Green and ITS

An overview of innovations for a sustainable transport system in Stockholm
Readers guide

The purpose of this book is to give visitors to Stockholm a brief, yet comprehensive, introduction to the wide range of activities that are taking place in Stockholm to make it the leading city in the strive towards a greening of transport. It has not been possible to include presentations of all valuable and interesting activities – this would have made the book too long. Instead we have tried to create a blend of articles that are representative of the breadth of initiatives - big and small, technology and policy - that together shape the future transport system of Stockholm.

The focus of the book is on how ITS - Intelligent Transport Systems - can contribute to greener transport in the future where Stockholm is, or deserves to be, world renowned for many of its ITS applications: congestion charging, ECO-ISA, etc. Nevertheless, ITS must be seen in the context of other policy measures with the same objective, i.e. to reduce the environmental impact from transport and the development of a true sustainable transport system. For this reason, we have also decided to include articles on the replacement of fossil fuels with bio-fuels and electricity. In addition to hosting the ITS World Congress in September 2009, the City of Stockholm will be the Environmental Capital of Europe in the Spring 2010.

In addition to the introduction that has been written by the Vice Mayor of Stockholm and a concluding statement from the VINNOVA (The Swedish Govermental Agency for Innovation Systems), the book is divided into five main sections. The key elements of these are:

- A policy section, describing the importance of collaboration
between regional stakeholders and how actors such as Stockholm Arlanda Airport, respond to the policies that have been set.

- A traveller information section, describing innovative applications and the use of data from many sources to enable travellers to make good and environmentally friendly transport decisions.
- A traffic management section, describing measures applied to reduce and smoothen the flow of road traffic.
- A section on Eco-technology, mainly describing the high ambitions and actions of Stockholm stakeholders with regard to the replacement of fossil fuels with more sustainable energy sources for their vehicle fleets.
- Finally, a short section on city logistics with examples of efficient planning and collaboration schemes to improve transport efficiency and bring about significant reductions in vehicle emissions.

The grouping of articles included in this anthology is quite arbitrary, many contributions fit equally well in two or more of the sections. Given the level of collaboration in many projects the reader may also notice that there is something of an information overlap. We from the editorial team have purposely allowed this overlap to remain, thus ensuring that each article can be read individually with the full background.

The book is the result of contributions from a lot of people and organisations devoted to the development of a greener transport system for Stockholm and Sweden. The authors are responsible for the contents of the articles they have written. In some cases the articles have also been adjusted in liaison with members of the editorial team. A list of contributing organisations is provided at the end of this book. From the editorial team we give you all our deepest thanks for your hard work!

The production of this book has been financed by generous contributions from VINNOVA (The Swedish Governmental Agency for innovation Systems), ITS Sweden and Sweco as an expression of their support to a Stockholm ITS World Congress with a green profile.

We welcome you to Stockholm and hope that you will find great interest in our achievements towards a general greening of transport and particularly in our development and use of ITS.

Stockholm, September 2009

The editorial team
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The City of Stockholm is the host city for the ITS World Congress in September 2009. For our guests this event represents an excellent opportunity to experience our beautiful city and discover some of our achievements within the ITS field. The City of Stockholm is continually working with the challenges of running a growing city and the ITS World Congress represents an important driving force that makes it possible for us to speed up current and future initiatives within ITS and related areas.

Other driving forces are the environmental and climate issues. Being selected as the European Green Capital 2010, we are keen to stay at the forefront by making further environmental improvements.

Stockholm is a great city in which to live and work, but as Stockholm is growing so rapidly, we are facing important challenges with regard to our transport system and the environment. Key areas of work at present include fighting congestion, increasing safety and
Internet and mobile travel information services. A new type of Intelligent Speed Adaptation (ISA) has also been introduced within our own vehicle fleet. By combining support for green-driving with the ISA-concept, we aim to reduce CO₂ emissions while at the same time saving lives.

In order to facilitate daily life for people travelling in the region, a key goal for Stockholm, we have established “The Stockholm ITS initiative”. This close collaboration consists of the City of Stockholm, the Swedish Road Administration, the Swedish Rail Authority, Stockholm Public Transport and Swedish Transport Agency. Together we will use the ITS World Congress 2009 as a driving force for implementing Intelligent Transport solutions throughout the Stockholm region.

Welcome to Stockholm – the Green Capital of Europe!

reducing climate impact. While the infrastructure is undergoing new development, we must encourage a more efficient usage of the transport system.

This is an area where ITS plays an very important role. ITS must be used together with physical and political measures to help resolve traffic and transport problems. Our standpoint is that congestion problems and the climate issue in larger cities cannot be solved without ITS.

In some areas we are already in the forefront. The Stockholm congestion charging scheme has reduced traffic in the city centre by 20 percent. Stockholm also has one of the world’s largest shares of green cars. At present 38 percent of all new cars are green.

With a target fleet of 100 per cent clean cars by 2010 for the City of Stockholm, and a vision of a city centre where only clean and silent electric cars travel the streets, Stockholm is leading the way towards a green and carbon-free society.

At the moment we are working hard to improve our Traffic Management Centre and the ability to handle traffic disturbances. We are also developing new and useful
The greening of transport is a broadly agreed global, European, national and regional policy goal, and ITS has been identified as an important tool in the realisation of this goal. This section describes transport policy issues in the Stockholm region and the role assigned to ITS by key stakeholders. A key element is how regional collaboration has been organised in order to gain an optimal effect from investments. This collaboration has evolved into what is now known as “The Stockholm ITS Initiative”.

The reader will also find examples on how knowledge, experience and general awareness of ITS - all an important prerequisites for deployment - have been disseminated to a wider audience and how high-level environmental policy requirements have been usefully explicated into a package of measures by the largest airport in Sweden, Stockholm Arlanda.
ITS has been an important component of the Stockholm traffic and transport system for a long time. It began as early as the 1930’s with the introduction of traffic signals. At that time the term “ITS” (Intelligent Transport Systems) had not yet been introduced. “Modern” ITS operations in Stockholm started in the early 1990’s in conjunction with the discussions surrounding the so-called “Dennis-package”. This proposed expansion of the infrastructure emphasized the importance of traffic routing. ITS is now an important, multi-faceted tool that can be used by stakeholders within the traffic sector to achieve political goals related to transport, but also to meet the needs and desires of all people when it comes to travel and transport.

For some time, there has been co-operation in the Stockholm region to further the development of the infrastructure. Many of these efforts include ITS solutions. The fact that Stockholm is the host city for the ITS World Congress in 2009 has helped provide some leverage for ITS-related efforts. It has also resulted in more in-depth co-operation between key organisations with regard to ITS. The following organizations are involved in this collaboration:

- The City of Stockholm
- Swedish Road Administration
- Stockholm Public Transport AB (StorStockholms Lokaltrafik AB – SL)
- Swedish Rail Administration
- Swedish Transport Agency – a new agency responsible for the congestion charging system, among other things.

These intensified co-operative efforts have formed 'The Stockholm ITS Initiative'. A demonstration of strength leading up to the ITS World Congress was one of the key starting points for this work.

A FOCUS ON CO-OPERATION
Each of the partner organisations listed above use ITS in their daily operations. The focus of the Stockholm Initiative is however on projects and activities that involve many of the partners. One point that should be clarified is that the activities undertaken are intended to benefit the citizens of Stockholm, rather than being spectacular one-
time investments for the benefit of the World Congress. From this perspective, it makes sense to focus on the ITS projects currently being run by various partners as a starting point. It is then possible to develop these important projects further, using the World Congress as an important milestone in the development process. This is how the World Congress helps provide leverage to ITS efforts in the region.

GROWING PAINS AND CAPACITY PROBLEMS
Currently, the Stockholm region has a population of approximately 2 million. The region is highly attractive and it continues to be a magnet for people and businesses. The forecast for 2030 implies that there will be approximately 500,000 more inhabitants.

However, the infrastructure has not developed at the same pace as the growth in population. There are significant capacity problems throughout the entire traffic and transport system. The system is characterized by long vehicle queues to and from Stockholm city during peak morning and afternoon hours and crowded metro and commuter trains. In addition, the transport system is quite vulnerable. One of the reasons for this is that the region consists of several islands with only a limited number of connections between north and south. Accidents and incidents on any one of the bridges can cause traffic chaos. A number of severe accidents have occurred in recent years illustrating its vulnerability. The lack of traffic network capacity causes many delays, especially for commuters. On average the delays represent a working week for a commuter every year. The socio-economic cost of these delays has been estimated to approximately 700 million euro.

For decades, the issue of expanding the infrastructure has been investigated and resolved in different ways. Currently, there are two large infrastructure expansion projects underway – the Northern Link Road (sw. ‘Norra Länken’) and the City Railway (sw. ‘Citybanan’). It is also important to note that infrastructure expansion within the region includes, amongst other things, new housing construction, and the development of services.

These ongoing infrastructure investments are regarded as highly positive. At the same time, it is known that they will not solve all of the traffic-related problems: bottlenecks will still remain and the new infrastructure may generate more traffic and cause
environmental problems. The need for infrastructure development while taking into consideration environmental impact represents a delicate balancing act. This is one area where ITS has much to offer. It would, for example, be unthinkable to build a new infrastructure without the use of integrated ITS solutions such as traffic control systems and real-time travel information. The congestion charging system is also significant in this context; not only does it provide a means to control traffic, the revenue that is generated is used to increase transport system efficiency.

During long periods of time, many parts of the Stockholm region’s transport system will be under construction and there will be a significant impact on traffic and other forms of transport. It is also likely to take some time before new transport system capacity is available. ITS will be needed to a greater extent in order to assist road-users during their daily travel. It is a matter of co-ordinating information as well as using ITS to control traffic in a flexible manner. ITS is viewed as an indispensable tool that can be used to facilitate travel during periods of major construction. At the same time, ITS is also a necessary component of a modern transport system.

Last but not least, it is clearly not the responsibility of any individual stakeholder to develop the region’s transport system single-handedly. It is important...
to avoid solutions that may only apply to one sector. Efforts must involve finding overall solutions that consider many sectors. In other words, it is important to work together and co-operate with other organizations in order to ensure a functioning transport system in the short and long-term.

FAR-REACHING AMBITIONS WITH CO-OPERATION

Co-operation through the Stockholm Initiative involves forming a vision in order to facilitate a continued collaboration after 2009.

The visionary goals, based on the use of ITS, are to:

- Support road-users so that they can make smart travel choices
- Contribute to a more efficiently utilized transport system that is also climate conscious

Co-operation suggests work on a strategic as well as on an operational level. The vision has evolved as a guideline from which goals, an action plan and joint projects can be derived. The initiative covers two perspectives:

1) Systems – efficient traffic management, and
2) Individual/client – support to travellers (particularly drivers). The co-operation includes technical systems, information handling and organisation.
POLICY STATEMENT
At an early phase in the co-operation, the Stockholm Initiative came up with a policy statement and a framework. This is built around the common interests of the organizations. However, a co-operative effort must also be firmly rooted in the individual organization.

Together we will create a transport system based on customer needs and climate limitations. The transport system shall be:
• Safe and secure
• Accessible and efficient
• Informative and flexible
• Innovative

In order to achieve these goals, the partners must not only work in close co-operation with each other, but with other stakeholders in the region as well. One prerequisite for being able to develop Stockholm’s transport system in the desired direction is more and better real-time traffic data. This can help provide more and better information and travel guidance. A considerable amount of data is today collected from many sources. Travel-times are, for example, generated from data from the main arterial roads in Stockholm. There are large areas of the network that have no monitoring capability and also some strategically important sections of the network that has limited or non-existing driver information. Floating-car data is also important and co-operation has started with road-carriers and bus operators. Information exchange between the partners will be developed further through methods that better utilise existing data and make it more accessible to other users.

Another important prerequisite is a regional digital geographic reference system. Efforts in this area have already been underway for several years. The existing system does not cover the whole region and, importantly, it does not include vital parts of the transport network such as networks for pedestrians and bicyclists.

Two other important building blocks to develop further are the central traffic management and control centre in Stockholm (‘Trafik Stockholm’) and the related website ‘trafiken.nu’ for real-time traveller information. A key aim here is also to develop new ITS-based services that benefit road-users and support ‘climate-smart’ travel.

TOWARDS A COMMON ITS ACTION PLAN
The Stockholm Initiative is currently in the process of producing an action plan for
continued ITS co-operation based on policy statements, goals and ongoing projects.

Project examples include:

1. **One Transportation System**
   This project is concerned with the idea of having one coherent system that offers smooth transitions between different types of transport to provide better efficiency. Reliability and coherent information are important components of good transport system. The use of ITS makes this possible.

   A key aspect of this project is related to establishing accessible/open interfaces and data streams, but also to developing cooperation. As mentioned, it is important to continue working towards a comprehensive regional digital geographic reference system that also includes pedestrian and biking paths. Connection points in the system are particularly important.

   There are several interesting projects underway in this area. These are primarily concerned with people transport, but The Stockholm Initiative is also looking into how ITS can enable flexible freight transport solutions.

2. **Customer in Focus**
   Improved knowledge and insight into customer’s needs and demands can help in the development of systems that help people make smarter travel choices and simplify the everyday situation for private and commercial road-users. The Stockholm Initiative strives to involve road-users to a greater extent when further developing the transport system. There are a wide range of activities included under this heading. Generally, it is important to stay updated on issues such as research relating to road-users/consumers, developing customer-oriented ITS services and using ITS to a greater extent to simplify the problems that inhabitants are likely to face during periods of regional growth and infrastructure expansion.

3. **Resource-efficient Travel and Transport**
   It is believed that utilizing different ITS measures will enable public transport to be used to a greater extent than it is today, and also that it will encourage the use of more environmentally friendly transport options. Stockholm already has a high-degree of public transport usage approximately 70% during peak-hour traffic. Information systems and trip-planners are important in this context. There are several
projects underway in this area. At present, congestion charging is one of the most effective means to control the environment in Stockholm. There has been a 20% reduction of vehicle traffic since it was introduced. Knowledge of the environmental effects and benefits of ITS will be reviewed in order to facilitate a greater impact of environmentally friendly ITS solutions. Beside congestion charging, there is not a great deal of traffic control in place that is based on environmental parameters. Work to enhance "green traffic control" is, however, on the agenda. Some work is already underway with mobility management and investments in the area will continue.

ITS — AN IMPORTANT PART OF TODAY’S TRANSPORTATION SYSTEM
ITS is currently used a great deal in our transport system. A few examples include:

- **Trafik Stockholm**: A central traffic management system that is operated by the Swedish Road Administration and the City of Stockholm. Some of the system’s tools include MCS (Motorway Control System), VMS (Variable Message Signs) and advanced traffic signalling.
- **Roadside assistance**: A flexible emergency service that assists during accidents and incidents. This co-operative effort also includes the Swedish Police.
- **Data collection**: Several different methods of collecting real-time data are currently used. This data is important to the central traffic management system and forms a basis for road-user information services. At present there are travel-time cameras, different types of detectors and FCD (Floating Car Data) in use in Stockholm.
- **Trafiken.nu**: This is the name of the website with real-time travel and traffic information. The Swedish Road Administration, the City of Stockholm and Stockholm Public Transport co-operate to generate the information displayed on this website.
- **Public transport**: This includes different ITS applications; a great many information services via media such as mobile telephones and the Internet. Travel-planning applications are also available. Tickets can now be purchased using SMS.
- **Congestion charging**: Vehicle traffic liable a fee when passing toll stations during the heaviest traffic periods. A ‘toll-ring’ surrounds the central area of Stockholm.

**STOCKHOLM IN 2020?**
By 2020, it is envisaged that the following will have been achieved:
• A well-functioning transport system.

• Travel information services will be well-developed to suit the needs of private and commercial travellers and road-users according to their needs and demands.

• Traffic control and management systems will optimize the efficiency of the transport system.

• ITS will be used to reduce environmental impact and increase traffic safety.

• Positive examples backed by statistics will show the progress that has been made towards the vision stated at the outset for projects such as:
  • One transport system
  • Customer in focus
  • Resource-efficient travel and transport

The aims and goals of the Stockholm Initiative will be achieved as a result of improved co-operation and a strengthening of the relationships that inspire confidence between partners. Closer co-operation and co-ordinated actions between partners have already resulted in getting ITS higher on the agenda in the Stockholm region. It has also highlighted the potential of ITS in the development of a greener transport system.

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Improving knowledge of ITS
Swedish ITS Training Programme

By Lilia Halsen Bidar, Sweco

The Swedish Road Administration (SRA) has developed a National Training Programme for Intelligent Transportation Systems (ITS) directed towards Transportation and Traffic Engineers and Planners. The goal of the ITS Training Programme is to increase knowledge relating to ITS systems, the effects they bring about and their relative costs and benefits. It is envisaged that improving awareness and skills regarding ITS at a local level will encourage ITS solutions to become a natural choice for solving traffic problems in urban and non-urban areas.

BACKGROUND
Tools for solving traffic and transportation problems are often characterised by physical measures. Changes in the physical design may be both costly and intrusive whereas ITS, in many cases, may be a cost effective solution and can have beneficial traffic effects. In particular, a number of evaluations relating to the use of local ITS systems have shown great potential both for traffic safety improvement and environmental benefit.

Local ITS systems are typically Variable Message Signs used to pass information to drivers with the objective of achieving a speed reduction. They can also be used to warn of crossing vehicles or pedestrians. Even though these systems are easy to implement and have documented beneficial effects the number of installations is low and the market potential quite high.

GOALS AND PROJECT DESCRIPTION
The aim of the training programme is to provide traffic and transportation engineers and planners throughout the whole of Sweden with qualified training and up-to-date information about ITS. The goal is that ITS will become a natural choice when planning and deciding upon measures to solve traffic problems. The training should provide information about the process of implementing ITS as well as information regarding the tools for deciding when ITS-
measures should be chosen, and how to evaluate their impact and effects.

Training and easily accessible information regarding ITS will contribute to the use of such measures as natural alternatives when choosing suitable solutions. A secondary aim within the project is to develop a method for assuring the quality of the information content in the training package, and to ensure that information about ITS measures and effects is kept up-to-date.

THE TARGET GROUP
Even though many advanced and effective ITS systems have already been implemented in Sweden, they are often located in large cities such as Stockholm, Gothenburg and Malmö where knowledge and skill-levels regarding ITS are high.

At the local, non-urban small-sized and even medium sized cities, ITS skills and experience are generally much lower. Therefore a key goal is to broaden the skill and knowledge base at the local level (small to medium sized towns and local authorities) in cities and municipalities.

INITIAL STATUS REVIEW
The result of an initial study showed that knowledge of ITS and road-telematics was very limited both within the local authorities and the local SRA offices. Awareness and knowledge of practical ITS implementation was very limited. Last but not least, there seemed to be a need for training, especially with regard to ITS systems in general but also related to effects and practical implementation guidelines.

INTRODUCTION OF LOCAL ITS SYSTEMS — A SUCCESS STORY
One of the local initiatives focusing on introduction and training of ITS was named “Local ITS systems”. The project was initiated in 2006 by the regional department of SRA in Western Sweden. The background to the project was that too few ITS systems were implemented in the region and it was thought that poor knowledge of ITS could be an underlying reason.

The idea was therefore that the regional ITS department of SRA should assist in the implementation process of local ITS systems, but that all the practical work should be performed by the responsible local authority. The rationale behind this is learning by doing. The project defined a set of supporting actions that would make the project manageable for the local offices. This included an
The evaluation of the whole project showed that those involved were pleased with the project, the training they received, and the level of follow-up activities during the project. Interestingly, one of the offices that expressed scepticism prior to the start of the project is now one of its strongest advocates and proponents of ITS systems.

With the new direction of the project focusing on ITS training and the good results from the local ITS systems in Western Sweden, it was decided to use the project as a model for the development of a National ITS Training Programme. The training programme would be built on more or less the same elements as the local ITS systems project. One important difference was that financing for the purchase of equipment was not included in the national training programme.

Based on this support, it was up to the local authorities to identify suitable locations for the installation of a system and decide what type of system to implement. All the systems chosen were Variable Message Signs (VMS) with feed-back information. The majority of the systems provided information about speed limits and one provided warnings for a pedestrian crossing.

THE NATIONAL ITS TRAINING PROGRAMME

It was decided that the first event (the pilot course) of the National ITS Training Programme should include a theoretical component with general information about ITS, various systems and their effects as well as practical guidelines for the implementation of ITS. It also provided an

VMS for warning of pedestrian crossings (photo Marie Karlsson)
opportunity for site visits, a key element of the training programme. Finally, the course also provided time for practical exercises in various workshops including playing an ITS board game.

One of the success criteria of the local ITS systems project was the personal contacts that flourished between local authority representatives and the personnel at SRA regional ITS departments. When personal contact is established it is much easier to seek information and support at a later stage. It was therefore important to have several key persons from the ITS department present even at the first pilot course of the National ITS Training Programme.

The main elements of the National ITS Training Programme:

- **Knowledge** – basic knowledge about roadside ITS applications and their effects
- **Tools** – practical guidelines and checklists for planning, implementing and managing ITS systems, i.e. the handbook together with other relevant publications
- **Network** – personal contacts with key representatives of the ITS department for help and support in the working process

THE DEVELOPMENT OF AN ITS HANDBOOK
With the project now focusing on ITS training, the goal of the ITS handbook is to support that training. The handbook reviews the list of systems presented and only include systems that are represented by more than one installation and where the effects on traffic had been shown to be promising.

The title of the handbook is ‘Roadside ITS’ and it is downloadable from the SRA website. (SRA 2009)

The ITS measures included in the ITS handbook are divided into the following three categories:

- User Information
- Traffic Management
- Traffic Monitoring (surveillance)
Most of the ITS measures in the handbook are related to the first category – User Information. This covers various types of variable message sign systems such as congestion warnings, travel time information and dynamic park-and-ride information. The Traffic Management section includes systems such as traffic signals, variable speed limits and motorway control systems. Finally, the Traffic Monitoring section covers systems like automatic speed control and tunnel control systems.

For each ITS measure the handbook provides information regarding practical implementation including best-practice, measures for monitoring system effectiveness and typical performance profiles for previously implemented systems.

In addition to being an upgrade of the 2001 catalogue, the handbook will present the benefits and advantages of ITS and highlight cases where ITS may represent a cost-effective alternative to physical measures. The handbook will present a lifecycle model for ITS implementation. The process of implementing ITS is based on a process-oriented model including various steps.

The description of each step in the process includes proposed guidelines and a checklist as well as practical advice about how to deal with each step in the process. The main steps of the implementation process are as follows:

- **IDENTIFY THE PROBLEM** – where, when and who. In this phase all relevant information including site visits, contact with relevant stakeholders and other information should be collected. The nature and presence of the problem should be described.
- **DEFINE THE NEEDS OF EACH USER GROUP** (car drivers, pedestrians, cyclists, neighbouring companies and private persons) and the **GOAL OF THE PROJECT**. The goal should be measurable.
• Do a cost-benefit analysis of the proposed measures (could be both physical and ITS based). As a general rule, the measure giving the most cost-effective solution should be chosen. Make a choice of ITS measure.

• Define a work plan for the whole project including purchasing, installation, verification, information and training, operation, service and maintenance as well as evaluation. Implement the system. After installation, verification and information, the system is set into operation.

• Before starting the operation and maintenance period all necessary information from the first part of the project should be transferred over to the operation and management organisation. The operation needs to be controlled to verify the correct operation over time and the system should be maintained.

• The final step is to evaluate the system to see that it provides the desired effects and meets the initial goals set up for the project. Specific guidelines for how to report evaluation results are provided. In this stage it is relevant to review the need for the system in order to discover if any circumstances have changed which might change the actual need for an ITS measure.

**FINAL REMARK — HOW MAY THE ENVIRONMENT BENEFIT FROM IMPROVED KNOWLEDGE AND BETTER TRAINING IN RELATION TO ITS?**

It may seem somewhat tenuous to claim any connection between knowledge of ITS and environmental improvements. But experience gained through the former project *Local ITS systems* in Western Sweden has shown that smart, well-prepared training does provide increased knowledge of ITS which in turn leads to greater numbers of systems being implemented.

We know that ITS measures and implementation often provide positive benefits to the traffic environment through better flow, longer headway and better distribution of speed along the road and between sections of the road. When the flow, headway and distribution is improved the number of incidents and accidents decreases. This generates fewer queues and less congestion. Congestion is a major contributory factor to CO₂ and particulate emissions. So the conclusion is that whenever good ITS measures are implemented there can be a positive contribution to the environment.

Another positive contribution occurs when ITS measures prevent less intrusion in the physical
landscape. This provides other benefits to the environment.

In order to fully benefit from all of the possible ITS solutions and to bring the market forward, it is necessary to share and distribute knowledge and awareness about ITS and its effects with planners and decision makers.

REFERENCES


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The Battle against CO₂ emissions at Stockholm-Arlanda Airport

Stockholm-Arlanda is Sweden’s largest airport and an important hub for both the Stockholm region and Scandinavia – with 167 destinations around the world, and extensive ground transport services to and from other parts of the Stockholm region. Efficient transport facilitates the exchange of ideas, goods and services – a prerequisite for economic growth and prosperity in the region and Sweden. Through the use of ITS Stockholm-Arlanda Airport has achieved a high efficiency in time and minimized environmental impact.

The LFV Group, previously called Luftfartsverket (the Swedish Civil Aviation Administration), is a Swedish State enterprise that is responsible for operating and developing 16 Swedish airports. These include Stockholm-Arlanda Airport, Göteborg-Landvetter Airport and Malmö Airport. Furthermore the LFV Group is responsible for air navigation services in Sweden.

Running an airport is all about maximizing the benefits of aviation while at the same time minimizing its negative consequences. For the LFV Group, the climate change...
issue has been a high priority for many years. Through a series of measures in the space of four years, LFV has more than halved the carbon dioxide emissions from its own operations at Stockholm-Arlanda Airport. These operations include space heating of buildings, electricity consumption and the company’s own airport vehicles. LFV’s goal is to reduce its own carbon dioxide emissions at Stockholm-Arlanda towards zero by 2012. LFV is also, together with stakeholders from public transportation, nearby

STOCKHOLM-ARLANDA’S EMISSION CAP

Stockholm-Arlanda is the only airport in the world with a carbon dioxide emission cap in its environmental permit. This stipulation means that emissions from aircraft take-offs and landings, road traffic to and from the airport, internal vehicle traffic and space heating of buildings may be no higher in 2011 than they were in 1990.

LFV, which owns, operates and develops the airport, is therefore responsible for organising its operations in such a way as to minimise overall emissions of carbon dioxide from space heating of all buildings at the airport as well as aviation operations and ground transport at, to and from the airport. However, not all of LFV’s actions can be counted within the cap. For example purchasing only green electricity and extensively streamlining the airport’s energy use.

Emissions from ground transport within the emission cap include emissions from all passenger, employee and goods transport services to and from the airport. The emissions that are counted include the emissions generated from the starting point of goods transport to the airport. For passengers and employees, it includes the emissions generated by ground transport from their home or workplace to the airport.

In recent years there has been a clear trend towards more passengers per aircraft taking off at Stockholm-Arlanda. Compared to 1990, the number of aviation passengers has increased by 21 per cent. Meanwhile aviation emissions at the airport have declined by 15 per cent. Carbon dioxide emissions from road traffic, however, have increased by 30 per cent and now account for more than half of the emissions within the cap. Emissions from energy use and internal vehicle traffic at the airport have through a series of measures decreased by 68 per cent since 1990. LFV’s share of the airport’s total carbon dioxide emissions, including the heating of its own buildings and emissions from its own vehicles, is about two per cent of the airport’s total emissions.
communities and infrastructural state authorities giving the highest priority to public transport, increasing the accessibility for trains and other public transport and thereby decreasing the environmental impact of road transport to and from the airport.

50 PER CENT OF THE PASSENGERS USING PUBLIC TRANSPORT BY 2012

Stockholm Arlanda Airport is one of Sweden’s largest workplaces, with about 15,000 employees. More than 250 companies operate at the airport. The number of passengers that travel through Stockholm-Arlanda every day is around 50,000.

In the Stockholm region, Stockholm-Arlanda is a ground traffic hub, with good road connections, buses and trains. Today 45 per cent of passengers take public transport to and from the airport. One major challenge for the coming years is to persuade more people, both passengers and airport-based employees, to choose trains or buses instead of their car.

Stockholm-Arlanda has one of Sweden’s largest train stations. The airport is served by regional trains, commuter trains and high-speed trains from central Stockholm. Air passengers and airport-based employees may also choose to travel on a number of different bus and coach routes. Several bus routes to and from the airport are already served by ethanol-powered buses, and during 2008 Airport Coaches began running its vehicles on locally produced rapeseed-based diesel. The intention of the public transport authorities serving the airport is to ensure that by 2011, 90 per cent of the buses providing service to and from Stockholm-Arlanda will be powered by renewable fuels.

Is it possible to increase the share of passengers and employees choosing public transport to 50 per cent when 45 per cent is already a high level? First of all, to enable as many people as possible to choose public transport, it must be sufficiently reliable and efficient. Timetables and the location of routes must be adapted to the existing needs of passengers as well as airport-based employees. Today LFV furnishes public transport authorities with facts about passenger flows to and from the airport, and on Stockholm-Arlanda’s website there is information about public transport to and from the airport. Stockholm-Arlanda has also expanded its marketing of public transport to and from the airport. Certain measures are already
in place, among other things clear information starting in the arrival hall about available public transport choices.

However, there is still a lot of room for improvement when it comes to regional public transport – today driving a car to Stockholm-Arlanda is the only alternative from a number of areas. When it comes to improving the accessibility of public transport to and from the airport, LFV has established a forum for ground transport companies where these actors can pursue a continuous discussion of improvement measures for public transport to and from the airport. Through this forum, opportunities are created for traffic operators to continuously coordinate public transport to Stockholm-Arlanda.

To support the use of environmentally clean cars among the passengers, electrical cars park free of charge and the best parking spaces at all parking facilities at Stockholm-Arlanda are reserved for environmentally clean vehicles.

Furthermore, an Internet-based service which is offered to all LFV employees at Stockholm-Arlanda makes it easier to find someone to share a ride to work with. The ride-sharing service works both for regular commuting and for single trips.

To increase the percentage of employees who utilise public transport alternatives to and from their workplace the public transport alternative’s attractiveness has to increase. The possibility of creating a common subsidised public transport card for employees based at the airport is therefore being investigated. The conditions for onward travel from the train station in Sky City to various workplaces in the airport area have also been improved through, for example, more bus links within the area. LFV also pursues a continuous dialogue with public transport authorities to better adapt timetables to the working hours of airport-based employees. The airport is open round the clock and employees must be in place before the large flows of passengers early in the morning and during the evening and night.

100 PER CENT “ECO-TAXIS”

BY 2011
Eco-taxis enjoy priority at Stockholm-Arlanda Airport. Each day 3 200 taxi cars transport passengers to and from the airport. As a major taxi market Stockholm-Arlanda generate a positive environmental effect on the whole region by increasing
the share of eco taxis serving the airport.

Since 2005 Stockholm-Arlanda Airport has had separate queues outside the terminals for hybrid or renewable fuel-powered taxis. Via their own queue in the existing system eco taxis can leave the holding area to easily access spaces to wait for customers. For the passengers this means that there is always an eco taxi waiting first in line outside the terminal.

All taxis that deliver and pick up customers at Stockholm-Arlanda are gathered in a designated remote parking area. To get physical access to the remote parking area, and participate in the queue system, a taxi has to be registered at the airport. This provides LFV with the opportunity to manage the taxi fleet by limiting the registrations and ultimately determine what taxi vehicles get in line for business at the airport. In this dispatching system from the remote taxi parking area to the terminals eco taxis enjoy priority. After three years of offering this privilege to eco taxis serving the airport the share of taxi vehicles meeting the official definition of environmentally ‘clean’ cars has increased from 1 percent to 43 percent. By 2011, at the latest, all taxis operating at the airport are obliged to be environmentally ‘clean’ vehicles.

100 PER CENT ENVIRONMENTALLY CLEAN AIRPORT BASED VEHICLES BY 2012

Stockholm-Arlanda is the first airport in the world operating biogas-fuelled buses. Operation of the buses started in 2006. Since then a strict policy stating that new vehicles must be environmentally clean vehicles has been implemented, resulting in an increasing fleet of cars and buses using renewable fuels.

During the past years airport-based cars and other vehicles have gradually been replaced by vehicles with the lowest possible level of emissions, for example biogas or hybrid cars. Other vehicle purchasers have been influenced by the discount

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**FUEL TRANSPORTATION**

Since October 2006, aviation fuel is transported to Stockholm-Arlanda exclusively by railway (from the Port of Gävle to Brista) and onward by pipeline to Stockholm-Arlanda. This solution has replaced the number of tanker lorries between Stockholm city and Stockholm-Arlanda by 50 per day.
LFV offers on the cost of vehicle permits for environmentally clean cars. A vehicle permit is required if the vehicle is to be used within the airport fence.

In 2008 Stockholm-Arlanda Airport initiated a project to reach 100 per cent clean vehicles and to ensure the supply of bio fuels for vehicles operating within the airport by 2012.

As a first step to involve other airport-based companies and organisations, LFV conducted a vehicle and machinery inventory focusing on the top-ten users of ground service equipment and vehicles. The next step is a plan for a bio fuel transformation or adaptation of all fossil-fuelled vehicles and machinery operating within the airport. To be able to make the special airport diesel-powered vehicles fossil fuel-free LFV is looking into the potential for using bio-diesel or bio-diesel blends, most likely based on rapeseed (canola) oil. A bio-diesel solution is likely to be the only short-term way to make special airport vehicles fossil fuel-free. In order to make way for modern electrical instead of diesel-powered machinery, electricity infrastructure is also being looked into.

Today, it is possible for airport vehicles as well as passengers cars to fill up the tank with both biogas and ethanol at Stockholm-Arlanda. However, in order to be able to reach the goal LFV are improving the infrastructure and thus the availability of renewable fuels, primarily biogas and ethanol E85, at the airport. In order to reduce fuel consumption among the vehicles operating at the airport, training in eco-driving is being implemented among employees.

Each biogas-powered bus operated by the airport saves approximately 50 tonnes of CO\textsubscript{2} annually. If all vehicles and machinery are de-fossilised by 2012, the emissions from ground service equipment and other airport based vehicles will be cut by about 6,000 metric tonnes annually.

So per cent of the approaches are offered a green approach by 2012

A green approach means that an aircraft descends continuously from its cruising altitude to the runway. By descending continuously, instead of in stages, the aircraft requires almost no engine thrust, thereby saving fuel and reducing emissions.

Green approaches was introduced at Stockholm-Arlanda during 2006 as a part of a collaborative project
For airlines, the advantages are fuel savings and a more optimally timed logistic process for aircraft turnarounds.

Since green approach trials started in January 2006, more than 10,000 such approaches have been conducted at Stockholm-Arlanda. By 2012, 8 out of 10 approaches to the airport will be offered a green approach.

Experiences to date shows that a green approach saves an average of 150 kg fuel per flight. This corresponds to a reduction in carbon dioxide emissions of about 450 kg.

If all approaches to Stockholm-Arlanda during 2008 had been
GREEN DEPARTURES

Reduced queuing time at the runway resulting in cutbacks in both noise and emissions could be the future at Stockholm Arlanda Airport with Green Departures.

Green Departures and Green Approaches are parts of the project Green Flights which the LFV flight management has been running since 2007. The project goal is to gather and coordinate environmental related measures within Air Traffic Management.

A combination of the pilot wanting to take off as soon as possible and the flight manager needing an available gate, result in a lack of synchronisation of the time for push back (the plane leaving the gate) and time for departure. The objective is that the aircraft should not leave the gate until it can actually take off, reducing queues, noise and emissions. This could be done by the flow optimisation tool, Departure Manager, DMAN developed by LFV at Stockholm Arlanda Airport. In contrast to the already implemented Green Approaches, Green Departures are still under development.

The Departure Manager calculates the aircraft’s actual time for both starting the engines as well as push-out from gate. Furthermore, DMAN calculates scheduled departure time and the distance between gate and runway. There is not a calculated number of the amount of fuel and CO₂ that is saved when making use of Green Departure for one flight. Nevertheless, approximations for the whole airport suggest the quantity to be between two and three tonnes CO₂ per hour throughout the whole day.

LFV’s vision for the future is that the flow of both departures and approaches shall be optimised by linking the Departure- and Arrival Manager (an optimization tool for arrivals). Coordination of these two systems will make traffic management more effective than today, benefiting the environment and cutting waiting times.
heaters at the airport and by 2010 the last oil-fired energy production units will be taken out of service. LFV, which owns, operates and develops the airport, purchases ‘green electricity certificates’ equivalent to its entire electricity consumption. These certificates guarantee electricity production from exclusively renewable sources, that is, wind, solar, hydropower and/or biofuels. LFV’s net carbon dioxide emissions from space heating of its own buildings and from the production of the electricity that it purchases are thus regarded as being zero.

Energy consumption is not only associated with environmental impact, but also with large costs. Through different measures over a two year period LFV has reduced its energy consumption at Stockholm-Arlanda by 24 per cent. This is equivalent to a full year’s consumption at Göteborg-Landvetter Airport, Sweden’s second largest airport. The target for 2010 is that LFV’s energy consumption at Stockholm-Arlanda should be 30 per cent lower than it was in 2005.

The reduction in yearly carbon dioxide emissions from space heating at the whole airport has been approximately 94%, or about 15,000 tonnes, since 1990. By
2010 the last 1,000 tonnes will be eliminated.

THE AQUIFER — THE WORLD’S LARGEST ENERGY STORAGE UNIT

The Brunkeberg Ridge runs in an arc from Stockholm via Stockholm-Arlanda to Uppsala. Within the ridge groundwater, confined between layers of sandstone and rock, there is a submerged aquifer area next to the airport. This has temperature storing properties like a giant ‘thermos’. This huge groundwater reservoir, the aquifer, is used to make energy production at Stockholm-Arlanda both cheaper and more environmentally friendly.

The construction of an aquifer-based heating and cooling storage system at Stockholm-Arlanda began during the autumn of 2008, and the system was taken into service during 2009. In the aquifer waste heat or waste cold is seasonally stored. Warm water is stored during summer to be used for heating during winter. Cool water is stored during winter to be used for cooling during summer. Utilising the geothermic properties of the aquifer will reduce the airport’s annual electricity consumption by 4 GWh and its district heating consumption by around 15 GWh. This is total equivalent to the energy consumed by 2,000 single-family homes each year.

How will this system work at Stockholm-Arlanda? In summertime cold water pumped out of the aquifer is used for ground source cooling in the existing district cooling system. The thereby heated water is then returned and stored on the warm side of the aquifer. In the wintertime the flow direction is reversed, and the aquifer storage system delivers low-grade heat from the aquifer storage system’s warm side, at about +15°C, to preheat ventilation intake air in buildings and in ground heating coils to melt snow in aircraft parking stands. When the water returns to the aquifer, it has cooled back down to about +5°C, and this cool water is stored on the cool side of the ridge until next summer.

The volume of the aquifer is about two million cubic metres of which 30 percent is water. In the system no groundwater is consumed; instead the same quantity that is pumped up is also returned to the groundwater reservoir.

With the aquifer-based energy storage system, renewable cooling and heating is supplied efficiently to the airport. The aquifer at Stockholm-Arlanda is up to now the world’s largest energy storage unit.
Since 2005, LFV at Stockholm-Arlanda has been using only “green” electricity and since 2006 only district heating based on bio fuel. The aquifer will make it possible for green electricity and bio-fuel based district heating, equivalent to 7,000 tonnes carbon dioxide annually, to become available for others to buy.

For more information visit www.arlanda.se

storage unit and up to six or seven times as efficient as other energy storage units. Earlier cooling of LFV’s buildings at Stockholm-Arlanda has used water from a nearby lake, Halmsjön, enabling the airport to reduce the number of cooling units containing environmentally hazardous CFCs (freons). With ground source cooling from the aquifer storage system in summertime and lake water cooling from Halmsjön in wintertime, one hundred percent of the airport’s cooling needs are provided by our own renewable energy production.
Traveller Information

It is generally assumed that well-informed travellers make the best travel decisions; i.e. when and how to travel. Stockholm is proud to be one of the cities in the world that has the highest proportion of public transport commuters. Over 70% travel across the city borders each day. Furthermore, there has been a rapid increase in the number of commuter cyclists in recent years, even during the colder winter months. Despite the tendency to shift to greener and more sustainable modes of transport, there are still thousands of car drivers stuck on congested roads every day as a result of unforeseen incidents and roadway maintenance.

This section provides the reader with information about the many different measures that have been developed by Stockholm Public Transport in order to reach its targets and stay competitive. The use of new technology is also discussed in relation to improving conditions for cyclists, and how the movements of a thousand taxis contribute to the provision of real-time information on the status of the road network. Further, the many sources of travel and traffic data that exist are now used to provide input into a new regional co-modal travel planner that provides travel information on available travel alternatives for both private and public modes of transport, separately or in combination.
Stockholm is an area that is undergoing a rapid population growth. At present the population of Stockholm County is approximately 2 million. This figure is expected to increase annually by about 30,000 up to and including the year 2020. Statistics indicate that the number of public transport journeys in the Stockholm area on a typical weekday during the spring of 2008 was close to 2.5 million. Furthermore, the average number of passengers per weekday during 2008 was in just over 700,000. From a public transport perspective, it would not be possible to cope with the sheer dynamics situation without supportive ITS-solutions in the form of information and communication technologies, and a devoted public transport organisation.

The business concept of Stockholm Public Transport (SL) is to provide everybody in Stockholm County with extensive, attractive and easily accessible public transport by road and rail. SL aims to meet the full range of customer requirements for simple, reliable

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**STOCKHOLM PUBLIC TRANSPORT FACTS AND FIGURES**

Travel frequency in the Stockholm Public Transport system during 2008 increased by 2% compared to 2007. The number of journeys on typical weekdays during the spring totalled 2,482,000. The average number of daily passengers on weekdays during 2008 totalled 701,000. SL conducts monthly customer surveys, which showed an average customer satisfaction rate of 72 percent in 2008.

Total passenger kilometres in 2008 amounted to 4,840 million kilometres, an increase of 1.7% on the previous year. Total transport capacity during 2008 measured in available seat kilometres rose by 3.3% to 15,674 million kilometres. Emissions of fossil fuel carbon dioxide from SL bus transport (kg/passenger kilometre) decreased in 2008 by 3.5% compared to 2007. Energy from renewable sources consumed in all SL operations increased by 3.5% in 2008 to 66% of the total energy consumption.
and affordable public transport. All journeys must be safe and secure, and contribute to long-term sustainability in the region.

**IMPROVED SERVICES**

As Stockholm grows and new residential areas are built, the SL bus network must be readily adapted to serve the increasing volumes of new passengers. Services are being expanded on approximately fifty existing bus routes and, during the year, several new bus routes have been started or consolidated to serve new residential areas.

Services should, as far as possible and within available means, increase in proportion to the growth of the region. Services are adjusted continuously to meet passenger demands with the aim of increasing travel frequency and fare revenues. Development is steered towards enhanced quality with regard to **reliability**, **accessibility** and **information**.

Regular and reliable services are regarded by SL as a **critical success factor**. A basic requirement for this is an efficient transport infrastructure and vehicle park. Service reliability is affected to a large extent by factors such as accessibility and stop-times at stations during boarding and alighting. Reliability is also affected by the performance of transport contractors. This applies both to contractors that operate transport services and to those that maintain and ensure that the infrastructure is working correctly.

During 2008, a new target campaign called ‘Customers on Time’ was introduced by SL. The purpose was to measure service reliability based on the number of passengers affected by service disruptions and delays. The results for ‘Customers on Time’ indicated a success rate of 86 per cent while the annual target was set at 89 per cent. It was found that the total number of service delays and cancelled departures was lower than in previous years. These were primarily caused by signalling, track and vehicle-related issues. General conclusions suggested that the service reliability for rail services improved and that it was

One of SL’s targets for 2010 is to reduce disruptions in the commuter rail system by 50 %
about the same as previous years for bus services.

In order to boost commuting from the peripheral areas of the Stockholm region, efforts to expand park-and-ride facilities are being continually introduced. During 2008 a total of 500 new parking spaces were added. These were divided among the municipal authorities of Vallentuna, Vaxholm, Södertälje, Huddinge, Nacka, Österåker and Täby.

RELIABLE AND ACCESSIBLE PASSENGER INFORMATION
To promote SL services and to encourage more people to travel with SL, reliable and easily accessible passenger information is essential. Passengers must have access to up-to-date information about their planned journeys whenever it is needed and wherever they are. This information must be accurate, current and easily understood. In 2006, it was decided that 110 of the 200 million Swedish Kronor that had been generated from congestion charges during the trial in Stockholm would be invested in SL passenger information systems. The funds were used to install a large number of dynamic real-time passenger information displays at bus terminals around the county. The panels display information about routes, destinations, departure times, re-scheduling, cancelled services, bus stop relocations and severe disruptions. Information is updated continuously.

To facilitate travel for passengers with visual impairments and reading difficulties, information displays are equipped with AOD (Audio on Demand), which announces scheduled bus departure times on a loud-speaker system. Passengers can activate AOD simply by pushing a button. The AOD system was developed as a joint-venture with the SL ‘Resource Group’ which includes representatives from various organizations for the disabled.

In future, the floor in front of AOD equipped displays will be fitted with tactile surfaces to help provide orientation for those who are visually impaired and make it easier to locate the AOD button that provides access to the information.

In conjunction with the installation of passenger information displays, maps that display the layout of a bus-terminal along with departure points, and a list of the bus-routes that operate from each departure point, were mounted at suitable locations.
SL has a close collaboration with Swedish Railways (SJ) and the Swedish Rail Administration to enhance transport circulation on the current rail infrastructure. The joint goal of this collaboration is to halve excess journey time in commuter rail services by 2010. This may be facilitated by the use of real-time information systems that enable passengers to plan their journeys with current and valid travel-information.

SL is in the process of developing passenger real-time information services through several different channels. This includes the Internet and the journey-planner on sl.se. On a typical day, over 200,000 enquiries are made via the journey-planner. In August 2008, an annual high was noted with over 250,000 enquiries in one day.

SL is currently testing new channels for real-time passenger information distribution. In a joint project with Svenska Bostäder AB, passenger information services were made available to people living in 20 apartments. Svenska Bostäder installed devices with a touch-screen interface (referred to as ‘SBoxar’) which enabled residents to monitor their energy consumption and access additional services such as real-time passenger information. Adjacent

SL bus stops and stations were displayed in this system. Research revealed that SL real-time passenger information was one of the most popular and widely used features among residents.

Mobile phones are another important and growing channel for passenger information. At the mobil.sl.se site, passengers can access timetables and service disruption information. From December 2009, this system will also include real-time information in the form of a journey-planner that can take cancelled services into consideration and suggest alternative routes. Today travel-tickets can be purchased by mobile phone simply by sending an SMS.

SL is committed to improving information for those who have mobility impairments, for example, information about lifts and escalators in stations. During the past four years, accessibility factors in the SL transport network have been catalogue. The results of this initiative will be integrated into the journey-planner during 2009.

**NEW TICKETING-SYSTEM AND SMART CARD SOLUTION**

The present SL ticketing-system that is based on the use of magnetic-stripe cards and paper-coupons that are time-stamped
has been around some time and is in need of renewal, SL has now introduced a new ticketing system referred to as ‘SL Access’. The main concept behind these new cards that provide access to the transport system is that they can be read from a distance of several centimetres. This means that they can be read while left in, for example, a wallet or purse when alighting a bus or train.

When this new ticketing system has been completed, it is anticipated that almost all SL tickets will be in the form of an SL Access Card. In the long-term there will be an option to charge the card with different types of tickets or with the amount of money needed for a single trip. It is intended that this new system will replace today’s system.

The Access Card can be recharged with credits once it has become empty. Every card also has a unique number and can therefore be blocked and potentially also traced. This enables a loss-guarantee system and creates possibilities for many new and interesting services. The new SL Access System makes life easier for both the traveller and for SL and has the added advantage of generating useful information for future planning.

The implementation of a new ticketing system is a large
and complex investment. The development of the system including: installations, planning, testing and education, has been underway for several years. The SL Access System has been developed specifically for the transport and travel needs of the Stockholm Region. Similar solutions can be found in other cities such as, for example, London, Hong Kong and Singapore.

User-surveys have shown that the new system has been received very positively by travellers in the Stockholm region.

**A PUBLIC TRANSPORTATION SYSTEM FOR EVERYONE**

SL has introduced extensive accessibility features for passengers that have mobility impairments. The goal is to make public transport a viable travel option by 2010 for any individual who alone or with assistance can access a station or bus stop. SL’s special programme of work in this area includes features such as: modifications to platform height, new lift installations and the introduction of tactile surfaces – an initiative that was intensified in 2008. Furthermore, a higher number of low-floor bus vehicles were taken into service during 2009. Currently, two out of three buses are low-floor vehicles.

In 2008, guidelines were drawn up for accessibility features in the public transport network. Empathy training courses were also conducted. This training was compulsory for all staff that have a responsibility to ensure that accessibility issues are taken into consideration in all SL activities. In future, all decision-making material submitted to the management and/or board
must include a description of the probable accessibility consequences. SL works actively with the distribution of information about planned service disruptions to organizations for the disabled and their member newspapers. Through SL’s customer services, disabled passengers can receive help in the form of, for example, enlarged timetables and information via text.

A SAFE AND SECURE PUBLIC TRANSPORT
A key goal for SL is to ensure that public transport services are perceived as safe and secure, regardless of the time of day. A number of initiatives have been started to enhance safety and security for both passengers and employees. For example, defective lighting, graffiti and vandalism in the passenger environments is rectified. The objective is to minimize crimes against individuals and contribute to rapid assistance in emergency situations through the SL Security Centre.

SL has made large investments in order to ensure safety and security in public transport services. About 150 security resources are attached to SL. During Friday and Saturday evenings most are present throughout the SL transport network. The security organisation ‘Lugna Gatan’ (which literally translated means: ‘Calm Streets’) carry out work with young people in a preventive capacity. This helps to reduce possible service disruptions. Other security officers deal with incidents of public disorder. SL also co-operates with ‘Stadsmissionen’, an organisation that helps homeless people.

SL has installed security cameras throughout the transport network. Cameras have been installed in the Metro-system and also on buses. Installations in commuter rail-stations and depots will be completed during 2009. Cameras in the SL transport network have also helped the Stockholm Police solve more crimes. This is due to the contribution camera images that help identify potential suspects. The security cameras are directly connected to the SL

Wheelchair sign (photo: Maria Marteuleur)
Economic growth and rising car ownership, coupled with a population spread over a wider area and longer commuting distances, has complicated the challenge to retain this share.

For SL, it is important to find ecological and cost-effective solutions that enhance accessibility in the public transport system but also those that contribute to a sustainable development. This will benefit the residents of Stockholm both now and in the future.

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For more information visit www.sl.se
The Stockholm Co-modal Travel Planner

By Jenny Sirland, Sweco

INTRODUCTION
The number of citizens in Stockholm is steadily increasing, which consequently places higher demands on the transport system. The increase in the number of travellers in the city also places high demands on the infrastructure and on the environment. One small incident can create long queues that rapidly spread throughout the network. Most people have at one time or another been caught in congested traffic on their way to or from work. Adding or redirecting more road-users to already overloaded streets is not ecologically sustainable for the transport system. Today it is known that the transport sector accounts for one third of all carbon dioxide emissions in Sweden; equivalent to 25 million tons per year. One way to improve this situation is to use the existing transport system more efficiently. A prerequisite for this is access to more accurate traffic information. It is also important to provide travellers with correct information about all transport alternatives available in order that the full flexibility of the transport system can be utilised.

Access to correct and up-to-date information gives the traveller an opportunity to make a better and more informed decision with regard to the available transport options.

To meet the increasing need for readily accessible information, a co-modal travel planner has been developed for the Stockholm area. The project “co-modal travel planner” was initiated in January 2008 and has been funded by Stockholm congestion taxes. Today the co-modal travel planner offers alternative travel suggestions for cars, public transport, cycling, walking and any combinations of these. The travel planner can be accessed through the website www.trafiken.nu, which has been the traffic information website for Stockholm since 2001. Trafiken.nu has been developed and is currently run by the Swedish Road Administration, Stockholm Public Transport and the City of Stockholm. A key aim is to offer a complete and current overview of the traffic situation in the city. This co-operation enables a unified way of presenting information relating to different modes of transport. Since the start of Trafiken.nu there have been plans...
to introduce an integrated travel planner.

NEED FOR BETTER TRAFFIC INFORMATION
Those who travel in Stockholm have many options available to them; they can walk, bike, or travel by car or public transport. It is also possible to combine various modes of transport such as public transport with cycling or driving. In most cases it is not in any way obvious to know the fastest and easiest way to travel and therefore also difficult to make (and find) the right choices. An important question is therefore how the co-modal travel planner can resolve this situation.

An important goal with the web service was to make travel planning and the choice of transport mode easier, but also to decrease the negative consequences of interruptions in traffic. Instead of traditional travel-planners, where public and private transport modes are presented separately, the co-modal travel planner (as the name suggests) aims to allow combinations of transport modes.

THE NEW TRAVEL PLANNER
The newly developed travel-planner, where you can search for a suggested route when travelling by car, public transport, cycle, or walking, or any combination of these, can be accessed through the website www.trafiken.nu.

In essence, the main benefit of the co-modal travel planner is the way it integrates public and private transport and thereby also facilitates a comparison between different transport modes. Information about time, price and environmental impact is provided. Another key asset of the travel planner lies in its ability to plan commuter travel. When choosing this option the traveller is provided with an overview of all travel options from one place to another.

Other features include information regarding: the locations of park-and-ride facilities; bus routes where cycles may also be taken onboard; and the location of all bus stops along a particular route.

In order to make the car travel-times dependent on the time of day for the trip, travel-times have been extracted from historical data together with a model of known bottlenecks in the transportation system. Correct and fair travel-times are essential since an important goal with the web-service is to decrease the overall amount of time spent travelling.
Presenting public and private transport options separately makes it more difficult to compare them. An aim of the co-modal travel planner is therefore to facilitate comparison and to provide the possibility for travellers to mix and combine from the total supply of transportation alternatives. With the travel-planner you can run a search on trips from one place to another and get alternatives for different transport modes and combinations of transport modes presented next to each other. Comparisons can be based on time, price and on environmental impact.

ADVANTAGES OF A CO-MODAL TRAVEL PLANNER
According to studies conducted in countries where co-modal travel planners have already been implemented, more information about different modes of transport usually results in more people choosing public transport. Furthermore, real-time information updates are shown to result in an increased willingness to change travel habits. Studies conducted in Sweden show that travellers want more information about different possibilities, especially where road traffic is concerned. Travel time information along one road at different times of the day, or along different roads at the same time of the day, can provide many people with a better opportunity to decrease the amount of time they spend travelling. Since all alternatives are presented together, regardless of the exact information the traveller may be looking for, more information is given than that requested. Travellers are presented with information about costs, time and emissions and are therefore more likely to consider the pros and cons of the various travel alternatives. Furthermore, if travellers try to avoid congested streets during peak hours, it decreases their own overall travel time as well as making the trip more energy efficient.

During the development of the co-modal travel-planner a user study was conducted in addition to discussions with experts in order to design the system to be as efficient as possible. A special feature that is included is the possibility to plan commuter travel. When choosing this option the traveller gets an overview on the total supply of travel options from one place to another. This alternative can be valuable, for example, when considering where to move in the city. Other features include the possibility to see the locations of park-and-ride facilities, and to discover the bus routes that allow bicycles. The travel-planner also shows the
NEW CHALLENGES
When presenting different travel alternatives side-by-side a number of new problems arise. Traditional travel planners handle travel times quite differently with regard to what is included in the time and how the time is estimated and approximated. As a traveller using different travel planners one must make judgements of what one believes is included in the travel time estimate. For example, is the time it takes to walk to the train station included in the journey time when travelling by public transport? Does one take for granted that the time it takes to travel by car also includes the time it takes to find a parking space? Do the times given take into consideration peak traffic hours?

When all the travel times are placed next to each other, as in the co-modal travel planner, high demands on comparability are required. In order to make the comparison correct and fair, the travel times have to be estimated realistically and on an equal basis. With this in mind a research project was carried out in parallel to the development of the co-modal travel planner. The aim was to generate knowledge that could be used to improve the calculation, presentation and comparability of travel times when it comes to travel planning that includes several alternative transport modes. The research focused on how to estimate travel times in the city of Stockholm for journeys by car, public transport, bicycle and walking.

REALISTIC AND COMPAREABLE TRAVEL TIMES
The investigation of available data on travel times has shown that currently used methods are lacking in some respects in order to achieve comparability. Car travelling times are the most complex to estimate and are today systematically underestimated. With today’s methods, the travel times for public transport are comparatively accurate. There is good knowledge of public transport travel times largely as a result of long experience in this area. In Stockholm there is little experience in developing route planners for walking or cycling. The first cycle planner is about to be released by the City of Stockholm. The research study concluded that cycling and walking should be treated as though it were unaffected during peak hours and by real-time updates. The opposite was true for car traffic and public transport. While cars and buses are affected by the surrounding location of all bus stops along a route.
traffic situation, travel times for pedestrians and cyclists are instead highly dependent on individual speed.

In order to highlight each section of a journey it was divided into segments as shown in the figure below. The green fields refer to sections of the journey where travel time data already exists or can easily be collected. The yellow fields are parts of the trip where some of the data for measuring time is missing but where work is still being done to try and fill in the gaps. The red fields refer to sections of a journey where data is missing and where there still is a lot of work to be done to collect relevant data.

When different sections of a journey have been identified it is important to measure the different sections on an equal basis for the different modal travel alternatives. For example, since the times stated for public transport currently take peak hours into consideration, this aspect should also be considered for car trips. This is, however, a complicated task and has been problematic for many years. A study within development of the travel planner has shown that the constant underestimation of car travel times has affected the way people plan their trips. The study showed that travellers were so used to adding congestion time onto their normal trip time that they no longer saw it as a problem. In theory one could argue that ignoring congestion time for car trips affects the comparability negatively, but also that the reality might be different.

The approach recommended by the study suggested calculating car travel times for different times of the day, different days of the week and different times of the year. This should be based on historical travel time data that has already been collected in Stockholm. The measured times do not fully cover the street network but there are different strategies to calculate

![Highlighting sections of a journey according to transport mode.](Sweco_mos_2.indd)
It is also of great value for the traveller to know the travel times that are likely to vary and those that are more likely to remain constant. With this information the traveller can make an active choice on the journey that is most suitable according to personal preferences.

**CAR TRAVEL TIMES IN THE CO-MODAL TRAVEL PLANNER**

There are many different solutions to calculate car travel times. Other co-modal travel planners are currently being developed in countries such as Germany, the Netherlands, Denmark and Austria. These countries use solutions based on data collected from vehicle GPS along with mathematical models to obtain measured travel times on certain roads. In Stockholm, car travel times provided in the travel planner, are extracted from historical data together with a model of known bottlenecks in the transportation system. The aim of this method was to cover the larger roads and the parts of the street network that suffer from significant regular delays.

The presentation of travel times was shown to be of great importance to offer a fair comparison. Different presentations of travel time are known to affect what kind of information the traveller is presented with. Clarity regarding what parts of the travel time are included makes it easier for the traveller to plan his trip. Knowing that the time for walking to the train station is included in the presented time (or knowing that it is not) is of importance.
As mentioned earlier there are still a number of obstacles to overcome, especially with regard to car traffic. It is not trivial to calculate accurate car travel times that include peak hours or to include parking time in a fair and comparable way. This can be done to some extent if travel times are calculated in monetary terms. The prediction of parking time is particularly difficult due to its random nature. Generally, many of the problems related to the representation and generation of realistic travel times are dependant on a lack of data and can therefore be improved by further work. An important long-time goal is to distribute real-time data through the co-modal travel planner. It is believed that the integration of real-time data can attract more users. Hopefully, we can follow the exciting development of the co-modal travel planner during coming years. This will help travellers to choose wisely among travel alternatives for themselves and for the environment.

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HOPE FOR THE FUTURE
A lot of work has already been done and the new co-modal travel planner at Trafiken.nu offers an exciting approach to a new kind of travel planning. This type of traffic information is essential for bigger cities to be able to handle growing demands and to be able to keep emission levels down. Hopefully more people will discover the advantages of taking their cycle instead of their car, or the benefits of getting to their destination on time by train instead of getting stuck in traffic when travelling by car. More and better traffic information also has the advantage of reducing the number of cars driving the wrong way. Knowing where to go and when helps make the traffic flow more efficient.
Improving And Maintaining A High Level Of Service For Cyclists In Stockholm

By Krister Isaksson, City of Stockholm

THE CURRENT SITUATION IN STOCKHOLM

Over the last ten years the number of cyclists has increased by over 50%. A normal day in Stockholm over 150,000 bicycle trips are made in and around the city centre. To cater for this growth the City of Stockholm has made large investments in the infrastructure to ensure a high level of safety and accessibility. A key goal is to improve traffic safety for both cyclists and pedestrians. Providing for the continued growth of cyclists is also an important step towards long-term sustainability and quality of life in the city of Stockholm.

In 2005 a master plan for the cycle-infrastructure extending to the outer suburbs was accepted by the government. This plan means that approximately 93 million Euros will be invested in the infrastructure between 2005 and 2020. These investments will be carried out in order to improve cyclist (and pedestrian) safety, but also to improve accessibility and to encourage more people to cycle. A large part of this investment will go to the maintenance and improvement of existing cycle-paths and points of interaction with other traffic. Where possible it is also planned to introduce new segregated bicycle paths to improve interaction between pedestrians and cyclists.

A similar master plan for the inner city of Stockholm was accepted in 2006 (Swedish: ‘Cykelplan 2006’). This plan also aims to build a number of completely new cycle-paths, and to maintain and improve the existing infrastructure.
problems associated with all-year-round cycling in Stockholm (and Sweden), the number of cyclists during winter months is increasing noticeably.

MEASURING THE UNEVENNESS OF CYCLE-PATHS

In 2007 the City of Stockholm started a new project; measuring unevenness of cycle-paths. The surface of cycle-paths is a key factor in relation to levels of for usage. Cyclists tend to increase in number if they find it easy and safe to travel by cycle compared to other modes of transport. Cyclists are known to be sensitive to surface-unevenness, poor levels of friction, and poor maintenance (e.g. the removal of snow). Investigations of cycle accidents indicate that approximately 30% of those that result in bodily injuries are related to the operation and maintenance of cycle-paths. Furthermore, 50% of all single cyclist accidents (where no other road-users are involved) are related to the quality of the cycle-path surface. Surveys among cyclists reveal a high level of dissatisfaction among cyclists in relation to the unevenness of the surface on which they cycle.

In Sweden, the quality of cycle-paths is typically investigated manually through an inventory process that involves visual
inspection. This subjective process often results in a great deal of variation in the quality of different sections and routes. More objective measurements of the unevenness of bicycle paths were therefore needed in order to create a consistent system and reliable method for standardizing what is acceptable and what isn’t with regard to unevenness. Such a method also allows for a better prioritisation of infrastructure investments. While systems for measuring the unevenness of vehicle roads have been in existence for some 20 years there are relatively few that have been designed specifically for cycle-paths. The existing systems that measure road unevenness can be carried out at relatively high speed (80 km/h) using large trucks designed specifically for this purpose. These vehicles would not be suitable on cycle-paths and the speed would need to be considerably less.

New technology and a new methods for measuring unevenness on cycle paths has recently been developed by the Dynatest company. This was tested in two Danish cities; Odense and Copenhagen. Measurements are performed at a speed of 20 km/h by a small SMART-car equipped with GPS, cameras, computers and advanced laser technology.

Every second the position of the car is registered and every 25mm the profile of the pavement is registered. A laser “scans” the surface, registering all unevenness. At the same time, all vertical movements are registered in a computer. The results are delivered in Excel-files enabling them to be synchronized with the City of Stockholm’s GIS-system. All together a BPI, Bicycle Profile Index, is calculated as an average value of unevenness for a specific 50-meters section. BPI is also representative of the experienced unevenness of the cyclist. The computer system that is used to calculate unevenness can, if required, also take other economical parameters into account in order to prioritise
among the sections requiring maintenance.

As a result of the success of these two test studies, the City of Stockholm decided to adopt this method. During the period May-June 2007, the specially-equipped vehicle collected measurements for 300 km of cycle paths. The results of this study will be used as a decision basis for prioritising investments and improvements in the cycle-infrastructure.

INVESTIGATING ACCESSIBILITY PROBLEMS IN THE STOCKHOLM CYCLE-NETWORK

The continual increase in the number of cyclists also creates greater demands on the cycle network and overall transport infrastructure. These demands are noticed in terms of the increase in both safety and accessibility problems. In particular, the congestion on some cycle routes leads to poorly adapted cycle behaviour such as dangerous overtaking and weaving that threatens the safety of other cyclists and pedestrians. Other problems such as poorly coordinated traffic lights for cyclists can result in red-light violations and unsafe interactions with vehicles. There are also cases where the infrastructure design is inadequate and has become unsuitable as a result of continued development and traffic and cyclist growth. Today there appear to be a great many problems of a temporary and more permanent nature that restrict accessibility and in some case also represent a threat to safety.

The identification of accessibility (and also safety) problems are of key concern in a project initialised and sponsored by the City of Stockholm and the Swedish Road Administration. It is hoped that this project will be able to use new technology to document the problems experienced by cyclists on their routes to and from work, and to assign priority to these problems in order that infrastructure investments can be prioritised to have the greatest effect in the short and long-term.

The project which began in the spring of 2009 is focused on cycle-commuters travelling more than 9 km to and from their place of work (a survey has shown that the average distance for cycle-commuters in Stockholm is approximately 9 km). A total of 17 cyclists, from approximately 30 applicants, were recruited to participate in this study. This choice was made on the basis of their cycle-route between their home and the city centre in order to cover as much of the cycle-network as possible. Most
During the busiest weeks of the year between May-June, participants were asked to cycle into the city during the morning peak-hour period (07.00-09.00), and then to return home during the afternoon peak-hour period (15.30-17.30). The cyclists were given special training in the handling of the equipment and were in some cases asked to follow a specific route that matched the Stockholm cycle-network map. Cyclists participating in the study were also asked to follow the prevailing rules and regulations.

For the project, data was collected using a GPS logger (recording time and latitude and longitude coordinates) and a small camera mounted on the handlebars of the bicycle. The data was collected through central Stockholm, shown in Google Earth™.
governing cycling in Sweden and to wear a cycle-helmet. Further information was also requested from the cyclists each day of the study period. This “e-diary” was collected via e-mail and consisted of a number of specific questions regarding weather conditions and events that occurred en-route.

The GPS-logger provided the most important data to this investigation since it enabled the locations where delays, stops and slow speeds occur to be pinpointed exactly. The film data provided a useful back-up and control check to the GPS-data and the e-diaries. In order to analyse the data, special software was developed in house which enabled the route position to be displayed in GoogleMaps™ at the same time the film was running. A graph of the speed profile over time or distance was also displayed in the application. The user of this software could then adjust a pointer bar under the graph to spool the film and GPS-information to the point of interest, i.e. those places where the speed dropped to a point below the average speed and where there was a noticeable stop or delay.

The application also generated information for each trip made such as average speed, standard deviation of speed, trip time, trip distance, number of stops, total stop time and several other variables of interest. The software also allowed 3D-speed and delay profiles to be generated in KML-files that could be opened directly in Google Earth™. The results are presented as pinpoints on a 3D-image of the Stockholm area. Each “Pinpoint” represents a documented problem at a specific location. The pinpoints also have different colours signifying the general types of problems encountered. Clicking on the pinpoint reveals a great deal of other information about the problem extracted and interpreted from the data collected in the study.

This project has received a great deal of local media coverage in Stockholm in order to provide feedback about what is being done to improve accessibility and safety for cyclists. Furthermore, it is believed to be a new, innovative and highly useful approach to studying cycle accessibility and safety problems. The next stage of the project beginning in the autumn will 2009 attempt to discover how the prioritised problems can be resolved.

Travel planning services designed to encourage cycling and walking can make an important contribution for environment and health, but also for a better usage of the transport system.
Cycling and walking put special requirements on route planning services, i.e. weather, bike lanes, stairs, hills, avoiding motorways etc. In most cities, available road databases do not include all information needed for proper planning of routes for cycling and walking. This makes it important for City and road administrations to ensure this data is collected and shared. To some extent, this can be made in co-operation with commercial service providers. The new bicycle planner and co-modal travel planner for Stockholm will be demonstrated at the ITS World Congress in Stockholm 2009.

**IMPROVED TRAVEL PLANNING FOR CYCLING AND WALKING IN STOCKHOLM**

Route planning services have been around for a while, but mainly for public transport and for car-driving. A few cities including Stockholm and Gothenburg, are now introducing internet based travel planning tools for cycling and, in some cases also walking. Cycling and walking, and changing modes of transport put special requirements on new route planning services. This section presents experiences related to the introduction of travel planning services for bicyclists and pedestrians in Sweden. It is important to include cycling and walking in travel-planning information services for a number of reasons: increased walking and cycling is good for the environment and for personal health; in many cities with congestion, more walking and cycling will lead to a better usage of the transport system; and, cycling and walking are important modes of transport to include in co-modal travel planning systems. Travel-planning services for cycling can be established as a stand-alone service, aimed at people who want specific routing. Cycling and walking are both recognised as important modes of transport to include in co-modal travel planning information services. This enables the generation of door-to-door routes that include all modes of transport. When developing applications such as these it is also important to recognise the requirements these systems have in comparison to vehicle-based route-planners. Cycling and walking are, for example, weather sensitive and not all roads are suitable for this purpose. It is also important to consider the fact that cycle travel time varies considerably depending on physical condition and weather conditions. Infrastructure conditions such as elevation (hills), dangerous roads and crossings, and bike parking facilities must be taken into account.
A cycle-route planner for Stockholm traffic is currently under development and will be released for use later this year. A cycle route planner for the city of Gothenburg has already been launched and is now in full operation. Examples of the interfaces are shown below. This development work has revealed that the available road databases do not always include all of the information needed for a proper planning of routes for cycling and walking. This makes it very important to ensure that suitable data is collected and shared among interested parties in the future.

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Stockholm cycle-route planner (prototype)

Gothenburg cycle-route planner with height profile
Generating Traffic Information from Floating Car Data
By Patrik Eveborn, Trelocity

INTRODUCTION
Accurate information about the current traffic flow and congestion in cities is an important enabler and quality enhancer for many ITS applications. Conventional techniques with fixed installations like traffic cameras and sensors provide useful information or data at the location they are installed. To cover an entire city however, camera and sensor techniques are unrealistic due to installation costs.

The Trelocity company has developed a technology that can provide traffic information covering most roads in a city network. The method and technology is based on data collected in traffic by floating-cars from various vehicle fleets.

When the data has been processed, traffic information is made available to individual drivers to enable them to make more informed choices. This helps drivers spend less time in congested traffic. Besides providing an individual benefit to each driver, the traffic information also has environmental benefits, as cars that drive in slow-moving traffic generally consume more fuel per kilometre.

This traffic information can also be used to plan and co-ordinate the movements of fleet vehicles so that driving assignments are carried out more efficiently given knowledge of the current traffic situation.

BACKGROUND
The Trelocity company is essentially a spin-off from the software company Optimal Solutions. Optimal Solutions works with fleet optimisation and a large part of the customer base provides services for maintenance, repair and installation of technical equipment. As part of their work, contracts are typically defined by a service-level agreement, in which a commitment is made to be on site to start work within a specified time after the receipt of a call. This can range from one-hour to several days, depending on the industry and type of assignment.

In order to schedule operations,
Optimal Solutions used advanced planning and optimization tools to ensure that the assigned technician could be on-site at the right time. A component of the planning involves estimating the travel-time required for the technician to get to the site. Usually, route optimization is used for this purpose. This is based on normal speed restrictions and average travel-times in the road network. A difficult problem arises from the fact that there are often large variations in travel-time depending on the prevailing traffic conditions. It was recognised that the availability of real-time travel information would make the planning far more accurate.

Trelocity was founded on the basis of this realisation, i.e. the need for accurate real-time traffic information, and a solution to overcome these problems was developed.

**TECHNOLOGY**

Today, more and more vehicle fleets are equipped with GPS-systems that have the ability track the location of individual vehicles. Tracking is usually used to provide better planning possibilities for fleet operations, or for safety reasons. However, the GPS-data collected by each vehicle can also provide important information about the current traffic situation.

In the Trelocity solution, data is collected directly from vehicles that automatically report their position in traffic at irregular intervals. The data is reported to Trelocity’s computer servers for further processing into traffic information. The processing also takes into account additional information about the road network. By a process that involves calculating the probable routes selected by vehicles, a number of further enhancements can be made.

The data-reports submitted by vehicles have to be validated before they are considered acceptable for further processing by the system. This is necessary to ensure that possible errors in the data do not invalidate the traffic information that is generated. Multiple filters are used to validate the data. All of the validated data reported by vehicles is aggregated to provide information about many individual road segments.

The accuracy of the information created from floating-car data is dependent on both the number of vehicles that report data, and the frequency of the reporting. By using additional data about the road network, the same coverage and quality can be provided by only one-tenth of the number of vehicle data-reports that would
otherwise be required. When compared to other techniques for analysing floating-car data that do not use route-analysis, the use of additional data means that vehicles can be sampled less frequently or that better information can be gathered from a smaller vehicle fleet.

**CURRENT STATUS**

Trelocity services have been in operation in Stockholm since August 2008 and in Oslo since December 2008. Taxi Stockholm, one of the largest taxi-operators with a vehicle fleet of over 1,000 vehicles, provides floating-car data to Trelocity in the Stockholm area. The data collected from Taxi Stockholm is the same as that already used for dispatch purposes, i.e. reports of position and status.

The number of floating-cars in traffic at any one time differs depending on time of day. During peak hours there are around 900 vehicles on the roads in Stockholm.

The coverage of the traffic information is quite extensive, as shown in figure below.
APPLICATIONS

As mentioned earlier, traffic information can be used by private motorists for better travel planning and by commercial enterprises for the management and efficiency of vehicle fleets.

The initial services provided by Trelocity have been targeted at car-commuters. Typically, a car-commuter travels the same route to and from work every day. The type of decisions that they are normally faced with concern whether or not to take an alternative route, and the time of their planned travel. These decisions can be facilitated by the type of information presented in Trelocity’s web-application. Current traffic information is presented on a web-map, showing the current level of traffic flow. Green indicates that there is good flow and that speeds are normal, yellow indicates dense traffic, and red shows slow-moving traffic or traffic jams. In addition, selected major routes are also monitored and expected travel-times along these routes are presented. This traffic information is presented on the website of ‘Dagens Nyheter’, one of Sweden’s largest newspapers, in order to reach a larger audience. The launch of further applications is now also planned.
When traffic information is made available to individual drivers they are able to make more informed choices regarding travel options thereby spending less time in traffic queues. The information also has environmental benefits, as cars that are driving in slow moving traffic consume more fuel per kilometre. A result from a study from southern California 2001 is presented in figure below. At slower speeds, CO₂ emissions are increased by as much as several hundred percent. [1]

When drivers are provided with information that allows them to make more informed choices, it is assumed that a route with less congestion will be chosen, or that the driver will choose to travel at a different time. As a consequence of more informed travel choices, both congestion and emissions are reduced.

When managing vehicle fleets and planning which vehicle to assign to a specific task, decisions are often made on the basis of estimated travel-time or distance. When these decisions are based on real-time traffic information, tasks can be performed more efficiently with less-time spent in congested traffic. More informed decisions

![Carbon dioxide emissions compared to average speed](image-url)
also have a positive impact on fuel consumption.

The applications shown above are only possible if there is a sufficiently large network coverage. The system developed by Trelocity needs to be able to provide information on all major routes in the area. If the road network coverage is too small, it is not possible to use the information for planning purposes. While it might be interesting to see that there are queues on some routes, an informed decision cannot be made if there is no information about the traffic situation on alternative routes.

There are many technologies available for collecting traffic data and information. Typically such systems involve the use of vehicle detectors and cameras. These more traditional technologies are more accurate at specific locations compared to methods based on the use of floating-cars. However, this technology would also be considerably more expensive in situations where the coverage of a large network is required. A system based on data collected from floating-cars is cheaper to implement. Furthermore, the coverage is more flexible and dynamic being based on reports from vehicles travelling around the network.

**SUMMARY**

The experience and knowledge gained from the Trelocity system, suggests that floating-cars can provide an effective and cost-efficient means to collect traffic flow data compared to more conventional techniques. As more vehicles are equipped with technologies that enable the collection of traffic data, the opportunities to expand network coverage will grow and the precision of the traffic information provided will be enhanced.

**REFERENCES**


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Strategies and measures that fall under ‘traffic management’ are mainly concerned with regulating traffic flow by various means. One of the most poignant examples in Stockholm is the congestion charging system, which together with other parallel measures has successfully reduced the flow of vehicles into the central city area and shortened travel times far beyond expectations. The congestion charging system is presented in this section.

Traditionally traffic management has been used to improve traffic throughput through various optimisation strategies designed specifically for this task. In this section, the reader will also be made aware of the environmental considerations that are now given considerable weight in these systems both on motorways and as part of intersection control strategies. It has also been shown that the road safety cameras that are used to detect speeders also contribute to environmental goals – a positive side-effect!
Congestion Charging in Stockholm

Editorial

A full scale trial with congestion charging was carried out in Stockholm between January 2006 and end of July the same year. Following the success of the trial, the citizens of Stockholm voted in favour of a permanent congestion tax in a referendum in 2006. The permanent system began in August 2007 and is now operated by Swedish Transport Agency as a governmental tax.

Stockholm Congestion Charging Trial

On 2 June 2003 Stockholm City Council proposed to suggest a trial period for environmental charges/congestion tax – the Stockholm Trial. The Swedish Parliament passed a law on congestion tax on 16 June 2004. The law enabled congestion tax to be charged in Stockholm until 31 July 2006 inclusively. On 28 April 2005, the government decided that the trial period for environmental charges/congestion tax in Stockholm would start on 3 January 2006. The main players in the Stockholm Trial were the City of Stockholm, the Swedish Road Administration and Stockholm Public Transport (SL). The trial was funded by the national government. The Stockholm Trial consisted of three parts: expanded public transport, environmental charges/congestion tax and additional park-and-ride sites in the city and in the rest of the county.

The goals of the trial can be summarised as follows:

- **A 10-15 per cent reduction in the number of vehicles that cross the inner city segment during morning and afternoon rush hours**
- **Improved access on the busiest roads in Stockholm traffic**
- **Reduced emissions of carbon dioxide, nitrogen oxides and particles in inner city air**
- **Better street-level environment perceived by people in the inner city**

The evaluation spans a wide range of fields. The studies do not only cover travel patterns and effects on motor traffic and public transport, but also environmental...
consequences, effects on trade and industry, pedestrian and cycle traffic, changes to the city environment as well as macro-economic impact and effects on the regional economy. Many of the effects of the trial are very dependent on factors in the surrounding world, such as the economic trend in the region and the country.

The Stockholm Trial confirms that a simple zone toll generates tangible effects in a large area – an issue that has long been discussed. Furthermore, congestion charging also has more positive effects on the environment and road safety. The increased level of public transport during the trial was however not solely responsible for reducing motor traffic to a measurable extent.

**MOTOR TRAFFIC DECREASED MORE THAN EXPECTED**
The traffic goals for the congestion taxes were that the number of vehicles crossing the inner-city segment during the morning and afternoon rush hours would
decrease by 10-15 per cent, and that access would improve on Stockholm’s busiest roads.

It was shown that traffic decreased most across the charge cordon. This includes all the approach roads to the inner city. The reduction for the entire congestion tax periods over 24 hours was about 22 per cent. This corresponds to nearly 100,000 passages over the charge cordon.

The decrease in traffic across the cordon was largest during the morning and afternoon rush hours. The largest reduction occurred in the afternoon, which was probably due to the fact that afternoon journeys are not as fixed in terms of times and destinations as morning commuter journeys. The decrease in traffic on the south-east approach road was larger than the average reduction for the entire zone. The reduction from Lidingö was however below the average. This smaller reduction from Lidingö was expected, because road users to and from Lidingö who were not travelling to inner city destinations were exempt from the congestion tax, the so called Lidingö rule.

The flow of traffic on major inner-city roads fell during the congestion tax period, but not as much as across the congestion charge zone cordon. In terms of the number of vehicle kilometres driven, traffic in the inner city fell by more than 15 per cent. It is natural that this reduction is smaller, because the traffic flow in the inner city also includes motor traffic from residents, etc who do not leave the charge zone; instead they use their vehicles for journeys inside the city. Furthermore, other studies besides the traffic counts indicate that the motorists who do not need to cross the charge cordon benefited from the drop in congestion and actually used their vehicles more. This might also partly explain why traffic fell less in the inner city than across the charge zone.

Previous fears of a collapse on the Essingeleden bypass and other ring roads did not materialise. Traffic on the Essingeleden bypass increased by 4-5 per cent compared with 2005 – quite a small increase if compared to the normal variations from week to week. As the bypass is already so busy however, even small increases in traffic tend to heighten sensitivity to disruptions. The changes on other ring roads were minor – a few had somewhat increased traffic while traffic on others decreased somewhat.

ACCESSIBILITY IMPROVED
Accessibility improved and travel times fell as a result of the
reduction in motor traffic. This had a major positive impact on the reliability of travel times, in that you could be more certain that your journey would take an expected amount of time. Travel times for motor traffic fell considerably in and around the inner city. Particularly large reductions were noted on approach roads, where queue times decreased by a third in the morning rush hour and were halved in the afternoon rush hour. This was a substantial improvement for commuters travelling by car to and from the inner city, because travel times were shortened and became more predictable. In severe congestion, the differences in travel times for the same route in different traffic conditions, which can vary from one day to the next, are extreme.

It is clear that the reduction in traffic volume and better access have improved the work environment of professional drivers. All studies of professional drivers – bus and taxi drivers, couriers and contractors – before and during the trial, suggest various levels of improvement.

**TRAFFIC REDUCTION LEAD TO LESS ENVIRONMENTAL IMPACT AND BETTER HEALTH**

Emissions from motor traffic account for a large proportion of the total pollution in a city. Exhaust emissions are diluted in the air with other emissions and thereby affect the city’s air quality. The amount of emissions caused by traffic depends on total Vehicle per Kilometre Driven (V KD) and emission factors, in other words the emissions of different substances from each VKD. VKD multiplied by the emission factor gives us the total amount of emissions (expressed in tonnes/year) of different substances. Emission factors are affected by the distribution of different types of vehicle and by how the vehicles are driven. For example, a driving pattern with large variations in speed produces more emissions than driving at an even speed. The emissions calculations made are based on different emissions models and differ depending on the factors that have been taken into account in the calculations.

The Stockholm Trial reduced emissions of both carbon dioxide and particles. The drop in carbon dioxide is approximately in proportion with the reduction in VKD, which means that the contribution from traffic in the county has been reduced by 2-3 per cent, and in the inner city by about 14 per cent. These are major reductions to have been achieved through one single measure, although when regarded
as a reduction for the county it can only be seen as one of several measures required to achieve national climate objectives. Carbon dioxide emissions are the most difficult traffic emissions to reduce.

Total particle emissions have fallen by about the same amount as traffic volumes, but in the case of these substances, the place where these emissions decrease is of primary importance, because they contribute to concentrations at local level. The Stockholm Trial reduced the contribution from traffic by about one twentieth for the county as a whole and a tenth for the inner city. However, besides lower levels of particles at street level, congestion charging reduced the levels of smaller exhaust particles – a reduction that is also beneficial to health.

Exposure to particles affects the health and mortality of the population. Calculations based on effects linked to premature death as a result of exposure to air pollutants show that the reduction in traffic due to the Stockholm Trial saves about five life years. This is also the expected reduction used in the cost-benefit analysis for the Stockholm Trial. New research findings, presented in one of the evaluation reports, indicate a much higher cause-effect relationship. Calculations, according to these research findings, demonstrate that up to 25-30 premature deaths can be prevented per year. This corresponds to about 300 lives per year.

To derive considerable benefit from a measure designed to achieve lower emissions, the reductions should mainly be made in the most densely populated areas, where many people are exposed to a negative impact on health. Congestion charging therefore has a greater effect on health per equal amount of emissions than a tax increase on fuel, for example. This is because the reduction of emissions can be controlled by deciding where to debit the congestion tax, i.e. where people are very exposed to pollution. The reduction in emissions as a result of congestion charging in the inner city has a health benefit for the whole county that is about three times higher than the benefit that would have been gained had the reduction in emissions been achieved through an increase in fuel prices evenly distributed throughout the county.

As expected, the Stockholm Trial in general only had a marginal impact on noise levels, because major changes in traffic flows are
required for people to perceive an increase or decrease in noise. The limit for people’s ability to discern a difference in noise level is 3 dBA, which in traffic contexts corresponds to an approximate doubling or halving of the traffic volume. Calculations of the noise level changes caused by the Stockholm Trial point to changes of about 1 dBA and at most 2 dBA for average levels over 24 hours. There are therefore very few places where the changes in noise levels can be discerned.

PUBLIC TRANSPORT WAS AN IMPORTANT PART OF THE STOCKHOLM TRIAL

Expanded public transport and additional park-and-ride sites in the city and in the rest of the county was an important part of the Stockholm Trial. Based on the data available, it is not possible to show that the investments in these areas had any visible effect on the total number of trips taken on public transport during autumn 2005, before the charges began to apply. This conclusion clearly reflects well known knowledge that it is only when car travel becomes ‘more expensive’ in the form of higher costs or longer travel times (traffic jams) that public transport can increase its market share to a considerable extent. This is precisely what has been happening in Stockholm over a long period of time. The city has a large proportion of public transport use. This means that improved public transport is not enough to reduce congestion on the roads.

Nevertheless, access for bus services to, from and within the inner city improved during the trial and the travel by public transport was six percent higher in spring 2006 than in spring 2005. Since the inner city timetables were not adapted accordingly during the course of the trial, improved access did not make travel time much shorter. Punctuality probably improved, and for bus services, travel times were reduced considerably. The congestion tax seems to have

Expanded public transport was an important part of the Stockholm Trial
WAYS OF PAYING

The Congestion Tax in Stockholm is operated by the Swedish Transport Agency. The department also administers and develops the road-traffic registry, which provides Swedish society with information about vehicles, driving licences and commercial transport.

All Swedish-registered vehicles driving into and out of the Stockholm inner-city zone, during weekdays (Monday to Friday) between 06.30 am and 06.29 pm are liable a congestion tax. During these hours, vehicles are automatically registered at control-points. The charge is time-dependent where each entry to, or exit from, the inner city costs between 10, 15 or 20 SEK, depending on the time of day. The charge is aggregated and paid monthly by the vehicle owner who is also the person liable for the tax.

It is not possible to pay the tax at the control points; instead several payment options are available including bank giro, Internet banking, electronic invoicing or direct debit. With direct debit and electronic invoicing the environment is spared thanks to paperless transfers. If the tax is not paid to the Swedish Transport Agency before the specified payment date a surcharge is issued.
caused in increase in travel by public transport by approximately 4.5 percent, while higher petrol prices and other global events probably account for the rest of the increase. The travel pattern study shows an almost equally large increase.

Crowding in public transport (measured as percentage of standing passengers) has increased somewhat on the underground while declining on commuter trains. On the average crowding seems to have been unchanged. The expansion in public transport is presumed to be part of the explanation for this.

However, a relatively well functioning public transport has been a prerequisite for the effects produced by the congestion tax. Good and comprehensive public transport makes it easier for people to switch from their cars to public transport alternatives. That is to say, that some of the effect of the congestion tax might be accounted for as an effect of the investments in public transport.

Research shows that road safety is primarily affected by changes in VKT and speed levels. Since traffic has declined as a result of the Stockholm Trial, this means a decline as well in the number of estimated personal injury accidents within the area of the congestion tax. The magnitude of the decline is of course uncertain, but based on the model estimates, personal injury accidents are expected to have declined by 9-18 percent. The reduced congestion however has led to higher speeds, which brings with it an expected increase of the number of personal injury accidents. This effect is not as large, however, as the effect of traffic reductions.

A cautious estimate is that the Stockholm Trial has entailed a decline in the number of personal injury accidents by approximately 5-10 percent within the congestion tax area. Converted into annual values this would be the equivalent of a decrease of between 40 and 70 personal injury accidents per year. This figure can
be set in relation to an average 2,155 people who are injured in traffic in Stockholm County every year and 23 who die. The majority of those who are injured, in the county as well as in the inner city, are motorists. In the inner city over one-third of those who are injured are cyclists and pedestrians.

THE CONGESTION CHARGING EXPERIENCED EFFECT ON THE CITY ENVIRONMENT
The results indicate significant improvements for all of the factors that demonstrated measurable changes, i.e. those that were linked to reductions in traffic. In the city environment study, three improvements were experienced: better pace in traffic, better air quality and greater accessibility by car. The same tendencies appear in interviews made with cyclists in the inner city and with children who live in the inner city. The latter group’s experience of the city environment has very clearly improved, and many cyclists experience fewer cars in the inner city and that the traffic environment is better. The experienced changes for the worse mostly involve accessibility – by foot, public transport and bicycle. This might be due to the difference in season of which the measurements have been made.

WAYS OF ADAPTING TO THE NEW SITUATION
There were two types of adaptations to the new situation – each having a different direction in terms of effect. One was to adapt so as to avoid the charges in any way possible, which led to reduced traffic. The other was to exploit the space freed up by the reduction in traffic volumes, which counteracted the traffic reduction. A further adaptation for avoiding the charges was to use a clean or eco-friendly vehicle, which – albeit marginally – reduced the environmental impact. The amount of eco-friendly vehicles was three to four percent during the trial. Increased use of eco-friendly cars did not however reduce congestion. Since even the use of “eco-friendly” cars gives rise to negative environmental consequences, the congestion charge could reduce positive effects on the environment, if people with access to clear cars exploit available increased access to increase their own car travel. In the travel pattern study, there were no signs of such an effect.

The new park-and-ride facilities built for the trial have filled up on the whole, but it is not certain if this is because of a repressed need or because of the congestion charges. It seems more likely that
the increase in parking space at the approaches has been filled up as a result of the former, a repressed need which has now been provided for. However the increase in the practice of parking-and-riding (about 2,000 cars a day) is almost negligible in relation to the number of cars across the charge zone (approximately 530,000 passages a day before the congestion tax) or the decline in traffic (approximately 100,000 fewer passages a day).

There is nothing however in the travel pattern study to show that car riders have changed the time at which they travel to any tangible degree, nor are there any signs that traffic increased during any period of the day as a result of the redistribution of traffic. Counts of the average number of people in each car have

TECHNOLOGY AND INTEGRITY

Equipment at the control points consists of cameras, laser detectors and information signs mounted on a set of gantries. The signs inform the road-user with regard to the congestion tax rate at the time of passage through a control point. The registration and identification of vehicles is carried out by a fully automated system. Photographs are taken of the vehicle registration number. Since the driver does not need to slow down or stop, traffic-flow is not affected.

When a vehicle passes a control point, a laser-detector senses movement and activates the cameras that take high-resolution photographs of the vehicle’s registration number, first the front plates, then the rear plates. Pictures are then cropped so that only the number plates and the small area around it are shown. The registration number is then identified directly in the camera using OCR-technology (Optical Character Recognition).

Information about each entrance and exit over the charge cordon (date, time, control station, registration number and amount charged) is registered at the control station and kept until the tax is paid, at which point is the transaction is closed. In this way the personal integrity of vehicle drivers is protected.
also shown that car pooling has not increased to any measurable degree. The average is a steady 1.27 people per car. Beside the counts, the travel pattern study also showed no affect of the trial on the number of passengers per car. It is interesting that the decline in car trips exceeds the number of public transport passages across the charge zone. Since public transport has not increased to the same extent that car travel across the charge zone has decreased, this must mean that certain trips across the charge zone simply go via other routes, to other destinations, or are never undertaken as a result of the trial.

**CONGESTION CHARGE CREATES ADDITIONAL VALUE TO THE AREA**

Both the general public and the business community became more positive to the charges and to the trial as time went on. Through their own experience they were able to see the benefits. Those who pay the most congestion tax and at the same time have the least direct benefit from the improved travelling time are inner city residents. The cost-benefit analysis thereby points to the inner city residents as the greatest losers from the congestion tax. Nonetheless, it was this group of people who had the most positive attitude towards the tax, according to the opinion surveys. This might
be due to improved environment and increased road safety.

For many cities, attractiveness is a crucial issue for development and survival in the future. From time to time it has been said that congestion charges have a negative effect on attractiveness. It should be pointed out that in other places around the world, serious accessibility problems are considered to be detrimental to the city, in terms of, for example, business life, and therefore reduces the cities’ attractiveness.

Research in recent years shows that a city’s appeal is vital to attracting a labour force, which in turn attracts businesses and generates growth. From this perspective the trial and the system’s permanent status could increase Stockholm’s attractiveness.

Permanent Congestion Charging

“It is remarkable that the numbers have remained so stable, particularly given that: Stockholm’s population has increased by 40 000, the number of vehicles has increased by 5 % and there is a much greater proportion of green vehicles.”

Quote Gunnar Söderholm, director Stockholm Environment and Health Administration

The Stockholm Trial ended on the 31st of July 2006 and on the 17th of September 2006 residents of Stockholm voted in a referendum to continue the experiment. Permanent congestion charging began on 1 August 2007.

The figure to the left illustrates the number of passages over the congestion charge cordon during the year 2005 to summer 2009, including the time after the trial period and before the permanent implementation. During the autumn of 2008 the average passing of the cordon was approximately the same as the year before. Note that the month of July is free of charge and will be so in the future.

The figure also shows that the number of passages over the

1 In May 2009 the number was 15 percent
A larger number of eco-cars might be one of the explanations to the increase in traffic.
growth of a functional region with a high quality of life and a minimal environmental impact.

**WHAT DO WE SEE AHEAD?**
The City of Stockholm, the government and other regional stakeholders have negotiated a long term solution for financing the development of the transport system in the region. In this solution which is based on the construction of a western bypass (Stockholm bypass), it has been agreed that also the Essingeleden bypass will be included in the Congestion Charging system. In addition a few modifications to the tax-base will be made; for example eco-cars will no longer be exempt from the congestion tax. More important is that these negotiations showed that also the initial opposition against the Congestion Tax now regard it as an important part of the future transport system for Stockholm.

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Variable Message Signs (VMS) as a means to improve the environment, mobility and traffic safety

By Tomas Julner, Swedish Road Administration

INTRODUCTION
Stockholm, the continually expanding capital city of Sweden, has a complex geographic location. The provincial areas to the north and south of Stockholm are effectively separated by water. Very few passengers travel today by road or rail over the natural water boundaries to the north and south of Stockholm. At the same time, the water creates a beautiful city environment where people want to live.

The transport system around Stockholm consists of a number of bottlenecks, both for road and rail, which make it particularly sensitive and vulnerable. This has become increasingly evident following a number of major incidents during recent years. Signs that can be used to display different messages to road-users (VMS) represent a useful means to increase mobility and traffic safety for road-users travelling on main arterial roads. Today, the VMS-system is used actively to advise road-users of potential obstructions, queues, estimated travel-times and traffic information regarding alternative routes and means of travel.

WHAT IS VMS?
Essentially, a variable messages sign can be described as any type of roadside display that has the ability to present information transmitted to it via a control signal. In a large city environment, VMS contribute helpfully in many different ways through the provision of useful and timely information to road-users.

Queue-warnings
Rear-end collisions are a common type of accident on urban motorways. The end of a queue is often difficult to distinguish for a vehicle driver that enters traffic that is moving at a slower pace. In Stockholm, a system with variable signs above each lane is used. The messages are changed depending on the traffic rhythm. In situations where the average speed is considered to be within normal threshold values, the signs are turned off and remain blank. However, when the traffic...
begins to become more dense the variable signs further upstream are turned on and warn road-users of the potential downstream queue situation by recommending a lower travel speed.

**Road Hindrance**
The system described previously is also used to warn drivers if a lane is closed for maintenance reasons or in cases where there is a stopped vehicle or other obstacle. In such an event, a sequence of arrows and crosses are displayed upstream to lead traffic way from the closed lane.

**Restricted Mobility and Accessibility**
In Stockholm drivers are also informed regarding mobility and accessibility restrictions through the use of large variable message signs situated at the side of the road. These events can be of a more acute nature such as when a car has experienced mechanical problems or been involved in an accident, or planned as is usually the case with road-maintenance. In the case of planned mobility and accessibility restrictions, pre-warnings are issued to road-users some time beforehand with information regarding closure dates and times as well as the roads that will be affected. This pre-warning allows road-users the opportunity to choose an alternative route or form of travel prior to the planned disturbance.

**Travel-times**
The same signs that warn for mobility problems are also used to provide information on travel times for routes with destinations accessible along the road on which road-users are presently travelling. This is particularly useful in cases where there are alternative routes to the same destination.

**Variable Speeds**
Trials are currently underway with VMS signs that change the legal speed limit on a road depending on the traffic volume and/or certain environmental conditions (high levels of CO₂).
**Reversible Driving Lanes**  
A relatively cheap way to increase capacity is to use one or more lanes of a roadway for the dominating stream of traffic. Traffic is normally directed in towards the city in the morning and out from the city in the afternoon. To achieve this functionality VMS signs situated by the roadside are used to inform drivers of the direction of the reversible lanes.

**Park-and-Ride Information**  
A new function that will be introduced in the autumn of 2009 is the use of variable message signs to advise road-users to use park-and-ride facilities. The system advises drivers to park their vehicle and instead take the train or bus to the central Stockholm region in order to avoid queues and delays.

**CONTROLLING THE SYSTEM**  
VMS-signs are controlled in many cases by autonomic systems. The queue-warning and variable speed systems are controlled through the use of traffic detectors that measure speed. When speeds go above or below predefined threshold values, the signs are activated and start to display speed information to drivers. The operators working at the traffic management and control centre in Stockholm (‘Trafik Stockholm’) have the possibility to override the information displayed on the signs if necessary.
The operators at the ‘Trafik Stockholm’ control centre use a specially developed event handling and decision-making system referred to as CTS (Central Technical System). When an operator handles a particular traffic event, all deployed measures are carried out according to a predetermined plan of action. Depending on the type of event and other factors such as location and the time of day, the CTS provides a suggested suitable course of action in order to support the operator in the best way possible. If the event is likely to affect mobility and accessibility for road-users, the information will be distributed to a number of predetermined variable message signs.

The method of working with a plan of suggested measures also means that all the subordinate systems are handled in a coordinated way. This is especially important in relation to the occurrence of extraordinary events.

Furthermore the operators have a number of different information sources at their disposal to verify various types of events. In particular, there are a large number of cameras distributed throughout the traffic environment for monitoring and surveillance purposes. There are also a large number of traffic detectors and sensors installed with the aim of measuring traffic. The information from these sources is also used to process travel-time information and warnings regarding the development of queues.

**BENEFITS**

A number of different surveys conducted in Sweden and elsewhere indicate large benefits in comparison to the monetary investments when VMS-signs are used to inform and warn road-users. Large benefits extend mainly from a reduction in the number of accidents found on those roads where the queue-warning and variable speed signs have been introduced.
The environmental benefits are derived from the fact that speeds become more even. This has the effect of reducing emissions as vehicles brake and accelerate to a lesser extent than previously.

Road-users stated one of the surveys that they felt a greater sense of well-being and less stress when they were informed of traffic disturbances, even if they couldn’t do anything about it or take a different route.

CONCLUSIONS
The Swedish Road Administration intends to invest more resources (using amongst others, funds collected from the Stockholm congestion charging system) to extend the VMS system. Along the European Motorway E4, the queue-warning system will be extended to the town of Södertälje some 30 km from Stockholm. This will be done in conjunction with a widening of the roadway to three lanes per direction from the Bredäng-junction in 2011. Furthermore a number of large information signs will be installed on the main routes leading toward Stockholm, for example, close to the Skuru-bridge.

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By the end of 2009, well over 1,000 road safety cameras will be in use throughout Sweden, where 115 are in Stockholm. The purpose of these cameras is to make the road transportation system safer by enforcing the posted speed limits. Road Safety Cameras are accredited with a 20-30% reduction in fatal and serious injuries on roads that are camera-equipped. Excessive speed is known to be an important factor relating to the cause of accidents and, more importantly, it also determines the outcomes of an accident and how seriously people are injured.

It is widely known among the road safety community that lowering speed saves lives. In addition, lower speeds also help to save the environment. Letting up on the accelerator and slowing down from 100 to 90 km/h can save 0.1 liter of fuel per 10 km travelled. Thus, even a relatively small change in average speed brought about by the road safety cameras can provide benefits in fuel efficiency and reduce the impact on the environment.
suggest that the reduction in CO$_2$ emissions caused by Road Safety Cameras is approximately 25,000 tons per year.

There is even more that can be done. According to the Swedish Road Administration, a further 700,000 tons of CO$_2$ could be saved in Sweden alone each year if everyone drove their vehicle at the posted speed limit. To put things into perspective, 700,000 tons of CO$_2$ is the same amount that would be generated if 15,000 vehicles made a 1,000 km round trip between Stockholm and Gothenburg every day of the year. With strict new climate goals being imposed, it is therefore not surprising that the wide-scale use of speed cameras is being discussed all over Europe - for good reasons and for green reasons!

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Reduced CO\textsubscript{2}-emissions through co-ordinated signal control

By Peter Kronborg and Fredrik Davidsson, Movea Trafikkonsult AB

INTRODUCTION
The main aim of the MATSIS project is to reduce the emissions of CO\textsubscript{2} through the use of co-ordinated traffic signalling. This project has been financed by environmental funding (Swedish: ‘Miljömiljarden’) from the city of Stockholm and by the Swedish Environmental Protection Agency (Swedish: ‘Naturvårdsverket, Klimp’).

As a result of the energy crises during the early 1970s, it is well-known that large reductions in fuel consumption can be achieved relatively cheaply through traffic signal retiming in co-ordinated areas. A reduction in fuel consumption also implies a similar reduction in CO\textsubscript{2} emissions. Today the use of co-ordinated signalling to improve energy efficiency has great potential given advancements in traffic signal technology and control strategies.

At the outset of the project different types of advanced adaptive signal control were considered. The most interesting of these was the SPOT system developed in Italy. It soon became evident however, that conventional Swedish signal control strategies could perform better, at least in Swedish conditions.

Conventional co-ordinated signal control in Sweden are far more complex than simple fixed-time control. It includes several types of vehicle-actuation functionality including past-end green and allocating start permission to subsequent signal groups as well as allowing vehicle-actuated time-plan selection.

Six co-ordinated areas were selected for treatment as part of the MATSIS project. This new form of signal control is now in operation on the street in each of these areas and is currently performing very well..

As a means of investigating and estimating the effects of the signal treatments, micro-simulation was used.
RESULTS
The results in terms of reduced CO$_2$ emissions are shown below for the six selected areas. It should be pointed out that the sites have different traffic characteristics which influences the magnitude of the effects that have been found.

The results are far better than anticipated. By comparison the cost per kg saved CO$_2$ is among the lowest of all environmental projects carried out by the city of Stockholm.

The results actually become even better if the effects of delay are also taken into consideration. Delay is reduced by as much as 19% in some areas.

CONCLUSIONS AND RECOMMENDATIONS
The general findings of the MATSIS project can be summarised as follows:

- By fine-tuning and performing minor adjustments in the co-ordinated traffic signalling system, reductions in terms of CO$_2$-emissions can be obtained that are more cost-effective than nearly all other treatments with the same objective.
- The effect is estimated to be about 10 times greater in a socio-economic calculation due to the positive effect on delays
- Even if the risk of “new” traffic is considered, at least 70% of the positive effect is expected to remain.

Reduction of CO$_2$ (1.000 kg) per area and year
Given the success of the MATSIS project it is recommended that the methodology is applied to all co-ordinated traffic signal systems in Stockholm and other parts of Sweden. This is likely to provide substantial financial benefits.

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Delay makes up of 80 % of the effects. CO2-emissions are only a small part of the positive effects
Traffic Signal Priority For Public Transport In Stockholm Suburbs

By Erik Hollander, Stockholm Public Transport & Mathias Nordlinder, City of Stockholm

BACKGROUND
Since 1999 Stockholm Public Transport and the City of Stockholm have established four bus lines that have been given special signal priority in central Stockholm. Findings suggest that providing signal priority for buses results in an average increase in mean speed of several kilometres per hour when compared to non-prioritised routes. As a result, Stockholm Public Transport has initiated a project to expand bus priority so that it may also benefit travellers in the Stockholm suburbs.

THE PRE-STUDY
A pre-study was undertaken to document the number of traffic signals and the number of buses that would be affected by the project. The study also intended to show how many hours of passenger travel-time that could be saved. By studying the theoretical time reduction per intersection and comparing this to the number of passengers onboard, an estimated total time-saving of approximately 35,000 minutes of passenger travel time (over 580 hours) was found for six bus lines during a normal day.

IMPLEMENTATION STRATEGY AND FINANCE
Implementation concept
The implementation strategy for public transport bus priority began in 1999 in a project involving both the City of Stockholm and Stockholm Public Transport. During 2008 Stockholm Public Transport initiated a new project that had implications for several organisations with an interest in the local road infrastructure. The new project was financed by the Swedish Road Administration through a special fund for traffic management in the Stockholm region. At the outset it was intended that the funding should cover all implementation costs, but that maintenance costs would be covered by the relevant road infrastructure organisations.

The implementation of all six bus lines was estimated to cost approximately 19 million SEK (1.85 million Euro), excluding project management costs. The effects on travel-time reduction
for both travellers and system operations was estimated to approximately 11.3 million SEK per year indicating that the project would break-even financially during the two first two years following implementation.

**Technical concept**
The technical concept utilises an existing system called PRIBUSS that has been developed by the City of Stockholm. PRIBUSS makes possible a number of different priority strategies depending on the position in the sequence of the traffic signal stages when the request for priority detection occurs. The detection of buses is made by a signal sent from the bus to the traffic signal. A GPS-device keeps track of the bus and recalculates the distance from every bus-stop so that the onboard bus computer can send a request signal to the intersection traffic signal controller at the right distance.

The onboard computer also keeps track of whether the bus is on-time, or ahead or after its scheduled time. Based on this and other data the traffic signal controller can give priority to the bus if it is late or on time, but also reject priority if the bus is ahead of schedule. Rejecting priority for buses that are ahead of schedule can ensure that they are on time at the next bus stop.

**CONCLUSIONS**
The general conclusions that can be drawn following this pre-study are as follows:

Bus priority can save up to 35,000 traveller minutes during a normal day on the six routes tested.
Bus priority can bring about a reduction of up to 1,400 operating minutes during a normal day.

The system for the six routes should break-even financially already during the second year of operation.

The implementation of bus priority in the suburbs of Stockholm began during the autumn of 2008 and during the same period in 2009. Two bus routes are now in operation with priority. An after-study will be carried out in 2010.

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Measurements and calculations show that the environmental quality standard (PM$_{10}$) for particles is exceeded in Stockholm and several other cities in Sweden. Action programmes to tackle particles have not had a sufficient effect in reducing these levels. We need to develop new measures and we believe that speed control involving, amongst other things, variable speed limits is an area with much potential. This action area is mentioned in the Road Administration’s strategic plan.

Our knowledge of the effect of speed on the spreading and levels of particles is limited, as the relationship is complex and depends on many local and regional factors. We need to develop and implement a link to these effects, to support work on road traffic planning.

The particle emissions during winter conditions that are due to the extensive use of studded tyres and gritting on roads, have a comparatively big impact on PM$_{10}$ levels.
In September 2007, the Road Administration introduced Variable Speed Limits in one direction – towards Stockholm. The aim of this measure is primarily to improve accessibility by achieving a more homogenous and stable flow and to give early warnings of tailbacks. It is also expected that this will limit the generation of particles and noise.

Environmental Quality Standards

As pollution from road traffic in the form of particles is believed to have a significant negative effect on human health, the EU has established limit values for particles (and also for other pollution), which, if exceeded, mean that an action programme must be introduced. For particles, limit values have been produced for PM$_{10}$. Even smaller particles, PM$_{2.5}$, have a great negative effect on human health, as they can be transported further down into the lungs.

Norrtäljevägen is an important approach road from the north-east to Stockholm with a traffic volume of between 50,000 and 65,000 vehicles a day (southern section). The maximum hourly flow rates are very high and are directional. During high-volume periods, traffic moves with great variation in speed and intermittent queuing. This contributes, particularly in winter, to a high level of particle emissions and noise problems.
standard must be complied with as soon as possible, and by a specific date for each substance. At present, there are environmental air quality standards for air for nitric oxide, particles (PM$_{10}$), sulphur dioxide, lead, benzene, carbon monoxide, ozone, heavy metals and benzopyrene.

The environmental quality standard for inhalable particles, PM$_{10}$, covers average daily values and average annual values. The standards mean that the highest permissible average value for an entire calendar year is 40 μg/m$^3$ and that daily levels must not exceed 50 μg/m$^3$ for more than a maximum of 35 days in an entire calendar year. In all continual measurements carried out in impacted environments in the counties of Stockholm and Uppsala, the average daily value of PM$_{10}$ has been the most difficult to meet. The mapping of PM$_{10}$ levels in the counties of Stockholm and Uppsala also showed that the standard value for 24-hour periods was the most difficult to meet already in year 2002. The average daily value is stated as the 90th percentile over a year. This means the level that falls below 90% and exceeds 10% of the average value per period. When the 90th percentile for average daily values is reported, it means that it is the average value during the 36th worst day during a year that is reported.

**Effects on Health: Particles and Nitrogen Oxides**

Our knowledge is unclear with regard to the effect on health the particles from wear and tear have. This, in turn, means that our knowledge is incomplete regarding how many people are exposed to this. It is not possible to separate the effects of human exposure to particles from road-traffic wear and tear and the exposure related to particle emissions from other sources in the measurement data. There are also few places with access to distributed models. Nor are emission models at street level a good measurement of people’s exposure, as we spend a large part of our time indoors (i.e. where the particles from roadway wear and tear are not as evident). For studies of effects on health, the levels in urban backgrounds (roof levels) in particular have been used, but only a few studies deal with the impact of particles from wear and tear (course particles) separately.

Our knowledge of the effects of particles comes mainly from toxicological and epidemiological studies. However, our knowledge of how they affect different processes in the human body is still incomplete.
Several studies in the Stockholm region have demonstrated a link between air pollution from road traffic and premature deaths. Those under 30 years of age who have lived alongside roads with a lot of traffic run a 50 percent higher risk of dying of an acute heart attack than those who have lived in the countryside.

Children and the elderly are particularly exposed groups in the population. Epidemiological studies have demonstrated the effect on foetuses, infants, asthmatics, those already suffering from respiratory or heart disease, as well as the badly educated and smokers. Children are particularly sensitive as they are growing, their lungs are still developing. Some of the respiratory effects are mortality from lung disease and cancer, and an increase in ailments such as asthma and bronchitis. Among the effects on cardiac/vascular systems are: increased risk of cardiac arrest and strokes.

**Long-term Consequences**

Particle emissions are strongly related to traffic volumes and the composition of traffic. In the long term, this will lead to a situation that deteriorates in proportion to increases in traffic volume. This could, in turn, lead to expensive measures being required in the long-term. These could involve finding completely new solutions for traffic routes and activities in housing areas located in the vicinity of roads with high traffic volumes. There is, therefore, a great public interest in attempting to master the negative consequences of air pollution caused by today’s traffic.

**CAUSAL RELATIONSHIP**

**Traffic Speeds and Particle Generation**

One of the factors affecting the emissions of PM$_{10}$ is vehicle speed. Higher vehicle speeds increase roadway wear and tear when studded tyres are used. Consequently this leads to higher emissions and an increase in exhaust emissions.

The company ‘SLB-analys’ has been commissioned by the Swedish Road Administration to assess air pollution levels at different speeds along the E18 roadway – the section between the Danderyd Hospital and the Danderyd Church. The aim is to provide evidence that can be used to assess the potential of speed reduction measures to reduce levels of inhalable particles (PM$_{10}$) along the trial section. A particular topic of discussion is the possibility of meeting the environmental quality standard at
Laboratory studies (Swedish National Road and Transport Research Institute on behalf of the Swedish Road Administration) where PM$_{10}$ from wear and tear has been measured with different types of winter tyres at different speeds, show a clear link between speed and emission levels. Emissions are considerably higher at higher speeds. Studies in the field with mobile measuring equipment carried out by Stockholm University on behalf of the Road Administration have also demonstrated this relationship.

Other Contributory Factors
In addition to vehicle speeds, emissions are caused by several other factors. The tyre type of the vehicle is a very important explanatory factor for PM$_{10}$ emissions. Using studded winter tyres causes significantly higher emissions than tyres without studs.

These emissions vary greatly depending on the time of year. The highest emissions occur in late winter/spring. During the winter, the emissions are low despite the high usage of studded tyres, which is due to the fact that roadways are frozen and/or wet, which means that the particles largely bind to the roadway. In summer/autumn, emission factors are lowest.
Other factors affecting particle emissions are

- The distribution of speeds between traffic lanes. Here, our knowledge is insufficient, but there are grounds for assuming that a wider distribution of speeds will lead to increased PM$_{10}$ emissions.
- Driving patterns. Intermittent driving with a lot of braking and acceleration increases the whirling up of particles from the roadway.
- Roadway moisture. Emissions of PM$_{10}$ are lower when the roadway gets wet.
- Wind speed. At high wind speeds, the whirling effect, emissions of PM$_{10}$ and also the spread of these particles increase.
- Temperature. It is somewhat unclear how the air temperature affects PM$_{10}$ emissions. These may increase or reduce depending on the simultaneous influence of other factors.
- Relative humidity. At low humidity, the roads dry out so that PM$_{10}$ emissions increase.
- The composition and condition of the road surface. Stone material in coatings is also important. Less solid stone may lead to increased PM$_{10}$ emissions. Stone size is also significant. Smaller stone sizes lead to increased PM$_{10}$ emissions.

**WHAT CAN BE ACHIEVED THROUGH SPEED CONTROL?**

*Environmental Potential of Variable Speeds*

The speed of traffic varies greatly over the day on many heavily-loaded traffic routes, including the E18 roadway. In addition, driving conditions during periods of heavy traffic are irregular with stop-and-go situations. Particle generation depends greatly on weather conditions and also varies depending on the time of the year.

The speed of traffic can be governed by permanent road signs or by using variable speed control or a combination of such measures. If a primary purpose is to improve air quality, there are reasons to consider how speed should be varied over both the day and the year. On a daily level, it is imperative that the variation is controlled in accordance with the weather conditions where possible. Over the year, it is most important that emission-reducing measures are imposed in late winter/spring.

On the basis of the Swedish studies carried out within this area, it is realistic to envisage an “optimal” tactic for speed control that could lead to a potential saving of between 10 and 20 percent compared to today’s emission levels. This is also
confirmed by studies in other countries including Norway, the UK, and USA.

Alternative or Supplementary Measures
Alternative options for reducing levels of air-borne particles have been investigated. The use of dust binding agents on the roadway improves air quality and has not been shown to lead to any environmental damage in ground or water environments. Dust binding can be performed using:

- CMA (calcium magnesium acetate) – spread as a water solution that when dry forms a dust-binding layer on the roadway, or
- A sugar solution – consisting of glucose \( C_6H_{12}O_6 \) in a water solution.

The effect of such measures may persist for 1-2 days and reduce emission levels by 20-40 percent. There is, however, a risk of reduced grip on the roadway as a result of dust-binding and the running costs involved are considerable. Measurements carried out in special testing equipment show that the wear and tear of surfaces caused by studded tyres results in 40-50 times more PM\(_{10}\) than winter tyres without studs. It is estimated that studded tyres wear away more than 100,000 tonnes of road surface per year in Sweden. Information campaigns may be one way to reduce the use of studded tyres. More radical measures include the introduction of a surcharge for the use of studded tyres (perhaps based on the number of studs) or the introduction of restrictions on their use in time and/or location.

In the case of exposed locations, the negative consequences of increased particle levels can be prevented through good ventilation. A review of ventilation systems may be a short-term solution while awaiting more permanent, long-term improvements.

STRATEGY FOR IMPLEMENTATION OF ENVIRONMENTALLY-ADAPTED SPEED CONTROL

Discussion on the Implementation Problem
It is difficult to decide upon the key factors that should govern the implementation and use of variable speed-limit signs. Environmental conditions, traffic conditions and weather conditions are all important variables to consider. The choice of measurement methods and criteria for speed control should arguably take into account weather conditions at the daily level as well as variations at different times of the year. It is
emissions. In order to achieve consensus regarding measures in this area, various aspects in relation to those concerned must be carefully weighed up and balanced against each other. Those living along a busy traffic route and others directly affected by sub-standard air quality may focus more on the local environmental situation. There are, however, other more general interests and transport policy targets for good traffic accessibility and transport effectiveness. The accessibility and effectiveness aspects apply particularly to traffic routes outside densely populated centres.

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While public transport is regarded as environmentally friendly per se, the ultimate goal is for the system to become completely climate neutral. This goal has been adopted by Stockholm Public Transport (SL), triggering a range of activities to replace fossil fuels with renewable and ecologically friendly alternatives. The progress that has been made is reported in this section. The City of Stockholm and other key stakeholders are also striving towards climate neutral transport. The City of Stockholm is now combining intelligent speed adaptation with eco-driving (Eco-ISA) and is heavily engaged in developing the necessary infrastructure for alternative fuels and plug in hybrid vehicles.

The Swedish railway system is almost completely powered by electricity, improvements in this area are concerned with providing a more competitive and service-oriented high-speed railway system. ICT applications are of key importance in rail transport as reported in this section.

(photo: Stefan Sjödin, Fortum)
The ‘Gröna Tåget’ Project – An Activity Approach For Information Communication Technologies

By Oskar Fröidh, Royal Institute of Technology

A HIGH-SPEED TRAIN CONCEPT

‘Gröna Tåget’ is a research and development project that has the aim of developing a high-speed train concept for lines with mixed traffic and standards. Specifically intended for the Swedish and Nordic market requirements, this concept, can in the future, provide guidelines and recommendations regarding how to design the train to suit customers’ needs. An attractive train concept and economy of operation are the most important objectives.

The future use of Information and Communication Technologies (ICT) is being considered in the project. Passengers want a smooth, uncomplicated journey and possibly also some form of entertainment or way of passing the time during their journey – these are the two fields where ICT is most likely to play a role in the future train concept. The aim of this chapter is to address how the economy of operations can be improved and the attractiveness of journeys increased though the use of ICT in such a future high-speed train concept.

MARKET DEMANDS

Market of future high-speed trains

Competition in the medium to long-distance travel markets consists of airlines, including low-fare airlines on longer routes, and coaches and cars over all distances. To be competitive, a new train concept must not exceed a certain level of operational costs. Having the ambition to be competitive for leisure travel also requires active yield management (see below). This is because the marginal cost for an extra passenger in a car is small. However, high speed is a means to achieve both low operational costs and higher revenues through a more attractive service supply.

The long-distance travel sector can be divided into sub-sectors depending on travelling times and fares. Before high-speed trains and deregulated airlines, train supply was typically found in sector C or D with relatively long travel times. Airlines operated in sector B and were fast but also expensive.
High-speed trains most often appear in sector A, or possibly B if the infrastructure costs are covered by fares. Low-cost airlines definitely operate in sector A, as do low-cost high-speed trains. Sector A combines short travelling times with low fares.

The suppliers in sector A will expand as they become market leaders in both travel times and fares. Other factors, like comfort and service, also have some influence. This creates opportunities for operators in sector B with regard to the less price-sensitive market segments like business trips. Sector C might be a niche for low-budget travellers or tourism, but hardly an expanding market with the present prerequisites given that there are competing suppliers in sectors A and B. This can be explained by the fact that time-values for many individuals exceed fare differences between different modes, especially for business travel.

The aim of the ‘Gröna Tåget’ project is to design a train concept which can be located in the expanding sector A in the figure.

**Principles of the ‘Gröna Tåget’ concept**

Model calculations of train operation costs clearly show that a high-load factor is paramount for both operating costs and energy consumption per passenger. Increasing the average load factor from 30% to 70% means halved costs per passenger kilometre. A train service with intermediate stops and a fluctuating demand between time-of-day, week or season, automatically gets lower load factors due to inflexibility in the supply of seats. In a point-to-point service such as an air stage, the load factor can be better optimised. However, there are other measures that can be taken, such as yield management for example.

Space utilisation is another highly important factor. A traditional train has a great deal of floor space that is not used for seats. Coaches...
and airplanes have significantly better space utilisation and therefore a lower share of the costs for surplus space. In designing the train concept, functionality and comfort must be compared to operational costs through analyses of passenger valuations. Travel demand must be considered.

To meet the demand for cost-effective operation and create an attractive train concept, some key factors have been identified for high-speed travel in the Nordic market.

- **Short travelling times, through the use of tilting trains**
- **Flexible, shorter train-sets, making services with less travel economically viable**
- **Effective space utilisation, through the use of wide-body trains**
- **Comfort and service for greater attractiveness**

ICT can first and foremost be used to increase service supply, including information about the journey. Hence, the rest of the paper will focus on ICT for increased attractiveness.

**ICT and activities on the journey**

Many train passengers have a good idea of what aspects do not function in the desired manner. Among the activities that are linked to ICT there are several that generate suggestions for improvement. These include, amongst others: service onboard, information and communication, and tickets and payment. The suggestions are, as a rule, relatively cheap to implement; sometimes requiring a degree of technical development but in general having a high customer value. Many suggestions concern less complicated ticket-handling and better information about the journey (level of detail and availability), train changes, and alternatives when delays occur.

Many of the problems probably have their origin in the fact that different travellers have different needs, knowledge, and ability to find their way into the transport system. But delays and other unforeseen events require considerably more relevant, updated information than that operators are able to provide. One conclusion is that the systems for ticket-handling and information to passengers are in many cases not sufficiently adapted to users and that the potential exists for further development.

Real-time information about arrival times at stops in the public transport system has been shown to have a number of positive effects
on travellers. Among the effects discovered are reduced perceived waiting time, increased willingness to pay, adjusted travel behaviour, higher customer satisfaction and better image. Experience shows that real-time information by ICT makes the journey more attractive.

The development of ICT is important in order to be able to provide easy access to travel information, including ticket-selling, orientation in a public transport system, and increased attractiveness. Train journeys often have connections to other modes such as buses and metro-trains in public transport systems. To be able to use the systems, plenty of information is required. For inexperienced travellers, this can be a serious problem.
A survey of rail passengers in Great Britain mapped passenger’s activities and access to ICT during the journey. Travellers’ assessment of whether the journey time was profitable or wasted was strongly linked to the degree to which they planned their journey. Of those who studied or worked onboard, almost all considered that the journey time could be used profitably.

The most common activity on board was reading for leisure, followed by window gazing or people watching. Then followed working or studying, talking to other passengers, sleeping/snoozing and listening to music or the radio. The activities chosen are dependent on journey time where shorter trips allow less time for reading, working and snoozing.

The most common objects that train passengers had with them were daily newspapers, closely followed by mobile phones. Books and food and drink were the next most common. Except for mobile phones, computers and other forms of ICT were relatively unusual at the time of the survey.

A look onboard a train today (author’s observations) shows that many passengers bring along a newspaper or book, a mobile phone with FM radio (amongst other features), recorded music, or a laptop with an internet connection and which also allows the traveller to watch a DVD during the journey. Operators may be able to provide other possibilities but experience thus far is that it is not possible to equip trains with ICT at the same rate as the equipment becomes outdated. This has become evident through earlier experiments with fixed mobile phones and computer displays. In this respect it is better to have passengers bring along their own diversions.

**INTELLIGENT SUPPLY**
How can a modern high-speed train provide an “intelligent” supply? In this sense, intelligent could mean a measure that affects both costs and revenues. Higher speed is thus an intelligent measure since it decreases costs through faster circulation and increases revenues through a more attractive supply on the travel market. Attractiveness can to a large extent be measured in monetary terms, although not all details and variations are evaluated. In this first stage passenger needs and ideas for a more attractive train journey are discussed and an activity based model formulated. In general, many measures taken for passengers’ improved access to
information and communication possibilities give comparatively high value for money.

An attractive train supply in terms of travelling times, comfort and service widens the rail market and reduces energy consumption in the transport sector as a whole, by replacing air and road journeys, and at the same time improving the economy of train operations. Better economy ultimately leads to lower fares, and the positive spiral of increasing rail travel continues until a new equilibrium in the travel market is reached.

Higher revenues can also be achieved by yield management, which has been introduced by many airlines. It is based on a simple economic concept of utility and aims to minimise consumer surplus through statistical analyses of demand. A characteristic of yield management is a limited and fluctuating number of extremely low price tickets to sell empty seats. Properly implemented, yield management can increase both demand and revenue.

THE ACTIVITY APPROACH
The ‘Gröna Tåget’ concept is primarily a mode of transport, i.e. a means of travelling. But travelling time can be filled with other activities – or sub-activities. The activities are different for different customers. Depending on the reason for their journey, their age and their interests, travellers make up a heterogeneous group with different desires and needs. A baby, for example, has completely different needs during the journey than a person travelling on business. The purpose might be to use the journey time, relax, or make the journey more attractive.

The activity approach involves describing and assigning a value to different possible activities during the journey. It is partly a question of observed behaviour with today’s prerequisites and partly ideas for future possibilities. On the basis of the assessment, a concept can be designed.

In order for the train to be operated at all, an initial, separate set of activities can be defined:

- Traffic production (driver’s cab, crew areas, work routines)

A model containing seven main activities has been outlined for passengers:

- Activities linked directly to the journey (boarding and deboarding, information, ticket handling)
- Relaxing (resting, sleeping, thinking, window gazing, people watching)
• **Working or studying** (reading, writing, talking)
• **Own diversion** (reading, watching a film, playing a game, listening to the radio or music)
• **Relations** (talking to other passengers or on one’s mobile phone, children’s games)
• **Refreshment** (eat and drink; brought along or bought on the train)
• **Sanitary** (toilets, hygiene)

Activities that require a relatively large amount of space, for example shopping where the shop has both selling space and stock, exercise activities, or activities that otherwise require a large area in addition to ordinary seats are not of interest as far as the ‘Gröna Tåget’ concept is concerned. Energy consumption and ticket price per passenger kilometre would increase if such activities were introduced. Therefore, they do not fit the profile as a fast, comfortable mode of transport where the journey is the means to achieve something else, but may naturally be of interest for other train products where the journey itself is the end.

**ICT in the Activity Framework**
In recent decades, ICT has gradually become a more integrated part of many types of technical equipment. However, many applications have also preserved old working routines and well-established behaviour rather than making the most out of the new possibilities.

By far the most versatile form of ICT for personal use is at present the mobile phone. Most people have access to a mobile phone nowadays and it is frequently taken along on train journeys. More functionality can be built in, but so far the interface for typing and viewing is a limiting factor due to the compact size of modern phones. New technologies might widen their

### Train operation activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Subactivity</th>
<th>Possible use of ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train operation</td>
<td>Planning, timetables, resources (rolling stock, personnel etc.)</td>
<td>Planning tools</td>
</tr>
<tr>
<td></td>
<td>Safety (signalling, control mechanisms)</td>
<td>Communication with support functions</td>
</tr>
<tr>
<td></td>
<td>Working routines</td>
<td>Railway radio (GSM-R)</td>
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<tr>
<td></td>
<td></td>
<td>Safety systems (ERTMS, ETCS, technical systems for control and train diagnoses)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ticket handling systems</td>
</tr>
</tbody>
</table>
use in the future, for example voice recognition/guidance and light, soft screens.

There are also demands for more wireless network capacity to allow larger amounts of information to be transmitted. Online games, TV and films require relatively high bandwidth.

The tables give an overview of different ICT applications that are used at present or are conceivable in the future.

**IDEAS OF DEVELOPED ICT**

Some ideas of developed ICT for the passenger rail sector are better travel information, operational simulations, and onboard passenger counts in real-time. The ideas are all intended to improve the attractiveness. Better information has also been requested by travellers especially

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### Passenger activities onboard during the trip

<table>
<thead>
<tr>
<th>Passenger activity</th>
<th>Subactivity</th>
<th>Possible use of ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inevitable on the journey</td>
<td>Boarding/deboarding, information, ticket handling</td>
<td>Technical systems for control and train diagnoses. Travel information (timetable, connections, orientation, service supply). Ticketing (contact free)</td>
</tr>
<tr>
<td>Relax</td>
<td>Relax, sleep, think, window gazing, people watching</td>
<td>Anything which provides peace and quiet, like electronic noise suppressors and variable opacity surfaces (transparent/dark glass panes)</td>
</tr>
<tr>
<td>Work or study</td>
<td>Read, write, talk</td>
<td>Laptop, mobile phone and other similar personal ICT equipment</td>
</tr>
<tr>
<td>Own diversion</td>
<td>Read a newspaper, magazine or book, watch TV/a film, play a game, listen to radio or music</td>
<td>Laptop or similar ICT, radio and TV receivers, mobile phone, music players</td>
</tr>
<tr>
<td>Relations</td>
<td>Talk with other passengers, talk on the phone, children's play, games with other passengers</td>
<td>Game console or other electronic games, mobile phone</td>
</tr>
<tr>
<td>Eat and drink</td>
<td>Food and beverages brought along or bought onboard</td>
<td>Sales systems, food processing systems, waste handling, water supply, sewage treatment, control and train diagnoses</td>
</tr>
<tr>
<td>Sanitary</td>
<td>Toilets, hygiene</td>
<td>Technical systems for water supply, sewage treatment, control and train diagnoses</td>
</tr>
</tbody>
</table>
when delays and other unforeseen events occur. New information systems should therefore have sufficient capacity to quickly provide accurate information at a highly specific level for the whole railway system, even for serious disruptions such as extensive network-wide delays.

Operational simulation of different timetables in a railway network provides a possibility to find some optima; for example the minimization of total delay given a set of prerequisites. There is also a possibility to make quick operational simulations of changes in plans (timetables) if, for example, a line became blocked. This would lead to a greater accuracy in arrival time estimates compared to a manual system.

It may also be possible to increase revenues through better demand monitoring. ICT should make it possible to count the exact number of passengers and therefore make the planning better and easier, and the revenues higher. By recording the correct number of passengers on every train at any moment the actual demand can be used for the planning of timetables, the required number of seats, personnel needs, food and beverage provision, etc. Revenues can be increased by supplying more accurate statistics and improved forecasts of passenger numbers for yield management calculations.

CONCLUSIONS

The new train concept presented here provides opportunities to integrate different functions on train journeys. The activity approach is suggested as a model that can be used to find new uses for ICT on trains. The aim is to make train journeys simpler and less complicated, and to increase their attractiveness. Better information systems and higher capacity in network connections are an important part of this concept. New developments, such as a passenger count in real-time, could increase revenues and improve service. General experience with ICT development shows that it can be highly cost-effective, generating more income (value) than it expenditure.
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For more information visit www.gronataget.se
Towards a Sustainable Public Transport System

By Stefan Wallin, SL

Stockholm Public Transport (SL) places a high priority on the environment. New solutions are continually being tried and tested to minimise negative environmental impact. At present, SL offers its travellers a public transport system that is among the cleanest and most environmentally friendly in the world. SL also plays an active role in the development of a sustainable transport system for the Stockholm region. Cleaner technologies such as those made possible through ITS are considered to be of vital importance to SL in order to reach important targets and goals.

WORLD’S CLEANEST BUS FLEET
The world is facing a major challenge in reducing greenhouse gas emissions generated from the transport system. One way to contribute to a cleaner environment is to encourage more people to travel by public transport. This is understandably one of SL’s key goals. The environmental impact of all public transport vehicles is also a major concern. As bus transport represents a large and important part of the services provided by SL, the environmental and health impacts of buses are highly prioritized in the work that is undertaken to ensure a cleaner environment.

ABOUT STOCKHOLM PUBLIC TRANSPORT
Stockholm Public Transport (‘AB Storstockholms Lokaltrafik’, abbreviated SL) is responsible for planning and procuring all public transport operations in the County of Stockholm. These operations include commuter trains, a metro system, local trains, light-rail, trams, para-transit and bus operations. Data from 2008 suggested that passengers in the Stockholm area made approximately 2.5 million public transport journeys per weekday and more than 417 million trips during the entire year. At present there are almost 2,000 buses in the public transport system. While the Public transport system accounts for 25 per cent of all travel in the Stockholm region, it is responsible for only 6 per cent of the total amount of greenhouse gas emissions.
environment. SL’s use of more environmentally friendly vehicles started more than 25 years ago. The first clean vehicles were battery-powered buses. Today, the interest in electric vehicles is growing rapidly and SL strongly believes that electrically-powered vehicles will play a central role in the transport system of the future.

SL has also been active in the use of renewable fuels such as ethanol and biogas. Another important environmental goal for SL is to completely phase out the use of fossil fuels by year 2025. As a step on the way to achieving this goal, it is decided that no less than 50 per cent of the bus fleet will run on renewable fuels by 2011. The strategy adopted by SL involves increasing the number of biogas and ethanol buses. However, there is also another parallel line of investigation that is concerned with increasing the proportion of rapeseed methyl ester (RME) and other biofuels for diesel buses. Similarly, there is an active interest in ethanol hybrids and the development of electrically-powered vehicles.

GO GREEN WITH BIOGAS BUSES
Buses that run on biogas were introduced into the SL-fleet in 2004. Presently, there are more than 80 biogas buses in use in Stockholm and the number is continually growing. Biogas is one of the cleanest fuels available today. When correctly handled, emissions consist of only carbon dioxide and water. Biogas buses presently operate in the Stockholm inner city where air quality is a particularly sensitive issue.

The biogas used by SL is produced from sewage at the Henriksdal Wastewater Treatment Plant in Stockholm. This is then distributed to the Söderhallen bus depot. The people of Stockholm therefore contribute to the production of fuel and a more environmentally friendly public transport system.

SL has secured a long-term supply of biogas through agreements with the main water supplier in Stockholm - ‘Stockholm Vatten’, and the Käppala Association. SL is looking to find more suppliers and ways to increase the flexibility of biogas use by establishing a suitable infrastructure for fuel distribution. Today, an expansion in biogas distribution is planned that will include four additional bus depots. The planned expansion will use both pipeline distribution and a container solution that involves the gas being distributed by vehicles. At each refueling station the technical solutions are being continually improved with regard to safety and economy. These improvements are based...
largely on SL’s growing experience with this type of fuel. The impact on the local environment is also taken into consideration.

**MORE THAN 400 ETHANOL BUSES**
The first ethanol buses were introduced in Stockholm in the late 1980s. Today, SL has the world’s largest ethanol bus fleet driving in the inner city and Stockholm County area. The number of ethanol buses is now in excess of 400.

Ethanol is produced through the fermentation of organic material. The benefit to the environment varies, depending on the production process and the organic material used. It is important to SL that the fuels used by the bus-fleet have been produced under good working conditions (for employees) and with the lowest possible environmental impact. For this reason, SL is currently carrying out a survey which is aimed at developing knowledge and understanding in relation to the ethical and environmental conditions that prevail when producing fuels for the bus-fleet. The intention is to be able to impose requirements not only on the type of fuel, but also how it is produced.

**FUEL-CELL BUSES**
During 2004-2006, SL participated in a pilot project with fuel-cell buses. A fuel-cell works like a battery that does not need to be charged owing to the fact that it is continuously fueled with hydrogen gas. The fuel cell uses oxygen to convert the hydrogen gas into electricity, heat and water-steam. This process generates power for the electric engine that drives the bus. The only bi-product emitted from this process is water.

The fuel-cell buses functioned very well in traffic, however the
technology was found to be too costly to be a viable alternative at the time it was trialled. This technology also needs to be developed further in order to increase the life-span of the fuel-cells and overall energy efficiency in terms of the amount of electricity generated.

PIONEER PROJECT WITH ETHANOL HYBRID BUSES
SL takes an active role in developing and testing new technology. Together with the companies Scania and Swebus, SL has now started a project with hybrid buses that are fuelled with ethanol but are propelled by electrical engines. The buses have the ability to store and recover energy that is generated when braking. This project is the first of its kind in the world.

The ethanol hybrid buses have both a conventional combustion engine that produces electricity via a generator, and an electrical motor that powers the drive-axle. When decelerating, the electrical motor acts as a generator, feeding brake-energy back to the energy storage module, which consists of supercapacitors mounted on the roof. During acceleration the stored energy is fed back to the electric motor. The ambition is to reduce fuel consumption by up to 25 percent in city traffic. The new power-train also features a step-less drive without the need for gear-changes. With this technology it is also anticipated that both drivers and travellers will experience a smoother and more comfortable ride.

NEW TECHNOLOGY AT THE NEXT BUS STOP — ELECTRIC-POWERED BUSES
Electric-powered buses may well be superior to the alternatives that are available today, provided that ‘green’ electricity is used. Apart from hydrogen, electric power is the only way to power buses with energy generated from the sun, wind and water. Already

Ethanol Buses have contributed to a reduction in diesel usage of approximately 16 million litres per year (Photo AB SL/Jan E Svensson)
today small fleets of electric buses are running in several cities around the world. SL believes that battery-powered buses will be technically and economically competitive within the next five to seven years. Once this technology is available, it may be possible for SL to introduce the first battery powered bus into operational service. For this to happen, it is critical that technical development continues as expected with regard to batteries, energy efficiency, and the weight of the vehicles.

Electrical buses have several advantages. They are energy-efficient, require less maintenance, are silent and do not release any emissions of NOx, SOx or particles. Electricity can be distributed over the existing power grid. The electricity supplier may need to upgrade the grid in order to meet the increasing demands of both public and private electric-powered transport. An infrastructure will also have to be established at each bus-depot with connection-points in each parking-bay. These infrastructure investments are believed to be relatively limited in terms of cost. SL also believes that it is reasonable to assume that electricity will be a cheaper source of energy in the long-run compared to other alternatives. There will of course be a greater demand for electricity if this is used to power transport in the future. Swedish research indicates that if every private car in Sweden were to switch overnight to 70 per cent electric power and 30 per cent other sources of energy, then the overall consumption of electricity would increase by only 7 per cent compared to the amount consumed today.

TOWARDS A SUSTAINABLE PUBLIC TRANSPORT SYSTEM
Stockholm Public Transport (SL) strongly believes that it is possible to build a sustainable transport system in the future. This is demonstrated by the high level of ambition and the willingness to test and invest in new technologies. SL continues to include challenging requirements in its procurement activities and hopes that external suppliers are willing to co-operate in the continual and ongoing transition to newer and better technologies as they become available. It is also vital that legislating bodies create foresighted, long-term policies, tax rules and legislation so that industry and vehicle users dare to take the next step.

For more information visit www.sl.se
Today, statistics indicate that 70 per cent of Swedes travel at most 50 kilometres per day. This distance can be run by an electric car on just 10 kWh using existing technology. Fortum as the grid owner in Stockholm needs to know how to meet future challenges. This is of great importance given that the existing grid is over-strained at present. For the city of Stockholm it is important to find out how to facilitate an introduction of clean vehicles in order to meet environmental challenges.

The project is also carried out in close co-operation with Test Site Sweden (TSS). The aim of this collaboration is to demonstrate technologies, methods and tools to increase knowledge about plug in hybrid vehicles and their use.

**AIMS AND GOALS**

Previous studies have indicated that alternative vehicle technologies, such as battery-electric vehicles and plug in hybrid vehicles, have a great potential to improve the environment. Today, these kind of vehicles are not yet available to the general public.
It is therefore uncertain whether or not such systems would be considered acceptable in terms of factors such as battery capacity, etc. Furthermore, there is some uncertainty regarding the changes that will be needed in the infrastructure to accommodate plug-ins.

The main goal of the MobilEL project is to demonstrate and evaluate the effectiveness and acceptance of plug in hybrid vehicles in order to achieve a number of primary transport goals. Most importantly this involves reducing negative environmental impact, and meeting the political aim to keep Stockholm as a leading clean-vehicle city.

Through demonstration it is envisaged that the project will generate knowledge regarding:

- Users appreciation and understanding of the advantages and disadvantages of plug in hybrid vehicles and the possibilities to adapt their travel needs
- Technical limitations and possibilities with full implementation (functionality, service needs, etc.)
- Environmental performance and energy consumption related to plug in hybrid vehicles

- Necessary adaptations to the infrastructure with regard to battery-charging, etc.
- Legal and safety issues
- Technical and infrastructure preconditions for a successful market introduction
- Impacts on environment and safety, but also on accessibility and transportation costs

The demonstration part of the project is seen as a learning process and a means to gain knowledge and generate objective data and factual information. Car manufacturers have stated that plug in hybrid vehicles are likely to be introduced onto the market in a couple of years. Both the city of Stockholm and Fortum need to be prepared for the anticipated growth of plug in hybrid vehicles once they are introduced on the market. Mainly for this reason, the demonstration constitutes an important tool that not only addresses the technology and infrastructure challenges, but also presents an opportunity to steer development in the intended direction.

Important knowledge will be generated in relation to ITS potential of these vehicles and how they are linked to the infrastructure, but also in relation to the different ways of assisting drivers to make smart choices.
A key aim is to extract data so that the energy flows between the different power sources can be studied and illustrated. Another aim is to obtain data on how much of the energy used is derived from petrol-powered motoring, brake-regenerated electricity and electric-powered motoring.

The logging system - ARDAQ (Argonne Real-time Data AcQuisition system) - has been developed by the Argonne National Laboratory in USA and provides onboard data collection and diagnostics for the PHEV. The ARDAQ is based on Controller Area Network (CAN) information collected on two separate CAN nodes. It is also possible to use

The technology used in the demonstration is a fully functional PHEV (Plug-In Electric Vehicle) system containing all the functionality of a future operational and market introduced PHEV with the exception of payment. The demonstration fleet consists of five Toyota Prius vehicles that are owned by Fortum and are used on a daily basis by Fortum staff.

The vehicles are equipped with a larger battery pack to increase the driving range in electric vehicle mode. The vehicles are recharged by simply being plugged into an electric socket on the wall. Vehicle batteries contain 22 NiMH-cells and are manufactured by the Swedish-American company NILAR. The system, including the software, originates from the American company Plug-in Conversions. The conversion to plug-in extends the original Toyota electricity performance at low speeds (up to 50 km/h) and makes it possible for drivers to rely more heavily on the electric motor.

For the purpose of the project, each vehicle are also equipped with a logging system. This system is continuously logging information about system performance, location and time.
GPS and simultaneously collect moment-by-moment data on vehicle performance measures (including driving and engine speed; fuel flow, use and economy; hybrid battery current; frequency of battery charge; hybrid watt-hours per mile; PHEV watt-hours per mile; and length and distance of trip).

EVALUATION

In order to address the challenges relating to the anticipated growth of plug in hybrid vehicles in Stockholm, there are a number of questions that need to be answered. One of the most important evaluation issues concerns user-reactions. There are also a great many other issues that will be investigated in this project including, for example, the demands plug in hybrid vehicles will place on the infrastructure. Questions such as these will be addressed largely through the use of practical testing.

Based on the MAESTRO guidelines for the evaluation of pilot and demonstration projects, an evaluation plan was prepared and a deductive research approach was chosen. Guided by the results from previous experiments, a number of hypotheses were put forward in the project group and experts in the field. The main purpose of this exercise was to identify the expected impacts of the project. These hypotheses have been given priority in the design of the evaluation and will be tested in the field trial. Further, an evaluation of the hypotheses will be carried out after the results have been analysed.

The hypotheses were divided into four main categories: those relating to the user (acceptance towards the PHEV); those relating to the vehicle (attitudes and system performance), those relating to the charging stations (system performance); and those relating to demonstration impacts (effects on environment, safety etc). For each specific impact/hypothesis, evaluation indicators were identified and extracted. Other evaluation indicators relating to the project objectives were also identified and formulated.

A number of different data sources will be used as a basis for the evaluation process. The data generated during the field trial will mainly emanate from: the vehicle logging system ARDAQ; survey data collected at different trial stages; and technical data about the system and its performance, etc. Survey data will be used mainly to determine user-attitudes, while the technical data will be used for a minor
technical evaluation of the system. A number of different evaluation surveys and studies will be carried out. The final results regarding users-responses to the system will be combined with the vehicle log data and other data, if needed.

A key aim in the evaluation of road-user responses is to measure how acceptance and self-reported behavior changes over time. The evaluation has therefore been designed so that the test drivers will be questioned before the trial (to establish preconceived notions); after half of the trial period has elapsed (to obtain first impressions and habits) and after the trial has finished (to get final reflections).

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Combining Eco-Driving With Intelligent Speed Adaptation

By Stefan Myhrberg, City of Stockholm

A new concept that combines Intelligent Speed Adaptation (ISA) with support for eco-driving has been implemented and is being tested by the City of Stockholm. The aim of this concept is to improve fuel-efficiency through a reduction in speeding while at the same time improving eco-driving abilities. Speeding is reduced through the use of an ISA-system installed in the vehicle, and eco-driving is improved through the presentation of feedback to the driver, before, during and after driving.

What is innovative about this project is the fact that the ISA-equipment has been specially adapted to include functionality for eco-driving. This makes it both easier and cheaper for the City of Stockholm to implement ISA and eco–driving. The goal is to reduce fuel-consumption by at least 10 percent. A corresponding reduction is also expected for CO₂ emissions. Vehicles equipped with this technology will be demonstrated and made available to delegates for a test-drive at the ITS World Congress in Stockholm 2009.

INTELLIGENT SPEED ADAPTATION
Intelligent Speed Adaptation, ISA, is a traffic safety function based on an in-vehicle device that informs the driver of the prevailing speed-limit and provides a warning if the limit is exceeded, i.e. when the driver is speeding. These systems also allow data to be logged for evaluation and feedback purposes. ISA has been tested in several projects in Sweden and abroad.
A number of municipalities and private companies have started to implement ISA in their vehicle fleets on a relatively small scale. Many others are also seriously considering the use of this technology in their vehicle fleet. The City of Stockholm has trialled ISA in 20 of its vehicles. Following the positive outcomes of this trial, the City of Stockholm has now set a target to have all vehicles driving for the City equipped with ISA before 2010. This target includes as many as 1,000 vehicles. An implementation strategy has now been agreed upon and implementation is due to commence during 2009.

Previous trials with ISA in Sweden have shown good effect with regard to a reducing speeding and improving traffic safety. The trial in Stockholm that included 20 of the City’s vehicles was conducted with the intention of increasing knowledge in relation to ISA and finding ways to improve acceptance; an important pre-requisite for future ISA implementation.

Two different kinds of ISA were tested:

- ‘Active accelerator’, generating resistance in the accelerator pedal when the speed limit has been reached
- ‘Vibrating accelerator’, generating vibrations in the accelerator pedal when the speed limit has been reached

Both types of ISA could be overridden by pushing down harder on the accelerator pedal. More than 1,500 hours of driving data were analysed as part of this trial. The results were mainly positive, both regarding the effect of ISA and the driver’s acceptance of the system. On average, ISA reduced speeding by as much as 30%. The effect was greater at higher speed limits. A major drawback was that the technology with an active or vibrating accelerator pedal involved mechanical adaptation. This made it expensive to install and maintain. Furthermore, the Swedish Motor Vehicle Inspection Authority demanded that each vehicle should undergo an inspection before being approved for road use. Based on the results of the trial, the City of Stockholm also decided to investigate an informative type of ISA-system. It was expected that this system should bring about a similar effect in relation to speeding.

IMPLEMENTATION STRATEGY FOR ISA IN STOCKHOLM
Following the Stockholm trial, an implementation strategy for all vehicles driving for the City
of Stockholm was developed. This has since been accepted by the City Council. The strategy highlighted, amongst others, the following key issues:

- **Co-operation must be established and co-ordinated with other purchasers of ISA in order to enable larger production volumes and better possibilities to include the necessary functionality at a reasonable cost per unit.**
- **The procurement of vehicles and transport services should include and specify ISA-requirements.**
- **The ISA-systems should be designed to enable data-logging, evaluation and feedback, especially in relation to the purchase of transport services from external providers.**
- **The ITS World Congress held in Stockholm 2009, should represent a driving force for implementing and demonstrating ISA in Stockholm.**
- **The possibilities to improve fuel-efficiency and reduce environmental impact through the use of ISA should be exploited as a key argument for implementing ISA.**

**IMPROVING FUEL EFFICIENCY AND REDUCING ENVIRONMENTAL IMPACT**

Previous trials indicated that ISA, by itself, could improve fuel-efficiency by several percent. It is envisaged that the new combined ISA and eco-driving concept can greatly enhance fuel-efficiency as a result of the fact that:

1. **Speeding is reduced**
2. **Vehicles are driven more economically when at or below the speed limit**

Speeding is reduced by the ISA-component. The amount of fuel saved as a result of a reduction in speeding depends on the extent of speeding before ISA is introduced and how effective the ISA system is in reducing speeding.

More economical driving can be achieved through a combination of the following:

- **Information before driving:** Incentives and information about why and how to drive more economically.
- **Information during driving:** Supportive information feedback from vehicle computer.
- **Information after driving:** Feedback to the driver and fleet management (driving data, and statistics)

The innovative part of this concept is that the ISA-equipment and organisational processes for handling drivers and driving related data is combined with eco-
driving functionality. In Sweden, education in eco-driving is said to give an initial effect in fuel-efficiency of approximately 10 per cent. It is well known, however, that the size of this effect will diminish over time. In the new concept, the possibility exists to provide both speed and eco-driving feedback to remind the driver while the vehicle is being driven. Together with the increase in fuel-efficiency, and as a result of reduced speeding, it is envisaged that an overall saving of at least 10 per cent can be achieved.

IMPLEMENTATION CONCEPT
As part of the implementation strategy, the eco-driving concept will be added to the already planned ISA-implementation. This makes it possible to use the same hardware, the same data-handling functions, and the same organisational processes. Earlier ISA-projects have shown that the possibility of improving fuel-efficiency and thereby saving on fuel costs is a very important argument for choosing to implement ISA, especially for transport and logistics companies. By combining ISA with support for eco-driving, the costs for implementation and maintenance can also be reduced. It is important to note that this new concept is based on an advisory ISA system. This is due to the fact that a system that totally prevents speeding is less likely to be accepted by drivers, and would also be more costly and difficult to implement with regard to the technology and may also have safety implications.

TECHNICAL CONCEPT
The technical concept of the system is based on a chosen ISA-system hardware architecture. In effect this means that the GPS-data that is logged will be used to assess both speeding and eco-driving behaviour. In order to be able to calibrate the models used for analysis and to obtain a baseline for comparison, actual fuel-consumption feedback information will be added to the system first during the after-analysis period.

EcoISA-system in vehicle
Sweden has been a pioneer in the field of Intelligent Speed Adaptation. A large-scale field trial was conducted between 1999 and 2002, which involved 5,000 equipped vehicles and more than 10,000 drivers. This trial was extensively evaluated. The main findings were:

- Better road safety without increasing travel-time
- If everyone had ISA, there could be 20% fewer road injuries in urban areas
- Drivers showed a high level of acceptance for ISA. After the trial most test drivers were of the opinion that ISA should be made compulsory in urban areas
- ISA vehicles were found to have a positive influence on surrounding traffic
- There are minor differences between different types of ISA-systems, with an overall average speed reduction of 3-4 km/h on stretches of road between intersections
- The systems must be improved to become more attractive.

Based on these results, various goals and a strategy for implementation were presented (several years ago) by the Swedish Road Administration. The key issues were:

- Provide quality assured speed data on the state and municipal road network across Sweden. In 2007, leading market players (content providers) will be handling speeds from the National Road Database (NVDB).
- The SRA and other parties, such as city municipalities, transport purchasers and transport providers, shall introduce support systems for speed compliance or similar systems in their own and leased vehicles as new vehicles are acquired.
- At least three suppliers of vehicle equipment should offer support systems for speed adaptation to commercial vehicles by 2007.
- Cross-border ISA on a selected number of Nordic corridors will be shown by 2009 at the latest.

Many of these goals have been achieved. Today there are several ISA-suppliers, and many organisations have implemented speed alert systems in their vehicle fleets. It is estimated that there are in total approximately 3,000-4,000 implemented ISA units.

Work is in progress today to find ISA-solutions for private drivers. ISA could, for example, be integrated as a function in a vehicle navigation system or as software in a mobile phone, or at some later stage integrated as a function in all new vehicles.
was already decided to implement the ISA system, the opportunity presented itself to test a first version of the combined ISA and eco-driving system. This new concept is not expected to reach its full potential with regard to fuel-efficiency. This is due to the fact that the ISA-system will be advisory rather than intervening in order to achieve a good level of driver acceptance. The main focus is instead on an initial introduction of the fuel-efficiency concept while implementing ISA.

Compared to many other system functionalities that have been implemented for ISA and eco-driving, a key strength of the new concept presented here is that there is an advanced data-logging capacity that allows all data to be stored in a central server. This enables the development and application of various types of organisational schemes that can be used to help promote safe and economical driving. These can also be enhanced by education and incentive schemes or other measures.

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Sustainable Vehicle Fuel – Biogas From Organic Waste And Sewage

By Daina Millers-Dalsjö & Karin Eberle, Sweco

The production of biogas was first introduced in Stockholm in 1934. At this time the treatment of municipal waste-water involved the anaerobic digestion of sludge. Since then complex and demanding European and Swedish environmental targets have evolved. Biogas development is today very rapid in Sweden. Stockholm is one of the most expansive areas in the world for the utilization of renewable fuels for district heating, power generation and for vehicles. The demand for biogas as a fuel for vehicles is now greater than the available supply. The synergies between waste-water treatment, waste-handling and energy demand from the transport sector have been the main driver for biogas development in Stockholm. The City of Stockholm is highly committed to the use of this renewable fuel. It is envisaged that, within a few years, all vehicles working for the City will be ‘green’-vehicles and that the public transport system will run entirely on renewable fuels.

ENVIRONMENTAL GOALS
Climate-change is one of the main drivers for the development of biogas as a renewable source of energy. The International Panel on Climate Change (IPCC) has estimated that temperatures must not be allowed to rise more than two degrees above pre-industrial levels. This is also the basis for the European Union (EU) climate policy objectives. EU plays an active role in the international negotiations on broad climate agreements. The new Directive of renewable energy sets ambitious targets that are to be met by year 2020:

The Eco-Cycle - Sustainability synergies for wastewater, energy and waste.
Source: Sweco
• To increase the proportion of renewable energy to 20%.
• To increase the proportion of renewable fuels in the transport sector to 10%.
• To increase the efficiency of energy use by 20%.

The Directive improves the legal framework for promoting renewable electricity and it requires national action plans that establish pathways for the development of renewable energy sources including bio-energy. It also develops co-operation mechanisms to help achieve the targets cost-effectively and establishes the sustainability criteria for bio-fuels. The new Directive should be implemented by Member States early in 2010.

In Sweden the national target is set even higher. Here, the share of renewable energy sources shall amount to 49% of the gross final consumption of energy by the year 2020.

Swedish legislation also sets higher targets than EU for waste-management. An example is the EC Landfill Directive. In Sweden, legislation was introduced in January 2005 forbidding deposits of organic waste as landfill. As a result, organic waste is either combusted in large-scale incinerators for power generation, or biologically treated for the production of biogas and/or organic fertilizer.

Some of Sweden’s 16 national environmental objectives directly address the recovery of organic waste and plant nutrients: “By 2010, at least 35 weight-% of food waste from households, restaurants, caterers and retail premises (municipal solid waste) will be recovered by means of biological treatment....”

“By 2010, food waste and similar wastes from food processing plants etc. will be recovered by means of biological treatment. This target relates to waste that is not mixed with other wastes and that is of such quality as to be suitable, following treatment, for recycling into crop production”.

Apart from the regulatory framework, there are several economic incentives to stimulate the transition from fossil to renewable fuels at both the national and municipal level. An example of this is the exemption of eco-vehicles from traffic congestion tax during rush hours in Stockholm. These vehicles are also subject to special investment grants and reduced energy tax, as well as free parking.

WHAT IS BIOGAS?
Biogas consists of mainly
methane ($\text{CH}_4$) and carbon dioxide ($\text{CO}_2$). Biogas is produced when organic matter is bio-degraded anaerobically, i.e. without access to oxygen. This is a natural process performed by anaerobic bacteria that already exist in the organic material. If there is access to oxygen, then composting, i.e. aerobic digestion, will take place instead.

The formation of biogas can be found in nature in, for example, swamps, bogs and cattle intestines. Examples of anthropogenic sources include, landfills, rice fields and open storages of manure. Proportionately, methane is a strong greenhouse gas being 24 times more more powerful than carbon dioxide. It is also flammable and can cause fires and explosions in landfills under certain conditions. This is one important reason why it is important to extract the biogas for combustion. Today, biogas is regarded as a renewable fuel. Purified biogas contains mainly methane, just like natural gas (CNG).

**WHY BIOGAS?**

In Sweden, anaerobic digestion has been applied to reduce waste-water treatment sludge volumes for decades. The resulting biogas was used mainly within the treatment plants to provide heat. In larger plants, gas turbines were installed that could generate electricity, the main focus was, however, still on the treatment of waste-water.

The municipal waste sector was interested in recycling food-waste to recover plant nutrients, but also in reducing the need for landfill space. In the 1970’s, the solution involved the composting of rather contaminated and centrally separated bio-degradable wastes. The composting process often caused emissions and odour problems. The equipment and practices also needed a lot of space and energy input, and the final product was a fertilizer of poor quality with no real market value.

Ten years later, people were becoming more environmentally aware and a ‘separation at source’ concept was being slowly introduced for household waste. Recyclables and hazardous components such as batteries could be sorted out before the composting of municipal waste and the quality of the produced soil was considerably improved. With increasing interest in energy aspects and hygienisation, the anaerobic digestion of separated food waste became an interesting prospect. When comparing anaerobic digestion with composting for 1 kg of inert sugar (an organic matter), the energy
In the mid 1990’s, the City of Stockholm started a project to promote the uptake of ‘Green vehicles’ (the Swedish title of the project was ‘Miljöbilar i Stockholm’). These vehicles were intended primarily for the City administration’s own use. A variety of green fuels were included in the scope of this project as was their distribution. The three municipal companies in water supply and sanitation, and energy and waste management, were involved in the development of the platform for today’s commercial setting.

Today, biogas is considered to be one of the most environmental friendly vehicle fuels on the market. It is even regarded as the best choice by the Swedish Board of Agriculture. Biogas is a renewable fuel and can be produced from basically any organic waste from, for example, the food industry or agricultural residues. A biogas engine is less noisy than a diesel engine and the combustion of biogas emits no hazardous exhaust fumes. In cities where there are many vehicles running on biogas, the total emissions of nitrogen oxides (NO\textsubscript{x}), hydrocarbons, carbon monoxide and dust have been noticeably reduced. Furthermore, air quality has been significantly improved.

**BIOGAS — CREATING SYNERGIES IN THE PUBLIC SECTOR**

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**BIOGAS FROM WASTE WATER**

The waste-water treatment plants in Åkeshov/Bromma and Henriksdal are both owned and operated by the municipal company ‘Stockholm Vatten’. These plants treat waste water from over 1 million people in the Stockholm area. The water treatment process generates a bi-sludge that can be anaerobically digested to produce biogas. Originally, the biogas was used within the treatment plants to provide heat for the water treatment process. Some of the biogas was also sold to a local power plant for district heating. Later, it was realized that the biogas could also be utilized as a pollution-free vehicle fuel.

The waste-water treatment plants were therefore upgraded and a distribution technology was developed for purified biomethane (compressed biogas, CBG). Following this, investments were made in a pilot fleet of biogas vehicles. In 2008, the waste-water treatment plants produced 6.5 million Nm$^3$ of CBG. This was distributed mainly to taxis, waste-collection trucks, city buses and private vehicles in the Stockholm area.

**BIOGAS FROM MUNICIPAL WASTE**

The municipal solid waste from households, retailers, restaurants, canteens, etc. contains about 35 weight-% of food-waste. In Stockholm County, it has been estimated that it would be economically viable to process some 100,000 tons of organic waste per year. This would correspond to a biogas yield of approximately 70 GWh.

There are two main alternatives currently under investigation (2009):

1. *Separate collection of food-waste in bins from households, restaurants, etc.*

**BENEFITS FROM WASTE-WATER TREATMENT PLANT GENERATED BIOGAS IN STOCKHOLM IN 2008**

- The capacity generated was 10 million Nm$^3$ biogas ⇒ 6.5 million Normal Cubic Metre (Nm$^3$) Compressed BioGas (CBG) ⇔ 62 million kWh = 62 GW-h per year.
- This energy is equivalent to 6,225,000 litres of diesel per year.
- Potential savings in CO$_2$-equivalent emissions amount to ~16,000 tonnes per year.
with central pre-treatment and input directly into the anaerobic digester at a waste-water treatment plant or external treatment plant.

2. Separate collection of food-waste in bins, with central pre-treatment and use of a separate pipe in the waste-water tunnel for pumping thick food waste slurry to the anaerobic digestion area at a waste-water treatment plant.

Another option for part of the food-waste from households is to use a food-waste disposer connected directly to a waste-water pipe. This would involve a process of application and approval by the municipal water company ‘Stockholm Vatten’. This is a limited solution for those parts of the city where pipe-conditions are favourable.

There are also other options available, for example, a connection to a waste-water pipe via a ‘fat and sludge trap’ that separates heavy particles, or a closed tank for ground food-waste that is transported directly by vehicle to the anaerobic digestion section of a waste-water treatment plant or external treatment plant.

**BIOGAS DISTRIBUTION**

Biogas can be distributed through natural gas grids, pipelines or by pressurized gas bottles. The Stockholm area has no grid for natural gas. Hence, the use of
purified and compressed biogas (CBG) as vehicle fuel has made it necessary to develop a “stand-alone” storage, back-up and distribution system. Biogas is mainly distributed on trailers in pressurized gas containers from the purification plants to filling stations. The gas containers are filled with biogas at a pressure of approximately 200 bar. The filled containers are then transported to a filling station and any empty containers are collected. A more unusual method involves emptying the containers on the truck into a stationary set of containers at the filling station.

Next year in 2010, bio-methane will be distributed by pipeline from the waste-water treatment plant run by the ‘Käppala Association’ directly to Stockholm Public Transport (SL). The gas will be distributed at 4-10 bar and will be transferred directly to SL’s bus depots. This will ensure a safe and stable supply for public transport and will help SL achieve their environmental targets.

Bio-methane that is to be used as vehicle fuel is pressurised after distribution and stored at a pressure of approximately 200-250 bar. The filling pressure for fuelling vehicles has a maximum limit of 230 bar.

**DOES BIOGAS HAVE A FUTURE?**

Biogas already has a long history in Sweden, but until recently it was only used for heating purposes. The relatively low cost of electricity in Sweden means that it is not economically profitable to generate electricity from biogas, although this could be possible in the future. At present, the most interesting development concerns the use of biogas as an environmentally friendly and renewable vehicle fuel.

During 2009, one of the largest biogas producers (‘Fordonsgas Sverige AB’) has for the first time received the Nordic Ecolabel for its renewable and environmentally-friendly biogas fuel.

Today, the demand for biogas fuel for vehicles is higher than the supply in the Stockholm region. The interest in bio-methane powered vehicles is also increasing. There are approximately 15,000 Swedish cars and buses using methane at present which represents an increase of around 60% during the past few years. By the end of 2008, there were more than 70,000 ‘Green vehicles’ registered in the Stockholm County area. Included in this number are approximately 3,700 passenger cars that can run on biogas or petrol (‘bi-fuel’ cars),
County (‘Himmerfjärdsverket’ and ‘Käppalaverket’) are planning to upgrade biogas to bio-methane as vehicle fuel. This will be mainly used for public transport buses. They are also preparing to receive more organic material, such as food waste to generate bio-methane. Following these upgrades, the total biogas volume from the four waste-water treatment plants in Stockholm and approximately 130 heavy vehicles that run on biogas, these are mainly local buses and waste-collection vehicles. One of the City of Stockholm’s targets is that all vehicles working for them should be ‘Green’ by 2025 (50% ‘Green vehicles’ by 2011).

A further two large waste-water treatment plants in Stockholm County (‘Himmerfjärdsverket’ and ‘Käppalaverket’) are planning to upgrade biogas to bio-methane as vehicle fuel. This will be mainly used for public transport buses. They are also preparing to receive more organic material, such as food waste to generate bio-methane. Following these upgrades, the total biogas volume from the four waste-water treatment plants in Stockholm and approximately 130 heavy vehicles that run on biogas, these are mainly local buses and waste-collection vehicles. One of the City of Stockholm’s targets is that all vehicles working for them should be ‘Green’ by 2025 (50% ‘Green vehicles’ by 2011).

FACTS ABOUT STOCKHOLM PUBLIC TRANSPORT’S (SL) BIOGAS BUSES (THREE AXLES ARTICULATED), 2008.

- SL has approximately 80 buses running on CBG, the majority of these operate in the inner-city area.
- By the end of 2009, the number of CBG buses will have increased to around 110.
- In 2008, SL used 1.82 Million Nm³ CBG (approximately 28% of the total production in Stockholm).

A further two large waste-water treatment plants in Stockholm
There is another potential source that remains unutilized for the purposes of increasing biogas production, municipal food-waste. Biogas production from this type of waste in the Stockholm area could reach more than 200 GW-hours per year. This amount is equivalent to 20,000 m$^3$ of fossil diesel and would bring an estimated reduction of CO$_2$-equivalent emissions from the transport sector of 55,000 tons.

The increased production of upgraded biogas must be closely matched by a controlled expansion of the biogas vehicle fleet and distribution system that makes this fuel accessible at filling stations. One of the biggest challenges is to recycle high-quality plant nutrients from the anaerobic digestion process back to arable land.

The long-term objective is not only to reduce emissions of CO$_2$-equivalents, but also to enhance sustainability and improve the environmental performance of important public services.

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Regardless of how energy efficient and climate friendly a mode of transport is, the ultimate goal must be to eliminate unnecessary transport and to make maximal use of the capacity that is available in the existing system. Efficient logistics can help achieve these fundamental goals. In this section, two examples of urban goods distribution are provided that shows how collaboration, even between competitive suppliers, can bring about reductions in transport demand in order to achieve environmental goals. In both cases, substantial organisational and planning work is required to achieve these targets – brain power is in itself replacing transport fuels!
Aftonbladet and Expressen, two of the biggest newspapers in Sweden, have jointly invested in a new route optimisation system for distribution. By using the system their distribution departments have been able to save 53,200 kilograms of CO$_2$ annually (equivalent to 30 homes) and the numbers are rising. Further benefits include reduced costs and increased internal and external efficiency.

The newspapers’ new route optimisation system is a tailored web solution developed by Sweco based on the route optimisation engine Logix IE.

**BACKGROUND**

Aftonbladet and Expressen are competitors in the newspaper business but their transport departments are a good example of fruitful co-opetition. In most parts of Sweden they share a common distribution network, which runs from printing presses to 12,000 retailers located all over Sweden. There are around 500 routes which remain the same each day of the week (including weekends). This complex network was previously managed using paper maps and simple lists until Aftonbladet and Expressen decided to jointly invest in a route optimisation system to fulfil their shared vision.

**VISION**

Aftonbladet and Expressen had several reasons for investing in a route optimisation system, the most important of which was cost. By improving route planning, fewer cars would be required to drive less mileage thereby cutting costs, particularly when recruiting...
was decided that the new contracts would be awarded using new routes optimized by Sweco (using the route optimisation program Plan-Logix). Under the previous system retailers in Sundsvall received their newspapers from four vehicles working a total of 9.5 hours. The goal of the pilot was therefore to make the current delivery system more efficient.

The process of simulation and optimisation was complex and iterative. A significant amount of input data had to be collected. Aftonbladet and Expressen were able to collect high quality data regarding the exact time of delivery to each retailer, including which vehicle was involved. Based on this information Sweco were able to simulate the routes in Plan-Logix, for the purposes of calibrating the system. Once the simulation was providing the same results as the input data suggested, the parameters that controlled which car delivered to which retailer were removed allowing the program to optimize more freely. Optimisation was performed iteratively. Following each iteration, comments and adjustments were made by staff at the route planning department. This input was then fed back into the program and the routes re-calculated. This was also the embryo to a formalised work

**THE PILOT TEST**

Despite having quite a detailed vision there was still many options available. It was therefore jointly decided to assess the various possibilities and potential savings by conducting a pilot test with a proof of concept.

The main focus of the pilot was to test the technology in a representative environment such that scaling-up would provide realistic estimates. Furthermore it was important that the trial be self-sufficient and that the three organisations involved collaborated effectively.

Sundsvall was chosen as a representative area in Sweden, partly because at the time of the trial delivery contracts were in the process of being renewed. It
process that would later be used as a guideline to the tailored web system.

The results of the proof of concept pilot were nothing but impressive. The number of cars used in Sundsvall was reduced from four to three while the work time and driving distance were reduced by 10%. When the results were up scaled to a nationwide perspective it became obvious that there were huge potential savings to be had for both newspapers. Estimates also showed that, in Sundsvall alone, CO$_2$ emissions could be reduced by as much as 2800 kilograms annually. At a national level the estimated reductions in CO$_2$ would be huge.

**TECHNICAL SOLUTION**

Aftonbladet’s and Expressen’s tailored route optimisation system is unique. It is integrated into their IT environment and connected to their strategic business systems. The business system holds information about their retailers, and the road network database which is connected to Logix IE – the integrated black box which contains the mathematical formulas to solve routing queries.

During the early requirements and specification stage of the project it became obvious that it was not going to be possible to use any existing off-the-shelf routing software. This was partly due to the complexity of such software but also because of the user interface and cooperative requirements that the two newspapers had. Consequently Sweco devised a system that employed the Logix IE routing engine through a simple and user-friendly web interface, this was fully integrated with the working processes of the planning and delivery departments. Text files used for specifying settings were converted into web forms with drop down lists which meant that more advanced settings could be implemented without making the interface more complex. The input could be collected from the existing core data systems for the two papers, and the results could be exported back into these systems to provide an excellent base for analysis and redesign of data.

The level of innovation required during system design required a very flexible and dynamic development process. To reduce uncertainty in the design process a number of standard components were chosen to form the foundation of the new system. An SQL Server was used as an intermediate data store between the core data systems and the
routing system. Microsoft’s MapPoint Web Service was used to display maps whilst their .NET platform served as the base for development. The small development team worked with the latest SCRUM methods to keep flexibility and dynamism high during the development process.

Logix IE supplied the core functionality in the system, but the software was not originally designed for the kind of multi user, asynchronous system design that a web solution usually consists of. A specialised queue manager function was developed to ensure that the web server did not get stuck in lengthy routing queries. The queue manager allowed jobs to be added to the queue and enabled the polling of job results. The queuing system was designed to run in its own thread, in parallel with other processes, making the system stable and reliable.

One of the key factors for success for the project was the common working processes employed by Aftonbladet and Expressen. However individual technical requirements meant that each organisation would require its own tailored installation of the software. This led to a number of technical challenges as unique functionality had to be provided at each newspaper, without creating two branches of code.

As stated earlier, Aftonbladet’s and Expressen’s tailored route optimisation system is truly unique.

**EFFECTS**
In September 2009 the system had been in use for more than a year with results from the first 12 months confirming the assumptions made in the pilot. After optimising twelve more regions, roughly the size of Sundsvall, the number of cars in use has been reduced from 78 to 59. This increase in efficiency has led to an annual CO2 reduction of 53,200 kilograms.

Other tangible benefits include a more streamlined and effective distribution department with
optimisation efforts addressing 78 of the existing fleets 500 vehicles resulted in a 24% reduction in the number of vehicles used. This implies that Aftonbladet and Expressen can remove more than 100 delivery vehicles daily from the road network.

AN EXAMPLE OF GREEN ITS
This example of green ITS is now spreading rapidly in Sweden. The financial and environmental benefits of route optimisation are tangible and easy to communicate. Many people are appreciative of the environmental efforts being made by Aftonbladet and Expressen. Other organisations now regard Aftonbladet and Expressen as leading companies using route optimisation and others are trying to learn how to implement something similar in their businesses.

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easy access to key indicators related to business performance. Aftonbladets Distribution Manager concludes:

Now it is easy for us to get an overview of our distribution as well as getting details about routes and retailers. Except for using the system to make new, more efficient plans using the optimisation tools, we also use it when new retailers want to join into our existing distribution network.

Future efforts envisage even greater economic and environmental benefits. Planned optimisation includes the rest of Stockholm city, other urban centres and rural areas. Initial
Efficient logistics in the Old Town of Stockholm

Editorial

INTRODUCTION
The Old Town of Stockholm is located on an island. The town structure is medieval with small and narrow streets that are today only used for pedestrian access. Many of the buildings date back to the 16th century. The Old Town is a popular area for tourists visiting Stockholm. It is also one of the oldest medieval town centres in Europe.

Business in the Old Town is dominated by tourism which explains the many restaurants, hotels and shops located in this area. Many companies are located in small and relatively unsuitable buildings with very little storage space. This means that restaurants and hotels require frequent deliveries of food. During delivery hours it is easy for traffic blockages to occur in the narrow streets and it is often impossible for delivery trucks to pass other vehicles in the one-way alleys.

The environmental impact is considerable. Apart from the carbon dioxide emissions, deliveries also cause pollution that erodes the beautiful décor of the buildings and gives rise to vibrations that shake and disrupt structures in this sensitive area. Noise is also a problem as is safety where vehicles on small narrow streets represent a potential safety hazard.

HOW IT ALL STARTED
The Old Town engages many local people and organisations. Discussions about the district’s history and future have continued for years. An important concern is traffic as this is known to be associated with environmental, health and traffic safety issues. The issue of private cars has

Due to the small and narrow streets it is difficult delivering goods in the Old Town.
(Photo Göran Sehlstedt)
always been tricky and there have been difficulties reaching a consensus due to the fact that some consider a private car to be a basic democratic right while others want to make the area pedestrian-only.

The issue of goods transportation has been less controversial which is why it has been easier to discuss different strategies. In the last ten years there has been a consensus among local inhabitants that a solution might be to find a premises close to the district that could be used for unloading goods. The goods could then be packed in a smart way from a logistics perspective and then delivered using small and environmentally friendly vehicles. The problems facing this solution have been to find the right premises and a company willing to do take responsibility for this concept. Eventually, the logistics company ‘Home2You’, undertook the challenge to develop a system of smarter deliveries in the Old Town.

In 2002, Home2You joined forces with the local Agenda 21 group and the Environment and Health Administration of Stockholm to start a project involving the consolidation of goods to the Old Town in Stockholm. All financing came exclusively from Home2You with the exception of a small contribution from the EU-project Trendsetter to cover measurements, meetings and reports.

**BUSINESS CONCEPT AND CHALLENGES**

Home2You’s business concept offers restaurants, hotels and other companies smarter deliveries through a consolidation of goods. The Logistics Centre (LC) co-ordinates and provides a co-transportation of goods within the Old Town. The business concept meets the demands for on-time and coordinated deliveries while at the same time reducing travel (and therefore also emissions, vibrations and noise) in the most optimal way.

It is not unusual that traffic blockage occur in the narrow streets. (Photo Göran Sehlstedt)
Starting a consolidated goods business is coupled with a range of critical issues. From a financial perspective logistics centres tend to be profitable only when a critical mass of users/customers is reached. In some cases this can take time. Laws and regulations can also cause problems and delays when logistics centres are established and put into operation. Further, anti-trust regulations can cause problems along with special delivery circumstances and obtaining permits for food deliveries. Initially, the logistic centres decided to focus on restaurants as these provide the best possibilities for improvement, due to the large number of deliveries and the relatively low number of suppliers.

Restaurants and other businesses that receive goods often experience difficulties when unloading many daily deliveries. Therefore they normally welcome a system with fewer deliveries. In spite of the advantages of more efficient

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**GENERAL PROBLEMS**

The following issues are common problems for all projects related to the consolidation of freight transport:

- The power of customer relations: with consolidated transports, the delivery company can lose (valuable) contact with their customer
- Tradition and values
- Attitudes towards change
- Insufficient support and information
- Dependence on a key person that is the driving force
- Drivers may perform value added services
- Special time windows, and orders with short-term advanced planning
- Variations in delivery frequency for different types of goods
- Cost reduction demands and large volumes (critical mass – hard to reach in a pilot project)
- Competition hinders co-operation
- Suppliers are bound to certain transport companies/distributors
- Purchase organisations are multi-facetted and are controlled by many parameters
- Deliveries and receiving
- Senders’ loading areas
- Logistics companies/transport companies are already co-ordinating transports (DHL, Schenker etc.)
- Difficulties in handling mixed goods
deliveries, companies are not always willing to pay extra for this service. Small delivery companies normally do not coordinate their driving or deliveries with each other. Reasons for this are, for example, that suppliers prefer to keep daily contact with their customers, they are also unwilling to co-operate with competitors.

**CRITICAL YEARS OF THE LOGISTICS CENTRE**

Initially Home2You experienced difficulties in finding a suitable building near the Old Town. Another challenge was to fully understand the business structure in the area and to define a concept to offer.

During the summer of 2003, Home2You took over a building along ‘Söder Mälarstrand’ that was well-suited to the business concept. A logistics centre (LC) was established at this address and the delivery company began offering services to restaurants and hotels in the area. At the same time an electric vehicle was purchased and a survey was made of the business structure in the area. A driver was employed in early 2004 with the sole purpose of delivering goods from this terminal.

In summer 2004, 14 customers used the LC for the consolidation of goods to their restaurants.

In November, the number of customers had increased to approximately 30-35. At this stage, it was found that in order to offer high quality service the business had to improve in several ways. This included the ability to keep food cold and to employ permanent staff between 6 a.m. and 3 p.m. Marketing campaigns were also required in order to attract more customers. Restaurants, hotels, shops and the Royal Castle were identified as target groups for marketing activities.

New measures were introduced in January 2004. A marketing campaign and the inauguration of the reconstructed terminal and introduction of a clean (biogas) vehicle occurred in mid-June. The operation of the terminal began in June, but introducing the LC to the customers takes time. Before the companies are able to make decisions on whether they should become customers of the LC, they need to review the advantages and disadvantages in relation to; costs (higher or lower), marketing possibilities (better or worse), and the threat of rival companies, etc. This analysis was made within each organisation, which took time.

In the Old Town there are restrictions on driving-hours. It is prohibited to drive in the area...
between 11 a.m. and 4 p.m. An application for exemption from this restriction was made in July 2004. The reason was that it is difficult to reach all customers before 11 a.m. The application for exemption was accepted in January 2005 and gave the LC vehicle permission to drive in the area until 4 p.m. The exemption was valid until 31 December 2005.

TECHNOLOGY AND INNOVATION
While there are no new technologies used in the Old Town logistics centre project, there are many new ways in which existing technologies are used. Previously, there was no consolidation of restaurant supplies in the Old Town and therefore establishing a logistics centre was, in itself, highly innovative. Trying to find methods for consolidating other types of goods, for example, those that are returned, was another innovative aspect.

The first vehicle that was used was electric. Today, a biogas-powered vehicle is used. A problem with the biogas vehicle was that the top that was too small. The refrigerating unit normally used in a delivery truck is run by diesel which causes both noise and emissions. In order to try and find a more environmentally friendly solution, contact was made with the Royal Institute of Technology (RIT) in Stockholm who are investigating techniques using natural refrigerants connected to batteries. RIT are interested in finding users who can test their technology in real life, so collaboration between real-world users and research is one result of this project.

The eco-labelling organisation in Sweden, ‘Bra Miljöval’ (which literally translated means ‘Good Environmental Choice’) invited this project to be a part of their new scheme for an eco-labelling of freight transport. The biogas-vehicle used qualified for this labelling. The label is assigned to products and services that comply with high-environmental demands. ‘Bra Miljöval’ is Sweden’s largest independent environmental organisation.

POSITIVE RESULTS
Overall the first phase of the project, which ended in 2005, gave promising results. A total of nine trips per day were saved which corresponded to 6 km. There is potential to reduce the number of vehicle kilometres further if the LC can attract more customers. A further reduction of traffic in the Old Town of Stockholm generates positive effects on the environment as well as improving the quality of living for inhabitants. The possibilities to
engage more customers in the area with marketing campaigns and the dissemination of positive results are considered to be good. One possible marketing initiative could be for customers to put up a sign on the front door to advertise the fact that they contribute to a better urban environment by only using the logistics centre for deliveries.

The investment costs for Home2You were high. There was no financial support from the City of Stockholm as the project was to be self-financing at the outset. Home2You now has a general interest in being a part of tomorrow’s logistics and market. There is also an interest in transforming Home2You into a sustainable company. The project has given Home2You some positive economical effects as well as goodwill, new customers, and perhaps some good marketing.

The City has shown interest in the Home2You LC as a good example of a local solution in the city. Many local political bodies and officials have also expressed their approval and admiration for the project. Furthermore, many local organisations are pleased with the project. To them the LC has become a symbol that exemplifies the possibility to make a difference.

**USEFUL EXPERIENCE FROM THIS PROJECT**

There are many lessons that can be learned from this project which could be useful when starting up similar projects in the future. The Old Town in Stockholm is a typical medieval city centre which can be found in many European cities. If a working system is developed, the concept may well be introduced in many other cities around Europe.

A key recommendation of this project is that a logistic centre is more efficient and successful when the geographical area is well defined (The Old Town is situated on a small island) and when there are identifiable problems.

The biggest motivator in the project has been the interest from other groups. This includes locals, politicians and officials, but also the media. All are convinced that the ‘LC model’ is a model for the future. A strong and dedicated leading spokesman is needed for a project of this nature. Another important aspect is that the company, Home2You, has a genuine interest in the consolidation of goods as well as environmental issues. This explains why the project has continued after 2005 in spite of the fact that the LC wasn’t commercially viable.
The biggest barriers in this project have been the lack of customer demand and involvement. There has also been lack of overarching knowledge and interest from different bodies and a lack of flexibility when it comes to testing new technologies and logistics concepts.

**WHAT HAS HAPPENED SINCE 2005?**

Formally the project on consolidation of goods in the Old Town of Stockholm ended in 2005 but the business continued after then. From a follow up made in May 2009 it was found that there are still much to be done before considering the LC as an ordinary business.

Initially, one critical issue for the company was the access restriction for vehicles in the Old Town of Stockholm between 11 p.m. and 4 a.m. The Home2You received a permission from the City of Stockholm to drive all times during the project (until 2005). The permission has become permanent as a result of their environmental profile; efficient logistics and use of biogas vehicles.

The LC has gradually gained more customers since 2005 but is still not profitable. A big problem seems to be convincing customers to pay extra for the service. However, the company is optimistic about the future and is seeking new customers in the Old Town as well as in neighbouring areas in order to become viable in the long-term.

Another problem to overcome seems to be that the suppliers are unwilling to let deliveries be made by a third party.

Today the logistics centre employs 11 people and has 10 vehicles, 4 of which run on biogas

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For more information visit http://www.trendsetter-europe.org
ITS solutions are a necessary part of dealing with the rising demand for mobility and problems with increasing traffic. With existing technologies, a lot can be done today with the right support from legislation as well as from committed politicians and other decision-makers. In the longer term a large shift towards a more sustainable development of the transport system is necessary. Sweden has a good chance to become a world-leader by developing and demonstrating good practices and newer and greener ITS technologies that provide environmental benefits and new business opportunities.

Today’s society is characterised by rapid change, with much of what we want to do requiring a good level of mobility for people and goods. With this increasing need for travel and transportation, an efficient transport system is crucial, both for our everyday life and for the economic development of our society. At the same time, transport within the EU accounts for one-fifth of all greenhouse gas emissions. In Sweden, where we have managed to reduce emissions from other sectors of society, transport contributes nearly one third of all emissions, and this proportion is increasing.

ITS development has so far not been driven by environmental demands, but the challenge of reducing climate impact is now becoming an increasingly important driver for innovation and new incentives in the field. The challenge is to develop Green ITS and enable different measures that help reconcile economic growth with a sustainable
transport system. At the same time, technical solutions are not sufficient on their own. There is also a need to change behaviour and attitudes among individuals and decision-makers, thereby setting the arena for future transportation. This goes hand in hand with adopting legal systems and policies that promote a more sustainable transport system. Environmentally-oriented ITS have the potential to offer more energy efficient transportation, better use of the infrastructure and reduced emissions of greenhouse gases. Various ITS solutions can reduce carbon dioxide emissions by as much as 25 percent, according to ERTICO – ITS Europe, and other actors[1]. Moreover, these solutions have the potential to
new vehicle technology, measures are needed for improving traffic management and adjusting the infrastructure; increasing the use and availability of alternative fuels; changing driving behaviour; influencing consumer demand through taxation; and enabling an integrated and seamless access to all modes of transport – both private and public. This requires

bring about other environmental benefits, such as a reduction in pollutants and noise. The efficient transportation of both people and goods also represents a major socio-economic gain.

Developing and enabling new ITS solutions demands the involvement of a wide range of relevant stakeholders. Besides
collaboration, where VINNOVA can serve as the enabler of Green ITS activities together with the different governmental agencies responsible for transportation.

**HOW CAN ITS CONTRIBUTE TODAY?**

Much is underway in the field of environmentally-oriented ITS. The examples provided in this guide have implications for the driver/traveller, as well as for actors managing traffic and transport. There are many technological solutions available, and “low-hanging fruit” can, if enabled today or in the near future, start a shift toward a more climate-efficient transport system.

Most Green ITS solutions can be found under the category of the driver/traveller perspective. Efforts can change travel behaviour and thus have a major potential to reduce carbon dioxide emissions, but in the current situation the utilisation rate is low. Actions targeted at the control of traffic and transport can have a substantial impact since such efforts will reach many users. On the other hand, carbon dioxide savings are not always so great as they streamline behaviour rather than changing it.

Low hanging fruit includes, amongst other things, different types of measures that save energy and provide more efficient transportation, e.g. eco-driving systems and route-optimisation. There is also development in terms of packaging and product design, which allows trucks and other transportation vehicles to be used more efficiently. In these examples, as is often the case, environmental and economic gain goes hand in hand, creating a strong incentive for users. Also needed are incentives in the form of legislation and policy decisions, for limiting traffic through different types of zones and charges. These might be environmental zones or access zones of various kinds.

Obstacles for the use of already known techniques are often of an organisational nature. Another obstacle is represented by users, who find it difficult to change ingrained habits and patterns. Here different incentives and more knowledge about consumer behaviour are needed in order for measures to have a greater impact.

**CHALLENGES IN THE LONGER TERM**

In the longer term there is a need for a shift toward a more sustainable transport system. The aim is to create future products and services and to use Green ITS for efficient and environmentally sound travel and goods transportation.
receives its data via various types of sensors, but also from vehicles that can act as gauges of the traffic situation (speeds, emissions, road conditions). Traffic-data service-providers can have agreements with individual drivers and fleet owners for conveying the latest information to these systems automatically.

Tomorrow’s goods transport can be based on advanced planning and information flows. This enables seamless transport with effective hubs for both national and international traffic. With standardised solutions for the interface between different modes of transport and vehicles, as well a new infrastructure of distribution centres and storage facilities – more climate-effective transportation is possible.

Activities in line with this include the concept of Green Corridors, where logistics companies and their customers, manufacturers, agencies and politicians are collaborating to establish multi-modal corridors for international goods transportation. ITS technologies are crucial for integrating and streamlining the transport systems. This is a high-priority task in Sweden and the government has formed a joint working party in the field. [2]

• Modern vehicles contain more and more computers and other IT equipment. This makes it possible for vehicles to communicate with each other and with infrastructure such as traffic management systems, this provides a resource for minimising fuel consumption and generating other positive environmental impacts.

Travel by car will to a greater extent be carried out using hybrid electric and electric vehicles. For these to function optimally, it is important with ITS support in various ways. This can include: planning tools for how to drive the vehicle for best environmental performance; information on where there are charging facilities; developing payment systems and business models for charging; and solutions for pay-as-you-drive systems.

• An important part of Green ITS development concerns systems that collects real-time information on everything from individual vehicles to the entire traffic situation in cities. This offers completely new opportunities to optimise the use of both vehicles and the infrastructure, for individuals as well as for public actors and companies.

Dynamic road traffic management of the future
• For travel, a shift toward modes such as public transport, walking and cycling, and to the railway, can be supported by ITS solutions. These can enable real-time information and planning tools that provide the user with the most efficient route when considering time, cost and environmental impact. Simple and transparent payment systems as well as the development of mobile services in other areas (shopping, entertainment) can also be linked to these information services.

At the same time, competition between passenger and goods transportation for use of the infrastructure will be tightened. There are huge capacity problems in the transport system and these will be even more severe in the future. This can also be resolved with various ITS solutions, e.g. more efficient traffic management systems for the railways.

ITS solutions that make transport more efficient can bring about substantial reductions in greenhouse gas emissions. But with traffic running smoothly, there is also a risk that more people take their cars. Hence incentives that serve to regulate the use of the infrastructure should go hand in hand with technical measures.

With the technical development, the need for some travel can also be eliminated through more extensive use of IT solutions for both work and recreation, a good example of this is video-conferencing. Downloading movies and digital access to music, newspapers and other printed information can also eliminate the need to transport these goods.

THE WAY FORWARD
To address the climate challenge several tools must be used at different levels – ranging from designing R&D programmes and promoting new technologies in Green ITS, to developing economic instruments and other policy actions in addition to demonstrating best practises. Part of the shift toward more sustainable transportation also requires innovative changes in the way information can be accessed and used to improve operational efficiency. There is also a need for new business models in the field, where some measures must be commercialised if they are to have an impact.

New innovations often require some form of public funding. VINNOVA, the Swedish Governmental Agency for
Innovation Systems, has a mission to promote sustainable growth by funding needs-driven research and developing effective innovation systems. Information and Communications Technologies (ICT), Environmental and Energy Technology and Transportation are some of VINNOVA's focus areas and these have been combined for promoting research into sustainable transport systems.

ITS, has long been funded by various R&D programs. This includes research into advanced logistics, vehicles that provide increased energy efficiency and safety, and the introduction of new fuels. VINNOVA now has a number of initiatives underway, including new programs for environmental innovation and vehicle research (FFI), both of which include ITS.

When it comes to Green ITS, all sectors of society are affected and need to contribute. VINNOVA can enable the development and introduction of new solutions, by setting up collaboration between different sectors with a broad approach. A vital part of the work is supporting and enabling strong research milieus in co-operation with public players and industry.

One of VINNOVA's efforts is the ITS Postgraduate School for building a common platform for research. It is funded jointly with the Swedish Road Administration and the Swedish Rail Administration and is a collaboration between several universities. The graduate school will work in close cooperation with the research that takes place in the business sector. Research needs are, for example, concerned with: consumer behaviour for providing solutions a greater impact; business models, since new technology crosses over traditional sectors and involves new players; organisation models; incentive models; mobile services; public transport; and, information and privacy.

There must also be collaboration at the European level. In December 2008, the European Commission took a major step towards the deployment and use of ITS in road transport by adopting an ITS Action Plan. [3] The plan suggests a number of targeted measures and lays down a framework for their implementation as well as proposals for directives.

The goal is to create the momentum necessary to speed up the market penetration of more mature ITS applications and services in Europe. This is done in order to promote a cleaner, safer and more efficient transport
system. The action plan is a first important step forward for broad collaboration in the EU. For its implementation, there is a need for the dissemination of good practices and research on business models and consumer behaviour.

In conclusion, the need for action puts a strain on society but it is also a powerful driver for innovative solutions. This creates business opportunities for Swedish industry in the automotive, logistics and ICT sectors. A recent survey by VINNOVA in relation to R&D in the ICT field with environmental applications showed that as many as 25% of the ITS solutions were classified as ‘Green’ by researchers.

Sweden has a tradition of taking a systemic view on transportation and for finding solutions that involve different modes of transport. This helps to put Swedish actors in a strong position in areas of potential growth in the transportation field. VINNOVA has the ambition to play a vital role in these developments, and there is great hope that both the ITS World Congress 2009 in Stockholm and the Swedish EU Presidency will put the area of Green ITS on the map and drive it forward.

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Published with contributions from the following organisations
The theme of the ITS World Congress in Stockholm 2009 is *ITS in daily life*. With this book a wide range of organisations, devoted to the development of a greener transport system for Stockholm and Sweden, contribute to a comprehensive overview of how ITS is implemented and used today in support of greening transport. Complementary to articles on ITS, you will find contributions on e.g. how ICT is used to improve cycling and develop next generations train system as well as articles on how fossil fuel is replaced by bio-energy and electricity. All in support of the same goal: A sustainable transport system.