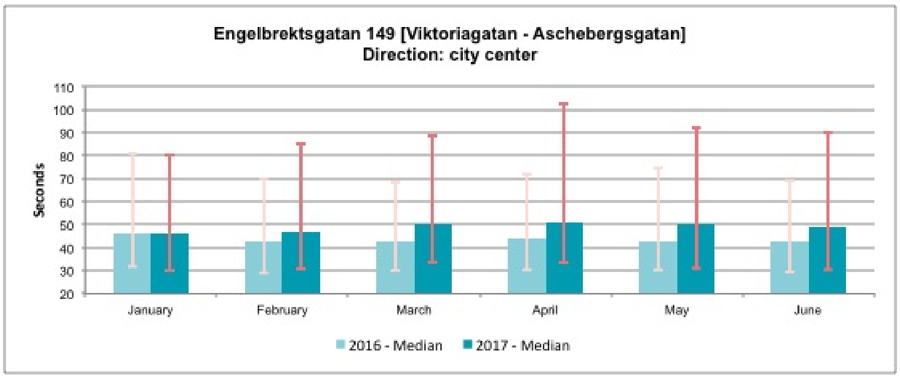


Figure 5.8: Median travel time, with 15th and 85th percentile for Engelbrektsgatan (149) in the direction towards the city center. For other direction see Appendix D.

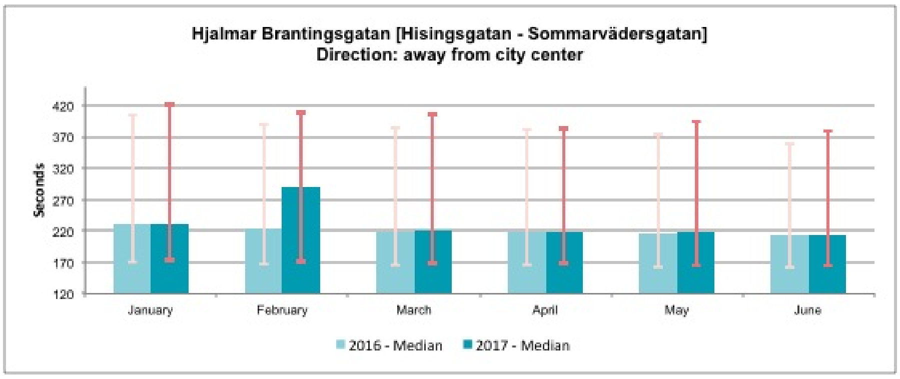


Figure 5.9: Median travel time, with 15th and 85th percentile for Hjalmar Brantingsgatan (away from city center). For other direction see Appendix D.

6 Analysis of Results

The affecting aspects analyzed are change in peak hours, traffic flow and travel time. It will also be discussed whether a increased travel time leads to a traffic flow reduction.

Some roads where a change in peak hours, traffic flow or travel time have been identified might not be discussed. This is because a connection with the ongoing construction works around Centralstationen cannot be made.

6.1 Unchanged Peak Hours - Pointing to Other Type of Responses

The roads around Centralstationen have very defined peak hours in the morning and in the afternoon, which probably is due to commuter traffic. This with the exceptions of Partihandelsgatan and Gullbergs Strandgata (towards the city center). Partihandelsgatan, that only had one peak during the day, that occurs around 9 am for both directions, which is a bit late for the general commuter traffic. This peak could be due to the delivery of goods, since a logistics terminal is located close by. Another exception to the general peak hours in the area are on Gullbergs Strandgata, in the direction towards the city center. On this road three peaks occurs, in the morning, middle of the day and during the afternoon. The additional peak in the middle of the day cannot be seen to the same extent on other roads in the area. This peak could be explained by that it occurs during lunch time. Areas that consists of offices and other workplaces to a high degree would probably experience this kind of peak.

The change in peak hours for the roads around Centralstationen, seen in Section 5.1, are not that vast. However, on Drottningtorget in the direction towards the city center the peaks occur somewhat earlier during the afternoon and last longer, see Figure 5.1. This indicates that some road users might have adapted to a new set of conditions planing their trip ahead, avoiding the worst traffic jams of the peak hour. This type of response is mentioned by Noland and Polak (2002), see Section 2.3. On Odinsgatan in the direction away from the city center the morning peak have almost been erased, pointing to that commuters are choosing another route during 2017 compared to 2015 and 2016, see Figure 5.2. This could possible be due to that the capacity of the road or connecting roads have decreased, creating congestion and discourage people from using the road to the same extent as before. This while there are other viable options for rerouting.

The alternative roads have the same structure as the roads around Centralstationen, with distinctive morning and afternoon peaks. The peaks have not changed that much between the years, but the peaks of Lundbyleden have had some interesting changes, see Figure 5.4. In the direction away from the city center the peaks occurs earlier in the morning compared to the reference years. The afternoon peaks in the direction towards the city center occurs a bit earlier as well. This could be in response to the construction work affecting the Götaälv Bridge, since these two roads are directly connected. The access to the bridge from Bergslagsgatan will be closed and the only access to the bridge will be via Drottningtorget, see Section 4.3.1. This might have the affect that road users adapt their time of departure to make up for the time lost. The morning peaks going away from the city center on Lundbyleden are not as distinct and have become somewhat wider, which could point towards this as well. The change in these morning peaks become more clear in March on wards.

The fact that the peak hours occur on the same time and are unchanged are probably due to that work hours are generally the same. If these were to change, or if flexible work hours were implemented to a higher degree, it is possible that the peak hours would have been more affected.

6.2 Reduced Traffic Flow - Rerouted Traffic and a Total Decline

The traffic flow have changed significantly on many roads in the area of Centralstationen and a clear decline can be observed. However, the fact that the decline varies a lot depending on the direction of the roads is interesting. This is especially clear on Friggagatan and Odinsgatan. That these two roads displays the same kind of pattern is not surprising since they are directly connected. One explanation to why this increase in traffic towards the city center is observed could be due to that the access to the Götaälv Bridge have changed. The road users that usually accessed Hisingen through the ramp by Bergslagsgatan, might have accessed the bridge via Friggagtan, Odinsgatan and finally Drottningtorget instead, see Figure 6.1. The traffic flow on the E45 declined in this direction towards the bridge by approximately 3 200 veh/day while Friggagatan in the same direction increased with only about 2 500 veh/day and Odinsgatan with 1 700 veh/day. Since there was a difference in the number of vehicles between the two connected roads it should mean that about 800 veh/day turns before reaching Odinsgatan. This only explains a part of the missing vehicles on the E45. The 800 veh/day, which turns before Odinsgatan, can partly be seen as a increase on Ullevigatan and Parkgatan leading towards the western parts of Gothenburg. The increase in traffic on this route can be seen already in January, which means that a part of this increase can be due to something else since the closing of the access ramp occurred in February, 2017.

One theory is that cars from the road E20 from Stockholm, that earlier accessed the Götaälv Bridge and Hisingen via the E45, as mentioned earlier in Section 4.3.1, go via Olskroksmotet, Firggagatan, Odinsgatan and Drottningtorget. This despite the attempt to reroute traffic to the Tingstad Tunnel, see Section 4.3.1. This seems to add up with that there has been no recorded increase in traffic on Redbergsvägen, which is the other road connected to Friggagatan. These road users probably have been discouraged from using the Tingstad Tunnel as well since it handles by far the most amount of traffic in Gothenburg and probably have a high degree of saturation. In this case the traffic have been able to reroute in the affected area fitting the second category mentioned by Goodwin et al. (1998). The capacity have declined on the affected road, but other roads within the area have enough spare capacity to be able to handle the extra traffic flow.

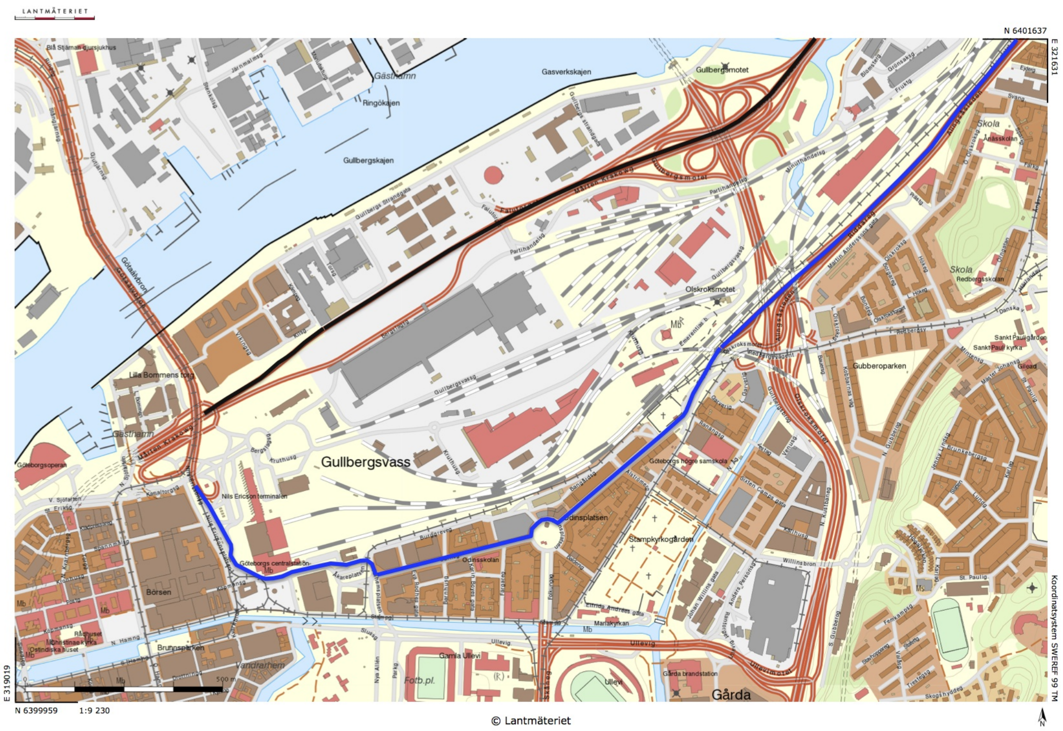


Figure 6.1: Overview over where traffic from Marieholmslede/E45 might have transferred. Blue line represent the new route and the **black line** represents the original route. ©Lantmäteriet with own symbols.

In the direction away from the city center on Friggagatan and Odinsgatan the traffic flow decreased. This decrease is more difficult to explain. It seems to match up with decline in traffic flow leading in this direction on the Götaälv Bridge, since the bridge leads to Nils Ericsonsgatan and later to Drottningtorget this decline could be a part of the explanation. Why this direction have not been affected in a similar manner as the direction towards the city center is probably due to that traffic rerouted in the Tingstad Tunnel and Angereds Bridge to a higher degree in this direction.

The Götaälv Bridge had a significant decrease in traffic flow of 22 and 23 % in the different directions compared to both reference years. This is probably due to the capacity reduction caused by the construction work of the Hising Bridge and the E45 directly affecting the bridge by closing down the access to the bridge from Bergslagsgatan. This can be seen in the direction away from the city center, where the traffic reduced significantly between January and February. The reduction in the other direction could possibly be due to the construction work on the E45, which would be a possible route for road users using the bridge. The complex situation on the E45 would be discouraging enough to reroute as well as the longer travel time. According to the study conducted by Brogren and Sjöstrand (2016) over half of the vehicles that uses the Götaälv Bridge also uses the road of Nils Ericsonsgatan. With a change in traffic flow only 28 % of the vehicles that used this route decided to stay on it, see Section 4.2. This cannot be seen to such a large extent, even though the traffic flow decreased on Nils Ericsonsgatan. It could simply be that the rerouted traffic was replaced by other traffic.

It was predicted that the traffic situation on Partihandelsgatan was going to be more strained, see Section 4.3.5. A increase of 22 % (2015-2017) and 25 % (2016-2017) in traffic flow can be seen in the direction towards the city center during this period. However, the measurement point is located just before the Gullbergsvass junction, which means that this increase is not due extra traffic coming from the E6 or the E45 by Falutorget. It could be that road users changed their choice of route even earlier, by Partihallsförbindelsen, where there is a possibility to exit the E45 towards the city center, see Figure 6.2. This would explain some of the lost traffic on the E45 as well. The road users that was taking this route probably have the central station or the area around Nordstan as their destination, since the exit by Norra Sjöfarten is closed, see Section 4.3.2.

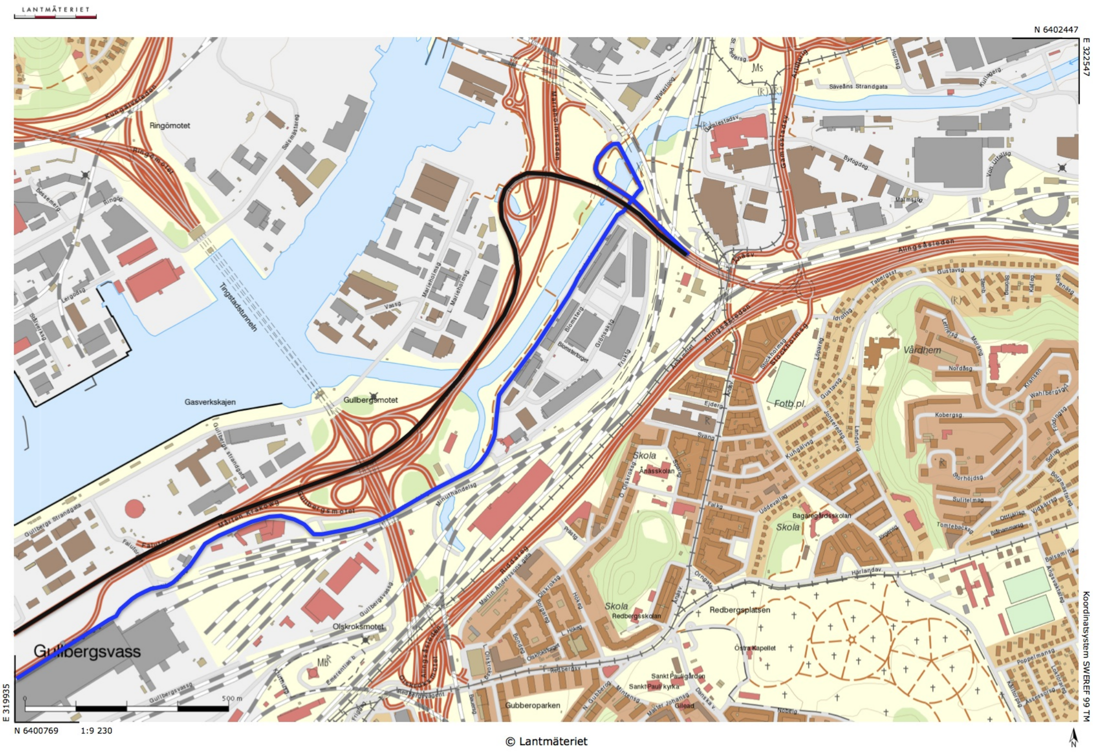


Figure 6.2: Overview over where traffic from Marieholmslede/E45 might have transferred. The Blue line represent the new route and the **black line** represents the original route. ©Lantmäteriet with own symbols.

The missing vehicles still unaccounted for on the E45 is probably road users that have chosen other means of transportation. This probably due to that the number of lanes was reduced and narrowed down, in both directions as well as the closed exits. This in addition to that the speed was reduced with 20 km/h. As mentioned in Section 2.2, these kind of changes ultimately leads to a reduced capacity on the road and could result in a bottleneck situation.

Concerns were also raised for the traffic situation on Gullbergs Strandgata. The traffic flow increased comparing 2015 and 2017 with 4 % towards and 3 % away from the city center. However, when comparing the years 2016 and 2017 instead a decreased of 6 % was observed on this road in both directions. During the months January, February and March the traffic clearly decreased between 2017 and the two reference years, see Figure 6.3. This could have been a response to the more strained situation on this road that discourage road users from taking this route. As mentioned in Section 4.3.2 it was possible that Gullbergs Strandgata could have reduced capacity in the beginning of 2017 due to a construction work east of Stadstjänaregatan as well as the construction of a roundabout. However, the predicted increased traffic cannot be seen during this stage of the ongoing projects.

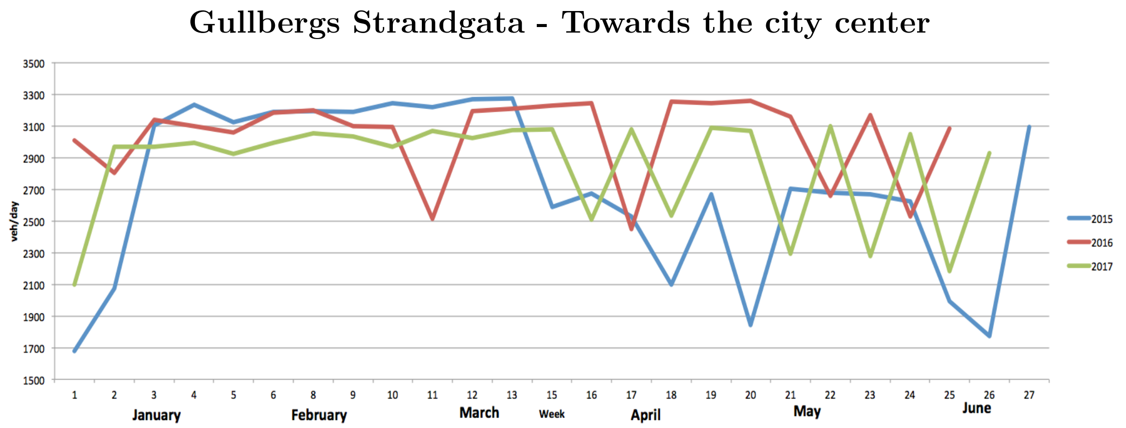


Figure 6.3: Traffic flow for an average day for each week between January and June for the years 2015, 2016 and 2017, for Gullbergs Strandgata in the direction towards the city center. See Appendix C for other direction.

As mentioned in Section 2.1 the intersection along a stretch of road is one of the main governing factors for the capacity of the road. This would be especially true for the area around Centralstationen, since the intersections in this area probably would have a high degree of saturation. Public transport and specifically trams is often prioritized in the intersection and should therefore decrease the capacity even further on the roads. However, no evidence of the contribution of intersection towards the situation around Centralstationen have been found.

As mentioned in Section 5.2 the total amount of traffic declined in the area of Centralstationen. However, where the traffic moved is uncertain. The change in traffic flow for the alternative roads have not been as distinguished as for the roads around Centralstationen. This should mean that the traffic have decline overall in whole of Gothenburg. A good indicator of this should be to study the passages over Göta älv, see Figure 6.4. The link in traffic flow between the different passings have been established before as mentioned in Sections 4.2 and 2.5.2. The traffic flow passing the Götaälv Bridge declined with about 4 500 veh/day. This while the Tingstad Tunnel increased with about 800 veh/day, the Angereds Bridge with 950 veh/day and the Älvsborg Bridge was on the same level of passings while comparing the years 2016 and 2017. This means that the remaining 2 750 veh/day vehicles probably are road users which transferred to other means of transportation. However, this cannot be verified in this report. The Älvsborg Bridge had about a 6 000 veh/day increase in the direction away from the city center but it declined with roughly the same amount in the other direction. This is almost without a doubt due to the maintenance work on the bridge, see Section 4.4, which affected different directions both years. The total number of passings over Göta älv indicates that the number of vehicles overall reduced in Gothenburg. Where these road users transferred is unclear, but it is likely that some was discouraged of using their car and started using the public transport system instead. This fits the third category of what happens when a road experience a capacity reduction mentioned by Goodwin et al. (1998), see Section 2.1. The roads in the affected area, in this case the passings over Göta älv, does not have enough capacity to handle the extra offset traffic and therefore a overall decline in traffic can be seen. It could also be due to that the detours that had to be made are to extensive travel time wise or just to complicated. As mentioned in Section 2.5.2 one link is missing and that is the bridge of Jordfallsbron, which serves as a link between the E45 and the E6. For a more secure result the traffic flow on this bridge has to be investigated.

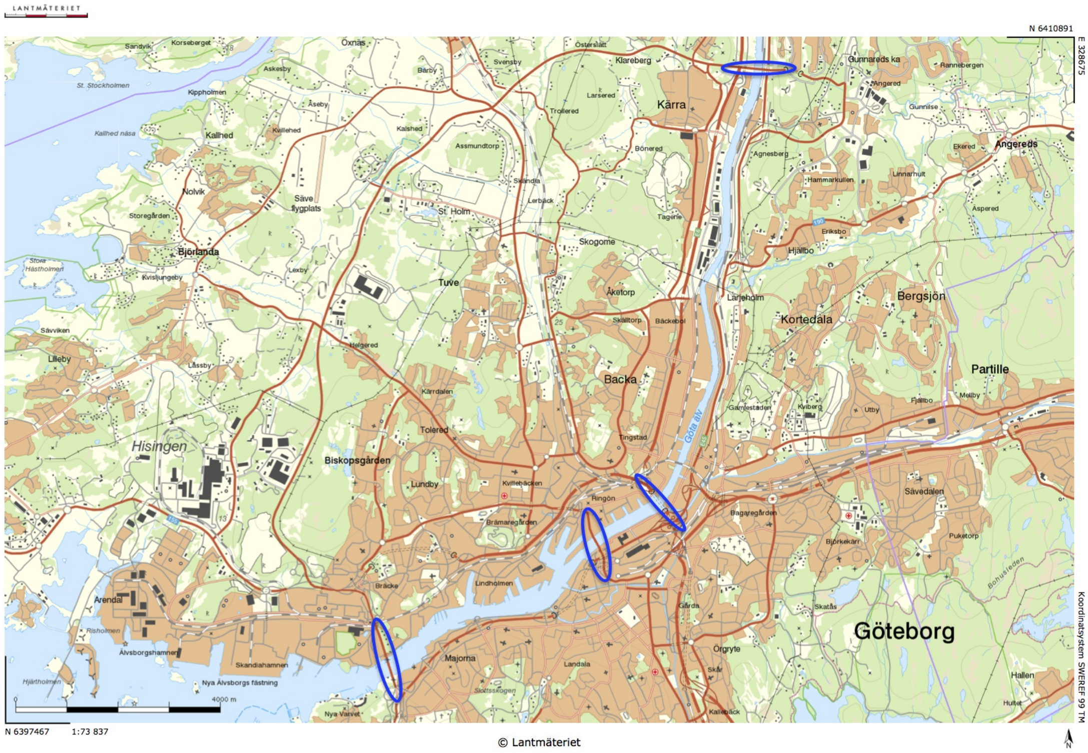


Figure 6.4: Overview of the possible passings over the river Göta älv. The Älvsborg Bridge, Götaälv Bridge, Tingstad Tunnel and Angereds Bridge. ©Lantmäteriet with own symbols.

The total decline in traffic flow for the area of Centralstationen was 7 % between 2016 and 2017. That is more than what the traffic declined with in the central parts between the years 2015 and 2016, which was 1,1 % according to Trafikkontoret (2016). In this study the traffic actually increased with 5,3 % for the analyzed roads around Centralstationen between 2015 and 2016. This could be due to that only a few roads in the area are considered. However, this indicates that the traffic flow in the area have been affected by something more than just the regular yearly change, which has been ongoing since 1988 for the central parts, see Section 4.1.

When the capacity in the Tingstad Tunnel was reduced, see Section 2.5.2, a redirection of traffic could be seen on the Götaälv and Älvsborg Bridge, in contrast to the case in this study. This could be due o that the Tingstad Tunnel is already running at maximum capacity, meaning that additional traffic is not possible. Another important difference between the cases are that during the time of the capacity reduction in the Tingstad Tunnel there were no ongoing maintenance work on the

Älvsborg Bridge, and therefore additional vehicles could be redirected. However, the perhaps biggest difference between the cases is that the capacity reduction in the Tingstad Tunnel was introduced during a weekend, when the traffic flow is usually lower and more even over the day.

Hjalmar Brantingsgatan is one of alternative roads where a change of traffic flow was noticed. The road have experienced a decline of 11 % towards the city center and 7 % away from the city center between 2016 and 2017. In total 2 000 veh/day for both directions. This could be due to that it is directly connected with the Götaälv Bridge and therefore should have a decline in traffic flow. But that leaves us with a large chunk of vehicles unaccounted for.

The other big link leading towards the Götaälv Bridge on Hisingen is Lundbyleden. On this road a total decline of 1 350 veh/day between 2016 and 2017 have been observed. However, in the direction towards the city center the traffic flow increased. These numbers are a bit uncertain since there a lot of missing data from 2016. A similar pattern can be seen comparing 2015 and 2017, with a increase in traffic towards the city center and a decrease in the other direction. This could be explained by that Lundbyleden is also connected to the Tingstad Tunnel and via Kungälvsleden also the Angereds Bridge, which are two of the possible routes bypassing the Götaälv Bridge. It is possible that this increase are vehicles which usually used the Götaälv Bridge but rerouted towards these two passings instead, see Figure 6.5. But then again the Tingstad Tunnel had a increase in traffic flow between 2015 and 2016 as well. This could mean that the increase is due to something else. The Angereds Bridge increased more significantly in 2017 compared to the reference years.

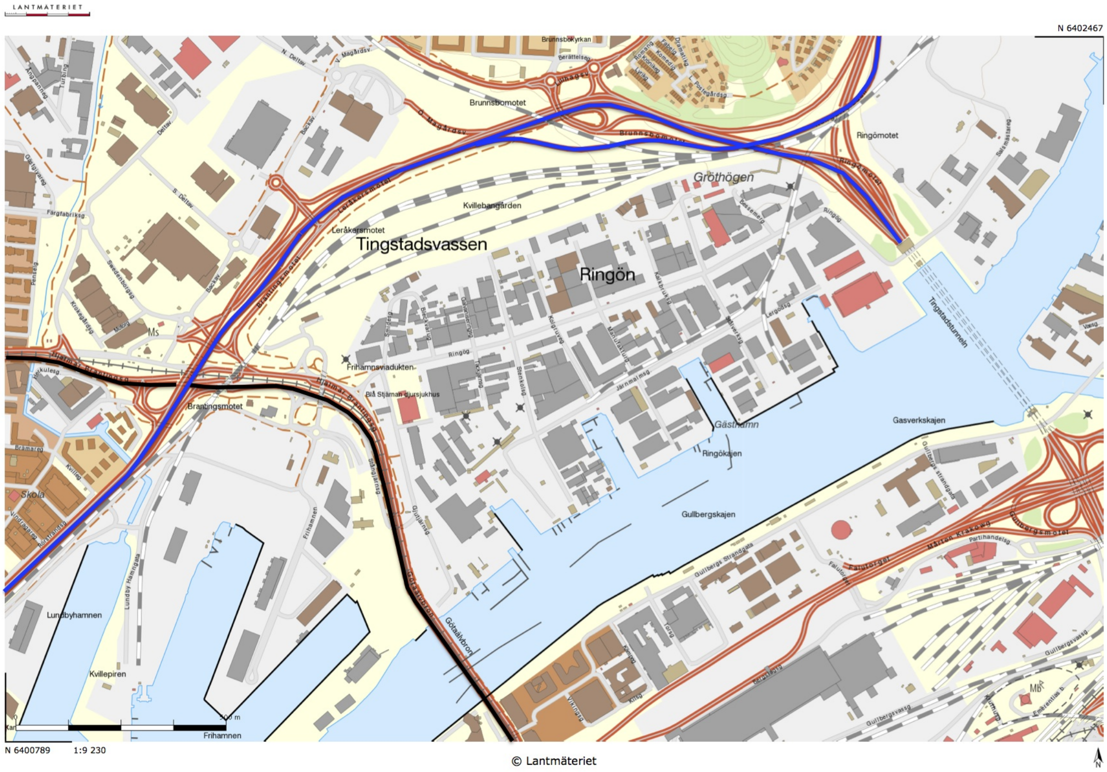


Figure 6.5: Overview over where traffic from Götaälv Bridge - Marieholmsleden/E45 might have transferred. The Blue line represent the new route and the **black line** represents the original route. ©Lantmäteriet with own symbols.

Another road outside the area of Centralstationen which has had significant changes is Oscarsleden. This road decreased with approximately 6 000 veh/day, 3 400 veh/day towards the city center and 2 800 veh/day away from the city center. This could be due to that this roads is directly connected to the E45 and the Älvsborg Bridge, both which experienced maintenance work during this time. However, the traffic flow declined even more than on the E45 this could perhaps be explained by that Oscarsleden serves as the link between the western parts of Gothenburg and the city center and due to the complex situation around Centralstationen road users have simply re-routed or been discourage to use their car.

As described in Section 4.3.2 road users traveling west on the E45 have the possibility to exit the road either by Falutorget or by Järntorget. This can be seen to some extent on Emigrantvägen, which leads from the exit by Järntorget the central parts of Gothenburg. In this direction, towards the city center, the traffic flow increased by 21 % (2015-2017) and 30 % (2016-2017). This increase started in February, which is the same time as the closing of the exit by Norra Sjöfarten.

According to the literature when a capacity reduction is introduced the traffic flow should stabilize within the first year of implementation, see Section 2.3. This seems to correspond with the traffic flows around Centralstationen. After a disturbance is introduced the traffic flow seems to reduce and after that stay on the same level not fluctuating that much.

6.3 Changes in Travel Time - A Total Increase

As described in the result the travel time of the roads around Centralstationen generally increased in both directions, especially on the Götaälv Bridge and the E45 (Marieholmsleden). The travel time on the Götaälv Bridge increased significantly, with January in the direction towards the city center as an exception. During this month the travel time actually decreased between 2017 and 2016, see Figure 5.5. However, if January were to be excluded from the numbers, the travel time increased with about 16 % towards the city center. This increased travel time is probably directly connected the closing of a access ramp to the bridge, which occurred in February, and the strained situation on the E45. The span between the percentiles have also increased during this time. This probably indicate that the difference in travel time between the hours of the day have increased. This makes it harder for road users to plan their trips ahead since the travel time is hard to predict. This big increase in travel time cannot be seen on the other roads directly connected with the bridge. However, during June the bridge was closed for trams, see Section 4.3.1, and extra buses had to replace them. This could be a explanation to the change seen on Drottningtorget in the direction away from the city center, where the travel time increased quite much, see Figure 6.6. During this time it was not only the median travel time that increased but also the span between the percentiles as well.

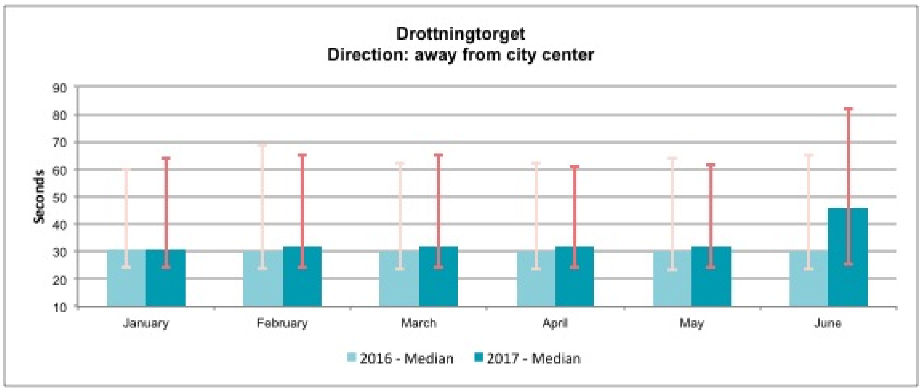


Figure 6.6: Median travel time, with 15th and 85th percentile for Drottningtorget in the direction away from the city center.

The other significant change in travel time that can be seen is on the E45. This road, as the Götaälv Bridge, is directly affected by the ongoing maintenance works. The median travel time have increased with about 10 % towards the city center and 7 % away from the city center. The travel time span have also increased, especially during February in the direction away from the city center, see Figure 6.7. This is probably due to that the lanes were narrowed down and the speed limit was reduced from 70 km/h to 50 km/h, see Section 4.3.1.

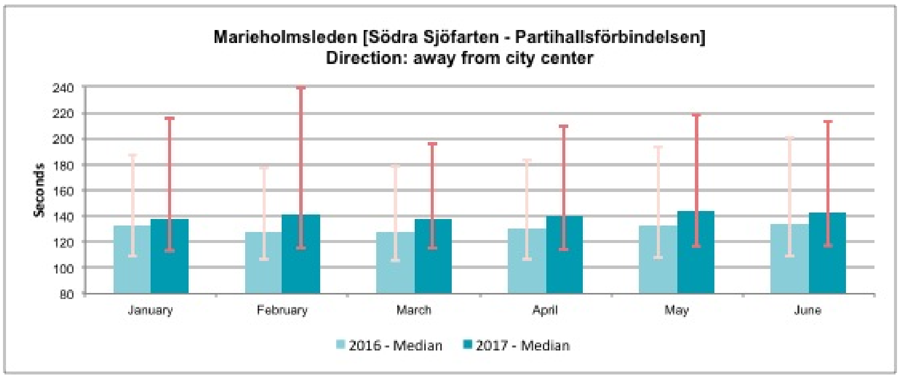


Figure 6.7: Median travel time, with 15th and 85th percentile for Marieholmsleden/E45 in the direction away from the city center.

On Odinsgatan and Friggagatan the travel time in the direction towards the city center increased slightly, probably due to the big increase in traffic flow. But a more significant change can be seen on Odinsgatan in June in this direction, especially the 85th percentile, see Figure 6.8. This change in June might be connected to the increased number of buses on the Götaälv Bridge and Drottningtorget, as mentioned before. The travel time also increased during April and May, this could be connected to the construction of the roundabout and bus stops by Åkareplatsen, see Section 4.3.4. For the roads Friggagatan and Odinsgatan in the direction away from the city center the travel time have increased just slightly. Since there have been no recorded disturbances on these roads this increase is hard to explain. However, the roundabout connecting the two roads by Odinsplatsen might be a part of the explanation. A larger number of vehicles have been observed taking a left turn in this roundabout from Friggagatan towards Skånegatan. This might lead to that cars going straight in the roundabout from Odinsgatan onto Friggagatan have to wait in order to cross.

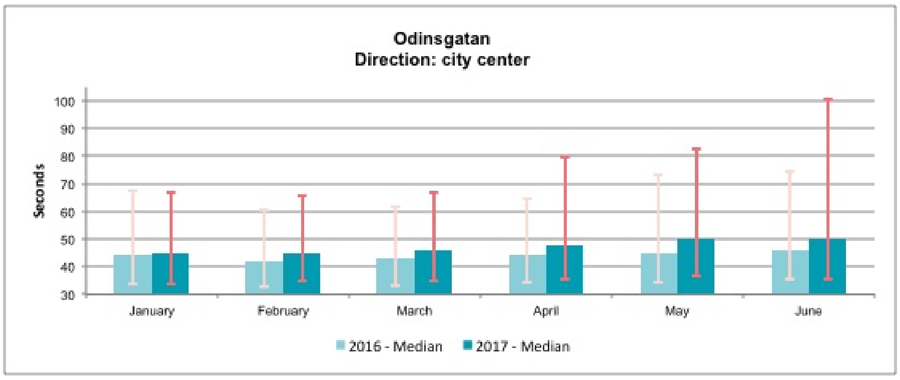


Figure 6.8: Median travel time, with 15th and 85th percentile for Odinsgatan in the direction towards the city center.

The decrease in travel time on Polhemsplatsen, in the direction away from the city center, see Figure 5.7, does not mean that the capacity of the road increased. It might say that the degree of saturation on the roads varies a lot during the day. This theory is supported by that the 85th percentile have stayed on the same level and during some months increased. The increase of the 85th percentile occurs during April and May, in both directions. This could be due to the construction of new bus stops and the roundabout as mentioned before, which started in April, 2017. It was predicted that this would decrease the capacity of the area as well.

A slight increase in travel time on Gullbergs Strandgata, maybe most clearly in January, 2017, in the direction towards the city center can be observed, see Figure 6.9. This is the same time as it was predicted to be more strained due to the construction work and the implementation of a roundabout as mentioned in Section 6.2. The travel time in this direction seems to have a declining and stabilizing trend, either the capacity of the road improves or road users adapt to the new conditions as mentioned in Section 2.3, choosing another route instead. The percentiles have a more narrow span compared to 2016 as well pointing towards improved conditions.

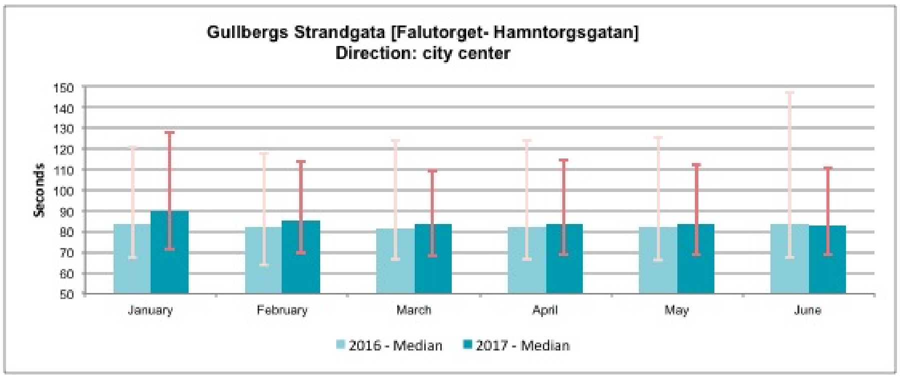


Figure 6.9: Median travel time, with 15th and 85th percentile for Gullbergs Strandgata in the direction towards the city center.

The travel time of the alternative roads did not change that much and probably not as a response to the rerouted traffic caused by the construction works around Centralstationen. On the road Hjalmar Brantingsgatan the travel time increased during February. However, since the traffic direction is away from the central areas it is not likely that the ongoing works around Centralstationen contributed towards this. The other roads which have had a huge increase in travel time, as mentioned in the result, is probably due to other construction works closing down parts of the road or errors on the data. A increase in travel time of 5-10 times compared to the reference year of 2016 is not deemed likely.

As mentioned in Section 6.2 the traffic missing on the Götaälv Bridge does not seem to have rerouted to the Tingstad Tunnel to a high degree. However, it can be seen that in the direction away from the city center the travel time have increased from February on wards in the Tingstad Tunnel, see Figure 6.10. This is the same time of the closing of the access ramp to the Götaälv Bridge from Bergslagsgatan. This indicates, contrary to the traffic flow, that traffic has indeed increased in the Tingstad Tunnel in this direction.

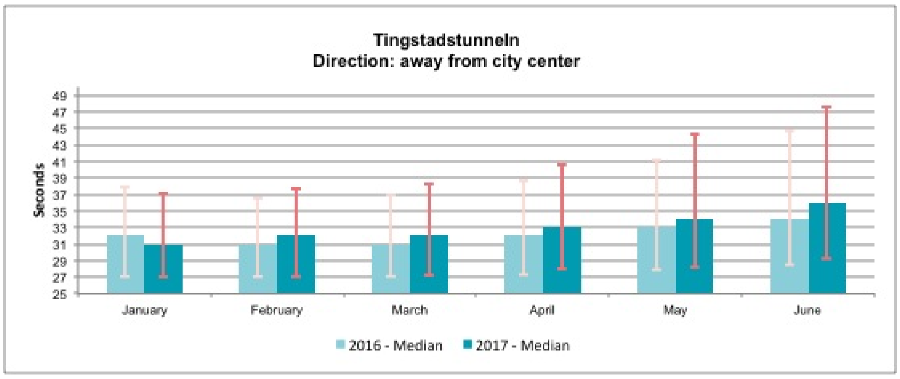


Figure 6.10: Median travel time, with 15th and 85th percentile for the Tingstad Tunnel in the direction away from the city center.

6.4 Relation Between Traffic Flow and Travel Time

Road works often lead to that lanes are closed or narrowed down, which could lead to a congested situation and increased travel time, see Section 2.2. According to the theory an increase in travel time should be followed by a decrease in traffic flow, see Section 2.1. This can be seen in the area of Centralstationen where the travel time generally increased and the traffic flow decreased dramatically. A response to the increased travel time could be that road users plan their trip ahead, starting earlier or later in order to avoid the most congested times of the day, see Section 2.3. This cannot be seen to a larger extent in the area, with the exception of Drottningtorget. Why this is not seen could be due to that vehicles probably have rerouted as a response instead. Another explanation to why no major changes in peak hours could be seen is that there are a lot of buses in the area. According to (Brogren and Sjöstrand, 2016) about 4 000 trams and buses traffic the central areas of Gothenburg and many of them around Centralstationen. The public transport cannot use alternative roads to avoid long travel times but have to stick to the planned route. They also need to keep the time table so to avoid the most congested hours of the day is not possible.

The relation between travel time and traffic flow is difficult to establish for single roads since there are many other affecting factors. However, this might been seen on the Götaälv Bridge in the direction away from the city center. During January the traffic flow increases, see Figure 6.11, increasing the degree of saturation of the road, and ultimately increasing travel time. During February the traffic flow decreases rapidly, while the travel time increases slightly, see Figure 6.12. The travel time seems to reach its maximum peak during February, which could mean that the travel time is higher because of a higher amount of traffic flow in the beginning of the month. According to the litterateur, drivers should be able to adapt to the new conditions in a few days, but in this example it seems to take much longer, see Section 2.3.

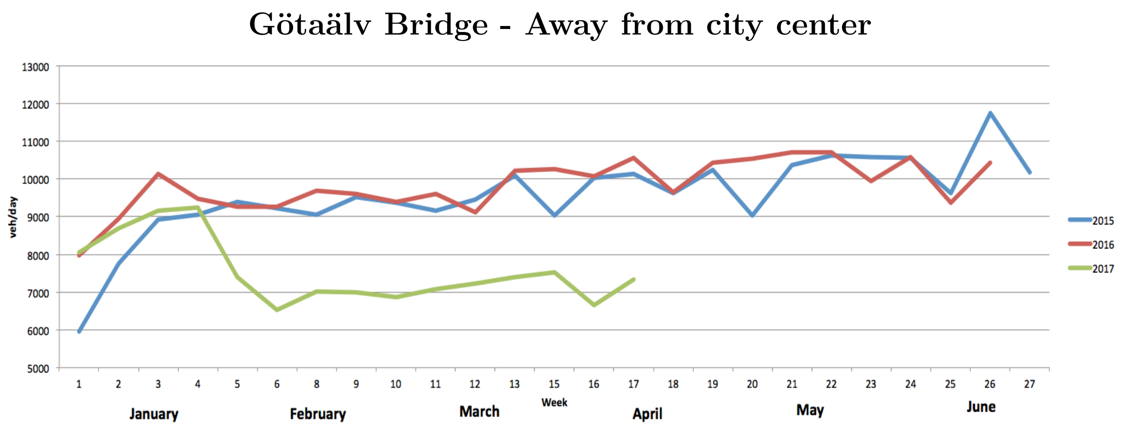


Figure 6.11: Traffic flow for an average day for each week between January and June for the years 2015, 2016 and 2017, for the Götaälv Bridge in the direction away from the city center.

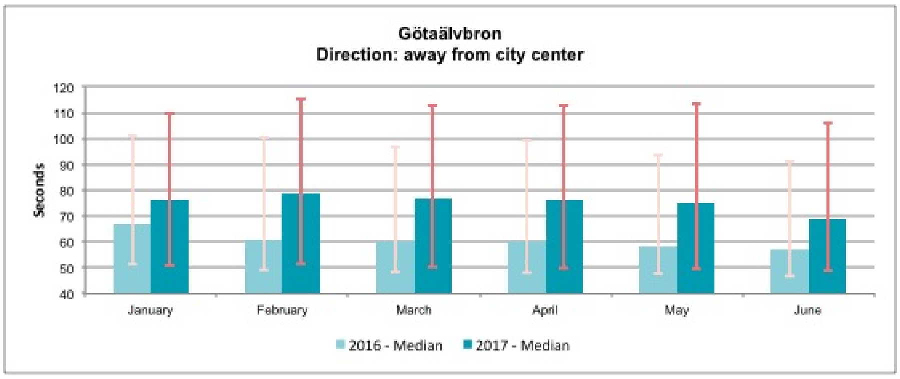


Figure 6.12: Median travel time, with 15th and 85th percentile for the Götaälv Bridge in the direction away from the the city center.

A transfer of vehicles to alternative roads could be seen to some extent but far from all of the missing vehicles on the bridge could be explained by this. This could mean that the alternative roads did not have the spare capacity to handle the increase, or that the alternative detour was more time consuming than the original route. Since no difference in peaks could be seen either little response has been made, at least until the number of vehicles dropped dramatically from February on wards. One explanation to why no or lite change in peak hours is seen could be due to that the bridge is used to a high extent of public transport.

If the decreased traffic is due to longer travel times cannot be proven even if a connection might exist. The decrease in traffic flow could be due to other factors as well, such as a more complex traffic situation and completely closed roads.

7
Discussion

This chapter will discuss what could have affected the result of the study and its reliability. Further research within the topic will also be suggested.

Selection of the Roads

The selected roads for the study, described in 3.1, have been selected on the basis that it goes through the area of Centralstationen or is a part of a stretch that does so. However, some roads have not been accounted for due to lack of data and therefore some trends and changes in the area might have been missed. Many of the roads in this area are connected to one another as well and affects each other to a high degree.

Some key roads around the area of Centralstationen that had missing data and could have been of importance for the study of where traffic might have diverted. This is especially true for Norra Sjöfarten, Västra Sjöfarten, Hamntorgsgatan and the E45 closer to Centralstationen. These roads are mentioned in the report describing the traffic during the time of the construction works.

It might be possible that the alternative roads chosen are not subject of rerouted traffic as well, but rather due other changes around Gothenburg.

Missing Traffic Flows and Data

For the traffic flow some errors have been identified. One could be the situation when a road is closed down entirely or traffic have been redirected into the other lane. This would mean that the numbers could be skewered. In some cases the direction of the traffic flow have been switched in the year of 2017. This could be seen clearly on the road of Säröleden were the peaks where inverted for 2017, see figure 7.1. This was corrected for this road, but this might have been missed where the peaks are not as distinct. However, for the roads of Friggagatan and Odinsgatan where a huge increase in one direction and a decline in the other was noticed, this might have been a possibility. The peaks for these roads seem to match between the years.

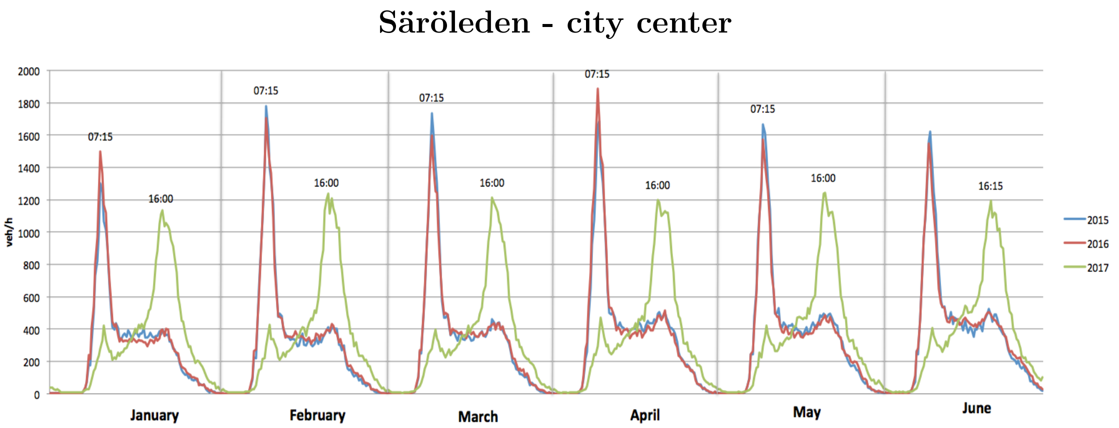


Figure 7.1: Average daily traffic flow variation each month for the years 2015, 2016 and 2017 for Säröleden with switched directions. The X-axis shows 24 hours for each month.

Some changes in traffic flow that are general for almost all of the analyzed roads are a big incline in the beginning of the graph as well as a dip by week 25. The incline in the beginning is probably due to the Christmas holidays. Since the roads are very commuter based it affects the traffic flow to a high extent. The dip by week 25 is probably due to Midsummer, which in retrospect should have been neglected.

Factors Affecting Travel Time Data

One source of error for the travel time that could be discussed, especially for the roads around Centralstationen, is that buses in the public transport system affect the recorded travel time. Since the travel time data comes from both the passenger and telematic data the result might be a bit skewered. This due to that the passenger data might be from passengers riding the buses, in which case the buses affect the result more heavily The decision of using both types of data was due to the telematic data was not extensive enough to give proper data for the roads, but the quality of the data is more reliable than for the passenger data.

The almost extreme increase in travel time on Oscarsleden starting from February and March 2017 in both direction is probably due to something more than just a reduced capacity, see Appendix D. This kind of extreme increase could be seen on Gullbergs Strandgata before it came to knowledge that a part of the road had been closed, preventing cars from using the road. In that case vehicles had to reroute much further before being recorded again by the point of destination, increasing travel time a lot.

The result could also have been affected by the fact that travel time data was only available for the years of 2016 and 2017, and not 2015. Additionally, only the average and median travel time was available for the years of 2016 and 2017.

The result of the study might not be that reliable concerning specific numbers. However, trends and changes seen are probably more so, since a clear distinction can be identified between the years.

Further Studies

To increase the understanding of the change in traffic flows during the construction works, a study to see if the number of travels with the public transport system increased could be interesting. This could explain some of the missing vehicles in the area. This as well as the number of cyclists, which also could be a alternative to the car as the mean of transportation. Although the road system is extremely complex, it would be interesting to see what happens after the construction works stops affecting the traffic. Will the traffic divert back to the original routes? Will it attract additional traffic? Since induced traffic is mentioned in 2.1 and could be evidence of the opposite, this would be a good complimentary study.

It would also be interesting to see what happens when the construction works concerning Västlänken goes into a more primary stage. This would affect the traffic around Centralstationen even more and more vehicles would have to use alternative roads or different means of transport to avoid longer travel times.

8 Conclusion

It is quite clear that the ongoing constructions works in the area have affected the traffic. The traffic flow decreased while the travel time increased.

The road users did not adapt to the new conditions by changing their time of departure to avoid the most congested times of the day. This can be seen because the peak hours did not change much between the years. As a response to the reduced capacity traffic seems to have rerouted to a larger extent instead.

Traffic reduced significantly in the area and moved to other nearby links to some extent. The big decline in traffic flow on the E45 was probably due to the reduced number of lanes, the narrowing of those lanes and the reduced speed limit. The missing traffic on the Götaälv Bridge could have rerouted to the Tingstad Tunnel and the Angereds Bridge, but only to a small extent. The closing of the access ramp to the Götaälv Bridge from Bergslagsgatan probably have had the biggest effect seen in this study. Road users affected by this have to a large extent rerouted from the E45 to Friggagatan and Odinsgatan to be able to access the bridge from Drottningtorget. The missing traffic on the E45 probably rerouted somewhat to Partihandelsgatan as well, but again only to a small extent. The lost possibility to exit the E45 by Norra Sjöfarten had the effect that more vehicles exit by Järntorget instead and access the central parts of the city via Emigrantvägen. The smaller ongoing construction works by Åkareplatsen affected the nearby road of Polhemsplatsen somewhat as well.

The other identified alternative roads did not receive extra traffic to the extent possible. This probably due to that the rerouting options were to extensive and did not reduce the total travel time. Traffic rather decreased overall in the area as a response to worsened conditions.

The travel time increased overall around Centralstationen especially on The Götaälv Bridge and the E45. On the alternative routes the travel time seems to be somewhat constant and therefore unaffected by the possible rerouted traffic.

To conclude, the traffic flow have declined and rerouted to some extent. The traffic, which rerouted, mainly did so to other roads within the affected area, but also somewhat to other links bypassing the river Götaälv. The travel time have increased in the affected area, probably contributing towards the changes observed.

Bibliography

Brogren, I. and Sjöstrand, H. (2016), Trafikutredning - centralenområdet, göteborg, Technical report, Trivector.

Downs, A. (2003), *Still Stuck in Traffic : Coping with Peak-Hour Traffic Congestion*, Brookings Institution Press, 1775 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Elefteriadou, L. (2013), *An Introduction to Traffic Flow Theory*, Vol. 84, Springer, Springer New York Heidelberg Dordrecht London.

Goodwin, P., Hass-Klau, C. and Cairns, S. (1998), 'Evidence on the effects of road capacity reduction on traffic levels', *Traffic Engineering and Control* .

Göteborgs Stad (2017*a*), 'Trafiknytt - åkareplatsen resecentrum'.

Göteborgs Stad (2017*b*), 'Trafiknytt - åkareplatsen resecentrum'.

Göteborgs Stad (2017*a*).
URL: *https://stadsutveckling.goteborg.se/sv/omradenprojekt/hisingsbron/*

Göteborgs Stad (2017*b*).
URL: *http://goteborg.se/wps/portal?uri=gbglnk%3a20160121430020581*

Göteborgs Stad (2017*c*).
URL: *http://goteborg.se/wps/portal?uri=gbglnk%3agbg.page.bb7386fd-1152-47cb-9da4-d06bd7780a77&projektid=TK0915/15*

Litman, T. (2017), 'Generated traffic and induced travel: Implications for transport planning', *Victoria Transport Policy Institute* **71**(4).

Noland, R. B. and Polak, J. W. (2002), 'Travel time variability: a review of theoretical and empirical issues', *Transport Reviews* **22**(1), 39–54.

Sjöholm, A. (2015), Trafikanalys tingstadstunneln, Technical report, Ramböll, Ramböll Sverige AB, Skeppsgatan 5, 211 11 Malmö.

Sjöholm, A. (2016), Trafikanalys tingstadstunneln uppföljning, Technical report, Ramböll, Ramböll Sverige AB, Skeppsgatan 5, 211 11 Malmö.

Sjöholm, A. (2017), Systemanalys, arbetsmaterial 2017-01-16, Technical report, Ramböll.

Strömgren, P. and Olstam, J. (2016), A model for capacity reduction at roadwork zone, Master's thesis, Royal Institute of Technology (KTH), Division of Transport planning, Economics and Engineering and Linköping University, Department of Science and Technology.

Tennøy, A., paal B. Wangsness, Aarhaug, J. and Gregersen, F. A. (2016), 'Experiences with capacity reductions on urban main roads – rethinking allocation of urban road capacity?', *Transportation Research Procedia* .

Trafiken.nu (2017).
URL: *https://trafiken.nu/goteborg/arkiv/2016/underhall-av-alvsborgsbron/*

Trafikkontoret (2013).
URL: $http://th.tkgbg.se/th_20132/sv-se/start.aspx$

Trafikkontoret (2016), Trafik- och resandeutveckling 2016, Technical Report 3617/16, Göteborgs Stad.

Trafikverket (2014), *TRVMB Kapacitet och framkomlighetseffekter: Trafikverkets metodbeskrivning för beräkning av kapacitet och framkomlighetseffekter i vägtrafikanläggningar*, Trafikverket.

Trafikverket (2017*a*).
URL: *http://www.trafikverket.se/en/startpage/projects/Road-construction-projects/e45-lilla-bommen–marieholm/*

Trafikverket (2017*b*).
URL: *http://www.trafikverket.se/nara-dig/Vastra-gotaland/projekt-i-vastra-gotalands-lan/Vastlanken—smidigare-pendling-och-effektivare-trafik/Om-Vastlanken/*

Trafikverket (2017*c*).
URL: *http://www.trafikverket.se/nara-dig/Vastra-gotaland/projekt-i-vastra-gotalands-lan/Vastlanken—smidigare-pendling-och-effektivare-trafik/aktuellt-i-ditt-omrade/deletapp-centralen/*

Trafikverket (n.d.), 'Information om ändring i trafiken e45 lilla bommen-marieholm februari 2017'.

Trafikverket, T. (2016), Trafik under byggtiden för centralenområdet år 2017, Technical report, Trafikverket and Göteborgs Stad, Trafikkontoret.

TRB (2000), *HIGHWAY CAPACITY MANUAL*, National Research Council, Transportation Research Board, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418.

Weng, J. and Yan, X. (2016), 'Probability distribution-based model for work zone capacity prediction', *JOURNAL OF ADVANCED TRANSPORTATION* **50**, 165–179.

Wood, D. A., Stewart, R. H., Coombe, D., Goodwin, P., Hills, P. J., Hutchinson, D. A., Mackie, P. J. and Taylor, M. E. G. (1994), 'Trunk roads and the generation of traffic', *The Depertment of Transport* .

Zaidi, K., Milojevic, M., Rakocevic, V., Nallanathan, A. and Rajarajan, M. (2015), Host based intrusion detection for vanets: A statistical approach to rogue node detection, Master's thesis, School of Mathematics, Computer Science and Engineering, City University and Kings College London.

A

Selected Roads

Table A.1: Selected roads in the area of the central station. The roads goes through the area. Internal roads in the area have been neglected

1. Drottningtorget	2. E45
3. Friggagatan	4. Gullbergs Strandgata
5. The Götaälv Bridge	6. Nils Ericsonsgatan
7. Odinsgatan	8. Partihandelsgatan
9. Polhemsplatsen	

Table A.2: Selected roads that could server as alternative routs bypassing the area around the central station

The Angereds Bridge	1. Dag Hammarskjöldsleden
2. Emigrantvägen	3. Engelbrektsgatan (149)
4. Engelbrektsgatan (150)	5. Första Långgatan
6. Hjalmar Brantingsgatan	7. Järntorget
8/9. Kungsbackaleden (1608)	8/9. Kungsbackaleden (1609)
Kungälvsleden	10. Lundbyleden
11. Nya Allén	12. Olskroksmotet
13. Oscarsleden	14. Parkgatan
15. Redbergsvägen	16. Skånegatan
17. Slussgatan	18. Stigbergsliden
Säröleden	19. Södravägen
20. The Tingstad Tunnel	21. Ullevigatan
22. Willinsbron	23. The Älvsborg Bridge
24. Örgrytevägen	

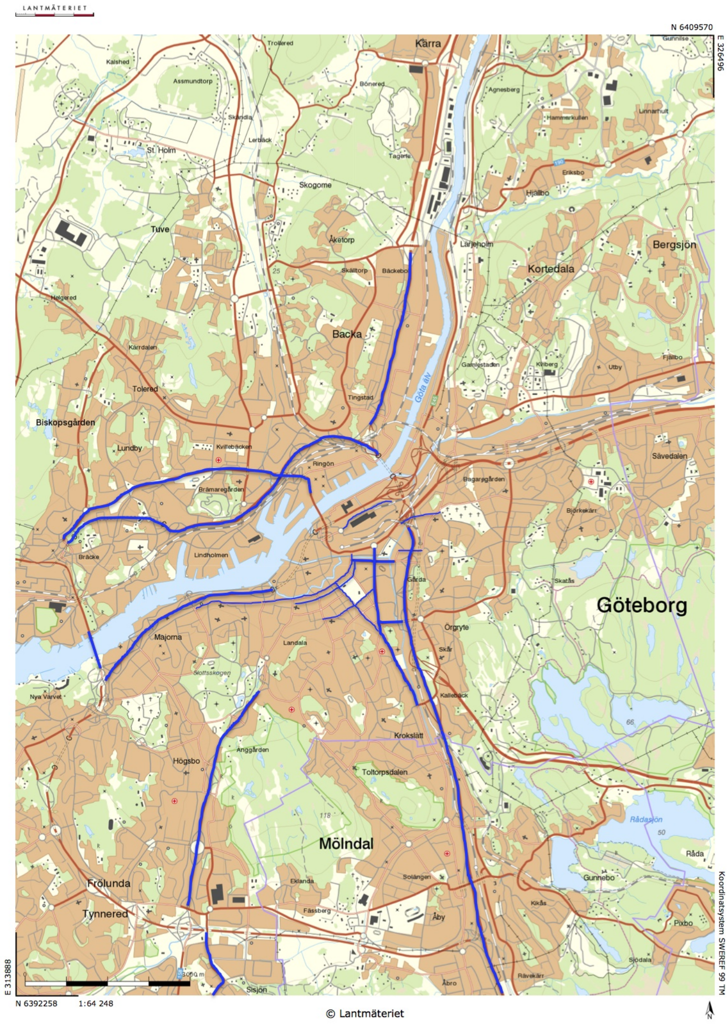


Figure A.1: Identified alternative roads bypassing roads going through the area of Centralstationen. ©Lantmäteriet with own symbols.

Figure A.2: Locations of measurement points in Gothenburg for the roads around Centralstationen. ©Lantmäteriet with own symbols.

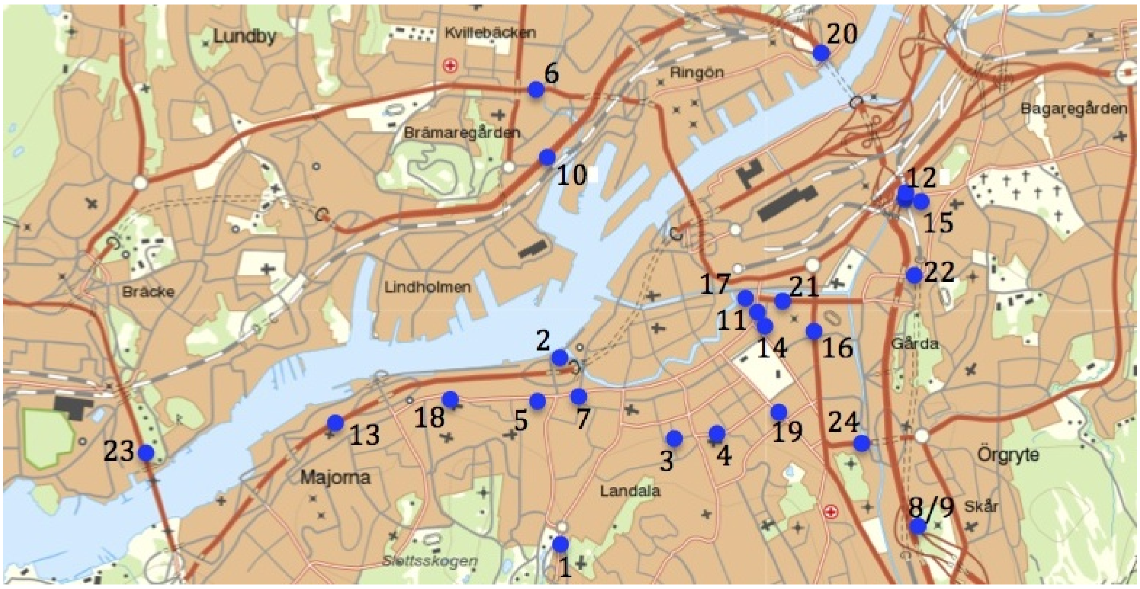


Figure A.3: Locations of measurement points in Gothenburg for the alternative roads. ©Lantmäteriet with own symbols.

B

Events of the Construction Works

Table B.1: Events carried out in the area of Centralstationen during the period of January to June 2017.

	Event
January	
	The main phase of the construction of the Hising Bridge starts
	Reconstruction of Bananbron with a new connection on "Shelltomten"
	The road of Norra Sjöfarten was closed between Stadstjänare-bron and Bananbron
	The possibility to access the E45 from Stadstjänaregatan east-wards is shut
	Construction of a temporary roundabout in the intersection of Gullbergs Strandgata-Falutorget starts
	Installation of distance heating in Norra Sjöfarten. Was on-going until April
	Demolition of the carpark by Åkareplatsen
February	
	The eastbound lanes of the E45 is pushed to the south
	Partihandelsgatan becomes a two-way street
	The exit from the E45 by Stadstjänaregatan is closed
	Stadstjänarebron is closed and demolition starts
	The temporary roundabout in the intersection of Gullbergs Strandgata-Falutorget is complete
	The access to the Götaälv Bridge via Bergslagsgatan is closed
March	
	Construction of the buss stops by Åkareplatsen starts
April	
	The construction of the northern part of the tunnel for the E45 starts
May	
	The carpark by Hamntorgsgatan is demolished (was delayed)
June	
	Construction of a new tram ramp leading up the Götaälv Bridge
	The Götaälv Bridge is closed to trams. Extra buses were introduced.

C

Traffic Flow of Selected Roads

Traffic flow of the selected roads displayed in graphs in the same order as of the tables A.1 followed by A.2. For each road the average day variation, average number of vehicles of a day and the variation over the whole period (January - June) are presented.

Table C.1: Average traffic flow for roads in the area of Centralstationen in vehicles per day between January and June. CC = City center, ACC = Away from city center.

	2015		2016		2017	
Direction	**CC**	**ACC**	**CC**	**ACC**	**CC**	**ACC**
Drottningtorget	6995	9408	7550	9563	8782	7650
Friggagatan	4205	7019	4449	7657	6939	6007
The Götaälv Bridge	10443	9569	10216	9721	8000	7440
Gullbergs Strandgata	2723	2737	3018	3018	2829	2827
Marieholmsleden/E45	23842	32034	26084	34675	22823	32535
Nils Ericsonsgatan	7218	9451	7435	9822	6947	8679
Odinsgatan	2679	3711	2734	3915	4438	2398
Partihandelsgatan	1850	1703	1808	1693	2266	1736
Polhemsplatsen	6487	6512	6443	6703	6309	6423

Table C.2: Average traffic flow for alternative routs in vehicles per day between January and June. CC = City center, ACC = Away from city center.

	2015		**2016**		**2017**	
Direction	**CC**	**ACC**	**CC**	**ACC**	**CC**	**ACC**
The Angereds Bridge	9672	8217	9771	8540	10297	8956
Dag Hammarskjöldsleden	13295	12616	13508	12553	13424	12148
Kungsbackaleden (1608)	30438	31760	31494	33884	30740	33840
Kungsbackaleden (1609)	23289	23771	25107	25831	24580	25405
Emigrantvägen	4439	5198	4147	4179	5373	4362
Engelbrektsgatan (149)	3296	3109	3282	2998	3167	2831
Engelbrektsgatan (150)	4211	4032	4296	4238	3201	3647
Första Långgatan	508	2560	517	2567	459	2351
Hjalmar Brantingsgatan	11266	11449	11372	11752	10141	10936
Järntorget	8755	8131	8564	9312	8871	9505
Kungälvsleden	26537	26789	26900	27157	25099	25797
Lundbyleden	22507	23165	23128	23601	23985	21394
Nya Allén		10974		11170		11237
Olskroksmotet	6206	2528	6341	2693	6764	2715
Oscarsleden	28172	26251	28558	26923	25163	24089
Parkgatan	10389		10570		11257	
Redbergsvägen	1132	4582	1289	4715	1182	4569
Skånegatan	7695	8479	7530	8655	7202	8792
Slussgatan	1364	3617	1360	3642	1461	3621
Stigbergsliden	1233	2295	1152	2290	1133	2341
Säröleden	7668	7780	7723	7800	8012	7842
Södravägen	2333	4407	2975	5036	2762	4484
The Tingstad Tunnel	53483	57331	57046	60382	57631	60572
Ullevigatan	7324	10455	7324	10772	7881	11105
Willinsbron	3527	3301	3702	3285	3563	3364
The Älvsborg Bridge	30928	29741	36728	29958	30668	36005
Örgrytevägen	11019	12143	10304	12172	10315	12212

Drottningtorget

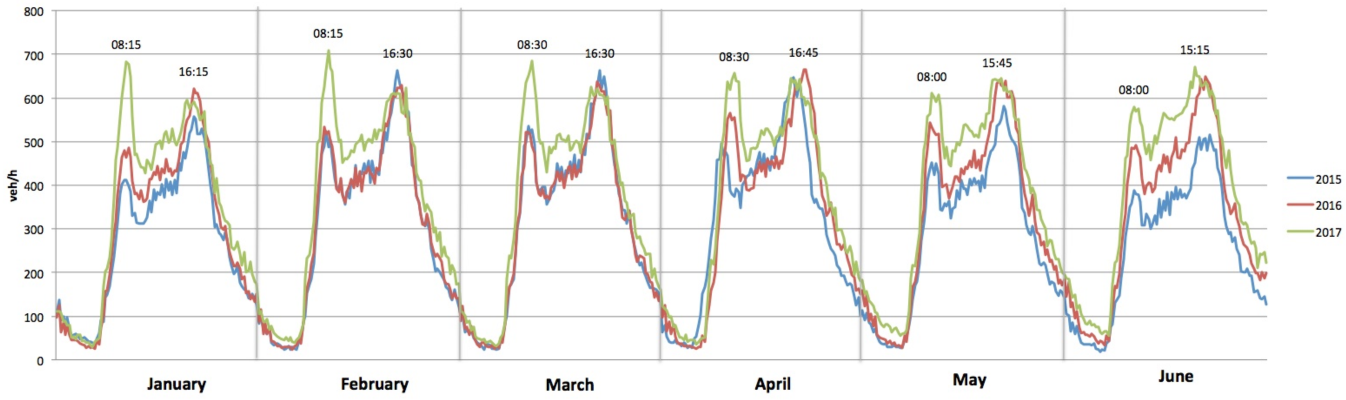


Figure C.1: Average day variation monthly. Direction: city center

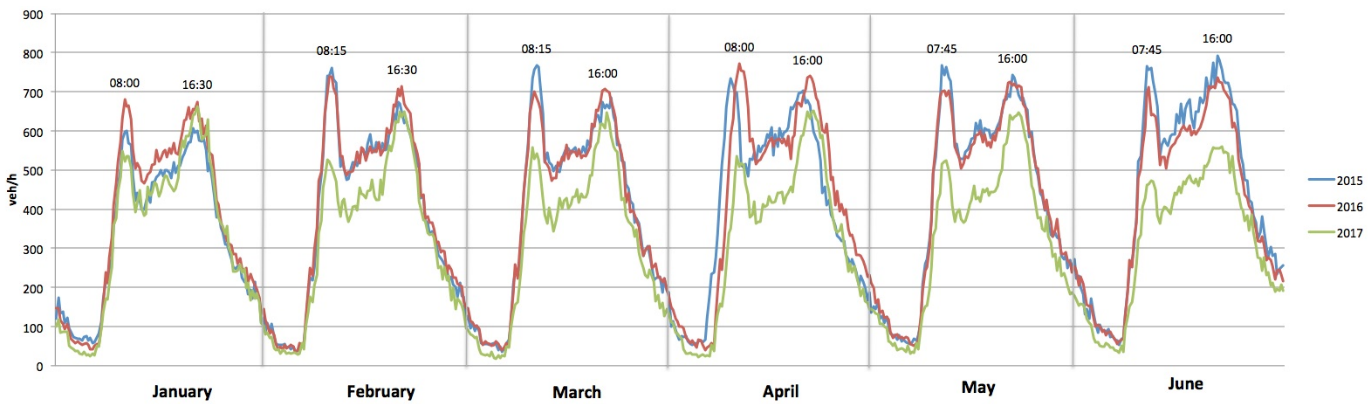


Figure C.2: Average day variation monthly. Direction: away from city center.

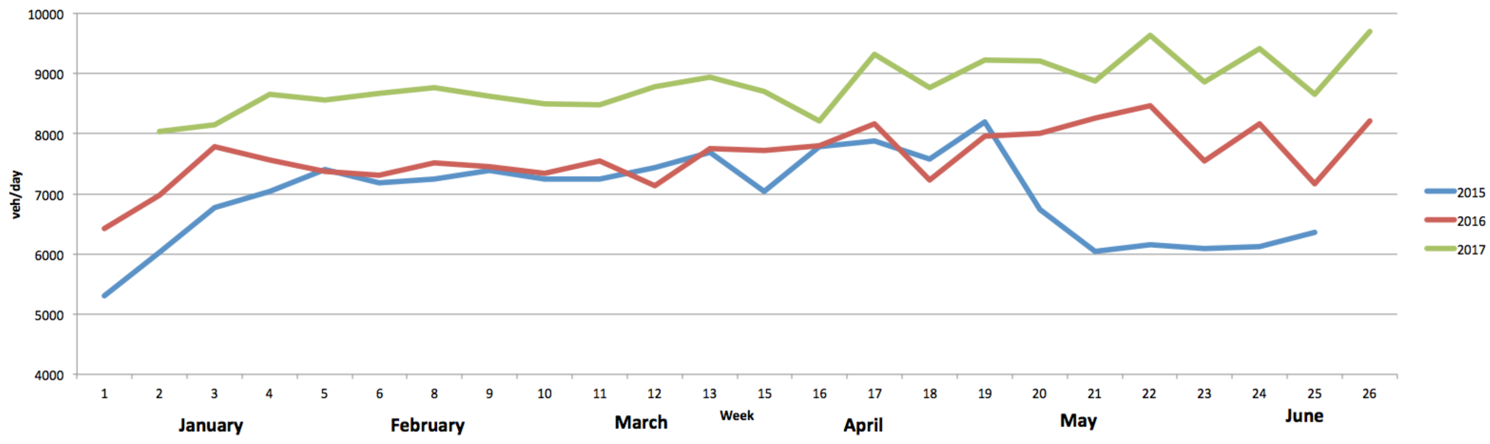


Figure C.3: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

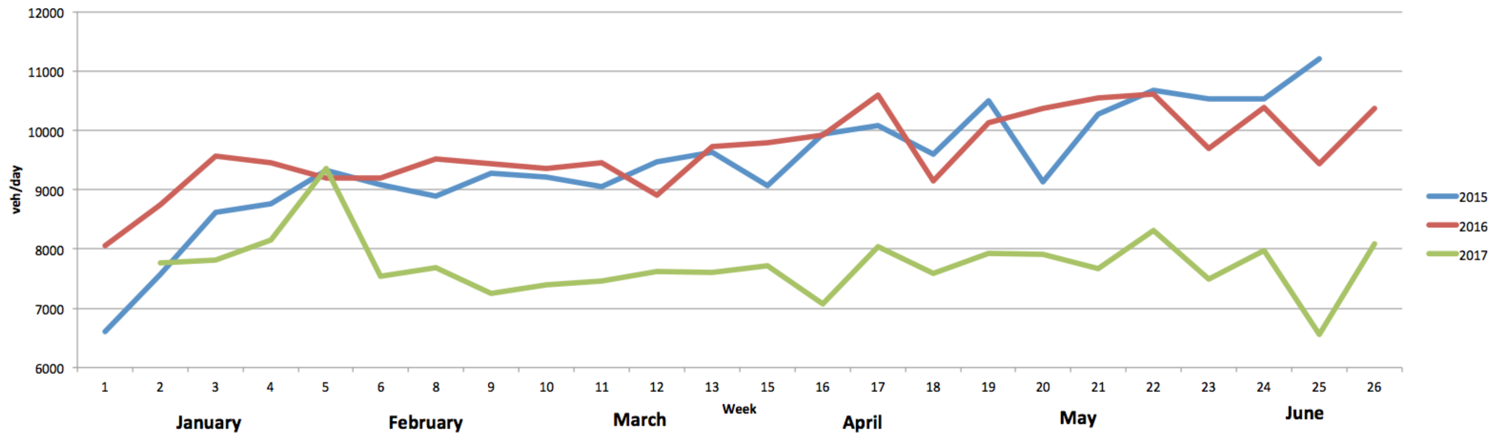


Figure C.4: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

E45/Marieholmsleden

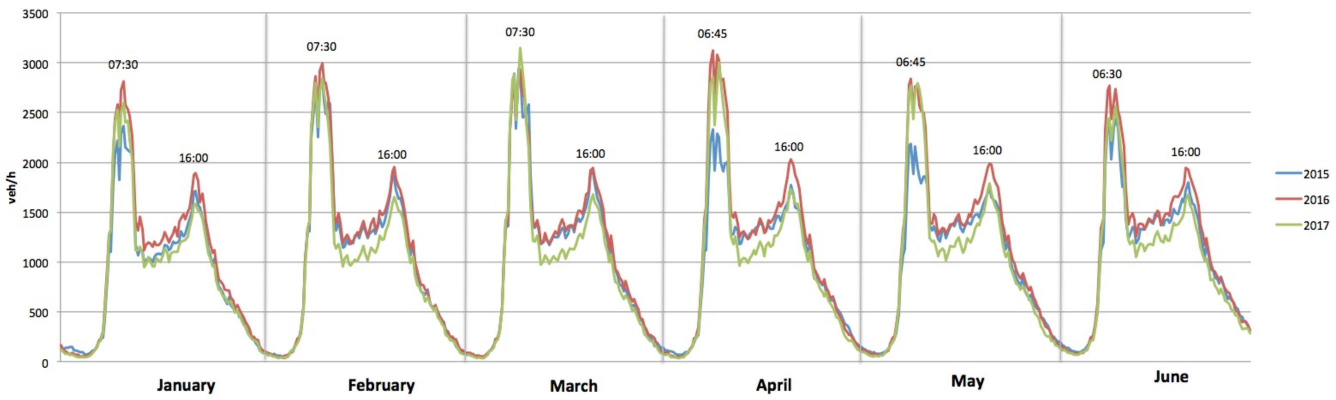


Figure C.5: Average day variation monthly. Direction: city center

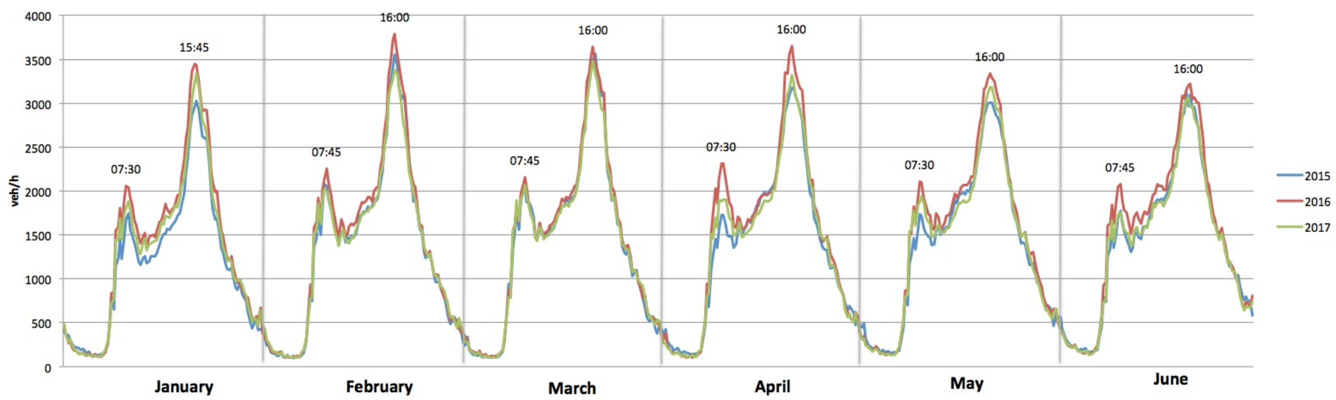


Figure C.6: Average day variation monthly. Direction: away from city center.

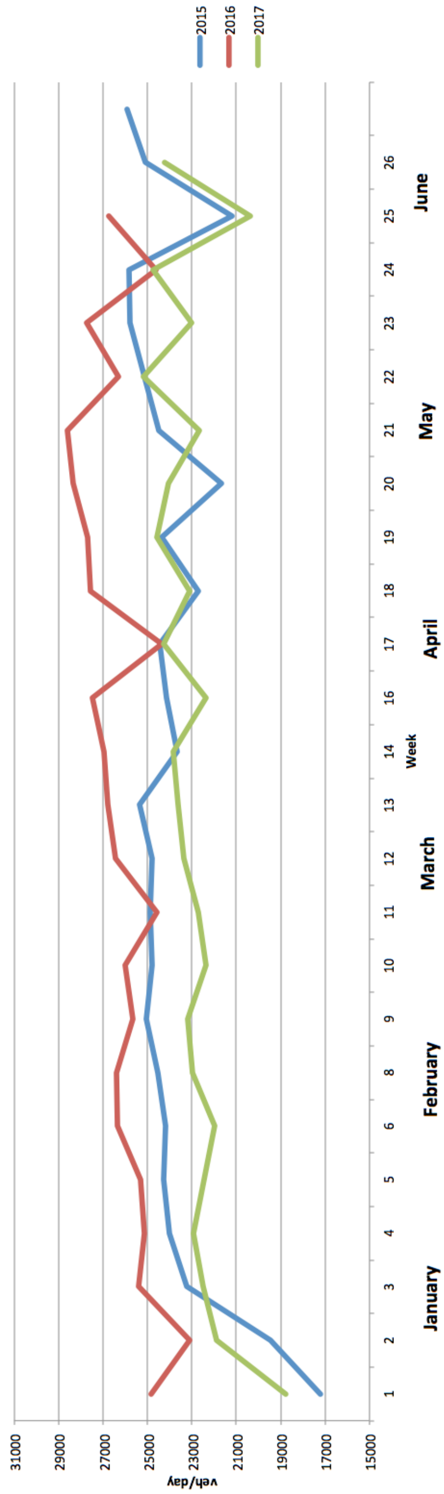


Figure C.7: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

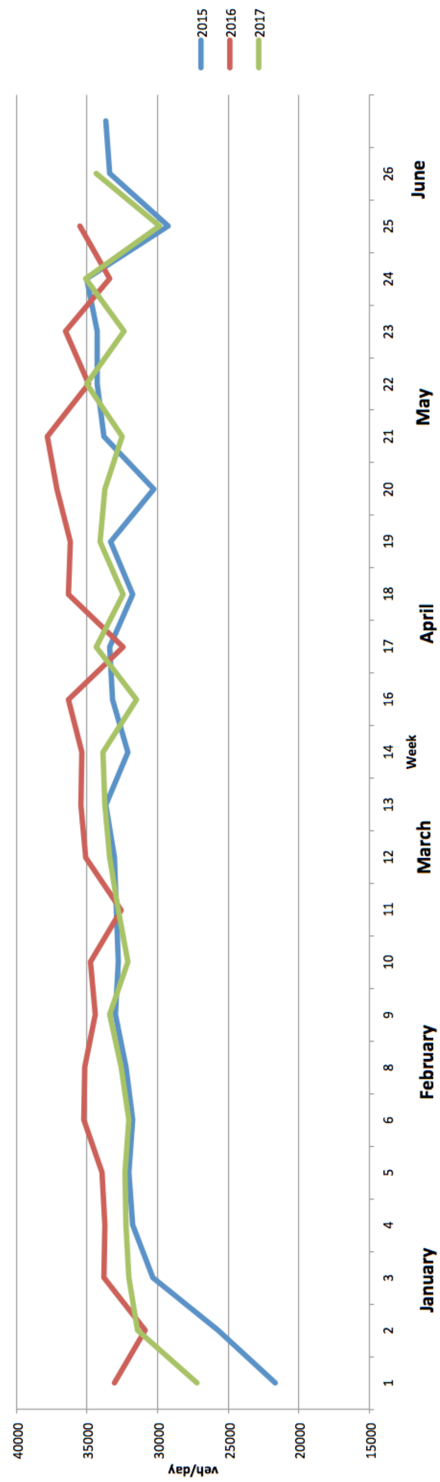


Figure C.8: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Friggagatan

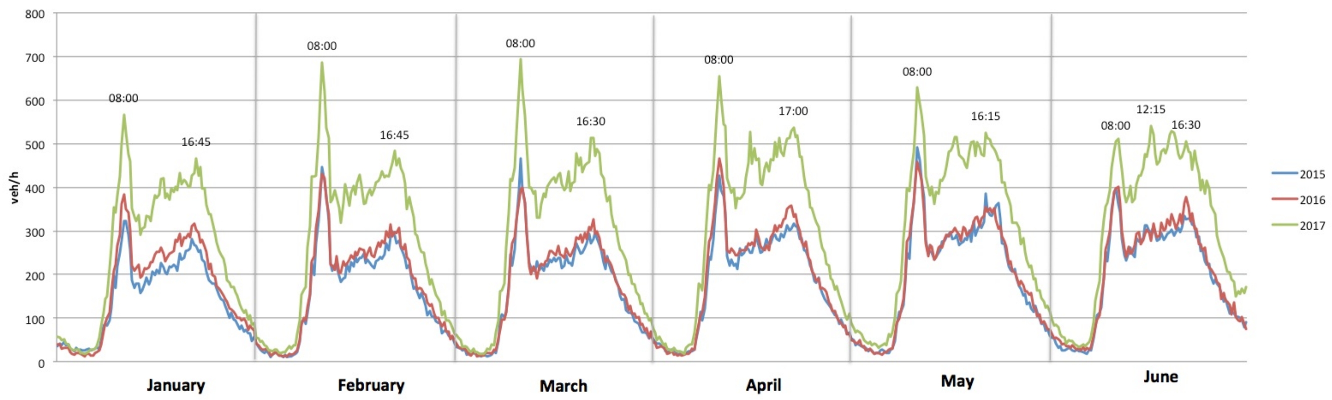


Figure C.9: Average day variation monthly. Direction: city center

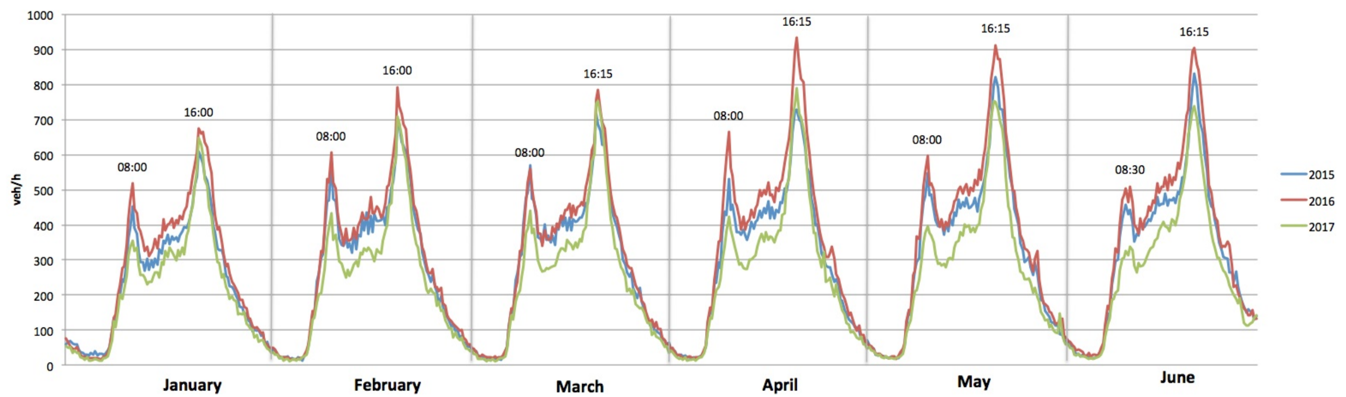


Figure C.10: Average day variation monthly. Direction: away from city center.

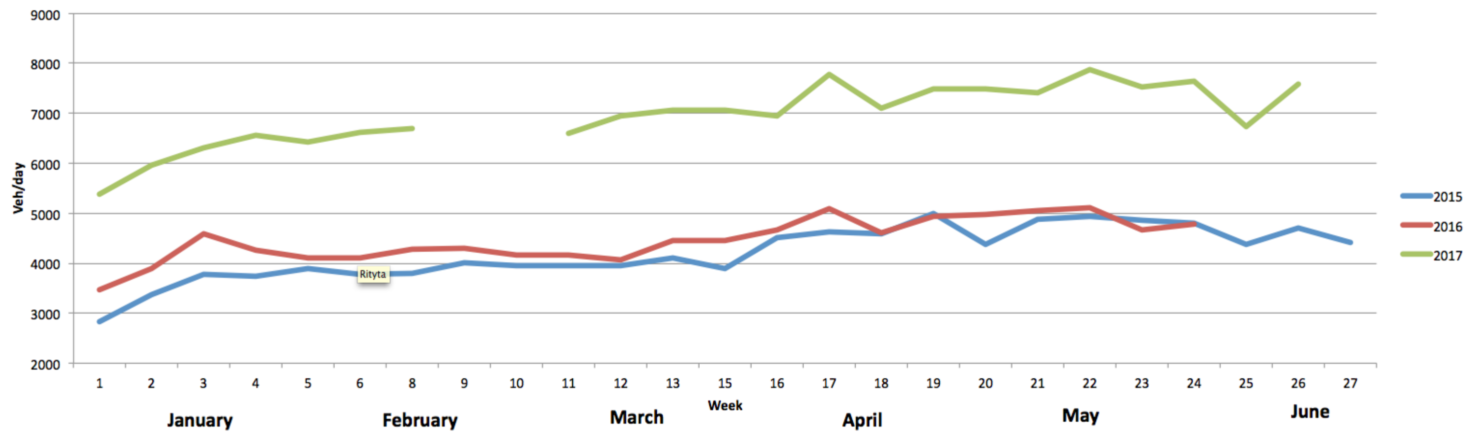


Figure C.11: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

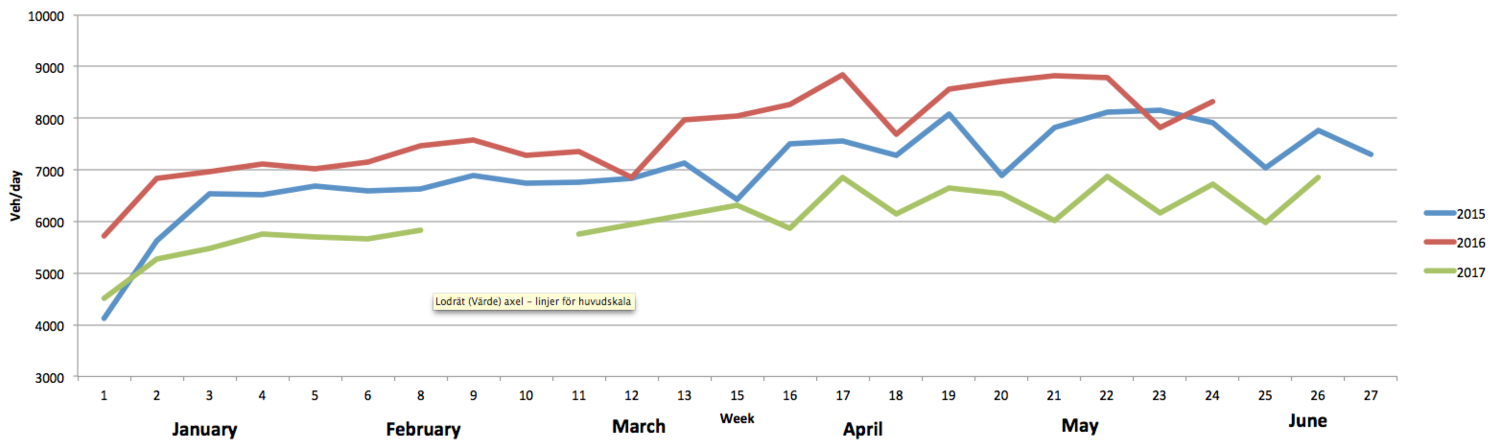


Figure C.12: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Gullbergs Strandgata

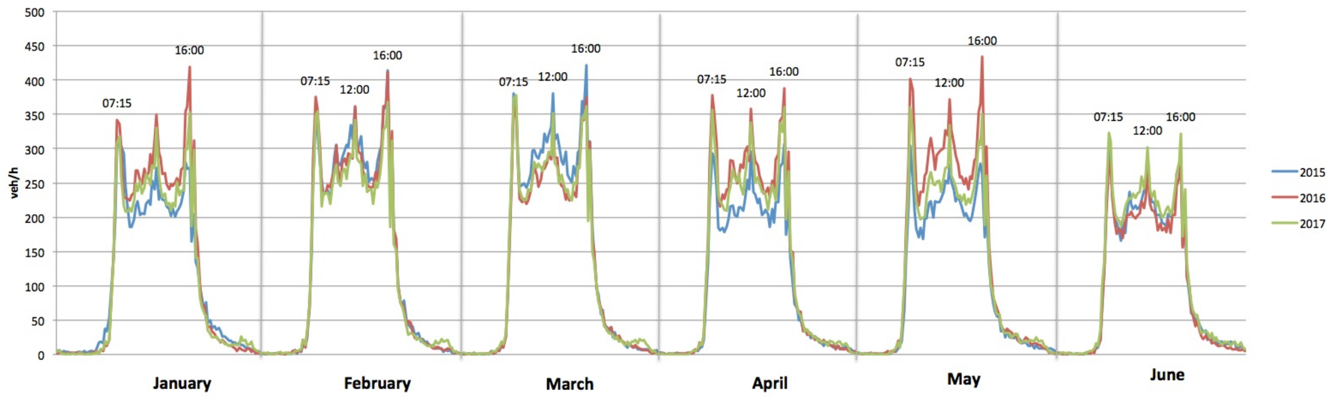


Figure C.13: Average day variation monthly. Direction: city center

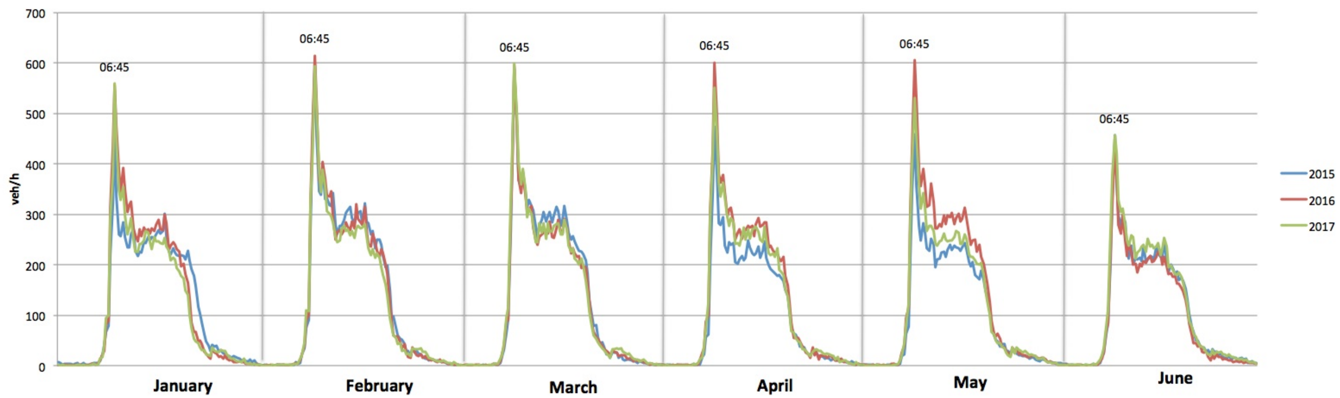


Figure C.14: Average day variation monthly. Direction: away from city center.

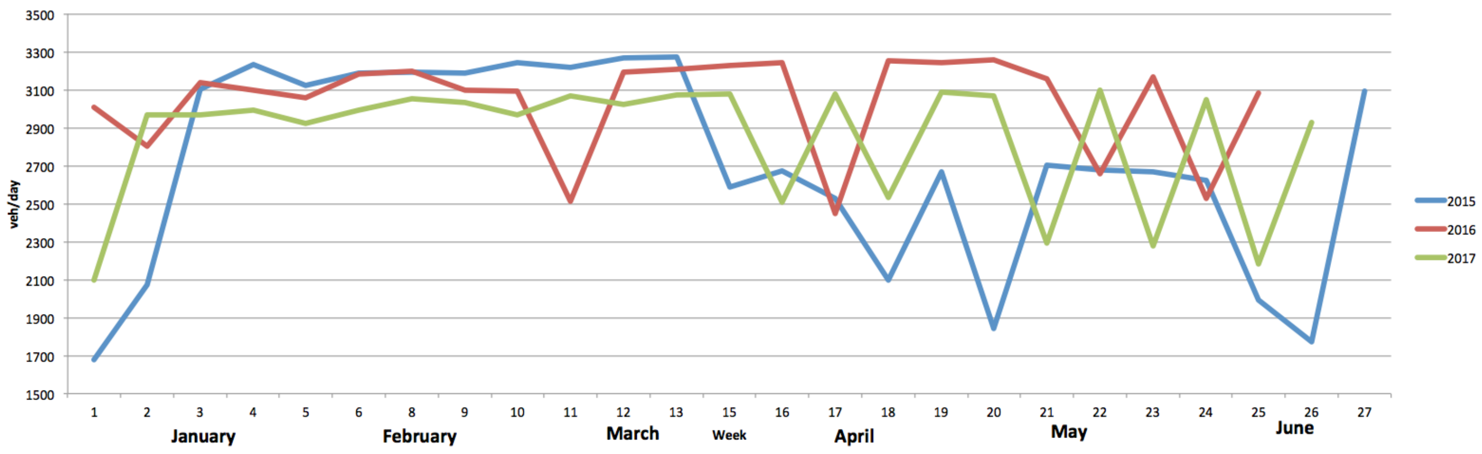


Figure C.15: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

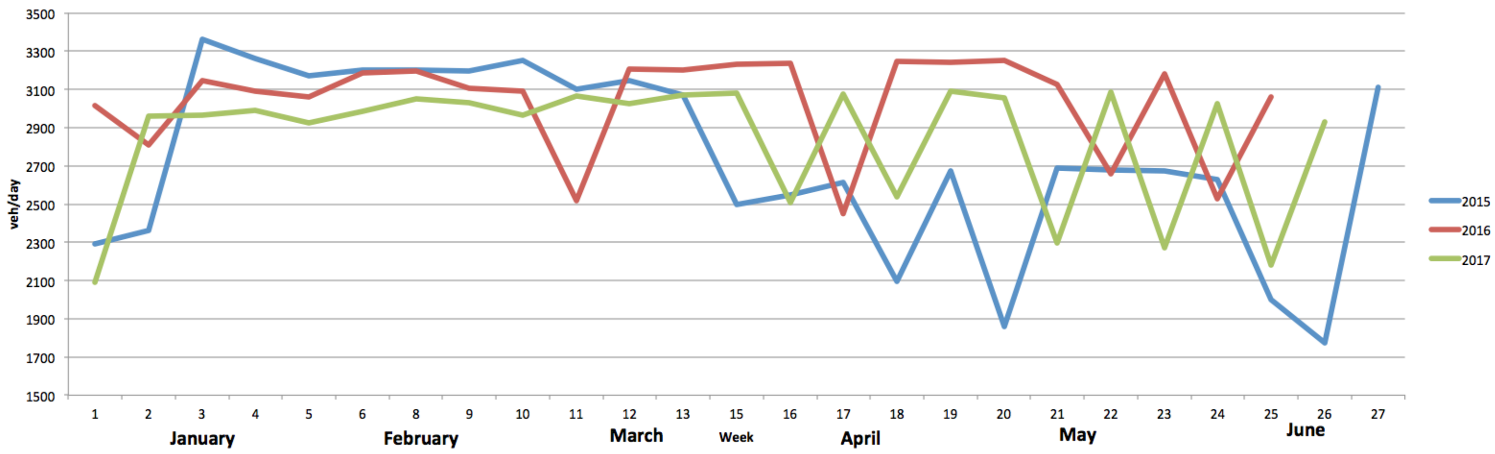


Figure C.16: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

The Götaälv Bridge

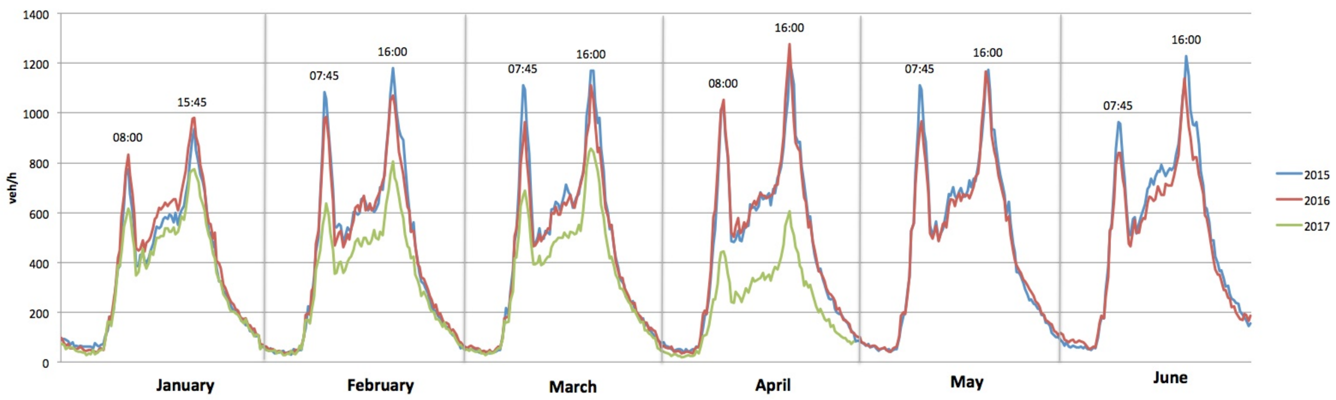


Figure C.17: Average day variation monthly. Direction: city center

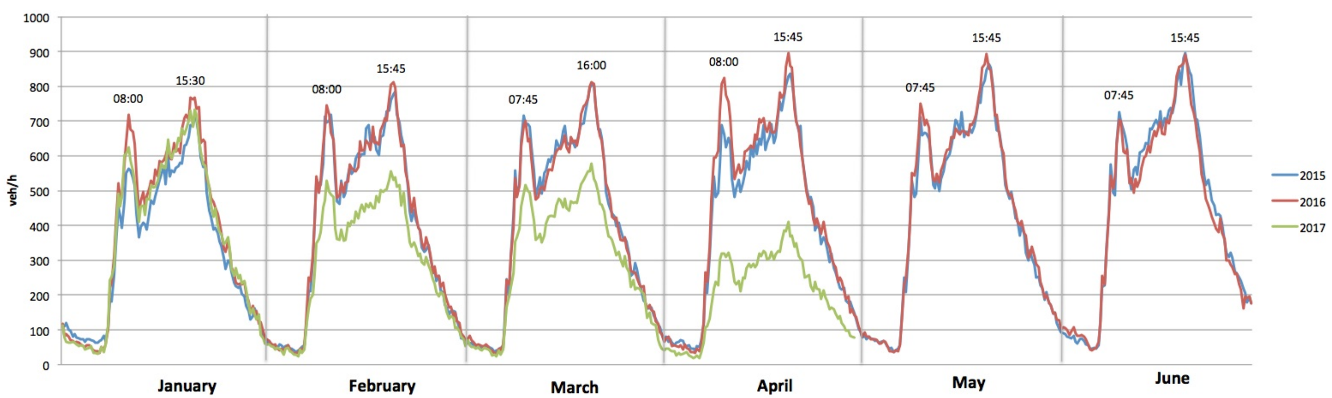


Figure C.18: Average day variation monthly. Direction: away from city center.

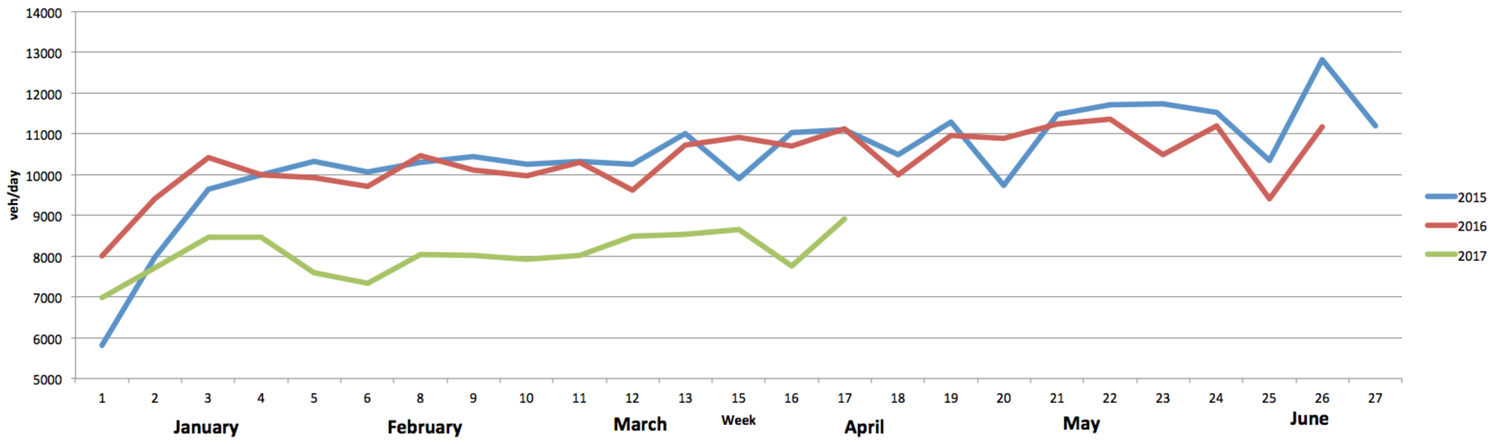


Figure C.19: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

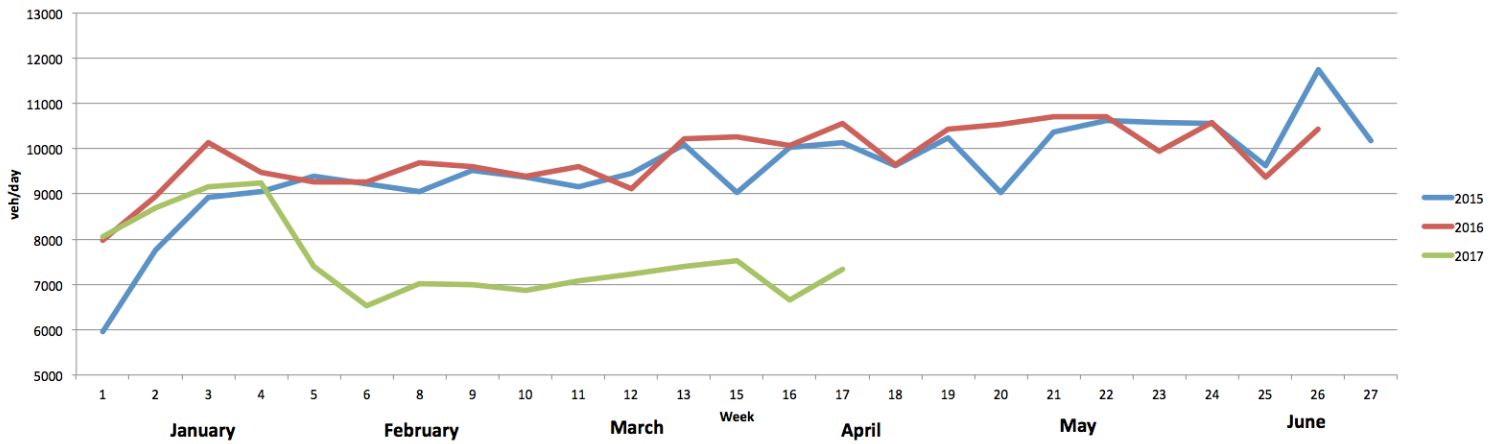


Figure C.20: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Nils Ericsonsgatan

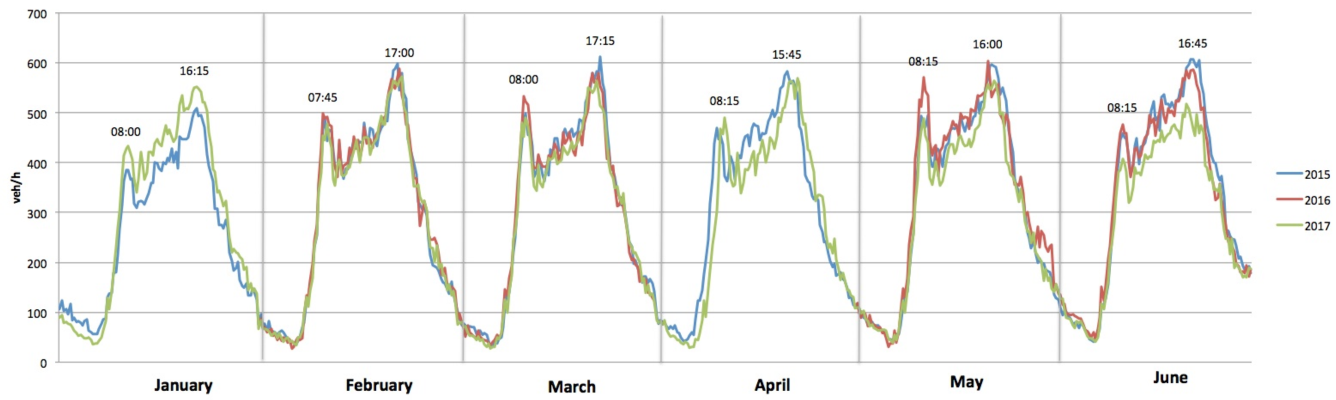


Figure C.21: Average day variation monthly. Direction: city center

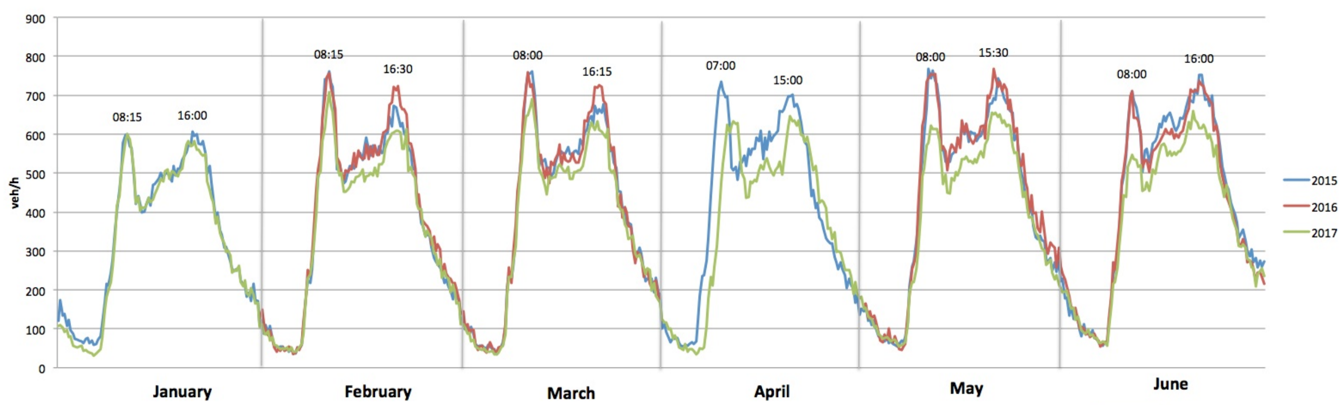


Figure C.22: Average day variation monthly. Direction: away from city center.

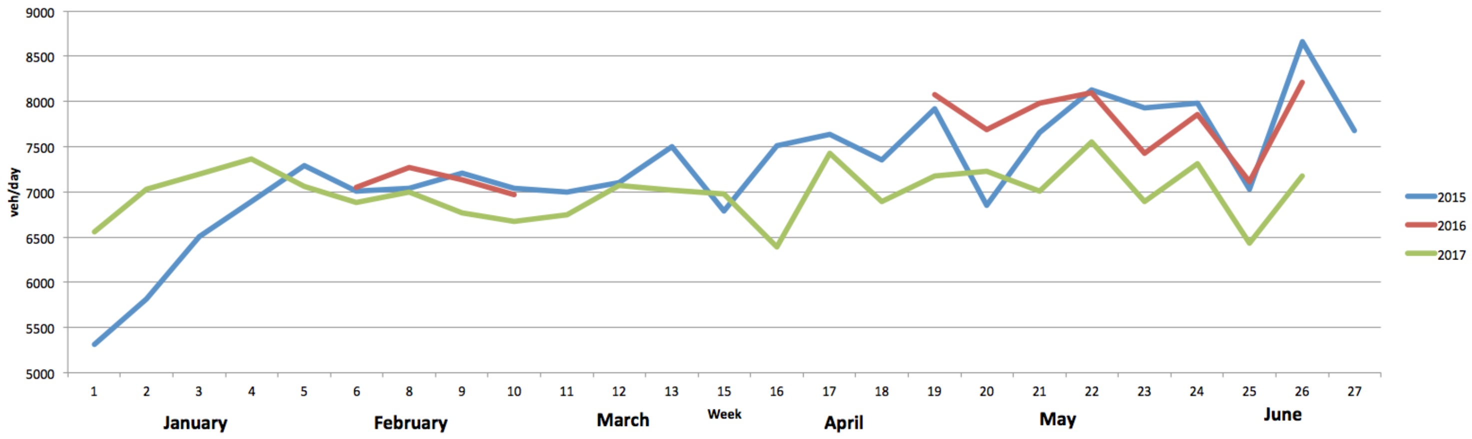


Figure C.23: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

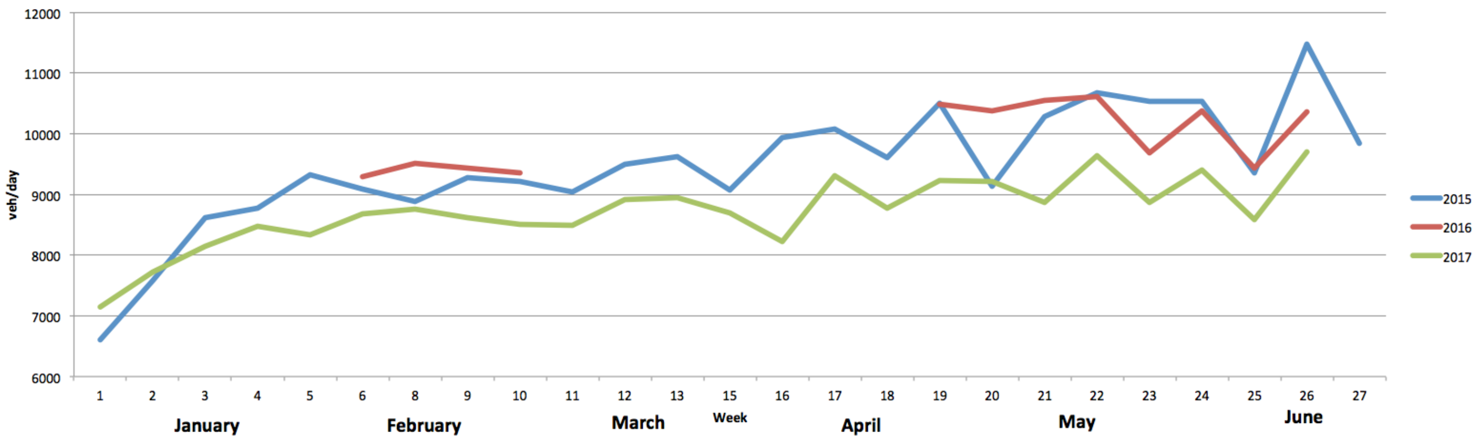


Figure C.24: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Odinsgatan

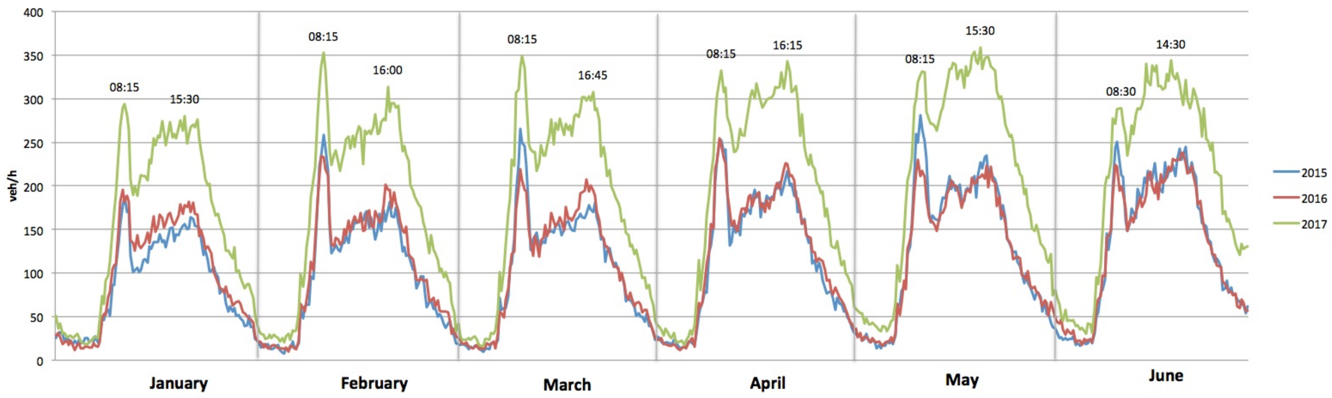


Figure C.25: Average day variation monthly. Direction: city center

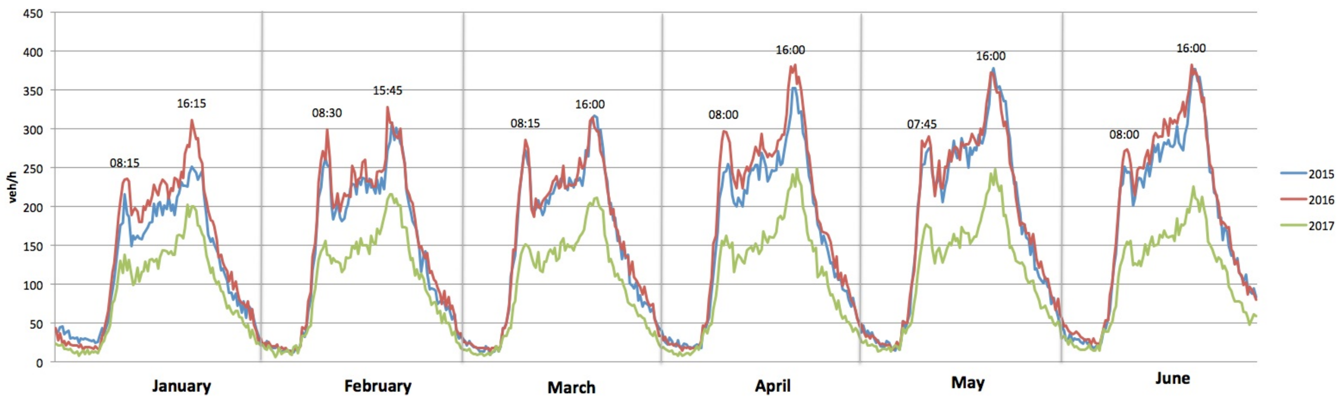


Figure C.26: Average day variation monthly. Direction: away from city center.

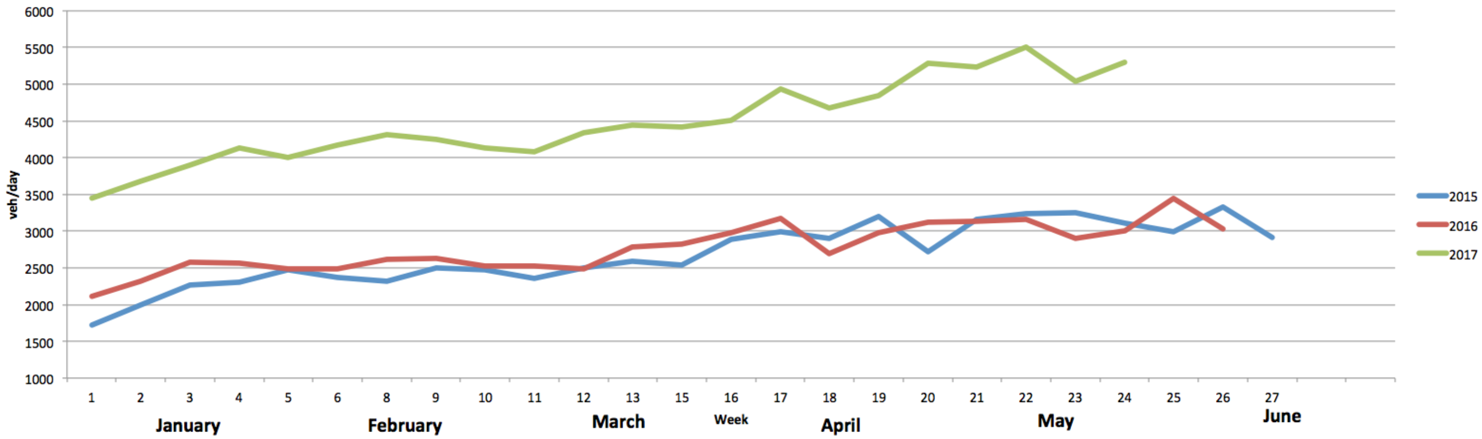


Figure C.27: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

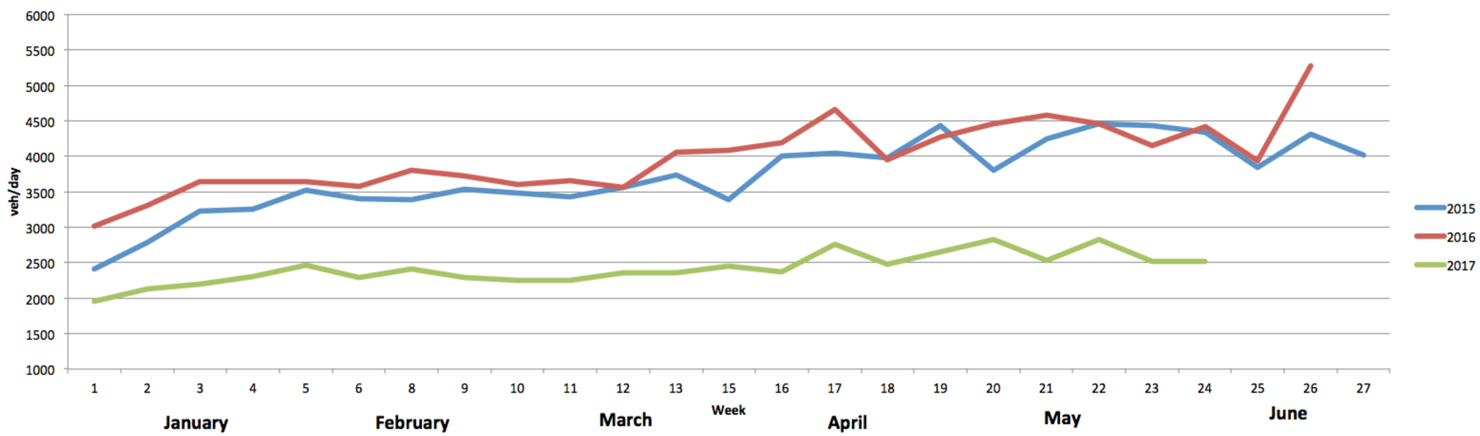


Figure C.28: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Partihandelsgatan

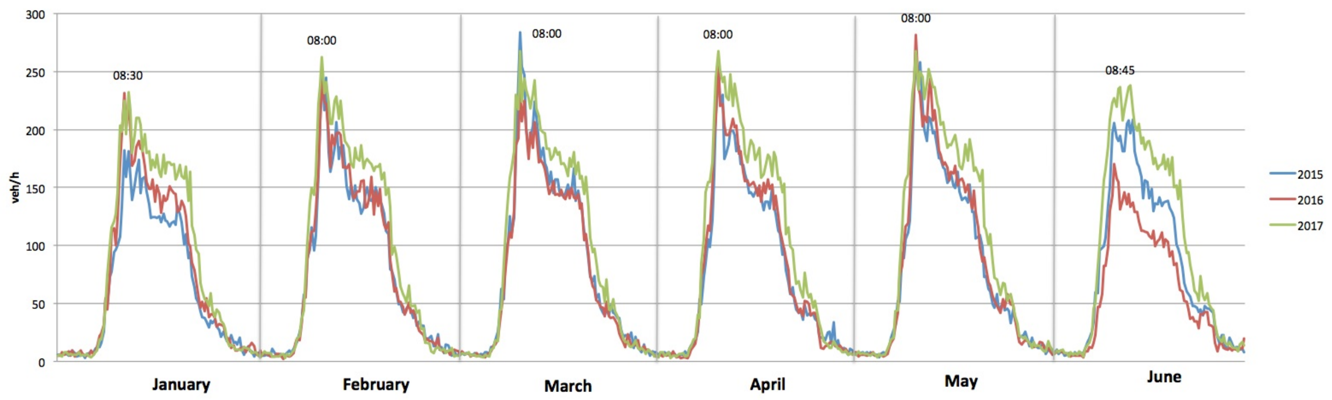


Figure C.29: Average day variation monthly. Direction: city center

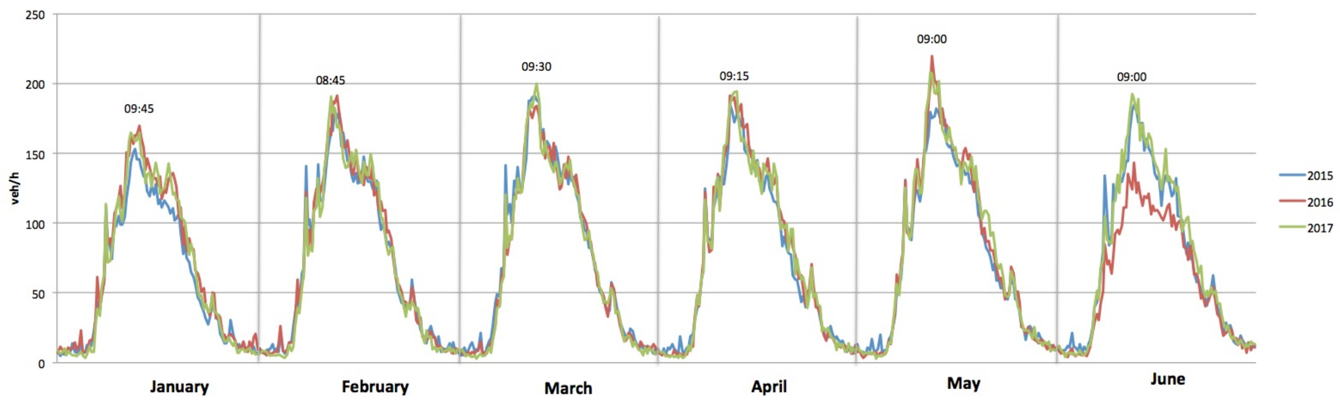


Figure C.30: Average day variation monthly. Direction: away from city center.

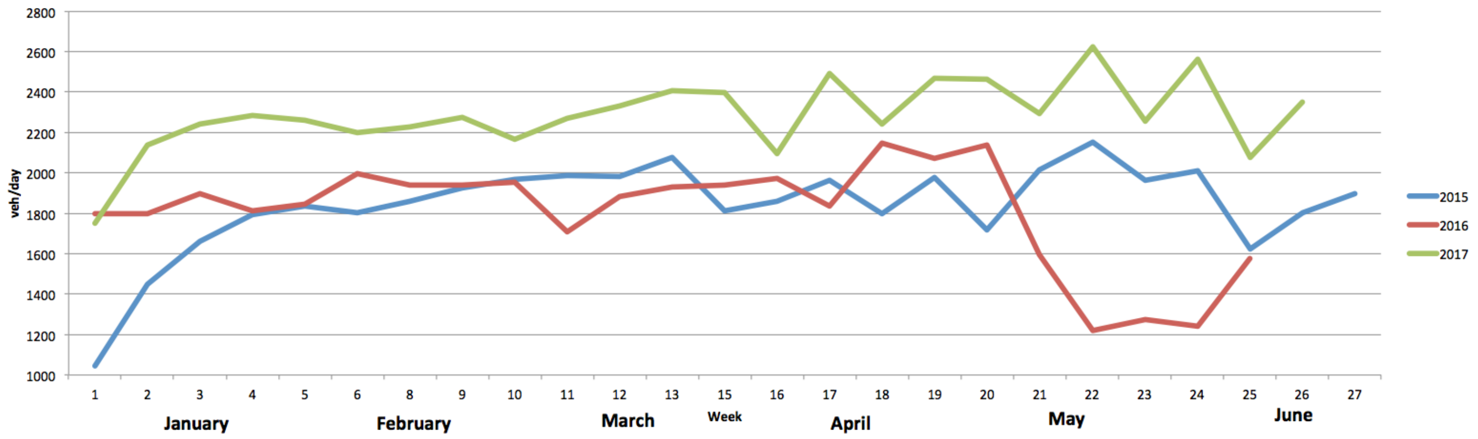


Figure C.31: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

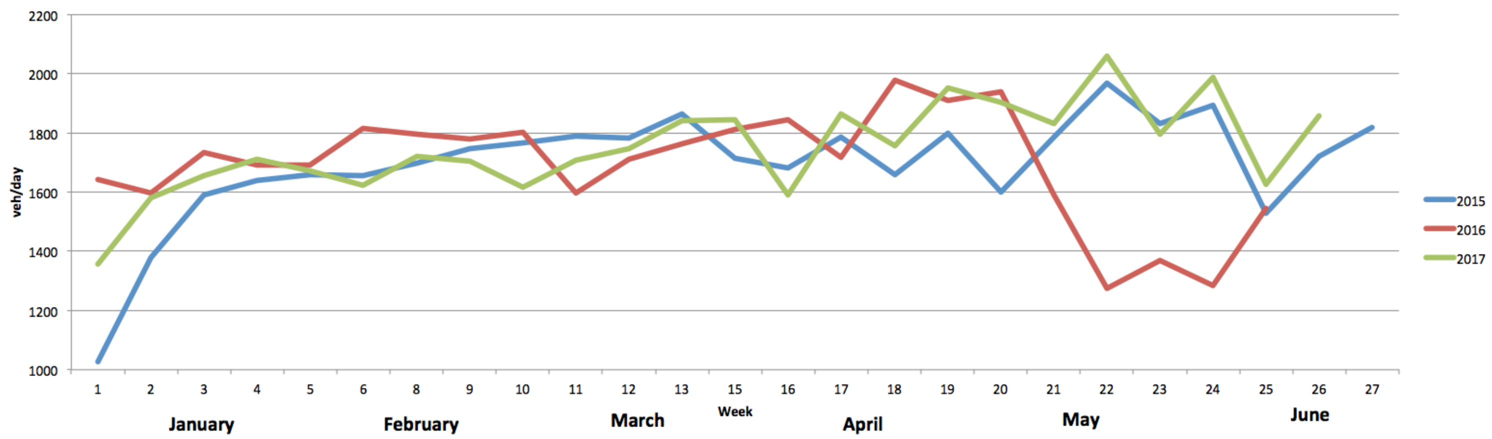


Figure C.32: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Polhemsplatsen

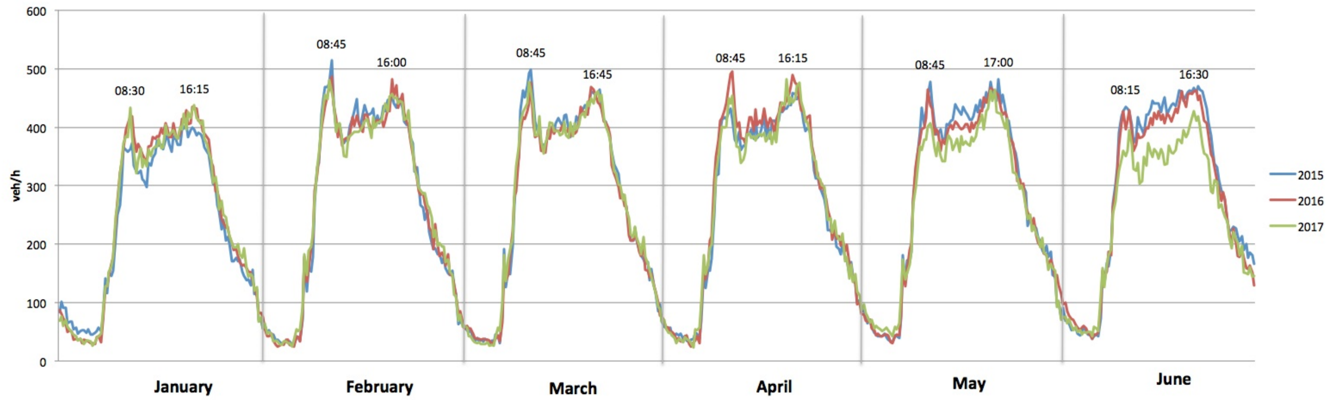


Figure C.33: Average day variation monthly. Direction: city center

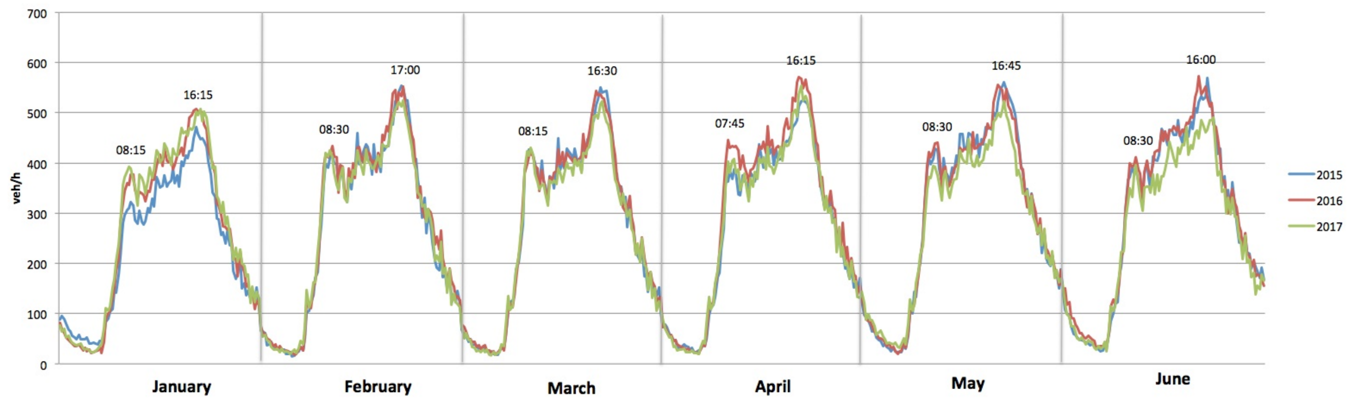


Figure C.34: Average day variation monthly. Direction: away from city center.

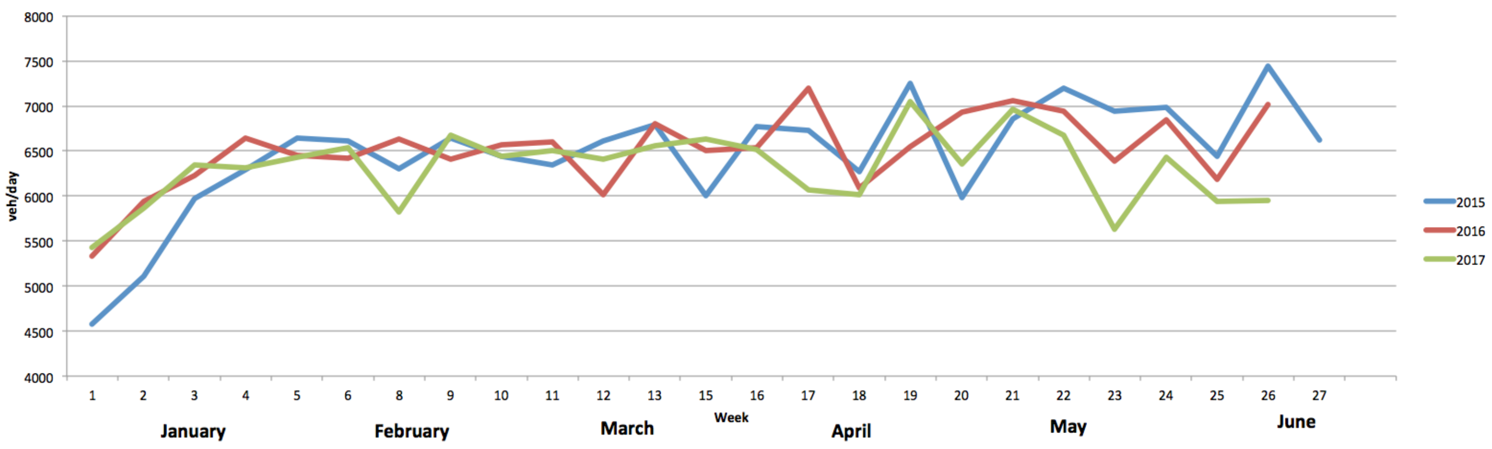


Figure C.35: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

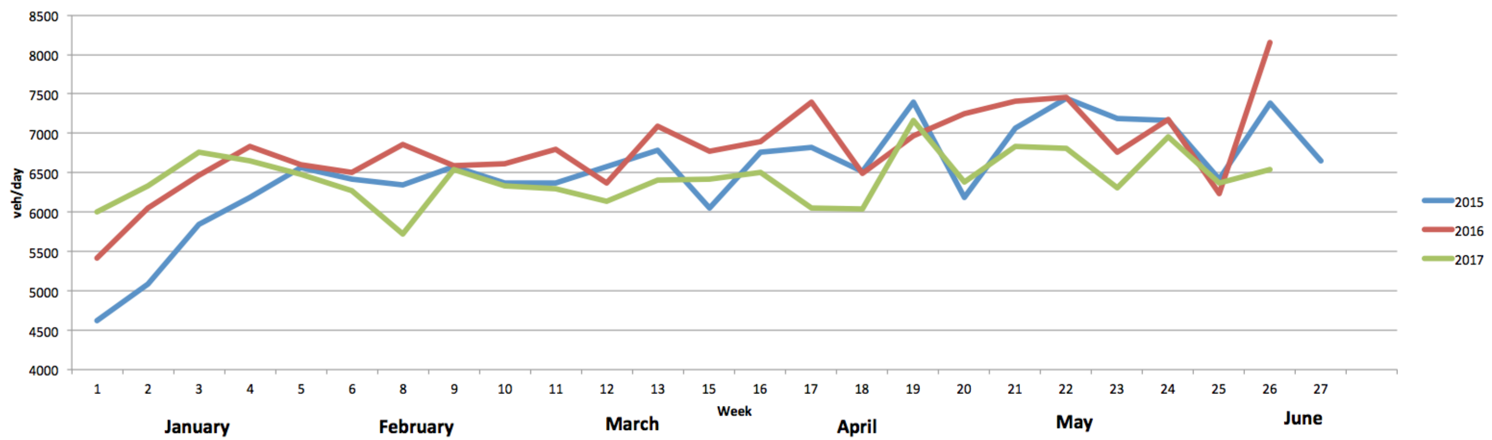


Figure C.36: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Angeredsbron

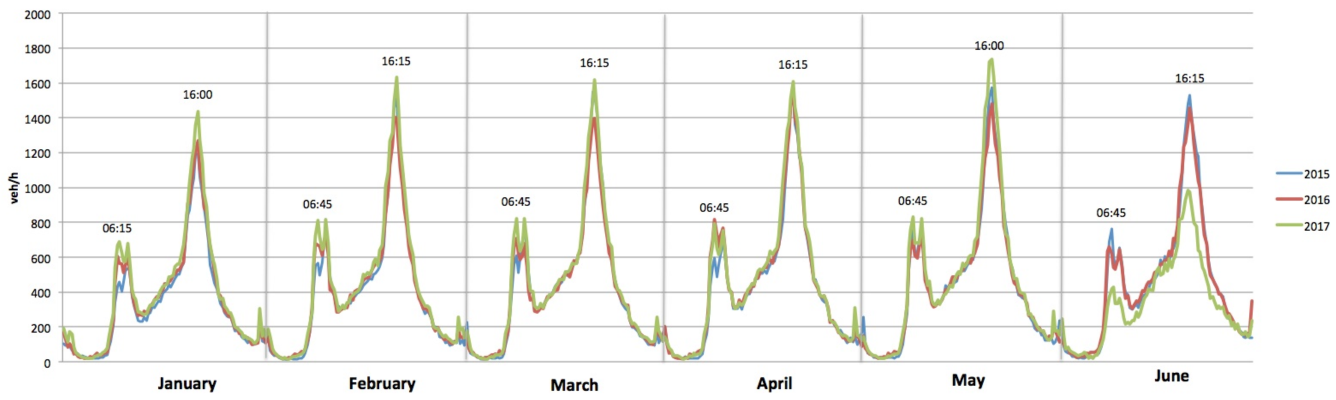


Figure C.37: Average day variation monthly. Direction: city center

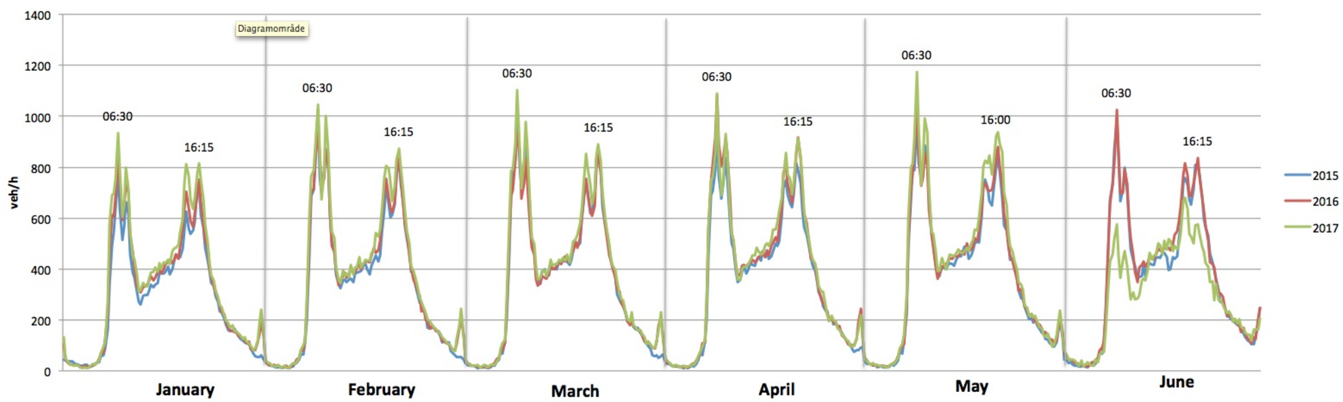


Figure C.38: Average day variation monthly. Direction: away from city center.

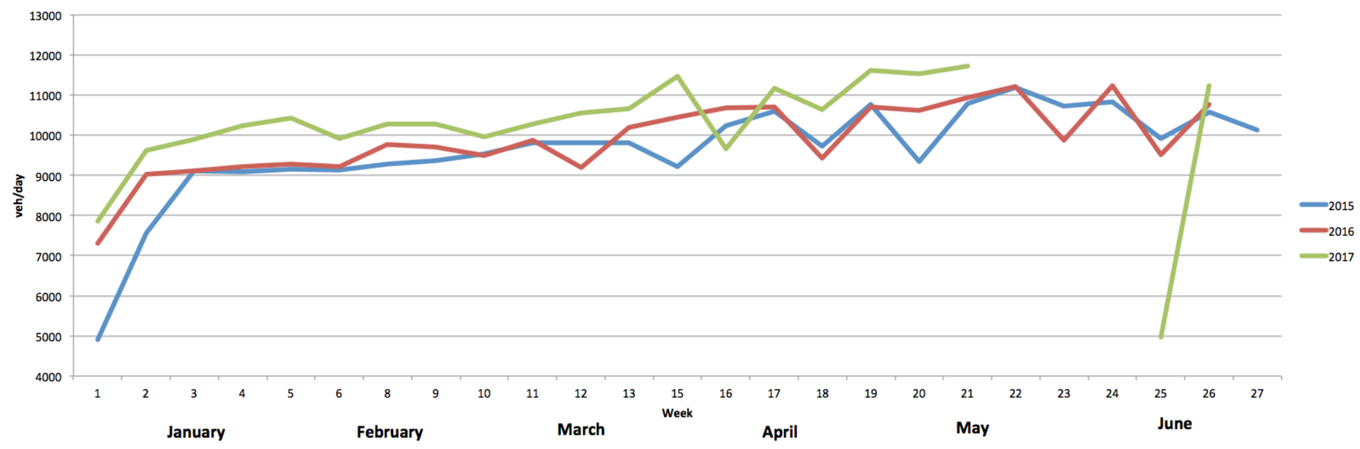


Figure C.39: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

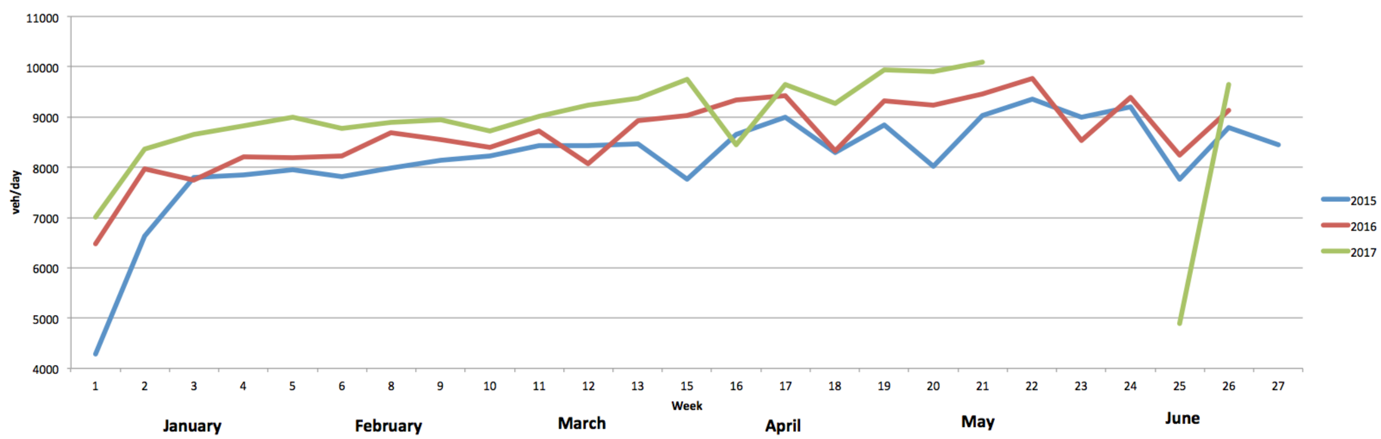


Figure C.40: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Dag Hammarskjöldsleden

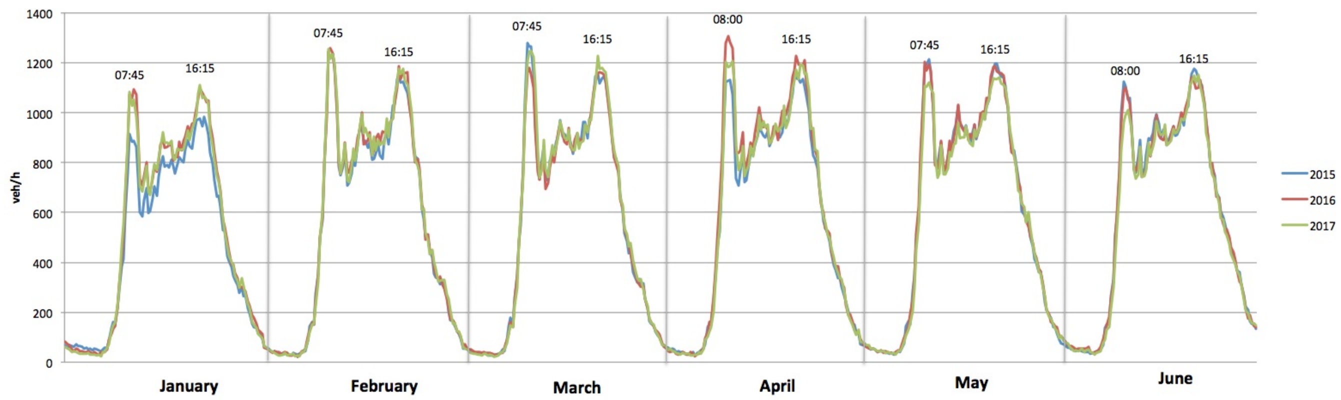


Figure C.41: Average day variation monthly. Direction: city center

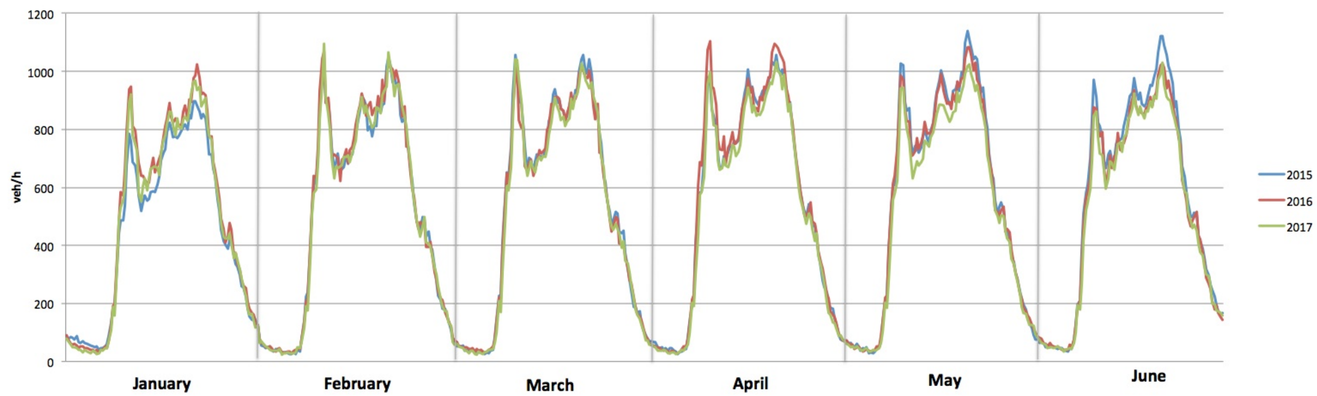


Figure C.42: Average day variation monthly. Direction: away from city center.

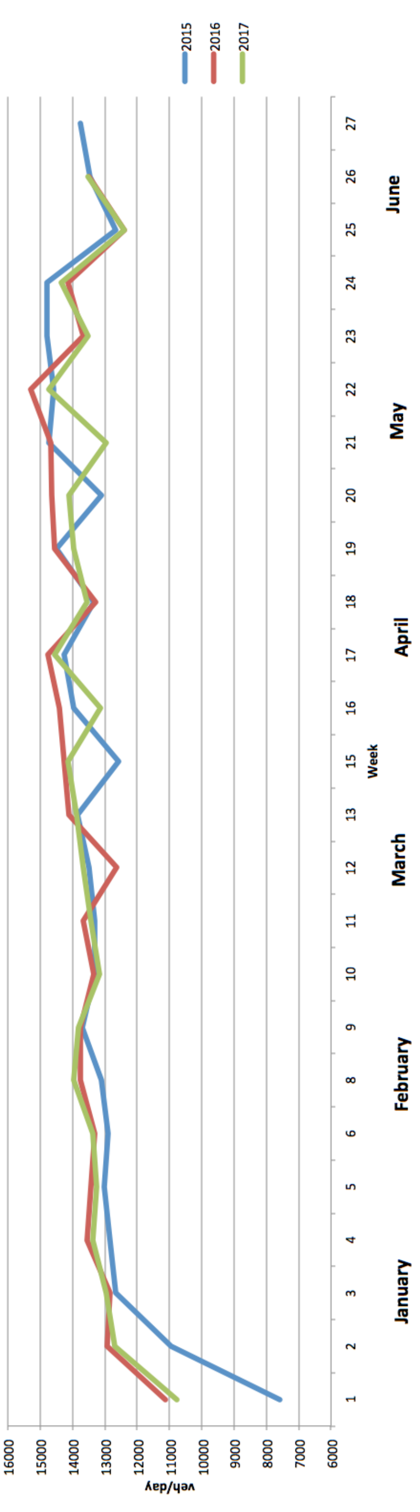


Figure C.43: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

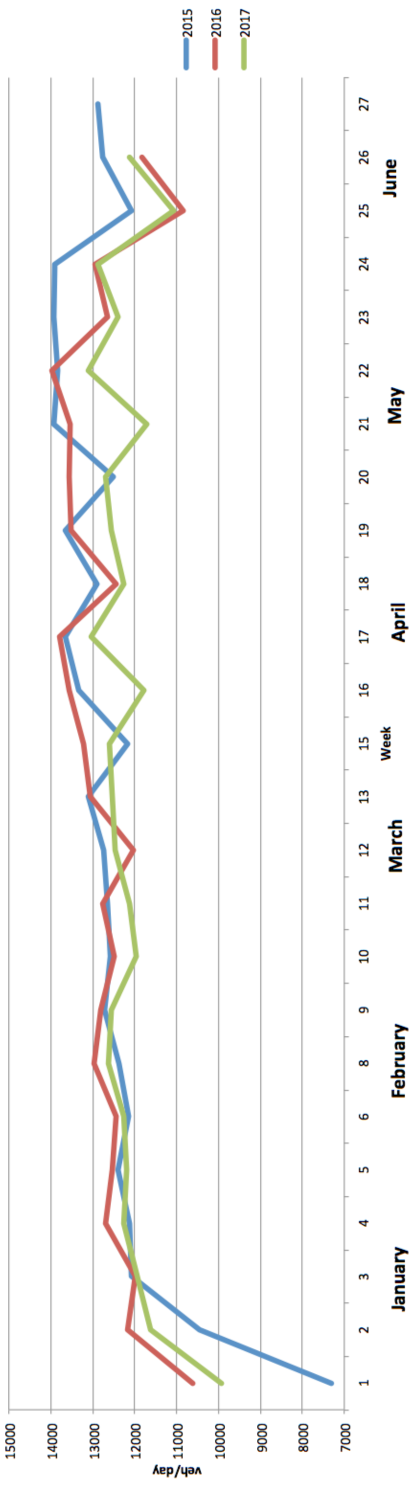


Figure C.44: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Emigrantvägen

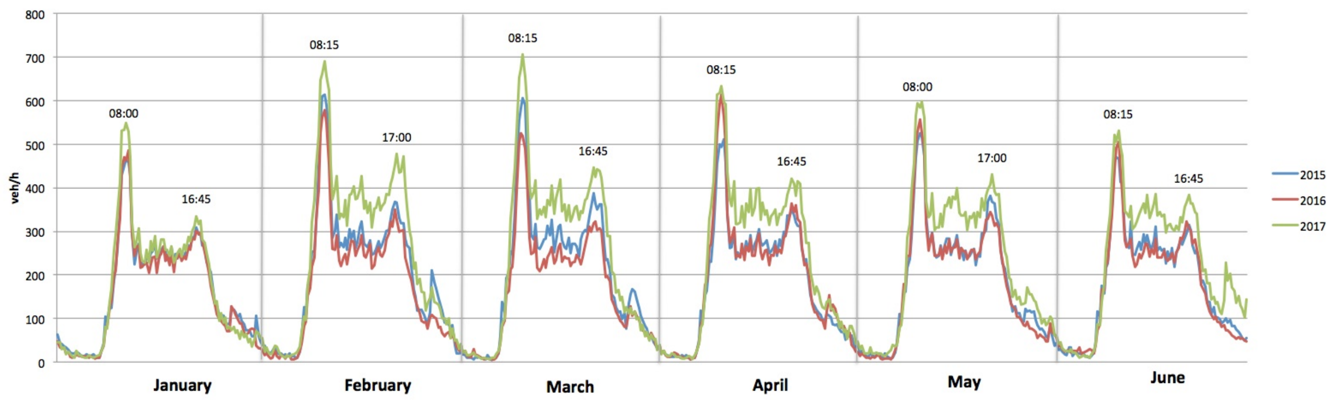


Figure C.45: Average day variation monthly. Direction: city center

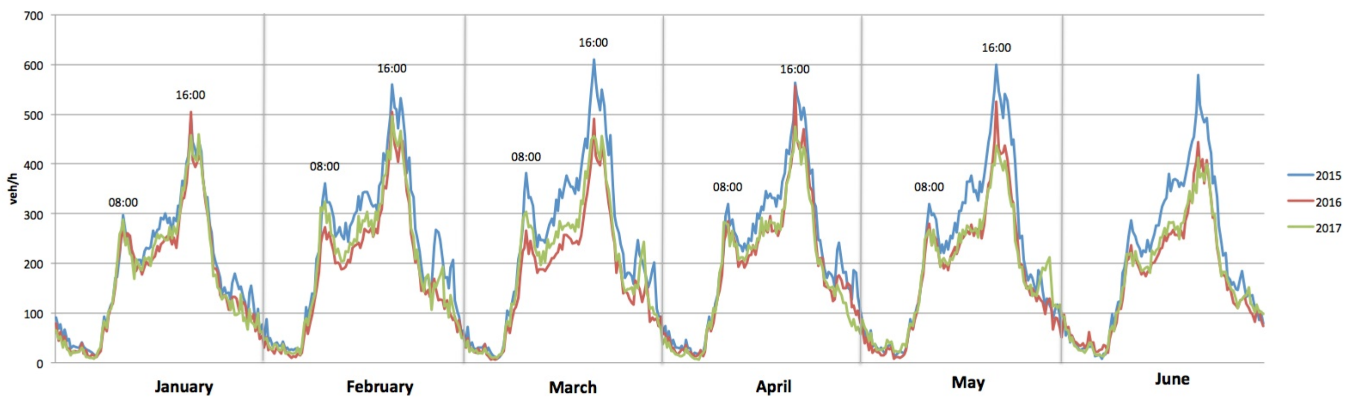


Figure C.46: Average day variation monthly. Direction: away from city center.

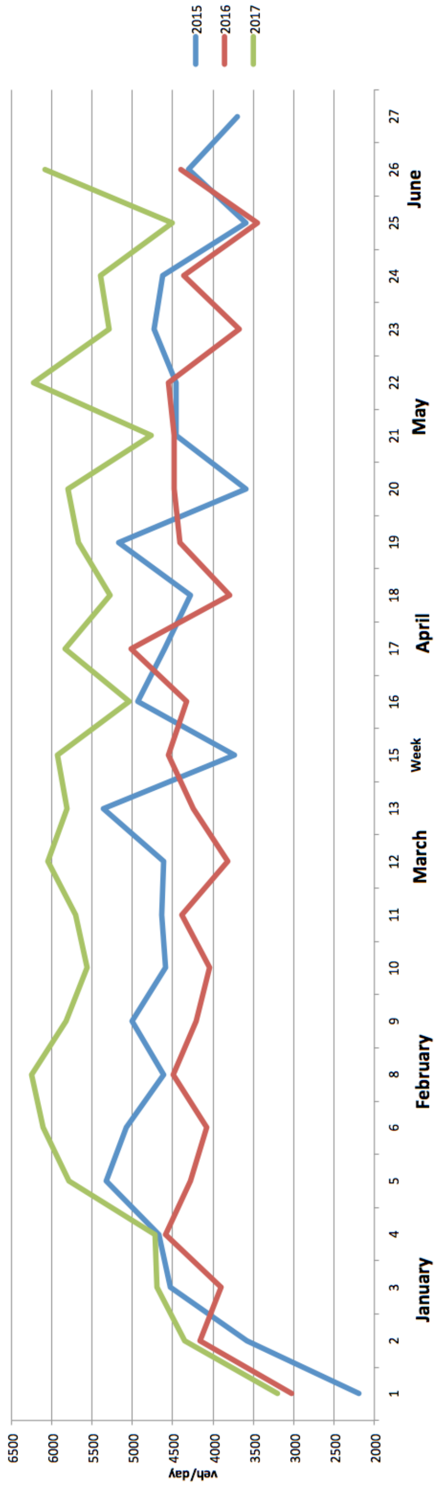


Figure C.47: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

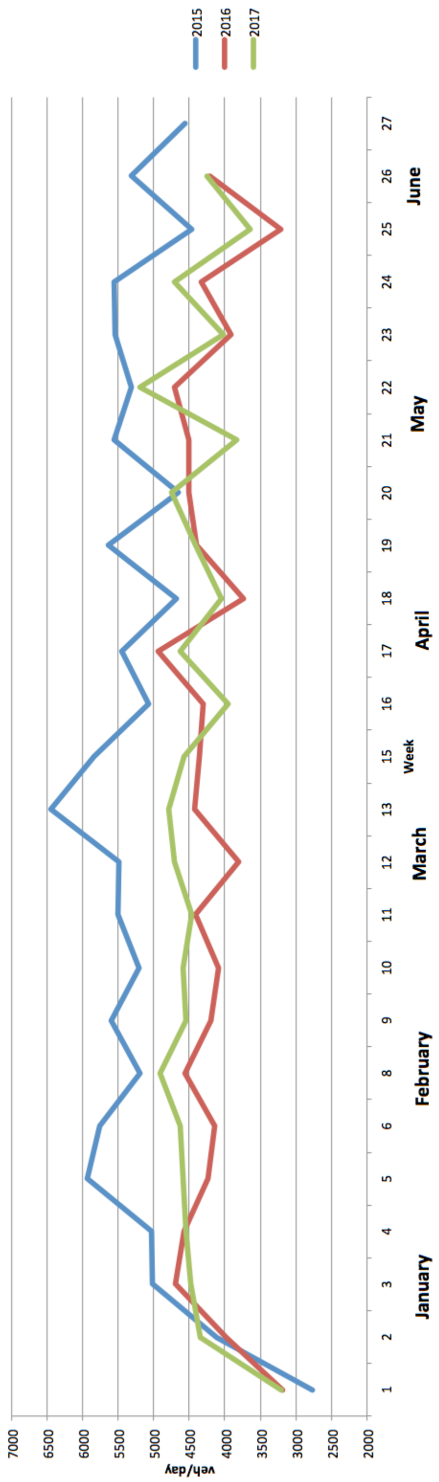


Figure C.48: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Engelbrektsgatan (149)

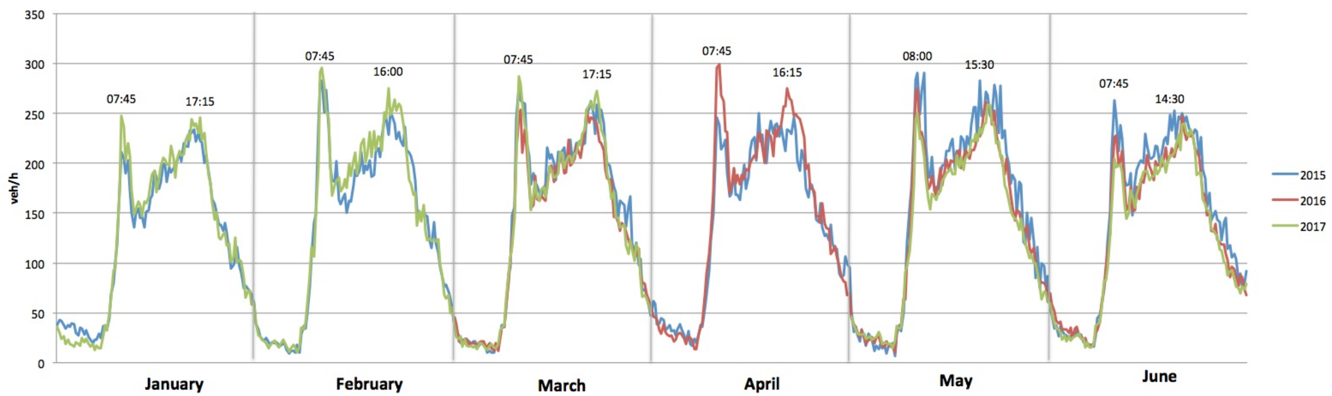


Figure C.49: Average day variation monthly. Direction: city center

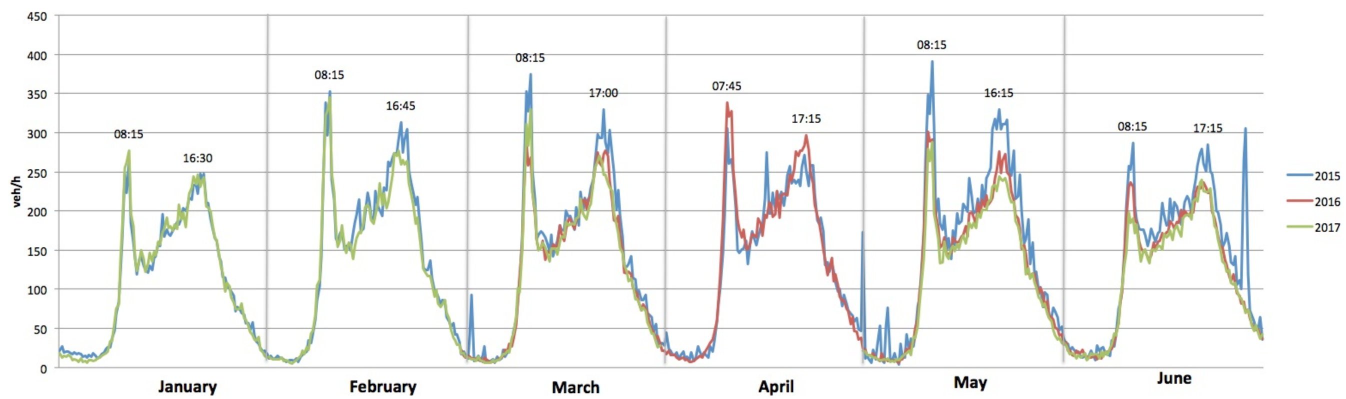


Figure C.50: Average day variation monthly. Direction: away from city center.

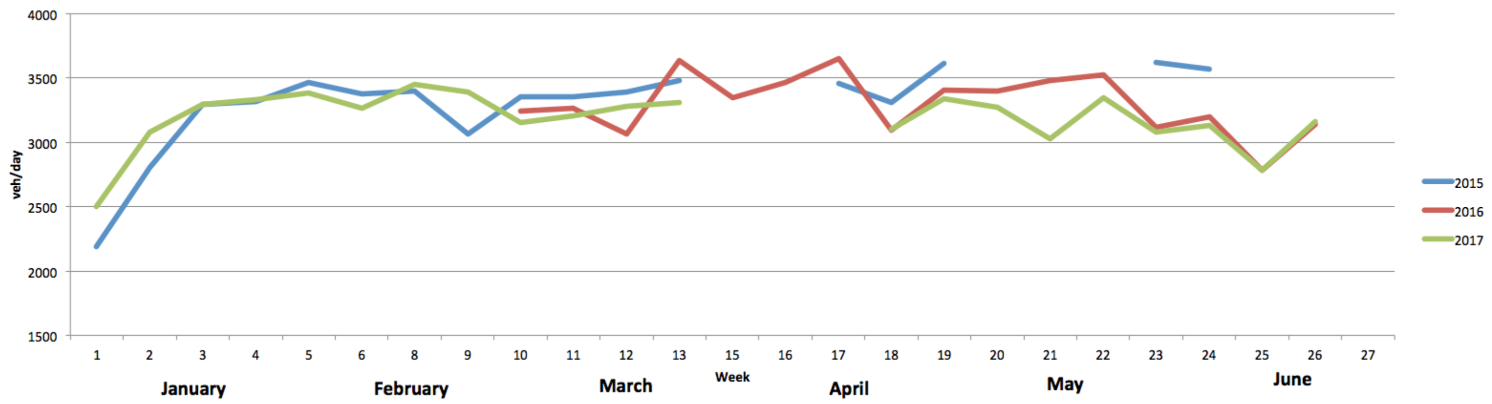


Figure C.51: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

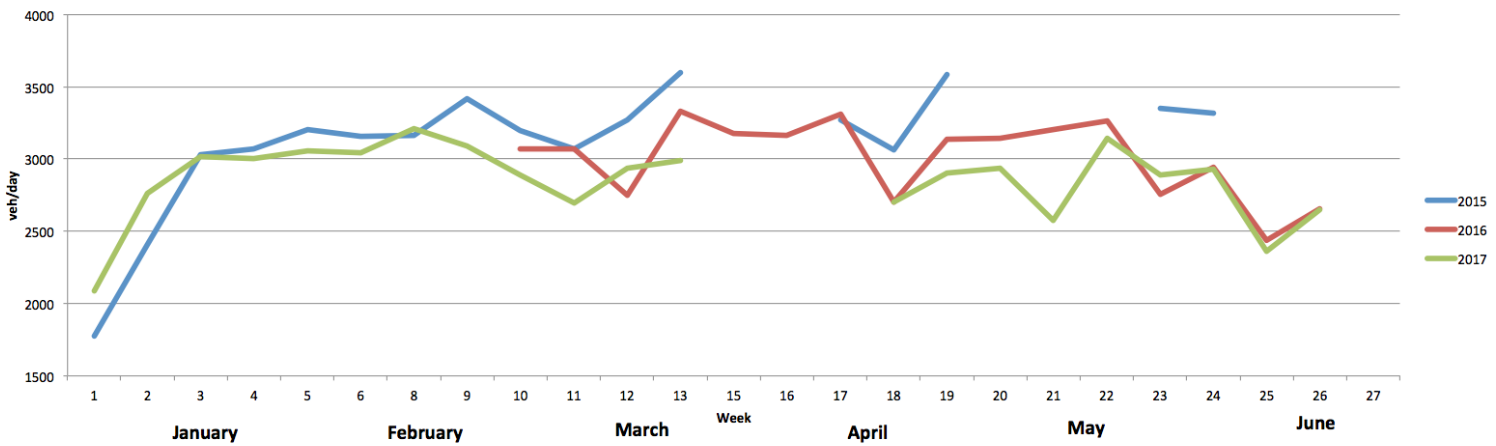


Figure C.52: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Engelbrektsgatan (150)

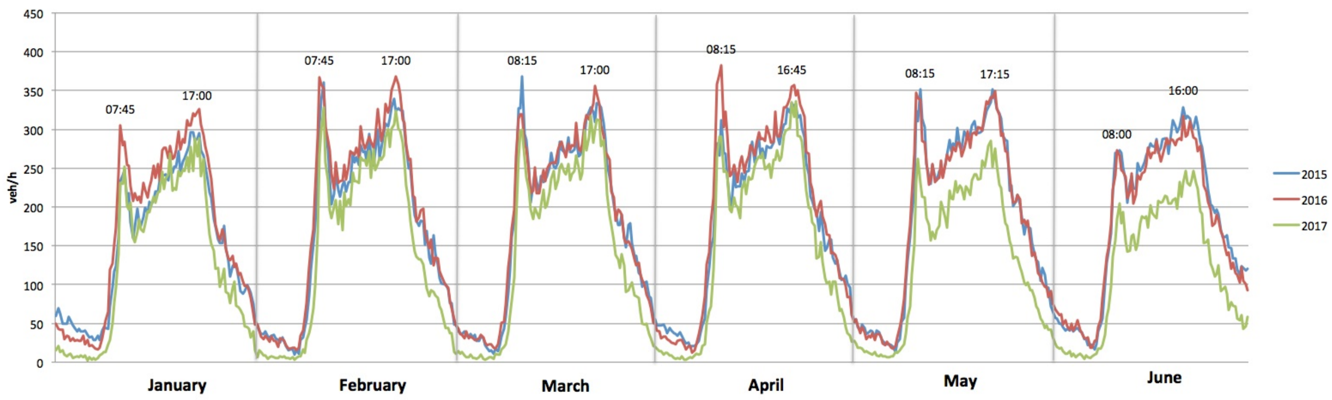


Figure C.53: Average day variation monthly. Direction: city center

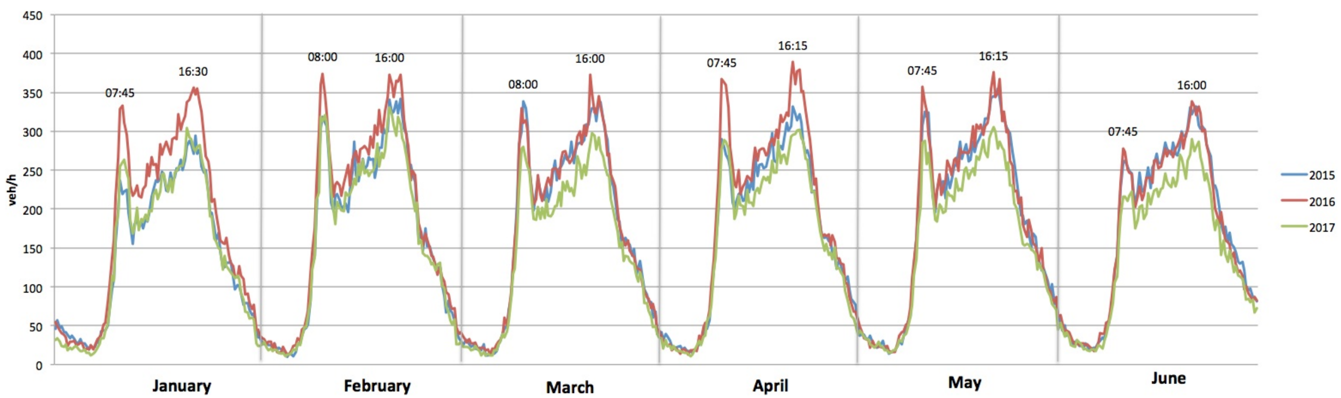


Figure C.54: Average day variation monthly. Direction: away from city center.

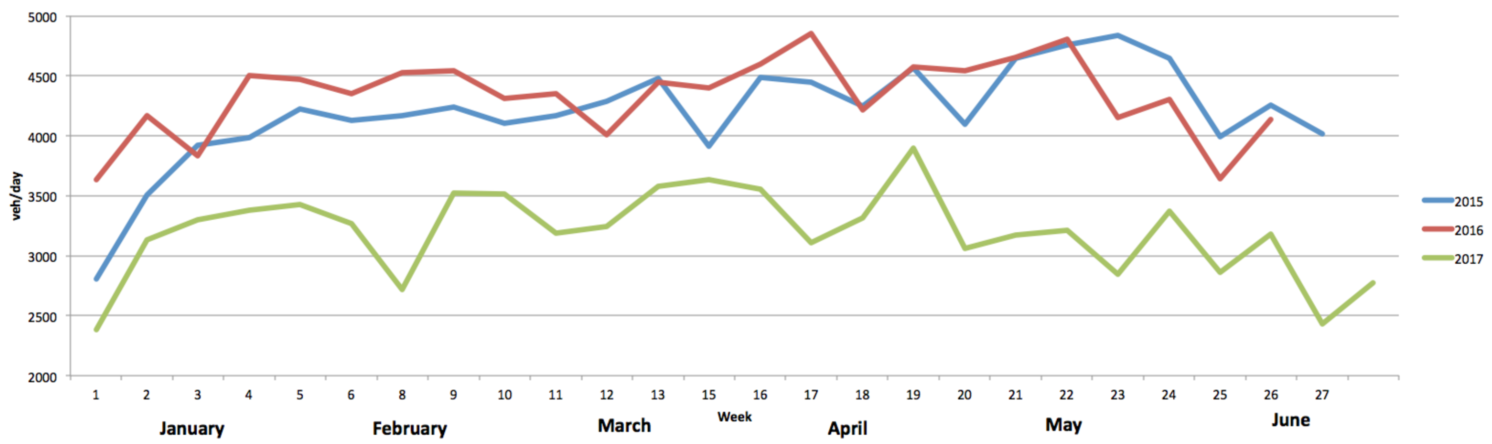


Figure C.55: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

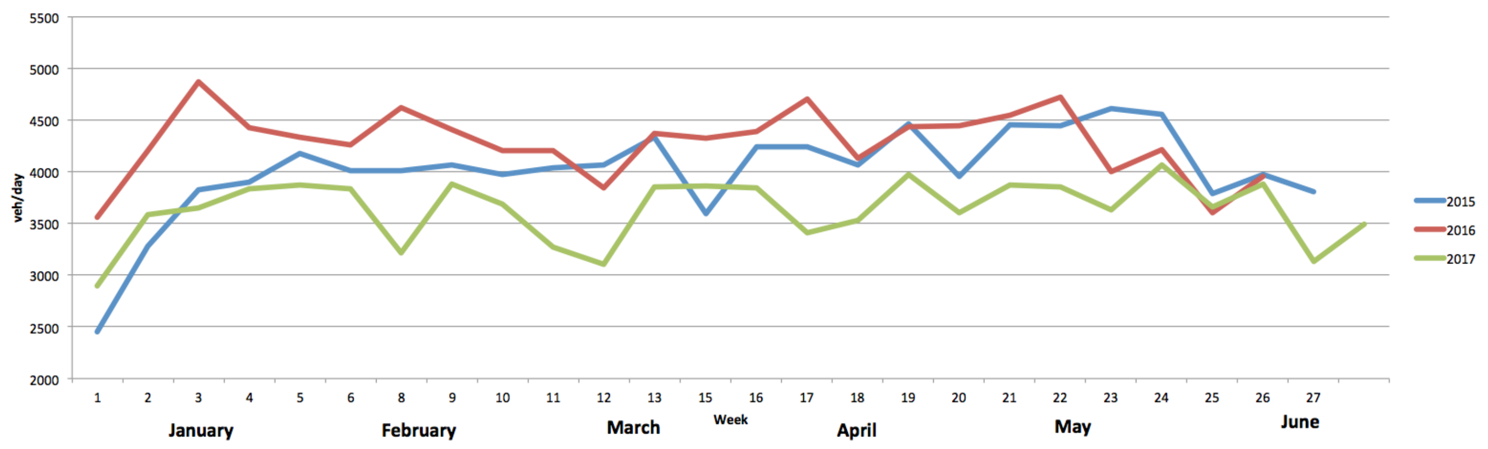


Figure C.56: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Första Långgatan

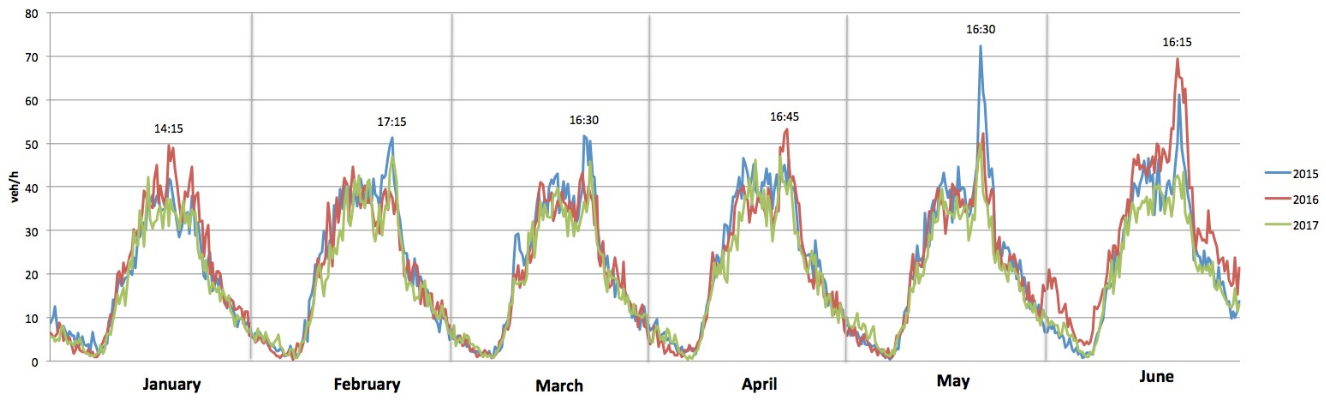


Figure C.57: Average day variation monthly. Direction: city center

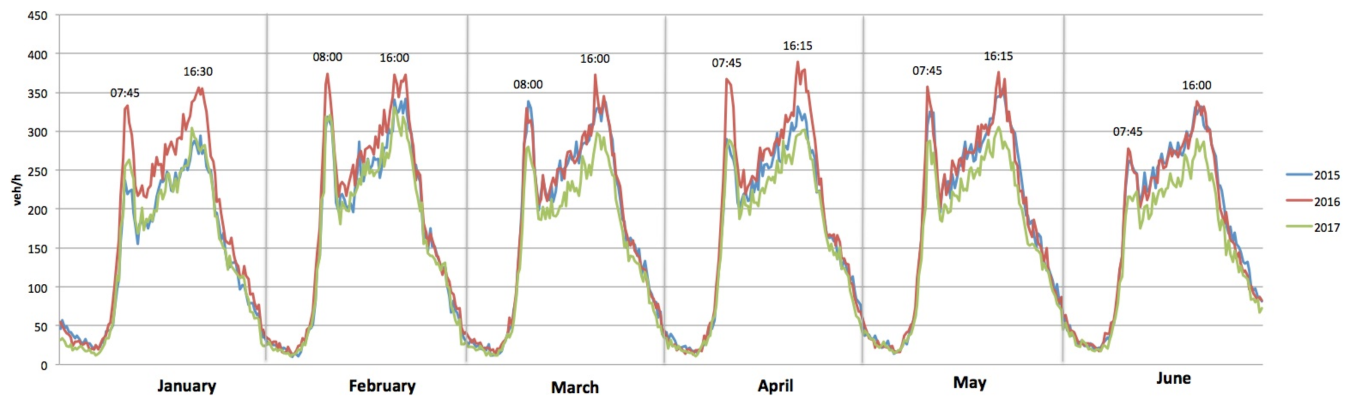


Figure C.58: Average day variation monthly. Direction: away from city center.

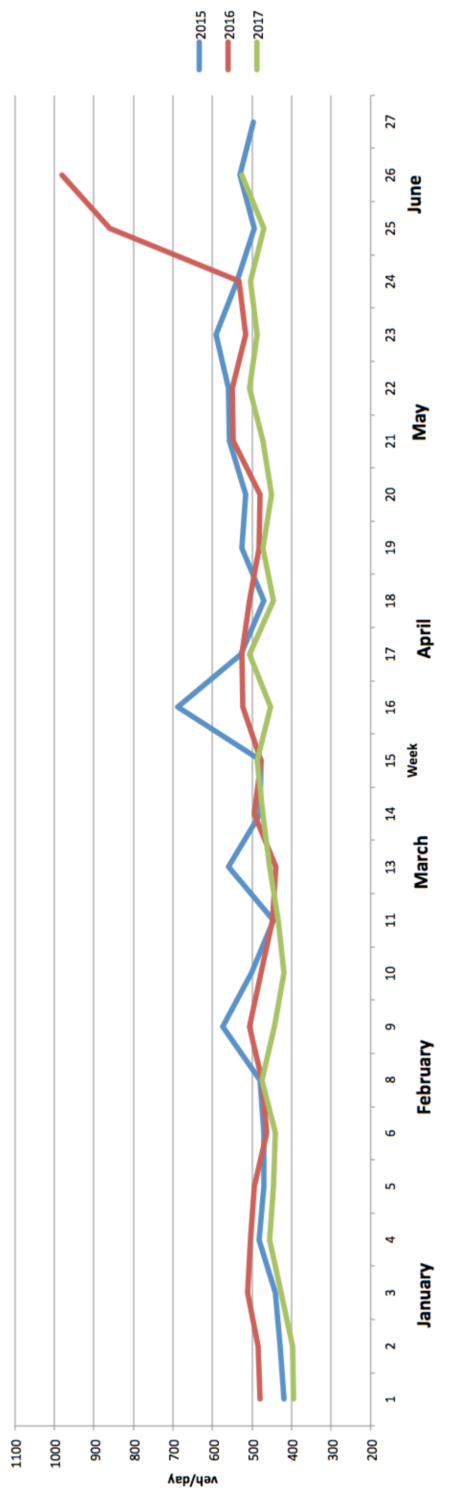


Figure C.59: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

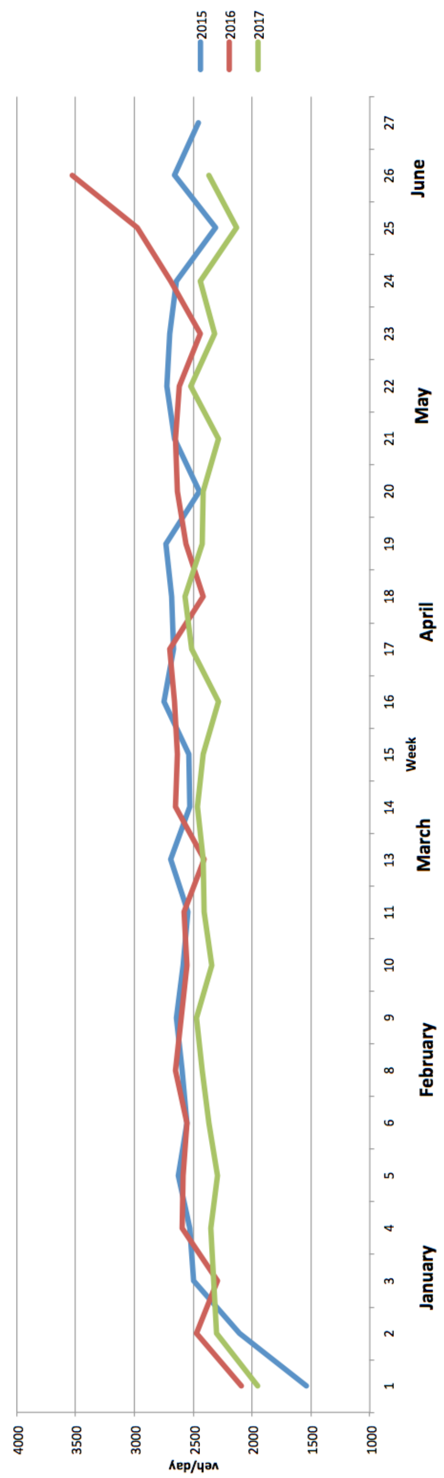


Figure C.60: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Hjalmar Brantingsgatan

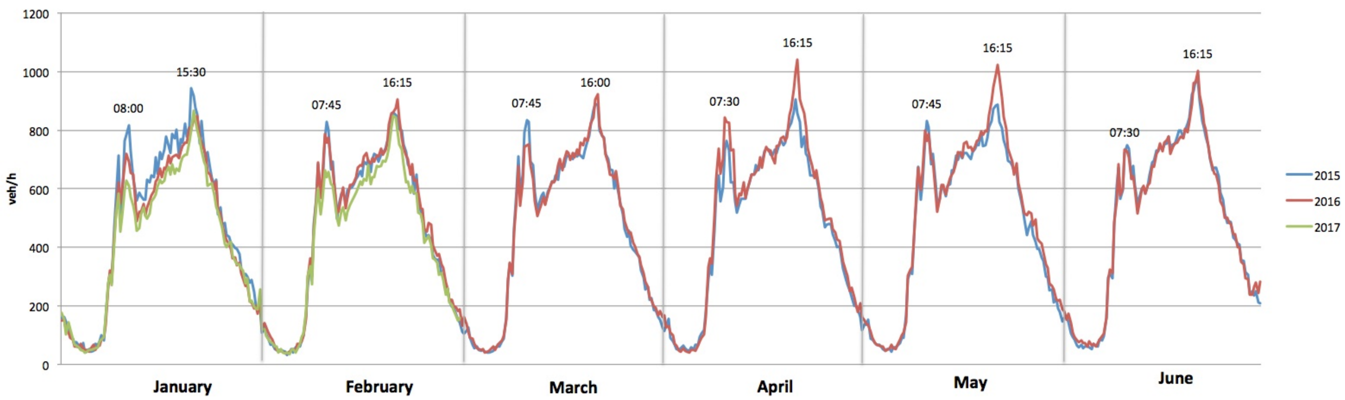


Figure C.61: Average day variation monthly. Direction: city center

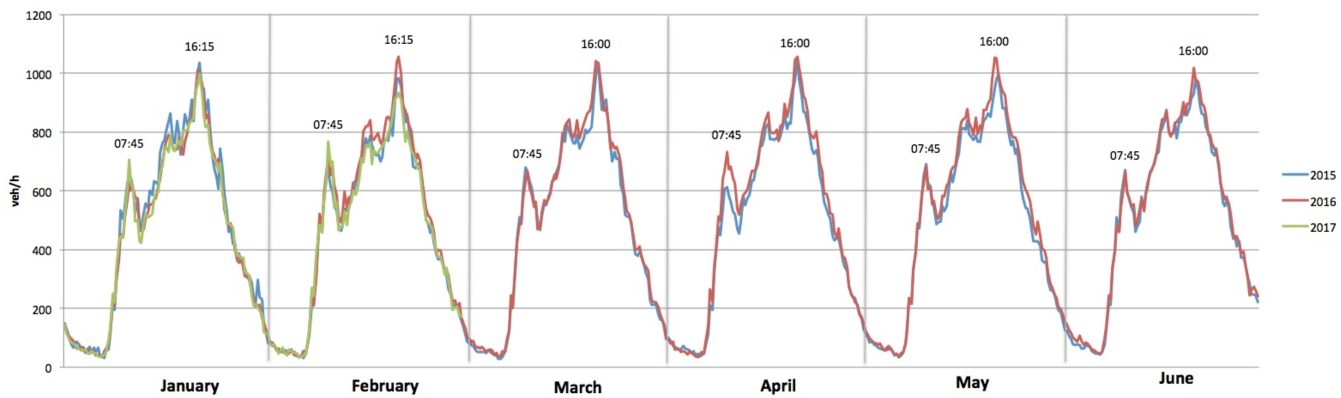


Figure C.62: Average day variation monthly. Direction: away from city center.

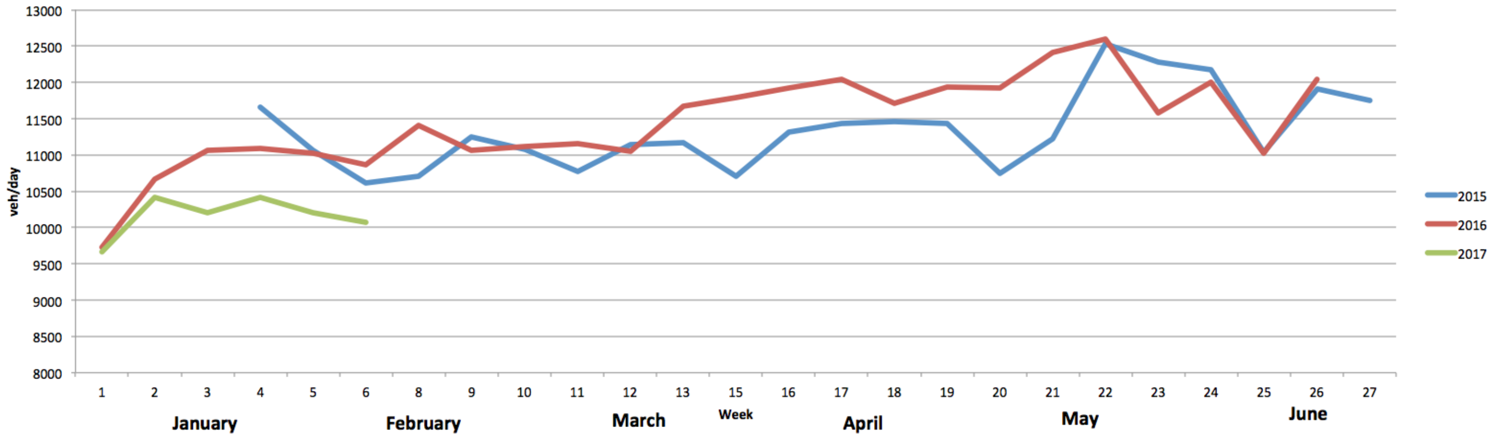


Figure C.63: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

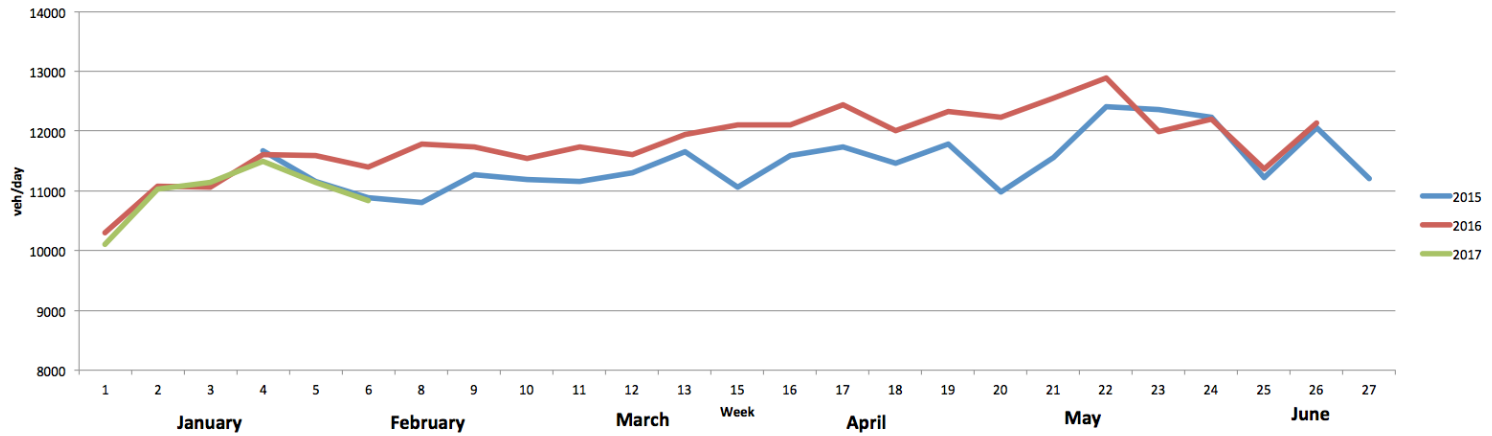


Figure C.64: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Järntorget

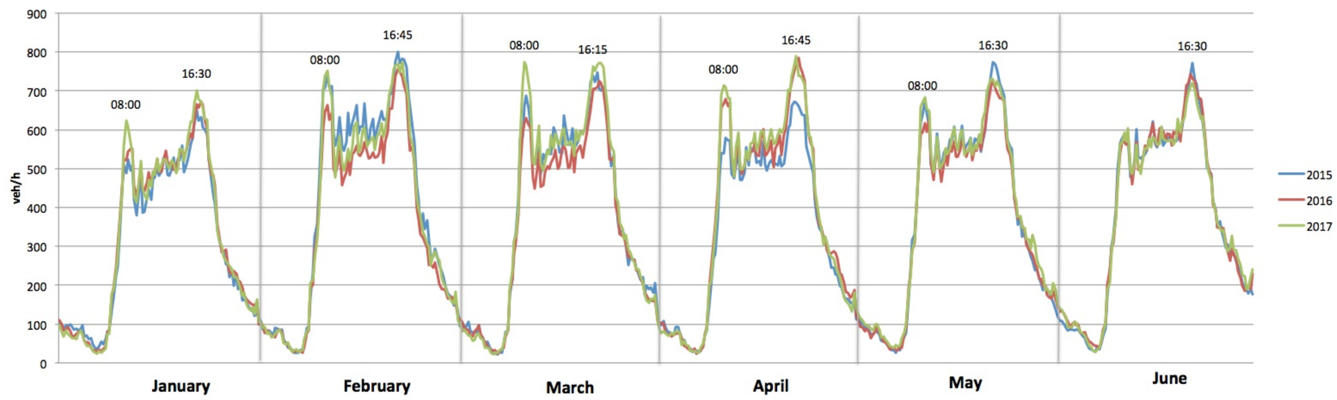


Figure C.65: Average day variation monthly. Direction: city center

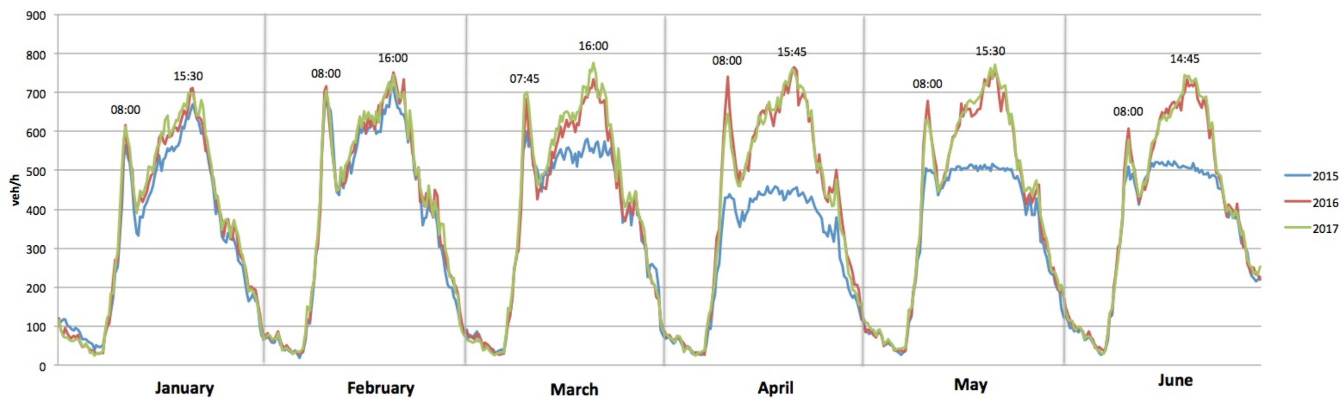


Figure C.66: Average day variation monthly. Direction: away from city center.

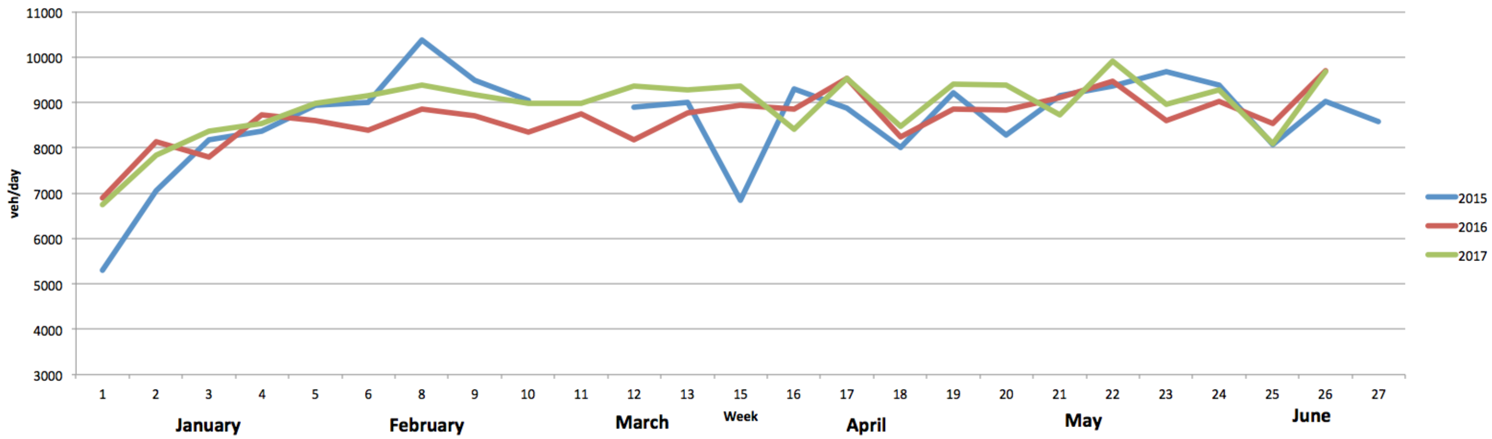


Figure C.67: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

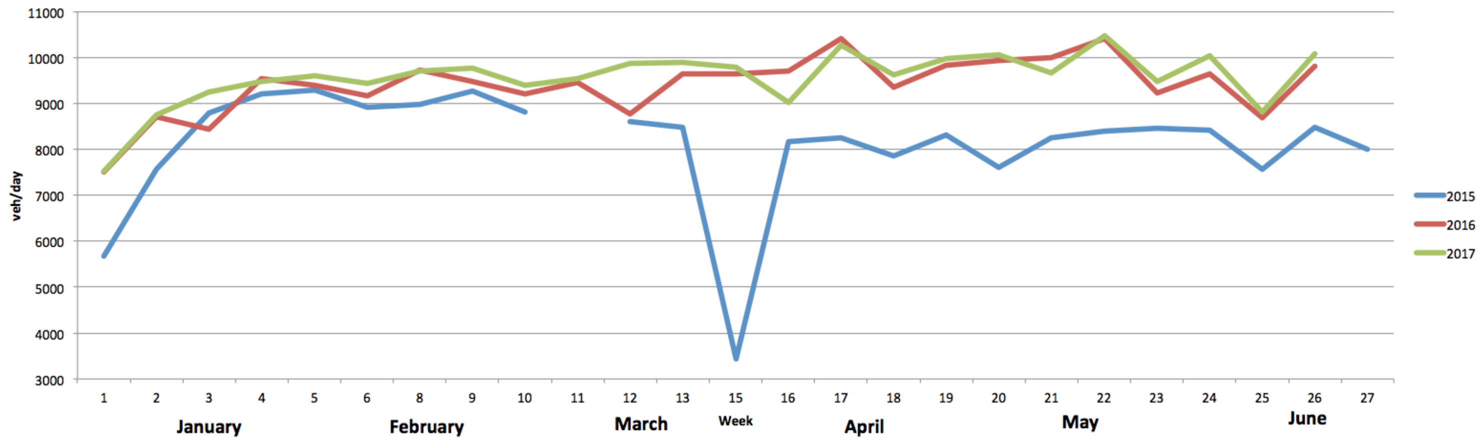


Figure C.68: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Kungsbackaleden/E6 1608

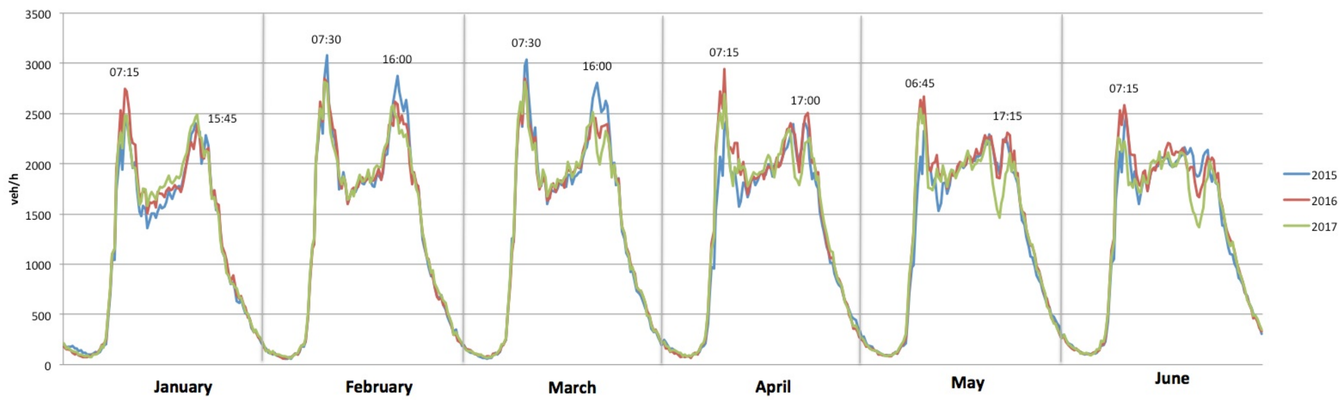


Figure C.69: Average day variation monthly. Direction: city center

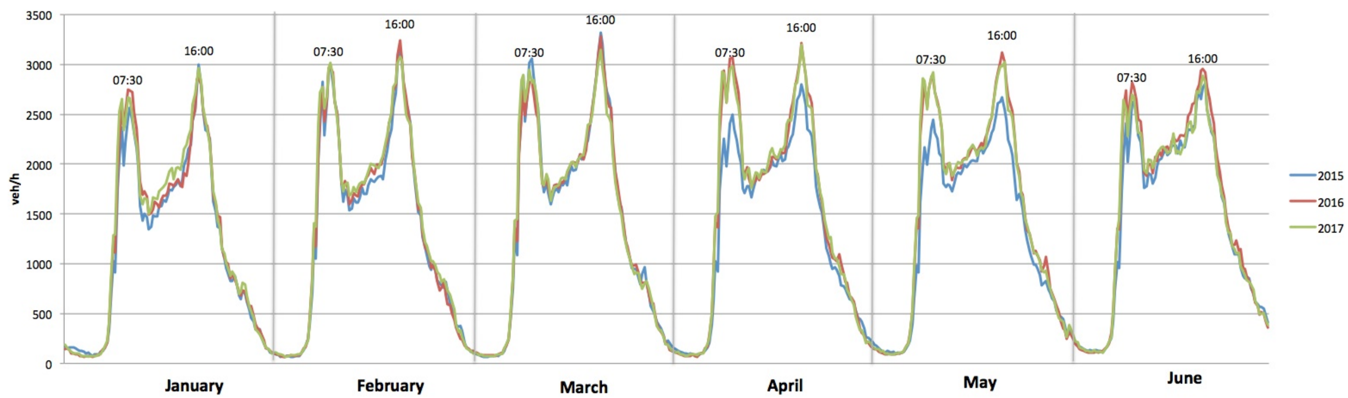


Figure C.70: Average day variation monthly. Direction: away from city center.

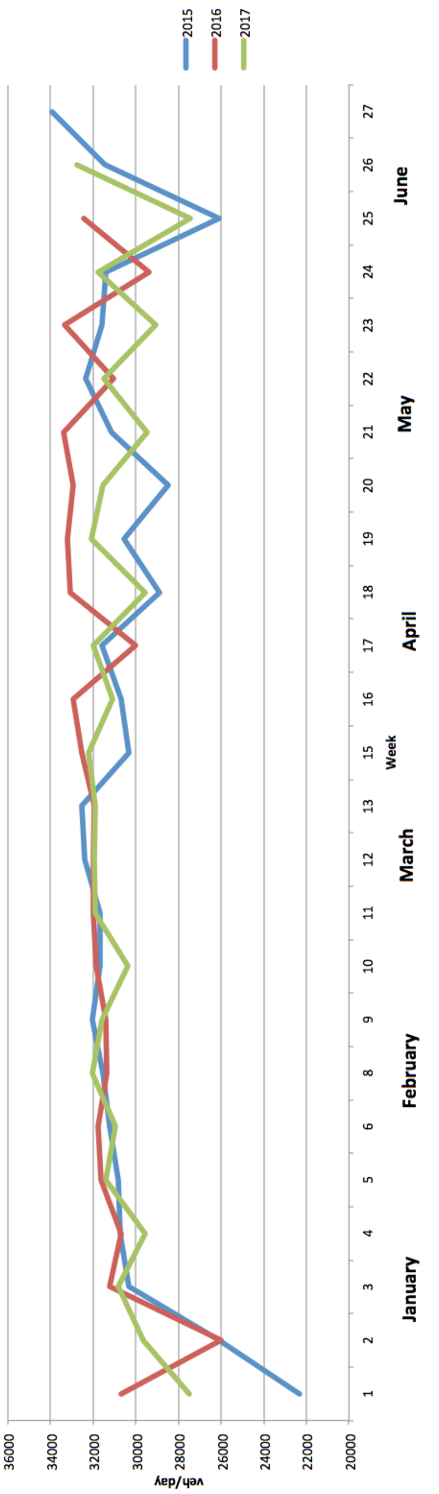


Figure C.71: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

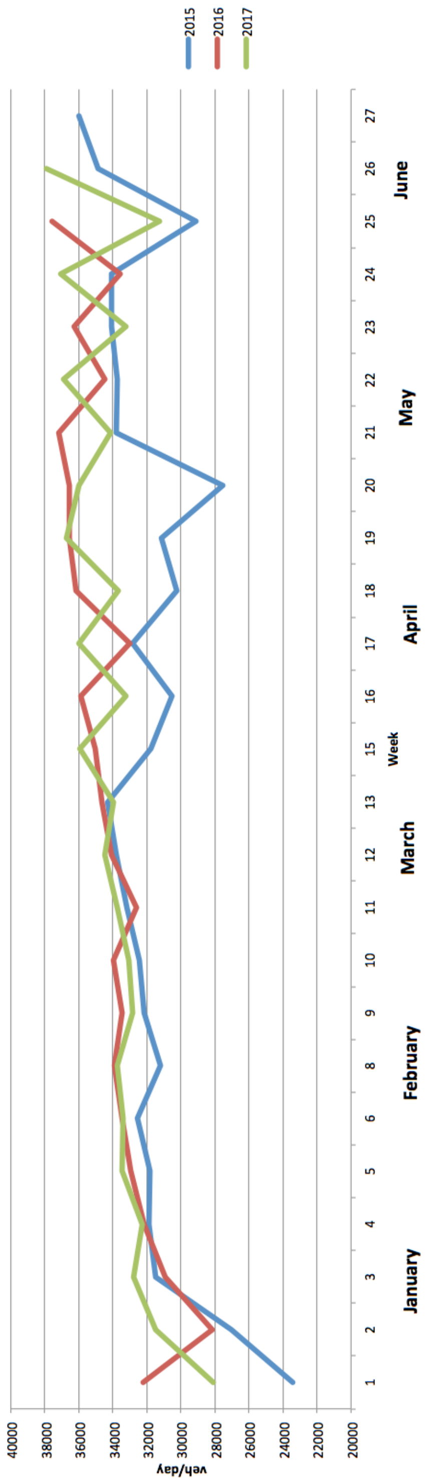


Figure C.72: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Kungsbackaleden/E6 1609

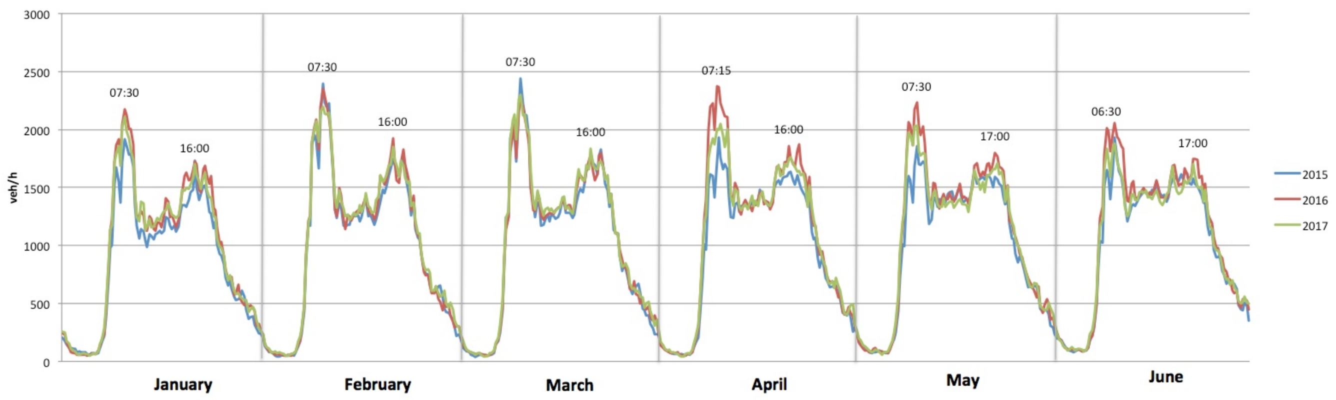


Figure C.73: Average day variation monthly. Direction: city center

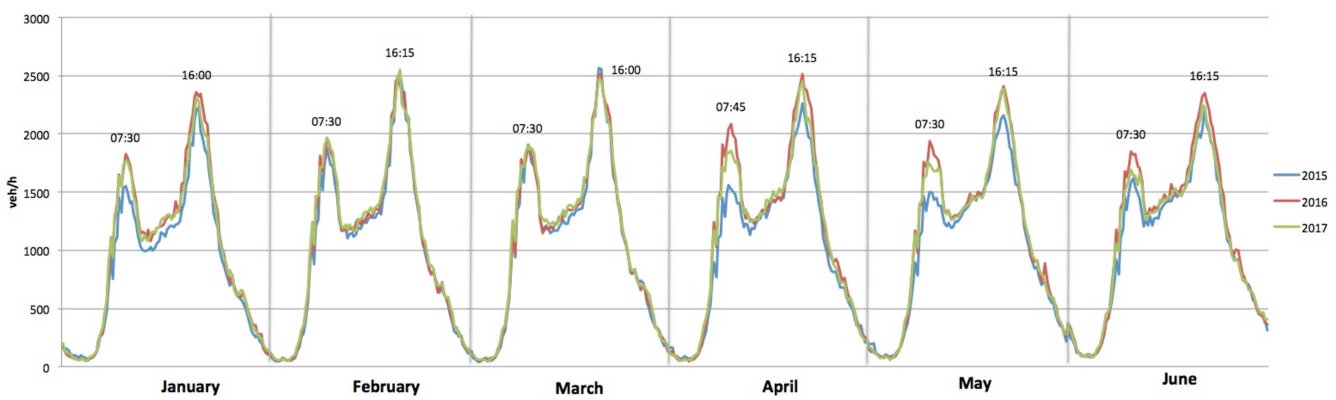


Figure C.74: Average day variation monthly. Direction: away from city center.

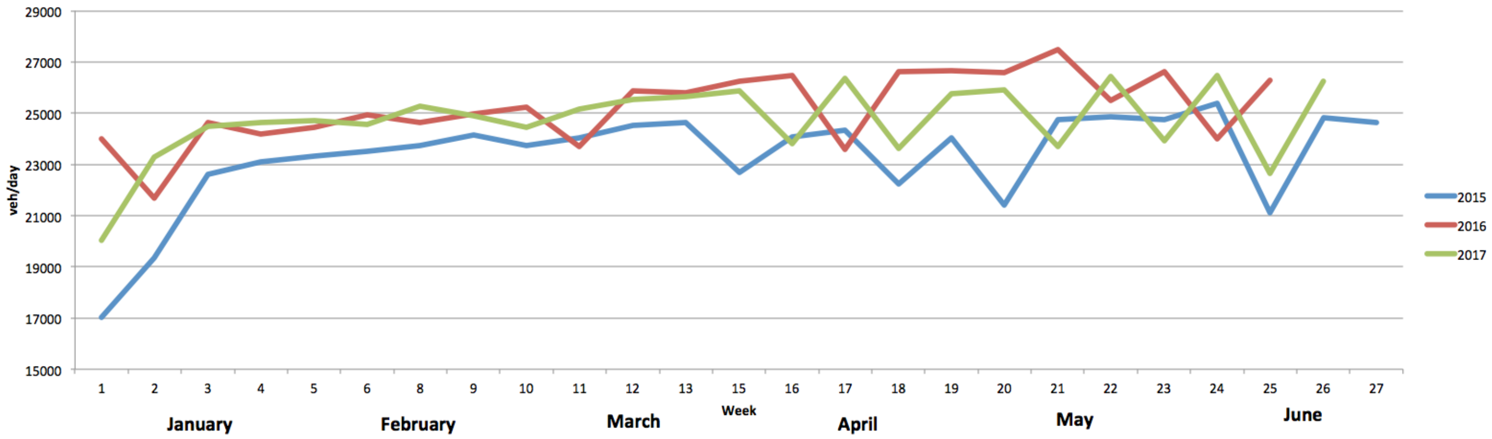


Figure C.75: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

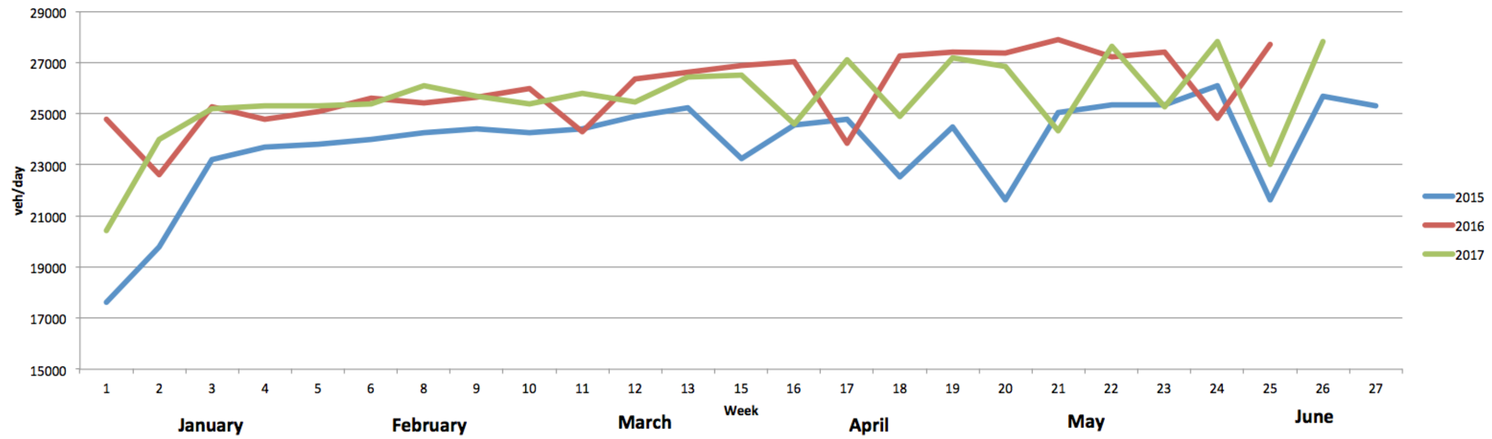


Figure C.76: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Kungälvsleden

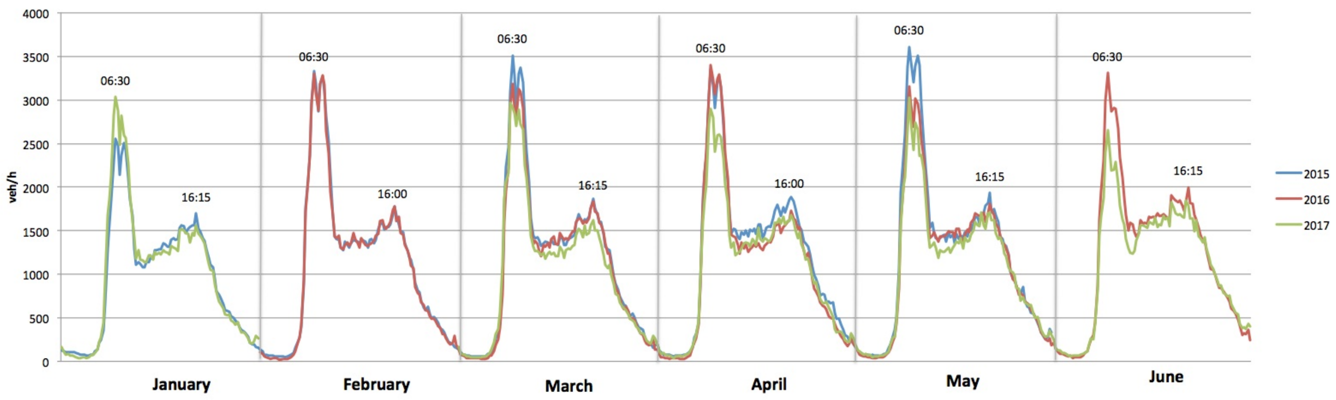


Figure C.77: Average day variation monthly. Direction: city center

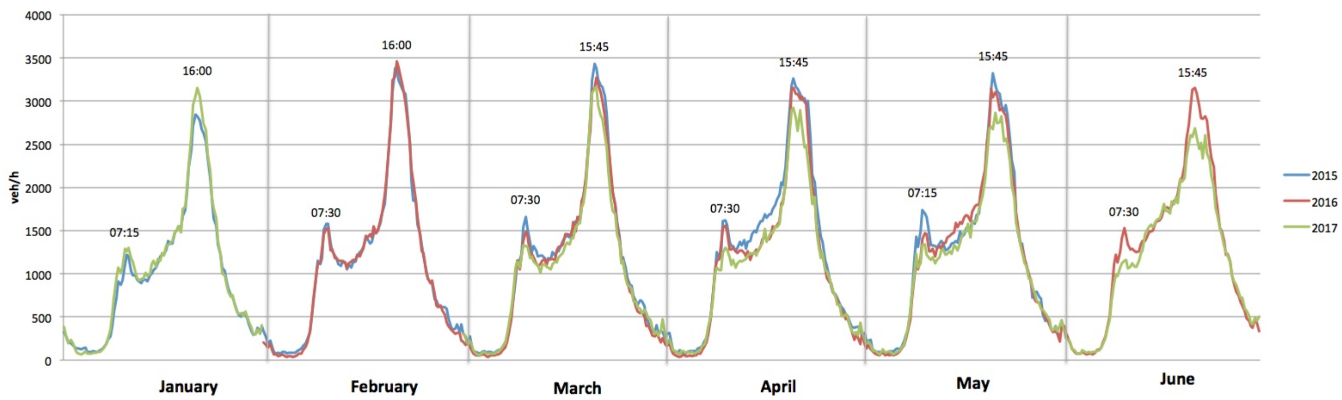


Figure C.78: Average day variation monthly. Direction: away from city center.

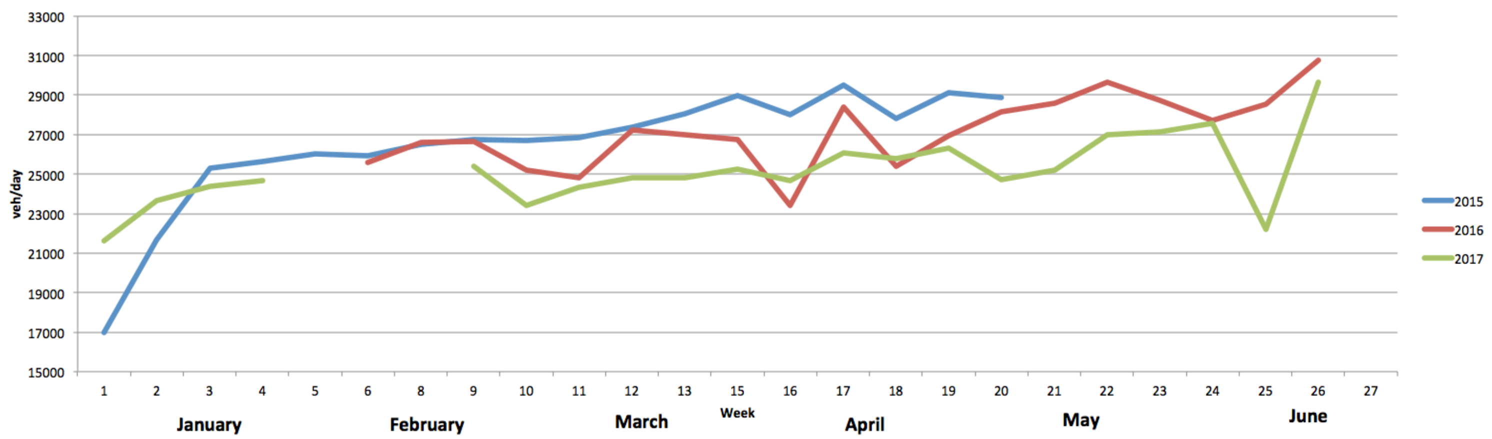


Figure C.79: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

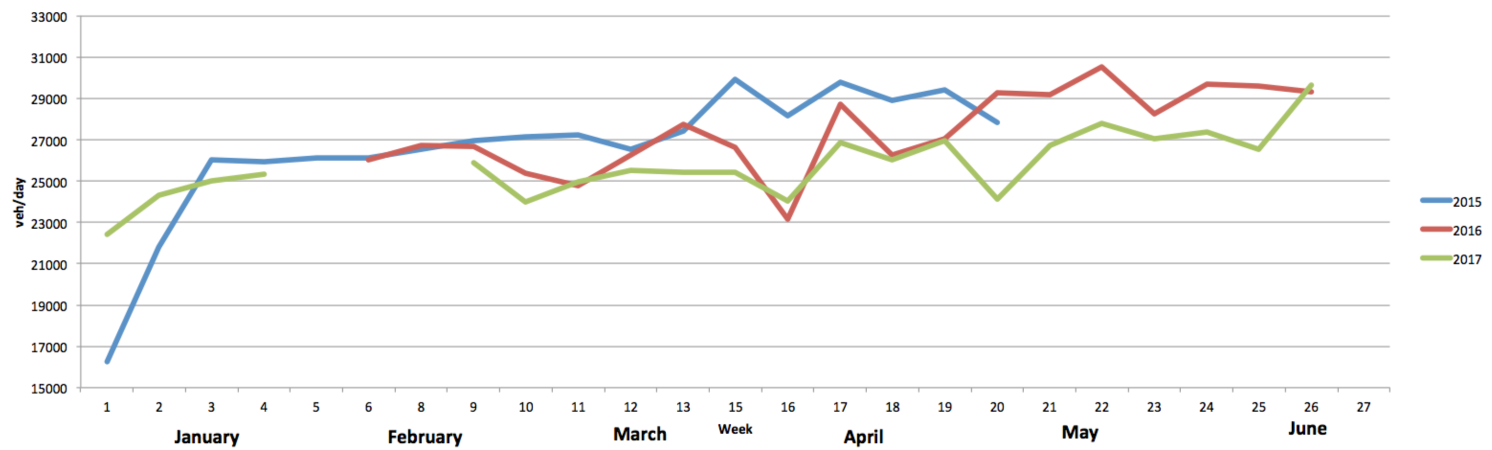


Figure C.80: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Lundbyleden

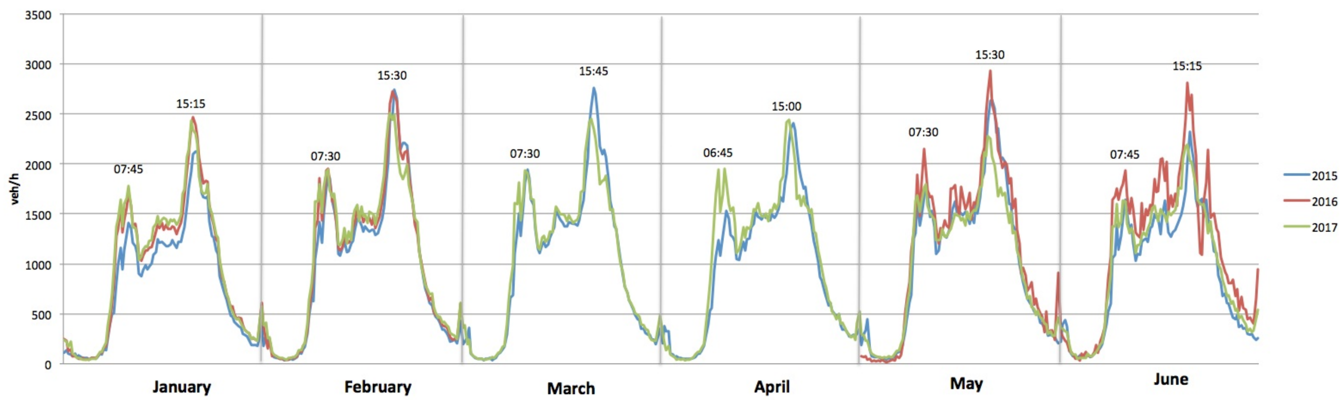


Figure C.81: Average day variation monthly. Direction: city center

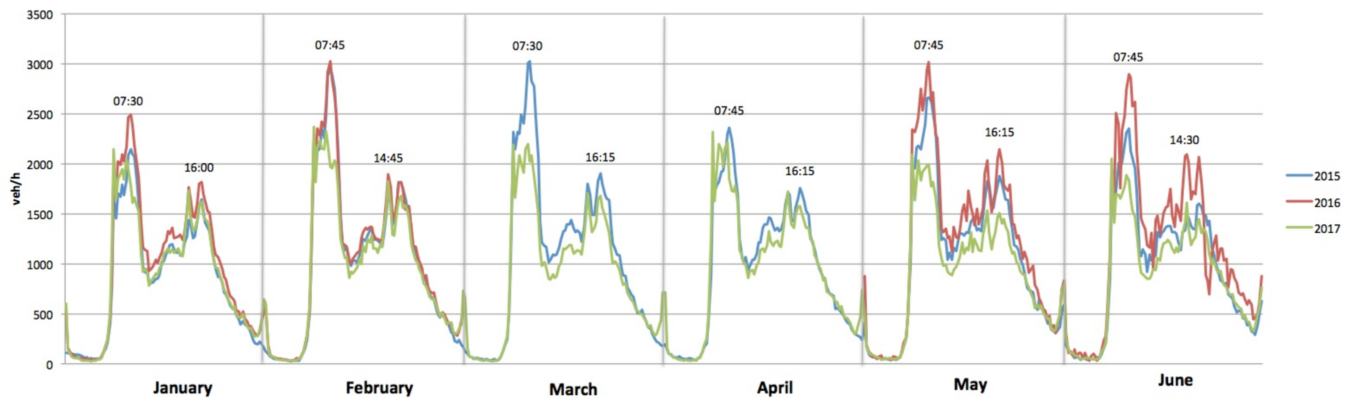


Figure C.82: Average day variation monthly. Direction: away from city center.

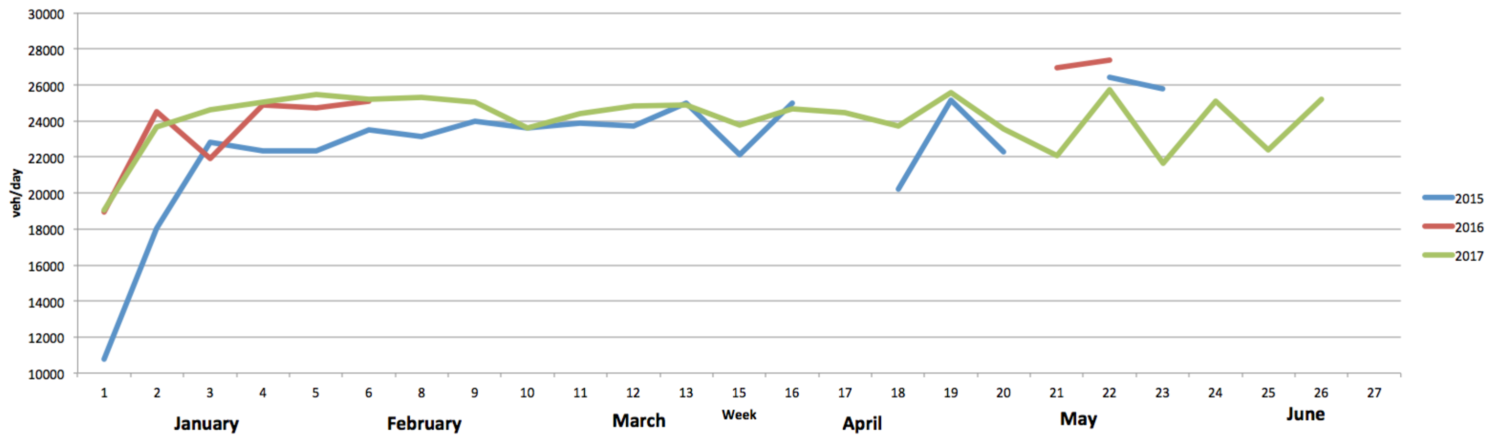


Figure C.83: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

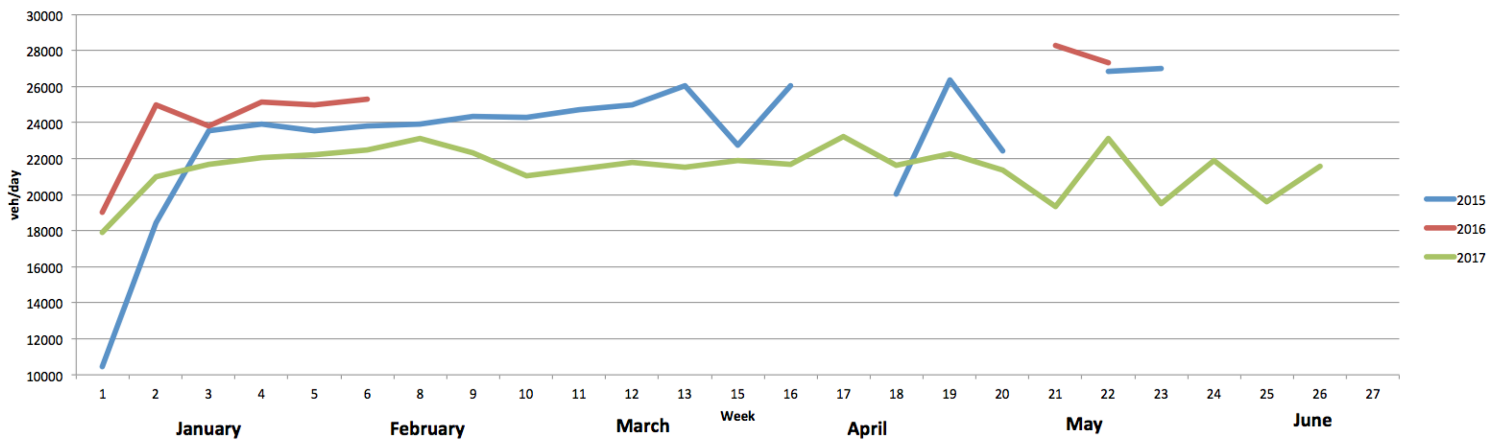


Figure C.84: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Nya Allén

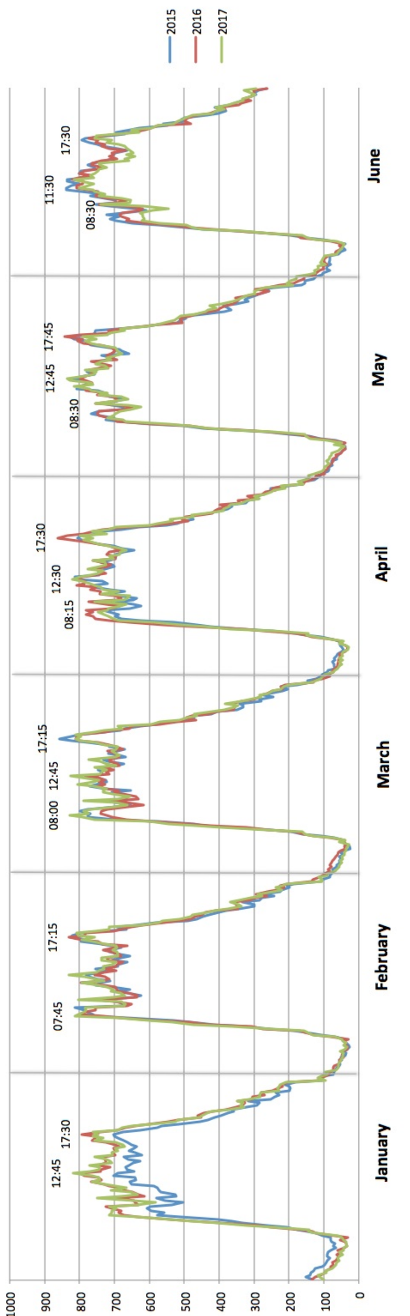


Figure C.85: Average day variation monthly.

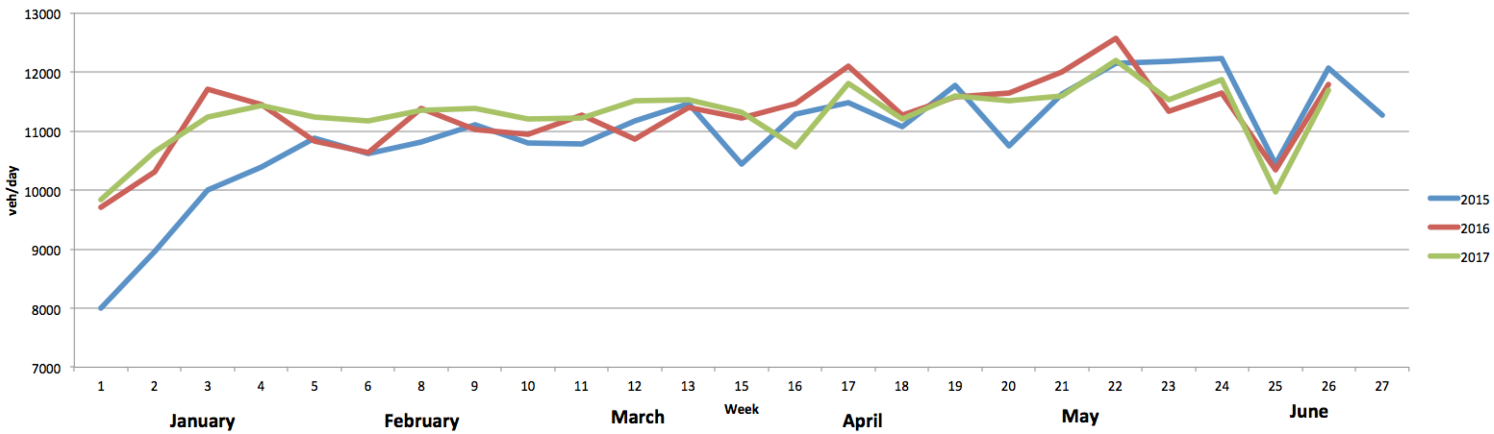


Figure C.86: Displaying an the average traffic flow a day each week between January and June.

Olskroksmotet

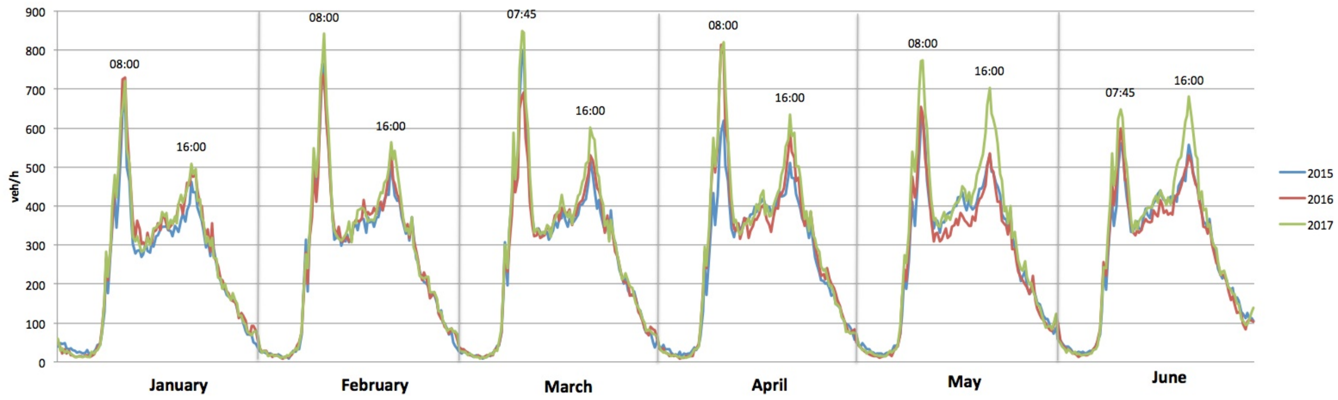


Figure C.87: Average day variation monthly. Direction: city center

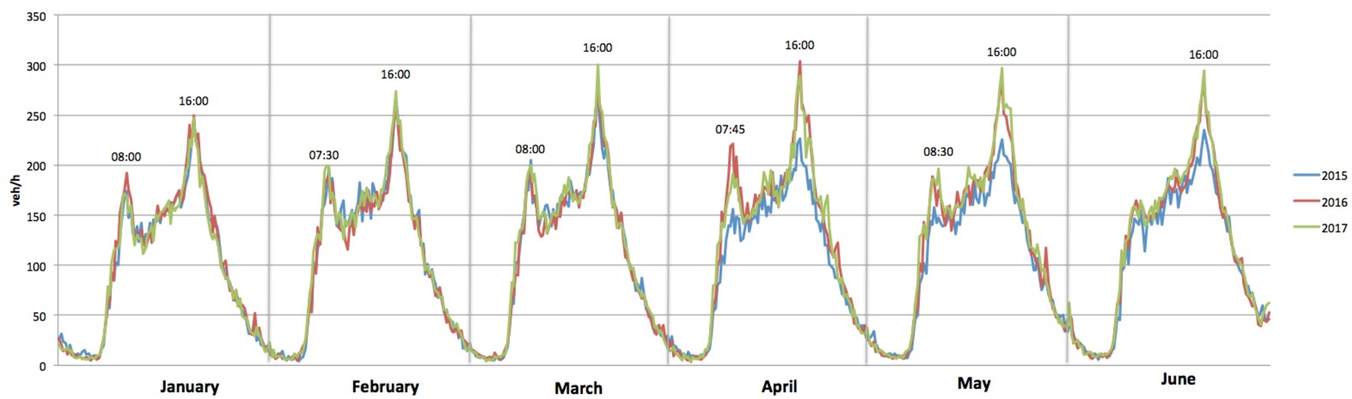


Figure C.88: Average day variation monthly. Direction: away from city center.

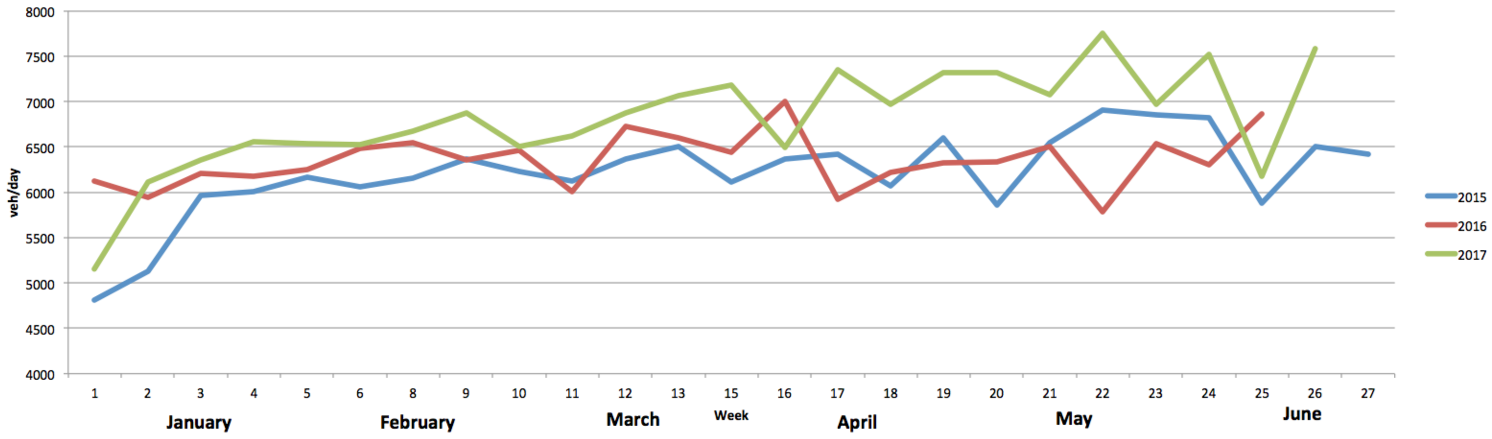


Figure C.89: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

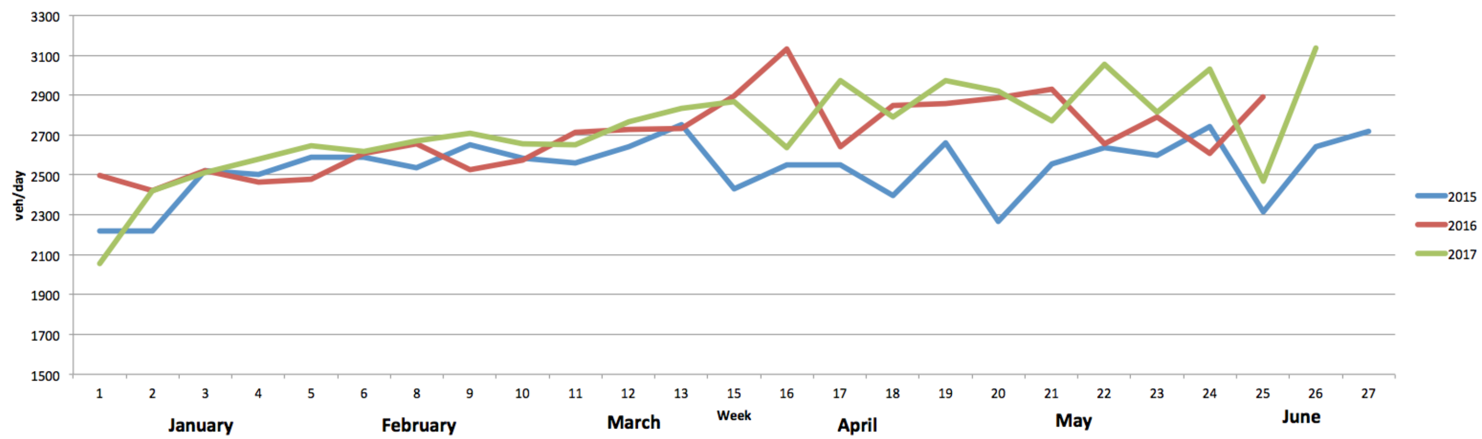


Figure C.90: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Oscarsleden

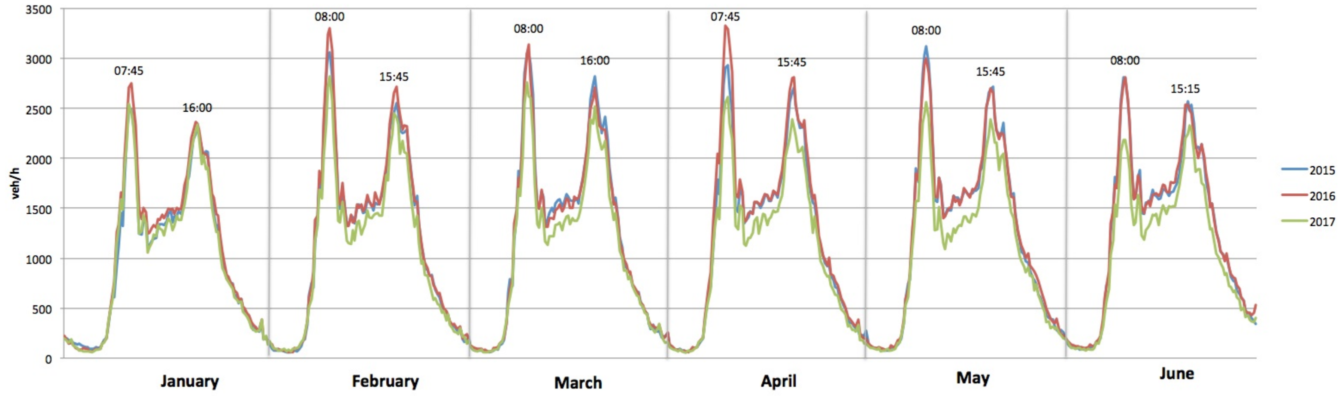


Figure C.91: Average day variation monthly. Direction: city center

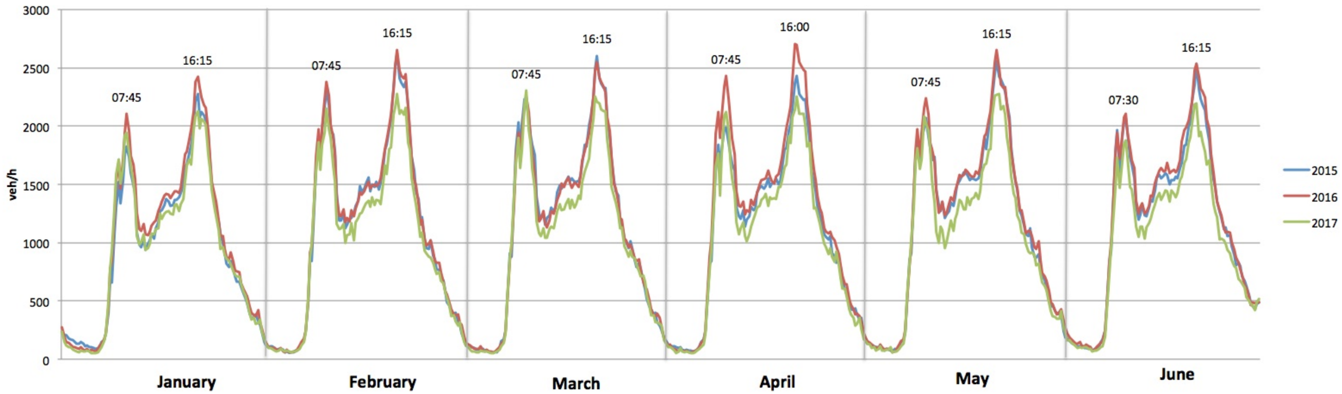


Figure C.92: Average day variation monthly. Direction: away from city center.

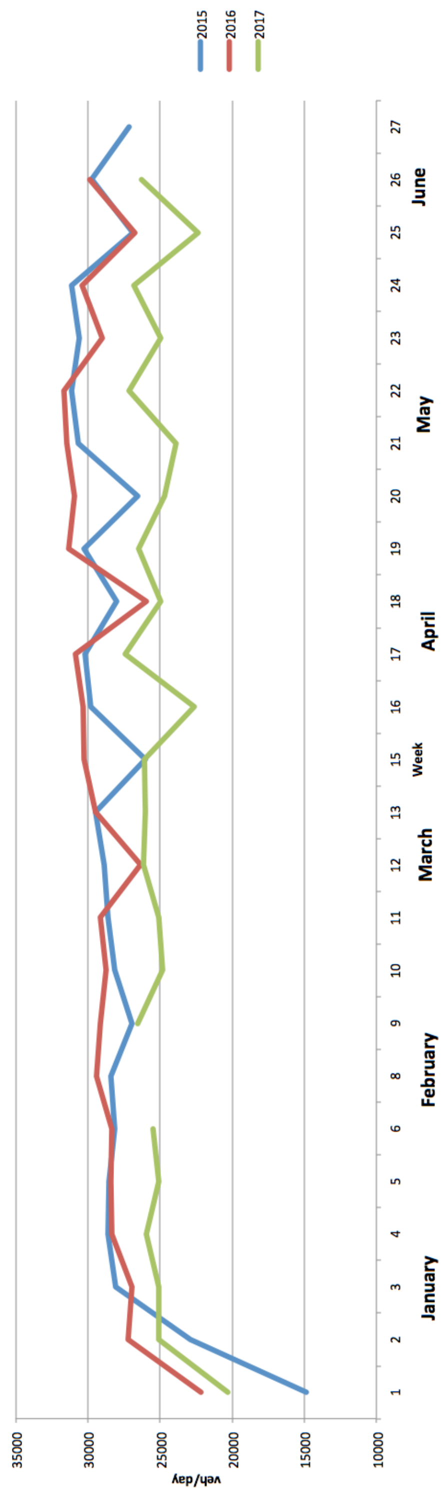


Figure C.93: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

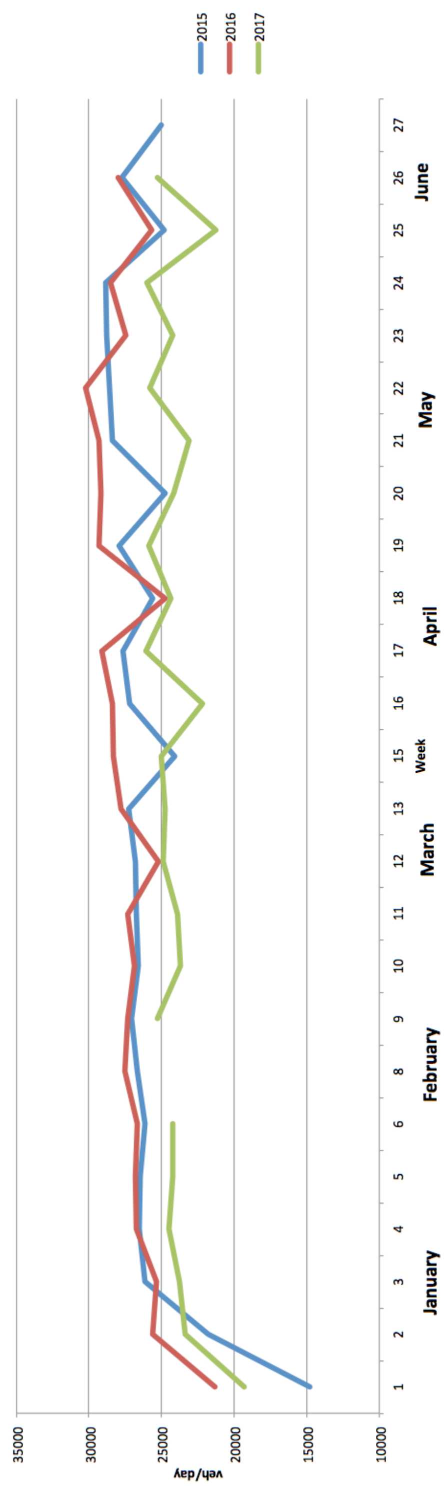


Figure C.94: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Parkgatan

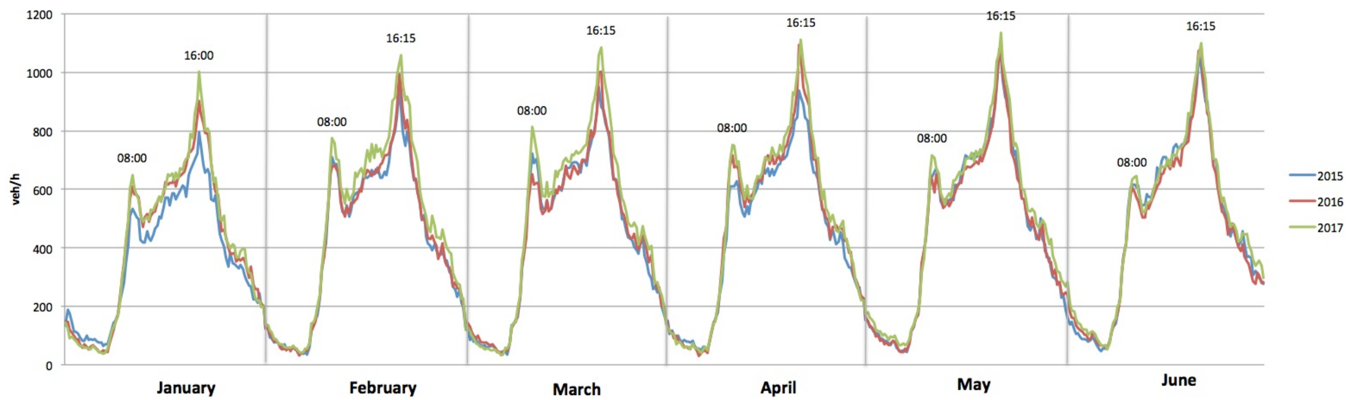


Figure C.95: Average day variation monthly

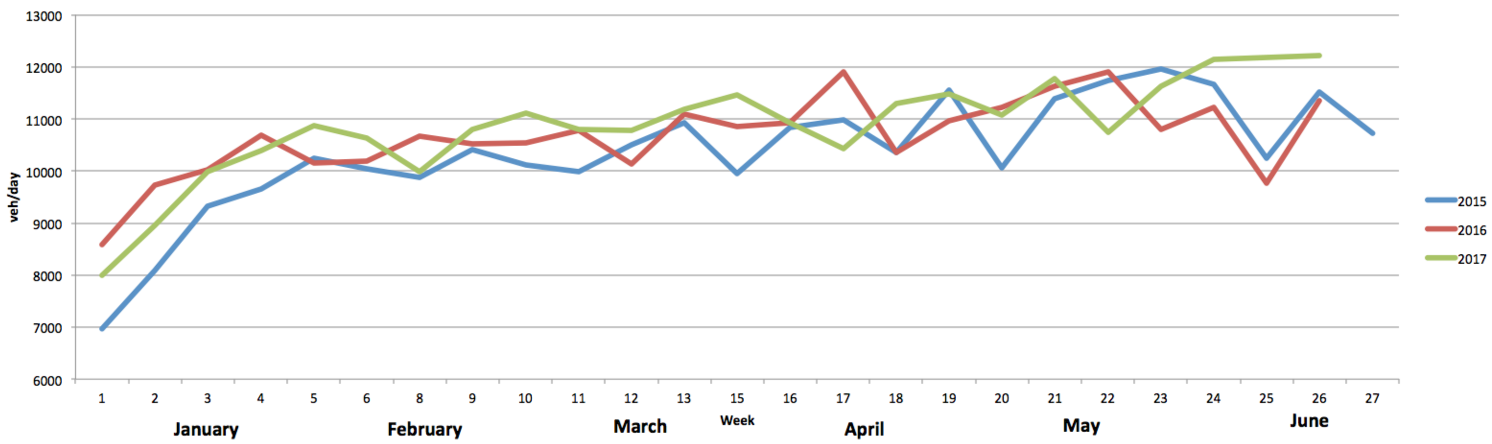


Figure C.96: Displaying an the average traffic flow a day each week between January and June.

Redbergsvägen

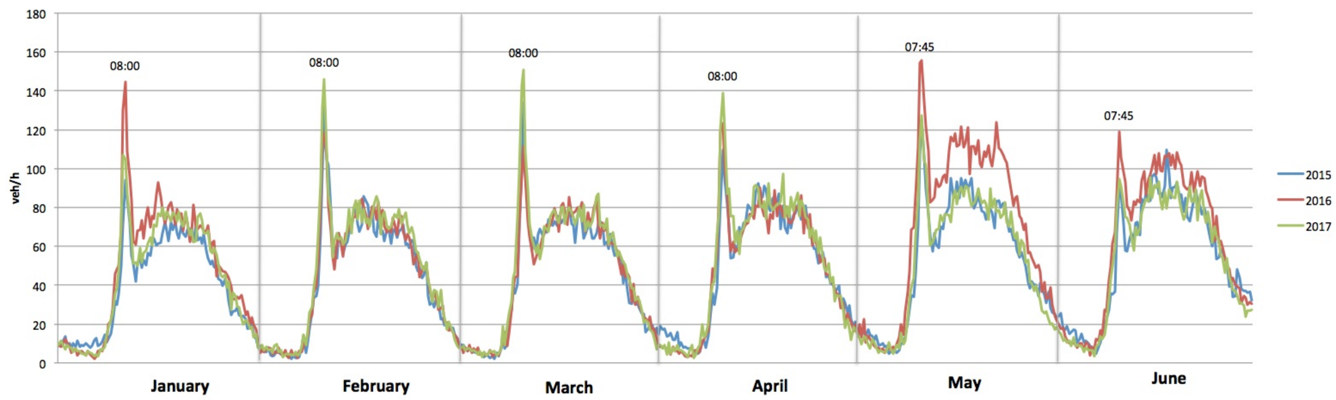


Figure C.97: Average day variation monthly. Direction: city center

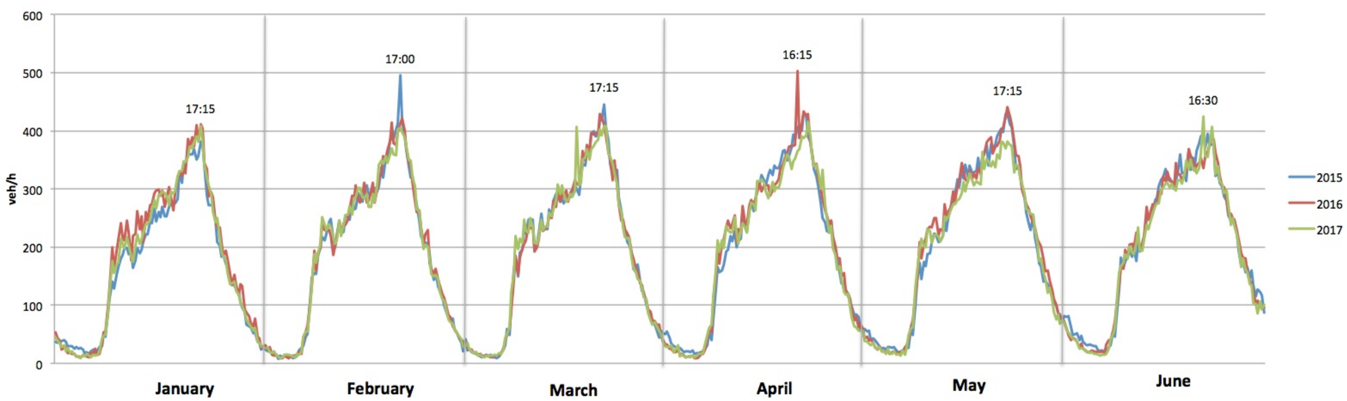


Figure C.98: Average day variation monthly. Direction: away from city center.

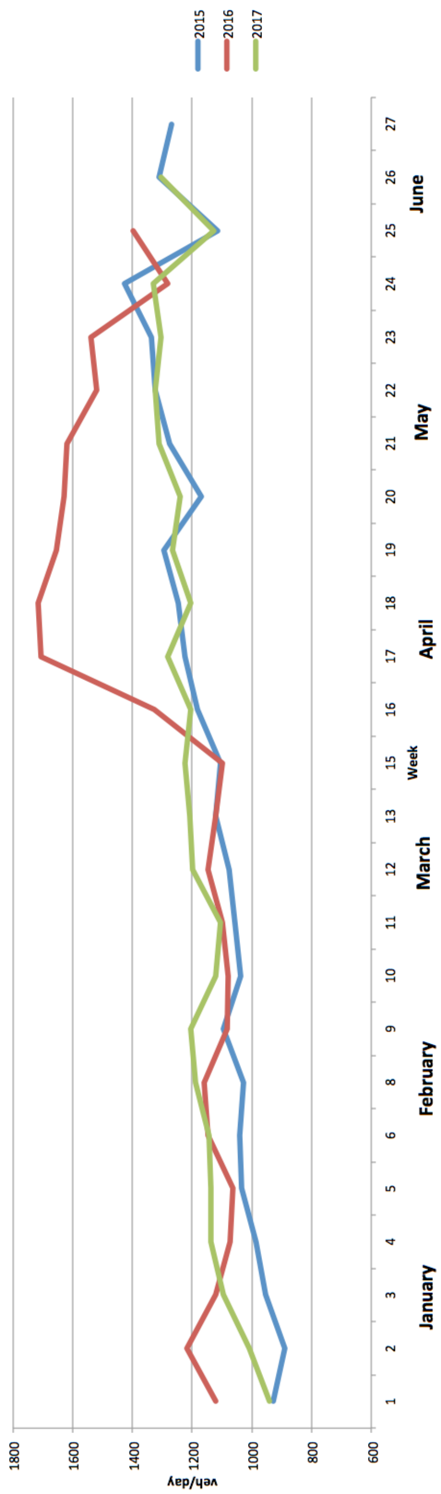


Figure C.99: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

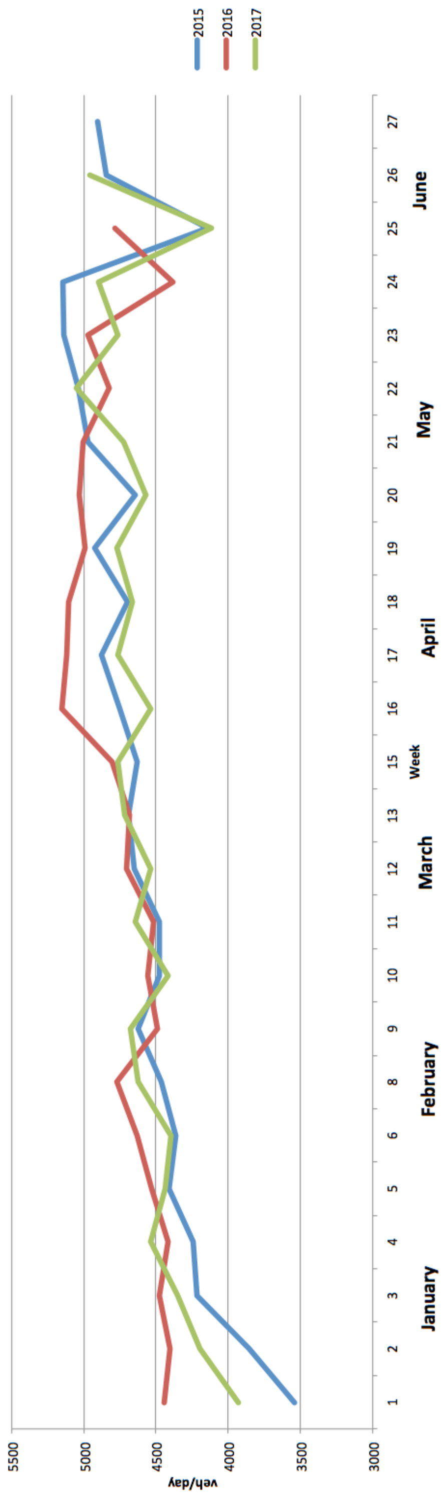


Figure C.100: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Skånegatan

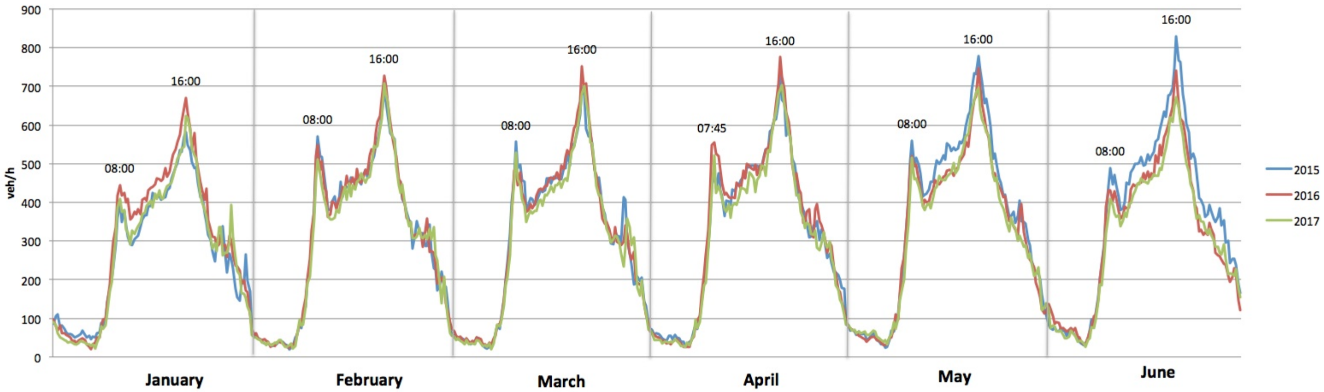


Figure C.101: Average day variation monthly. Direction: city center

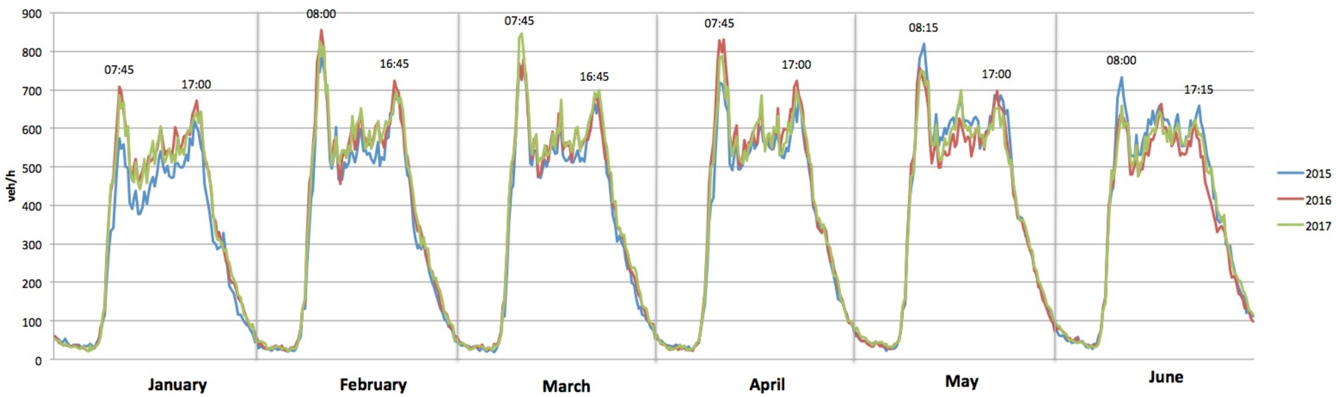


Figure C.102: Average day variation monthly. Direction: away from city center.

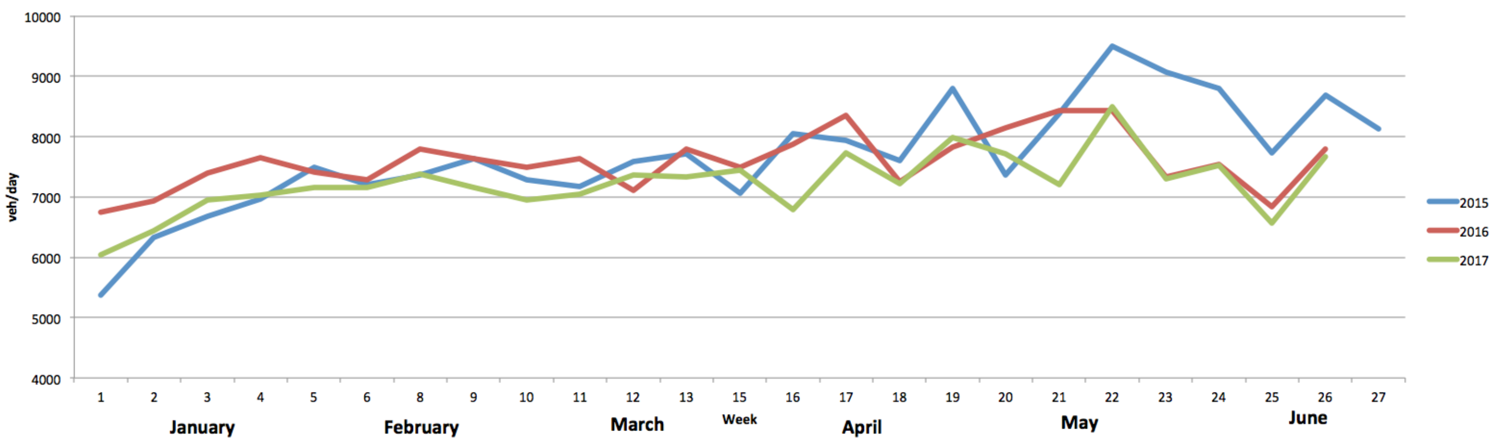


Figure C.103: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

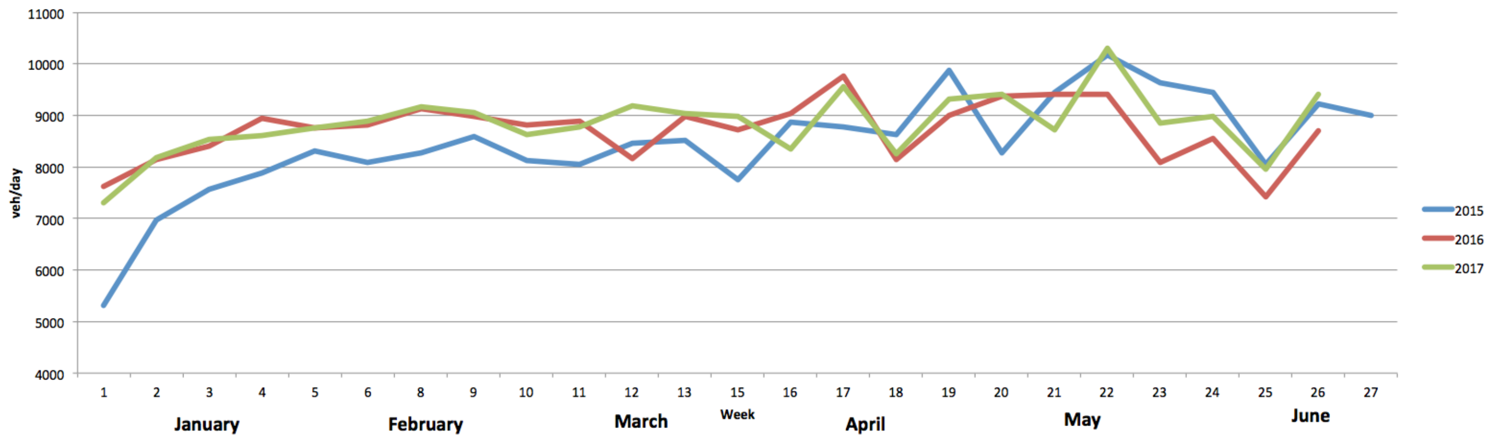


Figure C.104: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Slussgatan

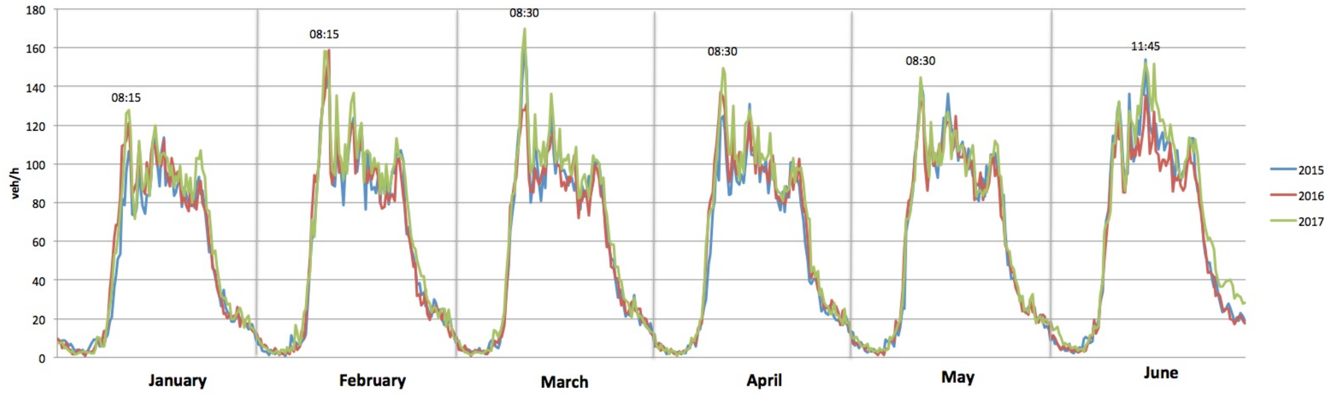


Figure C.105: Average day variation monthly. Direction: city center

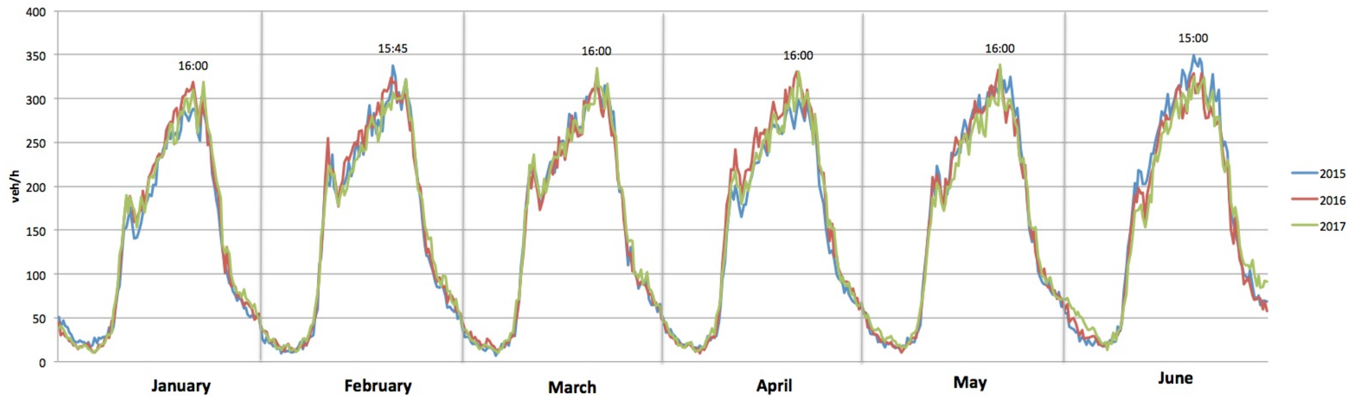


Figure C.106: Average day variation monthly. Direction: away from city center.

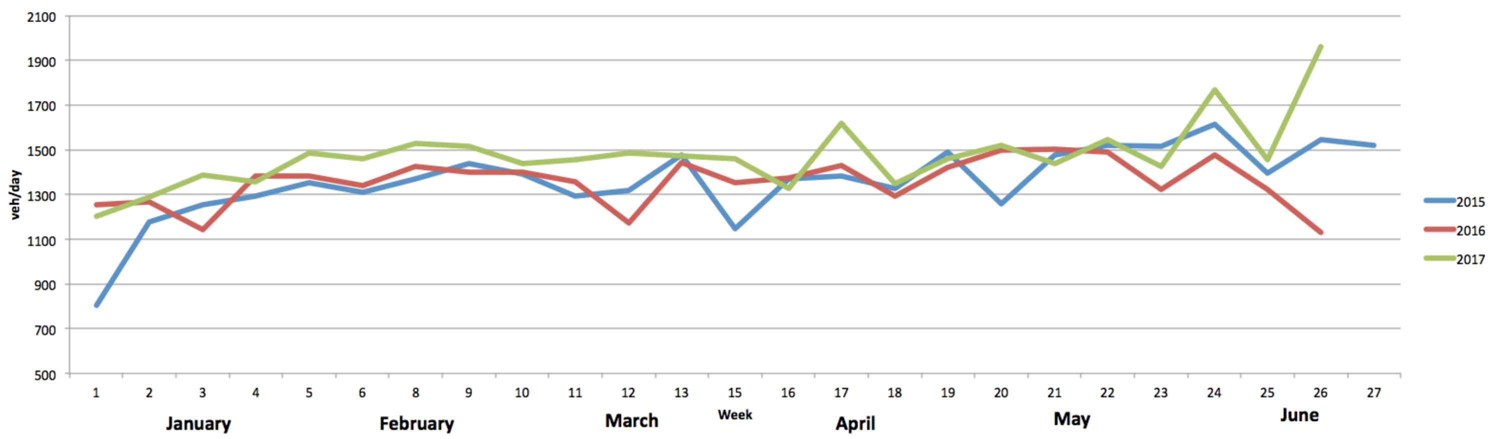


Figure C.107: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

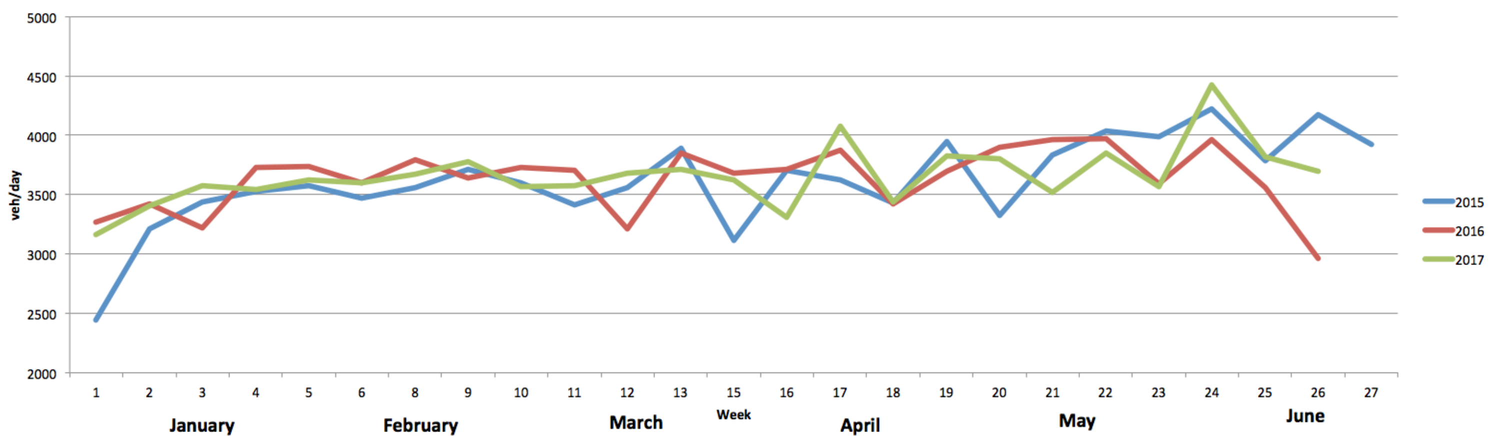


Figure C.108: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Stigbergsliden

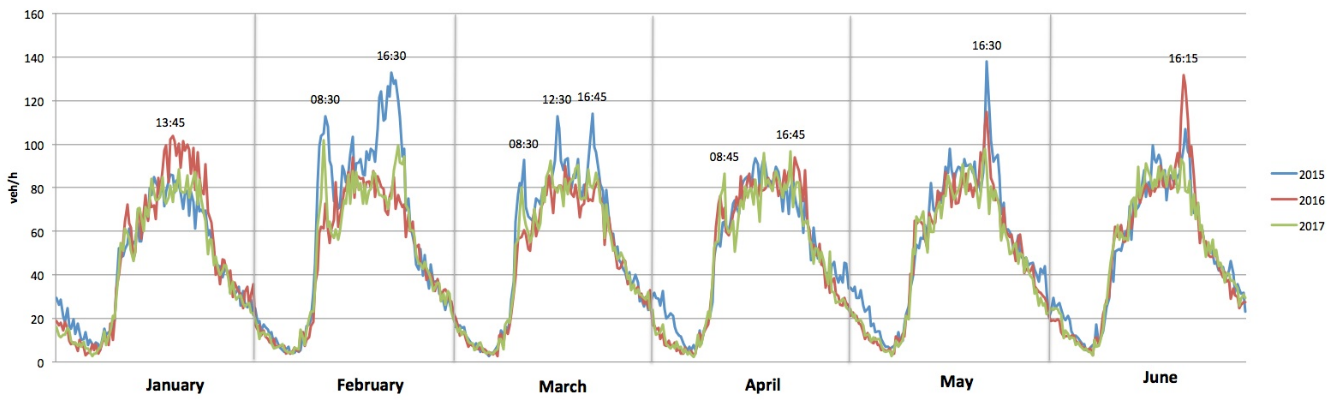


Figure C.109: Average day variation monthly. Direction: city center

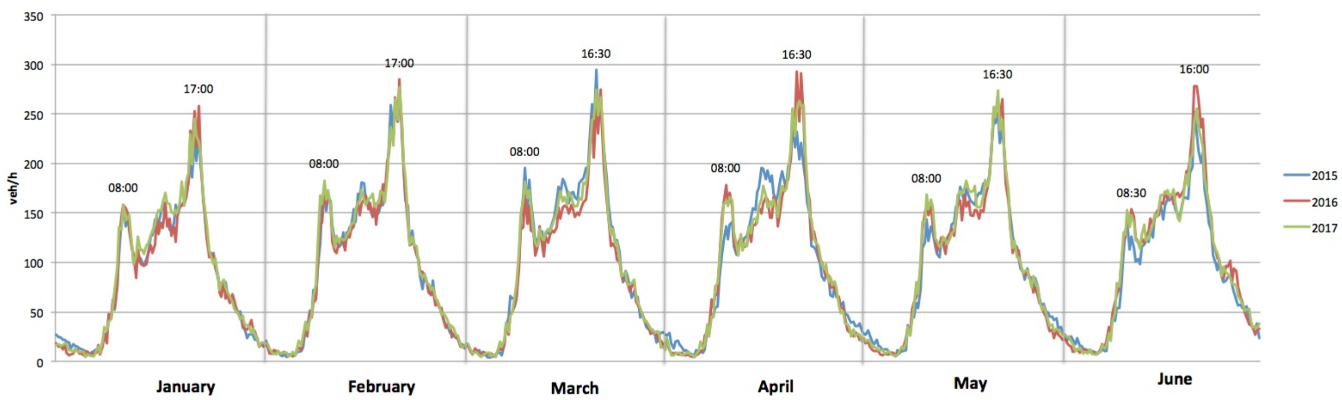


Figure C.110: Average day variation monthly. Direction: away from city center.

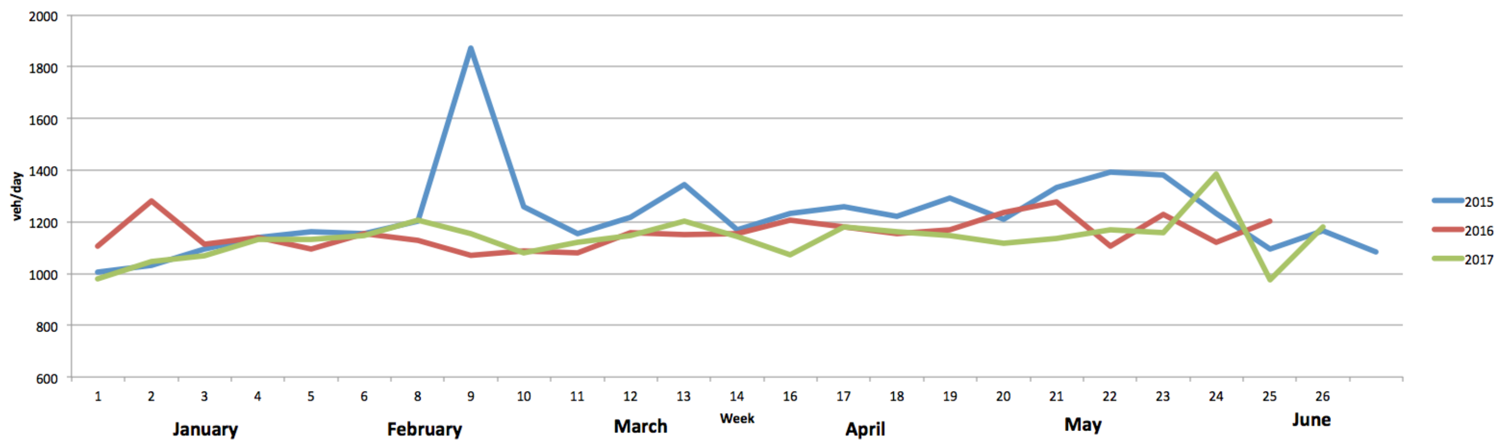


Figure C.111: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

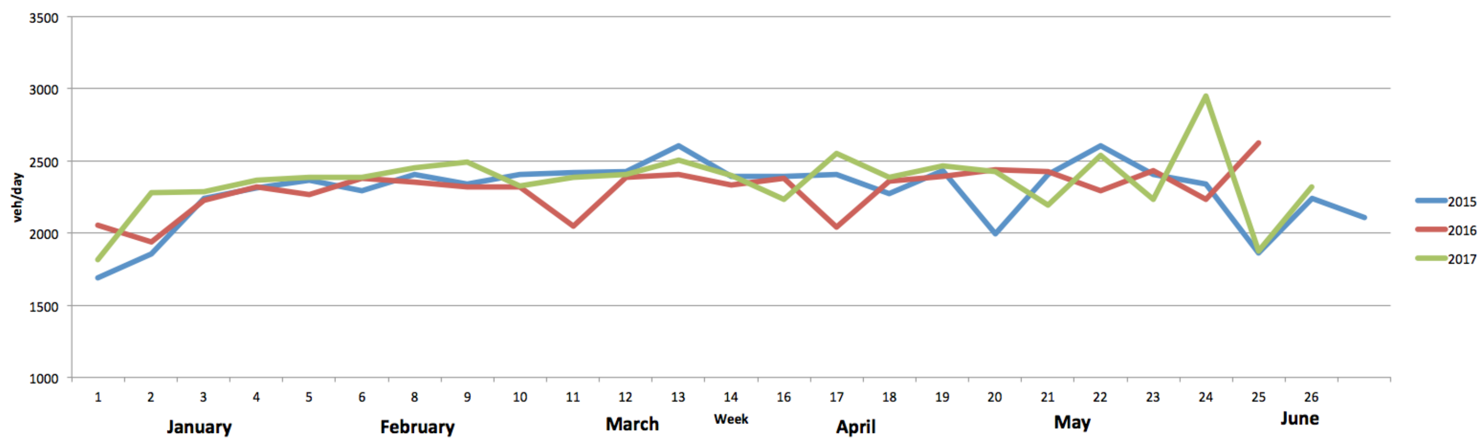


Figure C.112: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Säröleden

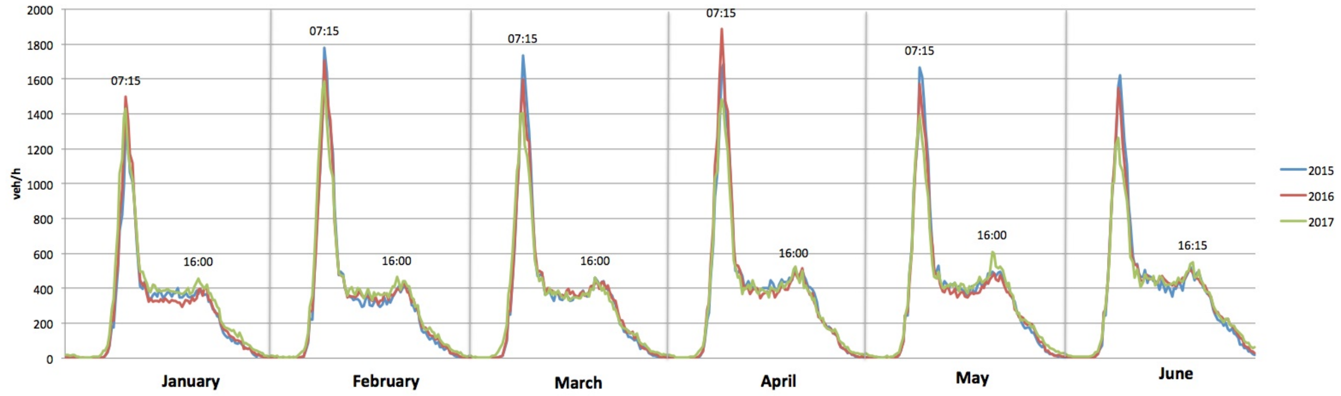


Figure C.113: Average day variation monthly. Direction: city center

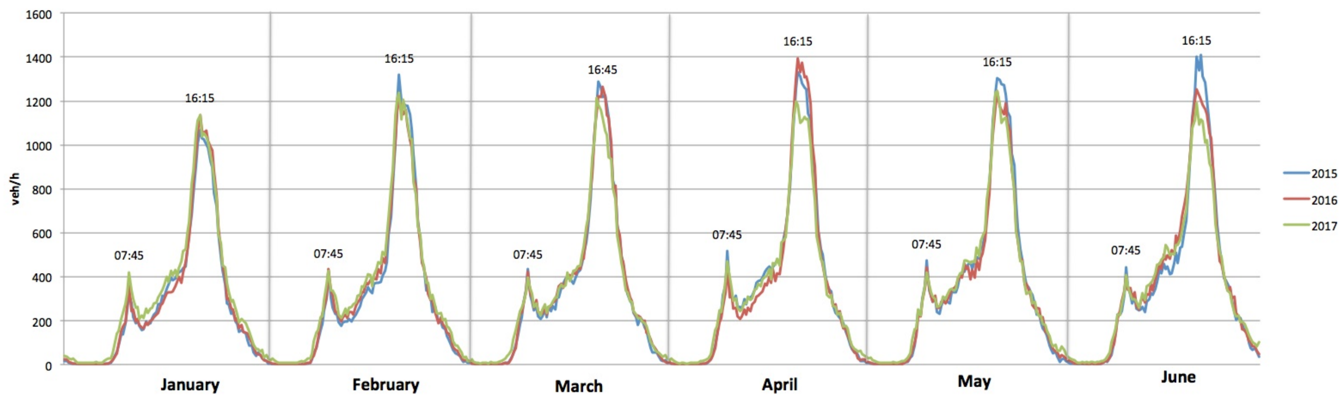


Figure C.114: Average day variation monthly. Direction: away from city center.

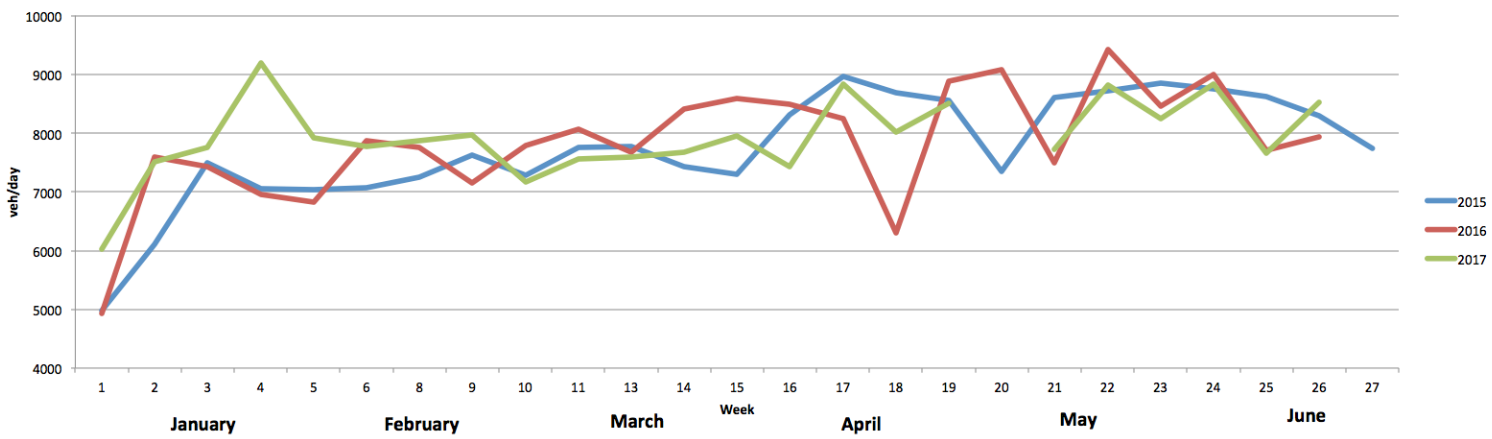


Figure C.115: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

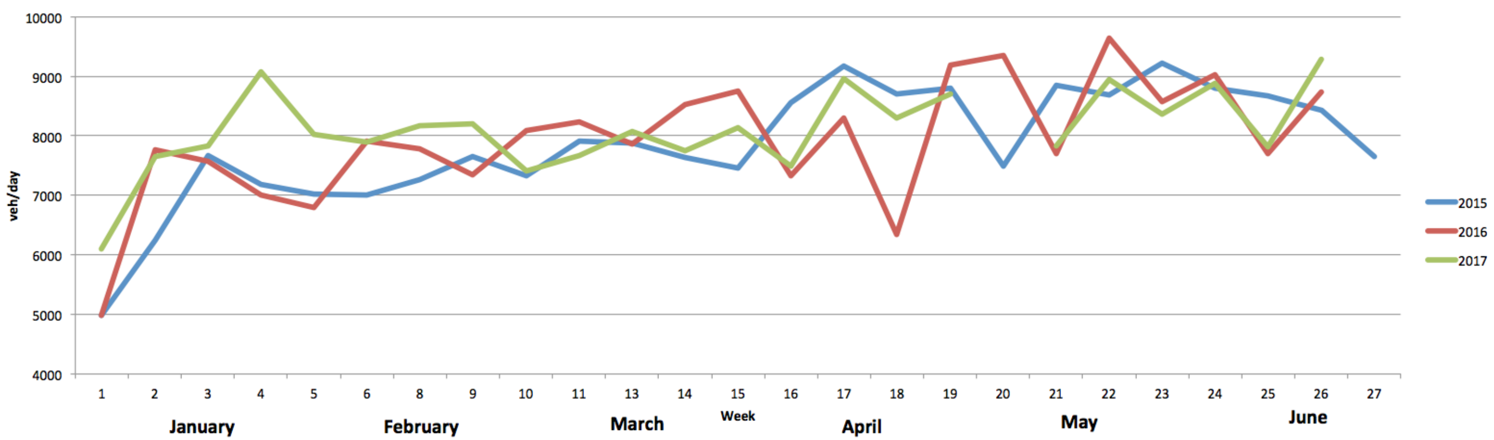


Figure C.116: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Södra Vägen

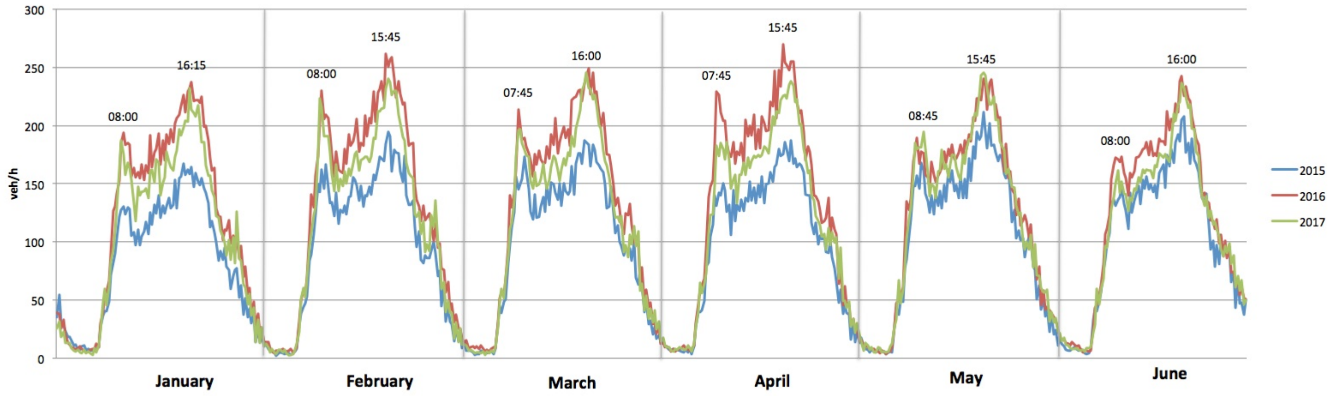


Figure C.117: Average day variation monthly. Direction: city center

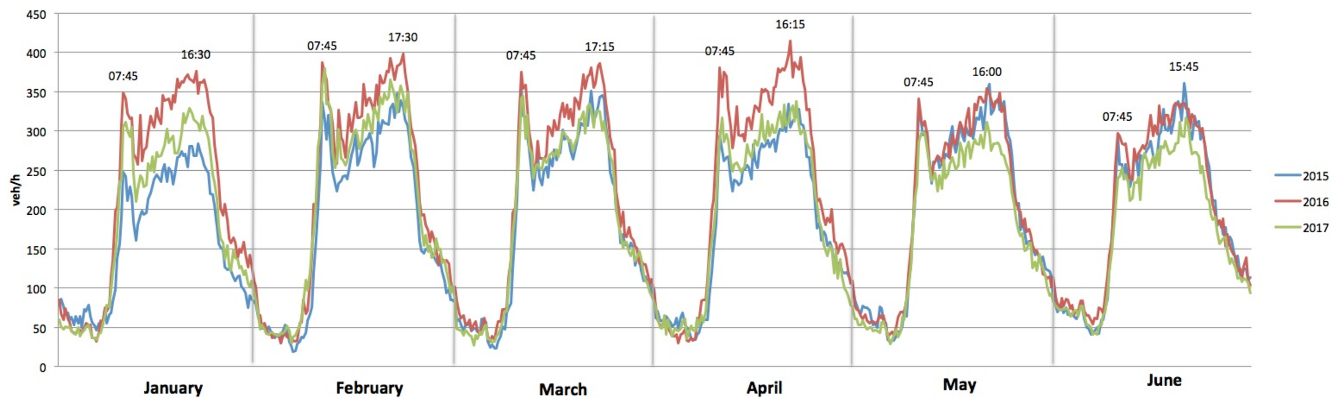


Figure C.118: Average day variation monthly. Direction: away from city center.

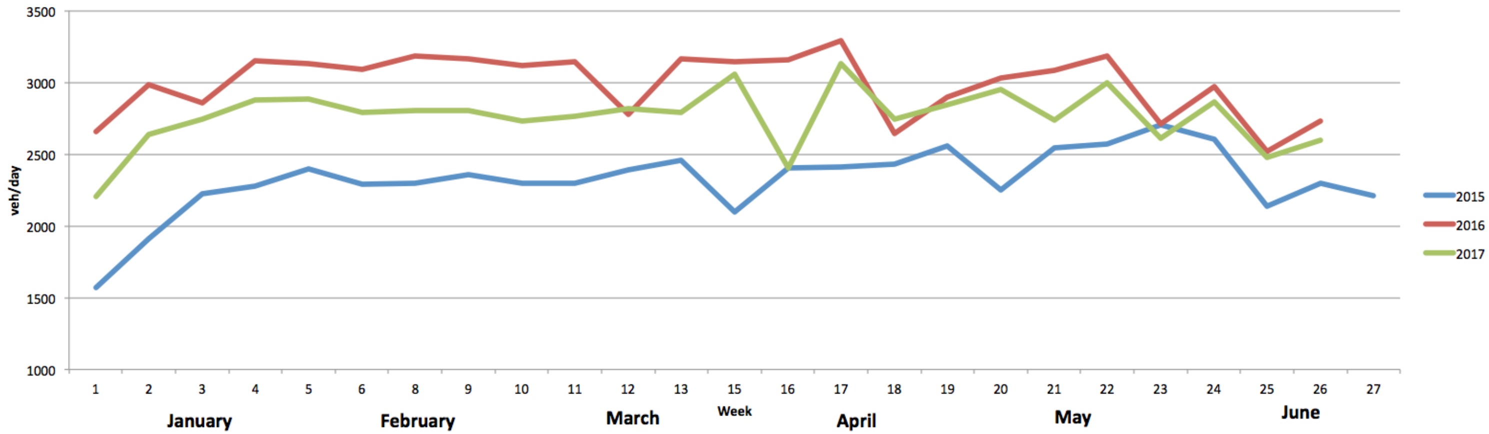


Figure C.119: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

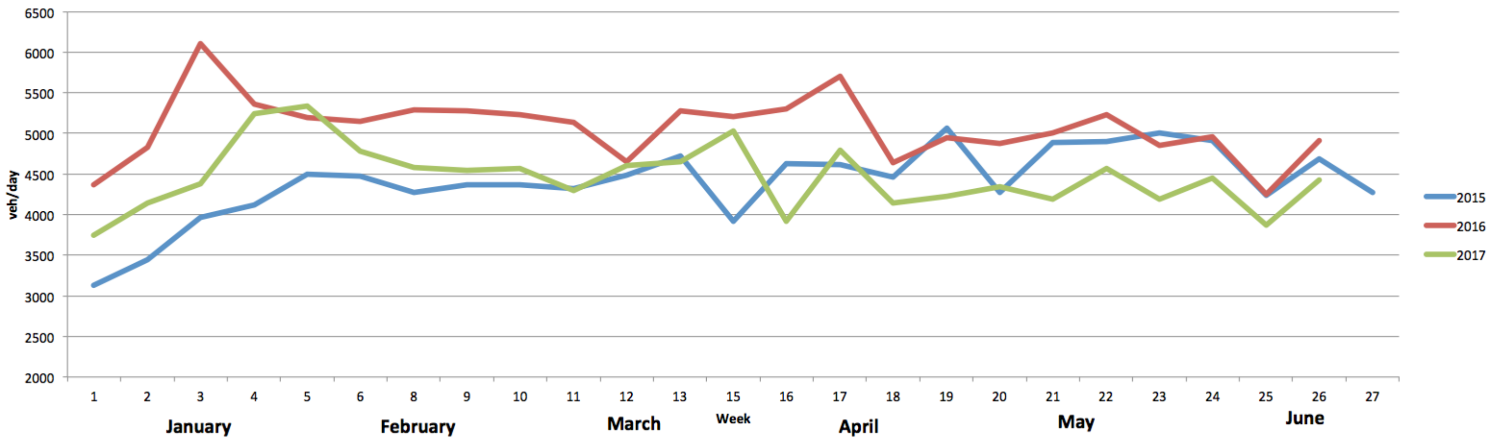


Figure C.120: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Tingstadsmotet (Tingstad junction

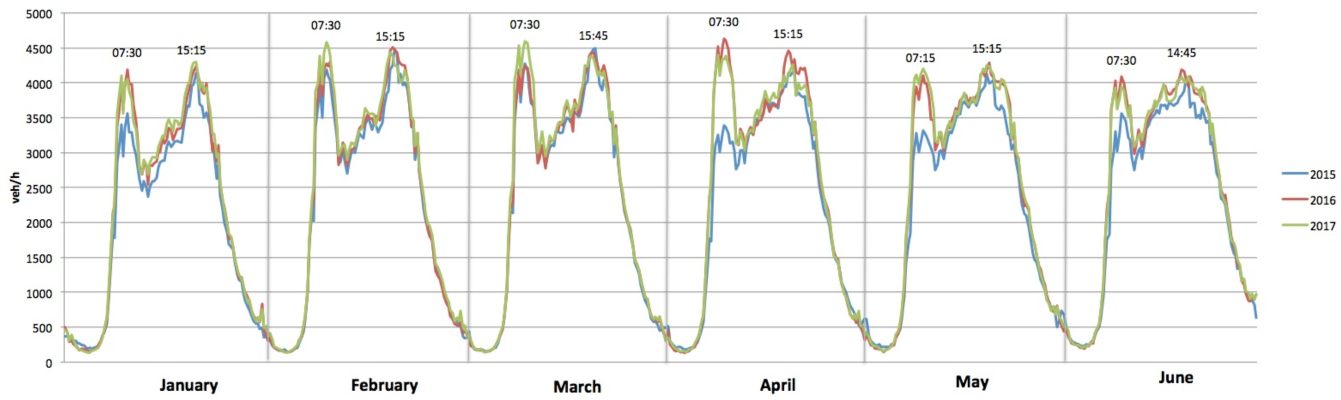


Figure C.121: Average day variation monthly. Direction: city center

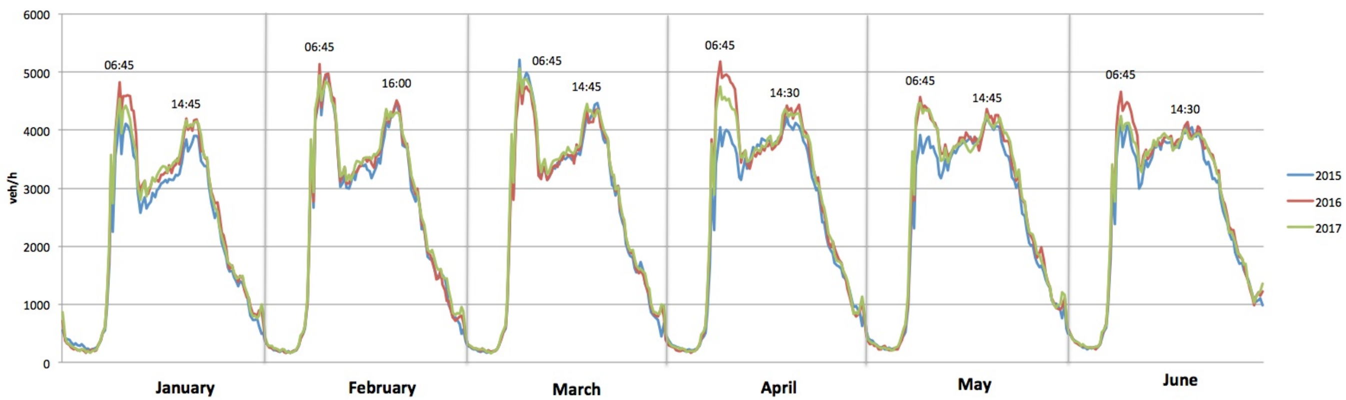


Figure C.122: Average day variation monthly. Direction: away from city center.

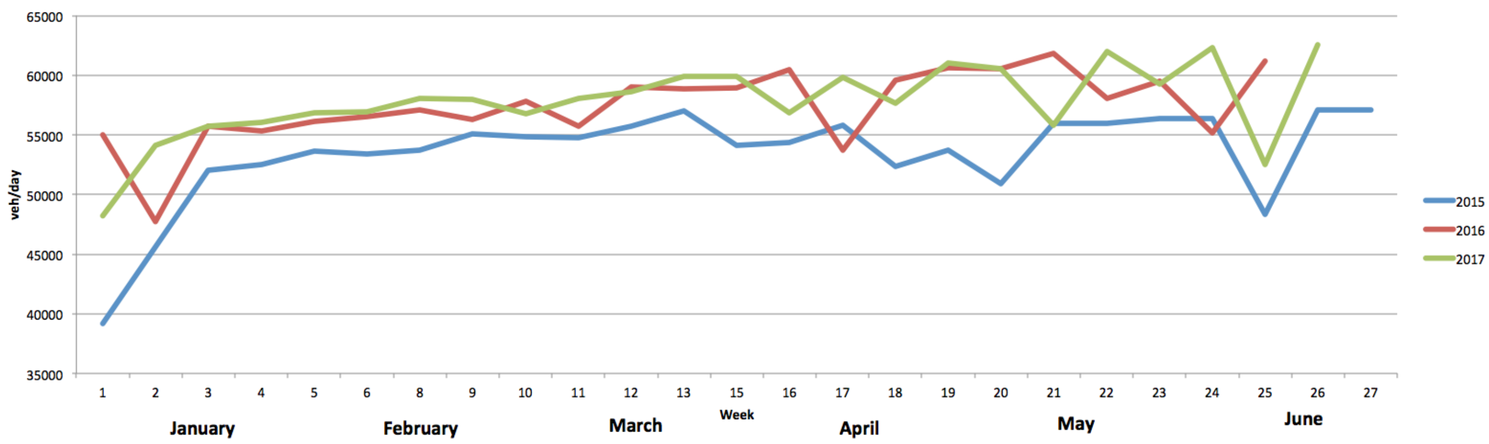


Figure C.123: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

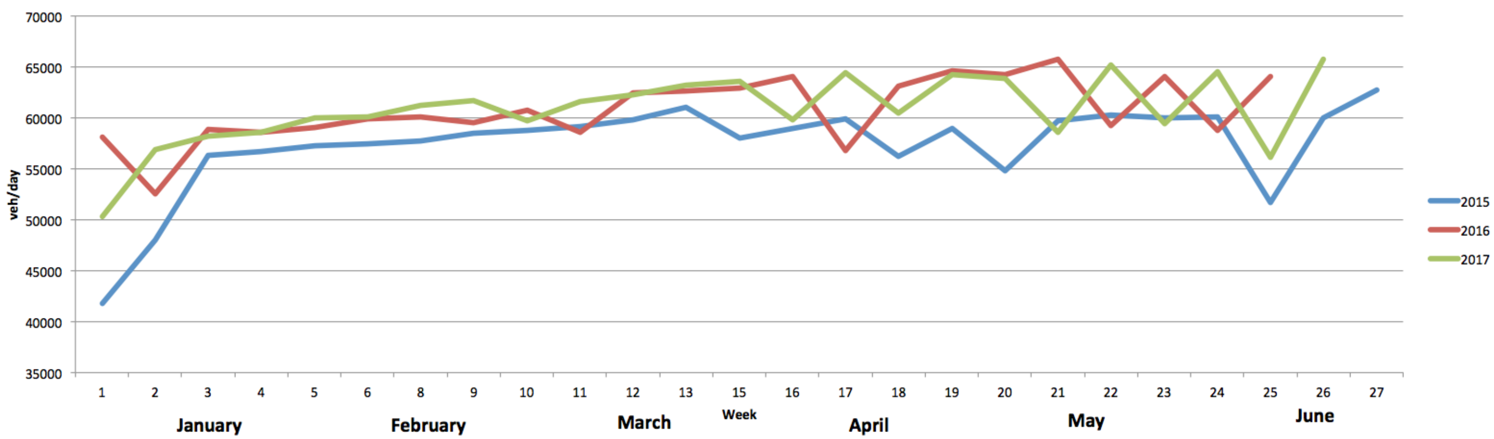


Figure C.124: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Ullevigatan

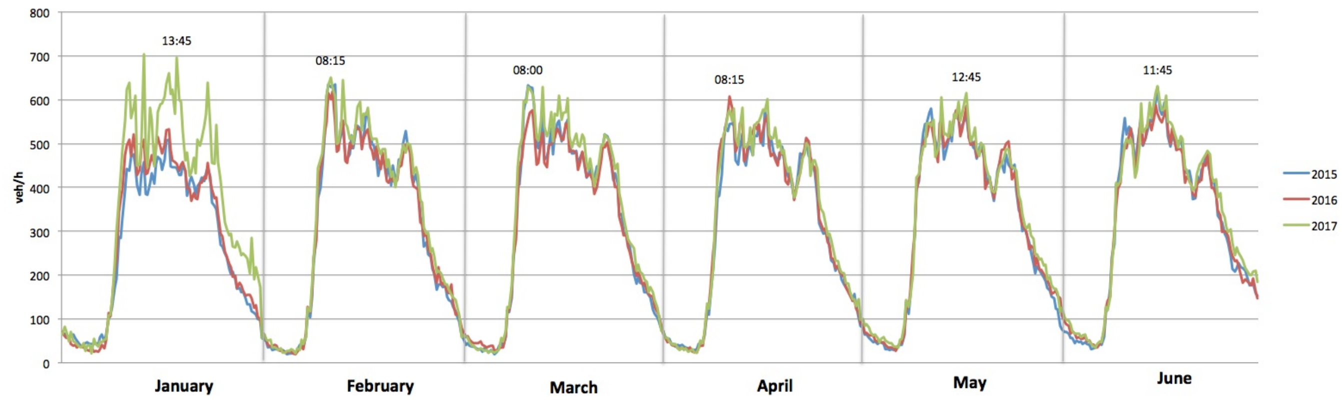


Figure C.125: Average day variation monthly. Direction: city center

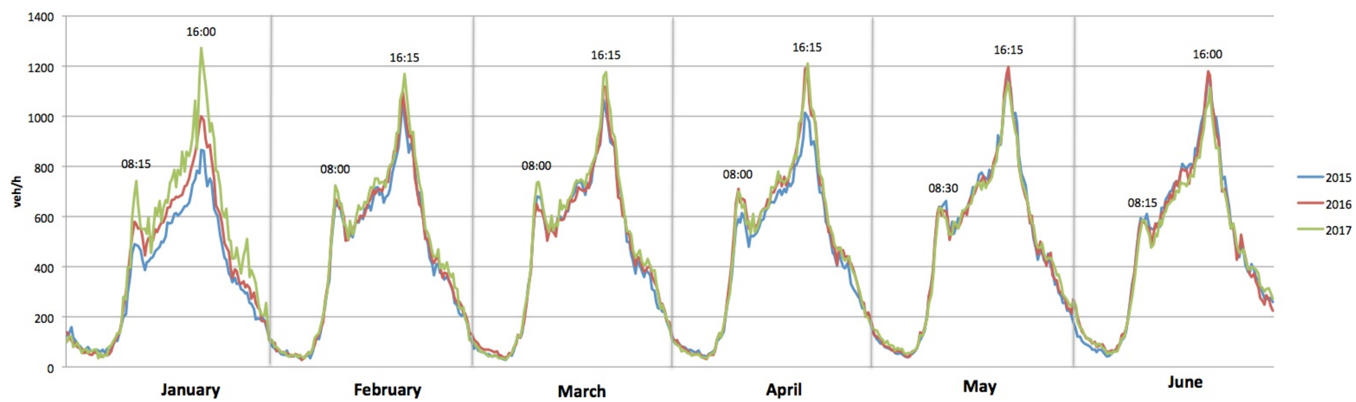


Figure C.126: Average day variation monthly. Direction: away from city center.

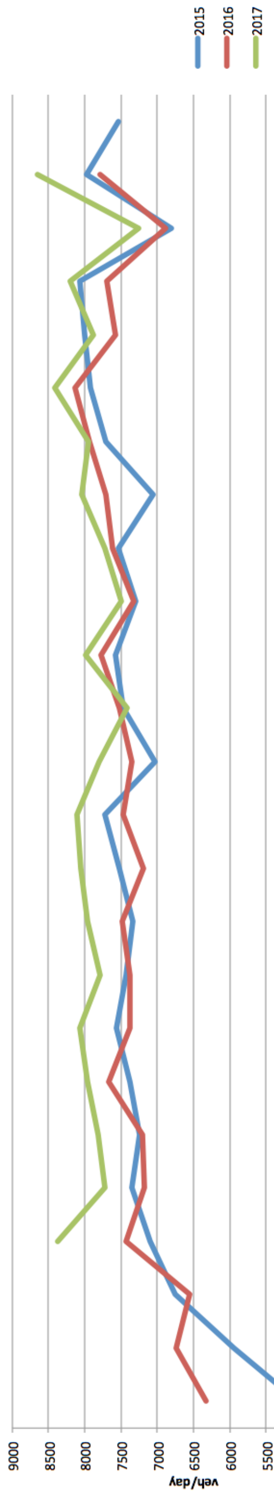


Figure C.127: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

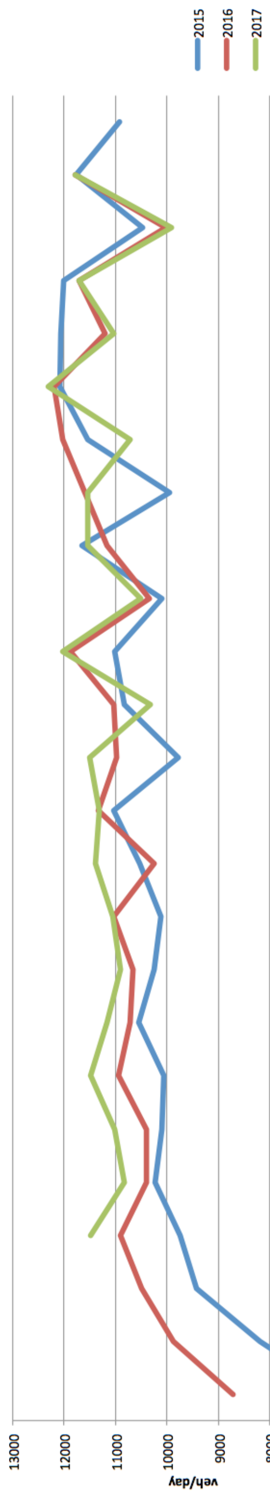


Figure C.128: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Willinsbron

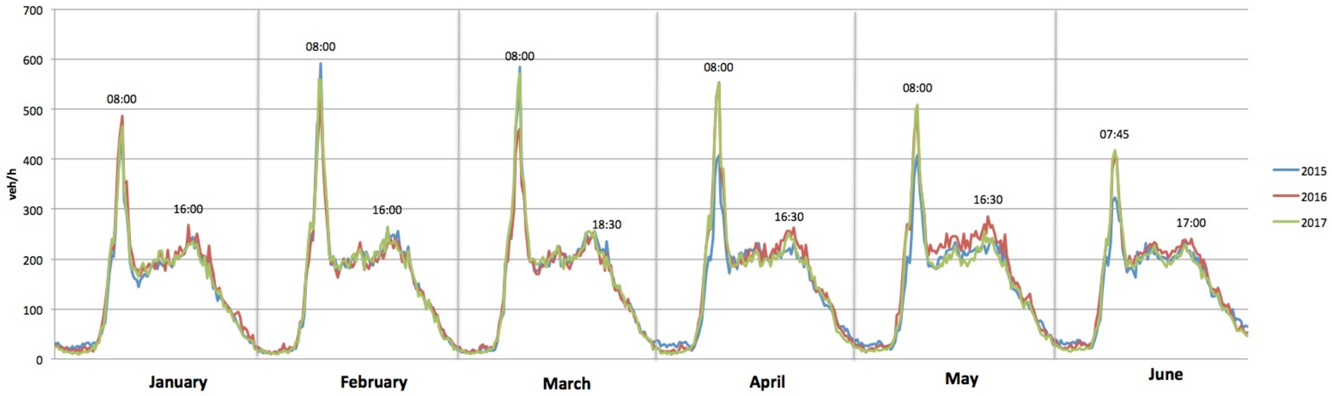


Figure C.129: Average day variation monthly. Direction: city center

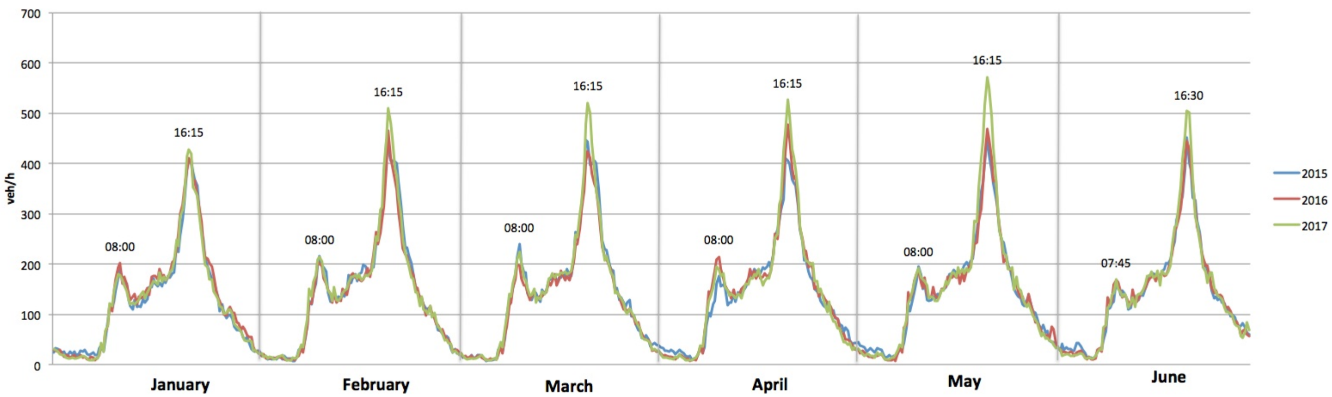


Figure C.130: Average day variation monthly. Direction: away from city center.

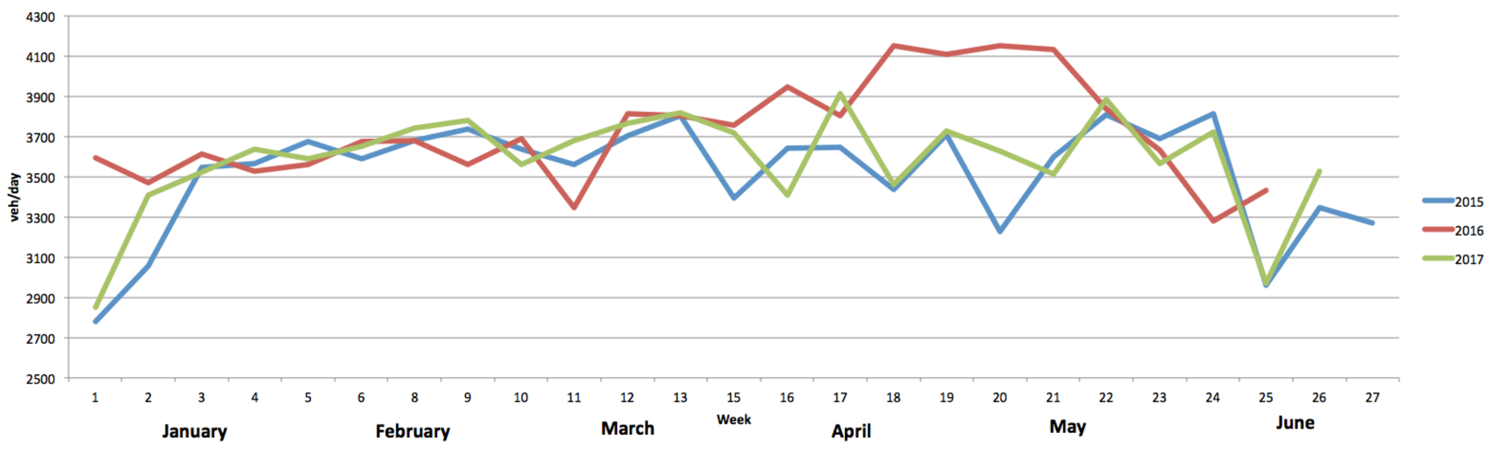


Figure C.131: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

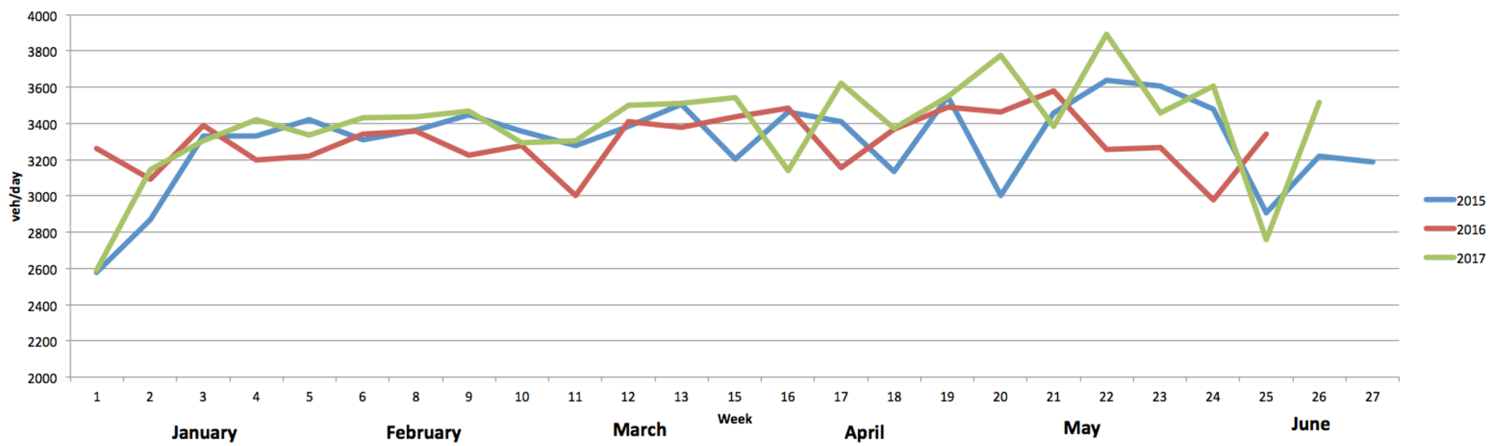


Figure C.132: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

The Älvsborg Bridge

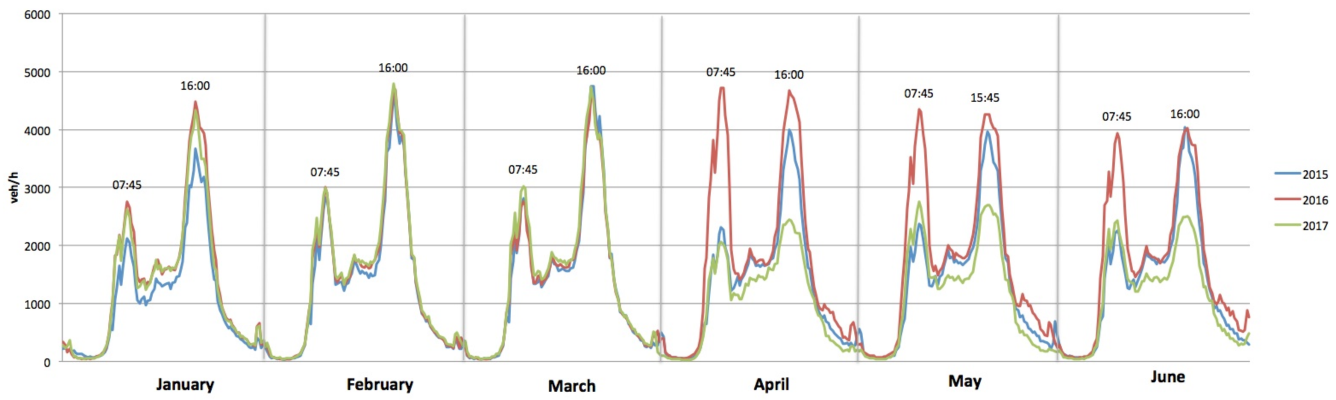


Figure C.133: Average day variation monthly. Direction: city center

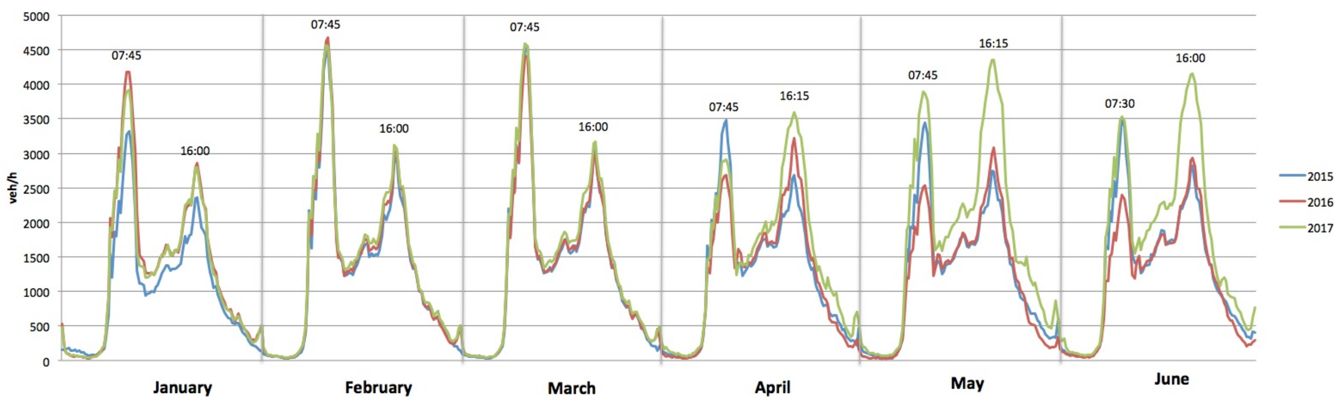


Figure C.134: Average day variation monthly. Direction: away from city center.

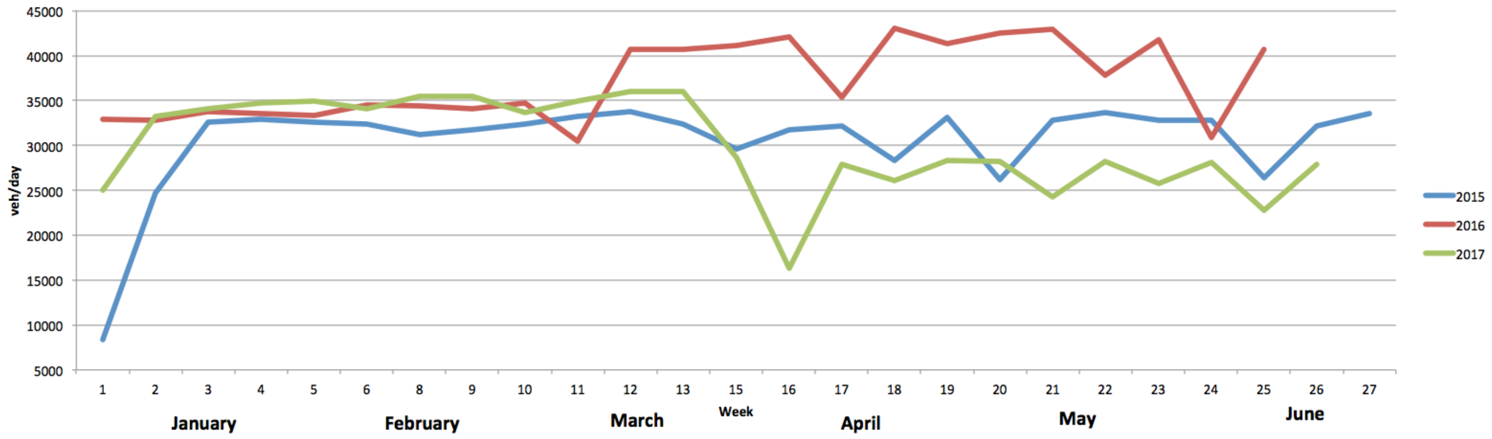


Figure C.135: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

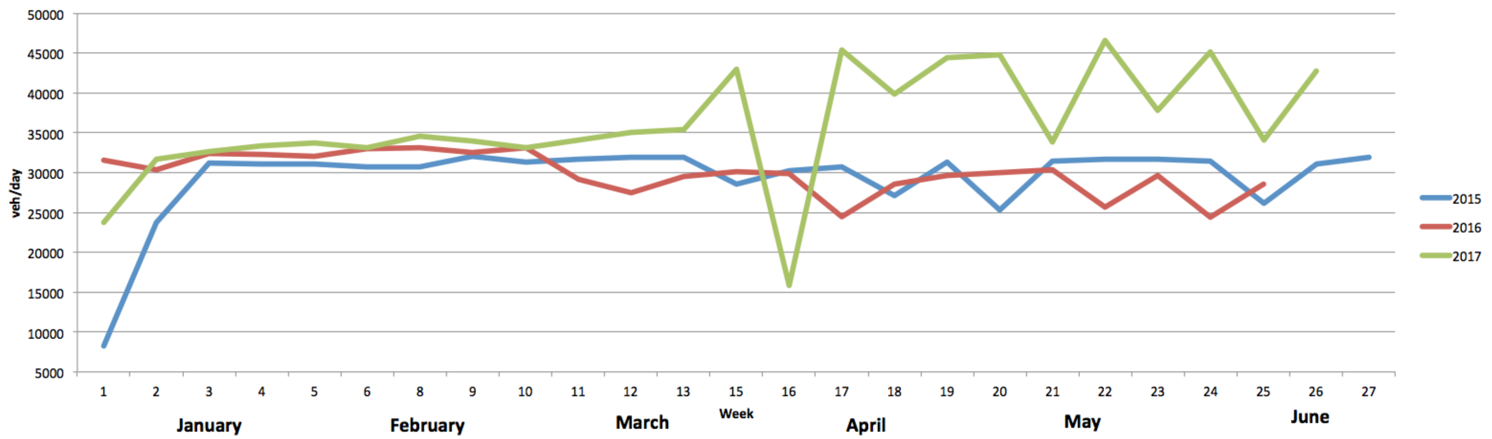


Figure C.136: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

Örgrytevägen

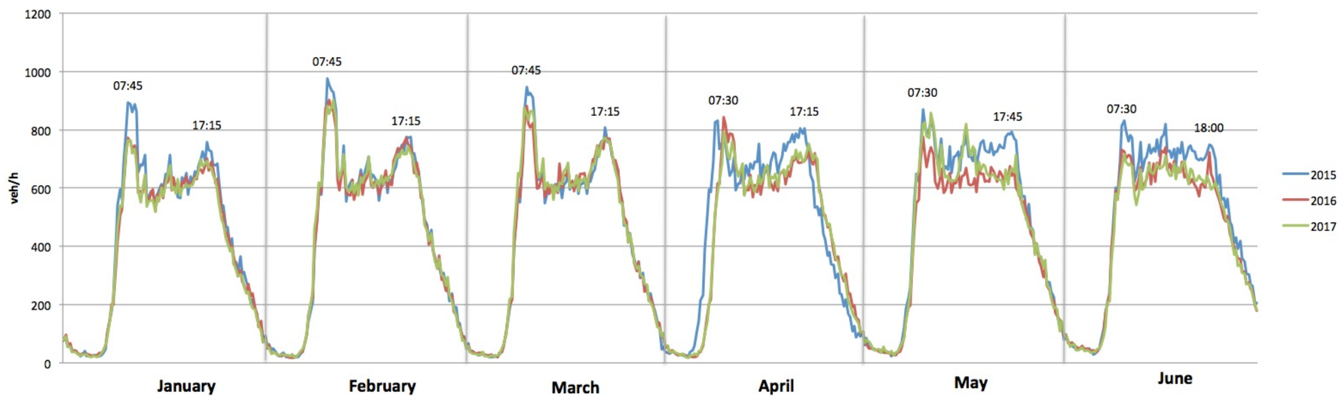


Figure C.137: Average day variation monthly. Direction: city center

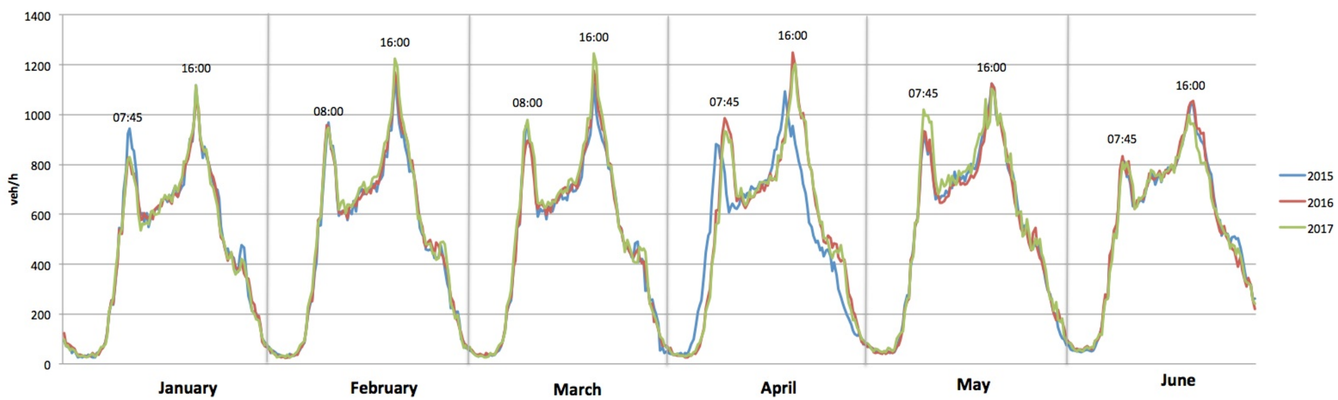


Figure C.138: Average day variation monthly. Direction: away from city center.

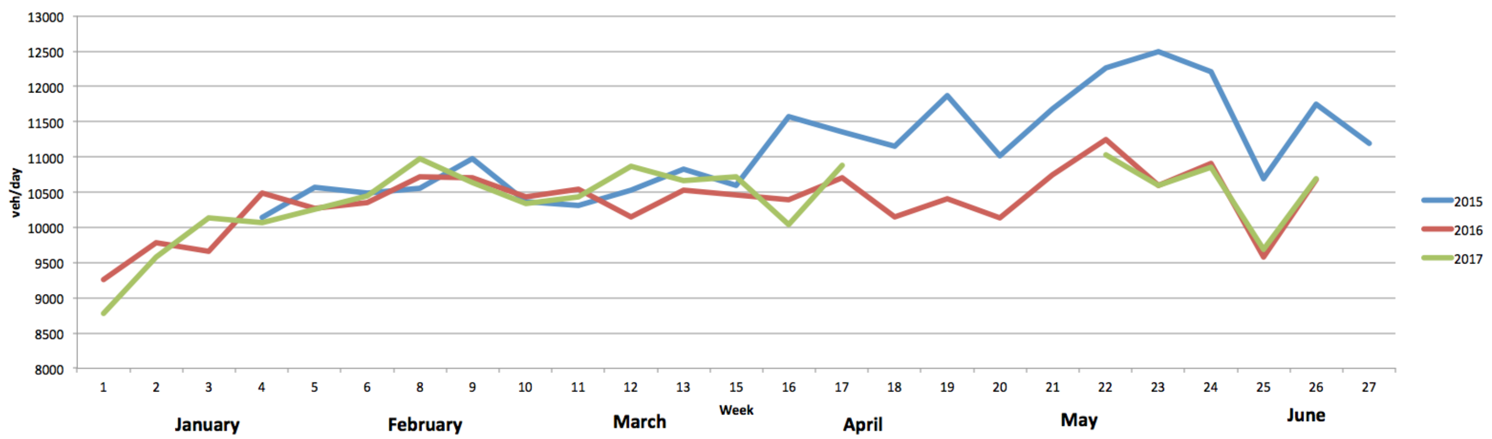


Figure C.139: Displaying an the average traffic flow a day each week between January and June. Direction: city center.

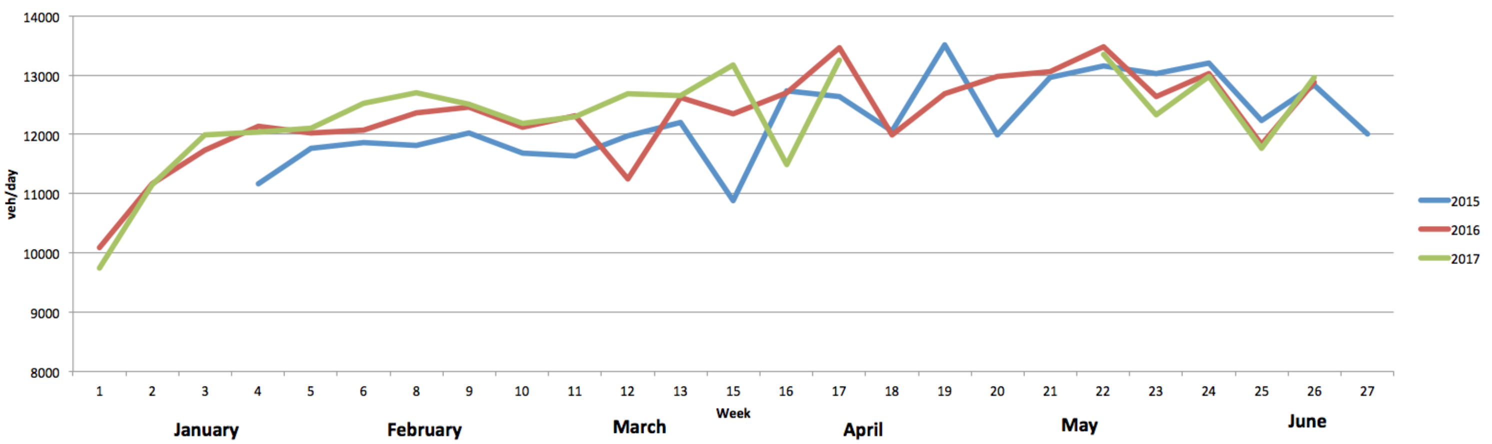


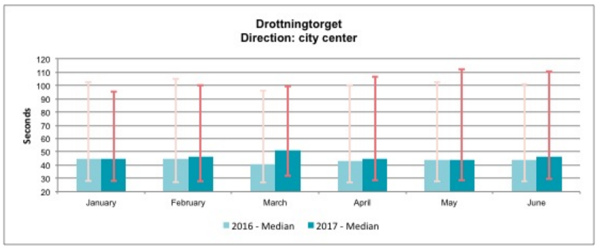
Figure C.140: Displaying an the average traffic flow a day each week between January and June. Direction: away from city center.

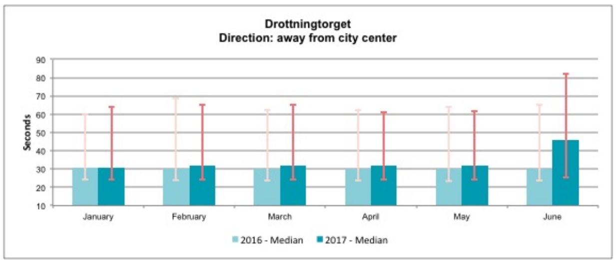
D

Travel Time of Selected Roads

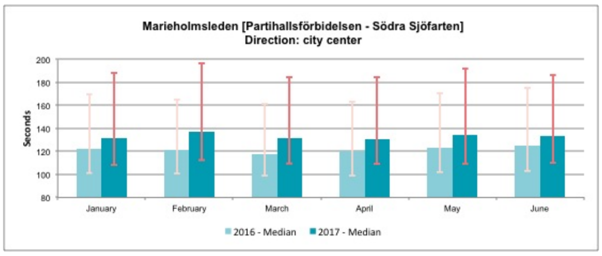
The Median travel time per month for 2016 and 2017 in seconds with the 85th and 15th percentile of the selected roads displayed in bar graphs. Appearing in the same order as of the tables A.1 followed by A.2.

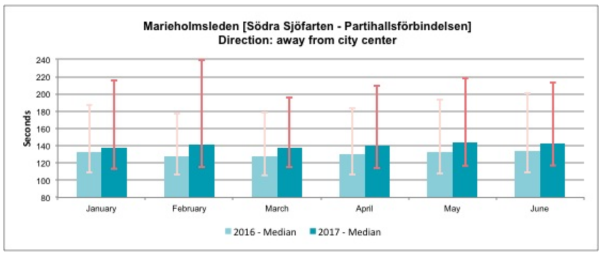
Drottningtorget



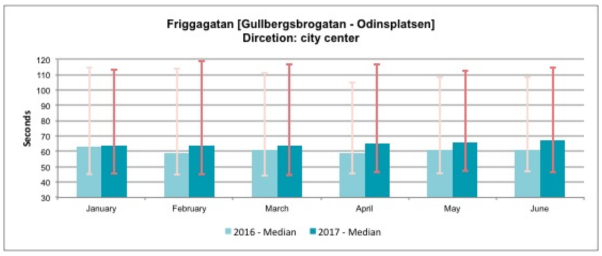


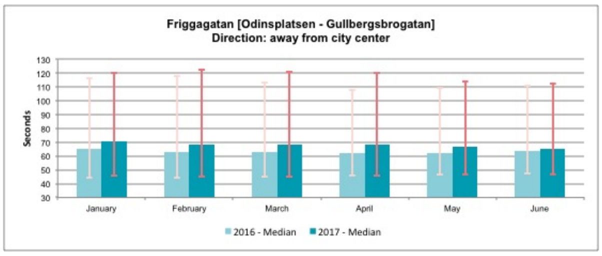
E45/Marieholmsleden



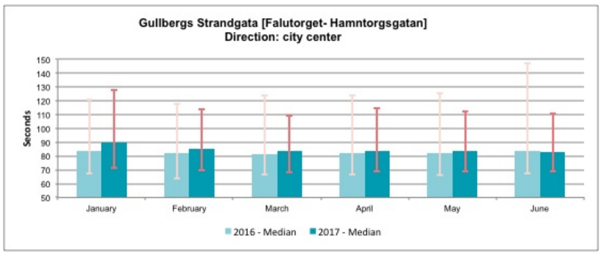


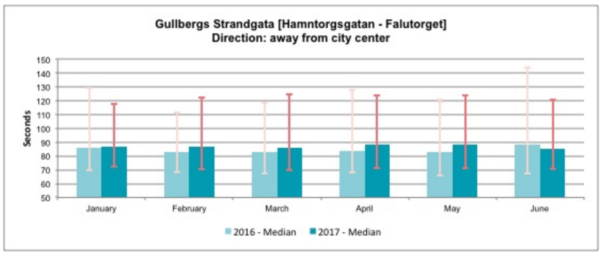
Friggagatan



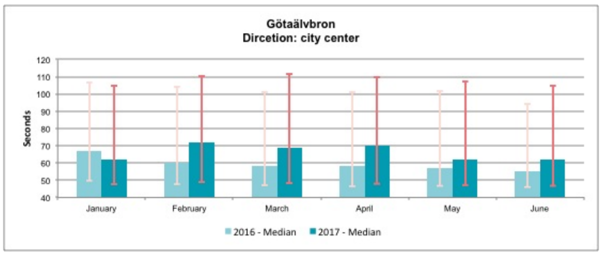


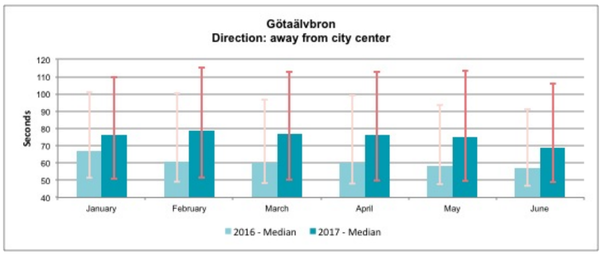
Gullbergs Strandgata



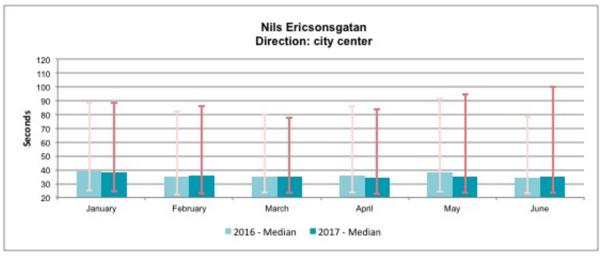


The Götaälv Bridge

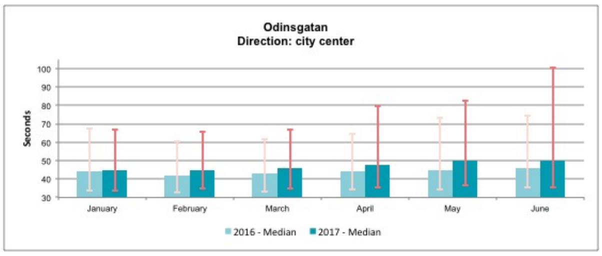


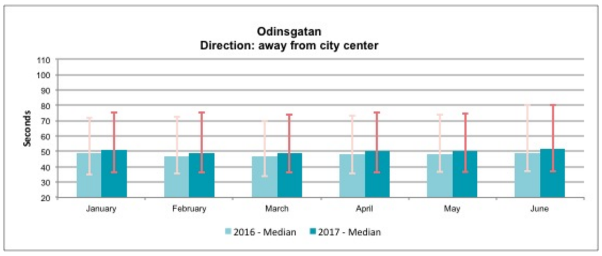


Nils Ericsonsgatan



Odinsgatan





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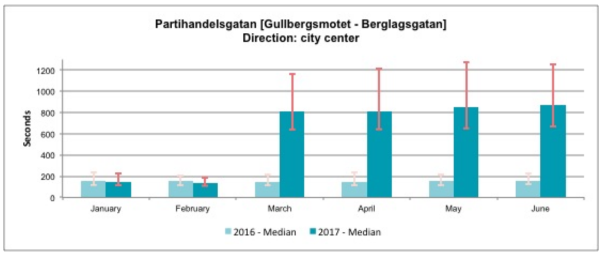
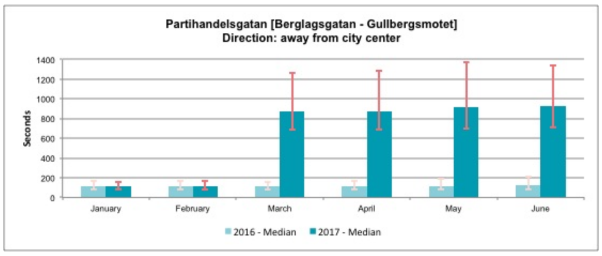
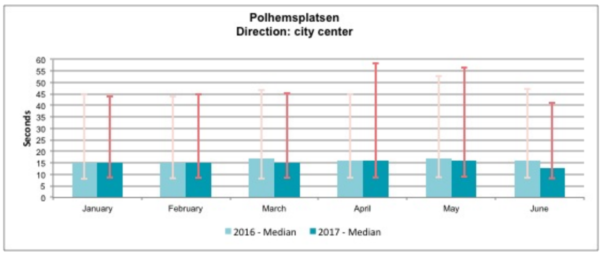
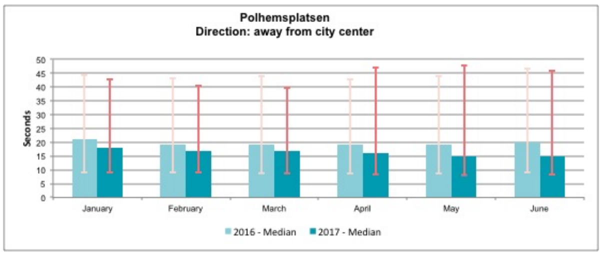


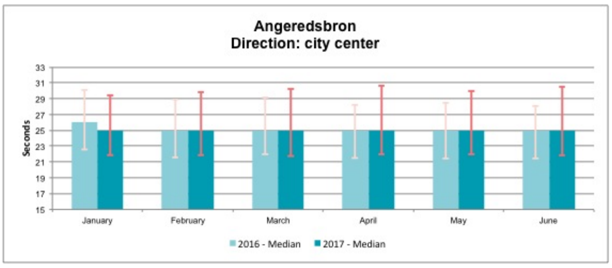


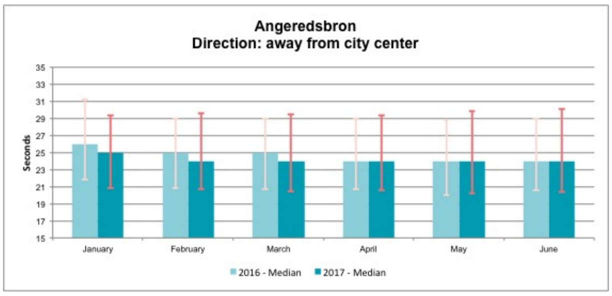
Polhemsplatsen



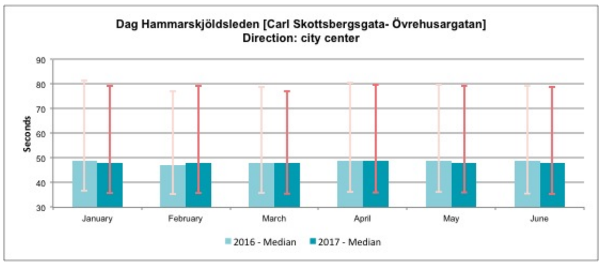


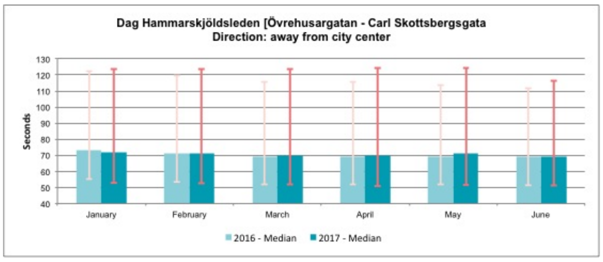
The Angereds Bridge



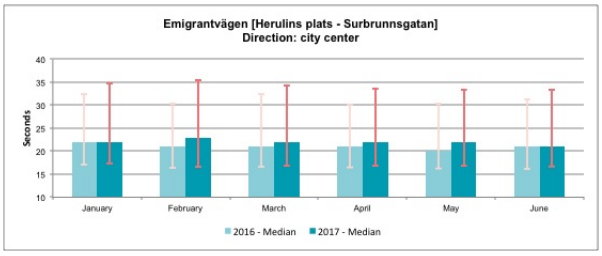


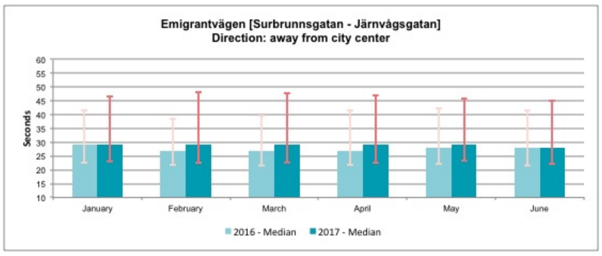
Dag Hammarskjöldsleden



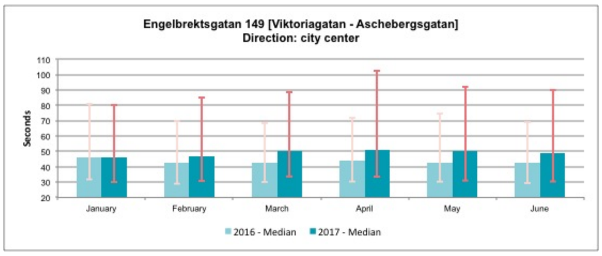


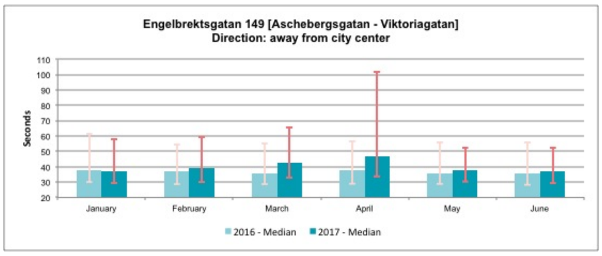
Emigrantvägen



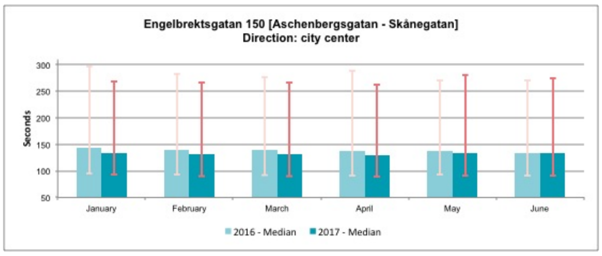


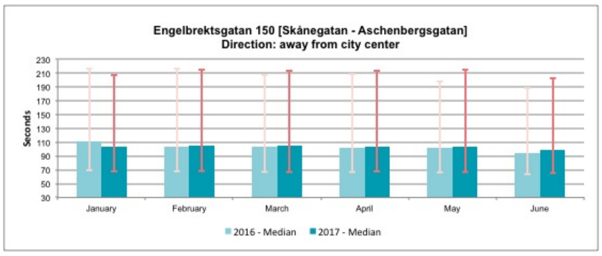
Engelbrektsgatan (149)



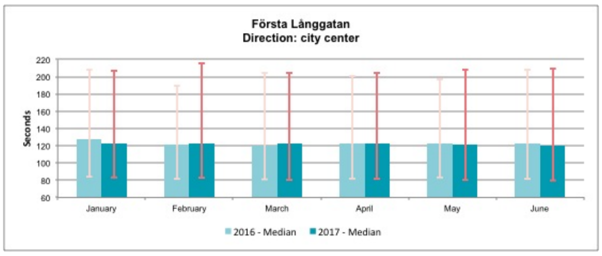


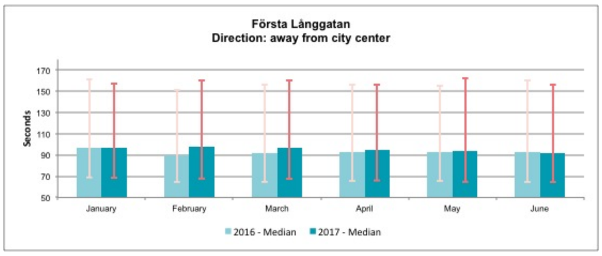
Engelbrektsgatan (150)



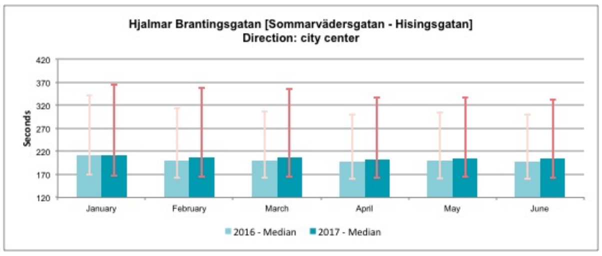


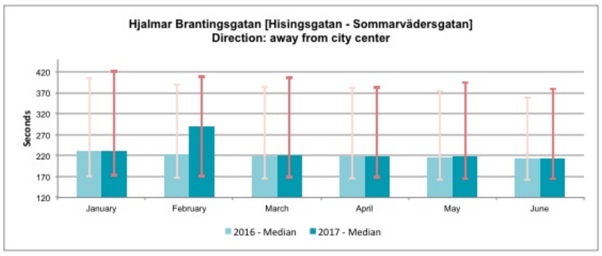
Första Långgatan



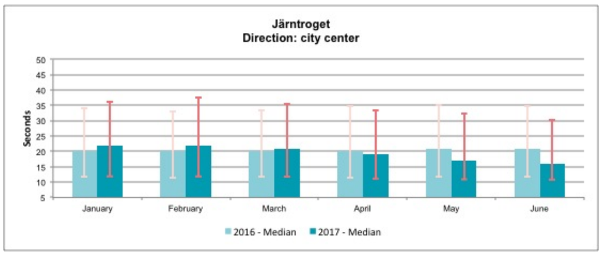


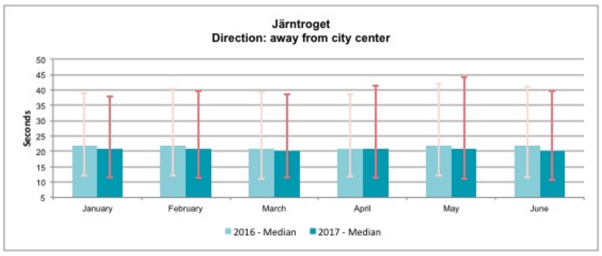
Hjalmar Brantingsgatan



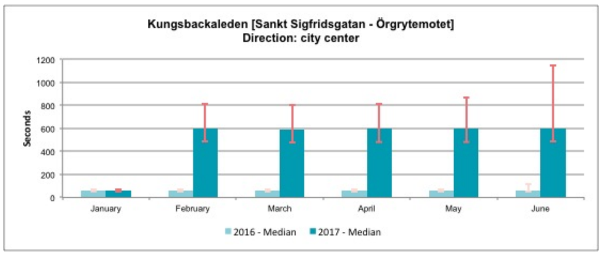


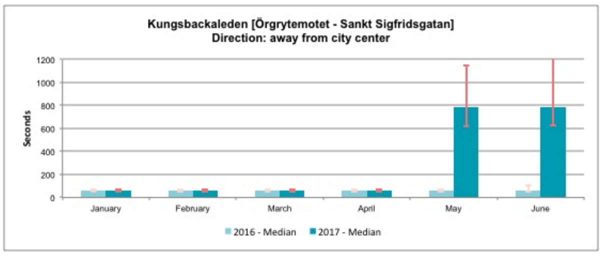
Järntorget



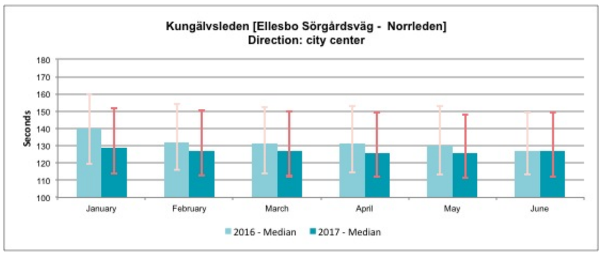


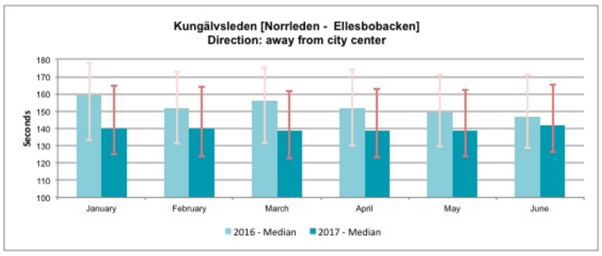
Kungsbackaleden/E6



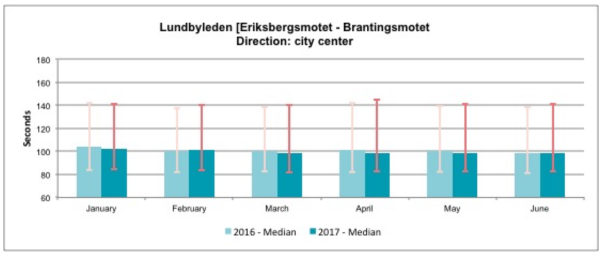


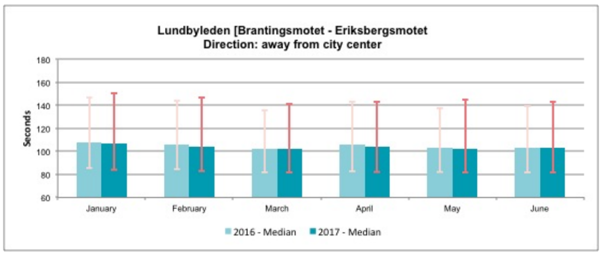
Kungälvsleden



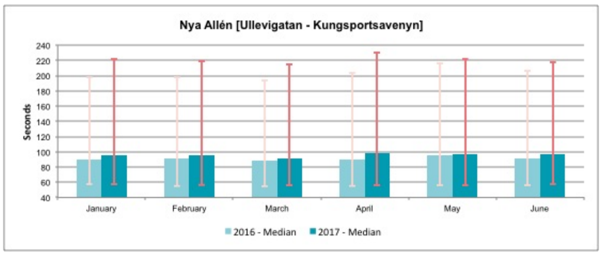


Lundbyleden

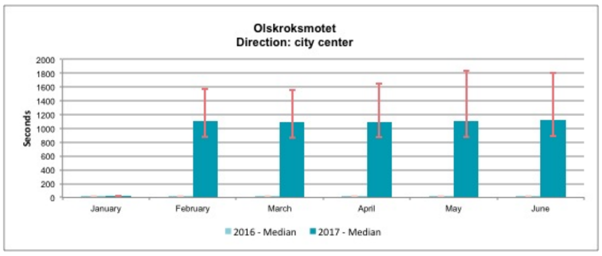


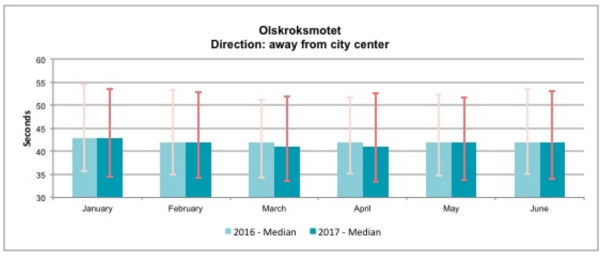


Nya Allén

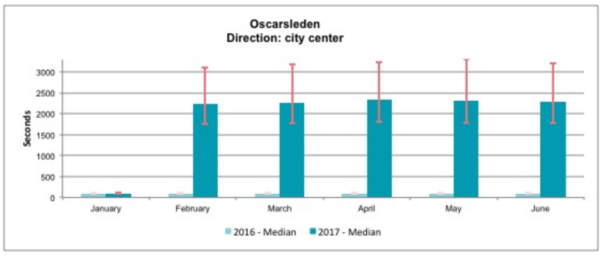


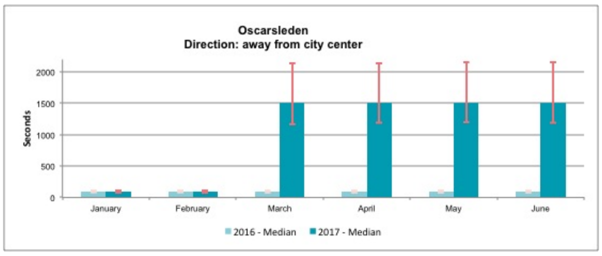
Olskroksmotet



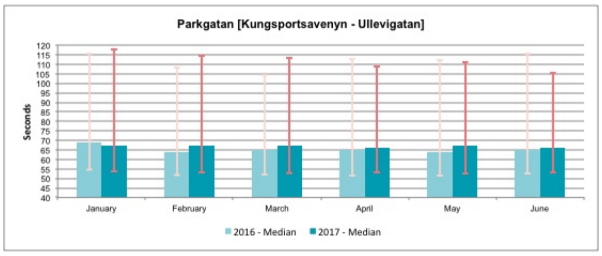


Oscarsleden

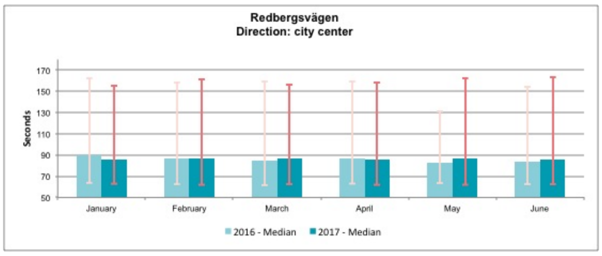


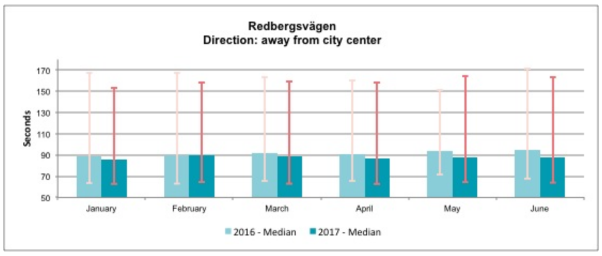


Parkgatan

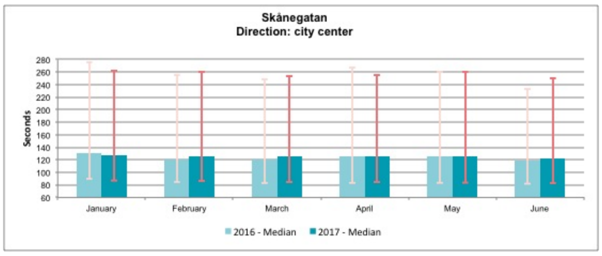


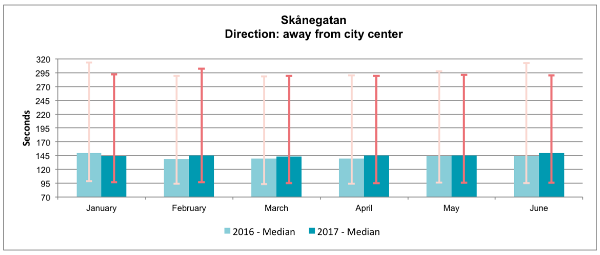
Redbergsvägen



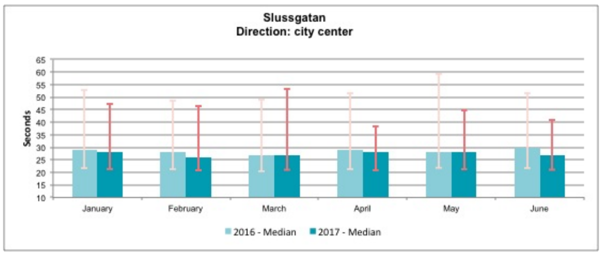


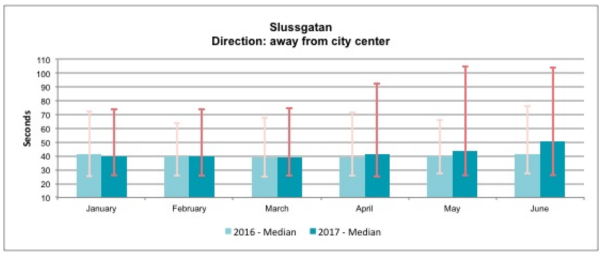
Skånegatan



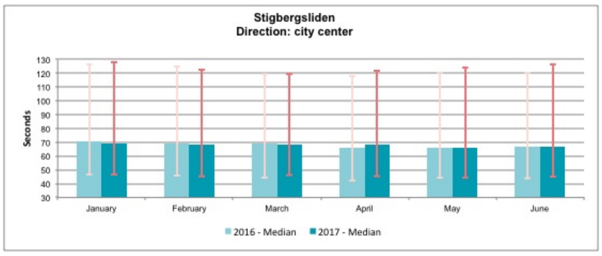


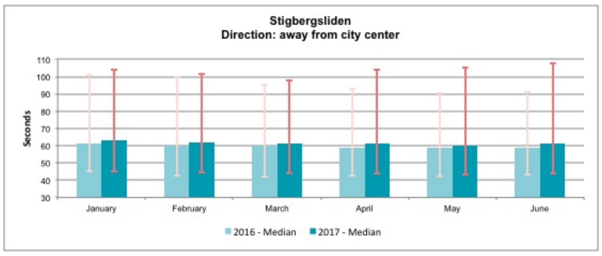
Slussgatan



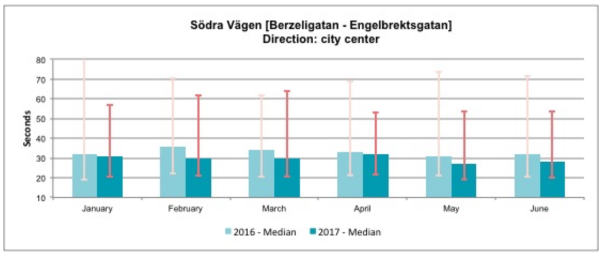


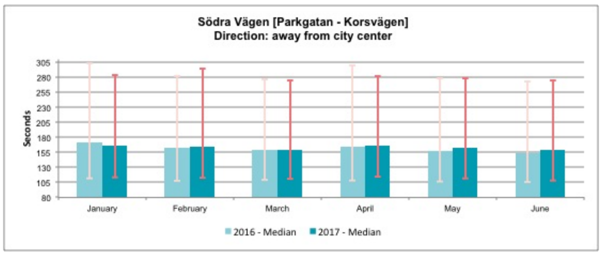
Stigbergsliden



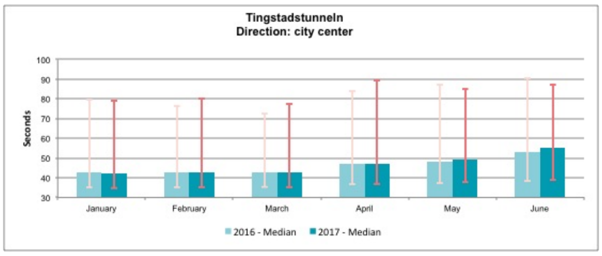


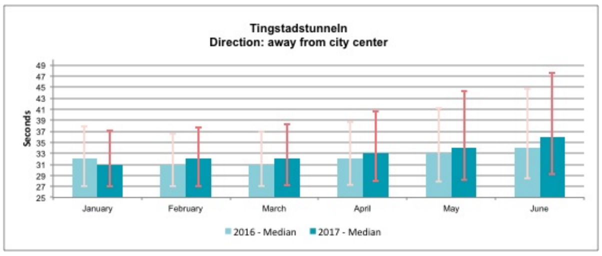
Södra Vägen



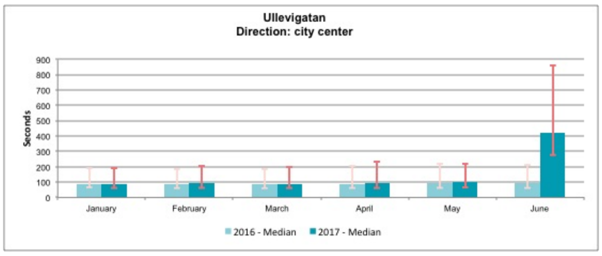


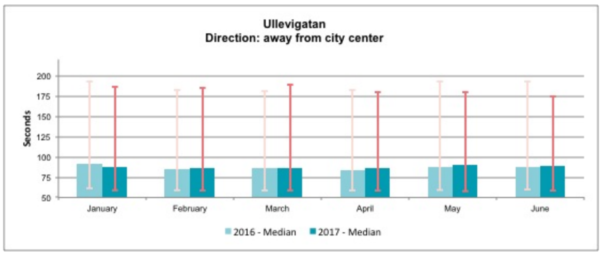
The Tingstad Tunnel





Ullevigatan





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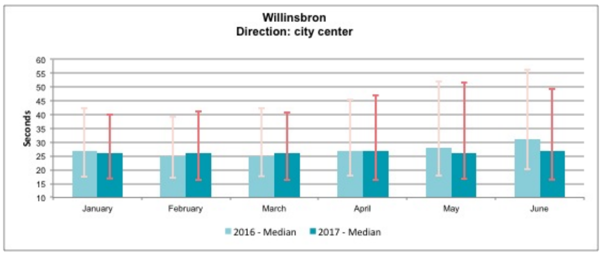
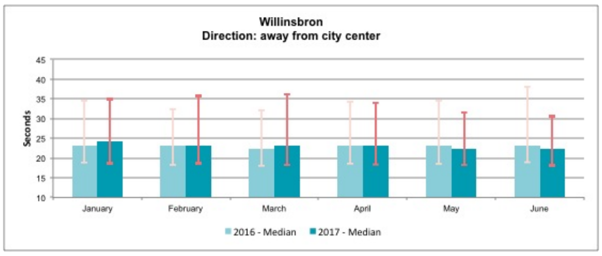
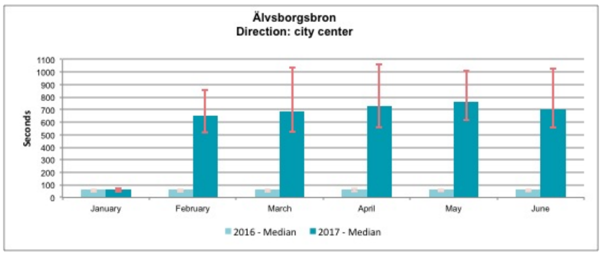
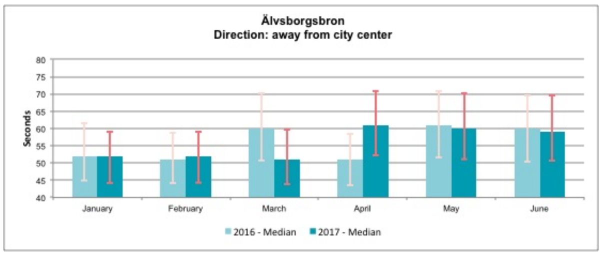




The Älvsborg Bridge





Örgrytevägen