Measure title: **Bus priority system**

City: **Malmo** *Project:* **SMILE** *Measure number:* **12.7**

A Introduction

To improve public transport in the urban and suburban area of Malmö bus priority systems were implemented in 42 intersections (appendix 12.7 Signal Map). The intersections were equipped with new hardware for communication with the buses and the software of the roadside controllers in the intersections was programmed to give buses priority. Onboard the buses the computer managing the destination sign will be programmed to communicate with the roadside controller for priority. The communication between the bus and the intersection is managed by the same system used for the real time application in measure 12.1.

In order to increase average bus speed, accommodate customer demands for increased punctuality and better information, Skånetrafiken planned to equip the entire city bus network with real time information during 2005. During 2004 it was decided to send out an AVL (Automatic Vehicle Location) tender. A supplier was selected and installation on all Malmö city buses was completed by October 2007. An open air interface between a vehicle/bus and roadside equipment has been specified for use in the Scania region. Malmö city will be the first user of this specification.

All buses operating in Malmö are included and 42 intersections within Malmö are also included. For the communication between the bus and the roadside controller, a radio modem Satelline 3AS from Satel Oy, Finland (or equivalent) is used.

A1 Objectives

The measure objectives are:

- **Objective 1** To introduce bus priority systems at 42 traffic lights
- **Objective 2** To improve the attractiveness of public transport in Malmö by decreasing the intervals from 10 minutes to 7.5 minutes intervals without increasing the number of buses. In the long term to reduce the use of private cars among commuters into the city centre

A2 Description

Buses spend a large amount of time, 11%, waiting at traffic lights. Prioritised traffic lights with bus lanes could solve this problem. The introduction of bus priority systems at 42 traffic lights is included in the project. Traffic light priority systems are one of the most important actions to increase bus accessibility and maybe the action that can be most effective. By 2004 all city buses and some regional buses were equipped with GPS and computers that can communicate with traffic lights, so in this project measures are only needed to install equipment in the traffic lights in order to establish a priority system.

B Measure implementation

B1 Innovative aspects

Innovative Aspects:

- New physical infrastructure solutions

The innovative aspects of the measure are:

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- **New physical infrastructure solutions, regionally** – The bus priority system includes all traffic lights where local and regional buses pass. This makes it a large system with considerable impact on travel times.

B2 Situation before CIVITAS

Bus traffic generally uses the same roads and streets as other road traffic, and car traffic has often had priority in traffic planning which has continuously damaged the competitiveness of public transport. Poor accessibility leads to increased travel times and problems keeping to timetables. Today's public transport users prioritise short journeys and reliable traffic, so these problems are essential to solve. Speed and punctuality are also key factors to appeal to new public transport users.

Research shows that average bus speed in Malmö was low due to a number of factors, both external (congestion, urban density creating short distances between stops etc) and conditions in the bus traffic system (many people getting on, slow ticket system etc). Regularity is another important measure of accessibility where there are problems in Malmö. In comparison with Copenhagen and many other European cities the number of priority actions for buses were limited.

Accessibility problems do not only cause difficulties for users, but also for bus drivers. Delays make it difficult to keep to the timetable, increasing stress and creating difficult working conditions. This difficult situation can lead to inappropriate communication with customers.

B3 Actual implementation of the measure

The measure was implemented in the following stages:

Stage 1: Consultants assignments Part 1 *(2005-05-01 - 2005-06-30) – Assign consultants for the work with traffic technical planning for 28 intersections.*

Stage 2: Traffic technical planning Part 1 *(2005-07-01 - 2005- 11-30) – Traffic technical planning of the intersection for 28 intersections.*

Stage 3: Consultants assignments Part 2 *(2005-08-01 - 2005-09-30) – Assign consultants for the work with traffic technical planning for 14 intersections.*

Stage 4: Traffic technical planning Part 2 *(2005-11-01 - 2006- 03-31) – Traffic technical planning of the intersection for 14 intersections.*

Stage 5: Programming controllers *(2005-12-01 - 2007-03-31) – Programming was done by our contractor for maintenance of traffic signals.*

Stage 6: Select a supplier and delivery of modems *(2005-10-01 - 2007-03-31) Skånetrafiken did use a contracted consultant already working with their AVL system to make the tender for selecting a modem supplier*

Stage 7: Installing modem *(2007-03-01 -2007-05-31) – Installation of modem was carried out by our contract for maintenance of traffic signals*

Stage 8: Programming bus computers *(2007-06-01 - 2007-09-30) – Programming of bus computers was done by Skånetrafiken*

Stage 9: Running in period *(2007-10-01 - 2008-02-28) – The work was done in cooperation between all involved participants.*

Stage 10: Bus lane in Per Albin Hanssons väg *(2007-10-01 -) – The work was given to the municipality on organisation for maintenance of streets and parks.*

B4 Deviations from the original plan

The deviations from the original plan comprised:

- **Deviation 1 Select supplier and delivery of modems** – Due to tender appeals there was a delay affecting the measure
- **Deviation 2 Bus lane in Per Albin Hanssons väg** – Difficulties getting a contractor for the work.

B5 Inter-relationships with other measures

In the original application to CIVITAS II 12.7 is related to other measures as follows:

- **Measure 12.1 (Use of real time information for travellers)** – The communication between the bus and the intersection will be managed by the same system used for the real time application in measure 12.1.
- **Measure 8.1 (Marketing of new bus routes), Measure 8.3 (Integration of cycling with public transport in Malmo), 12.2 (Traffic Monitoring in Malmo), 12.3 (Mobile internet services in connection to bus information in Malmo)**– these are all part of the new bus route system and the goal of a 10% increase in travels by the end of 2006 and with 30% until end of 2010 are a result of all these measures working together.
- Therefore for the overall goal of increased patronage by 2010 (outside the SMILE framework) it will be difficult to establish which part of the increase that is a result of which measure since for the traveller, all the measures together form the new travel opportunity.

C Evaluation – methodology and results

C1 Measurement methodology

C1.1 Impacts and Indicators

Table of Indicators.

Nr.	*Relates to GUARD Nr.*	*INDICATOR Name*	*Possible DESCRIPTION*	*DATA /UNITS*
13		Awareness level	Degree to which the general publics awareness has changed	Survey
14		Acceptance level	Survey of opinions on part of general public	Survey
18		Accuracy of PT timekeeping	Percentage of services arriving/departing on time compared to timetables	%, quantitative collected measurements
23		Average vehicle speed - peak	Average vehicle speed	Km/hr, quantitative, derived
24		Average vehicle speed - off peak	Average vehicle speed	Km/hr, quantitative, derived
		Delay time by vehicle type - peak	Total delay time per vehicle	Seconds per vehicle, quantitative, derived by simulation
		Delay time by vehicle type - off peak	Total delay time per vehicle	Seconds per vehicle, quantitative, derived by simulation

Detailed description of the indicator methodologies:

- **Indicator 13** (*Awareness level*) –
- **Indicator 14** (*Acceptance level*) –
- **Indicator 18** *(Accuracy of time keeping)*- data derived by logged information from the buses collected by Skånetrafiken.
- **Indicator** (*Delay time by vehicle type - peak*) – data derived by using a simulation tool, VISSIM5.07, based on actual traffic counts “in situ” for three intersections.
- **Indicator** (*Delay time by vehicle type - off peak*) – data derived by using a simulation tool, VISSIM5.07, based on actual traffic counts “in situ” for three intersections.
- **Indicator 23** (*Average Vehicle speed - peak*) – travel time from data derived by logged information from the buses collected by Skånetrafiken during peak hours divided by distance
- **Indicator 24** (*Average Vehicle speed - off peak)* – travel time from data derived by logged information from the buses collected by Skånetrafiken during off peak hours divided by distance

C1.2 Establishing a baseline

The baseline for this measure is the situation with no bus priority installed in the 42 traffic signals. The baseline will show the travel time for different routes without priority in these signals. This measure has developed over several years with different stages and different groups of traffic signals. The timetables for the routes change several times each year and minor changes take place in the bus network. To be able to establish a baseline that will serve as a comparison with the situation when all 42 signals are equipped with bus priority, you need to have a situation with the same timetable and the same route network.

Another important effect of the bus priority is how other traffic in the system is affected when one mode of travel is prioritised in the signals. Some of the intersections have heavy traffic flows and when one direction is prioritised, the other directions are suffering more delay. This has to be taken into consideration as well.

In Malmö during the Smile-period, a lot of construction work has been going on. This has resulted in changes of the traffic load on mayor links and detours of the buses occasionally.

Ideally a baseline should be established prior to the measure. However, all of the problems mentioned above make a "before the measure" baseline not relevant, neither for the bus traffic, nor for the other traffic modes. Instead, for this measure, a baseline has been constructed after the measure was in place. This was realised by turning off the bus priority system for one week and using this data as a baseline. Then the priority system was turned on again the week after. During these two following weeks, data was captured that showed different times at different coordinates for different buses. The data collection was carried out by Skånetrafiken. This was used to calculate the travel times for the bus routes through the system.

In order to estimate the effect on other traffic than buses, three intersections were chosen as "model intersections" where traffic flows were counted during peak and off peak hours.

Table C1.2.1 *Time periods for data collection*

Period	Date	Weekdays
Bus priority turned off	7-11/4-2008	Monday to Friday
Bus priority turned on	15-18/4-2008	Tuesday to Friday

C1.3 Building the business-as-usual scenario

A business as usual scenario shows the situation in the future if this measure has not taken place. That is if these 42 signals in Malmö were not equipped with bus priority.

The objective with the bus priority is to speed up the buses and as a result of that, be able to use the saved time to increase the number of circulations each bus can make during the traffic period. This will, from the passengers view, result in a shorter travel time due to 1) a faster trip from bus stop to bus stop and 2) a shorter waiting time between the buses because the headway for the routes has decreased. It will take some time before these improvements are clear for the passengers and result in increased travelling.

As pointed out in section B5, this measure is related to several others with a common goal of a 10% increase in number of trips. The "business-as usual" scenario that will work for all measures related together concerning the number of trips would be the trend in passengers without the new bus route system and without any of the SMILE measures in place, including this one with bus priority in 42 intersections.

Year 2005 is the base year since it is the start period for SMILE. The route change (not a part of SMILE but included in the overall goal of increased travel) took place in June 2005. Measure

8.1 was running for around 6 month after the change. During 2007 measure 8.2, 12.1 as well as 12.3 were fully installed/implemented. This measure, 12.7 were in place during spring 2008.

Figure C1.3.1 shows the development in the number of passengers for the period 2002-2008. A trend line based on the yearly totals before SMILE and before the change of route system represents "business as usual".

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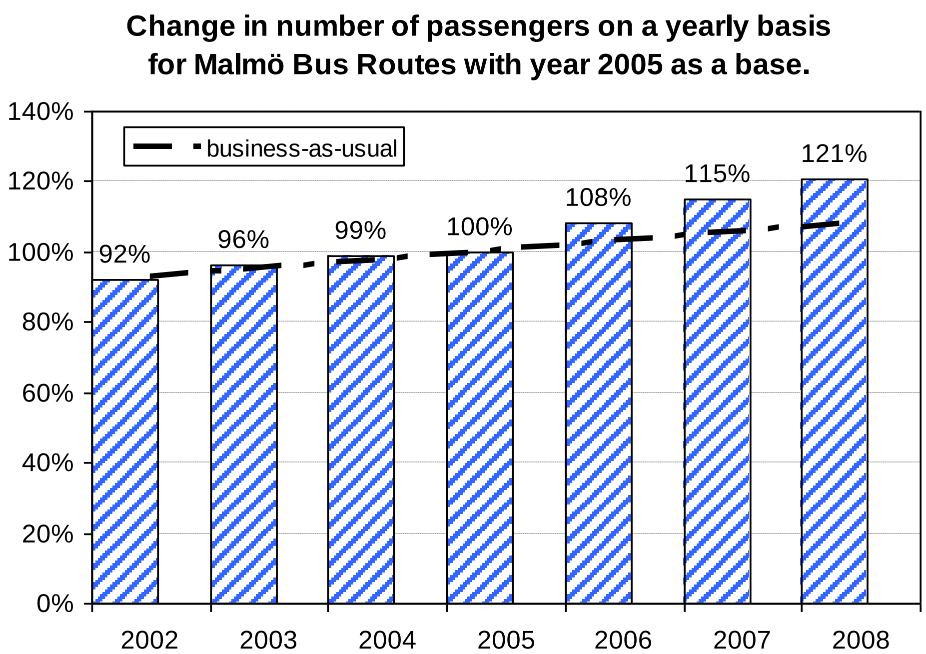

Figure C1.3.1
Number of passengers on Malmö Bus Routes on a yearly basis shown in relation to year 2005, the base year for SMILE. The trend line "business as usual" is based on the situation before SMILE. The new bus route system was implemented in June 2005 and bus priority in 42 intersections were installed in spring 2008.(Skånetrafiken)

A business-as-usual for travel times for the buses (or vehicle speed) is perhaps more relevant for this particular measure. This is the first step towards increased bus patronage. Travel times for a route depend on the exact route plan, number of intersections and traffic flow. The trend in travel time for Malmö bus routes with all construction work going on during the past years is hard to say something about. The best example of business-as-usual for travel times is the snapshot baseline for this measure.

C2 Measure results

The results are presented under sub headings corresponding to the areas used for indicators – economy, energy, environment, society and transport.

C2.1 Economy

This measure has no indicators in this category.

C2.2 Energy

This measure has no indicators in this category. The energy consumption may be slightly affected for the major traffic flows as a result of changes in delays.

C2.3 Environment

This measure has no indicators in this category. The emissions may be slightly affected for the major traffic flows as a result of changes in delays.

C2.4 Transport

The evaluation of bus traffic aims at studying changes in travel speed, which in turn will allow shorter intervals between buses without increasing the number of buses as well as improved quality of bus traffic. The indicators for this are:

- Average travel time by vehicle type (buses) - peak and off peak
- Accuracy of time keeping, punctuality

Study design and sample

The aim of the study is to achieve a general picture of the effects of the bus priority system. That would require studies in different road and traffic environments, and studying effects on different levels – from intersection to bus line level.

Studies of intersections give detailed knowledge of the effect on different types of intersections with different bus manoeuvres (intersections where bus traffic pass straight forward or turns left or right or intersections with crossing bus traffic in two directions).

Previous experience shows that the effect of priority measures increase when they are coordinated in a route. Therefore it would be desired to study some routes to see the total effect of several intersections with bus priority. To evaluate the more general effect of bus priority a study of bus lines would be desired.

The study design chosen is shown in TableC2.4.1. The intersections are the same as for the study of effects on car traffic. The studies include bus traffic in both directions

Table C2.4.1 *Study design for travel times for bus routes, from intersection to bus line level.*

	Study
Bus line:	1
Route:	**G A Torg-Mellanheden**
Intersection:	**36, 404**

36 = Bellevuevägen-John Ericssons väg, 404 = Regementsgatan-Mariedalsvägen,

Indicators of travel speed

Data for different time periods during the day have been analysed. Two indicators of bus travel speed are used to describe the changes for bus traffic:

- Changes in average driving time (sec per intersection and sec per route),
- Changes in the variation of driving time (eg. the difference in maximum and minimum driving time per intersection or route)

Data collection

The data collection was carried out by Skånetrafiken during one period when the bus priority was turned on and one period when it was turned off, see table C1.2.1 Data collection was carried out all day and night, but only the period between 6-18 has been used.

The data collection was done with equipment that registered when buses arrived at and departed from bus stops. On the basis of these two points the driving time was calculated. For buses that did not stop, the registered time is associated with such a large measurement error that these times were excluded from the data set. This causes a drop out of 10-40 % according to Skånetrafiken. In general the drop out is smaller in peak hours and bigger during non-peak hours. Thus, the registered driving times do not represent all departures.

Analyses

Changes in average driving time were studied by comparing driving times when the bus priority was turned on and off. A t-test was performed to study the statistical significance level for the difference. Changes in the variation in driving time were studied by comparing driving times when the bus priority was turned on and off. An f-test was performed to study the statistical significance level for the difference.

The effect of bus priority is assumed to be the biggest during peak hours. Three periods are studied in this study: morning peak at 7-9 o'clock, midday traffic at 10-12 o'clock and evening peak at 16-18 o'clock. The aim is to present the effects for these three different periods. In addition all day between 6 and 18 o' clock is studied, in order to get a larger data basis.

Overall description of studied route of bus line 1

The route goes on bus line 1 between Mellanheden and G A Torg, see figure C2.4.2 below. In total the route on line 1 between Mellanheden and G A Torg includes seven intersections with bus priority. Of these, two intersections are included in this study, No 404 and No 36.

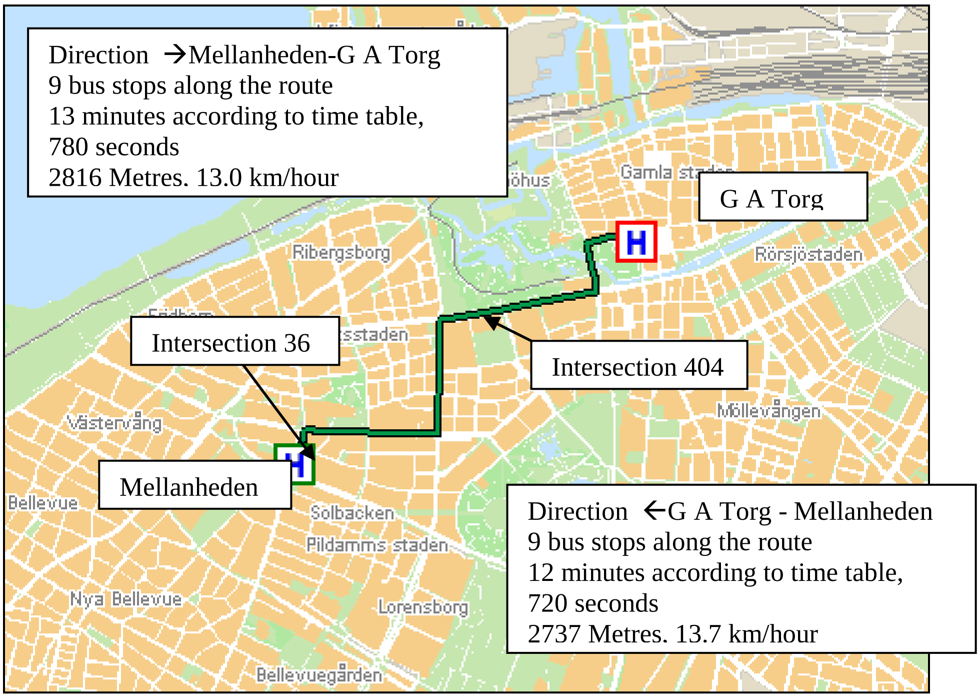

Figure C2.4.2 *Description of studied route and intersections included in the study*

Intersection 404: Regementsgatan-Mariedalsvägen, is located between the bus stops of Fågelbacken and Kronprinsen in the direction towards G A Torg. In this direction the intersection is passed via a right turn. The distance between the bus stops is 265 metres.

Intersection 404:
Direction → towards G A Torg
Right turn between bus stop
Fågelbacken and Kronprinsen
265 Metres apart

In the other direction (towards Mellanheden) intersection 404: Regementsgatan-Mariedalsvägen, is located between the bus stops of Aq-va-kul and Kronprinsen. Here the intersection is passed via a left turn. The distance between the bus stops is 578 metres.

Intersection 404:
Direction ← towards Mellanheden
Left turn between bus stop
Aq-va-kul and Kronprinsen
578 Metres apart

Intersection 36: Bellevuevägen-John Ericssons väg, is located between bus stop Major Nilssons väg and Mellanheden for the direction towards Mellanheden. In the other direction the intersection is outside the route.

Intersection 36:
Direction ← towards Mellanheden
Straight forward passage between bus stop
Major Nilssons väg och Mellanheden
208 Metres apart

Results at intersection level

Table C2.4.3 below presents results on intersection level for intersection 404 for each direction and time period. Average driving time was generally somewhat smaller (when the prioritised signals was turned on), but only significant at 95% level when all hours were considered in the direction towards G A Torg (which represents the right turn in this direction). The variation in driving times was also smaller with bus priority turned on for this direction.

The effect for intersection 36 is larger than for intersection 404 both regarding effect on average driving time and its variation, see table C2.4.4. However, there are some differences in the drop out rate for the different intersections and periods, but it is not quite clear how this affects the results. See table C2.1.5.

Table C2.4.3 Intersection 404: Average driving time and corresponding standard deviation when the signal prioritising was turned on and off, respectively, and the difference in these values between the two situations for each direction and time period.

Driving time (s) crossing 404		**Number of observations**		**Average**		**Standard Deviation**		**Difference On-Off, for**	
Direction	Time period	On	Off	On	Off	On	Off	Average[1]	std dev[2]
to G A Torg	All day (6-18)	272	236	66	70	21	23	**-4 p<0,05**	**-2 P<0,05**
Distance=2816 m	7-9	57	52	70	78	22	23	-7 p=0,09	-1 p=0,08
	10-12	46	42	62	60	12	14	+2 p=0,5	-2 p=0,5
	16-18	35	31	87	90	30	30	-4 p=0,6	0 p=0,9
to Mellanheden	All day (6-18)	207	206	96	100	27	26	-4 p=0,15	+1 p=0,9
Distance=2737 m	7-9	49	51	86	91	28	27	-5 p=0,3	+1 p=0,7
	10-12	35	40	98	102	20	25	-4 p=0,5	-5 p=0,25
	16-18	26	21	83	92	26	31	-9 p=0,25	**-5 p<0,05**

[1] statistical significance level according to two-sided t-test.

[2] statistical significance level according to F-test.

[1, 2] Differences at 95% significance level are marked in bold.

Table C2.4.4 Intersection 36: Average driving time and corresponding standard deviation when the signal prioritising was turned on and off, respectively, and the difference in these values between the two situations for each direction and time period.

Driving time (s) crossing 36		**Number of observations**		**Average**		**Standard Deviation**		**Difference On – Off, for**	
Direction	Time period	On	Off	On	Off	On	Off	Average[1]	std dev[2]
to Mellanheden	All day (6-18)	149	139	34	39	9	11	**-5 p<0,05**	**-2 p<0,05**
	7-9	20	19	34	38	9	12	-4 p=0,3	-3 p=0,1
	10-12	12	20	32	36	7	9	-4 p=0,2	-2 p=0,1
	16-18	41	33	34	39	8	11	**-5 p<0,05**	-3 p=0,07

[1] statistical significance level according to two-sided t-test.

[2] statistical significance level according to F-test.

[1, 2] Differences at 95% significance level are marked in bold.

Table C2.4.5 Coverage rate for data collection for intersection 404 and 36. Coverage rate is the opposite to drop out rate, ie the percentage of departures that have been observed.

Intersection 404		**Number of observations**		**Number of departures**		**Coverage rate**	
Direction	Time period	On	Off	On	Off	On	Off
to G A Torg	(6-18)	272	236	425	340	64%	69%
	7-9	57	52	75	60	76%	87%
	10-12	46	42	60	48	77%	88%
	16-18	35	31	80	64	44%	48%
to Mellanheden	(6-18)	207	206	420	336	49%	61%
	7-9	49	51	75	60	65%	85%
	10-12	35	40	60	48	58%	83%
	16-18	26	21	75	60	35%	35%
Intersection 36	Time period	On	Off	On	Off	On	Off
to Mellanheden	(6-18)	149	139	420	336	35%	41%
	7-9	20	19	75	60	27%	32%
	10-12	12	20	60	48	20%	42%
	16-18	41	33	75	60	55%	55%

In figure C2.4.6-8 all measured driving times on intersection level are illustrated. Generally bus priority has a larger effect on the longest driving times (eg. 75-percentile), than on median driving times, and an even smaller or no effect on the shortest driving times (eg. 25-percentile).

Through intersection 404 towards G A Torg the 75-percentile has decreased from 85 to 75 sec, whereas the median and shorter driving times are about the same for both periods.

In the other direction of intersection 404 the 75-percentile decreased from 121 to 112 seconds with bus priority, and here there was also an effect on shorter driving times, see figure C2.4.7.

For intersection 36 both the 75-percentile and the median of driving times were shorter when the bus priority was turned on, whereas there was no effect on the 25-percentile.

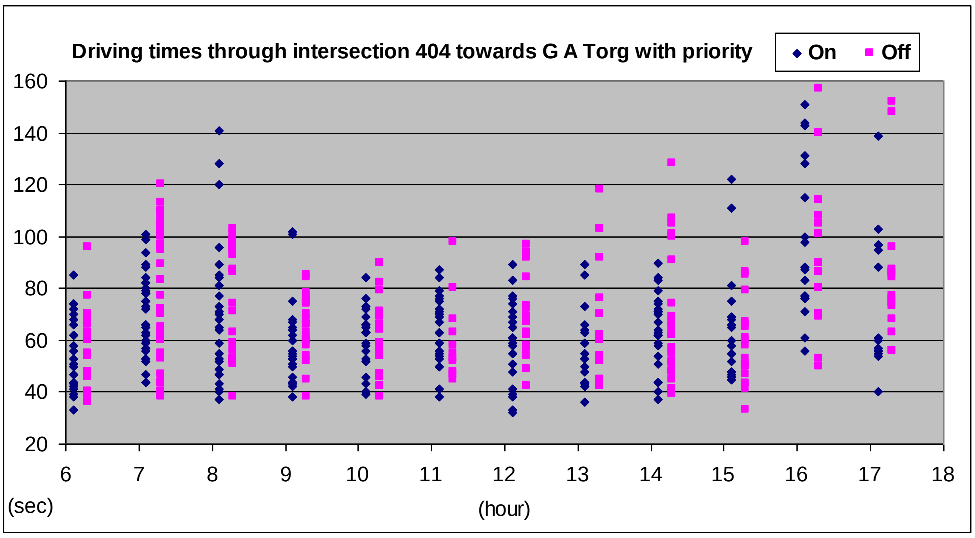

Figure C2.4.6 *Driving times through intersection 404 towards G A Torg with priority turned on and off for different hours during the day*

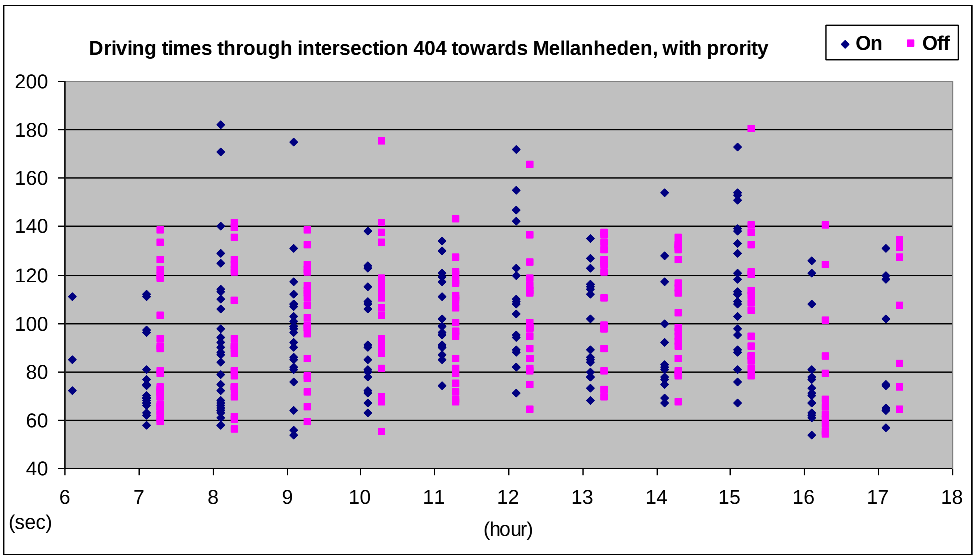

Figure C2.4.7 *Driving times through intersection 404 towards Mellanheden with priority turned on and off for different hours during the day*

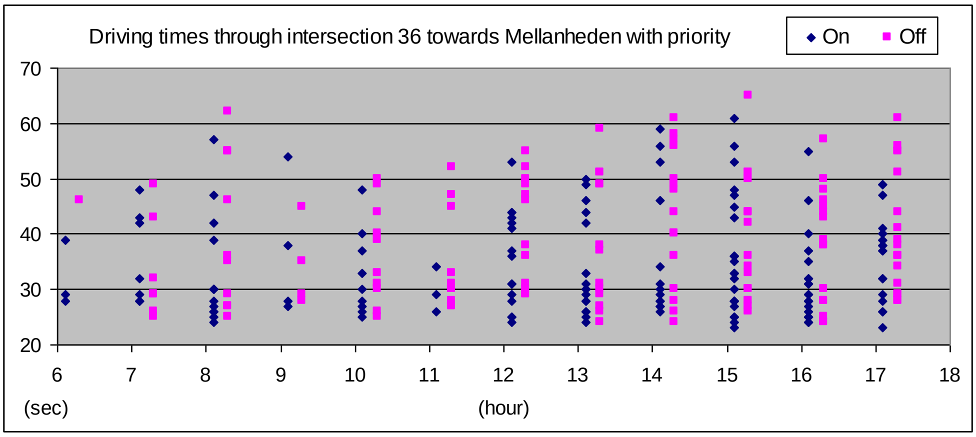

Figure C2.4.8 *Driving times through intersection 36 towards Mellanheden with priority turned on and off for different hours during the day*

Results at route level

Table C2.4.9 below presents results on route level for each direction and time period. Average driving time was significantly smaller when the prioritised signals were turned on in both directions when all hours were considered, and also for some specific time periods. The difference in speed was calculated for each direction and the time periods with significantly smaller driving times.

There is also a tendency that the variation in driving times is smaller with bus priority turned on, but this effect is not statistically significant. The differences do not seem to be an effect of different drop out rates, see table C2.4.10

Even though the changes in variation for this data material are not statistically significant, smaller variations in driving times are probably a sign of better time keeping for the buses.

Skånetrafiken define punctuality as: a departure from a bus stop within 30 seconds before and 3 minutes after timetable. Based on Skånetrafiken statistics, the punctuality for bus line 1 has increased since bus priority was installed in April 2008. The percentage of buses departing in time before the bus priority was 23-25% depending on direction and after 25-29%. (Skånetrafiken) The result is based on ~500 departures during Jan-Mar 2008 and ~2500 departures during Jan-Mar 2009. The data comes from the technical system described in B3. This system had a running in period at the beginning of 2008 and that is the reason for the smaller sample for 2008.

Table C2.4.9 Average driving time and corresponding standard deviation when the signal prioritising was turned on and off, respectively, and the difference in these values between the two situations for each direction and time period.

Driving time (s)		**Number of observations**		**Average (s) (Speed (km/h))**		**Standard Dev**		**Difference on – off, for**	
Direction	Time period	On	Off	On	Off	On	Off	Average[1]	std dev[2]
to G A Torg	All day (6-18)	312	259	630 (16,1)	658 (15,4)	83,5	89,5	-28 **p<0,05**	-6 p=0,24
According to timetable 780 seconds	7-9	60	54	633 (16,1)	660 (15,4)	83	96	-28 **p<0,05**	-13 p=0,28
Distance=2816 m	10-12	41	39	623	637	73	78	-14 p=0,2	-5 p=0,67
	16-18	63	41	644	663	65	84	-19 p=0,11	-18 p=0,08
to Mellanheden	All day (6-18)	216	181	597 (16,5)	621 (15,9)	86	98	-24 **p<0,05**	-12 p=0,07
According to timetable 720 seconds	7-9	38	30	569	577	75	80	-8 p=0,34	-5 p=0,7
Distance=2737 m	10-12	23	26	574	570	56	56	+4 p=0,4	-0,4 p=0,98
	16-18	51	42	636 (15,5)	698 (14,1)	85	107	-62 **p<0,05**	-22 p=0,12

[1] statistical significance level according to two-sided t-test. Differences at 95% significance level are marked in bold

[2] statistical significance level according to F-test. Differences at 95% significance level are marked in bold.

Table C2.4.10 Coverage rate for data collection for route between Mellanheden and G A Torg. Coverage rate is the opposite to drop out rate, ie the percentage of departures that have been observed.

Route		**Number of observations**		**Number of departures**		**Coverage rate**	
Direction	Time period	On	Off	on	Off	On	Off
to G A Torg	6-18	312	259	425	340	73%	76%
	7-9	60	54	75	60	80%	90%
	10-12	41	39	60	48	68%	81%
	16-18	63	41	80	64	79%	64%
to Mellanheden	6-18	216	181	420	336	51%	54%
	7-9	38	30	75	60	51%	50%
	10-12	23	26	60	48	38%	54%
	16-18	51	42	75	60	68%	70%

In figure C2.4.11-12 all measured driving times on route level are illustrated. Driving times are generally shorter with bus priority turned on. Towards Mellanheden (see figure C2.4.11) the longest driving times (eg. 75-percentile) have decreased more than median and shorter driving times. Extreme single maximum values still exist with bus priority turned on for both directions including stop times within the route in the driving times. In figure C2.4.11-12 driving times up to 900-1000 sec are present, which represents the time it takes to drive along the route according to the time table. Even if this is the case, it can be assumed that the effect on driving time is an effect of the bus priority.

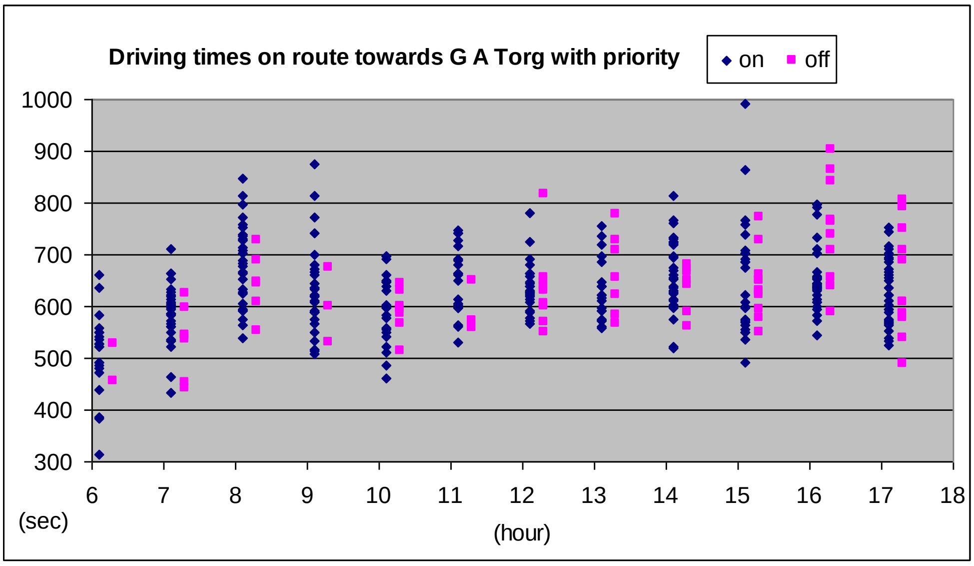

Figure C2.4.11 *Driving times on route towards G A Torg in the situation with bus priority turned on and off for different hours during the day*

According to the time table it takes 780 seconds to drive this distance. Most of the observations in table C2.4.11 show driving times shorter than 780 seconds, with bus priority on as well as off. It is during the morning and afternoon peak that some observations exceed 780 seconds and it is for those hours that the variation is the greatest as well. The bus priority seems to have a diminishing effect on the variations in driving time and will probably increase the punctuality.

Even though the total effect on driving times according to this study is only around half a minute, it can be just as important to decrease the variations during peak hours and by that be able to have a tighter driving schedule. This could mean that the mean driving time with priority (630 seconds) could be the new time according to the time table, and that means a vehicle speed of 10.5 minutes instead of 13 minutes.

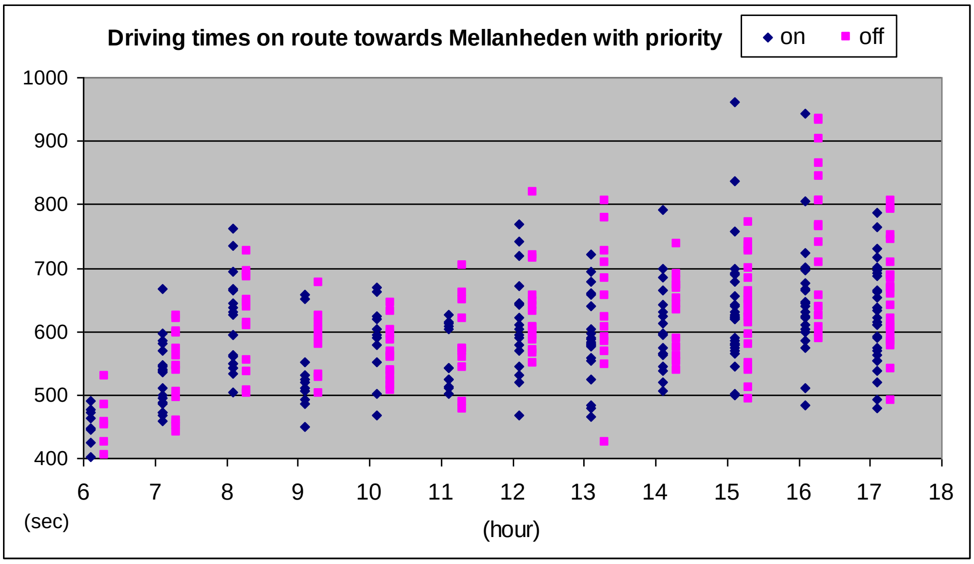

Figure C2.4.12 Driving times on route towards Mellanheden in the situation with bus priority turned on and off for different hours during the day

Conclusion for the travel time.

The study supports the hypotheses that bus priority reduces average driving time and variation. Especially the longest driving times have been shorter with the priority. The speed has increased by 0.6-0.7 km/hour during all day (06-18) for the test distance. During morning peak, the speed increased by 0.7 km/hour towards the centre and during afternoon peak with 1.4 km/hour out from the centre. The data set is too limited to draw any conclusions about effects during the rest of the different time periods during the day. The drop out rate is rather big and the observations are not representative for all departures which make interpretations difficult.

(*Effects of Malmö Bus Priority System on bus traffic*, Trivector Traffic AB, Report 2008:xx, Appendix 12.7)

Traffic delay in three intersections

Another important effect of the bus priority is how other traffic in the system is affected when one mode of travel is prioritised in the signals. Some of the intersections have heavy traffic flows and when one direction is prioritised, the other directions are suffering more delay.

The indicators in this category are:

- Delay time by vehicle type – peak and off-peak.

Method

The analysis of the three intersections was made with the micro simulation tool VISSIM 5.07 together with VisVAP 2.16-03 to control the signal logistic.

Traffic flows

Students from Lund University counted traffic flows during two weeks in April 2008 for the three intersections (number 36, 219 and 404 as presented in Appendix 12.7 Signal Map) chosen. The intersections were filmed as well. The intersections were chosen as representatives for intersections affected by the bus priority with different levels of traffic flow.

The traffic was counted for each signal rotation for the time interval 07:00-09:00 (morning peak), 10:00-12:00(off-peak) and 16:00-18:00 (afternoon peak), both with and without bus priority. The flows for each signal rotation were added in order to calculate a flow per hour over time. The "peak hour" during morning and afternoon are entered in VISSIM. For off-peak hours, an hourly mean are used. (Appendix 12.7 Flows, for more details).

The same peak flows are used in the simulations for the bus priority as well as for the base line simulation. Those flows are from the first week with no bus priority on.

Limitations

Models are simplifications of the reality. In the models used here, the signal logistics are simplified to a certain extent. The difference compared to the real situations is in practice small but in theory rather large. The signal logistics are shown in Appendix 12.7 Signal logic

The traffic count for intersection 36 is not complete, the afternoon situation is missing. Since the traffic flow for this intersection is low, the difference between morning and afternoon is small and the results acceptable.

In reality all signals are parts of a greater network that are not considered in the model.

Bus routes

FigureC2.4.13 shows a detail of the route map of Malmö with the three intersections present. The map shows that each intersection has two or three bus lines crossing from different angles. The headways differ between the bus lines according to the table below. This means that, depending on traffic hour and intersection, at the most 32 buses crossed intersection 36, 40 buses crossed intersection 219 and 32 buses crossed intersection 404. This is to show that the number of buses entering the intersections is very low compared to the number of cars and other vehicles.

Bus Line	**Intersection**	**Buses/hour/direction**
Line 1	36, 219, 404	~ 8
Line 3	36	~ 8
Line 4	404	~ 6-8
Line 32	219	~ 4
Line 35	219	~ 4-8

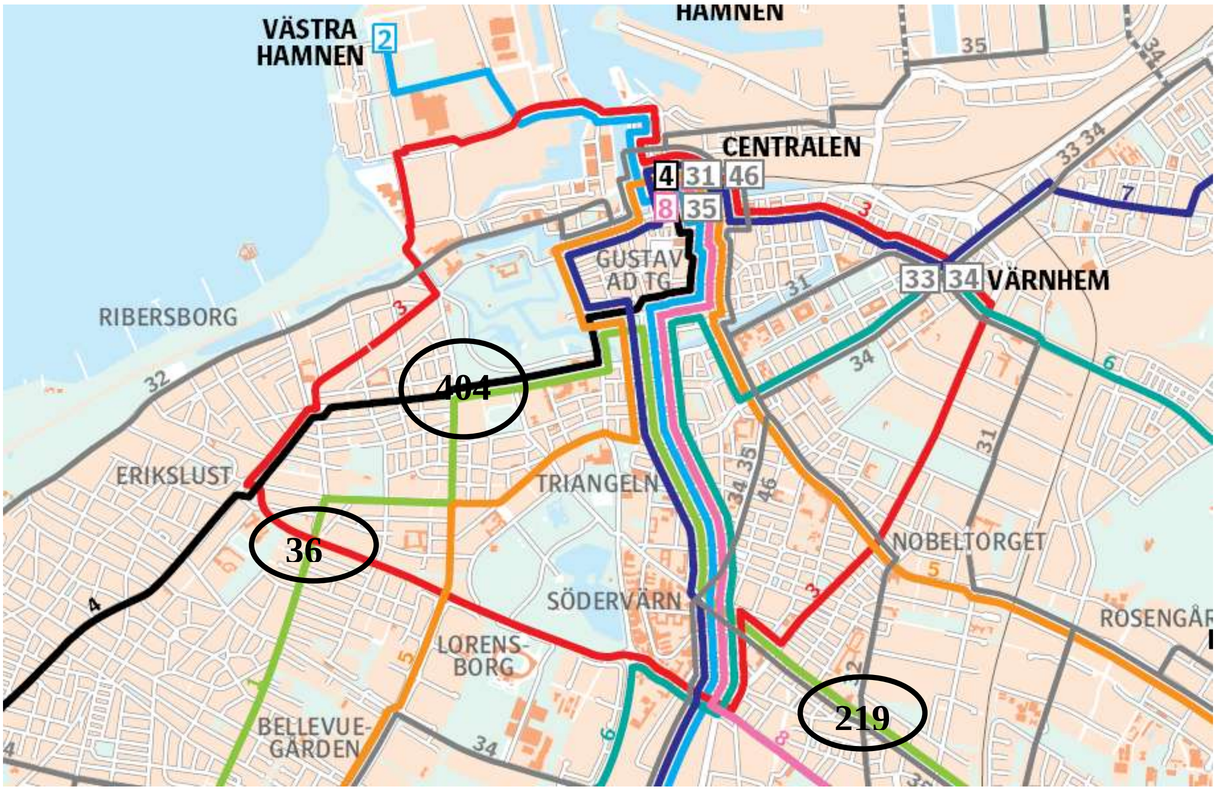

Figure C2.4.13 *The intersections chosen for the traffic flow study. The lines are different bus routes and it is clear that all three intersections have several bus routes passing in different directions.*

The results for intersection 219, 36 and 404 are shown in tables below. The values show the delay in seconds for each vehicle when passing the signal system during peak and off-peak traffic for cars and buses. The values are calculated in the simulation program VISSIM5.07 and show the mean delay when the bus priority is working and when it is not. The total delay for all traffic is also calculated for those two situations.

Intersection 219 morning traffic, peak hour (1920 vehicles)
Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	21	28	23	27	794 minutes
Cars, without	21	29	22	29	807 minutes
Buses, with priority	-	31	-	23	
Buses, without	-	37	-	27	2% less delay with
Incoming traffic flow	350	583	647	340	bus priority for cars

Intersection 219 afternoon traffic, peak hour (2530 vehicles)

Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	32	24	30	19	1161 minutes
Cars, without	32	24	29	20	1163 minutes
Buses, with priority	-	31	-	20	
Buses, without	-	34	-	22	~0% difference in
Incoming traffic flow	805	695	700	330	delay

Intersection 219 off-peak traffic, hour (1427)

Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	19	21	20	20	476 minutes
Cars, without	19	21	19	20	475 minutes
Buses, with priority	-	31	-	19	
Buses, without	-	32	-	22	~0% difference in
Incoming traffic flow	327	458	435	207	delay

Figure C2.4.14 *Intersection 219. Bus routes passing according to Figure C2.4.13*

For intersection 219 buses enter Leg 2 and 4. The results show that the differences in delay between priority or not for the buses passing is rather small, between 1 and 6 seconds per bus. The other traffic entering the same leg is experiencing some priority as well, between 0 and 2 seconds per vehicle. The incoming traffic from Leg 1 and 3 is affected with some extra delay when bus priority is working, between 0 and 1 second per vehicle.

In total, bus priority means less delay for all incoming traffic for intersection 219. The difference is rather small, at the most 2% during morning peak hour.

Intersection 36, morning traffic (the same situation assumed for the afternoon) (1278 vehicles)
Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	15	15	16	13	322 minutes
Cars, without	15	15	16	14	325 minutes
Buses, with priority	10	13	18	13	
Buses, without	16	15	18	19	1% less delay with
Incoming traffic flow /hourly	295	221	602	160	bus priority for cars

Figure C2.4.15 *Intersection **36**. Bus routes passing according to Figure C2.4.13*

For intersection 36 buses enter all four legs. The results show that the differences in delay between priority or not for the buses passing is rather small, between 0 and 6 seconds per bus. The other traffic is not affected at all with the exception of leg 4 where the delay increases by one second for each vehicle passing when the bus priority is off.

In total, bus priority means less delay for all incoming traffic for intersection 36. The difference is small, 1% during morning peak hour.

Intersection 404 morning traffic, peak hour (2816 vehicles)
Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	88	21	42	30	1989 minutes
Cars, without	125	19	46	25	2309 minutes
Buses, with priority	-	19	35	27	
Buses, without	-	20	57	37	14% less delay with
Incoming traffic flow	539	718	886	673	bus priority for cars

Intersection 404 afternoon traffic, peak hour (2941 vehicles)
Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	48	18	39	28	1599 minutes
Cars, without	61	16	49	24	1839 minutes
Buses, with priority	-	17	33	21	
Buses, without	-	18	59	17	13% less delay with
Incoming traffic flow	852	1052	639	398	bus priority for cars

Intersection 404 off-peak traffic (1887 vehicles)
Mean delay in seconds for each vehicle entering the intersection from different legs.

	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**	**Traffic*delay, total**
Cars, bus priority	19	21	18	18	601 minutes
Cars, without	19	22	18	19	606 minutes
Buses, with priority	-	23	19	15	
Buses, without	-	27	22	23	1% less delay with
Incoming traffic flow	516	584	477	310	bus priority for cars

Figure C2.4.16 ***Intersection 404.*** *Bus routes passing according to Figure C2.4.1*

For intersection 404 buses are entering the intersection from three legs. The incoming traffic for Leg1, without buses, suffers significant increases in delay during peak hours, between 12 and 37 seconds per vehicle, when the other three legs prioritise buses. The buses, on the other hand, are experiencing some real changes, the delay decreasing with up to 26 seconds during peak hours. For the incoming car traffic from a leg with bus priority, the situation differs from an increased delay of 5 seconds to a decreased delay of 10 seconds.

In total, bus priority means less delay for all incoming traffic for intersection 404. The difference is significant, 13-14% during the morning and afternoon peak hour. During off-peak hour, the difference is smaller, 1% less delay when bus priority is on.

The bus priority seems to increase the total delay for all traffic in these three intersections, more in peak traffic and less in off-peak traffic. This is probably because the signals are far from optimised as they are. The effect on total delay for all traffic is described in Table C2.4.17

Indicator		Morning peak (7-9)	Afternoon peak (16-18)	Off-peak traffic
Delay time by vehicle type with bus priority	cars	2-14% less delay	0-13% less delay	0-1% less delay

Table C2.4.17 *the results for indicator Delay time by vehicle type*

Bus priority means a shorter travel time (decreased delay per bus) for the buses, more during peak hours than during off-peak hours, table C2.4.18. The total change for each route depends on the number of intersections with bus priority and the traffic flow.

Indicator	All day (6-18)		Morning peak (7-9)		Afternoon peak (16-18)	
	towards the centre	from the centre	towards the centre	from the centre	towards the centre	from the centre
Average Vehicle speed, km/h without bus priority, (baseline)	15.4	15.9	15.4	No significance	No significance	14.1
Average Vehicle speed, km/h with bus priority	16.1	16.5	16.1	No significance	No significance	15.5

Table C2.4.18 *the results for indicator 23 and 24. Average vehicle speed*

One of the results of the analysis is that bus priority means less variation of travel times for a certain distance. This implies a better punctuality. More long term statistics from Skånetrafiken shows an increase in punctuality for bus line 1, table C2.4.19

Indicator	towards the centre	from the centre
Accuracy of public transport time keeping, Jan-Mar 2008 (baseline) percentage of departures "in time"	23%	25%
Accuracy of public transport time keeping, Jan-Mar 200. percentage of departures "in time"	25%	29%

Table C2.4.19 *the results for indicator 18, Accuracy of public transport time keeping. The percentage of departures "in time" (departure not earlier than 30 seconds and not later than 3 minutes after time table)*

C2.5 Society

The awareness and acceptance of the public (potential and actual passengers) for this measure is important. If here is no awareness of the increased travel speed and the decreased headways, there will be no change in behaviour because of that. The bus priority was in place during late spring 2008 and the effects of next time table in terms of changes in headways is still to come. Prior studies in SMILE show the importance of travel time. It was not possible to evaluate these indicators within SMILE because the time between the implementation of the bus priority system and the evaluation needs to be longer.

C3 Achievement of quantifiable targets

No.	Target	Rating
1	**Objective 1** To introduce bus priority systems at 42 traffic lights	★★
2	**Objective 2** To improve the attractiveness of public transport in Malmö we want to increase the intervals from 10 minutes to 7.5 minutes intervals without increasing number of buses. In the long term to reduce the use of private cars among commuters in to city centre.	0

NA = Not Assessed 0 = Not achieved ★ = Substantially achieved (> 50%)
★★= Achieved in full ★★★= Exceeded *A – No T* = Assessed but no target to compare with

C4 Up-scaling of results

Bus priority is installed in 42 intersections in Malmö. The evaluation is made on a sample of data, including three intersections. It shows that the effect of priority is greater for the buses during peak traffic and for intersections with heavy traffic. Not all intersections are suited for bus priority because the traffic flows are too low and other intersections have conflicting interests with other buses and bicycle flows.
This measure is rather "up-scaled" as it is and the effects of bus priority in these 42 signals will result in changes in headways for some routes when the system is more mature. Since this is not the case at present, it is hard to estimate the up scaled effects.

C5 Appraisal of evaluation approach

The evaluation had an ambitious data collection. This technical measure had needed a longer period of running before the data collection was made in order to get a lower "drop out" rate.

The awareness and acceptance of the public is yet to be evaluated. The awareness and acceptance of the increased punctuality and decreased headways is important if this measure should lead to increased travelling. This could have been evaluated if more time had passed between the installation and the evaluation.

C6 Summary of evaluation results

The key results are as follows:

- **Key result 1** – Bus priority in intersections increases the travel speed for the buses with at the most 1.4 km/hour during afternoon peak. During other times the travel speed increased by 0.6-0.7 km/hour.
- **Key result 2** – Bus priority does not imply more delay for other traffic. In fact, it meant less delay as a whole for those three intersections evaluated. Depending on the intersection, the delay

decreased with 0-1% during off traffic, 2-14% during morning peak and 0-13% during afternoon peak. This would probably not be the case for optimised signal systems.

- **Key result 3 –** Bus priority means increased punctuality. The variation of driving times for a specified distance is smaller with bus priority and as a result of that, the percentage of departures "in time" (departure not earlier than 30 seconds and not later than 3 minutes after time table) have increased by 2-5% for the bus line studied.

D Lessons learned

D1 Barriers and drivers

D1.1 Barriers

- **Barrier 1** – Tender appeals delayed the measure
- **Barrier 2** – Bus priority signals at intersections can affect and delay other modes of transport in the transport system

D1.2 Drivers

- **Driver 1** – Prioritised traffic light systems at interchanges can improve bus journey times and reliability and make bus travel more attractive to existing and potential users and can also achieve modal switch and increase environmental benefits
- **Driver 2** – Improving bus journey time reliability by prioritised traffic light systems can be achieved without an increase in the number of buses
- **Driver 3** – By 2004 all city buses and some regional buses were already equipped with GPS and computers which can communicate with traffic lights, so for this measures only installation of equipment in the traffic lights was needed in order to establish a priority system

D2 Participation of stakeholders

- **Stakeholder 1 –** Streets and Parks Department of City of Malmö
- **Stakeholder 2** – Skånetrafiken is a principal participant responsible for public transport in the region of Skåne and in city of Malmö
- **Stakeholder 3** – Public transport users
- **Stakeholder 4** – Supplier of modems

D3 Recommendations

- **Recommendation 1 -** Incorporate the installation of bus priority system with a wider transport strategy.
- **Recommendation 2** – To measure the success of bus priority system and evaluate its results the system need to be in place and running for some months; after which surveys need to be repeated again to gain better and more reliable data and results for this system
- **Recommendation 3** – It is recommended to support the bus priority system by marketing and promotion of bus journey reliability to attract more users and achieve modal switch and its associated benefits

D4 Future activities relating to the measure

It would be technically possible to install bus priority system at all intersections in Malmo to achieve greater bus reliability for all bus services and increase attractiveness of travelling by bus. More travellers will benefit from better and more reliable bus journeys which will result in an increase in the number of journeys and achieve the modal switch to public transport.