Measure title: **Congestion Monitoring Using Telematics in Aalborg**

City: **Aalborg** *Project:* **ARCHIMEDES** *Measure number:* **70**

0 Summary

This measure includes 2 different initiatives that focus at reducing congestion levels within Aalborg:

Congestion Monitoring System through data from TomTom navigation units

Congestion data and data on travel times are continually collected by all TomTom navigation units. 100 units have been implemented in taxies as part of this measure, to improve the amount and quality of data available in the Aalborg area. On basis of these data, new travel times and congestion information have been calculated, and communicated back to the all TomTom units – to influence choice of travel route and travel time. These data are included in all regularly map updates that forms the base for the route directions in the units and are therefore available for all users of TomTom navigation units. As approximately 48% of the Danish cars are equipped with a navigation unit and as TomTom is one of the largest providers of navigation units, it is reasonable to assume that the collected data might improve traffic information for 10-15% of the drivers in Aalborg.

Data on different aggregation levels have been bought from TomTom as part of this measure. Data on speed and congestion levels are presented on the web (measure AAL 09), and have been utilized for setting up the task 8.3 Congestion Monitoring System. The data on the web is accessible for everyone. Road users thereby have the possibility to use these data to plan their trips on times with less congestion.

The congestion monitoring system has been evaluated through analysis of the acquired data and through a questionnaire among the drivers of the 100 selected taxis in order to reveal how the drivers perceive the new data. The main result regarding the Congestion Monitoring System is that:

- The project has established a congestion monitoring system, with two types of data. The one capable of giving congestion / speed level information on day-of-week level, in 5 min intervals, for all roads but aggregated over all days for 2-3 years. The other capable of giving congestion / speed level information on peak hours / off peak hours, accumulated for weekdays, for the 4 seasons in a specific calendar year.
- The data shows the expected outcome. Congestion is highest towards the city in the morning and in the opposite direction in the evening. The congestion level is different on the different road-types and locations, with bottlenecks in a number of places in the road network etc. But the monitoring system shows exactly where the problems are, how much the congestion is on each road segment.
- In average over all routes and directions, and for the whole year, the commuters in Aalborg use 34% more transport time in the morning peak hour, and 30% more in the evening peak hour due to the traffic density.
- The peak traffic affects the whole the major road network in its traffic-accessibility.
- Congestion has risen in 2010, compared to 2009. The travel time over the complete length of all routes has increased by 2% in the morning peak hours and by 3.3% in the evening peak hour.
- 74% of the taxi drivers state that the system more often than ‘a few times’, saves them from unnecessary driving when they are driving to an unknown address.
- 43% of the drivers states the system saves them from unnecessary driving because it shows a shorter route that the driver would have chosen himself more often than ‘a few times’,
- More than half of the drivers states, that they have changed route as a consequence of disturbance information given in the system.

Adaptive Traffic Signal Control System (SPOT system)
Furthermore, this measure has introduced an advanced signal control system. An Adaptive Traffic Signal Control System was planned and implemented on the most congested part of the main ring road, Østre Alle, outside the centre of Aalborg. An Adaptive Traffic Signal Control System is a system, which optimizes the traffic flow from a network point of view. Furthermore, the system in Aalborg allows central monitoring and gives expanded possibilities for operating the traffic signals.

The main results regarding the Adaptive Traffic Signal Control System were:

- Transportation time decreased in average with 25 sec (8.5%) per trip in the peak periods. It is mainly due to a significant effect in the most congested period of the day, the afternoon peak. No positive effects were found regarding the off-peak results.
- When the variation in traffic flows is taken into account, the total reduction in transportation time per year equals to 35,500 hours per year on the section of the ring road.
- The change in speed results in most cases in increase of the low speeds, i.e. fewer and shorter decelerations in front of the intersections.
- Due to smoother driving pattern has the estimated fuel consumption decreased with 2.45%, or equal to a 33,000 litres reduction per year on the section of the ring road.

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A Introduction

A1.1 Objectives

The measure objectives are:

(A) High level / longer term:

- To improve the management of traffic within the city centre.
- To reduce traffic congestion.
- To improve the quality of travel information.

(B) Strategic level:

- To provide new and innovative information to all road users and thereby maybe influence their choice of route and travel time of the day. This will lead to a reduced congestion during the rush-hours.
- To demonstrate impacts of advanced signal control systems on traffic flow and congestion during rush-hours.

(C) Measure level:

(1) To influence the car drivers' choice of route and travel time in order to reduce congestion during rush-hours.

(2) To reduce congestion in peak periods will provide better conditions for public transport which thereby will be a more attrative transport mode.

A1.2 Target groups

- City level: data will be collected for arterial roads on city level. Therefore, people travelling within and through the city on arterial roads is the target group of the information.
- Car drivers, the level of congestion influences on the car drivers' driving behaviour.

A2 Description

The objectives of the actions taken in this measure were to influence the car drivers' choice of routes and travel time and, thereby, reduce congestion during rush hours. Measurements of congestion during the day enable actual information of travel time savings if journeys are re-scheduled away from the peak period.

Reduced congestion in peak periods provides better conditions for public transport and bicycling, and thereby makes them more attractive transport modes. Another positive effect is less energy consumption and less wasted travel time due to fewer tailbacks.

This measure includes two different initiatives that focus at reducing congestion levels within Aalborg:

Congestion Monitoring System through data from TomTom navigation units
Congestion data and data on travel times are continually collected by all users of TomTom navigation units. TomTom navigation units are one of the most common navigation units in Denmark. 100 units

have been implemented in taxies as part of this measure, to improve the amount and quality of data available in the Aalborg area. On basis of these data new travel times and congestion information have been calculated, and communicated back to the units – to influence choice of travel route and travel time. This data is included in all regularly map updates that forms the base for the route directions in the units and is therefore available for all users of TomTom navigation units. As approximately 48% of the Danish cars are equipped with a navigation unit and as TomTom is one of the largest providers of navigation units, it is reasonable to assume that 10-15% of the drivers in Aalborg contributes to the collection of data and that the same 10-15% gains benefit from the improved traffic information.

Data and analysis have been bought from TomTom as part of this measure. Data is presented on the web (measure 9), and have been utilized for setting up the task 8.3 Congestion Monitoring System. The data presented on the web includes information on speed and congestion levels. This data is accessible for everyone. Road users thereby have the possibility to use the data on travel time and congestion to plan their trips on times with less congestion.

Adaptive Traffic Signal Control System (SPOT system)
Furthermore, this measure has introduced an advanced signal control system on a part of the main ring road, Østre Alle. An Adaptive Traffic Signal Control System was planned and implemented on the most congested part of the ring road outside the centre of Aalborg.

An Adaptive Traffic Signal Control System is a system, which optimizes the traffic flow from a network point of view. Furthermore, the system in Aalborg allows central monitoring and gives expanded possibilities for operating the traffic signals.

The network optimizing differs from the common strategy of optimizing a single intersection or the intersections on a route. Adaptive Signal Control method is that all traffic signals in an area are optimized every third second based on the in- and outgoing traffic in each lane of all intersections.
On basis of these data a forecast for the flow of the traffic through the area the next 2 minutes is generated and cycle of all signals are adjusted within the predefined rules in a traffic model to secure optimal flow.

The rules are fixed on the basis of a traffic model for the area. The traffic model is based on traffic counts on all lanes and congestion registrations on the critical approaching lanes. Each intersection includes a unit, which communicates with the traffic signal, the other intersections and the central server. The network optimization is based on various cost elements for each subsection, and the most important are; the cost for stopping a vehicle; the cost of the vehicle giving way; and the cost of tailbacks.

A3 Person in charge for evaluation of this measure

Name of person	Jens Mogensen
Name of organisation	City of Aalborg
Direct telephone	+45 9931 2329
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B Measure implementation

B1 Innovative aspects

The innovative aspects of the measure are:

- Use of new technology/Intelligent Transport Systems (ITS). As one of the first public authorities in Europe, the City of Aalborg has used GPS probe travel times and congestion data from navigation units to calculate and inform on congestion trying to influence car drivers' behaviour and thereby reduce congestion.
- Targeting specific user groups. The aim is to change the car drivers' behaviour, and thereby reduce congestion.
- Aalborg University research in next generation navigation systems.
- An Adaptive Traffic Signal Control System is implemented by the City of Aalborg to demonstrate impacts of Advanced Signal Control Systems on a main ring road.

B2 Planning of Research and Technology Development Tasks

Task 11.8.1 Study "Next generation navigation system". A study has been carried out by the University and an independent consultant and was delivered in M14.

The main findings from the research study were:

- Traffic has been increasing almost steadily for many years. This is a worldwide trend and there is no indication of change in the next many years.
- In 2001 it was estimated that congestion costs in EU would increase by 142% to approximately 1% of the GNP until 2010. This was partly due to increased congestion problems in the cities. In Denmark the development has been concurrent to the overall EU. In Denmark traffic has increased on average by approx. 2% per year. Motorized road transportation has increased by 2.7% per year from 1980 to 2007. Therefore the road networks have become more and more congested over time. In many medium-sized and big cities it has resulted in traffic collapses. In some cities it is still only a peak hour problem while in other places it is virtually the case all day. It should be noted that when traffic volume on a road network reaches a certain level, the step from relative free flow conditions to virtual traffic collapse is short.
- An advanced congestion monitoring system can provide information to road users concerning routes and travel time and can thereby be a tool to reduce congestion. With reliable and preferably real time information about congestion on the driver's desired route, the driver can select another route or postpone or bring forward the desired trip. A provider of navigation systems for cars estimates that available congestion information based on historical data can result in a faster route selection in more than 50% of the trips in congested areas.
- Even though the amount of traffic reduced e.g. in the rush hours might be small, it might be sufficient to postpone any frequent traffic collapses by a number of years.

Basically there are two approaches for collecting congestion data: spot speed measurement and measurements based on floating car data (FCD). The report describes the different approaches. It presents 4 different spot measurements techniques and 4 different FCD measurements techniques. The overall conclusion is that floating car data result in more reliable and wide covering data than do traditional spot speed registrations. Moreover, it is concluded that the most efficient - and cost-efficient approach to reach enhanced congestion information is from existing providers of navigation units.

In the second part of the study the challenges concerning congestion analyses -from data to results – is shown, illustrated by experiences from a Case Study in Aalborg. The section also demonstrates that it is possible to do detailed analyses of speed level and congestion level, expressed by time used to pass different branches of an intersection, calculated on basis of FCD.

The third part of the study is elaborating on the three types of data: static, variable and dynamic speed and congestion data that can form the basis for information about transportation time and congestion level to the road-users.

The study concludes that information aimed at avoiding congestion shall be at the 'Variable level'. Data on 'Dynamic level' could prove even better, but was not a realistic alternative at the time of finishing the report.

In the last section of the report it is concluded that data about congestion should be from FCD to get sufficient coherent information. FCD should preferable be based on GPS data. Also, it should be collected from standard navigation units providing historical (variable) congestion data.

B3 Situation before CIVITAS

About 20% of the traffic in Aalborg is handled within 2 hours during the morning and afternoon peak hours. Due to congestion and tailbacks the energy consumption within these periods is particularly high. Moving 10-20 % of the peak hour traffic 15-30 minutes would reduce or remove congestion, reduce energy consumption and environment stress, and would postpone the need for great infrastructure investments in a new connection over the inlet, Limfjorden for some years.

Until a few years ago, a heavily congested two-lane carriageway ran on the old harbour side and cut off the central city centre from the revitalised harbour areas. To give access to the Limfjord, during the first year of the ARCIMEDES period, the carriageway was changed to a single-lane city street with bicycle paths. As planned, the capacity of this road was reduced and substantial parts of the traffic were moved to other arterials roads. To address this changed traffic pattern, it was necessary to increase capacity on the main ring road, Østre Alle, and in particular on the most congested eastern part of the ring road. The Central Harbour Front and the ring road with the most congested part highlighted appear in Figure 1.

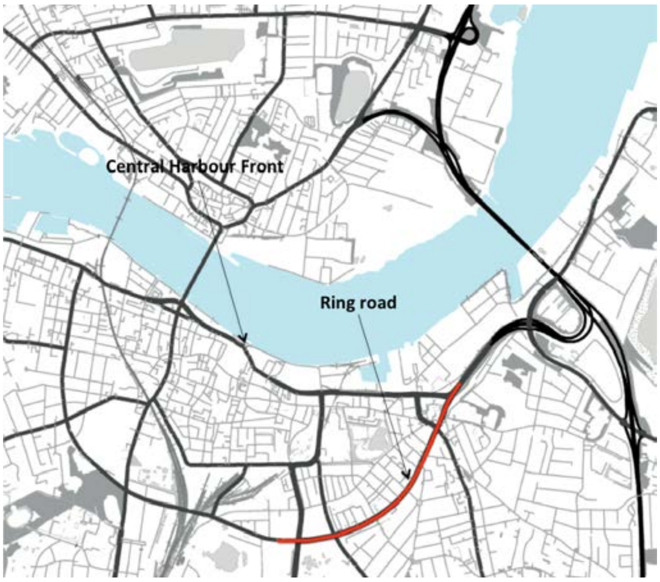


Figure 1: Map with the arterial roads in Aalborg. The Harbour Front is located in the centre of the map, and the road section where the Adaptive Traffic Signal Control System was implemented as part of Archimedes is marked with red.

B4 Actual implementation of the measure

The measure was implemented in the following stages:

Stage 1: Planning and Research – *(September 2008 – March 2009) Aalborg University undertook a research in next generation navigation systems. See section B2. The research evaluated different types of data and different means of collecting data. The research report recommended use of FCD from navigation units as the base for setting up a congestion monitoring system.*

Stage 2: Commissioning *(March 2009 – April 2010) As part of the planning and research procedure it was revealed that all navigation units from TomTom collect FCD when ever turned on. These data are automatically delivered to the TomTom back-offices system each time a navigation unit is connected to the Internet – if the user has not rejected this during the first installation. As a consequence TomTom does have billions and billions of speed/ congestion measurements among others also covering all roads in the Aalborg area. The amount and the coverage of data were of a magnitude that was not possible to achieve by setting up our own data collection system.*

Thus, a contact was made with TomTom to buy these data for use in setting up a congestion monitoring system. After a clarification and negotiation process, a contract was signed with TomTom on buying the FCD. The contract was the first with a public body outside the Netherlands for use of these data to traffic monitoring purposes. Data was bought to be delivered in 2010 and 2011, covering the years 2009 and 2010. The projects budget and time schedule did not allow for a data deliverance in 2012.

In parallel, planning was done for an Adaptive Signal Controlling System for a part of the inner ring road, Østre Alle. After the negotiations a contract was signed.

Stage 3: Implementation and monitoring (April 2010 – project end)

1 Congestion Monitoring System through data from TomTom navigation units

During all trips TomTom units collects data on speed level on all road segments with date and time stamps. That is, data on accessibility. This data collection is active on all trips regardless of whether the device is used for route guidance or not. Due to the great number of devices, and the strategy of continuous data collection in all situations, the accumulated collected data sums up to enormous amounts.

To accelerate the data collecting in the Aalborg area the City of Aalborg bought 100 navigation units that were installed in 100 local taxis. As one taxi runs maybe 6-8 times more than an ordinary car, the 100 units accumulates as much data as 600-800 private cars – and on different roads, where a private car typically does most of the distance driven on the same road between home and work.

Before the City of Aalborg bought the data, TomTom did some analyses to evaluate if there were enough data on the roads in Aalborg to do significant analyses. It was concluded that even on a small data sample only including data for the morning peak hour in the summer season (only defined as 6 weeks) there were enough data to do reliable congestion analyses.

The data were real historical data aggregated on two different levels. One level is speed data on 5 min interval, for each day of the week. The other aggregation level is data aggregated to Morning peak hour, Afternoon peak hour, Day time and Night time / Spring, Summer, Autumn, and Winter.

Based on the first aggregation level, a congestion monitoring system was set up. The purpose of the system is to make it possible to complete analyses on speed level and congestion level, to be used as input to, and qualifying, the planning process.

The output can be graphical presented as spreadsheet graphs or be exported as KMZ format to be visualised on Google maps. See Figure 2*.*

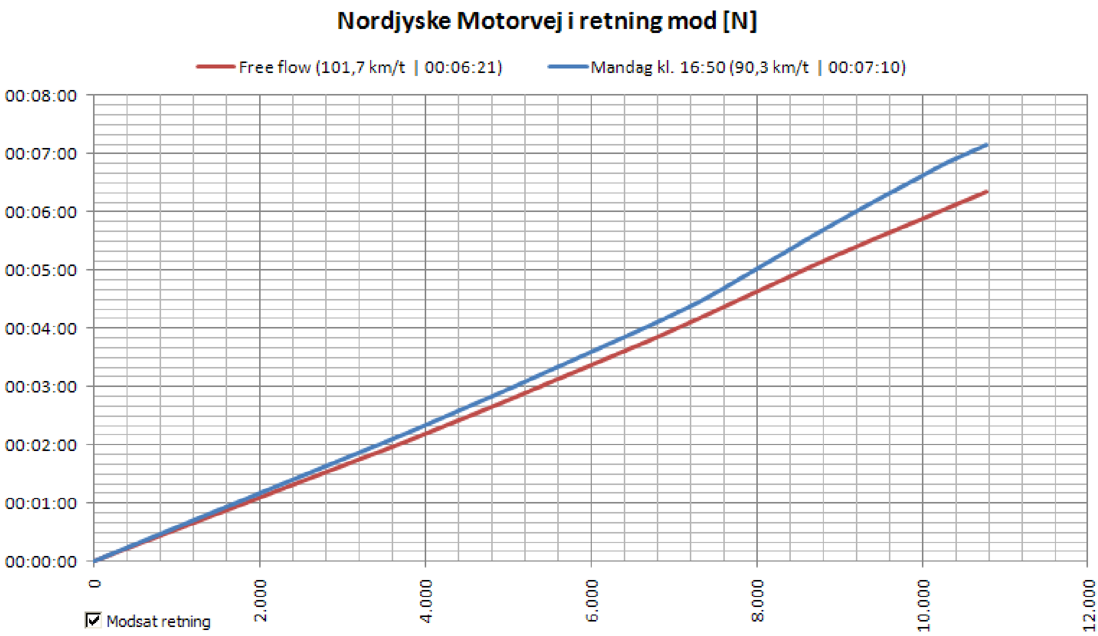


Figure 2 Effect on congestion illustrated on spreadsheet graphs. Travel time for a selected road stretch in peak hour compared (blue line) to travel time under free flow (red line).

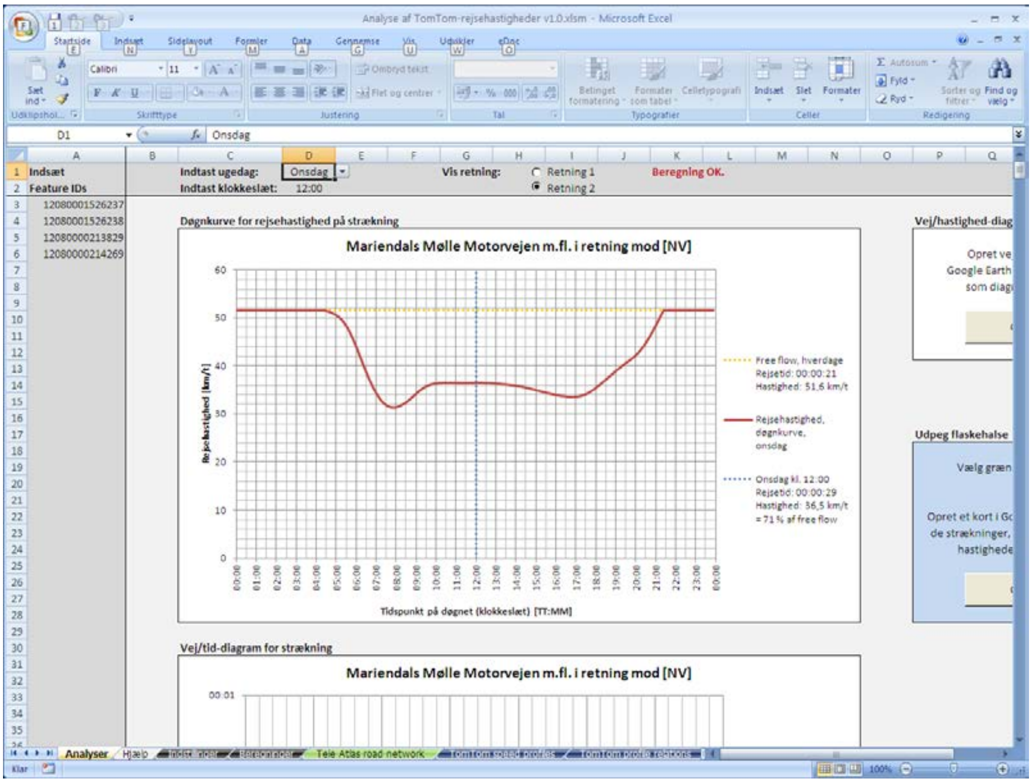


Figure 3 Speed level / congestion as a function of time of day for a part of one of the approach roads to the City.

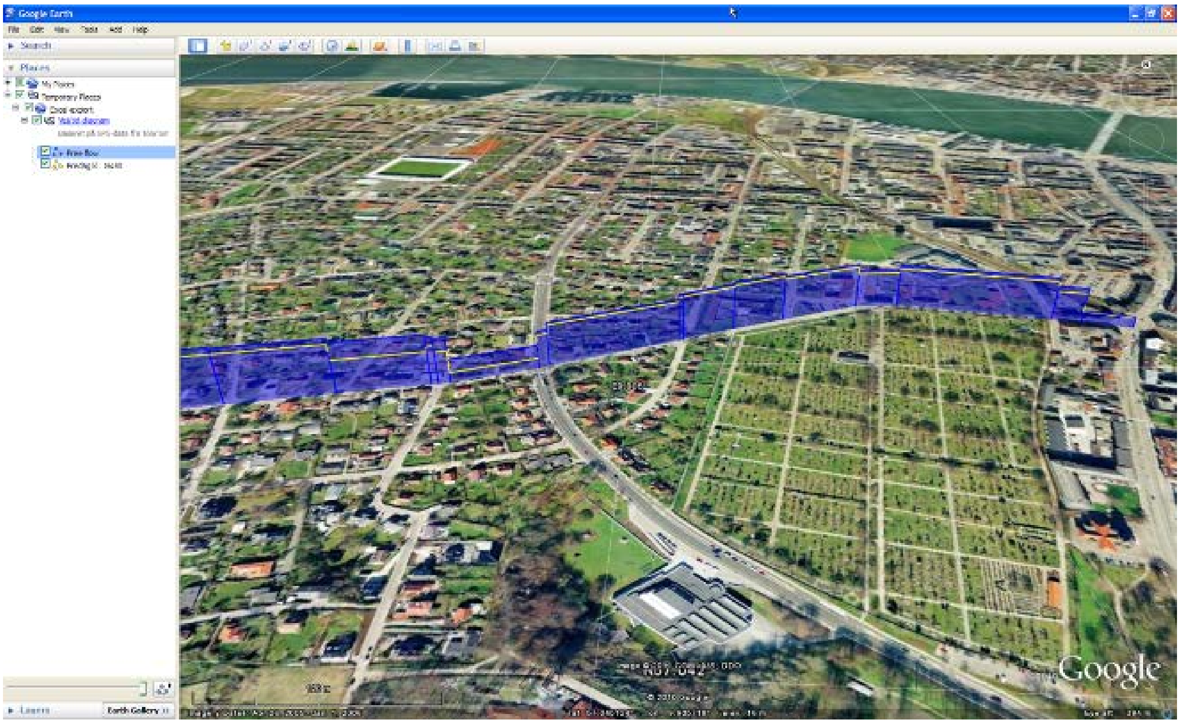


Figure 4 Effect on congestion. Analyses from congestion monitoring system automatical outputed on Google maps.

Figure 5 Bottleneck analyse showing bottlenecks where speed level drops to less than 50 % of free flow. Analyses from congestion monitoring system output on Google maps.

Based on the second aggregation level congestion data is presented to road users via the Internet.

*Analyses have been completed on road segment level for the selected road network. Data for weekdays have been sorted by year, four seasons and time of day (Morning peak hour, day time, evening peak hour, night time). For each of these combinations analyses have been done for speed and congestion level. The 40 resulting analyses for all road segments have been combined into 40 KMZ files – with information labels on road segment level. The result can be utilised by all users of the national transport information site www.trafikken.dk/nordjylland. Examples of the available information appear in Figure 6 to***Figure 9**.

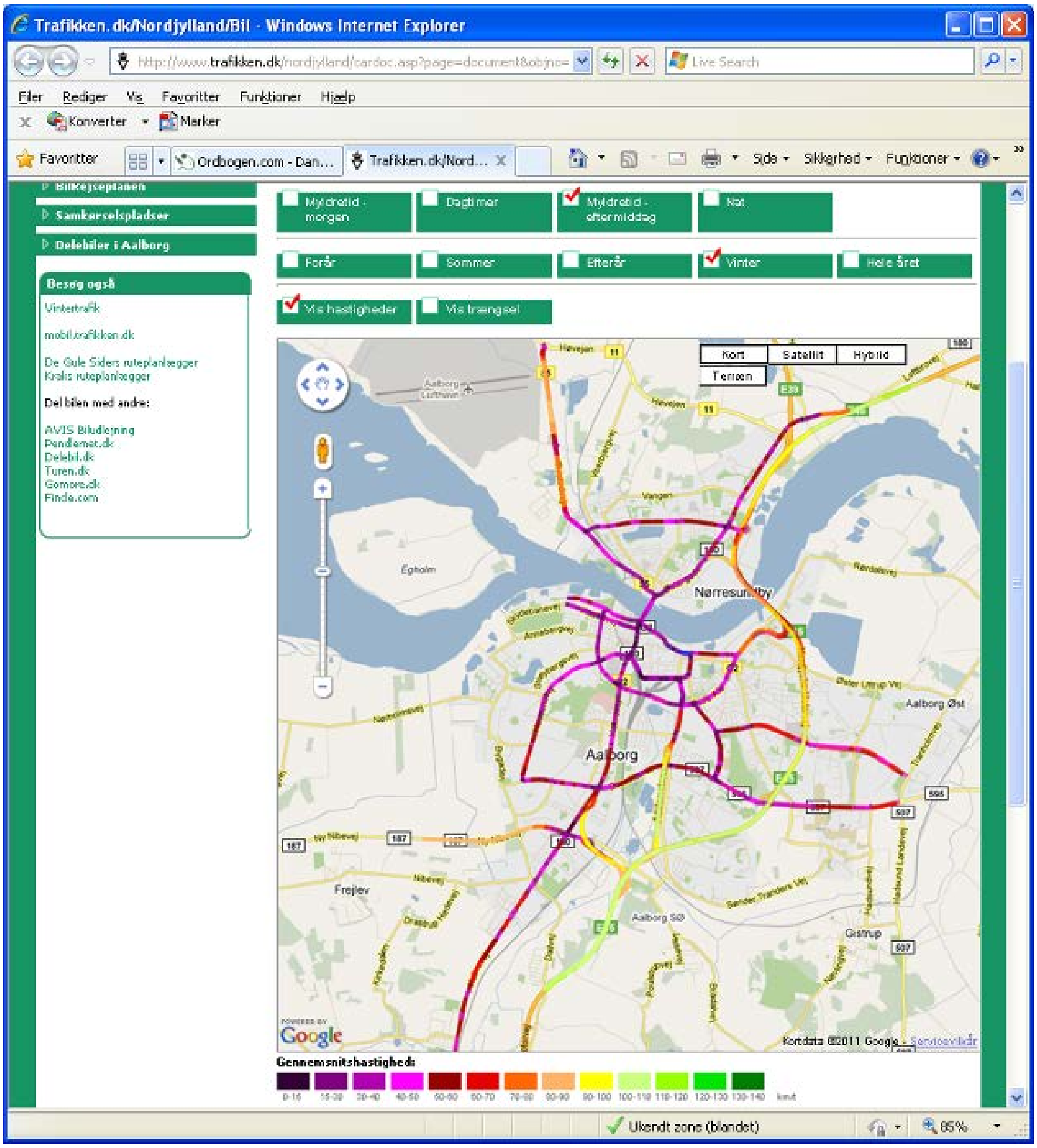


Figure 6: Congestion data and speed level data available on the Internet for the public.

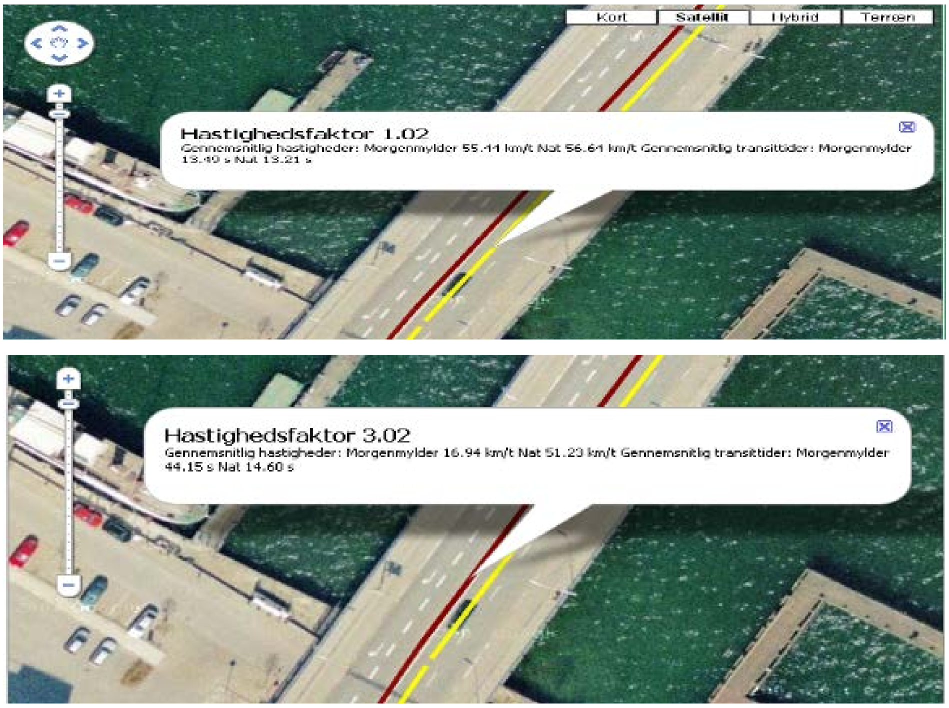
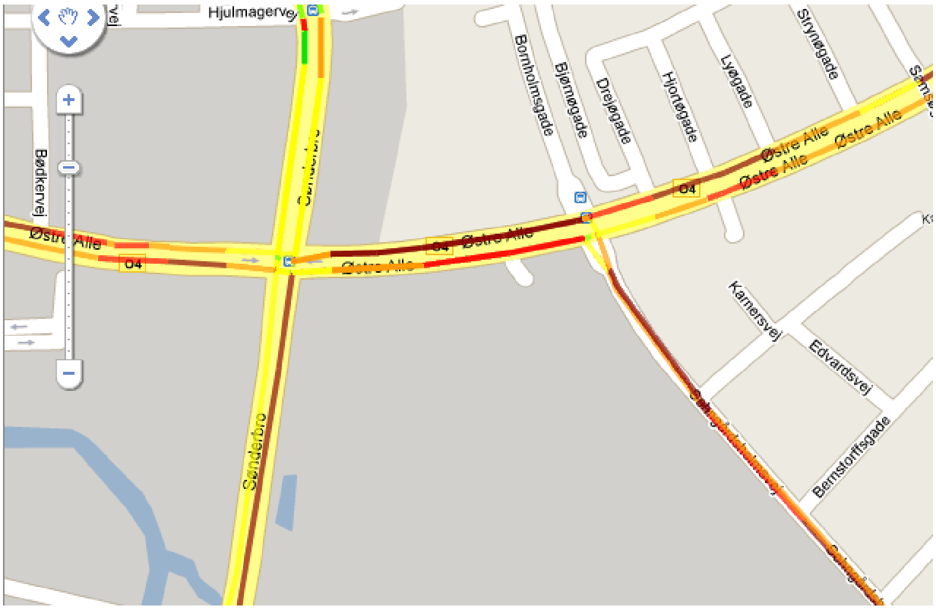
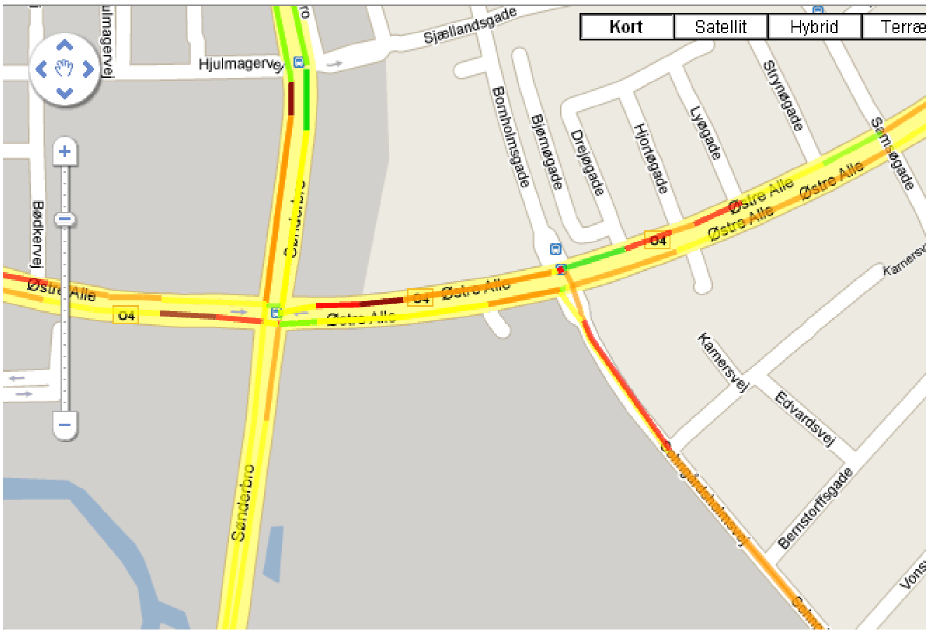


Figure 7: The congestion information system available on the Internet shows that there are very different congestion levels from the Aalborg City period between the direction going out of the City in peak hour compared to the direction entering the City. There is almost no effect on outgoing traffic, but speed is reduced up to 1/3 of night level for incoming traffic.





Figur 8 The congestion information system available on the Internet. Top: Congestion in the winter. Below: Less congestion in the summer

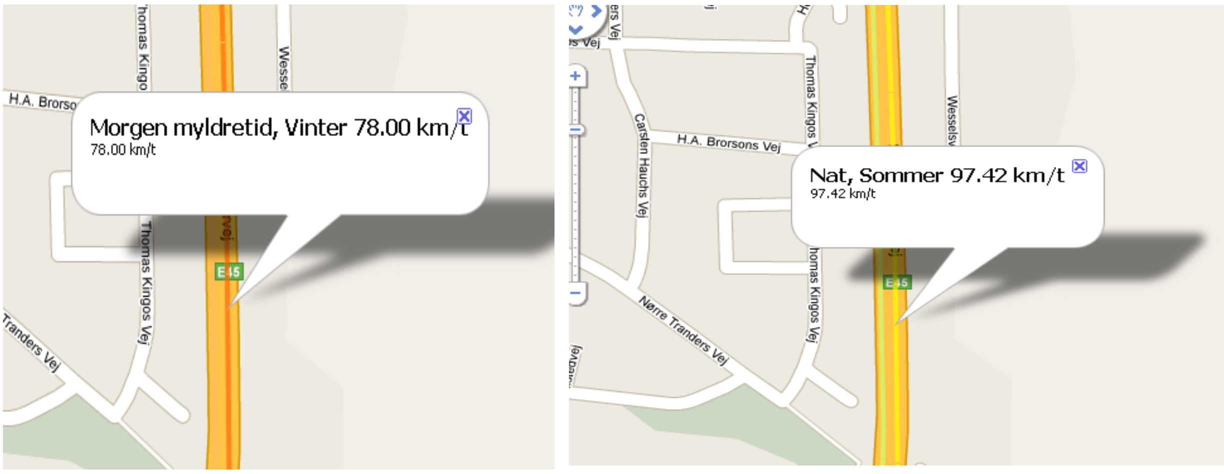


Figure 9 The congestion information system available on the Internet. Motorway traffic: Left: Congestion in peak hour. Right: Well above speed limit in the night

2 Adaptive Traffic Signal Control System (SPOT system)

With the purpose to demonstrate impacts of advanced signal control systems on optimising the traffic flow, an Adaptive Signal Control System (SPOT system) was implemented on the main ring road.

The SPOT system is adaptive in the sense that each signal is controlled more dynamically as a part of a model that calculates a prognosis for the traffic flow at all the intersections in the SPOT area, aiming to minimise the accumulated waiting time for road users in the system.

Where the optimisation of one intersection in the previous system was only dependent on measurements of the traffic flow going into the intersection, in the SPOT system the optimisation takes into account traffic going out of the other intersections in the road network comprising the system.

As one of the parameters in the optimisation are priority requests from the bus prioritisation system for public transport, public transport can be given priority by giving buses a higher weighting factor, while other means of transport are still taken into consideration.

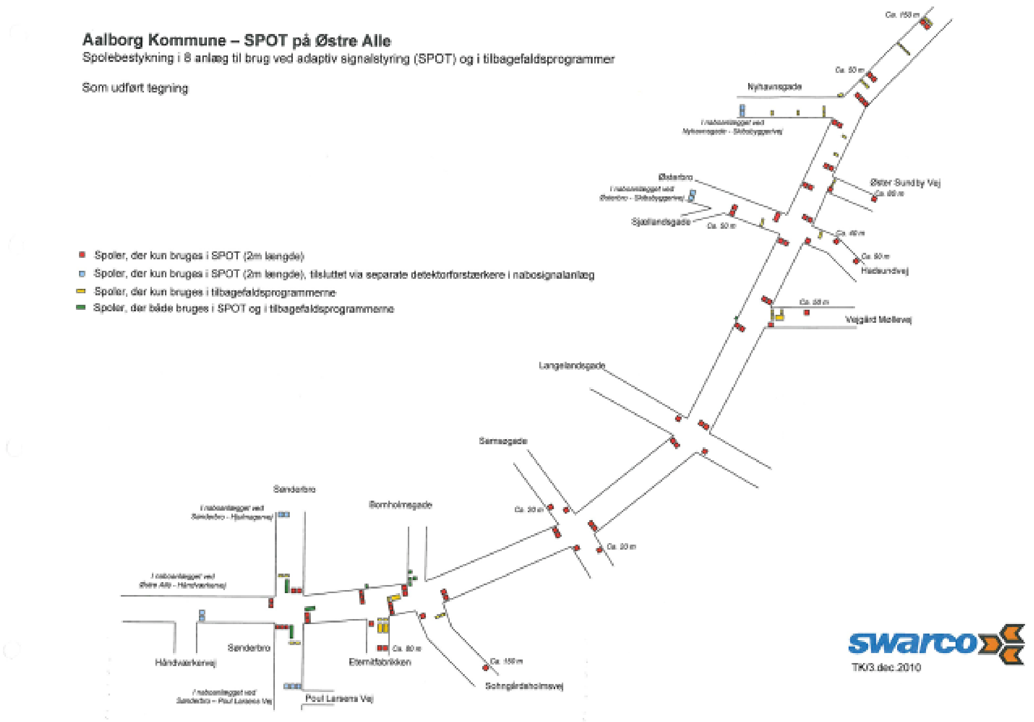


Figure 10: The location of signals and detectors on the section of Østre Alle, which has been implemented with Adaptive Traffic Signal Control System.

The Adaptive Traffic Signal Control System was implemented on the most congested part of the ring road, Østre Alle. It was implemented on a 1.7 km section (2.2 km including approaching lanes) of the ring road (two-lane arterial road with bicycle paths) with high-frequent bus routes and significant bicycle-traffic crossing the ring road. The Adaptive Traffic Signal Control System includes 8 intersections of which 1 is a double intersection. The intersections and detectors appear in Figure 10.

In implementing the Adaptive Traffic Signal Control System a minor delay appeared. The implementation of the system was initiated in the autumn 2010 and was planned to be finished in November 2010. However, due to an extra-ordinary cold winter in 2010 and partly 2011 the implementation was delayed.

Meanwhile a significant additional traffic flow was added from the new road, Synergivej (see Figure 11for location of Synergivej) intersection in the spring 2011, which required additional work on the Adaptive Traffic Signal Control System. Therefore, the last parts of the implementation were carried out in the first half of 2011. During this process, it became clear *that subsequent careful monitoring and calibrating of the Adaptive Traffic Signal Control System was required and very time-consuming. This calibration procedure went on until the end of 2011.*

Figure 11 : Map with the included intersections in the Adaptive Traffic Signal Control System. Left: the location of the section of the ring road. Right: all equipped intersections. The intersections with Synergivej and with Bornholmsgade are together the double**.**

Stage 3: System operation:

Since the midsummer 2011 the Adaptive Traffic Signal Control System has been in operation, although on-going additional calibration have been made. However, to evaluate the effect of the Adaptive Traffic Signal Control System, it was closed down approximately one week in October 2011. During this period, a traditional Time Controlled Traffic Signal System operated the traffic signals (see below). The on-going calibration has increased the effect of the system significant and even though the initial calibration is brought to an end now, small-scale adjustments will continue to appear as part of the operation of the system.

B5 Inter-relationships with other measures

The measure is related to other measures as follows:

Measure 9 – Providing information on congestion. Measure 9 provides updated and reliable traffic information to enable travellers to make sensible choices in terms of modal choice and timing of their journeys – based on this measure.

Measure 51. Cycle Motorway. The implementation of the Adaptive Traffic Signal Control System on the ring road, Østre Alle facilitates better connections for the cyclists on the new improved bicycle paths between the city centre and the university area because it eases the connection to the city centre.

C Planning of Impact evaluation

C1 Measurement methodology

C1.1 Impacts and indicators

C1.1.0 Scope of the impact

By implementing this measure less congestion will occur in peak hours in the morning and afternoon. Less congestion will lead to less energy consumption and reduced pollution, due to a more smooth traffic flow with less breaking and accelerating, and due to less idle running.

C1.1.1 Selection of indicators

NO.	EVALUATION CATEGORY	EVALUATION SUB-CATEGORY	IMPACT	INDICATOR	DESCRIPTION	DATA /UNITS
	SOCIETY					
14		**Acceptance**	Acceptance	Acceptance level	Attitude survey of current acceptance of the measure	Index (%), qualitative, collected, survey
	TRANSPORT					
23			Congestion Levels	Average vehicle speed Average travel times	Average vehicle speed on selected road segments in different seasons.	Speed in Km/h, traveltime im min:sek, Congestion rate as traveltime in peak hours and Off peak compared to travel time in free flow.
23				Average vehicle speed Average travel times Speed variation - Peakhour – daytime off peak	Variations of speed and traveltimes on the ring road.	Speed in Km/h, traveltime im min:sek.
			Route choices	Survey with drivers of 100Taxis	The route choice from the same A to B.	Route

C1.1.2 Methods for evaluation of indicators

No.	INDICATOR	TARGET VALUE	Source of data and methods	Frequency of Data Collection
14	Acceptance level	To improve the quality of travel information.	Questionnaires. Target groups are taxi drivers with navigational units. The questionnaire survey has been distributed to all drivers of the 100 taxies equipped with navigation units. 42 drivers answered the questionnaire. The survey focused at: - Did the drivers use units? Did the drivers use the new information and how?	1 time
23	Congestion Levels	To improve the management of traffic within the city centre. To reduce traffic congestion. Speed variation Average speed Transportation time	Analysis on GPS data from all TomTom users covering the Aalborg area. 10 routes leading to the city centre or covering the major roads has been analysed. Analyses divided into 2 peak hours, and free flow (night) and into 4 seasons pr. year. Analyses were repeated for 2 years. Sample is so big, that data is statistical significant for each road segment within each time of day and season. A before/after study and a 'with/without' study on the ring road were carried out. While the Adaptive Traffic Signal Control System gives additional time to crossing traffic in selected intersections, the effect on through traffic was studied. A student helper in a car followed the through traffic carefully according the method called 'the chasing car'. The car was equipped with a GPS logger, and driving data were collected during the studies. The before study was interrupted by extreme weather and was made in November 2010 and January 2011. The after study was carried out in March 2011. However, due to weather conditions and the fact that a significant additional traffic flow was added from the Synergivej intersection in the spring 2011, a new data collection for the evaluation was carried out in the fall of 2011. To avoid the direct comparison of a traditional Traffic Signal Control System (with errors, and ready for a larger maintenance operation) with a newly implemented Adaptive Traffic Signal Control System, the data collection in the 'with/without' study without the Adaptive Traffic Signal Control System activated was made after the implementation of the system. Then it was turned off subsequently and the data collection with the traditional Time Controlled Traffic Signal System activated was carried out. Hence any disrepair bias would be avoided. It is therefore assessed that the second data collection was more reliable than was the first. The second 'with/without' study was carried out in September-October 2011. However, it became clear that further adjustments on the Adaptive Traffic Signal Control System were required to ensure sufficient effect. This task was ongoing until the end of 2011. Hence, an additional 'with' data collection was carried out in March 2012.	2 times each covering one year. 2 times 2 periods with data collection

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No.	INDICATOR	TARGET VALUE	Source of data and methods	Frequency of Data Collection
	Route choices	To improve the management of traffic within the city centre. To reduce traffic congestion.	Questionnaires. Target groups are taxi drivers with navigational units. The questionnaire survey has been distributed to all drivers of the 100 taxies equipped with navigation units. 42 drivers answered the questionnaire. The survey focused at: - Did the drivers use the new information and how? Did the drivers themselves evaluate that the new information made them change transport behaviour?	1 time

C3 Planning of before and after data collection

EVALUATION TASK	INDICATORS INVOLVED	COMPLETED BY (DATE)	RESPONSIBLE ORGANISATION AND PERSON
Baseline data collection	Average vehicle speed – peak, Average vehicle speed - off peak, Attitudes, GPS data from vehicles	M27-29, M38	City of Aalborg, Jens Mogensen
Collection of after data	Average vehicle speed – peak, Average vehicle speed - off peak, Attitudes, GPS data from vehicles	M31, M37-38	City of Aalborg, Jens Mogensen
D12.2 Baseline and first results from data collection	All indicators	Month 39	
D12.3 Draft results template available	All indicators	Month 46	
D12.4 Final version of results template available	All indicators	Month 48	

C1.2 Establishing a baseline

The baseline for the congestion monitoring system is an analysis of GPS data from all TomTom users covering the Aalborg area. Selected streets on 10 routes leading to the city centre or covering the major roads have been analysed. Analysis are done for the 2 peak hours, for daytime and free flow (night) and for 4 seasons per year. Analysis of data from 2009 is the baseline, and analyses of new data from 2010 constitute the after-data.

The analysis of the after data will show two different trends. Partly, a supposed continued rise in congestion, and partly the effect of the project generating more precise data for the congestion. There might be a challenge in dividing these two trends from each other.

The baseline regarding the Adaptive Traffic Signal Control System was the section of the ring road equipped with the old Time Controlled Traffic Signal System. The old system operated with three different circulation periods in each intersection to reflect the variation in traffic flows over the average day. Regardless of the current traffic volume but depending on the normal traffic volume on a certain time of day the signal system selected one of these circulation periods. These periods were formerly adapted to the current traffic volume, but had not been updated for a long time. Hence, it was a very static and unadapted system when cooping with the traffic flows today and the variations in the traffic flows in general. To establish a baseline, data about the through traffic speed and time consumption were collected with the old Time Controlled Traffic Signal System.

The after study was carried out in March 2011. It appeared due to weather conditions and the fact that a significant additional traffic flow was added from the Synergivej intersection in the spring 2011 that the data collection was insufficient. Therefore it was decided to undertake a new evaluation study.

Also, to avoid comparing a traditional Time Controlled Traffic Signal System with errors, and ready for a larger maintenance operation with a newly implemented Adaptive Traffic Signal Control System, the without data collection was carried out after the installation. The Adaptive Traffic Signal Control System was simply deactivated in a period while the data were collected. This data collection was carried out in October 2011 – the Adaptive Traffic Signal Control System was fully installed although still under adjustment at that time. It included 120 trips. Hence any disrepair bias was avoided. The 'with' data were collected in September-October 2011 and included 110 trips. Both Data collections were in these periods: on Tuesday, Wednesday, and Thursday morning peak hours, midday off-peak and afternoon peak hours. Additional adjustments on the Adaptive Traffic Signal Control System were required to ensure sufficient effect. This task was ongoing until the end of 2011. Hence, an additional 'with' data collection was carried out in March 2012. It resulted in another 129 trips used to measure the effects from the Adaptive Traffic Signal Control System.

The 'without' data formed the level of baseline: The baseline results are presented in the following ways:

- The transportation time on the entire section of the ring road equipped with the Adaptive Traffic Signal Control System and the related approaching lanes
- The speed variation on the section
- The average speed on the entire section

The baseline level of congestion is available in section 2.

C1.3 Methods for Business as Usual scenario

If nothing is done, congestion level will continue to rise. It is the case in general, but in particular in medium and bigger cities. The following main reasons for this can be identified:

- During the last 30 years traffic has increased with about 2% per year in Denmark on average,

- This increase has been particular significant between cities and hence arterial roads in cities are affected significant,
- The rate of car ownership in Denmark is low (about 0.4 cars per inhabitant), and
- The new Danish Government has noticed that small environment-friendly cars will be cheaper – al thing equal more cars will be bought and then also used – it is also the experience from other countries.

This general tendency is also present in Aalborg, where about 20% of the traffic is handled within 2 hours during the morning and afternoon peak hours.

Due to congestion and tailbacks the energy consumption within these periods is particularly high. Also, until a few years ago a heavily congested two-lane carriageway ran on the old harbour side and cut off the central city centre from the revitalised harbour areas. To open the city centre to the Limfjord, the carriageway was changed to a single-lane city street with bicycle paths. As planned the capacity of this road was reduced and substantial parts of the traffic were moved to other arterials roads. To address this changed traffic pattern, it was necessary to increase capacity on the main ring road, Østre Alle. The ring road is in particular congested on the eastern part. Hence, B-a-U would within few years result in increasingly congestion problems. The arterial roads near the city centre appear in Figure 12.

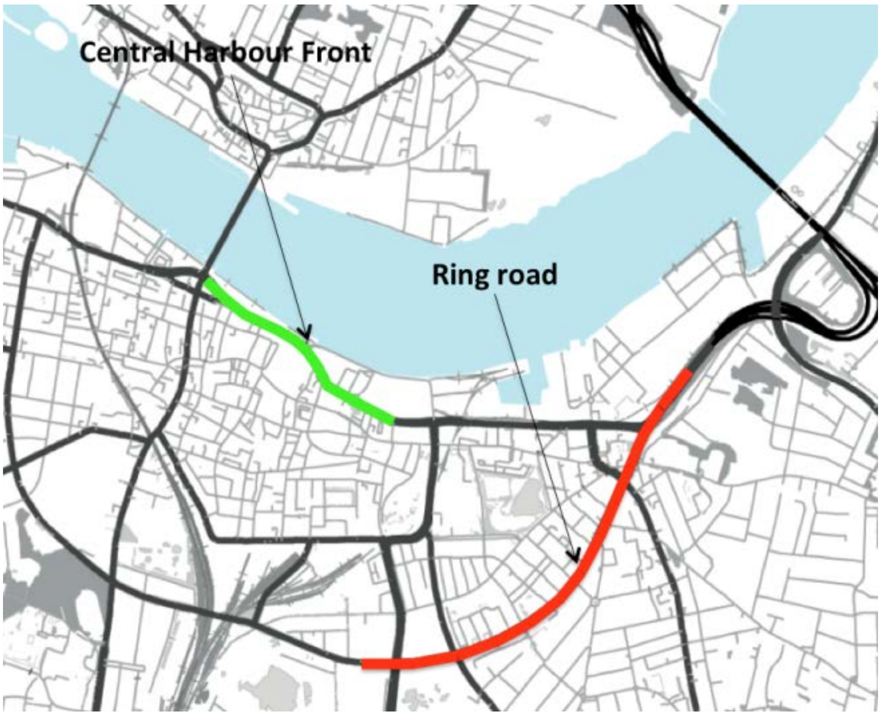


Figure 12: Map with the arterial roads in Aalborg. The traffic-calmed road on the Harbour Front and the most congested part of the ring road are highlighted.

C2 Measure results

C2.1 Transport

C2.1a Adaptive Traffic Signal Control System (SPOT system)

This subsection includes the two indicators 'Congestion Level in peak periods (23)' and 'Congestion level in off peak periods at daytime (24)'. As the effects in the Business-as-Usual scenario cannot be foreseen in quantitative units further considerations are not included in this section. However, it seems reasonable, that the 'without' results can be seen as a fair measurement of B-a-U level. An overall approach to B-a-U scenario is available in section C1.3.

Level	Before (without)	After (with)
23 Congestion – peak	6 – 13 Oct 2011	28 Feb – 21 Mar 2012[1]
24 Congestion – daytime off peak	6 – 13 Oct 2011	28 Feb – 21 Mar 2012

Table 1. Details on data collection congestion peak and off-peak areas (indicators 23 and 24)

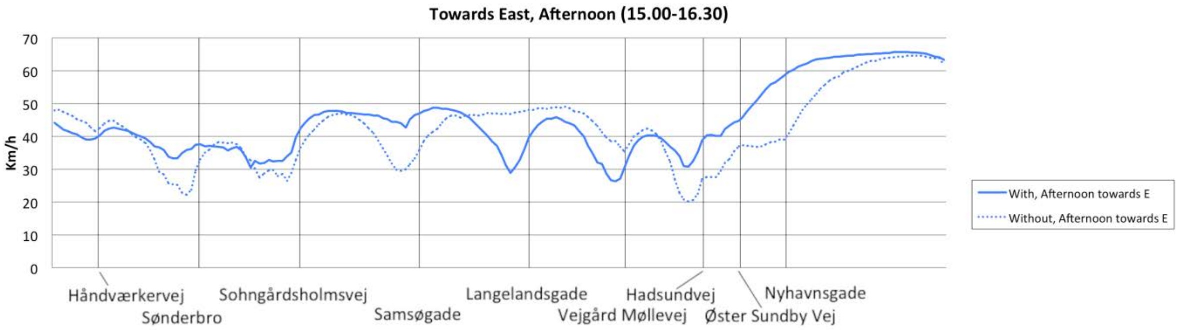
Data for the Congestion Level in peak periods (23) were collected 07.00-08.30 & 15.00-16.30 on Tuesday, Wednesday, and Thursday and the data for off peak (24) were collected 11.00-12.30 the same days. The collected data included among other information the position, the speed, and the driving direction. In total data include 249 trips (both directions) were loged with a 1 Hz GPS logger. The 'without' data formed the level of baseline: The baseline results appear in table C2.1.1.

Table C2.1.1: The congestion levels in peak periods with and without implementation of the new Adaptive Traffic Signal Control System.

Congestion Level peak (23)	Before (without)	B-a-U	After (with)	Difference: 'with/without'	Difference: 'With' – B-a-U
Transportation time	4.37 min	NA	4.11 min	-25 sec; -8.5%	NA
Speed variation	See below	NA	See below	See below	NA
Average transportation speed	28.5 km/h	NA	31.4 km/h	2.9 km/h	NA

The implementation of the Adaptive Traffic Signal Control System resulted in significant reduced transportation time on the section of the Ring Road in the peak periods. Transportation time went down with an average of 25 sec or 8.5% in the peak periods. This is mainly due to significant effect in the most congested period of the day, the afternoon peak period. The effect in the less congested morning peak period was smaller. Similarly the average transportation speed went up with 2.9 km/h from 28.5 km/h to 31.4 km/h. The speed variation differs significantly due to the Adaptive Traffic Signal Control System compared to the baseline level. In Figure 13 appear the speed variation through the entire section regarding the afternoon-peak period.

[1] The planned dates were February 28, March 1, 7. However, due to significant snow in the afternoon on Mar 7 this data collection was substituted with March 21.



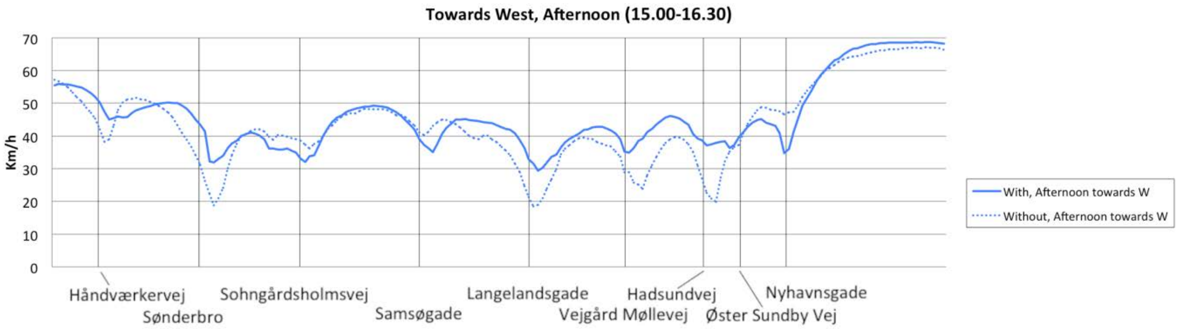


Figure 13: Speed profiles including the afternoon-peak-period. Above the speed profiles towards east, and below the speed profiles towards west.

The speed profiles show an increased minimum speed on most of the section. In most of the situations where the traffic was going at low speed due to congested intersections, the speed level increased significantly. A similar although less clear result appears for the morning peak periods. However, it indicates a reduced speed variation. It should be noted that a significant stop with a relatively long duration does not appear clear here as this way to measure the effect is distance-based. Hence, the average speed levels on these speed profiles cannot be compared directly with the average speed shown in the table above, since the speed profiles in the table includes the stop time over the whole distance.

Table C2.1.2: The congestion levels in off-peak periods with and without implementation of the new Adaptive Traffic Signal Control System.

Congestion Level off peak (24)	Before (without)	B-a-U	After (with)	Difference: 'with/without'	Difference: 'With' – B-a-U
Transportation time	3.48 min	NA	3.56 min	8 sec/4.3%	NA
Speed variation	See below	NA	See below	See below	NA
Average transportation speed	34.6 km/h	NA	33.4 km/h	-1.2 km/h	NA

The implementation of the Adaptive Traffic Signal Control System resulted in slightly increased transportation time on the section of the Ring Road in the off-peak period. Transportation time went up with 8 sec or 4.3%. It is equal to a reduction of 1.2 km/h from 34.6 to 33.4 km/h due to the implementation. The speed variation in off-peak periods differs significantly due to the Adaptive

Traffic Signal Control System compared to the baseline level. In Figure 14 appear the speed variation through the entire section in the off-peak periods.

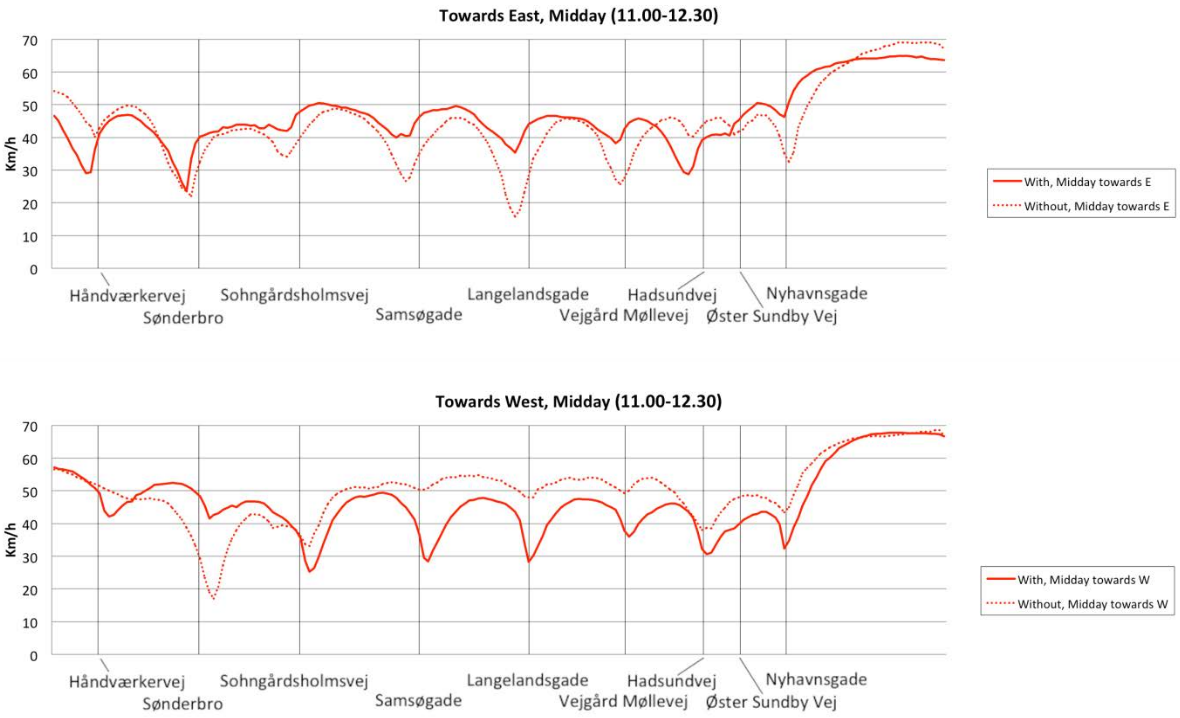


Figure 14: Speed profiles including the midday-off-peak-period. Above the speed profiles towards east, and below the speed profiles towards west.

The speed profiles show a blurring effect from the Adaptive Traffic Signal Control System regarding the off-peak period towards east. Towards west the speed is in general reduced apart from the Sønderbro intersection – the most congested intersection on the section. It is due to the fact, that the speed is significant higher without the Adaptive Traffic Signal Control System implemented. The latter results fit well with the fact that the Adaptive Traffic Signal Control System results in a transportation time, which only differ infinitesimal from the transportation time in the peak periods, while the transportation time without the Adaptive Traffic Signal Control System implemented was lower. The result also indicates that traditional time-based traffic control systems can give same results, when the congestion level is low.

As the last element, the effect on time consumption and fuel consumption is estimated for the section.

The estimated effect on fuel consumption is calculated on the basis of the 249 trips in the final and valid data collection, and includes all stops and low speeds. The overall effect on the fuel consumption is a reduction of 2.45% due to implementation of the Adaptive Traffic Signal Control System. Towards east the fuel consumption is reduced with 3.8% while it is 1.1% towards west. A smoother driving with less very low speeds mostly causes the reduced fuel consumption.

The Adaptive Traffic Signal Control System results in significant reduced costs to fuel consumption. The Annual Daily Traffic (ADT) is well over 20,000 cars, and the section equipped with the Adaptive Traffic Signal Control System has a length of 2.2 km (1.7 km equipped with the Adaptive Traffic Signal Control System and the approaching sections). This equals a daily distance driven of 44,000 km or approximately 16 Million km per year.

Despite the fact that an average Danish car drive some 14 km/litre overall it seems reasonable that the fuel consumption is higher on a heavy congested road sections in the city and 12 km/litre is a more realistic figure for the fuel consumption. Hence, with a 2.45% reduction in fuel consumption the Adaptive Traffic Signal Control System on Østre Alle will result in almost 33,000 litres reduced fuel consumption a year.

The Adaptive Traffic Signal Control System results also in significant reduced transportation time. With an ADT of 20,000 and with a reduction of 17.5 sec per trip the reduction in transportation time accumulates to 35,500 hours each year. This result is mainly due to reduced transportation time in the afternoon peak hour. The effects on fuel consumption and on transportation time appear in table 2.1.3.

Table C2.1.3: The effects from the Adaptive Traffic Signal Control System on fuel consumption (litres of fuel) and time consumption (hours of driving) per year.

Indicator	Before (without)	B-a-U	After (with)	Difference: 'with/without'	Difference: 'With' – B-a-U
21 Traffic level	1,338,000 litres	NA	1,305,000 litres	-33,000 litres	NA
21 Traffic level	537,400 hours	NA	501,900 hours	-35,500 hours	NA

C2.1b Congestion Monitoring System through data from TomTom navigation units

This subsection includes the two indicators 'Congestion Level in peak periods (23)' and 'Congestion level in off-peak periods at daytime (24)'. As the effects in the Business-as-Usual scenario cannot be foreseen in quantitative units further considerations are not included in this section. An overall approach to B-a-U scenario is available in section C1.3.

C2.1b.1 Congestion Levels

As described above, the GSP data gives the possibilities to analyse the traffic situation both on route level and on road segment level.

In this evaluation the analyses on route level are done on 10 different routes through and around the Aalborg City, covering the entire major road network. As the ten routes are analysed in both directions, the route analyses contain 20 different elements.

Figure 15shows the extension of the 10 routes.

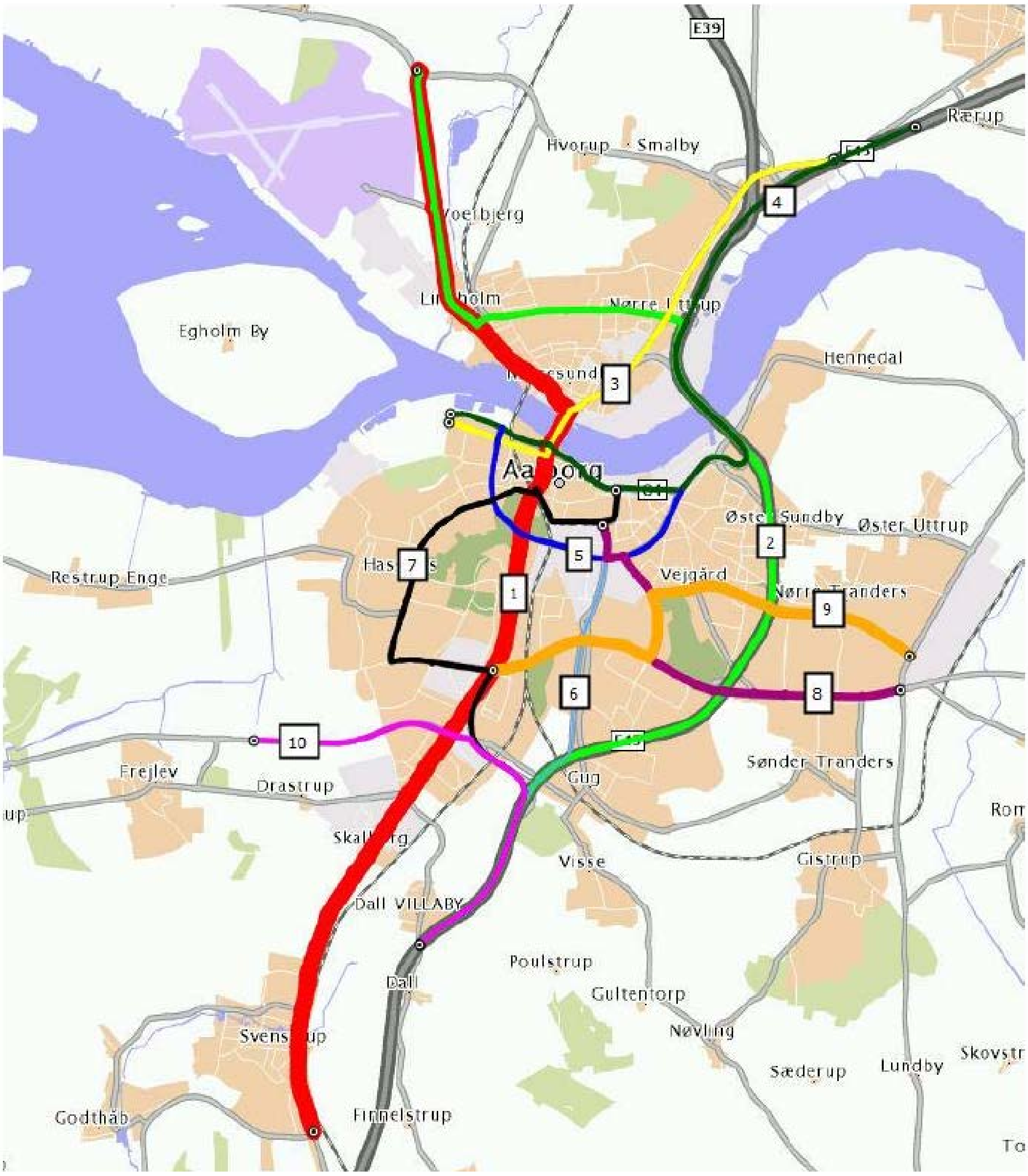


Figure 15: The ten analysed routes.

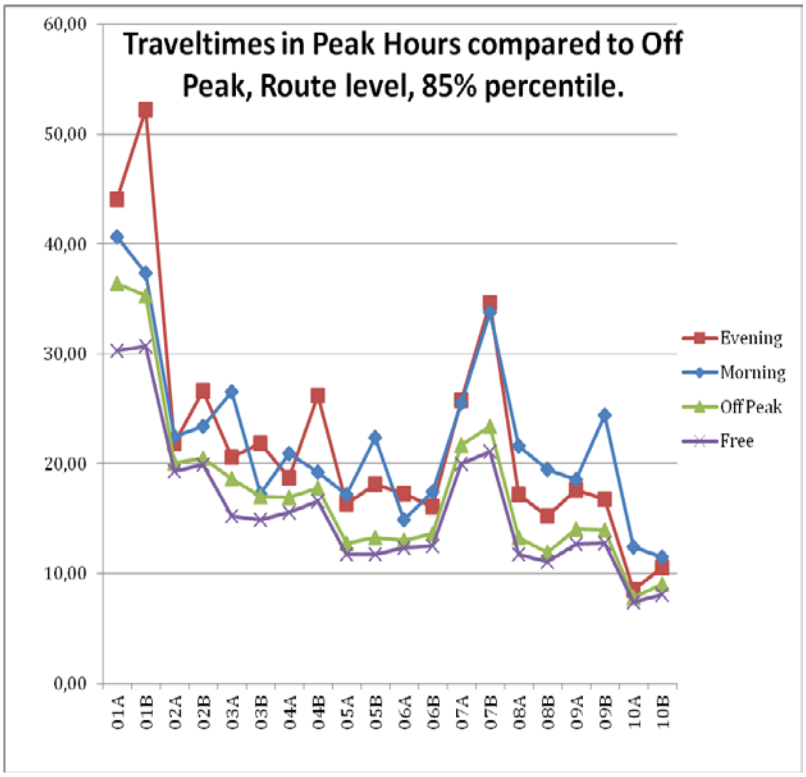


Figure 16: Travel times in Peak Hours compared to Off Peak, route level, full year.

Figure 16 shows, that the travel time on all routes is shorter in Off Peak hours than in Peak hours. On no part of the major road network is the traffic-accessibility unaffected by the peak hour traffic.

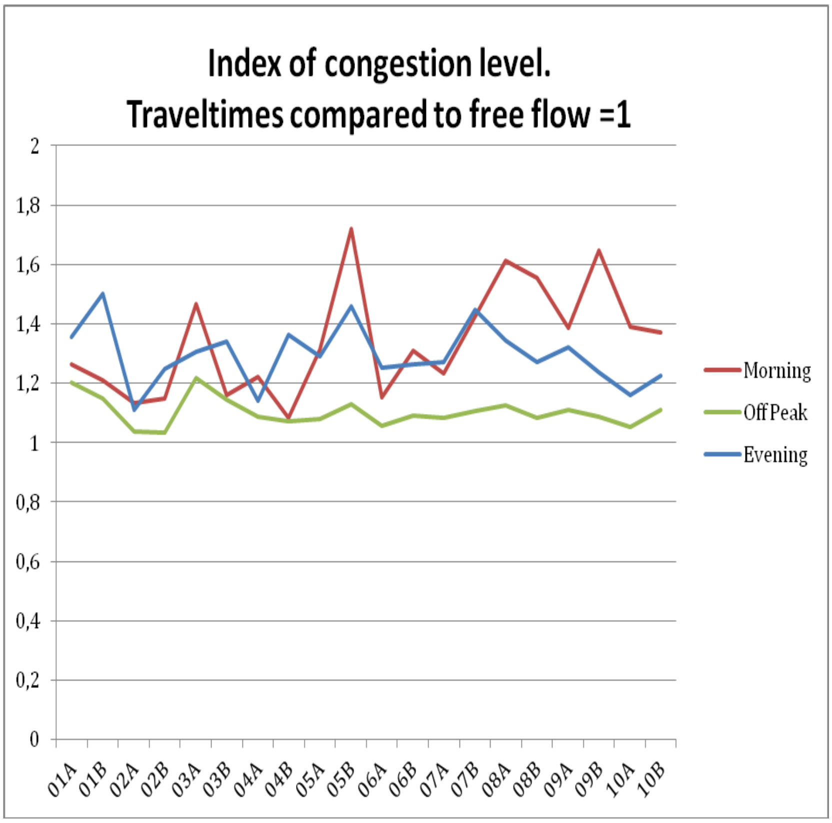


Figure 17 Congestion level.

The traffic on route level is differently affected, from one route in one direction, where the travel time is only 3% longer in the peak hour than in a free flow situation, to another route, where the travel time is more than 72% longer in peak hour than in a free flow situation. As a grand average over all routes and directions, and for the whole year, the commuters in Aalborg uses 34% more transport time in the morning peak hour, and 30% more in the evening peak hour due to the traffic density.

The roads less affected in % is the highway around Aalborg in direction North (2A), where as the inner ring road going Vest (5B), is road most affected by congestion – seen on complete route level.

These conclusions are only valid on route level. When the analyses is done on smaller parts of the road network, for example the inner city or only on roads going to or from the city, it shows, that locally the consequences of the congestion are much more significant.

Figure 18 show the road segment where the traffic in the peak hour flows with less than 50 % of the free flow speed, that is, where the transit time is double or more in peak hour.

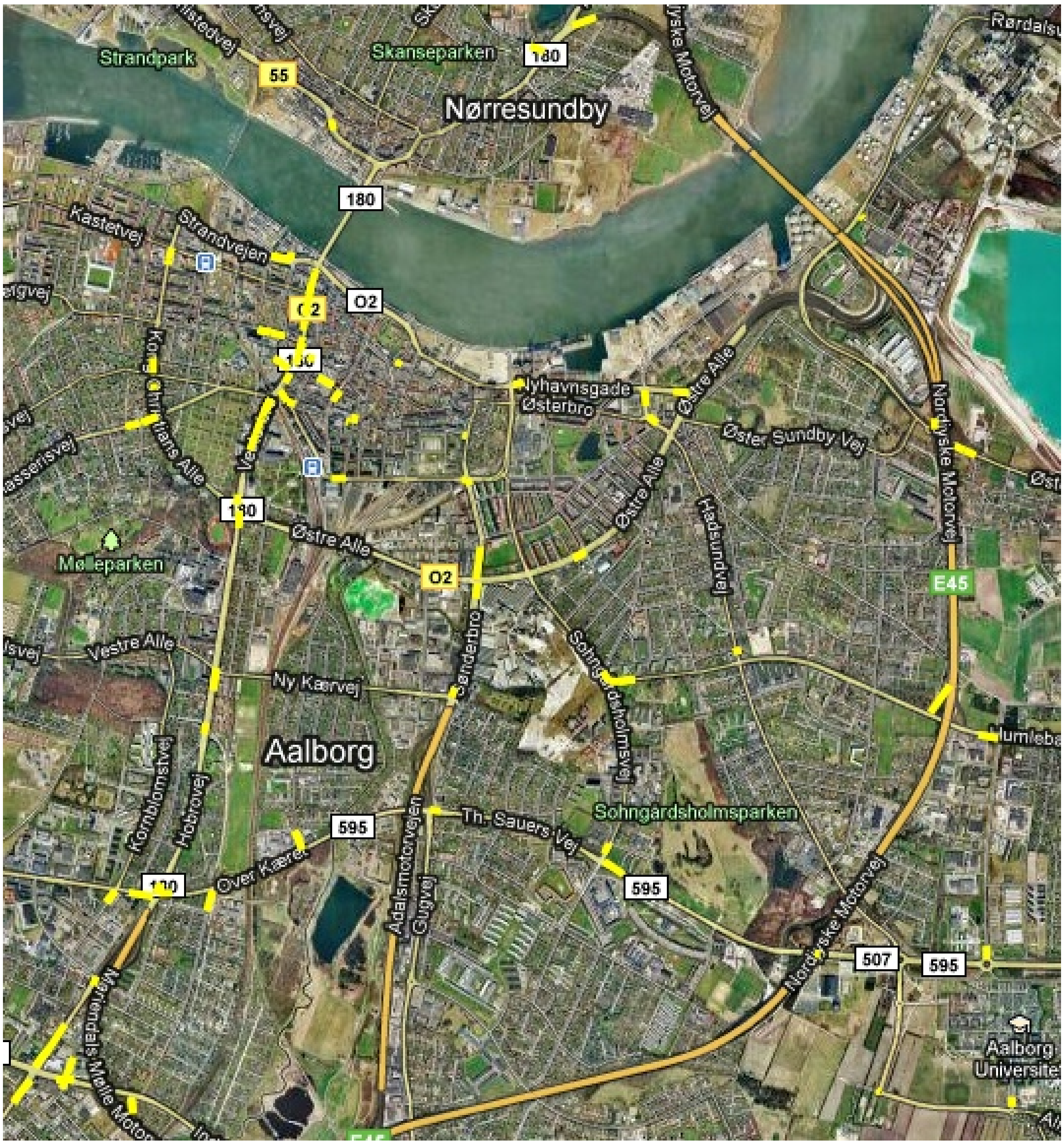


Figure 18. 50% bottlenecks. Analyse on all roads.

Another way to illustrate the difference between the 10 routes is to look at the averages speed on each route in the different times of day.

Figure 19 illustrates, that even if all routes is affected by time-of-day, the basic speed level is very different from route to route. The four elements with the highest speed level is of course two directions of two routes with a large part of the stretches on the highway, and the elements with the lowest averages speed level is the inner ring route.

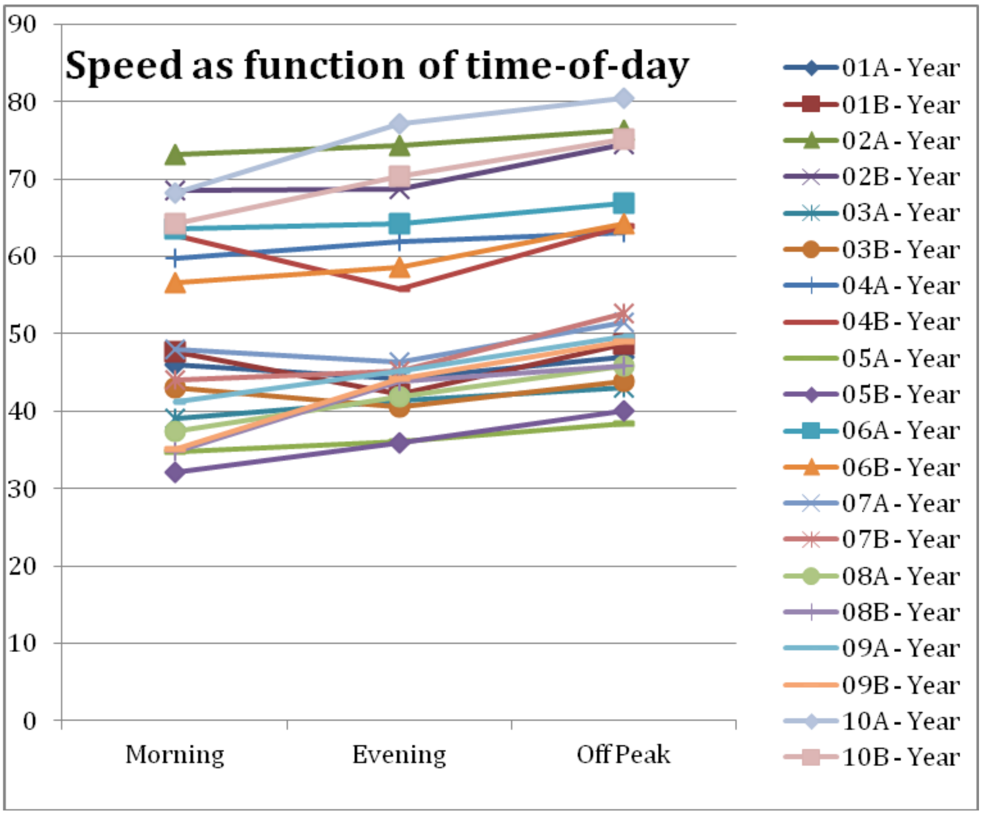


Figure 19 Speed on each route as function of time-of-day

The speed level and thus the accessibility vary over the year as a consequence of the state of the roads, and the composition and amount of travellers.

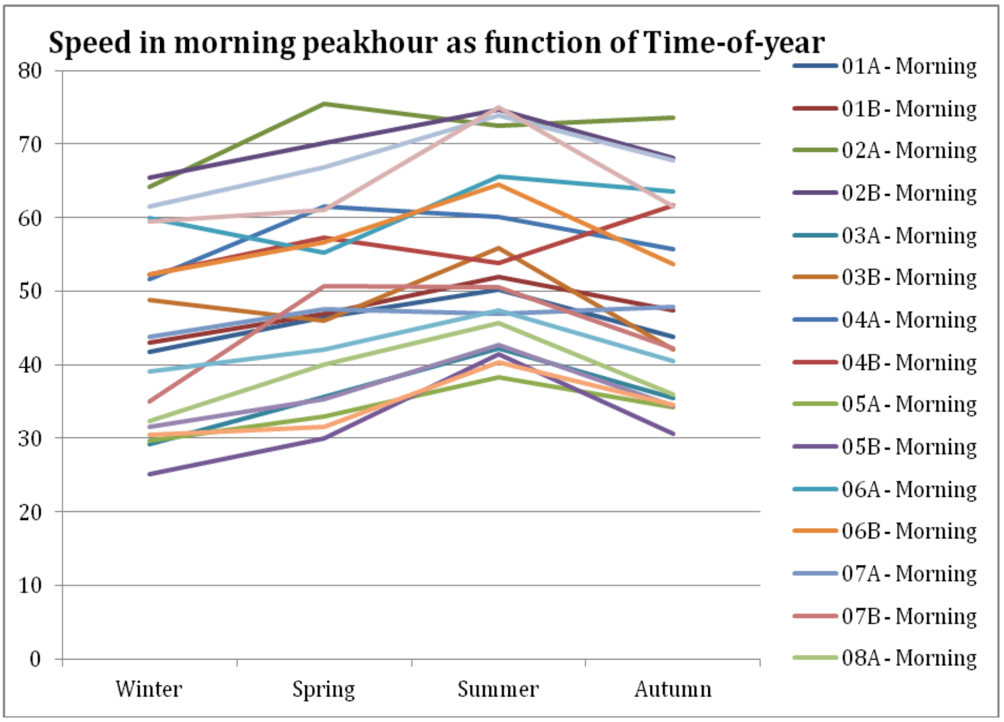
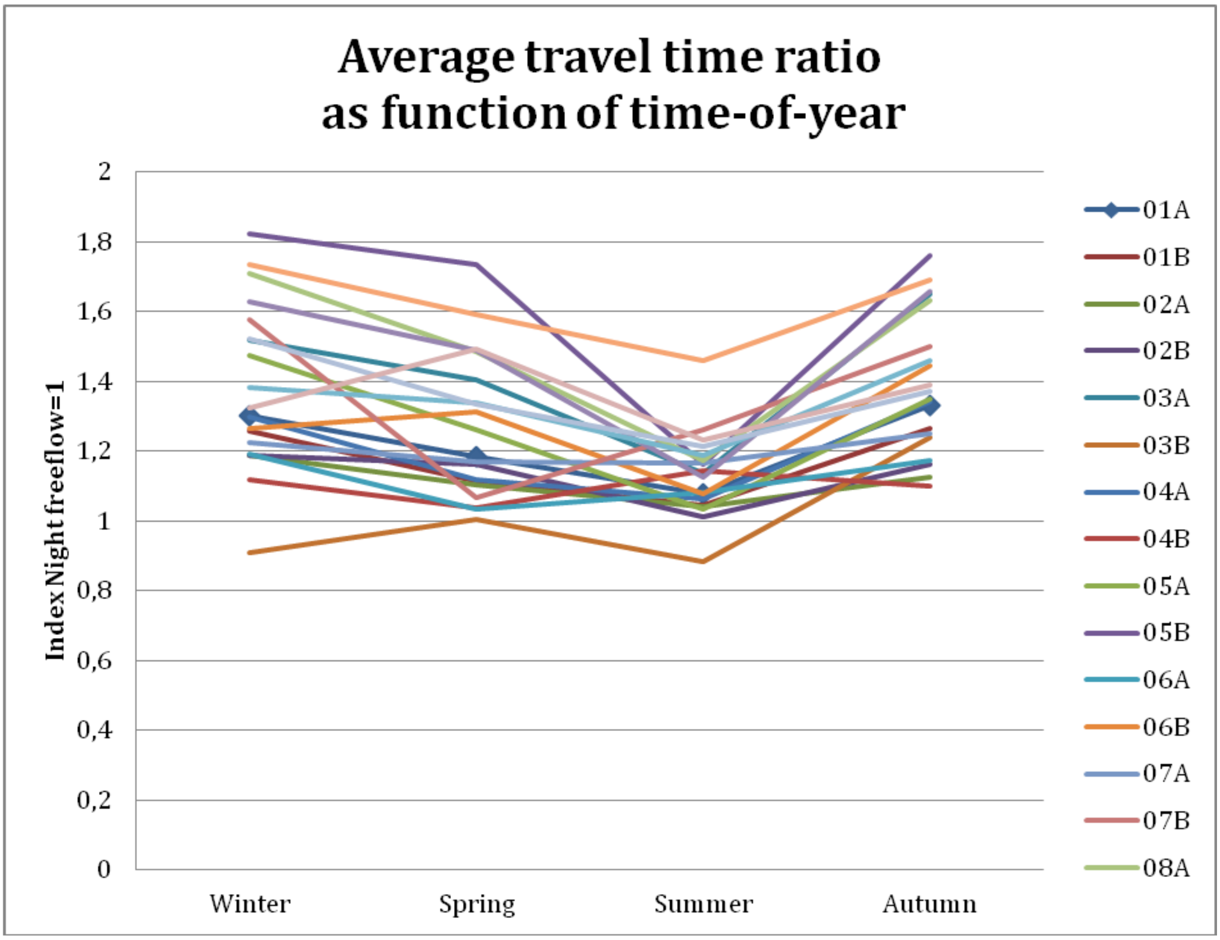


Figure 20 speedlevel as function of time-of-year

Figure 20 shows a medium speed level in the spring and autumn, lower speed and accessibility in the winter and higher in the summer. The spring / autumn level can be seen as the normal flow, where as the low speed in the winter is the result of the conditions of the road, and the higher speed in the summer on most of the roads is a consequence of fewer cars in the holiday time. On the highway (number 2 and 4), the speed level is lower in the summer holiday time, due to more traffic and primarily due to the holiday traffic having more time and not being so familiar with the roads.

Using the Average travel time ratio as an indicator Figur 21 shows the same relationship. The travel time ratio is high in winter because the bad weather affects the accessibility more in the peak hours than during free flow, and low in the summer because low traffic intensity has more effect on speed in the peak hour than in a free flow situation where the intensity always is low.

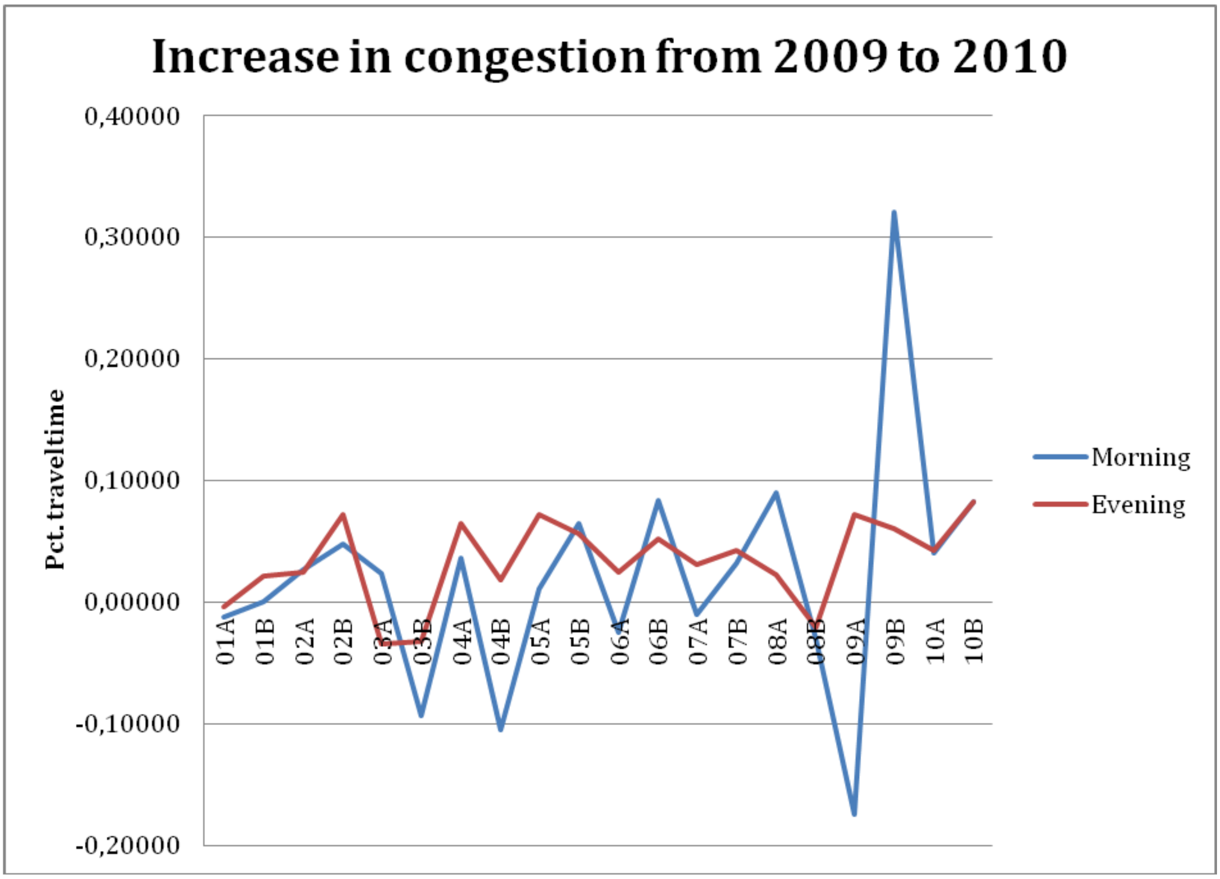


Figur 21 Average travel time ratio as function of Time-of-year. Morning Peak Hour

When data from 2010 is compared to data form 2009, a rise in congestion can be seen. In Figure 17 the increase in congestion from 2009 to 2010 (Whole Year-basis) is shown.

Users of most routes have experienced increased travel times. The travel time over the complete length of all routes have increased by 2% in the morning peak hours and by 3.3% in the evening peak hour.

Correcting the data for the two large fluctuations caused by road construction work in the two years, does not change the picture, as they are located with one in each year.



Figur 22 Increase in congestion from 2009 to 2010. Measured as pct. change in traveltime

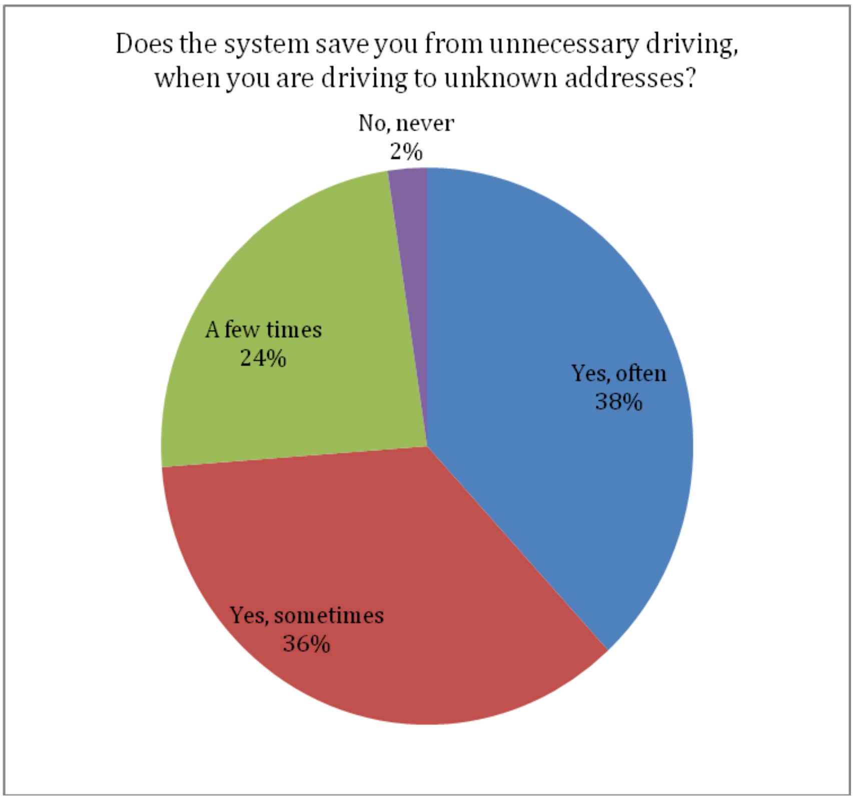
Route choice

To answer the question if the information from the navigation units made the drivers change behaviour, and thus save time, fuel and emissions, data from the taxi survey were used.

In section C2.2 it will be shown that the navigation units were used to a fair part of the trips, and that the main purpose was to locate unknown addresses, but that almost 1/4 of the drivers also use the system for finding a shorter route.

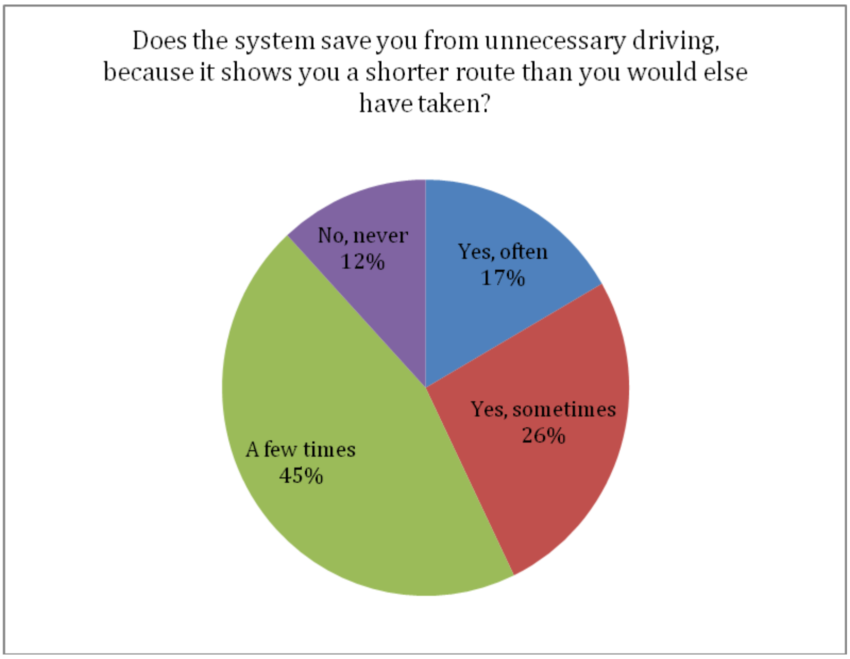
In this section we shall analyse, if the drivers themselves evaluate that the information from the systems saves them for unnecessary driving.

As Figure 12 shows 74% of the drivers state that the system more often than ‘a few times’, saves them from unnecessary driving when they are driving to an unknown address. Only one person states that he is always as capable in this respect, as the system. This high figure illustrates that there is a good potential for saving fuel and emissions.



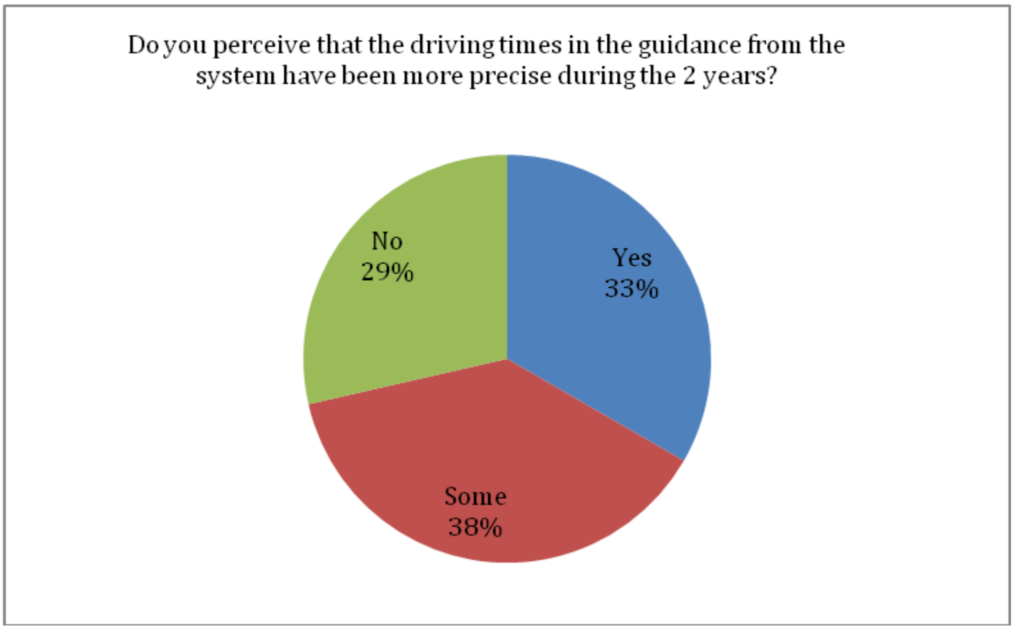
Figur 23 Does the system save you from unnecessary driving, when you are driving to unknown addresses?

When asked if the system saves him from unnecessary driving because it shows a shorter route that the driver would have chosen himself, 43% of the drivers states, that this is the case more often than ‘a few times’, and only 12% answers ‘Never’. And this 43% result shall be seen in the light of the information from section C2.2 that only 22% deliberately uses the system for finding the shortest route.



Figur 24 Does the system save you from unnecessary driving, because it shows you a shorter route than you would else have taken?

The quality of the guidance from the system improves over time, as the systems collect driving times and speed levels from the taxies, and from other cars with same equipment. The taxi drivers were asked if they had been able to register any improvement over the relatively short period, they have used the system.



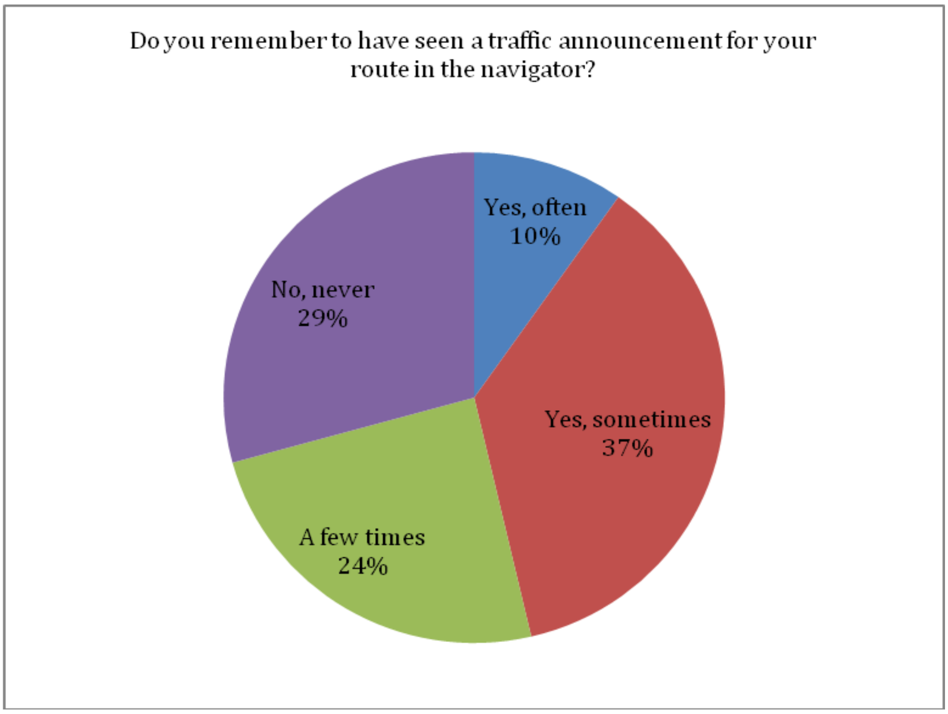
Figur 25 Do you perceive that the driving times in the guidance from the system have been more precise during the 2 years?

More than 70 % feels that the guidance has been more precise during the project period, and should thus be motivated for using the system.

The above questions have dealt with route guidance from the system, based on historical knowledge of travel times and congestion levels from the last 2-3 years – updated every 3 months.

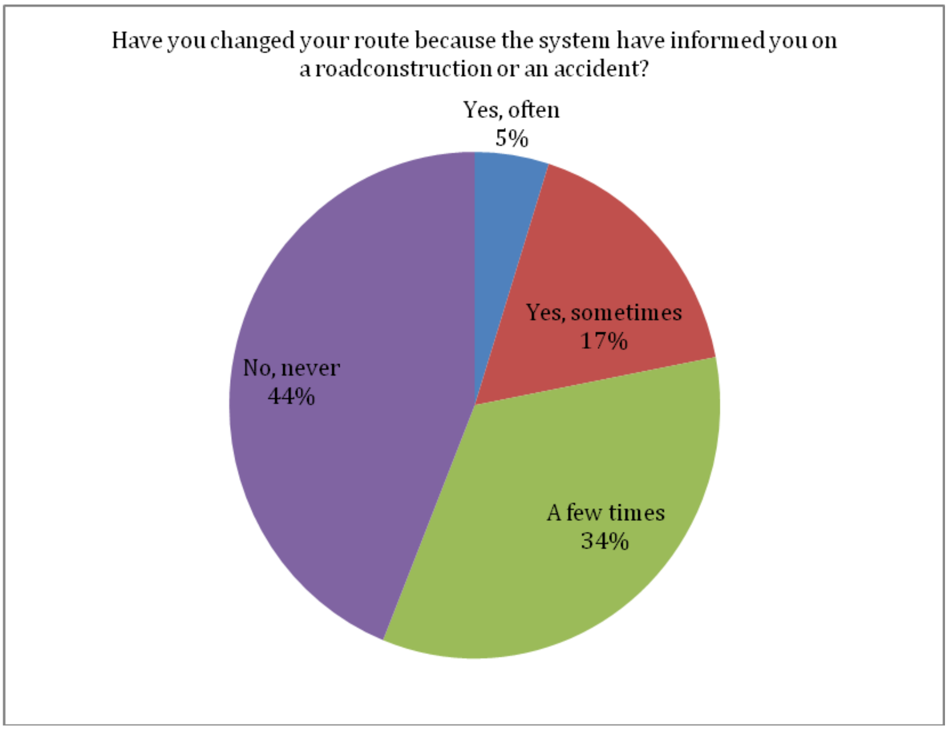
But the system is also able to inform of changed travel times and changed route guidance based on semi-real-time TMC data. That is, based on planned disturbances as road constructions and on larger disturbances in real-time as larger traffic accidents. But by using TMC data the system is not able to give information on congestion in smaller scale or to guide on changed route based on small incidents or on incidents on less important roads. If the demonstration were to start in 2012, this would be possible due to the technological evolution.

The taxi drivers have been asked, if they have observed the traffic announcements in the unit, and if they have changed route as a consequence of seeing such announcement.



Figur 26 Do you remember to have seen a traffic announcement for your route in the navigator?

70 % remembers to have seen an announcement. The rest must have seen announcements too, but have obvious not taken notice of the announcements. This is probably due to the fact that the announcements is only really clear – and will only change the route guidance – if the destination is keyed into the system, that is, only for 18% of the taxi trips. This weakens the possibility for guiding the driver and for optimising the trip when congestion or accidents occur.



Figur 27 Have you changed your route because the system have informed you on a road construction or an accident?

Never the less more than half of the drivers states, that they have changed route as a consequence of information given in the system. This figure is rather high, considered that the road structure in Aalborg, with the city divided by the Limfjord with only two crossing connections, has the consequence, that there is often no faster alternative route, if the traffic breaks down.

C2.2 Society

C2.2 Society

Data from the taxi survey was used to investigate the acceptance level.

As indicator for the acceptance level the two questions ‘Did the drivers use units? And did the drivers use the new information and how?’ were posed.

When trying to pass information on the car drivers via a navigation unit, the problem is that different types of drivers use the unit to different levels. If you are tourist in an unknown geography going to an unknown address, it is most likely that you will use the unit and give a great attention to it. In the opposite situation, when you are commuting to work, you are most unlikely to plan your route in the unit, unless it often happens that the unit can give you information on irregularities in the traffic.

The taxi drivers are somewhere in between these two extremes. Usually per definition they know the geography very well- even though they might not know the precise location of all addresses, and they do have a clear ‘congestion model’ in their head, by experience. A logical assumption would thus be, that the drivers would only be motivated to use the units actively on very few trips.

But the degree to which the drivers actively use the unit is crucial for the potentials for influencing their behaviour and thus save driving – fuel and emissions – by leading them of shorter routes, avoiding search driving with unknown addresses and leading around traffic jams.

The inquiry shows that on a grand total the units are used actively in no less than 18% of the trips and that 15% of the drivers uses the units actively on 50% of the trip or more !. On the other end of the scale only 13% uses the system on less than 5% of the trips.

For how many pct. of the trips do you use the system?

Averages		17,9%
0%	0	0,0%
1-24%	31	79,5%
25-49%	2	5,1%
50-74%	5	12,8%
75+ %	1	2,6%
tot	39	100,0%

Table 2: Average percentage of trips using the system (survey to taxi drivers)

The conclusion is that the system has been accepted to a better degree that could be expected under the existing circumstances.

But, are the young drivers and the more inexperienced drivers more motivated for using the system that the older, or more experienced drivers?

Relationship between Age and use of system.

21 – 29 years	0	-
30 – 59 years	31	18.6%
60 + years	11	15.8%
Tot	42	17.9%

Table 3 Age and use of system

Relationship between experience and use of system.

0-3 years	2	25.5 %
4-9 years	2	20.0 %
10 + years	37	17,.6 %
Tot	41	18,2%

Table 4 Experience and use of system

The figures shows, that both correlations exists, but is rather weak. At the same time, the distribution over the age and experience variable makes the computation of percentages rather questionable. While the 30-59 years old uses the system on 18.6 % of the trips, the 60+ years only uses the system 15.8% of the trips. The drivers having less than 4 years of experience uses the system 25,5 %, the drivers having 4 to 10 years experience uses the unit 20% but the drivers having over 10 years experience only uses the system on 17.5% of the trips.

And in which situation is the taxi drivers motivated for using the system?

Purpose for use of system

Mostly for unknown addresses	32	78,0%
Same amount	9	22,0%
Mostly for shortest route	0	0,0%
Tot	41	100,0%

Table 5: Purpose for use of the system

The table shows that according to the drivers own perception the system is almost only used for finding unknown addresses. Only 22% of the drivers also use the system for finding the shortest route.

C3 Achievement of quantifiable targets and objectives

No.	Target	Rating
1	To influence the car or taxi drivers' choice of route and travel time in order to reduce congestion during rush-hours.	**
2	To reduce congestion in peak periods will provide better conditions for public transport which thereby will be a more attractive transport mode.	***
NA = Not Assessed O = Not Achieved ★ = Substantially achieved (at least 50%) ★★ = Achieved in full ★★★ = Exceeded		

C4 Methods for up-scaling

Congestion Monitoring System

This measure can be up-scaled by extending the same principles to other cities having rising congestion problems. This measure is sat up to covers all arterial roads with congestion problems in Aalborg, so local up-scaling is not relevant.

Adaptive Traffic Signal Control System (SPOT system)

Up-scaling the results presented above to the entire city area seems not an appropriate way to go. It is due to the fact that even though an Adaptive Traffic Signal Control System can be implemented city wide on the arterial roads, it is uncertain which effect that can be expected on each section. Reasonably a more clear effect can be found on some sections while it will be less clear on other sections.

In addition, the implementation of the Adaptive Traffic Signal Control System is a real-time study to assess how efficient ITS can increase capacity in middle-size cities as Aalborg. The implementation therefore has a broader perspective than the congestion reducing effect on the ring road in Aalborg. The system, which monitors the Adaptive Traffic Signal Control System is scalable and more arterial roads in Aalborg can be added in the future.

C5 Appraisal of evaluation approach

The survey among drivers of 100 taxis has been answered by 42 of the drivers. The total numbers of drivers are estimated to around 150. If this estimate is correct, the response rate is 28%. This rate is not as high as could be preferred, but the numbers are sufficient to give reliable results, if the analyses are not dividing the respondents into to many subgroups.

On the age dimension, there were no respondents in the youngest age category 21-29 years. This is probably partly an indication of a relative high average age among the drivers. As a consequence investigating the ages influence on use of this new technological means, cannot be done as detailed as preferred.

Regarding the Adaptive Traffic Signal Control System it was found that the way to measure the effect was as it should be. However, the lessons learnt are that there might be allocated sufficient time and resources to ensure that both the physical equipment (loop detectors, wires etc.) are fully operational before a positive effect can be reached, but also, that sufficient time and resources are needed to optimise the Adaptive Traffic Signal Control System, after the physical installations are updated. On the other hand these prolonged update procedures and results of first evaluation have been used to ensure that sufficient effort was made to optimise the system. It appeared in this perspective that the additional costs of the second re-evaluation were suitable as it resulted in a better working Adaptive Traffic Signal Control System than else. Hence, no significant changes in the evaluation procedure can be suggested.

C6 Summary of evaluation results

Congestion Monitoring System

The main result regarding the Congestion Monitoring System was that:

- The project has established a congestion monitoring system, with two types of data. The one capable of giving congestion / speed level information on day-of-week level, in 5 min intervals, for all roads but aggregated over all days for 2-3 years. The other capable of giving congestion / speed level information on peak hours / off peak hours, accumulated for weekdays, for the 4 seasons in a specific calendar year.
- The data shows the expected outcome. Congestion is highest towards the city in the morning and in the opposite direction in the evening. The congestion level is different on the different road- types and locations; Bottlenecks exits a number of places in the road network etc. But the monitoring system shows exactly where the problems are, how much the congestion is on each road segment in what point-of-time.
- As a grand average over all routes and directions, and for the whole year, the commuters in Aalborg uses 34% more transport time in the morning peak hour, and 30% more in the evening peak hour due to the traffic density.
- On no part of the major road network is the traffic-accessibility unaffected by the peak hour traffic.
- The roads less affected in % is the highway around Aalborg in direction North (2A), where as the inner ring road going Vest (5B), is the road most affected by congestion.
- The speed level is at a medium in the spring and autumn, but the speed level and accessibility is lower in the winter and higher in the summer. The low speed in the winter is the result of the state of the road, and the higher speed in the summer on most of the roads is a consequence of fewer cars in the holiday time. On the highway, the speed level is lower in the summer holiday time, due to more traffic and primarily due to the holiday traffic having more time and not being so familiar with the roads.
- When data from 2010 is compared to data form 2009, a rise in congestion can be seen. The travel time over the complete length of all routes have increased by 2% in the morning peak hours and by 3.3% in the evening peak hour.
- 74% of the taxi drivers state that the system more often than ‘a few times’, saves them from unnecessary driving when they are driving to an unknown address.
- 43% of the drivers states the system saves him from unnecessary driving because it shows a shorter route that the driver would have chosen him selves more often than ‘a few times’,
- More than half of the drivers states, that they have changed route as a consequence of disturbance information given in the system.

Adaptive Traffic Signal Control System

The main results regarding the Adaptive Traffic Signal Control System were:

- Transportation time decreased in average with 25 seconds (8.5%) per trip in the peak periods. It is mainly due to a significant effect in the most congested period of the day, the afternoon peak. No positive effects were found regarding the off-peak results.
- When the variation in traffic flows is taken into account, the total reduction in transportation time equals to 35,500 hours per year based on the 20.000 cars per day on the section of the ring road.
- The change in speed results in most cases in increase of the low speeds, i.e. fewer and shorter decelerations in front of the intersections.
- Due to smoother driving pattern has the estimated fuel consumption decreased with 2.45%, or equal to a 33,000 litres reduction per year on the section of the ring road.

C7 Future activities relating to the measure

TomTom data has shown reliable and very precise results. It is, however historical data and the future will be real-time dynamic traffic information. It does not mean that the TomTom data will be of no use. They will be a necessary basis for the future real-time traffic information from other sources, because a basis level is useful to provide data regarding traffic flows were no real-time data are collected and to monitor if the real-time traffic information data are reliable. Hence this basis is required to ensure that any extreme (and unreliable) data not will be used and result in erroneous traffic information. At the time of writing the City of Aalborg is testing number plate recognition and bluetooth devices as data source for real time traffic information. Although promising test results they are still under development and are only cowering the central arterial roads. Hence the more detailed data from TomTom are still required to get the full pattern of traffic flows on the arterial roads.

The Adaptive Traffic Signal Control System has shown positive effects on the congestion level. It is especially in the most congested peak period – the afternoon peak period. This points towards a system, which will be more beneficial for the road users and the City of Aalborg if the congestion level continue to increase in the future. Hence, at the moment it is considered to up-scale the system to include other parts of the most congested arterial roads in Aalborg.

D Process Evaluation Findings

D0 Measure / focussed measure

The measure is not selected as a focussed measure.

D1 Deviations from the original plan

In the DoW data collection from, and information into, 10 cars were foreseen. During the planning phase this approach was refined to data collection from and information to all cars with TomTom units, supplemented with the installation of 100 extra units in taxis. This different approach was not due to delays or unexpected challenges. It was a changed approach due to the fast-running development in this area, which made the first proposed solution obsolete. The selected solution was of much higher quality and reliability than the planned one.

Regarding the Adaptive Traffic Signal Control System, a delay appeared. The implementation of the system was initiated in the autumn 2010 and was planned to be finished in November 2010. However, due to an extra-ordinary severe winter in 2010 and partly 2011 the implementation was delayed. Also, meanwhile a significant additional traffic flow was added from the Synergivej intersection in the spring 2011, which required additional work with the Adaptive Traffic Signal Control System. Therefore, the last parts off the implementation were carried out in the first half of 2011. During this process, it became clear that subsequent careful monitoring and calibrating of the Adaptive Traffic Signal Control System was required and very time-consuming. This calibrating procedure went on while the system was running until the end of 2011.

So the main reasons for the delay were:

- **Deviation 1: Bad weather conditions.** An extraordinary cold winter caused significant delays in the work with loops, wires etc. during the installation.
- **Deviation 2: Change land use.** Changed land use and, hence, significantly changed traffic flow from a side road, resulted in significantly increased work with the Adaptive Traffic Signal Control System. The time schedule for the last signal in the Adaptive Traffic Signal Control System had to wait for the time schedule for rebuilding the changed road structure.
- **Deviation 3: Extensive time use for repair and calibration.** Unexpected time-consuming updating of the equipment and the subsequent adjustment of first the physical equipment and then the calibrating of the Adaptive Traffic Signal Control System.

D2 Barriers, drivers and activities

D2.1. Barriers

Planning Phase:

Spatial: a barrier delaying the implementation of the Adaptive Traffic Signal Control System has been the changed land use of a rather big industrial area along the ring road, from industrial to tertiary uses (shops and offices buildings). A new connecting road infrastructure had to be developed, with a new intersection being placed in the middle of road network controlled by the new Adaptive Traffic Signal Control System. As the traffic optimisation is network based, the optimisation for the rest of the network could not be calibrated before all part were completely implemented and up and running.

Implementation & Operation phase:

No specific barriers experienced.

D2.2. DRIVERS

Planning Phase:

Political / strategic / positional : As the numbers of cars are growing in Aalborg and the congestion is rising, as in all other comparable cities, there are increased political and administrative focus on congestion data as an input to local and national planning. In Aalborg especially the two infrastructure bottlenecks, the tunnel and the bridge over the fiord, together with the debate in advance of the decision on new motorway link over the fiord actualise this focus.

Political / Financial: Aalborg' deliberate position as a green and sustainable city urges the work with cleaner mobility, and makes it possible to invest the required resources in the congestion system and the Adaptive Traffic Signal Control System.

Political / Spatial: The waterfront is changing status from an old industrial harbour to a new green leisure and culture area. To link the city centre with this new area a 4 lane road dividing the two has been reduced to a 2 lane road and the traffic has been transferred to the inner ring road. To secure the traffic flow on the ring road, it was necessary to increase the capacity. Via the ARCHIMEDES Adaptive Traffic Signal Control System it has been possible to increase the capacity by improving the flow without expanding the road infrastructure.

Implementation

No specific barriers experienced.

Operation phase:

Technological: By implementing the Adaptive Traffic Signal Control System it has been possible both to achieve a network optimisation of the inner ring road, and also to get a network surveillance system for all intersection in the city and thereby better possibilities for interfering.

D.2.3. Activities

No specific activities undertaken.

D3 Participation

D.3.1 Measure partners

City of Aalborg, City, Leading role. As the leading ARCHIMEDES partner in Aalborg, The City of Aalborg has been responsible for the planning and implementation of the two initiatives in this measure. The City is the measure partner having the direct interest in the successful implementation of the two initiatives. The City has the role as project manager for both initiatives.

Cowi, Simon Bojer, consultancy, Principle participant. The consultant Simon Bojer, with speciality in analyses of Floating Car Data, from the Consultancy, Cowi, was temporary hired to develop the congestion monitoring system based on the TomTom data.

Aalborg University, Knowledge institution, Principle participant. Two associate professors from two different departments produced the Task 11.8.1. deliverable 'R70.1 Study of next generation navigation systems'. One of them, Niels Agerholm, was hired to do the data collection and evaluation of the Adaptive Traffic Signal Control System.

Aalborg Taxa, Private company, Principle participant. A cooperation with the taxi organisation has been established wherein 100 navigational units in the taxies is collecting Floating Car Data. The taxi organisation is responsible for the contracts on use of the navigation units with the taxi entrepreneurs, and was involved in collecting evaluation data.

D.3.2 Stakeholders

Danish Road Directorate, Public Authority, Occasional participant. Information to the drivers on passability and congestion level with the purpose to influence the drivers choice of route and departure time is communicated to the drivers on the regional part of the national traffic information site, www.trafikken.dk/Nordjyland (ARCHIMEDES measure no 9.). The information site is a cooperation between the city of Aalborg and the Danish Road Directorate (DRD). The positive participation from DRD has thus been a prerequisite for this solution.

Several suppliers. Both initiatives involve new untried technical solution. The positive participation from more innovative suppliers has helped to reach success on both initiatives.

D4 Recommendations

Recommendations regarding Congestion Monitoring System through data from TomTom results in the following recommendation regarding measure replication:D.4.1a Recommendations: measure replication

- Information regarding traffic flows is a fast-developing area. The future will be with real-time dynamic traffic information, which is not provided with the data used in ARCHIMEDES. Within the next years, however, even with dynamic real-time traffic information there will be a need for a basis for the future real-time traffic information from other sources. It is because a basis level is useful to provide data regarding traffic flows were no real-time data are collected and to monitor if the real-time traffic information data are reliable.

Recommendations regarding the Adaptive Traffic Signal Control System:

D.4.1b Recommendations: measure replication

- The Adaptive Traffic Signal Control System has shown significant positive effect on the traffic flows where implemented. It can be recommended to other mid-size cities with congestion problems on the arterial roads.

D.4.2b Recommendations: process

- **Recommendation 1 –** There must be allocated sufficient time and resources to ensure that the physical equipments (loop detectors, wires etc.) are fully operational before a positive effect can be reached.
- **Recommendation 2 –** There must be sufficient time and resources to optimise the Adaptive Traffic Signal Control System.
- **Recommendation 3 –** The evaluation procedure might preferably be integrated within the optimisation procedure and hence contribute to an iterative procedure between the optimisation and the evaluation procedures, so a higher level of optimisation can be reached.

Measure title: **Congestion Monitoring Using Telematics in Aalborg**

City: **Aalborg** *Project:* **ARCHIMEDES** *Measure number:* **70**

E Summary time schedule

		YEAR 1												YEAR 2												YEAR 3												YEAR 4											
Task No.	**Task name**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
8.3	Congestion monitoring and countercting using telematics												E1						P								X				E2												E3						
11.8.1	Next generation navigation systems						P						E1		X																E2												E3						
Evaluation tasks																																																	
Congestion Levels																																																	
Congestion Levels																																																	
User attitudes																																																	
Route choices																																																	
Process evaluation report																				X													X											X					
Deliverables																																																	
M12.1 Draft MLEP										X																																							
D12.1 Final MLEP														X																																			
D12.2 Baseline and first results																																									Z								
D12.3 Draft results Temp																																																	X
D12.4 Final result temp																																																	X