The Road to ITS

A guide to the process of introducing road-based ITS solutions, with examples of implemented applications
ITS
– An instrument for improving accessibility and safety

- What is ITS?
- How can ITS be used?
- What traffic effects can be achieved through the use of ITS?
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Foreword

The overall objective of the Swedish Transport Administration is the creation of an accessible and equitable transport system. Everyone, regardless of the mode of transport, should be able to proceed smoothly, safely and in an environmentally sound way. In the same way, goods and products should be transported in an efficient, secure and sustainable manner throughout the country.

ITS is an important tool to help us achieve these objectives. With ITS solutions, we can contribute to more effective traffic planning with a better utilization of the existing transport system. At the same time we can make the road environment safer and more environmentally friendly.

When we published the first edition of The Road to ITS we turned primarily to traffic engineers and traffic planners at the then Swedish Road Administration, as well as the municipal and regional levels in Sweden. Interest, however, turned out not only to be great from this target group, but also from elsewhere - and from other countries. The interest was so great that there is now a corresponding ITS Manual, inspired by the Swedish one, in both Norway and Denmark. Several other European countries are also interested, as is the USA.

Why has The Road to ITS aroused so much interest? Here, located in the same place, we have a unique bank of experience and simultaneously a tool-kit for anyone looking to introduce some form of ITS solution, or anyone facing decisions on the maintenance and evaluation of ITS initiatives.

In The Road to ITS, we highlight successful and well-documented examples of how, with the help of customized ITS systems, solutions were achieved for everything from urgent traffic problems to meeting more comprehensive traffic policy objectives. Furthermore, the manual contains valuable information about good and accessible ITS-systems as well as checklists for various types of initiatives. This is all done in order to facilitate each step in the process - from needs analysis and planning, through implementation and management, to evaluation and further development.

ITS-based systems and services are playing an increasingly important role in our road environment. We hope that with this updated and upgraded edition of The Road to ITS and/or via the compressed training version on Lärtorget¹, we will be able to inspire more people to create a better and safer traffic environment with the help of ITS.

Lena Erixon
Deputy Director General of the Swedish Transport Administration

¹ See the Swedish Transport Administration’s Education Centre at http://www.trafikverket.se/Utbildningscenter/
1.1 Introduction and purpose

The Swedish Transport Administration has a national responsibility to inform and promote knowledge about Intelligent Transport Systems, ITS. This manual is intended, together with other publications, to provide support for traffic engineers and traffic planners in the implementation of ITS measures.

The manual describes what ITS is, how ITS is used, as well as what traffic effects can be achieved with ITS.

The purpose of the manual is to show that ITS is a viable alternative to traditional physical measures in accordance with the four-step principle. The manual is intended to function as an aid in choosing the right ITS measures and may thus be an important tool to facilitate the planning and implementation of ITS measures.

The target group for the manual consists mainly of traffic planners and traffic engineers in the Swedish Transport Administration’s local offices, as well as municipalities and other stakeholders.

An ITS measure is to be used when it is the most cost-effective way of solving a problem.
1.2 **Scope**

The manual focuses on applications in the physical road environment, initiated by road authorities and directed at road users. ITS applications at the roadside include adjustable road signs, signals and electronic systems designed to:

- Inform and warn road users
- Control and manage traffic
- Monitor traffic

**This manual covers ITS applications and services that are installed at the roadside and that are directed at road users.**
The manual is constructed in accordance with the process model that is suggested for the implementation of ITS measures. Each step of the process is described with a colour, which is also used to separate the different sections of the manual.

The manual contains the following sections:

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<tr>
<th>Colour</th>
<th>Section</th>
<th>Description</th>
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<tbody>
<tr>
<td>White</td>
<td>White section</td>
<td>Contains an introduction and outlines the purpose of the manual: what is meant by ITS as well as a summary of the ITS implementation process.</td>
</tr>
<tr>
<td>Blue</td>
<td>Blue section</td>
<td>Corresponds to the needs analysis stage of the work process. This section describes what problems can be solved by ITS from a road maintenance perspective with the support of strategic plans and policy documents for ITS. Furthermore, suggestions are made regarding how to identify traffic problems.</td>
</tr>
<tr>
<td>Green</td>
<td>Green section</td>
<td>Corresponds to the implementation phase of the process. The main part is comprised of a directory of ITS systems and services that are implemented in Sweden today. For each ITS process a description is provided of the method of application, good advice for implementation, and the effects that have been achieved with existing installations as well as references to good examples. This section describes the elements that comprise the planning and implementation phases of the work process. These include procurement, installation and commissioning.</td>
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<tr>
<td>Orange</td>
<td>Orange section</td>
<td>Corresponds to the management phase in the work process. Management includes operation and maintenance, as well as customer support services. Good management is crucial if ITS measures are to have the desired effect. Evaluation entails pilot studies and follow-up studies to find out whether the ITS measure has had the desired effect.</td>
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Background – What is ITS?

- What role does ITS play?
- What does the life-cycle perspective entail?
- What are the critical factors for success?
Measures taken in the physical road environment are intended to increase road safety and accessibility and/or to improve the environment. According to the four-step principle\(^2,3\), a step-by-step application method is used when proposals for measures are presented.

- **STEP 1** – measures that can influence the need for transport and the choice of transport mode.
- **STEP 2** – measures that provide a more efficient utilization of the existing road network or vehicles.
- **STEP 3** – measures that include road improvements and minor modifications.
- **STEP 4** – measures that include new investments and larger modifications.

### 2.1 ITS – A wide range of applications

Intelligent Transport Systems (ITS) aim to influence the road user to change their behaviour in order to achieve an improvement in the traffic system. The concept of ITS embraces all applications that in some form use Information and Communications Technology (ICT) to create a service or dynamic function in a traffic or transport system. Another name for ITS is road informatics. In this manual we use the term ITS.

ITS has a broad range of applications that include vehicle-based driver support, communication between roadside and vehicle, traffic control systems, information systems and payment systems.

The use of ITS is increasing. Within Europe and other parts of the world, there is on-going and widespread research and continuous standardization within the ITS field.

It should be mentioned in this context, that the EU Commission has composed a joint action plan for ITS\(^4\) in Europe which has resulted in an ITS Directive. Information about the Directive can be downloaded from the EU Commission's website.\(^5\)

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\(^2\) SRA’s involvement in community-building, VV publication 2005:141.
\(^3\) Four-step principle for planning - for sustainable measures in the transport system, SKL.
\(^4\) [http://www.its-sweden.se/working-programme-for-its-direktivet__537](http://www.its-sweden.se/working-programme-for-its-direktivet__537)
2.2 ITS from a life cycle perspective

It is important to have a holistic approach to the implementation of ITS measures, where all factors that contribute to a successful implementation are taken into account from the outset. This means that it is important to plan and budget for all aspects of the implementation process during the initial phase of the project.

Technical systems are often viewed from a life cycle perspective, as illustrated in the following model.

![Diagram 1. Life cycle model for the implementation of ITS.](image-url)

When a need has has been identified, the measure that is the most cost effective for a given level of investment is chosen. In order to perform a cost/benefit assessment, all aspects of the introduction of the ITS measure must be taken into account: investment in the system, implementation, operation and maintenance and evaluation.

When the correct measure has been chosen the ITS system is implemented. The implementation phase generally lasts until the system is fully commissioned.

The management period follows implementation. Sound management and good routines for operation and maintenance are often crucial in order for ITS measures to be successful and have the desired effects.

Sometime after a system has been put into operation, the evaluation phase begins. Systems must be evaluated effectively in order to ensure that ITS measures are having the desired effect and are providing an appropriate return on the investment made. If a system is not working and/or is not producing the desired effect, then perhaps it should be removed and the money used in a better way.
2.3 Critical success factors

Experiences from the introduction of various ITS measures show that there are great differences, both in how effective they are and in how readily they are accepted by road users. Each separate installation has its own specific local preconditions that affect the expected function.

Below we have summarized a few important factors for the successful implementation of ITS measures:

► The planning of a measure shall proceed from a problem. It is important to create a clear picture, at an early stage, of what the problem is, what is causing the problem, and what the consequences are for different road users and community groups.

► Apply the right measure in the right place. The planning of the measure shall proceed from local conditions.

► ITS often involves a customized solution and is seldom standard. In most cases, since systems must be adapted to a particular site, careful preparation in the form of investigations and project planning is required.

► ITS aims to influence the behaviour of road users. Measures must be fair in order to have an effect. If road users do not understand the connection between traffic conditions and the messages given via ITS systems, the measures will not lead to the desired behaviour.

► Information and support during the introduction process is crucial for a successful system. This means that it is important to create a mutual understanding between road users and local stakeholders.

► The planning of an ITS measure should occur from a life cycle perspective in which it is not just the actual investment that is considered, but also management, operation, maintenance and evaluation. All costs and benefits throughout the life-cycle should be included. The benefits of a measure may be difficult to calculate, but as far as possible, all possible effects should be listed, even if it is not possible to quantify them or assess their value.

► Effects should be sustainable over time. Evaluation of the effects shall verify whether or not a measure has solved the problem. Long-term effects should also be measured to ensure sustainable benefits. At the same time there should be a reassessment of the need, to see whether conditions have changed. If the need no longer exists or if the desired effects fail to materialize, the system should be removed.

► Establish long-term commitment from the road maintenance authority. A crucial factor for a successful implementation is that the parties believe in the measure even when the project goes into the management phase.
2.4 The implementation process - A summary

Implementation of ITS is an iterative process involving several successive steps. The steps in the process are the same as in traditional planning, but the content of the respective steps may differ slightly on certain points.

ITS measures differ from other physical measures as IT systems need an electricity supply and often digital communication. In addition, the equipment may need to be installed in a protected environment (humidity, temperature, security, etc.). IT equipment often has a limited lifespan, which is why depreciation and reinvestment costs should be included in the planning process.

ITS implementation can be summarized in the following steps:

- **Initiation - Identifying the problem**
  Either through public opinion or political initiatives, a regional office or a municipality’s traffic department notices that a problem exists. Before proposed measures are established, a clear picture of the problem should be created, and the consequences that it has for different road users and groups in the community.

- **Needs analysis and the formulation of objectives**
  By means of observations at the site and the gathering of supporting documents, (such as traffic measurements, reported incidents as well as contact between local stakeholders), a needs list is created for every road user and community group. A description of objectives is then drawn up with quantified goals and a defined method for measuring them.

- **Choosing a measure**
  Based on the needs list, a number of possible measures are proposed. The alternatives might include both ITS systems and other physical measures. A cost/benefit assessment is then conducted for each measure.

  Through a balanced assessment of needs and the different measures, a suitable measure is chosen. As a general rule, the measure that provides the most benefit for a given level of investment is chosen. But, there may be local conditions or strategic political decisions that create reasons to deviate from this rule.
Implementation
The implementation phase includes procurement, installation and commissioning. Good planning of all aspects of the process from procurement to management and evaluation, is critical for the successful implementation of ITS. An equally important factor is support and information. Good support and transparency in decision making are crucial for internal acceptance, while clear information to the public is crucial for external acceptance.

Management
ITS measures are usually comprised of several IT systems that are dependent on one another. For a chosen measure to be reliable, the system must be accessible and function properly. This requires good operating routines and customized maintenance. Management is also responsible for any necessary customer support.

Evaluation
There are two parts that should be included in the evaluation of an ITS measure. The first is evaluation of the effects. Has the problem been solved? This evaluation takes place through preliminary and post management measurements as well as the measurement of long-term effects. The second task is reassessment of the need: Have external factors had an effect on whether the need still exists?
The Road to ITS – What problems can be solved?

- What does the Swedish Transport Administration want to do with ITS?
- When is ITS a good alternative?
- What does access to quality assured traffic information actually mean?
3.1 The Swedish Transport Administration’s role and strategy for ITS

Within the roads sector there is on-going practical work aimed at promoting ITS both within the Swedish Transport Administration and in municipalities all around the country.

ITS operations are organised under two operational areas of the Swedish Transport Administration: “Society”, which is responsible for issues of coordination, congestion taxes, metropolitan area issues and regional cooperation and “Traffic” which covers issues regarding traffic management centres, traffic information, investment, operation and maintenance, planning, education and the effects of ITS.

The point of departure for national efforts is the assertion by the EU Commission that implementation of ITS in the transport system is proceeding too slowly. A European ITS directive has therefore been drawn up which prioritizes certain measures that the member countries shall strive towards.

In September 2009, an ITS investigation was initiated and lead by the then Swedish Road Administration. The assignment was “to produce a comprehensive intermodal strategy and action plan for the use of Intelligent Transport Systems (ITS) in the transport system”. The strategy and action plan were to be developed in cooperation with relevant authorities, enterprises and organisations. This process coincided with the establishment of a new authority, the Swedish Transport Administration. The ambition was and is to increase the use of ITS solutions and exploit their potential contribution to achieving transport policy objectives.

The overall objective of these goals is to ensure a socio-economically effective and sustainable provision of transport for citizens and for trade and industry throughout the country. The potential of ITS to increase the efficiency and usability of the transport system as a whole is not being fully exploited. On 1 March 2010 the document was handed over to the Ministry of Enterprise, Energy and Communications.

The investigation is based on the following overall goals that aim to increase the use of and speed-up the implementation of ITS:

- Contribute to the development of a sustainable, safe and secure transport system.
- Benefit the individual, companies and society.
- Facilitate general multimodal journeys and transport from door to door.
- Strengthen the competitiveness of Swedish industry and contribute to new job opportunities.

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6 http://ec.europa.eu/transport/its/road/action_plan_en.htm
7 http://publikationswebbutik.vv.se/shopping/ShowItem._______4620.aspx
8 Multimodal ITS Strategy and Action Plan, the Swedish National Road Administration, 2010:16.
With regard to measures, the strategy involves six focus areas with underlying action plans being established.

1. Planning and innovations in the transport system
   This area includes: how ITS can be used in the physical planning process, important conditions for ITS being able to produce a greater impact in planning and execution, and knowledge accumulation and innovations within the ITS area.

2. Data and information
   Measures regarding the supply of data and information to all the other focus areas are described under this heading. Data is the basic precondition for the development of services.

3. Vehicles/craft, communication and physical infrastructure
   This section focuses predominantly on road transport, including measures such as the introduction of different driver support systems and other selected ITS applications.

4. Freight transport
   This area covers national and international freight transport for all modes of transport. Other measures that comprise freight transport are also included under the areas of ”Data and information” and ”Metropolitan regions”.

5. Passenger transport
   This area comprises measures with a national character. Measures for passenger transport are also included under ”Data and information” and under the heading ”Metropolitan regions”.

6. Metropolitan regions
   ITS for passenger as well as freight transport also apply for metropolitan regions, but in this section measures are discussed that have particular relevance for metropolitan regions.
The Government has given the Swedish Transport Administration the responsibility of coordinating the implementation and follow-up of this intermodal strategy and action plan. An ITS Council has therefore been appointed to support the Swedish Transport Administration in this role. The Council will be an arena for the exchange of information and consultation between public authorities, private enterprise and academia. Furthermore, a special secretariat has been established in order to support the ITS Council in its role as coordinator.

The Swedish Transport Administration also aims to stimulate creative thinking and diversity by spreading knowledge and arousing interest for ITS in regions and municipalities throughout the country.

In the same way that the Swedish Transport Administration has a road maintenance responsibility for national roads, the municipalities have the same responsibility for the municipal roads and streets. Each municipality can draw up municipal policy documents such as, Road safety programmes, Environmental programmes, etc. The Swedish Association of Local Authorities and Regions (SKL/SALAR), often in collaboration with the Swedish Transport Administration, issues manuals and guidelines for road design and road planning. Some examples are VGU, TRAST, Exempelbanken, etc.

### 3.1.1 Establishment in the regulations

In the same way as with other traffic measures, ITS must follow the rules and regulations that apply, for example, the Traffic Sign Ordinance. ITS is often a matter of strengthening and clarifying the rules and regulations that already apply in order to attain better compliance. Vehicle-activated speed limit reminders are an effective way of drawing a driver’s attention to the current speed limit. ITS solutions can also be used to heighten the awareness of drivers at pedestrian crossings, intersections, bicycle crossings, roundabouts, wild animal passages and curves, as well as to warn for crossing work vehicles, ghost-drivers, school buses at bus stops and school children on the road.

### 3.2 The road authority perspective

With the general challenges within the road sector as a point of departure, the ITS strategy and action plan presents concrete measures and efforts that are to contribute to the attainment of the transport policy objectives. The use of ITS is supported by applicable steering documents and regulations.

ITS has the objective of directly or indirectly influencing road user behaviour to achieve the objectives set within the road sector. In order to gain user acceptance, it is important that measures are followed up with information that explains the reasons why a particular measure has been introduced. This is often a prerequisite for attaining the desired effect.

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9 www.skl.se
The overall objectives of the transport policy were formulated in 2008 in the proposition *Objectives for journeys and transport in the future, prop. 2008/09:93*. This document describes two equally important intermediate objectives:

► **The Function** objective is concerned with creating accessibility for journeys and transport. The design, function and usage of the transport system shall assist in providing all users with basic accessibility, with good quality and usability, as well as contribute to developmental effects throughout the country. At the same time, the transport system must be equitable; conditions for the disabled and children shall be improved. The possibilities for choosing public transport, walking and cycling shall be improved.

► **The Consideration** objective is concerned with road safety, environment and health. They are important aspects which a sustainable transport system must take into account. The transportation system’s design, function and usage shall be adapted so that nobody is killed or seriously injured. The transport system shall also contribute to achieving environmental quality objectives and to improved health.

When a problem is to be solved, the needs of all road users and concerned parties must, as far as possible, be met. Based on the transport policy intermediate objectives “Function” and “Consideration”, a number of ITS measures that are linked to these areas are described below. These ITS measures are also presented in the catalogue section of the manual.

11 http://www.sweden.gov.se/sb/d/11771
3.2.1 Measures to improve availability (Function objective)

ITS measures, especially in metropolitan areas, aim at reducing congestion and improving availability and accessibility to the traffic system. By using measures that affect the time of travel, route or mode choice, ITS can contribute to the more efficient use of infrastructure.

Different factors affect the possibilities for people to reach their destinations within an acceptable journey time. The journey time affects the possibilities for commuting. More efficient commuting aims to facilitate traffic and reduce congestion on major commuting routes.

- Measures targeted at motorists seek to provide incentives to walk, cycle or use public transport, instead of taking the car. For those who choose to drive, it is about reducing queues and unnecessary searching for parking spaces, particularly on approach roads and in urban areas. In this way, the environmental impact is also reduced.

- For public transport users this means improving the accessibility and punctuality of public transport, and providing better information about departures and disruptions.

- For pedestrians and cyclists, it is about improving conditions for these road user groups so they can make use of the transport network in an efficient and safe manner.
ITS measures that can contribute to the improvement of accessibility, availability and/or safety are, for example:

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<tr>
<th>Chapter</th>
<th>ITS measure</th>
<th>Effect on</th>
<th>Road safety</th>
<th>Environment</th>
<th>Accessibility</th>
<th>Security</th>
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<td>5.6</td>
<td>Vehicle-activated speed-limit reminders</td>
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<td>5.8</td>
<td>Ghost driver warnings</td>
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<td>5.9</td>
<td>Dynamic parking information</td>
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<td>Real-time travel information public transport</td>
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<td>Public transport priority at traffic signals</td>
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<td>Variable speedslimits</td>
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<td>Hard shoulder control</td>
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<td>7.3</td>
<td>Tunnel monitoring and control*</td>
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* Refers to personal safety.

Public transport is perfect for the use of ITS; road users moving in a complicated system and requiring information.
3.2.2 Measures for improved road safety (Consideration objective)

Improved road safety is mainly about creating increased compliance among road users for existing speed limits and other traffic regulations. Speeding and alcohol or drug abuse are among the main causes of road accidents, while speed and seat belt use are factors that influence the severity of an accident’s outcome. There is an unequivocal link between high speeds and the severity of accidents. High speeds and violations of speed limits also create dangers for vulnerable road users who travel on or alongside the road.

► For motorists, improved road safety through increased compliance is about being made aware of obstacles and disruptions, and the applicable speed limit as well as monitoring that the speed limit is obeyed.

► For pedestrians and cyclists, improved road safety is about increased safety through motorists being made aware of their presence on or alongside the road.

► For society, increased road safety means fewer and less severe accidents, which reduces the social costs of deaths and injuries, while enhancing public confidence in the authorities’ social responsibility.

ITS measures aimed at improving road safety include:

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<th>Chapter</th>
<th>ITS measure</th>
<th>Effect on</th>
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<td>Queue warnings</td>
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<td>Weather warnings</td>
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<td>5.3</td>
<td>Operator controlled traffic information</td>
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<td>Information about temporary diversions/roadworks</td>
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<td>Vehicle-activated speed-limit reminder</td>
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<td>Vehicle-activated warnings for pedestrians/cyclists</td>
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<td>Ghost-drivers warnings</td>
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<td>Traffic signal control</td>
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<td>Variable speeds limits</td>
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<td>6.7</td>
<td>Motorway control</td>
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<td>7.1</td>
<td>Automatic speed monitoring</td>
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<td>7.2</td>
<td>Monitoring and control of hazardous goods transportation*</td>
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<tr>
<td>7.3</td>
<td>Tunnel monitoring and control*</td>
<td>** * **</td>
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</tbody>
</table>

* Refers to personal safety.

Variable speed limits that change with regard to road conditions have been shown to contribute to a reduction in the number of serious injuries and deaths by over 20 per cent.
3.2.3 Measures for an improved environment (Consideration objective)

ITS can be used to effectively achieve improvements in air quality in urban areas and to reduce the road sector’s climatic impact. Measures aimed at improved accessibility also have positive effects on the environment, since traffic flow improves and is more harmonious. In certain cases it might be necessary to combine these with other measures to counteract attracting new traffic where accessibility has been improved.

Measures aimed at making public transport more attractive, for example, through prioritization and real-time information, can contribute to a transfer of trips from private cars to public transport. Powerful measures aimed at control of demand and traffic regulation also have a positive impact on the environment. ITS can also be used in urgent measures to reduce emissions on days with particularly poor air quality, for example, congestion taxes in urban areas.

ITS measures that have a positive effect on climate and air quality are, for example:

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS measure</th>
<th>Effect on</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Road safety</td>
</tr>
<tr>
<td>5.1</td>
<td>Queue warnings</td>
<td>***</td>
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<tr>
<td>5.3</td>
<td>Operator controlled traffic information</td>
<td>**</td>
</tr>
<tr>
<td>5.9</td>
<td>Dynamic parking information</td>
<td>3</td>
</tr>
<tr>
<td>6.1, 6.2</td>
<td>Traffic signal control</td>
<td>3</td>
</tr>
<tr>
<td>6.3</td>
<td>Public transport priority at traffic signals</td>
<td>3</td>
</tr>
<tr>
<td>6.4</td>
<td>Ramp metering</td>
<td>3</td>
</tr>
<tr>
<td>6.5</td>
<td>Variable speed limits</td>
<td>**</td>
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<tr>
<td>6.7</td>
<td>Motorway control</td>
<td>**</td>
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<tr>
<td>6.9</td>
<td>Road-user charging in urban areas</td>
<td>3</td>
</tr>
<tr>
<td>7.1</td>
<td>Automatic speed monitoring</td>
<td>3</td>
</tr>
</tbody>
</table>

Journey planners describing the environmental impact of different choices of transport mode (car, bus, bicycle, etc.) can help road users who want to achieve climate friendly travel.
3.3 ITS versus physical measures – Examples

Measures for solving a traffic problem traditionally consist of some form of physical action. Traditional physical measures have been implemented in many locations without achieving the desired effect. Alternatively, there is no space to build a solution to the problem. In these cases, ITS is an option for making traffic more efficient, safer and/or more sustainable.

An example of a problem that ITS can solve more effectively than traditional physical measures is high speeds through communities where pedestrians and cyclists are also present. A traditional physical measure is to make the road narrower or build speed bumps. One possible ITS measure is to set up a sign that reminds drivers of the speed limits, or warning signs informing of pedestrians and cyclists.

Below are two examples where ITS measures have proved to be effective in comparison with traditional physical measures.

3.3.1 Excessive speeds through Våxtorp

One example which shows how an ITS solution may have a better effect in reducing speeding is Våxtorp, a small community along national road 24, between Laholm and Örkelljunga. The speed limit through the community is 50 km/h, but was previously 70 km/h. There are sparsely-populated areas with entrance and exit roads along the stretch of road. Both police and residents have reported major problems with speed violations on the section of road in question.

An initial physical measure was to make the road narrower with the aid of an urban gateway, with portable traffic islands (concrete foundations), traffic dividers, and accompanying road markings. Traffic measurements before and after showed that the average speed fell by two to eight per cent, depending on the type of vehicle. The greatest effect was recorded for lorries with trailers.
When this measure did not have sufficient impact on speed reduction, electronic signs were erected to remind drivers of the speed limit in each direction. The concrete foundations were then removed. The signs are activated only when vehicles are driving too fast.

![Figure 4. Speed reminder sign, Våxtorp.](image)

Traffic measurements before and after the implementation of the speed reminder signs demonstrated that the proportion of motorists driving too fast was reduced by 37 per cent, compared with the measurement carried out before narrowing the road. The average speed was reduced by between 11 and 16 per cent, with the greatest reduction being for heavy vehicles.

![Figure 5. Average speed before (2006, wk21), after improved road markings and traffic islands (2006, wk.48), as well as after ITS measure (2007 wk.23)](chart)
3.3.2 Accessibility problems on Road 222, Värmdö

Road 222 between Mölnvik and Ålstäket on Värmdö has had a long history of congestion and accessibility issues, particularly during the summer when traffic increases from 18,000 to 28,000 vehicles per day. Queues formed in the west-bound direction towards Stockholm in the morning, while in the afternoon, queues formed in the opposite direction.

In order to resolve the traffic problem, the road was redesigned with three narrow lanes, including a reversible lane in the middle. In the morning, when the westbound traffic towards Stockholm is at its peak, the middle lane is used for city-bound traffic. In the afternoon, the middle lane is used for traffic driving in the eastbound direction.

The system was initially controlled manually, but an automated ITS system was introduced in the autumn of 2008. With the help of mechanical barriers, adjustable road signs and the possibility of remote control and monitoring, the driving direction of the middle lane can be switched remotely. The barriers and signs are controlled from the Traffic Management Centre – Trafik Stockholm\(^\text{12}\).

Overall, the measure has had a favourable effect on accessibility\(^\text{13}\). The queues that previously had developed have disappeared and public transport has also benefited. Only one out of ten interviewees now complains about accessibility. In addition, the solution is cost-effective. To build a four-lane road would have cost SEK 140 million, while the solution with the reversible lane cost only SEK 20 million.

Experience with reversible lanes is limited in Sweden, and local conditions can lead to high costs for the necessary physical measures, something that should be considered when introducing such measures.

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\(^{13}\) Evaluation of reversible lane on road 222, Swedish Road Administration, 2006:134.
Measures, systems and services

- In what areas have ITS solutions been tested?
- What can we learn from successful ITS projects?
- What areas are most suitable for different ITS solutions?
In this section of the manual, examples of different ITS measures are highlighted. We focus on measures in the physical road environment, initiated by the road authority and aimed at road users.

ITS measures at the roadside include variable message signs, signals and electronic systems designed to:

» Inform and warn road users.

» Control and manage traffic.

» Monitor traffic.

The systems and services described are as follows:

**Chapter ITS systems and services**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS systems and services</th>
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<tbody>
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<td>5.1</td>
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<td>5.2</td>
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<td>Journey time information</td>
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<td>Information on temporary diversions/roadworks</td>
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<tr>
<td>5.6</td>
<td>Vehicle-activated speed-limit reminder</td>
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<tr>
<td>5.7</td>
<td>Vehicle-activated warnings for pedestrians/cyclists</td>
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<tr>
<td>5.8</td>
<td>Ghost-driver warnings</td>
</tr>
<tr>
<td>5.9</td>
<td>Dynamic parking information</td>
</tr>
<tr>
<td>5.10</td>
<td>Park and Ride information</td>
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<td>5.11</td>
<td>Real-time travel information public transport</td>
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</table>

**Control and manage traffic**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS systems and services</th>
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<tbody>
<tr>
<td>6.1</td>
<td>Traffic signal control</td>
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<tr>
<td>6.2</td>
<td>Operation and maintenance of traffic signals</td>
</tr>
<tr>
<td>6.3</td>
<td>Public transport priority at traffic signals</td>
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<td>6.4</td>
<td>Ramp metering</td>
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<tr>
<td>6.5</td>
<td>Variable speed limits (weather and trafficactuated)</td>
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<tr>
<td>6.6</td>
<td>Reversible lane control</td>
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<tr>
<td>6.7</td>
<td>Motorway control</td>
</tr>
<tr>
<td>6.8</td>
<td>Hard shoulder control</td>
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<tr>
<td>6.9</td>
<td>Road-user charging in urban areas</td>
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</tbody>
</table>

**Monitor traffic**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS systems and services</th>
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</thead>
<tbody>
<tr>
<td>7.1</td>
<td>Automatic speed monitoring</td>
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<tr>
<td>7.2</td>
<td>Monitoring and control of hazardous goods transport</td>
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<tr>
<td>7.3</td>
<td>Tunnel monitoring and control</td>
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</table>
Each system is described with the following headings:

<table>
<thead>
<tr>
<th>x.1</th>
<th>Application</th>
<th>Describes how the system works in conjunction with other infrastructure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>x.2</td>
<td>Effects</td>
<td>Describes the effects that have been achieved when applying the system in Sweden.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The system’s effects on traffic safety, environment and quality of transport, etc. illustrated graphically with four levels:</td>
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<tr>
<td></td>
<td></td>
<td>••• Large positive effect.</td>
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<tr>
<td></td>
<td></td>
<td>•• Medium positive effect.</td>
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<td></td>
<td></td>
<td>• Small positive effect.</td>
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<td></td>
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<td>&lt;blank&gt; No demonstrated effect.</td>
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<tr>
<td>x.3</td>
<td>Actors</td>
<td>Describes the actors involved in the implementation of the ITS service.</td>
</tr>
<tr>
<td>x.4</td>
<td>Good advice for implementation</td>
<td>Advice and things to consider when introducing the ITS service.</td>
</tr>
<tr>
<td>x.5</td>
<td>See also</td>
<td>Reference is made to other systems that are linked to the system described.</td>
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</tbody>
</table>

Each chapter also includes references to good examples where actual implementations of the ITS system or service are described.
4.1 Assessing effects

The basic principle for assessing the effect of ITS measures is based on a comparison of different evaluative methods. The purpose is to identify if there is a clear trend in observed results.

The assessments of effects are therefore not an absolute truths, since local conditions and special circumstances can have a significant impact.

In certain cases it is possible to point out a few important fundamental principles or conditions to consider during implementation. These are described under each system chapter.

To give an indication of the type and magnitude of effects that can be expected a three-level scale is used for illustrative purposes.

The effects are categorised into:

- Road safety.
- Environment.
- Availability, accessibility and security.

The following scale is applied:

- Large positive effect.
- Medium positive effect.
- Small positive effect.
- No demonstrated effect.

An example is shown below:

<table>
<thead>
<tr>
<th>Effects</th>
<th>Level</th>
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<tbody>
<tr>
<td>Road safety</td>
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<tr>
<td>Environment</td>
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<tr>
<td>Availability,</td>
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<tr>
<td>Accessibility,</td>
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<tr>
<td>Security</td>
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</tbody>
</table>
4.2 Costs

The cost of ITS measures varies greatly depending on the complexity and size of the system. An ITS measure may also be integrated with other measures, making it difficult to isolate the ITS cost. During the planning of ITS, all costs should be included at an early stage. This is described in the Planning section of the manual.

Examples of cost factors are:

- Pilot study including an inventory of the problem and needs analysis.
- Project management during the implementation phase.
- Investment costs for equipment and software, electricity supply and communication costs.
- Superior system for operational monitoring and control.
- Installation and commissioning costs.
- Construction costs for ground work and other physical measures.
- Management costs (operation and maintenance).
- Reinvestment costs.
- Evaluation costs.

The Swedish Transport Administration publication, Effektsamband\textsuperscript{14}, gives some examples of actual investment costs for different types of systems. Among other things, it is stated that annual operating costs range between five and ten per cent of the investment cost.

For each system in the catalogue section, costs are separated into three levels according to a standard model, as described below. This is presented alongside the effects assessment.

Simple, often independent, installations which in many cases can be powered by batteries, solar or fuel cells. Cost range SEK 10 000 to 500 000.

\begin{tabular}{|c|c|}
\hline
Cost & \textbullet \\
\hline
\end{tabular}

This category requires more extensive planning and project management.

Electricity, communications supply and ground work is costly. It is advisable to use a superior system for operation and monitoring. Cost range SEK 500 000 to 3 000 000.

\begin{tabular}{|c|c|}
\hline
Cost & \textbullet\textbullet \\
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\end{tabular}

Large systems are in many cases controlled and monitored by a Traffic Management Centre. Planning, introduction and operation of this category type is a process that requires resources, commitment and perseverance from the road authority. Cost range SEK 3 000 000 or more.

\begin{tabular}{|c|c|}
\hline
Cost & \textbullet\textbullet\textbullet \\
\hline
\end{tabular}

\textsuperscript{14} Effektsamband 2008, the Swedish Road Administration.
Providing information to the road-users

- What does better information mean for accessibility and safety?
- What ITS measures can be used to provide information to road users?
- What effects can the measures provide?
The main heading **inform and warn the road user** includes the following ITS measures:

- Queue-warning.
- Weather warnings.
- Operator controlled traffic information.
- Journey time information.
- Information about temporary diversions/roadworks.
- Vehicle-activated speed-limit reminder.
- Vehicle-activated warnings for pedestrians/cyclists.
- Ghost driver warnings.
- Dynamic parking information.
- Park and Ride information.
- Real-time public transport travel information.
5.1 Queue-warning

Queues can develop quickly on roads with heavy traffic, such as access roads to metropolitan areas during rush hour or in other situations, such as large popular events. High traffic density in combination with stressed motorists can result in multiple collisions with serious injuries and major traffic delays as a consequence. On such roads, the introduction of a queue warning system can increase safety.

A precondition for queue warning systems is that there are systems in place for measuring flows. Vehicle speeds are also registered at different points along the road. Queue warning systems can also be connected to journey time information and route guidance through operator-controlled VMS; a good example of traffic management.

5.1.1 Application

The primary objective of queue warning systems is to reduce the risk of rear-end collisions, which is a common type of accident. Motorists are warned of upcoming queues in advance, and have time to adjust their speed and prepare to stop. Although some motorists may already be well aware of locations with a high risk of queues building, it has been demonstrated that queue warning systems are of great benefit.

5.1.2 Effects

Queue warning systems have an effect on the number of rear-end collisions and contribute to a less aggressive driving style. Additional effects are harder to substantiate. A study in Gothenburg has shown that queue warning systems can also contribute to smoother driving behaviour. With the help of floating car data the study showed that the number of instances of rapid deceleration (less than 300 metres) decreased from 75 per cent to 40 per cent, and that the average braking distance in queues increased from 260 metres to 420 metres when the queue warning system was activated.

Even if other adjustable road signs and fixed, free text signs have an effect on rear-end collisions, the queue warning system gives earlier warnings. In order to obtain better data, the incidence of rear-end collisions should also be studied on stretches of road with fixed adjustable road signs and free text signs.

5.1.3 Actors

It is the road authority – the Swedish Transport Administration or the municipality – who is responsible for introduction of the measure.
5.1.4 Good advice for implementation

It is important to consider that adjustable road signs require regular maintenance. Responsibility for management, operating and maintenance costs should be included in the planning stage.

5.1.5 See also

- Motorway control.
- Tunnel monitoring and control.
- Operator-controlled traffic information.

Good examples: Queue-warning

In 2001, a queue warning system was installed on the southbound E6 in Gothenburg. The first part of the system was three kilometres long and stretched from the Bäckebo junction to the Ringö junction. The stretch of road is equipped with seven queue warning signs at intervals of 500 to 1000 metres, as well as sensors for measuring vehicle flow and speed. Traffic measurements conducted by the Swedish National Road and Transport Research Institute15, before and after installation showed clear improvements in accessibility and a reduction in traffic disruptions during peak hours. The number of rear-end collisions has been halved and the amount of rapid decelerations has been reduced by 50 per cent, while injuries have decreased from 0.61 accidents/month to 0.24 accidents/month.

According to the study, it is precisely when the flow is close to its capacity limit that the system provides most benefit.

Something that would certainly have affected the studies in a positive manner was the simultaneous opening of a new lane south of the Tingstad tunnel. It is the cumulative effect of all measures that has led to the positive result.


5.2 Weather warnings

Severe weather conditions occur regularly in some areas, for example on mountain roads in border areas in the north. The roads in these areas are used by tourists and professional drivers who sometimes lack local knowledge particularly with regard to the unpredictability of the weather. For six months of the year motorists drive in winter conditions and in darkness.

On these roads and in such conditions motorists can easily become disorientated and run off the road. For this reason adjustable message signs with weather warning are installed on selected roads. Traffic information can be displayed on these signs. One example is information about slippery roads, snow drifts and decrees of platoon driving and times for these. Motorists can thus choose another road or wait to drive in an organised platoon.

15 http://www.vti.se/templates/Page____2783.aspx
Another application for weather warning systems can be on bridges where for example strong winds can cause a hazard to road users.

Adjustable road signs with queue warning systems contribute to less aggressive driving behaviour and fewer accidents about current weather conditions from SMHI (Swedish Meteorological and Hydrological Institute), radar and satellite images and the VViS system (The Swedish Transport Administration’s system for weather information), as well as cameras.

5.2.1 Application

A wide variety of other information channels can be used to provide motorists with a comprehensive and up-to-date picture of the prevailing weather situation, enabling them to make informed decisions about their journey. Such information channels include: trafiken.nu, ”Läget på vägarna” (online real-time traffic information), phone text messages, radio and variable traffic information boards for weather warnings.

Systems for weather warnings are in some cases combined with physical measures such as road barriers which efficiently prevent road users from embarking on dangerous sections of road.

5.2.2 Effects

Studies show that weather warning systems increase road safety and provide security for road users.

A survey by the then Swedish Road Administration in 2004 also showed that free text signs provide more effective weather warnings and result in better compliance than simpler warning systems such as flashing lights, which on mountain roads tend to be ignored by users.

5.2.3 Actors

The responsibility of the measure is the road authority. The physical closure of a road is the responsibility of operating contractors.

5.2.4 Good advice for implementation

If weather warning systems are established in border areas, it is important that the information displayed can be understood by road users from other countries. Foreign road users are the ones most likely to miss information distributed through other communication channels such as radio.

It is also a good idea to coordinate information about closed mountain crossings with Norway.

5.2.5 Please refer to

- Operator controlled traffic information.
- Variable speed limits.
Good examples: Weather warnings

The then Swedish Road Administration placed eight VMS signs at strategic locations along the mountain roads E10, E12 and road 95 in Northern Norrland to inform road users about road closures. Car journeys to Norway in heavy snow and severe weather can go through E10 Riksgränsen. If the road is closed information signs are illuminated in Svappavaara, Kiruna and Björkliden. If road 95 is closed an information sign will illuminate outside Arjeplog and at the intersection of road 625/national road 95, Laisvallsvägen.

In 2003, the then Swedish Road Administration conducted an evaluation of how information displayed by weather warning signs along road E10 is received by road users and what they think about these types of message. The study showed that road users perceptions of the signs are positive in regards to appearance, position and message. They feel safe and appreciate information about road closures. With the help of the signs they can chose how to act well in advance.


5.3 Operator controlled traffic information

Operator controlled traffic information makes it possible to dynamically inform road users of current traffic conditions and unforeseen road incidents. This increases the likelihood of maintaining free flowing traffic, whilst reducing motorist stress levels and providing improved support for journey planning.

Operator controlled traffic information systems are mainly used to provide disruption information, queue warning, journey time and alternative route information. Prerequisites for such systems are roads equipped with traffic information boards and established communications between roadside infrastructure and the Traffic Management Centre (TLC).

5.3.1 Application

Disruption information displayed on traffic information boards is usually provided on motorways and major roads that are heavily trafficked and susceptible to disruption. Text messages can readily be combined with appropriate graphical symbols.

Although it is appropriate to communicate information regarding traffic disruptions via messages on traffic information boards, such messages should be supplemented with a queue warning system or other warning system, particularly if there is risk of unexpected and sudden queue formations on high speed roads.

If there is frequently significant variation in journey times this should also be communicated to motorists. Studies show that road users are interested in alternative routes and estimated journey times for these.

5.3.2 Effects

Information about disruptions has a major impact on accessibility as it can provide accurate event information, recommend alternative routes and provide
journey time estimates. How great the diversion effect will be depends foremost on the type of disruption, the message design, what and how well-known the alternative routes are and how motorists perceive the traffic situation and what information they receive through other channels, especially radio. For example, diversion rates can reach over 50 per cent at major roadworks and when direct advice on different routes is given, compared to normal conditions without disruptions. Road users also experience improved comfort with less stress and irritation because they are better informed.

Road safety is largely dependent on speed and changes in speed as a result of messages on free text boards and queue warning systems. By reducing the speed over a longer distance at queue ends, a positive effect on road safety can be achieved.

In 2010 the Swedish Transport Administration evaluated the effect of environmental messages displayed on variable message boards in the Gothenburg area. When users received information about poor air quality, without any reduction in the current speed limit, the average speed was reduced by two to three per cent. The study showed that traffic information about environmental disruptions has the potential to reduce road traffic emissions.

5.3.3 Actors

The introduction of operator controlled traffic information is the road authority’s responsibility.

5.3.4 Good advice for implementation

Studies have shown that operator controlled traffic information offers the greatest benefit on roads that are particularly affected by disruptions due to high traffic density, high speeds or difficult weather/road conditions.

The formulation of messages is of great importance for their impact. It is important to describe the consequences of an event rather than describing the actual event. Messages should be specific and strongly formulated. The benefit for the road user is greater using words like Accident rather than a more vague word like Incident.
5.3.5 See also

Queue warnings.

Good examples: Operator controlled traffic information

Systems with adjustable message signs for automatic queue warning, diversions and information about roadworks have been installed on the E6 and E22 on the northern approach road to Malmö. Surveys show that about 20 per cent of road users respond to queue warning messages and recommendations to choose an alternative route.

Source: PM – Trafikstyrning och Tillgänglighet” (Traffic Control and Accessibility), Movea, 2007.

5.4 Journey time information

Registration of journey times is conducted mainly in larger cities or in heavily used traffic systems, to monitor and control traffic flow. Such information is also of interest to commuters in the event of accidents or congestion.

Dissemination of information about the traffic situation and the current journey time is dependent on the existence of a system for measuring the volume and speed of traffic. Calculation of journey times is based on data from detectors which are placed along set routes.

One way to measure journey times is to photograph vehicles license plates at several points along the road network. By combining the different journey times for each section it is possible to generate a reliable journey time over a longer distance. Thus it is possible to identify changes in journey time and these can then be displayed on variable message signs.

Real time journey time information can balance the traffic load between different roads.
5.4.1 Application

Journey time information can serve several purposes. On the one hand, such a service can act as an informational aid to road users which may reduce motorists stress levels. On the other hand, the service can contribute to improved accessibility by enabling road users to choose a different route when faced with congestion and incidents. Studies show that road users want information about accessibility as early as possible in order to be able to plan their journey. In addition, they want information via multiple channels to guarantee its credibility. Therefore, it is advantageous to communicate such information via parallel communication channels such as variable message signs and radio.

5.4.2 Effects

The purpose of journey time information is to improve accessibility for motorists and make traffic planning more efficient for road authorities. Whether or not the display of journey times on variable signs actually causes a change in driving habits, (thereby increasing traffic safety, improving accessibility and reducing the environmental impact), depends on how the system is implemented and whether there are alternative routes available when an incident occurs. Trials and studies show that between 20 and 30 per cent of motorists change their route when informed of an incident. Several studies show that journey time information is popular with road users even if they do not change their behaviour.

5.4.3 Actors

The road authority is responsible for the collection and presentation of journey time information via variable message signs. Dissemination of journey time information through other channels can be performed by external actors such as the media.

5.4.4 Good advice for implementation

When introducing a system for displaying journey times, it is important to inform road users about what the content of a journey time message actually means. Experience shows that it is journey time information road users want, not journey time anomalies. It is therefore important that the information is reliable. Start by implementing the system on a limited scale and follow up with traffic surveys to gauge the reactions of road users before proceeding with larger scale implementation.

5.4.5 Please refer to

- Operator controlled traffic information.

**Good examples: Journey time information**

In October 2006, a journey time information system was trailed on a northbound stretch of the E4/E20 Södertäljevägen at Bredäng (traffic junction 152). Information about estimated journey times was displayed on the signs every day between 7.00am and 9.00am during the trial period. Estimated journey times were displayed for...
journeys to two major junctions further north: junction Nyboda (155) and the junction Norrtull by Eugeniatunneln (164).

An evaluation was conducted after the trial period, which showed that the system provided a significant improvement in service levels to road users. Consequently the system was point into permanent operation from November 2007.

Source: The Swedish Road Administration Region Stockholm.

5.5 Information about temporary diversions/roadwork

Road workers working on multilane roads are constantly subject to the risk of accidents. Excessive speeds and negligence by road users is an important cause. Thus there is a need for more effective and safer methods for diverting traffic and reducing speeds at roadwork sites.

5.5.1 Application

Mobile variable message signs are used to provide clear and accurate signage in connection with roadworks. Previous studies have shown that dynamic signs are better perceived by road users than traditional fixed signs.

One particularly dangerous task at roadwork sites is the opening and closing of the site at the beginning and end of the working day. Traditionally this task involves someone going into the “danger zone” to rig the signs. With remote VMS signs, this dangerous activity can be minimized or eliminated altogether. As well as reducing risk this also leads to time savings.

The use of vehicle-mounted signs for displaying recommended maximum speed was permitted by new road sign legislation, which came into force in 2007.

5.5.2 Effects

Mobile variable message signs and boards can be assumed to have the same effect as corresponding fixed signs. As part of the ‘Arbete på väg’ (Work on the road) project, the Swedish Transport Administration has studied the effects of different speed-reducing measures at roadwork sites. The study included looking at the performance of speed reminder signs that are activated when vehicles approach roadworks with excessive speed. Such systems (and others, including mobile traffic safety cameras), resulted in lower average speeds and reduced the distribution of speeds before, during and after work sites.

5.5.3 Actors

In Sweden, a number of trials of mobile variable message signs have been carried out. In these cases, it is the road authority, namely The Swedish Transport Administration who has been responsible for the trials. Since this topic encompasses a wide range of health and safety issues, it is important that union representatives are part of the process.
5.5.4 Good advice for implementation

It is beneficial to consider other measures for reducing speeds in conjunction with the introduction of dynamic variable signs at roadwork sites. One such measure might be mobile traffic safety cameras connected to active road humps; the feature means that only those vehicles driven at excess speed are affected by the hump.

5.5.5 Please refer to

- Automatic speed monitoring.
- Vehicle-activated speed-limit reminder.

Good examples: Information about temporary diversions/roadwork

Eight mobile VMS for controlling speed were installed at a road construction site on the E18 in Västerås in 2007. The aim was to affect speeds to improve road worker safety during construction. Speed reductions were applied during working hours, but relaxed outside working hours (evenings and weekends) when no work was in progress. The safety level for workers at the site was improved as a result of the system.

In another Swedish Transport Administration Project, field studies with dynamic variable message signs for roadwork markings were conducted on the E4 (between Uppsala and Arlanda), the E18 (between Arninge and Rosenkälla) and road 73 (at Jordbro). The project aimed to investigate, under real conditions, if using variable message signs to display roadwork markings could improve safety and create a better mental and physical work environment. The trial was evaluated through surveys with road users and road workers. Ninety nine per cent of road users felt that the VMS signage was clear and simple and 78 per cent said that it was more visible than traditional signs. Seventy five per cent of road workers found that the dynamic signage was better than traditional signage.

Mobile message signs at roadworks can be equipped with environmentally friendly and efficient electrical supplies such as solar cell or fuel cells. Compared to conventional battery power, methanol-based technology provides longer operating times and increased safety for field staff who do not need to spend as much time in the “danger zone” changing batteries. The core of the environmentally friendly systems are accumulators that are trickle charged by solar cells and fuel cells.

The newer systems require only infrequent refuelling with methanol. This leads to reduced maintenance costs, road safety improvements and time savings for contractors.

5.6 Vehicle-activated speed-limit reminder

Vehicle activated speed-limit reminder road signs are installed to solve local traffic problems in places where traditional physical remedies either don’t work or are not cost-effective. The systems increase road user awareness as they are only activated when the current speed limit is exceeded.

Detectors (for example radar) measure the speed of approaching vehicles and activate signs which inform speeders of the current speed limit.

5.6.1 Tillämpning

A common application for speed-limit reminder systems is to increase road safety on roads through small communities. In typical cases, the stretch of road is lined with pavements and buildings on both sides. Along the road are schools and residential buildings and there are unregulated pedestrian crossings at regular intervals. Visibility may be obscured. Vulnerable road users, such as children, are at risk when vehicles exceed the posted speed limit.

One solution might be to install vehicle-activated speed-limit reminder signs, these can be seen from a distance and give road users time to adjust their speed.

Another application is speed damping on sections of road that are prone to accidents as a result of sharp corners or poor visibility.
5.6.2 Effects

Speed-limit reminder signs can, for example, be used to increase compliance and reduce speeds in 30km/h zones outside schools. Studies have shown that the average speeds are reduced by 10 to 15 per cent. Field surveys have shown that many think road safety is increased and that the variance in speeds is improved and that they would like to see more such systems on the road network.

5.6.3 Actors

The action is carried out by the appropriate road authority: municipalities and the Swedish Transport Administration. It is beneficial to coordinate implementation with relevant local actors such as schools and police.

5.6.4 Good advice for implementation

Before a speed-limit reminder system is introduced, a problem inventory should be performed through traffic surveys, collection of public opinions and accident analyses. Is there an actual or perceived road safety issue and are speed reminder signs an appropriate measure?

After implementation, it is advisable to conduct follow-up traffic surveys. Did the measure have the desired effect? It is also beneficial to conduct an information campaign to inform the public about the system’s function and purpose.

Fine-tuning and other adjustments should be performed immediately after installation to increase road users’ trust in the system. If signs are only to be active during certain time periods, for example, during school hours it is also important that system time settings are properly implemented. One advantage of dynamic signage over traditional fixed signage is that it is possible to set the dynamic sign to correspond with the school term, thus avoiding speed reductions during school holidays. If such measures are combined with automatic speed surveillance, an even better traffic calming effect is usually achieved.

5.6.5 Please refer to

- Vehicle-activated warnings for pedestrians/cyclists.
- Automatic speed monitoring.

**Good examples: Vehicle-activated speed-limit reminder**

In 2006, a vehicle activated speed-limit reminder system was installed in Björketorp, Växtorp and Bovalstrand in the west of Sweden as part of an investment in local ITS. The systems were later evaluated.

The results were generally positive and road users showed good acceptance of the systems. In Bovalstrand speeding was reduced by as much as 56 per cent in the southbound direction after the system was installed. Engaging local stakeholders such as municipalities, the transport administration and schools in the implementation process proved to be an important factor for successfully establishing the systems. In an interview survey 60 per cent of respondents said that they believed that the systems contributed to a higher degree of road safety. 84 per cent felt that the signs should remain and 75 per cent wanted several similar systems on other roads.

*Source: Utvärdering lokala ITS-system (Evaluation of local ITS systems), Sweco, 2007.*
5.7 Vehicle-activated warnings for pedestrians/cyclists

An ordinary traffic signal automatically detects vehicles approaching whereas pedestrians and cyclists who wish to cross must make their presence known by pressing a button. As a result there is a risk that pedestrians and cyclists walk or cycle through a red light. At pedestrian/cycle signals with high vehicle traffic flows there may also be a safety issue related to long green times given to vehicles. In such circumstances drivers may be so used to seeing green that they fail to check properly whether the lights are green or red.

An alternative to traditional signal control in such cases is to implement a system for pedestrian/cyclist warnings. Junctions can be made safer by equipping pedestrian/cycle crossings with motion sensing detectors and dynamic warning signs. When a road user enters the detection zone, the sign will automatically be activated. The warning sign display time is pre-set and the sign shuts down automatically when the time has expired.

5.7.1 Application

Pedestrian and cycle traffic can be particularly high close to bus stops and schools. This can create a potential road safety problem, particularly if combined with high volumes of vehicle traffic. A permanent speed reduction is not always desirable if the aim is simply to reduce speeds when pedestrians or cyclists are in the area. To increase safety, a pedestrian/cyclist warning facility can be installed. Since the system only has a warning function, pedestrians and cyclists are encouraged to remain vigilant for vehicle traffic.

5.7.2 Effects

Warning systems for pedestrian/cyclists have a positive effect on road safety since signals are activated only when crossing occurs. The risk of children forgetting to press the button for a green light is eliminated through automatic activation. Delays for vehicle traffic are typically marginal, and often the result is a smoother driving style at pedestrian crossings. An increase in compliance from vehicle traffic leads to an increase in safety and security for pedestrians.

5.7.3 Actors

The action is carried out by the relevant road authority: municipalities or the Swedish Transport Administration. It is beneficial to coordinate implementation with schools and police. If implementation takes place at a bus stop the local public transport authority should also be consulted.
5.7.4 Good advice for implementation

In order for vulnerable road users to feel safe, it is important that warning signs are reliable. It is therefore important that the functionality of a pedestrian/cyclist warning facility is regularly checked. Goals should be established for the performance of a system and studies conducted to assess both the short and long-term effects. If the intended effects do not occur, examine why and consider whether improvements can be made.

There is always a risk for accidental activation of the system. False detections can occur due to weather conditions, birds and when people who do not intend to cross the road are detected. If this happens frequently, road users may lose respect for the system.

A variation on warnings at crossings is FIVÖ (Förrstärkt Information vid Övergångsställe – Reinforced Information at Pedestrian Crossings), which consists of lights mounted on the existing signage at pedestrian crossings. FIVÖ lacks unambiguous support in current legislation. There is therefore a need to develop clear strategies and policies for implementation for this type of measure.

5.7.5 Please refer to

- Vehicle-activated speed-limit reminders.

Good examples: Vehicle-activated warnings for pedestrian/cyclist

Along national road 49 outside Skövde (Hjovägen), there is a company that manufactures and sells machines. The nearby Lichron senior technical high school has close ties with the company. Many high school students travel by bus to and from the school and the bus stop is located on national road 49. Students must cross the road to get to the school. The speed limit is 70km/h. Two VMS signs have been installed adjacent
to the bus stop to alert motorists that there are pedestrians crossing the road thereby improving road safety for pedestrians. The signs are designed as warning signs for pedestrians. Movement at the bus stop and movement on the pavement towards the pedestrian crossing are detected. Movement along the pavement parallel to the road is not detected.

An interview survey used to evaluate the system showed generally positive results. Almost half the surveyed students felt that the environment around the pedestrian crossing had become more secure and motorists also responded that they, to a great extent, had changed their driving behaviour and reduced their speed at the site. This indicates that the sign has had a positive effect. The majority of road users wanted the sign to remain on the site.

A FIVÖ system was installed at Svedmyraplan in Enskede in 2007: a previously accident prone location as a result of a wide carriageway encouraging high vehicle speeds.

After FIVÖ was installed observations were conducted by the Traffic and Public Transport Authority in Stockholm to see how traffic at the crossing had changed. Following installation pedestrians felt safer as a result of the blinking signs. Many pedestrians look up at the lights to check that they are activated before proceeding to cross the street. The number of conflicts between pedestrians and motorists has decreased. Interaction and eye contact between pedestrians and motorists has improved. Motorists pay attention to the signs and are more willing to let pedestrians cross than they were previously. Finally the crossing is more visible particularly from a distance.

VTI (VTI notes 16-2010) has also evaluated FIVÖ in southern and central Sweden. In line with the findings of other studies, the systems provide greater perceived safety for vulnerable road users, and have some impact on vehicle speeds. However some of those interviewed felt that the flashing warning lights could be improved and made more visible.


5.8 Ghost-driver warnings

Motorists who drive onto the motorway in the opposite direction of travel, referred to in Sweden as ghost drivers, pose a serious problem. A mistake of this kind can have serious consequences potentially resulting in head-on collisions and fatalities. These types of incident often lead to major media interest.

Overall, accidents related to driving in the wrong direction are relatively few compared to other types of accidents. A survey conducted by The Danish Road Directorate showed that less than half a per cent of all accidents were due to driving in the wrong direction.

Traditional safety measures designed to prevent driving in the wrong direction include better signage, road markings and the physical separation of traffic lanes. These types of measures can make it more difficult to make the mistake, but provide no warning to other drivers once the mistake has actually occurred. In this context, ITS can be an effective tool for reducing the risk of accidents.
5.8.1 Application

On the continent, ghost drivers are an all too familiar occurrence. The Danish Road Administration has noted that the problem is increasing and the problem has also been highlighted in Sweden. ITS systems in Sweden and Denmark have been developed to prevent and mitigate the effects of ghost driving.

A fully developed system against ghost drivers may include the following elements:

- A detection system that records driving against the flow of traffic.
- Alerting the ghost driver through the use of LED’s in the roadway or other types of warning signs or audible warnings.
- Information passed to other drivers as a result of an alarm being raised at a Traffic Management Centre (TLC). From there, information can be passed to police and emergency services. Traffic information can also be distributed via RDS/TMC and radio.
- Systems such as barriers for opening or closing slip roads.

5.8.2 Effekter

There is limited experience of these types of systems in Sweden; there is currently only one installation at Varberg in southern Sweden. A number of systems are in place in Denmark, but even here experience is limited.

Lack of experience is thankfully a result of the fact that such accidents are relatively uncommon. For this reason, gathering experience about such systems takes time. However, it is clear that every serious accident that a warning system can prevent will save lives and money.

5.8.3 Actors

It is the relevant road authority, (Transport Administration or municipalities) who are responsible for the introduction of the measure.
5.8.4 Good advice for implementation

It is important that the road system is as self-explanatory as possible. Accidents can occur because of ambiguous signs or road markings. On stretches of road that are particularly vulnerable to ghost drivers it is important that the road geometry highlights the road's function. This is especially true at motorway ramps and connections to motorways.

Preventive information measures can provide advice about how motorists should respond if they encounter a ghost driver. In an emergency situation time is of the essence and quick action can mean the difference between life and death.

5.8.5 Please refer to

- Motorway control.
- Tunnel monitoring and control.

Good examples: Ghost driver warnings

The first ever warning system for ghost drivers in Sweden has been installed at Gunnestorp near Varberg. The site has been selected based on a perceived problem regarding ghost drivers. Over the course of a year three ghost driving incidents have occurred, one of which had fatal consequences.

Detectors located on a seven metre high mast detect vehicles heading in the wrong direction. Flashing yellow warning lights are activated further along the road alerting the ghost driver. The message is further reinforced by cautionary driving lane lights installed in the roadway. Only a short time after the system was established the first ghost driver was caught on camera; the driver noticed the warnings and turned around.

The problem of ghost drivers on the Öresund Bridge Link is managed through the bridge's traffic management and control system. The issue of motorists who reverse or perform a u-turn and drive in the wrong direction is something that has been worked on for years. Unfortunately when the link was first opened the danger of ghost drivers was not considered in the initial risk assessment for the crossing. Subsequently when ghost drivers were identified as a problem initial efforts focused upon improving the signage. During 2007 there were 68 incidents involving ghost drivers or cars reversing in the tunnel portion of the link.

If a ghost driver is identified on the bridge or in the tunnel, the traffic centre at Lernacken can take several courses of action: speed can be reduced, traffic lanes may be closed and the police, and if necessary, emergency services can be informed. Broadcasts on Swedish Radio Malmöhus, Danish Radio P3 and P4 are interrupted and warnings are sent out to motorists.
Technology wise, the Öresund Bridge Link is equipped with a security system that includes surveillance cameras, dynamic signs, barrier systems and speed reductions in the tunnel section. Generally, the ability to detect ghost drivers exists as a standard feature in systems for tunnel monitoring and control.

Source: The Swedish Transport Administration. The Öresund Bridge.

5.9 Dynamic parking information

Motorists who drive around looking for parking spaces can contribute to a decrease in road safety. The hunt for parking spaces can lead to traffic jams, queues, as well as frustration and reduced attention from motorists.

It is estimated that anywhere between 10 and 40 per cent of traffic in large cities is made up of cars looking for parking spaces.

Better information about available parking facilities can make it easier for drivers looking for spaces. The benefits are a reduction in the volume of search traffic, less congestion at parking facilities and more efficient use of available parking spaces. A reduction in search traffic means less pollution and better air quality.

Dynamic parking information systems count the number of vehicles entering and exiting car parks using detectors. This information is then sent to a central system for processing. From there data is sent to dynamic signs which show the number of spaces available or if the car park is fully occupied.

5.9.1 Application

The system is designed to show motorists where there are empty spaces available and where they are located. The goal is to reduce the volume of search traffic and make it easier for motorists visiting the city centre. In addition, the system can be used to improve accessibility to the city centre, thus increasing the city’s attractiveness.

5.9.2 Effects

Dynamic parking information can lead to a reduction in kerbside parking, increased traffic safety and a better environment. The system allows motorists not familiar with the city to feel more comfortable and secure. Another benefit is that the system generates useful parking data which can be readily applied in the local transport planning process.

5.9.3 Actors

It is important to involve all relevant stakeholders during the design and decision phase of a project. Such stakeholders include: parking operators, politicians, road authorities, municipalities, owners of parking facilities, the local business community and environmental interest groups.
5.9.4 Good advice for implementation

Implementation should be based on clear strategic objectives for the system in question. Strategic objectives should be based on experiences from the introduction of similar systems elsewhere. In the initial phase of project implementation, responsible actors should monitor relevant trends, for example, through study visits to other cities. Such visits can help in the formulation of an image and vision of how the system should be designed and what should be achieved.

During implementation it is essential that an appropriate project organisation is set up. Such an organisation will allow representatives from all parties to follow the project from concept to implementation and provide input where necessary.

Operation and maintenance should be planned and budgeted for at an early stage. In addition, systems should be built with room for flexibility so that alterations and expansion can take place at a later stage. After a period of operation, it is appropriate to evaluate and investigate the reliability of the system. This provides valuable feedback to operators. Systems for dynamic parking information can also be expanded to include other media like the Internet, where information on the availability of spaces can be communicated.

5.9.5 Please refer to

- Park and Ride information.

Good examples: Dynamic parking information

The parking management system P-Evenemang went into operation in Gothenburg in 2005. The system provides guidance to large parking facilities in conjunction with major events taking place in the central part of the city. The purpose of the system is to minimize search traffic thereby reducing congestion and pollution. Variable message signs on the key approach roads to the city provide motorists an early warning of events taking place in the city centre. As motorists approach the city centre, dynamic parking signs provide clear directions to suitable car parks. The signs show the number of spaces available and whether it is an indoor or outdoor parking facility. The system enables existing car parks to be used more efficiently.

Another key goal of the system is to make the city more attractive. This in turn assists event organisers in their efforts to advertise and attract visitors to major events. Major events should be an asset to the city while traffic in connection with them should flow as smoothly as possible. Event-related traffic information is also shown on the municipality run website evenmangstrafiken.nu.

Interviews conducted as part of an evaluation of the system have shown that both event organizers, parking companies and the Swedish Transport Administration and the Traffic and Public Transport Authority are satisfied with the system. In particular the system has been successful in reducing the volumes of search traffic and ensuring that visitors are directed to the right facility and find adequate parking within a particular area in the right time.

A survey of motorists showed that the system is especially helpful for those travelling longer distances into the city. Nine out of ten motorists think the signs are good. Those living in Gothenburg and the surrounding municipalities estimate that on average they have saved 15 minutes as a result of the system. For those living in the rest of the region and further afield, the corresponding figure is 19 minutes.

5.10 Park and Ride information

Commuting by car has increased in recent years and people are commuting longer distances and more frequently. One consequence of this is traffic jams and adverse environmental effects. Measures designed to facilitate public transport and car-pooling can reduce these problems. Public transport can move people in large numbers and with greater energy efficiency. Park and Ride information systems make it possible to combine the freedom of movement of the car with the efficiency and environmental friendliness of public transport.

Park and Ride information systems are not common in Sweden, but are frequently used abroad to provide information about parking availability or train departure times. Dynamic signs showing the number of available parking spaces can also be used to guide motorists between adjacent car parks or provide guidance within a large, multi-sectioned parking facility.

5.10.1 Application

A Park and Ride system makes it possible for motorists to park their cars and continue their journey by bus or train. Dynamic information signs are used to inform motorists about the current traffic situation and journey times, allowing them to choose the best option.

The volume of car traffic is reduced which can have other positive benefits in the form of a reduced requirement for parking spaces in a city centre.

5.10.2 Effects

Experiences from several British cities show that users appreciate the system; half of them use the opportunity at least once a week.

A system in Fröttmaning, Munich reduced car traffic on an approach road by two per cent, corresponding to a reduction in CO2 of 1000 tonnes per year. In addition journey times were reduced by 30 per cent.

A study of the effects of road user information in Helsinki estimates that the socio-economic benefits of road users switching modes from car to public transport will increase. It is estimated to be EUR 2 500 per hour in 2025.

5.10.3 Actors

The introduction of commuter parking and associated dynamic information systems is the responsibility of the road authority in collaboration with public transport operators and municipalities.
5.10.4 Good advice for implementation

A basic premise for the system is that there is a car park where motorists can park their car when changing modes of transport. The means of public transport must also be separated from other vehicles: i.e. that they either have a separate lane or another route. Otherwise there is a risk that the public transport service will get caught in the same congestion as other motorists. The best example of a successful execution of commuter parking is where the rail and road routes run in parallel; where departure frequency is high during rush hour; and where trains have competitive journey times compared to using a car.

The correct placement of information signs is essential for the system’s effectiveness. Combing the cost and payment methods for parking and travelling on the public transport service is also key to encouraging use of the service.

5.10.5 Please refer to

- Dynamic parking information.

**Good examples: Park and Ride information**

During the spring of 2010 a field trial was conducted in Sickla shopping centre, where a new solution called Smart Park & Ride was tested and evaluated. Motorists in Nacka and Värmdö were given the opportunity to become test drivers in the trial. Participants had access to a mobile phone service providing traffic information from SL (Stockholm Public Transport), including the possibility to pre-book parking as well as commercial service offers.

The hope was to make life more convenient for users of the Park & Ride system allowing motorists to combine their car and public transport journeys whilst giving people the opportunity to perform some of their everyday chores.

Admittance to the parking area was coupled with the SL ticket, using the latest SL smartcard ticketing system. Specific parking spaces (for example with power points for charging electric vehicles) could be booked in advance via mobile phone or the internet.

The results of the evaluation showed that the number of habitual motorists was halved. About a quarter of test drivers said their shopping habits changed a lot or in part and nine out of ten of the test drivers wanted the smart commuter parking to be implemented permanently.

The initiative was a collaborative effort between SL, the Swedish Transport Administration, the municipality and commercial actors.

*Source: www.smartinfart.se. PM workshop 21/10/10, Samverkan för effektivt transportsystem i Stockholmsregionen (Cooperation for an efficient transport system in the Stockholm Region), Office of Regional Planning Stockholm.*
5.11 Real-time public transport travel information

Real-time travel information means that current information about public transport is conveyed to travellers via monitors adjacent to a stop. The information may concern current schedule, expected arrival, delays, temporary changes or directions.

A reliable vehicle tracking systems is a prerequisite for providing accurate departure times at public transport stops. Systems must be able to make accurate forecasts about estimated departure times and transmit this information to passengers.

Better information about public transport is one of the key methods for improving public transport competitiveness. Together with other measures that contribute to an improved public transport supply, this may imply rearranging routes or changes in ticket fares.

5.11.1 Application

At bus stops and terminals information is conveyed via signs, monitors, dynamic display boards and audibly over speaker systems.

Typically information is provided about forthcoming departures as well as information regarding any service disruptions. Such information makes it possible for passengers to plan their journey more effectively and take appropriate action in the event of disruptions.

Automatic announcements are one way of increasing accessibility and quality of service for the disabled. Systems must be designed in accordance with policies and guidelines for the disabled as produced by the Swedish Parliament.
5.11.2 Effects

Passengers feel that the service works better as information allows them to make informed travel choices based on the prevailing traffic situation. Known waiting time can be used to perform another errands for example. Studies have shown that waiting time is perceived as three times shorter if information about the estimated time of departure is provided in advance.

When major disruptions occur, passengers are informed about what has happened and given information about the consequences for their intended journey. The perception that public transport is more reliable is enhanced and this in turn may lead to an increase in passenger numbers.

5.11.3 Actors

Key players for systems implementation are: municipalities, public transport operators and public transport providers.

5.11.4 Good advice for implementation

It is vital that passengers trust the information being provided. Trust is built on the quality of the real-time information. It is also important that real-time data is presented in an easy to understand and unambiguous fashion.

5.11.5 Please refer to

- Public transport priority.

**Good examples: Real-time public transport travel information**

In the Gothenburg region Västtrafik (a public transport company in Western Sweden) has widely adopted real-time information at stops and major terminals. In Gothenburg, information is conveyed to the signs and monitors via the "KomFram system". The focus on developed real-time information has particular been prioritized at the major stops where many travellers pass through.

In a user survey conducted by Västtrafik, nine out of ten travellers said that they often or always looked at the real-time display. Nine out of ten thought that the time estimate was accurate. In summary, travellers were satisfied with the information and they did not feel a need for further information.


As early as 15 years ago, real-time information about the next bus through mobile phones was tested; now travellers expect access to such information to always be available.
Controlling and managing traffic

- How can traffic be managed through signal control?
- What does the introduction of variable message signs involve?
- What effects do traffic management measures have?
Within the category of “control and manage traffic” the following ITS measures are included:

- Traffic signal control.
- Operation and maintenance of traffic signals.
- Public transport priority at traffic signals.
- Ramp metering.
- Variable speed limits (weather and traffic actuated).
- Reversible lane control.
- Motorway control.
- Hard shoulder control.
- Road-user charging in urban areas.

### 6.1 Traffic signal control

*In the right location, traffic signals are an efficient means of improving road safety, accessibility and the environment. Despite many of the country’s signal controlled crossings having been rebuilt as roundabouts, traffic signals will continue to be used in the future.*

Traffic signal control can either be **isolated**, with each intersection signal controller working completely independently, or **coordinated**, where traffic signals at several intersections are synchronized. Coordinated systems are typically designed to reduce the total delay and number of stops in the area covered by the coordinated system. Approximately 1000 of Sweden’s traffic signals are part of coordinated systems and they are mainly in urban areas.

#### 6.1.1 Application

Traffic signals are introduced when conflicting traffic flows have become too great to be self-regulating. They are particularly appropriate at intersections where one road has significantly more traffic than another. Signals can also be used to good advantage to regulate conflicts between vehicles and vulnerable road users. In addition traffic signals can be used to give priority to a vehicle category, such as buses or emergency vehicles.

Traffic signals are important for disabled road users, and especially for the safety and security of the visually impaired. In addition, traffic signals require less physical space than roundabouts making them highly suitable in physically constrained urban environments.
6.1.2 Effects

Isolated traffic signals often work smoothly and efficiently as they do not need to take into account the traffic situation at other intersections. Installing traffic signals at appropriate locations can lead to significant road safety improvements. At four-armed junctions accidents can be reduced by as much as 30 per cent. Three-armed junctions typically experience a reduction in accidents of around 15 per cent.

Coordinated traffic signals are typically designed to optimise traffic flow on a major road. This poses a traffic engineering challenge in terms of providing suitable access to and from side streets. Traffic signals require monitoring and regular maintenance, both of the equipment itself but even the relevance of the different signal programs to prevailing traffic conditions. By employing modern traffic signal control strategies, coordinated systems can provide significant cost savings to society in the form of reduced journey times, less congestion, fewer stops, lower emissions and a reduced number of accidents. With improved coordination, delay times can be reduced by 10 to 20 per cent or more, depending on the effectiveness of the existing system.

Conflicts of interest can arise at congested intersections between different groups of road users. The introduction of traffic signals can be used to increase accessibility for particular road user groups such as public transport or pedestrians. Traffic signals can also have a significant localised impact on the environment. There is a clear relationship between the number of stops and emissions levels: fewer stops at red signals result in lower vehicle emissions.

6.1.3 Actors

Relevant road authorities are responsible for implementation: municipalities or the Swedish Transport Administration. In some situations collaboration is required, for example, when a signal controlled junction affects both municipal and Transport Administration roads.

6.1.4 Good advice for implementation

It is important to conduct a thorough delivery inspection during the installation of traffic signals. This is particularly important since the correct operation of the traffic signal has a direct impact on road safety.

Operation and maintenance is very important in achieving and maintaining the positive effects of traffic signals (this is discussed under section 6.2 Operation and maintenance of traffic signals).

6.1.5 Please refer to

- Public transport priority.
- Operation and maintenance of traffic signals.
Good examples: Traffic signal control

Considerable social and economic benefits can be made by adapting existing coordinated traffic signals to current traffic flows. One such example is the MATSIS project (Minskade CO2-utsläpp genom Adaptiva Trafiksignaler I Stockholm [Reduced carbon dioxide emissions in Stockholm through adaptive traffic signals]) conducted between 2004 and 2008. Improvements were made at six locations controlled by a series of coordinated signals. At one site (Valhallavägen) the improvements were estimated to an annual reduction in carbon dioxide emissions of 850 tons.

Computer simulations carried out in the project showed that emissions could potentially be reduced by 2900 tonnes of carbon per year, or seven per cent; all as a result of optimising the time settings in the signal controllers. In addition, delays in the signals were reduced by 19 per cent. Overall, the socio-economic benefits were estimated to be SEK 118m per year.


6.2 Operation and maintenance of traffic signals

It is essential that sufficient resources are set aside for the operation and management of traffic signals. All too often, there is a tendency to make cost savings through neglecting maintenance activities. However, regular maintenance and time plan updates are essential for ensuring the best financial and environmental returns from traffic signal controllers.

Continuous operational updates and systematic maintenance are important, since lack of maintenance leads to delays, vehicle costs, an increased number of accidents and increased carbon emissions. Small, inexpensive efforts on a regular basis can bring substantial socio-economic gains. This applies to both isolated and coordinated traffic signals.

6.2.1 Application

Operational measures for traffic signals are divided into preventive, corrective and technical maintenance services.

Preventive maintenance includes repairing defective posts and signal boxes, cleaning lenses, adjusting acoustic signals and functional control of detectors and buttons.

Corrective operational measures include the repair of broken detectors, damaged posts, broken electronics and cable faults.

Traffic-engineering supervision means ensuring that the signal controllers programming and functionality is continually updated to take account of prevailing traffic conditions and traffic management strategies and legislation.

Fine-tuning of traffic signals is unbeatably profitable; it creates order in traffic.
6.2.2 Effects

Preventive and corrective maintenance is especially important for accessibility, e.g., for people with disabilities, as this group are dependent on push buttons and lights working correctly. It is also important for road safety. If a traffic signal is blinking yellow during off-peak, the number of personal injury accidents are estimated to increase by about 50 per cent.

Properly functioning controllers are essential for business travel and transportation in order to reduce congestion and thereby cost.

The effects from improving the signal control, from socioeconomic perspective, the cost of accessibility dominates. The time and the vehicle cost due to delays at an average signal coordinated system in Sweden is SEK 4 million per year in delays and lost time. The cost of accidents and environmental impacts is estimated to be about half the value of the cost of delays.

Frequent, small and inexpensive remedial measures can reap substantial socio-economic gains. Normally, the repayment time on operating and maintenance measures for traffic signals is short, often less than a year. Studies from a number of junctions in Stockholm have shown that fixing a broken detector can repay itself in a day (savings of SEK 2.5m/year, cost of repair SEK 7000). Fine tuning poorly adapted signal timings can have a payback period of about a month (gain SEK 0.5–1m/year; cost SEK 50 000), based on reduction in delays of 10 to 20 per cent.

It is estimated that as a result of changes in traffic conditions the average signal program becomes less efficient at the rate of one to five per cent annually. Small, regular changes are therefore extremely cost effective.

6.2.3 Actors

Responsibility for implementation and maintenance lies with the road authority: the municipality or the Transport Administration.

6.2.4 Good advice for implementation

The operation and maintenance of traffic signals should be given greater priority given the scale of the socio-economic benefits available.

6.2.5 Please refer to

- Traffic signal control.
- Public transport priority at traffic signals.

Good examples: Operation and maintenance of traffic signals

A 2008 report published by the then Swedish Road Administration gave examples of the social costs caused by poorly maintained signals. The report estimated that around 1000 of the country’s traffic signal controllers have detector faults which cost SEK 2.3bn per year in terms of journey time losses, fuel and emissions.

In contrast Helsingborg regularly maintains its traffic signals throughout the city by conducting routine traffic-engineering overhauls of the controllers. The signals are reviewed and the programming is fine-tuned so that traffic flows better. This work also includes taking into account accident rates for intersections to improve traffic safety.

6.3 Public transport priority at traffic signals

A functioning and efficient public transport system is very important, both in cities and rural areas. To prevent and reduce congestion in city centres it is essential that public transport is good enough to encourage people to leave their cars at home and use public transport instead. One way of achieving this is to get public transport moving faster by giving it priority at signalised junctions.

There are a number of essential preconditions for providing effective public transport priority at signals. These include: real-time vehicle systems, radio communication, road user information and traffic management.

The bus prioritization part of the public transport system is small, but sets a high demand on speed, precision and reliability in the detection and radio communication systems.

6.3.1 Application

The attractiveness of public transport is perceived to be, in relation to how frequent it is, how punctual it is and how long it takes to complete a journey. Public transport priority at signalised junctions can lead to an increase in the efficiency and thereby the attractiveness of public transport. Traditionally waiting times at traffic signals for buses can be considerable as they must sit in the same queue of traffic as every other vehicle.

Bus priority provides up to 15 per cent reductions in bus journey time in the inner city.
However, with modern traffic signal technology, it is possible to provide effective bus priority at both isolated and coordinated signal controlled junctions. In situations where it is difficult to provide dedicated bus infrastructure such as bus lanes, public transport signal priority can be an effective alternative. Bus priority can also improve accessibility for bus routes on minor roads that cross busy main roads.

Using similar equipment as on buses, the technology in place can also be used to provide priority to other types of vehicles such as the emergency services.

### 6.3.2 Effects

The major benefit of public transport priority is that buses and trams are more likely to arrive on time and suffer fewer interruptions along their journey.

European evaluations have shown anything from 5 to 15 per cent improvements in bus journey times as a result of public transport priority at signals. In some cases, delays to public transport have been reduced by as much as 40 per cent. Of course frequent and substantial public transport priority can have a detrimental effect on accessibility for other road users. Careful planning is therefore required to achieve the right balance between improving public transport and maintaining accessibility for other road users.

Giving priority to public transport vehicles can lead to vehicles being used more efficiently; fewer buses are needed to move the same number of people.

### 6.3.3 Actors

Normally, the road authority is responsible for traffic signals and associated road side equipment, while public transport operators and transport companies are responsible for vehicle systems.

### 6.3.4 Good advice for implementation

Experience has shown that public transport priority systems can be difficult to maintain. The systems are frequently complex involving interaction between detection systems, vehicle computers, road side units and traffic signals. This level of complexity places greater demands on monitoring, operation and fault rectification. It is essential that these aspects are taken into consideration at the planning stage prior to systems implementation. It is also important that the different stakeholders involved (road authorities, transport operators and operating contractors) clearly establish their areas of responsibility.

Particular focus should be placed on fine-tuning the system, in particular radio coverage, waiting times, detection distances and queues for other traffic.
6.3.5 Please refer to

- Traffic signal control.

**Good examples: Public transport priority at traffic signals**

Linköping is a good example of a medium sized town with a well-functioning bus priority system. Buses are given priority at 70 traffic signals throughout the town. Currently only city buses receive priority but plans are underway to include some regional buses in the system. A rolling schedule of maintenance and improvements ensures that the system is always working at its best.

Jönköping introduced a bus priority system in 1996 and the system has gradually been expanded over time. Today 13 signals can give bus priority within the urban area. As in the case of Linköping there is an effective operations and maintenance schedule in place. The Fault reports received by the municipality, go directly to the operating contractor’s emergency centre. In addition, the county public transport authority, municipality and bus operators hold joint review meetings where operational issues can be raised.

In Stockholm approximately 100 bus rapid transits (BRT) are given priority at about 100 junctions. The current system was introduced in 1998 and has been so successful that a major expansion of the system throughout Greater Stockholm is underway. One unique feature of the system is that buses running ahead of schedule do not receive priority. This feature improves frequency and punctuality and reduces the risk of buses “clumping” together.

*Source: Bättre Bussprioritering (Better Bus Prioritization), the Swedish Transport Administration, 2010. RETT – ett pilotprojekt för bättre regularitet i busstrafiken (RETT – a pilot project for better regularity in bus traffic), SL, 2003.*
6.4 Ramp metering

On busy motorways, traffic joining the main carriageway from slip roads can create friction and lead to a significant reduction in capacity on the main carriageway. Ramp metering makes it possible to release traffic onto the main carriageway in controlled amounts to achieve smoother weaving and prevent queues, thereby maintaining capacity on the main carriageway. Special traffic signals are used which display green-yellow-red at short intervals to slow down the ramp flow.

Ramp metering systems can also be used to reduce cut-through traffic making use of local roads to avoid motorway queues. Cut-through increases traffic on local roads reducing security for vulnerable road users and causing disruption to local public transport.

Ramp metering is common throughout North America but less so in Europe. In Sweden ramp metering is used at a number of motorway junctions on the E4/E20 Essingeleden.

6.4.1 Application

Ramp metering is used at locations where it is beneficial to limit ramp flows joining the main carriageway under periods of high traffic density. Systems work best when the main carriageway is at 80 to 85 per cent of capacity.
Ramp metering is controlled by conventional traffic signals. Signal posts carry additional signage with the following text: "ONLY ONE VEHICLE PER GREEN PERIOD". During the off-peak period the signals are switched off.

Traffic volumes are measured upstream and downstream of the slip road and this data is used by the system to determine when ramp metering should be activated. Flows are also measured on the ramp to prevent large queues building, resulting in blocking back at other junctions upstream of the ramp.

### 6.4.2 Effects

The system has many potential benefits: smoother flow on the main road, better accessibility and reduced journey times. The traffic signal on the slip road splits up platoons of vehicles making it easier for individual vehicles to join the main carriageway. As a result, the risk for local shock waves is decreased. A smooth traffic rhythm is maintained on the main carriageway, increasing capacity, reducing the risk of accidents and to some extent reducing vehicle emissions.

However ramp metering can sometimes have profound implications on the secondary, local road network. It is therefore vital to perform a thorough traffic impact assessment of the consequences before installing a ramp metering system. This can usefully be performed through traffic simulation.

### 6.4.3 Actors

The establishment of a ramp metering system is the responsibility of the road authority, which in practice is the Swedish Transport Administration. Given the potential impact of such systems on the secondary road network, it is important to open a dialogue with the local road authority.

### 6.4.4 Good advice for implementation

Ramp metering is not always viewed in a positive light by road users. Red lights may be ignored particularly during the busiest periods.

Ramp metering systems should be traffic controlled, operating only during the busiest periods.

Any system must have the ability to monitor and regulate queues on the slip road to avoid blocking back onto the secondary road network. In the same way, ramp metering systems should only be installed on slip roads that are sufficiently long to cope with a certain amount of queuing.

Any public transport routes using the slip road should have the ability to pass outside the signal controlled lane.

Ramp metering can lead to some traffic choosing alternative and sometimes unexpected routes. Such behaviour can have unexpected consequences for the local road network.

Experience from systems implemented abroad has shown the importance of conducting a wide ranging information campaign, to ensure that road users understand why the system has been installed and how it works. Any such campaign should be carried out well in advance and in conjunction with system implementation.
6.4.5 Please refer to

- Motorway control.
- Queue-warning.
- Variable speed limits.

Good examples: Ramp metering

During the planning phases of the Stockholm congestion charge it was anticipated that the new charge would lead to an increase in traffic on Essingeleden. Following discussions between the Swedish Road Administration and the City of Stockholm, ramp metering was suggested at three locations to help mitigate the effects of the expected increase in traffic.

Following installation, a number of positive effects were observed. Through traffic on Essingeleden increased without a corresponding increase in delay. Flows through Nyboda and Ärstalänken increased by 300 to 400 vehicles per hour during the peak period. Furthermore congestion on the Southern Link was reduced and local congestion at exits was virtually eliminated. The negative effects were the journey times. They increased between 1 and 10 minutes for traffic using the signalised ramps and there were some negative impacts for local public transport.

6.5 Variable speed limits (weather and traffic actuated)

In 2003 experiments began with variable speed limits at 20 locations around Sweden. The purpose of the experiments was to test systems for dynamically adjusting speed limits based on deteriorating road or weather conditions. The experiments showed that variable speed signs resulted in a better response from traffic to speed adjustments than traditional fixed signs. The risk of accidents was reduced and traffic flows were generally smoother. Only marginal environmental benefits were observed.

The first variable speed limit system was put into operation on a stretch of road at Kyrkheddinge in October 2003. This was subsequently followed by twenty or so other trial installations split across a variety or urban and rural locations. Following positive experience from the trials a further 10 sites were planned in 2010.

6.5.1 Application

Variable message signs, displaying the maximum speed limit are installed at suitable locations on the road network. The speed limit is changed based on a number of different events occurring such as: risk for slippery roads, queues, hidden junctions or the presence of vulnerable road users.
Regulating the traffic flow with variable speed limits leads to calmer driving, less sudden braking, and a reduction in accidents of approximately 10–20 per cent. Meaning that the speed limit sign is only activated when weather conditions are worse than normal. If a speed limit sign is not switched on, the normal speed limit will apply.

The three fields of areas for variable speed limits are:

- Road junctions with intersecting and turning traffic.
- Road manage by variable weather conditions - mainly road and wind conditions.
- Road manage by traffic intensity - e.g. traffic flow, speed, queues, pedestrians or crossing traffic.

6.5.2 Effects

At intersections speed reductions of up to 10 km/h can be achieved with a corresponding reduction in the risk of accidents. At locations susceptible to changing weather and road conditions typical speed reductions are between 12 to 20 km/h. In the event of congestion, variable speed limits help to reduce the risk of sudden braking and rear-end collisions. Some reductions in average speeds have also been observed when variable speed limits are applied at pedestrian crossings.

There is generally a very high acceptance of variable speed limits among motorists and many feel that their driving behaviour has improved. In addition, the effects are reinforced over time and the majority of road users are very satisfied. Pedestrians are also generally satisfied, but still feel that some people do not reduce their speed enough.
### 6.5.3 Actors

The Swedish Transport Administration has the power to introduce variable speed limits based on trial legislation (SFS 2002:713 försöksverksamhet med varierande högsta tillåtna hastighet). The police are responsible for enforcing speed limits and it is essential that the road authority cooperate with the police when establishing a new system. In addition there is a larger body of interest groups and organisations that would like to see variable speed limits applied at different locations, such as schools or hospitals.

### 6.5.4 Good advice for implementation

The use of variable message signs is regulated by: the Swedish Traffic Sign Regulation, SFS 2002:713, other regulations and VGU ‘Vägar och Gators Utformning’ (the Design of Roads and Streets). A special VGU supplement for variable speed junctions is being developed and is scheduled for completion in 2011.

It is important to note that variable message signs require regular maintenance. Management responsibilities and operating and maintenance costs should be fully considered at the planning stage.

### 6.5.5 Please refer to

- Motorway control.
- Tunnel monitoring and control.
- Operator-controlled traffic information.

**Good examples: Variable speed limits at intersections**

High vehicle speeds through a four armed junction along national road 21 in Vanneberga caused problems for vehicles trying to enter from side roads.

A variable speed limit system was introduced that reduced the speed limit through the junction to 50 km/h during certain situations: with traffic approaching from a minor road, or when traffic wants to turn left from the main road.

In the first case the speed limit is reduced in both directions on the main road. In the second case the reduced speed limit applies only to oncoming traffic approaching the vehicle that wants to turn left. Variable message signs are used to display the reduced speed limit.

A study conducted some time after installation showed that road users have become more cautious and that average speeds through the junction have been reduced by more than 10 km/h when the system is active. Road safety has been improved and it is now much easier for vehicles to enter the junction from minor roads as well as turn left from the major road.

*Source: Variabel hastighet i korsningar - tillämpningsrapport 2006:141.*
### 6.6 Reversible lane control

*In many cases, problems arise when the traffic increases and capacity on the road is limited with little or no opportunity to build additional lanes. For this reason, the road authority tries to find effective ways to improve accessibility.*

Constantly increasing volumes of traffic can lead to increasing congestion on the road network. In many cases physical constraints make it impossible to provide extra lanes to ease congestion. Road authorities need to find new and flexible ways of increasing capacity and improving accessibility.

#### 6.6.1 Application

Reversible lane control systems are used for traffic control on three-lane roads where the direction of travel on the middle lane can be switched. The direction of travel on the middle lane is typically regulated by variable message signs. Reversible lane systems can lead to an increase in road safety and make more effective use of available road space.

#### 6.6.2 Effects

Only one reversible lane control system is currently in operation in Sweden along a 1.5 km stretch of road through Värmdö just outside Stockholm. An evaluation of the system found that it has, for the most part, functioned satisfactorily. The critical points were found to be pedestrian crossings with traffic islands, where some vehicles ended up on the wrong side of the road. Extensive speed measurements and road user surveys were conducted both before and after system installation. The vast majority of road users have been extremely positive towards the system, with the exception of cyclists who have experienced some difficulties. These include less space available for cyclists and fewer opportunities for crossing the road. Accessibility for motorists, however, has been greatly improved. This improvement has led to higher speeds, so much so that many now drive over the permitted speed limit of 50 km/h.

#### 6.6.3 Actors

The road authority is responsible for the implementation of traffic control systems using variable message signs. Consultation with municipality, police and local interested parties is important.

#### 6.6.4 Good advice for implementation

It is very important to consider pedestrians and cyclists when implementing reversible lane control. Experience from Värmdö has shown that there is a risk of these road users suffering reduced accessibility. It is also important to involve all interested parties: individuals, companies and organizations from the beginning of the project and have a clear and comprehensive information strategy.
Reversible lane control systems should be controlled automatically; manual control entails significant safety risks for road personnel.

The Swedish Traffic Sign Regulations and VGU supplement: Reversibla Körfält, 2004:80 stipulate requirements for the implementation of reversible lane control.

It is important to note that variable message signs require regular maintenance. Management responsibilities and operating and maintenance costs should be considered in the early planning stages.

6.6.5 Please refer to

- Motorway control.
- Tunnel monitoring and control.
- Operator-controlled traffic information.

Good examples: Reversible lane control

Road 222 between Mölnvik and Ålstäket on Värmdö has suffered from serious congestion for some time, particularly during the summer months when traffic increases from 18,000 to 28,000 vehicles per day.

According to a survey conducted by the then Swedish Road Administration (based on telephone interviews) nine out of ten Värmdö residents said that accessibility was poor. All road user groups were critical, motorists most of all.

In order to solve the problem, the road was widened in 2006 to three narrow lanes with a reversible lane in the middle.

In the morning when westbound traffic towards Stockholm is most intense, the middle lane is used for traffic going into the city. In the afternoon the majority of the traffic is travelling eastbound and the middle lane is then used for traffic in that direction.

Initially the process of reversing the middle lane was carried out manually however from 2008 the system was fully automated. Mechanical barriers and variable message signs are used to switch the driving direction of the middle lane. The entire
system can be controlled and monitored remotely from the Traffic Management Centre – Trafik Stockholm.

Overall, the system has had a beneficial effect on accessibility. Queues have all but disappeared and public transport has also benefited. Following implementation of the scheme only one out of ten is critical of the accessibility issue. In addition, the system is cost-effective at a cost of only SEK 20M. To build a four-lane road would have cost SEK 140M.

Source: Utvärdering av reversibelt körfält på väg 222 mellan Mölnvik och Älstedet, the Swedish Road Administration; 2006:134.

6.7 Motorway Control

Motorway control has been used as a measure throughout the world to increase network efficiency, reliability, safety and to reduce environmental impacts. Motorway control is designed to optimise the available road capacity through a variety of different means. One or more lanes may be closed on a section of road in the event of accidents or roadworks and speeds can be adjusted to reflect current conditions. In Sweden there are currently installations in Stockholm and Gothenburg.

6.7.1 Application

Motorway control systems are typically introduced to facilitate smoother traffic flow and increase road safety. Control is achieved through lane signals often combined with variable speed signs. Motorway control systems can provide road users with information or instructions about speed and lane restriction. The goal is to maximize traffic throughput, avoid queues and maintain free flowing traffic. Motorway control may be supplemented by variable message signs providing a wide variety of warnings and other useful information, such as queue warnings or information about diversions.

6.7.2 Effects

The use of motorway control systems is widespread in European metropolitan areas. On the continent, journey time savings and capacity increases are often around 50 to 10 per cent as a result of the introduction of MCS (Motorway Control System). Such effects however, have not been verified in Sweden.

Motorway control systems are estimated to reduce accidents by approximately 25 per cent. They lead to improved accessibility through the more efficient and rapid closure of lanes at planned road maintenance works and can lead to reduced delays in connection with incidents.
6.7.3 **Actors**

Primary access roads and bypasses in metropolitan areas are most suited to the use of MCS. MCS systems are currently one of the most expensive forms of ITS. Key stakeholders are the Swedish Transport Administration, municipalities, emergency services and the police.

6.7.4 **Good advice for implementation**

Previous studies have shown that a significant number of road users do not fully understand the meaning of certain lane signals. It is therefore crucial to mount an effective information campaign when implementing MCS to reduce the risk of road side information being misunderstood or ignored. Lane signals shown by the system should be designed in accordance with the guidance available in VGU.

6.7.5 **See also**

- Tunnel Control and Monitoring.

**Good examples: Motorway control**

Copenhagen’s M3 motorway ring road has recently been enlarged to six lanes. At the same time the area controlled by the city’s MCS system has been expanded. A user survey of commuters showed that 58 per cent believe that the system makes traffic flow better, while 12 per cent think that traffic has become worse. Eighty two per cent understand that the speed sign (with a red ring) means it is a prohibited to exceed the displayed speed. In the case of closed lanes, which are controlled through lane symbols in the form of red crosses, 96 per cent understand the concept.

Source: *Aktiv högtrafikledning: Kunskapsdokument och tillämpningsråd*, the Swedish Transport Administration, 2011.

6.8 **Hard shoulder control**

The use of the hard shoulder as a temporary extra lane can be considered on busy motorways if speeds regularly drop by more than 20 km/h during peak periods. The aim is to increase road capacity and reduce congestion. ITS systems aiming to control the use of the hard shoulder can either be time based or based on traffic volumes. The decision as to whether to implement a hard shoulder control system should be based on a robust cost/benefit assessment. Hard shoulder control has not yet been implemented in Sweden, but it is found in countries such as Germany, the Netherlands and United Kingdom.

6.8.1 **Application**

The aim of the measure is to maximize road capacity during peak periods without compromising road safety. Variable message signs at the road side and
on gantries inform road users about the status of the hard shoulder. Access to the hard shoulder can be controlled using two main methods:

Time controlled, where the hard shoulder is opened at predetermined times, typically the rush hour or other suitable time period. It is important that the hard shoulder is clear of any obstacles or stationary vehicles before being opened.

The other method is to open the hard shoulder based on prevailing traffic volumes. This method requires an advanced traffic control system which is capable of real-time monitoring of traffic conditions. One advantage of flow controlled systems compared to time controlled is their ability to adapt to unexpected changes in traffic conditions.

6.8.2 Effects

The system is most useful when traffic volumes are at their highest, and is of particular benefit during peak periods creating useful extra capacity. Other benefits include improvements in traffic safety as a result of calmer traffic conditions. In the off-peak period the system can be used to increase accessibility by allowing an increase in speed. There are also environmental benefits as a result of the reduction of stops caused by congestion.

6.8.3 Actors

Typically the Swedish Transport Administration is responsible for hard shoulder systems since the measure is best suited to busy roads and access roads to major cities.

6.8.4 Good advice for implementation

The measure is not currently supported by the Swedish regulatory framework. There are a number of questions surrounding road markings, road signs and winter maintenance which need to be addressed prior to implementation.

Before the hard shoulder can be used additional parking pockets for roadside assistance, emergency services and access routes must be provided, to offset the loss of the shoulder.
Camera coverage of the entire route must be in place to ensure that there are no obstacles on the hard shoulder prior to it being opened for traffic. For time controlled systems, traffic managers can check all cameras along the relevant stretch to ensure that there are no obstacles or stationary vehicles on the hard shoulder. For flow controlled systems traffic managers should have access to an automated detection system to detect obstacles on the shoulder. This system should be integrated into the traffic control system for the route.

6.8.5 Please refer to

- Ramp metering.
- Motorway control.
- Queue-warning.
- Variable speed limits.

Good examples: Hard shoulder control

In Germany there are almost 200 km of road where temporary use of the hard shoulder is permitted. The hard shoulder is opened during peak periods to increase capacity and at other times when incidents occur on the main carriageway. Before the hard shoulder is opened to traffic VMS is used to reduce the speed limit to 100 km/h. Lorries are banned from overtaking when the hard shoulder is in use.

Results from the trial have been good. Capacity has increased significantly with 20 per cent more throughput during rush hour with the hard shoulder in use.


6.9 Road-user charging in urban areas

Road user charging can be used to control traffic volumes (reduce congestion or protect sensitive environments), and also to generate revenue for financing infrastructure projects. Dynamic road pricing is a tool that can be used in a number of different ways depending on the design of the system.

Under current legislation in Sweden, road user fees are only levied on newly built roads and bridges. Other forms of road user fees are regarded as taxes. Since municipalities are only allowed to tax local citizens, road user taxes must be collected by the state. The Swedish Parliament (Riksdag) makes decisions about the introduction and extent of congestion taxes in Sweden. Stockholm is currently the only place in Sweden to levy a congestion tax. The Stockholm congestion tax is designed to reduce congestion and thereby improve the environment. In 2013, Gothenburg will also implement a congestion tax. The Swedish Transport Agency is responsible for administering congestion taxes.
6.9.1 Application

Road user charging can help manage road capacity more effectively and increase accessibility. The constant growth of traffic in cities leads to greater demands on streets and roads and the pressure to build new roads is ever present. City road networks are at full capacity during peak periods causing long queues and delays. Road user fees can be used to manage the demand for road space by encouraging the use of other means of transport such as public transport or car-pooling.

A reduction in vehicle traffic has benefits for noise and emissions, including a reduction in greenhouse gases and hazardous particulates. In Norway road user fees are used to generate revenue for major infrastructure projects.

6.9.2 Effects

Socio-economic benefits arise as a result of traffic being redistributed from congested roads, to other locations, other time periods or other modes of transport. This is achieved by putting a fairer price on road capacity, from a socio-economic perspective.

During the Stockholm trial, accessibility was improved and journey times were reduced significantly in and around the inner city. The improvements in traffic conditions remain at almost the same level as during the trial period. Particularly large reductions were found on the access roads to and from the city, where queuing times were reduced by a third during the morning rush hour, and were halved during the afternoon rush hour. Journey times also became more predictable allowing motorists to plan their journeys more easily. However, it was also found that journey times increased greatly on the Southern Link in the westbound direction. On individual subsections, both an increase and reduction in congestion were noted at different times of the day and in different directions.
The measure is considered to have had a significant environmental impact. A reduction in transport mileage leads to reduced emissions and improved air quality in the cities where this measure has been implemented. Environmental and cultural values are also affected in a positive manner when interference from traffic in the form of air, ground, and water pollution is reduced. Furthermore, both noise and vibration are reduced. It is expected that there will be fewer new encroachments on natural and cultural environments as the need for new roads is reduced.

As traffic is reduced in areas where there are a large number of inhabitants, the reduction in particles has a major positive effect on health. The number of premature deaths in Stockholm’s inner city is expected to decline by between 20 and 25 per year.

6.9.3 Actors

Presently, this type of measure can only be implemented by the Swedish Transport Administration and the Swedish Transport Agency. As the measure not only affects transport within the area that is subject to the charge, but also surrounding areas, the organisations responsible for the administration of roads in adjacent areas are also affected by the implementation. Other actors that should participate in the implementation are local politicians and public transport companies.

The Swedish Transport Administration has the operational responsibility for the toll stations and the Swedish Transport Agency is responsible for fiscal decisions and collection of the congestion tax. The Swedish Tax Agency County Administrative Court are responsible for reviews and appeals.

6.9.4 Good advice for implementation

User fees and congestion taxes in urban areas are politically very sensitive issues. Many planned systems for collecting fees (not least in Sweden) have been apposed because of problems with political acceptance and negative public opinion. It is therefore important that the decision for introduction is locally anchored, among politicians and citizens. The purpose and consequences of user fees should be made clear. The system must be designed so that it is easy to use and road users must feel that they gain something from the system, such as reduced journey times.

From a socio-economic point of view, user charges can usually only be motivated at congested locations and times. This means that the measure may be particularly relevant in big cities during rush hour. The introduction of congestion charges in Stockholm and London has shown that similar systems could be effective at locations with similar environments and similar problems. How large of an effect will depend on the charges’ design and the availability of other travel options.

Good examples: Road-user charging in urban areas

In order to reduce congestion and improve the environment the so-called Stockholm trial was conducted. The trial consisted of a congestion tax, expanded public transport and more parking spaces located along Stockholm’s access roads. It had three
actors, the city of Stockholm, Storstockholms Lokaltrafik (SL) and the Swedish Road Administration. The Stockholm trial began on 22 August 2005 in conjunction with the investment in expanded public transport and ended on 31 July 2006. The solution was then made permanent after a decision by the Riksdag. The congestion tax is levied on vehicles registered in Sweden.

During the trial period public transport patronage increased by 40,000 during a typical weekday, compared with the previous year. This is an increase of six per cent. Approximately four per cent of the increase is considered to be as a result of the Stockholm Trial. Over the roads leading to and from the city centre the increase was just over 20,000 passengers during a weekday. This is the equivalent of around 45,000 journeys in, out or through the inner city. Travel on the Stockholm underground system increased the most, with 25,000 journeys per 24-hour weekday period, followed by bus transport, which increased by 16,000 journeys.

From 1 January 2013, a congestion tax will be levied on vehicles that are driven into and out of the central parts of Gothenburg. The idea is for Gothenburg to use the same system as that in Stockholm.

The purpose of the congestion charge is to improve accessibility and the environment (nitrogen dioxide emissions) in central parts of Gothenburg, as well as help finance investments in public transport, rail and roads. Projects to be funded include the Western Link (a rail tunnel under central Gothenburg) and a new river connection at Marieholm.

Monitoring traffic

- What systems can be used to monitor traffic?
- What effects will automatic speed monitoring have?
- What have our experiences of tunnel monitoring systems been?
Under the main heading of monitor traffic, the following ITS measures can be found:

- Automatic speed monitoring.
- Monitoring and control of hazardous goods, transport.
- Tunnel monitoring and control.

The last two include both monitoring and control, but the main purpose is considered to be monitoring which is why these systems have been placed under this heading.

### 7.1 Automatic speed monitoring

*Deaths and injuries from road traffic accidents is a major public health problem. The Riksdag's decision on Vision Zero in 1997 prescribed a long-term vision that no one should be killed or seriously injured in traffic. Studies show that speed is the most significant factor for how serious the consequences of a traffic accident will be.*

It is well-known that too many drivers do not respect existing speed limits. With the help of an automatic speed monitoring system vehicles driving over the limit can be identified. The aim is not to fine citizens, but to reduce speed violations in a cost-effective manner. Monitoring leads to a lower average speed, as well as a reduction in the variation in vehicle speeds, which in turn leads to fewer deaths and injuries.

Speed is monitored by roadside radar detectors. If vehicles passing the detector exceed the permitted speed limit, automatic cameras are activated. The cameras register and photograph the driver and the license plate of the offending vehicle. Any passengers are removed from the photo by retouching. The owner of the vehicle is identified through the vehicle licensing register. A fine is then sent via mail.

#### 7.1.1 Application

Systems for automatic speed monitoring can be used as a supplement to police controls and installed on accident prone sections of road sections with high average speeds.

There are currently about 1100 cameras across the country. In addition, the police have a number of buses equipped with cameras. As a complement to the fixed traffic safety cameras there are also mobile road safety cameras which can be used at roadworks or outside schools.

The traffic safety cameras measuring system, contains technology that can measure traffic flows and record time and speed of passing vehicles even when not activated. This information is used as a basis for further road safety projects.

| Road safety | ••• |
| Environment | ** |
| Accessibility | ** |
| Availability | ** |
| Security | ** |
| Cost | ** |

*Automatic Speed Control (Punkt-ATK) reduces the average speed by 5-10 km/h.*

*An overall assessment indicates that injuries decrease by 15-20 per cent with Punkt-ATK.*
A number of countries operate systems that measure average vehicle speed over a certain distance, instead of at individual fixed points, which is the case in Sweden. These systems use a series of cameras that photograph vehicles at different points along a stretch of road. The average speed is calculated and any vehicles exceeding the speed limit are recorded. For legal reasons it is not currently possible to use this method in Sweden.

7.1.2 Effects

Road safety cameras have proved very effective at reducing speeds. Average speeds on roads where cameras have been deployed have been reduced by about five per cent. The number of speeding violations has fallen by 20 to 30 per cent. Measurements made by the Swedish National Road- and Transport Research Institute (Statens väg- och transportforskningsinstitut, VTI), have shown that the number of fatalities has decreased by roughly 30 per cent and the number of seriously injured by 20 per cent on roads equipped with cameras.

There are also environmental benefits to be gained from reducing the number of speeding motorists. Lower speeds mean reduced carbon emissions and road safety cameras are estimated to reduce carbon dioxide emissions by roughly 20,000 tons every year.

7.1.3 Actors

The Swedish Transport Administration (Trafikverket) and the police jointly administer the system of road safety cameras. The Swedish Transport Administration is responsible, in consultation with the police, for the setting up, operation and maintenance of the fixed cameras as well as for the transfer of data to the police. The police are responsible, in consultation with the Swedish Transport Administration, for the placing of mobile road safety cameras. The
police are also responsible for determining at what speed fixed cameras are activated, and for all analysis of the speeding violations that are registered by the road safety cameras. In order to manage the road safety cameras as efficiently as possible a special group has been setup between the Swedish Transport Administration and the police.

7.1.4 **Good advice for implementation.**

Decisions about the introduction of Automatic Road Safety Control (Automatisk trafiksäkerhetskontroll, ATK) should be based on local conditions such as: the occurrence of speed violations, traffic intensity and number of accidents on the road section in question.

7.1.5 **Please refer to**

- Speed reminding information.

**Good examples: Automatic speed monitoring**

During 2006 automatic speed monitoring cameras were set up on national highway 50 in Bergslagen (national highway 50E, county boundary-Åsbro). This was the first road section with the new generation of road safety cameras. Ten units were installed on a 240 km stretch of road. Before and after studies were performed to evaluate the effect of the cameras. The results were very positive and showed that the average speed on the stretch of road had decreased by roughly eight per cent. The proportion of vehicles that drove faster than the speed limit fell by roughly 40 per cent. The speed differential between vehicles was also reduced. Finally the benefits of the cameras were found to be constant over time; from May to November 2006 the reduction in speed remained stable.


7.2 **Monitoring and control of hazardous goods transport**

*Fortunately there are relatively few road traffic accidents involving dangerous goods. But even if the risks are small there is always potential for accidents with very serious consequences. However the risks can be limited significantly with the use of appropriate technical systems.*

The need for the monitoring, control and management of dangerous goods transportation increases as the number of transports increases and the traffic system becomes more complex. Systems that control and register the transport of dangerous goods make good sense from a traffic safety standpoint whilst maintaining accessibility.
The transport of dangerous goods is not only a potential danger for road users but also for residents in areas trafficked by dangerous goods vehicles. Therefore it is important to design systems that also protect third parties i.e. people that have not chosen to take the risk of setting off into traffic.

A system for controlling the transport of dangerous goods is designed to prevent or minimize the risk of accidents. This is achieved by giving carriers specific instructions prior to a journey or influencing the choice of route on a journey that is already underway.

A vehicle can be directed with different degrees of complexity; everything from simple signposting and manual monitoring to more automated systems. This can involve a local system (freestanding, for example, at a tunnel) or a central system (centrally at a road Traffic Management Centre), which makes real time decisions about which vehicles are allowed to travel on particular stretches of road.

### 7.2.1 Application

By combining different types of systems, emergency service centres and rescue services can receive real time messages about position and cargo content at the time of an incident/accident. This information makes it considerably easier for rescue services to quickly get to the scene and know how a spillage, fire or similar event should be controlled. The risk of terrorism also contributes to an increased interest from the authorities to monitor dangerous goods.
Experimental work is also being carried out concerning web based services, where a road authority, rescue services, SOS Alarm and police can access the same information (pictures, digital consignment notes etc) about an accident and then cooperate in the best way to minimize the consequences.

7.2.2 Effects

The measure reduces the risk and the consequences of accidents involving dangerous goods, but above all, a personal safety effect is achieved. This applies to society at large as well as in specific environmentally sensitive areas. Monitoring of dangerous goods with the aid of Intelligent Transportation Systems (ITS) can in addition reduce action and departure times by providing rescue services with detailed information about the type of accident and contents of a dangerous load.

Since a large portion of accidents within the dangerous goods area are related to isolated accidents, like a vehicle turning over, an ITS system can contribute to warning drivers of vehicles with dangerous goods about dangerous traffic conditions, thus contributing to their increased personal safety and that of their fellow road users.

7.2.3 Actors

The road authorities are responsible for implementation. SOS Alarm has an important role; to transfer alarms to rescue services and the police. The freight operators, Swedish Rescue Services Agency (Räddningsverket) and rescue services take part in setting standards for the design of systems. Other actors that may be affected are customs and the police.

7.2.4 Good advice for implementation

The measure is seen as an additional function to other IT based measures to make the freight operators more effective and adapted to customers. If there are systems for monitoring goods, location of vehicle and transport guidance installed, the conditions for introducing this type of measure are good.

The control of dangerous goods is affected by the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) regulations, which are a European set of rules and regulations, that specify how dangerous goods should be classified, handled and transported. This set of rules and regulations is in turn based on the UN’s recommendations. ADR allows the use of electronic data processing or electronic data exchange instead of, or as a complement to, paper documentation.

Since the ADR regulations are very extensive the introduction of control systems for dangerous goods should also be aimed at simplifying the handling of information.
7.2.5 Please refer to

- Tunnel monitoring and control.
- Motorway control.

**Good examples: Monitoring and control of hazardous goods transport**

The development project “Mobile IT for goods on the road” was started in 2007 by Blekinge Tekniska Högskola (University) in cooperation with Sweco and was concluded in 2009.

The aim of the project was to study how authority related applications can be integrated with telematics applications connected to heavy transports. Important areas for the project are safe transports with a focus on dangerous goods as well as showing how mobile IT can make heavy transports more effective.

A number of different organisations are interested in the ability to monitor dangerous goods: the Swedish Rescue Services Agency, Trafiken.nu in Stockholm and Gothenburg and also the Swedish Transport Administration. These organisations view the monitoring of dangerous goods as a key preventive measure for avoiding accidents and for mitigating the impact of those accidents that do occur. The Swedish Rescue Service is of the opinion that telematics services are one of the few cost-effective ways available to control dangerous goods.

*Source: Slutrapport Mobil-IT för gods på väg, BTH, Sweco (Transport Telematics R&D Group Sweden), 2009.*

### Road safety

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* Refers to personal safety.

7.3 **Tunnel monitoring and control**

The aim of monitoring and control in road tunnels is to maintain a safe and effective flow of traffic with minimal queues and delays during normal traffic conditions.

In Sweden discussions concerning tunnel monitoring and safety have been in focus since the city agreements about traffic solutions with tunnels came into existence at the beginning of the 1990s. The Swedish Transport Administration has developed a general technical description for the construction and improvement of tunnels; Tunnel 2004 in which the requirements placed on project management, construction, construction of new tunnels and improvement of tunnels are specified.

To handle incidents there is equipment for information and control in both the actual tunnel and in connecting slip roads and access roads. Documented control strategies with instructions for handling incidents can be found in the Traffic Management Centre. This is also where fire alarms, fans, pumps and lighting, remote-controlled gates, adjustable road signposting and other adjustable traffic signs, are monitored and controlled.
7.3.1 Application

Systems for surveillance and control of traffic in tunnels, are only of interest for the most highly used road tunnels and are controlled by existing legislation (Tunnel 24 and EU directive). They are mainly of interest in major urban areas.

Tunnels exceeding 500 meters in length that are covered by EU directive (2004/54/EG) come under a tunnel authority (respective county administrative board). In these cases the authority responsible for project management, construction or operation on public roads is the Swedish Transport Administration and on other roads and streets it is the municipality. Officially the National Board of Housing, Building and Planning (Boverket) determines the safety requirements that a tunnel should meet, after consultation with the Swedish Transport Administration and the Swedish Rescue Services Agency. Prescribed safety requirements include; traffic signs, signposts and information, surveillance systems, equipment for closing a tunnel and parts of the communication system.

7.3.2 Effects

Being able to close lanes or parts of the tunnel when incidents occur, increases safety for rescue staff and road users. Lane control systems are more effective at closing lanes for roadworks; the amount of time required for setting up a work area decreases. By adjusting the speed limit to prevailing traffic conditions, road capacity through a tunnel can be optimised.

Incidents can be managed quickly and efficiently, reducing delays. Furthermore early warnings about planned disruptions lead to an improved level of service. The consequences of accidents can be minimized thanks to early warning systems that facilitate a quick response from rescue services. Tunnel control systems lead to an overall increase in personal safety.

7.3.3 Actors

The relevant road authority is responsible for the implementation of tunnel control systems. Such systems are most likely to be installed in new tunnels and in busy tunnels in major urban areas as they fall under the EU directive and Tunnel 2004. Other interested parties include the rescue services and operating contractors.

7.3.4 Good advice for implementation

Tunnel control systems involve considerable financial investment and every control system must be adapted to local conditions. In areas of high traffic density motorway regulation systems can be integrated with tunnel systems.

7.3.5 Please refer to

- Motorway control.
Good examples: Tunnel monitoring and control

During 2006 a training exercise involving a simulated evacuation attempt was carried out in Götatunneln (Göta tunnel) in Gothenburg. The experiment was organized by the University of Lund in cooperation with the Swedish National Road Administration, West Region (Vägverket Region Väst). A total of 29 individuals participated, using their own cars.

None of the test subjects had been informed beforehand about the evacuation, but had instead been told that they were going to participate in an exercise where driving behaviour and technical installations would be tested.

The test subjects had to drive into the tunnel, which was closed to other traffic. Only one lane in the middle of the tunnel was open and the participants were therefore forced to drive one after another in a long line. At a certain point in the tunnel the participants were stopped by a simulated accident consisting of horizontally placed cars and artificial smoke. Two and a half minutes after the first car had stopped, the evacuation alarm was activated. The alarm consisted of a spoken evacuation message, traffic information signs with the text “Stop engine, Evacuate tunnel” and green flashing lights at two emergency exits.

The experiment was recorded by 15 video cameras mounted at ceiling level. After the test subjects had been evacuated they had to fill in a questionnaire about the evacuation, evacuation facilities and other technical installations in the tunnel.

In addition four people were interviewed about their behaviour and their observations. The test subjects also participated in group discussions about the evacuation.

Many of the test subjects said that the evacuation alarm was an important factor for their decision to leave the car. An audible signal alerted road users to the fact that something abnormal had happened and made them look for additional information. The text message on the traffic information signs and the green flashlights at the emergency exits were also perceived as important by the test subjects.

## Summary of effects

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<th>Effect Estimates:</th>
<th>PROVIDING INFORMATION TO ROAD USERS</th>
<th>CONTROLLING AND MANAGING TRAFFIC</th>
<th>MONITORING TRAFFIC</th>
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<td>*** Large positive effect</td>
<td>Queue warning</td>
<td>Weather warning</td>
<td>Operator-controlled traffic information</td>
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<td>** Medium positive effect</td>
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### ROAD SAFETY

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### ACCESSIBILITY

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### TRANSPORT QUALITY, OTHER

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Implementing ITS – Step by step instructions

- What should we think about before the implementation of ITS measures?
- How do we choose appropriate ITS measures?
- How to manage and follow up the installations?
8.1 How is a traffic problem identified?

Planning for a traffic measure is triggered by the identification of a problem. Opinions about difficult traffic conditions, hazardous roads and other problems can be obtained through customer service channels and contact with the public.

Schools may contact authorities regarding the difficulties faced by children in getting to school. There may also be political decisions or initiatives or policy provisions that mean a problem must be solved.

A description of the problems associated with various proposals and solutions often follows. However, the proposed solution is often influenced by the person who describes the problem, and is based on their needs. In this phase, an objective analysis of the problem is important.

- **What is the problem?** What characterizes the problem: accessibility, traffic safety, environment, transport quality, security?
- **Who is affected by the problem?** Is it motorists, public transport users, vulnerable road users or local stakeholders?
- **Where and when does the problem occur?** Data and statistics.
- **What consequences does the problem have** for different groups of road-users, local environment, society?
- **What could be causing the problem?**

The process of questioning, highlight on the problem from a variety of different standpoints.

The result of an inventory of the problem is a written expression of how the problem is presented with a possible causal connection.
8.2 The planning process

The planning of an ITS measure begins when a problem has been identified and when the need for a solution has been accepted by the road maintenance authority.

The manual describes and lists the key steps in the process and gives good advice for its introduction. The manual aims to offer support and suggest ways of working, but does not claim to be exhaustive regarding methods for planning and implementation of ITS measures.

The goal is that the manual may be used for both simple and more complex measures with the ambition of providing a checklist rather than a detailed description of each component.

8.2.1 Steps in the planning process

The planning of ITS is not different in principle from the planning of physical measures. The Swedish Transport Administration has published a large number of manuals and support documents for planning. For instance, there are several documents that describe how the four-step principle is used in the planning\(^{16,17}\).

For the planning of measures with a long term perspective or if the solution may involve several measures, there should be an collective plan, so that coordination benefits can be achieved. When the measures affect several stakeholders, for example, the Swedish Transport Administration, the municipality and the County principal, joint planning with all parties concerned is recommended.

The steps included in the planning process are described below. Depending on the complexity of the problem, each step differs in comprehensiveness.

- **Initiation.** Includes start-up activities such as establishing the project description, defining the project managers and reference groups, contacts with concerned stakeholders and possible engagement of a consultant. The person responsible for decisions regarding the choice of measure and the person responsible for decisions regarding economic issues shall be identified.

\(^{16}\) The four-step principle in feasibility studies (2006:122).
\(^{17}\) Analysis of measures in accordance with the four-step principle (2002:72).
Inventory and background analysis. Contains information from a variety of sources including: maps, local traffic regulations, incidents that have occurred, any traffic measurements, opinions from residents, local business and authorities. National and/or local focus or policy documents are identified. In order to develop a clear picture of the situation; observations should be made at the site from different perspectives in order to illustrate how motorists, public transport users and pedestrians/cyclists are affected. Video and photography of the traffic situation will be an important aid for the planning and implementation phases.

Needs analysis and definition of goals. When the problem is identified and the implications for the various stakeholders involved are understood, a structured needs analysis can be produced and clear goals defined. Since different road user groups have different needs, the needs should differentiate between:

- Pedestrian and cyclist needs.
- Public transport user needs.
- Motorists needs.
- Local population and local business needs.
- Authorities (and road maintenance groups) needs.

The authorities needs, can be formulated through strategic political decisions or local policy documents. A clear set of goals is defined in light of each identified need. The goal should be measurable and the method of measurement identified.

EXAMPLE

NEEDS: Traffic safety and security shall be improved for pedestrians and cyclists travelling beside the road, especially at crossing points.

GOAL: The average speed of cars shall be reduced by 5 km/h and the percentage of drivers who exceed the speed limit shall be reduced by 50 per cent. The perceived safety of pedestrians and cyclists shall increase by 50 per cent.

METHOD OF MEASUREMENT: Traffic measurements and field surveys.

Choice of measure. When there is a clearly defined set of goals it is possible to analyze which possible measures may solve the problem. In this phase, this manual may be used for support. Additional support can be obtained from Trafikverkets Effektsamband för vägtransportsystemet 2008\textsuperscript{18,19,20,21} as well as contact with the Swedish Transport Administration and ITS-suppliers.

- Consider that there might be several alternative solutions. The list of proposed measures should include two to five possible measures including both traditional physical measures and ITS solutions. A cost/benefit assessment should be performed for each measure to see if it is capable of meeting the specified goals. Costs should include an estimate of the costs of investment, operation and maintenance, evaluation as well as other project costs. “Effects” refers to how the measure affects accessibility, traffic safety, environment, quality and security.

\textsuperscript{18} Effect relationships, Common preconditions (2008:9).
\textsuperscript{19} New construction and improvement, Effect catalogue (2008:11).
\textsuperscript{20} Operation and maintenance, Effect catalogue (2008:8).
\textsuperscript{21} Sector activities and authorities’ practices, Effect catalogue (2008:12).
If there are several alternatives that could achieve the specified goals then a further feasibility analysis should be performed. The most important tool is a cost/benefit assessment. Even non-quantifiable benefits should be described. The publications mentioned can also provide useful support at this stage.

A general rule is to choose the measure that is the most cost effective. However, non-quantifiable benefits or political strategies can have great influence on the choice of measure.

The results of the analysis should be summarized in an implementation plan (the basis of the decision), which consists of proposals for implementation, cost estimates and recommendations for the decision.

Compile planning document. Once a measure has been selected it is possible to begin detailed planning of procurement, installation, administration and evaluation. See Section 8.2.2 below.

### 8.2.2 Planning document

In order to ensure a life-cycle approach to the implementation of the ITS measure, the planning activities should cover all phases of the project.

A number of planning documents have been identified below, which can either be designed as independent documents or contained in one planning document. The link to the steps in the implementation process is shown in the figure below.

![Figure 7. Planning document at every step of the implementation process.](image-url)
In order to provide adequate support for implementation, a first version of the planning document should be drafted in the planning phase of the project. Several of the documents should be adjusted and updated later on, when contracts with different suppliers have been concluded.

**Basis for the decision regarding measure selection**
Before selection of a measure, there should be a clear basis for the decision incorporating cost estimates for the investment, operation and maintenance, as well as evaluation of the measure which is being recommended. Costs can be described in a separate document (see below in the section about the financial plan). The benefits (profitability) of the proposed alternative measures should be described in enough detail to enable a decision about implementation.

In the design and implementation of ITS, current regulatory frameworks such as the Traffic Sign Ordinance should be applied. In order to ensure agreement with the responsible authority (Swedish Transportation Agency or other authority) they should be informed of the ITS measures that are being planned.

The following components should be included in the decision making process:
- Needs analysis for different road user groups.
- Formulation of goals.
- Proposed measures with cost estimates and an assessment of effects.
- Implementation analysis for the proposed measures
- Recommendation for selection of measures.

**Implementation plan**
This document should contain a detailed plan of all phases from procurement to installation and commissioning. The plan should clearly indicate who is responsible for each phase and the time schedules that apply. Document management and approval procedures should also be included. Sub-documents that are included in the implementation plan are:

- **Requirements specification**
  Procurement of technical systems and installation services must be through competitive tender in accordance with the Swedish Public Procurement Act (LOU). A requirements specification and tender documents must be produced requesting quotes from ITS suppliers. The main elements of this procedure are described in Chapter 8.3.2.

- **Financial plan**
  The financial plan should be as detailed as possible including an estimate of all costs (external and internal) associated with implementation of a measure. The cost estimate shall encompass all phases of the project; from planning and procurement to installation, operation, maintenance as well as evaluation. It should be made clear how the measure will be financed.

- **Administration plan**
  The plan shall describe who will operate and maintain the ITS system and how. Other issues that the administration plan should describe are: how shall customer support be managed? What level of readiness should there be for error handling and repairs? Within what time intervals is maintenance expected to be carried out and how will
system updates and changes be managed? The plan is expected to be updated on a continuous basis in collaboration with selected suppliers (of systems, installation services, and operation and maintenance services).

– Evaluation plan
The plan shall describe how the chosen system is to be evaluated including: traffic measurements and surveys, when pre and post installation measurements shall be conducted, and by whom. If an external party is engaged in the evaluation, the plan must be updated afterwards in collaboration with this party. Suggestions regarding the content of an evaluation model are described in Chapter 9.2.4.

8.2.3 Human-machine interaction and behavioural aspects of ITS

Human-machine interaction refers to how humans behave in contact with machinery and IT systems in their surroundings.

ITS systems are based on IT systems that transmit one or more messages that road users are expected to understand and react to. As mentioned earlier, ITS measures aim to get road users to adapt their behaviour in traffic, which in turn leads to effects at the individual, traffic or community level.

Messages can be divided into the three following types:

▸ Control messages.
▸ Warning messages.
▸ Informational messages.

How people are affected by a message depends on whether and how it is understood. If road users do not understand how a message should be interpreted and react accordingly then the message has been ineffective. Poorly designed ITS solutions or messages can even lead to road users unwittingly violating traffic regulations and getting fined, or worse, causing accidents.

Messages should be clearly presented and preferably consist of symbols in combination with free text\(^\text{22}\).

An important prerequisite when designing ITS messages is to send the right message at the right time in the right place.

Behavioural aspects of road and traffic design\(^\text{23}\) are a growing area of interest. However, there are still large gaps in knowledge about road user behaviour which means that dangerous situations may arise. Continuous focus on research within this topic will hopefully lead to individuals and society gaining even more from measures that are introduced.

\(^{22}\) Better Traffic Information, Fasan 2, the Swedish National Road Administration (2006:101).

\(^{23}\) The Road, Technology and Man, the Swedish National Road Administration (2004:183).
### 8.2.4 Summary of the planning process - a checklist

Planning of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Working operation planning</th>
<th>OK*</th>
<th>Doc. approved**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there a clear (written) description of the problem?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an inspection been conducted on-site?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have viewpoints from concerned stakeholders (local environment) been obtained?</td>
<td></td>
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</tr>
<tr>
<td>Have maps/drawings, LTF, strategy or policy documents been examined?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a needs analysis been performed for different stakeholders and road user groups?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a description of goals been produced with associated methods for measuring goal achievement?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a decision basis for the selection of measures been designed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the selection of measures been made?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an implementation plan (for installation) been prepared?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a requirements specification been prepared?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a financial plan been prepared?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an administration plan been prepared?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an evaluation plan been prepared?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The component has been carried out or document produced (signed project leader).
** The document has been approved (signed project owner).
8.3 The implementation process

The implementation process starts with a decision to implement an ITS measure. The steps included in implementation are:

- Preliminary investigation
- Procurement.
- Location and project planning.
- Installation and verification.
- Commissioning and information.

8.3.1 Preliminary investigation

In the initial phase of the implementation process, a preliminary investigation should be carried out. If this has already been done in the analysis and planning phase, it is important to go through this investigation again.

The purpose of the preliminary investigation is to have a baseline-measurement that can be compared with a post installation measurement to see whether the system has had the desired effect. An example of a zero-measurement is given below.

The preliminary investigation should include both traffic measurements and attitude surveys. How these are carried out should be described in the evaluation plan. Proposals for execution of traffic measurements and attitude surveys are given in Chapter 9.2 of the Evaluation process.

The results of the preliminary investigation should be checked against the description of goals to ensure that the factors measured in the survey correspond to the effect goals that were set.

EXAMPLE OF BASELINE-MEASUREMENT

The results of the traffic measurements are that 40 per cent of road users exceed the speed limit and the average speed of speeders is 62 km/h (the permitted speed is 50 km/h). The aim is to reduce the percentage of speed violations to ten per cent, and the average speed for violaters to 55 km/h. Further, the attitude survey shows that 70 per cent of pedestrians and cyclists feel that cars drive too fast, while 30 per cent of motorists feel that they drive too fast.
8.3.2 Procurement

Procurement of systems and services are among the most extensive and perhaps most difficult parts of the implementation. Procurement involves requirements specification as well as tender documents. The requirements specification should preferably be designed so that it is function-oriented; functional requirements have priority over technical requirements. This provides more room for a supplier to propose solutions.

Procurement of single systems can be relatively expensive compared to buying multiple systems simultaneously. It may therefore be worthwhile to contact the Swedish Transport Administration or the municipality to investigate what plans may exist for the introduction of similar ITS systems.

Procurement can be performed according to different models, such as:

- **System procurement** – The purchaser is responsible for installing, commissioning and management.

- **System and installation procurement** – The purchaser takes over the system after installation and is responsible for management.

- **Function procurement** – The purchaser buys and pays for a service, and the supplier is responsible for system installation and management for a defined operational period.

Since ITS measures encompass technical systems, there are a few important parameters that should be included in a requirements specification, in addition to the services that the system is expected to deliver. Depending on the type of procurement model chosen, tender documents should specify requirements related to:

- **Availability** – percentage of its operational life that the system is functional.

- **Electricity and communications provision**. The system should use open, standardized interfaces and IT protocols.

- **Superior system for operational monitoring and control**.
  With major ITS installations, the demand for this feature increases.

- **Possibility for modifications and additional features at a later stage**.

- **Training and documentation**.

- **Installation instructions and criteria for purchaser approval of the installation**.

- **Operation and maintenance requirements**.

- **Guarantees and financing**.

- **Roles and responsibilities**.

**Procurement will result in a supplier being chosen for the assignment. The agreement with the selected supplier should at the very least include the specification of the above points.**
8.3.3 Location and project planning

In consultation with the supplier, an onsite inspection should be performed to determine the location of the equipment. Several factors determine the location and design:

- Critical points in the traffic environment where the problems are greatest, such as a specific intersection or an accident prone stretch of road.
- Distance between the critical point and where the equipment should be placed to give the desired effect.
- Geography and visibility (free sight).
- Power supply and communications provision.
- Prospective restrictions in regards to landowners.
- Prospective physical barriers/difficulties for excavation work, assembly of gantries or other construction.
- Definition of message formats and other time parameters.
- Programming of control equipment and “superior” system.
- Definition of the message – the right message in the right place. The message should be clear and preferably use known and self-explanatory symbols. Behavioural aspects, such as those described in Section 8.2.3 must be considered.

The project planning should be carried out by the purchaser or by the supplier on the purchaser’s behalf.
8.3.4 Installation and verification

The system should be installed by the supplier, a contractor or both depending on the procurement model. Ground works such as excavation, assembly of gantries, the laying of cables etc., is often carried out by the road maintenance authority’s contractor. The supplier is responsible for the assembly of technical roadside equipment and central back office systems, electricity and communication connections, as well as conducting the necessary functionality tests.

The distribution of responsibility between the parties that are performing the installation should be clarified in advance.

Once the installation is completed and approved by the installer, the purchaser should perform their own verification of the system. It is often the supplier who defines the verification procedure and they should participate in the purchaser verification process. In order to avoid confusion, the verification procedure should be approved by the purchaser before it is implemented. Criteria for the approval of the installation (verification) shall be defined in agreement with the supplier.

8.3.5 Commissioning and information

The most important part of the commissioning process is providing information about the system to concerned parties. Above all, road users must be informed.

Information should be made available well in advance, preferably on several occasions and through multiple channels. A good way to distribute information is to advertise in newspapers and through radio and TV channels, as well as trying to encourage media to write or do a feature about the measure. Information should also be available on the road maintenance authority’s website. For residents and local stakeholders, direct mailing may also be necessary in order to create an understanding and confidence about how road users should respond to the system.

Other stakeholders such as municipalities, police and rescue services must also be informed. Prospective customer services must receive sufficient training and information to address any customer inquiries before and during the operational phase.

The operator must have gained the necessary training and be available to manage operational tasks before the system is commissioned.

When road users and other stakeholders have been informed and when customer services and operators are in place, the system can be commissioned.

The responsibility for commissioning and information should always be managed by the purchaser (road maintenance authority).
### 8.3.6 Summary of the implementation process – a checklist

Implementation of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Working element implementation</th>
<th>OK*</th>
<th>Doc. approved**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has a preliminary investigation (baseline-measurement) been conducted?</td>
<td></td>
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<tr>
<td>Do the factors measured in the preliminary investigation correspond with those stated in the description of goals?</td>
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<tr>
<td>Is there a signed agreement with the system supplier?</td>
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<tr>
<td>Has the location of the equipment been determined?</td>
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<tr>
<td>Has project planning of the system been carried out?</td>
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<td></td>
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<tr>
<td>Has a verification procedure for the approval of the installation been designed?</td>
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<tr>
<td>Is there a signed agreement regarding the installation of the ITS system?</td>
<td></td>
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<tr>
<td>Are there signal agreements regarding on groundwork, the laying of electricity and communication lines, and physical construction?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has installation been completed and approved?</td>
<td></td>
<td></td>
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<tr>
<td>Are there signal agreements regarding on operation and maintenance and support?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the necessary information been disseminated to road users and other stakeholders?</td>
<td></td>
<td></td>
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<tr>
<td>Has the operator for customer support gained the necessary training?</td>
<td></td>
<td></td>
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<tr>
<td>Has the administration plan (including operation and maintenance) been adjusted in consultation with the selected contractor? See points in Section 9.1 of the Administration Process.</td>
<td></td>
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<tr>
<td>Has the system been made operational?</td>
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</tbody>
</table>

* The moment has been executed or document produced (signed project leader).
** The document has been approved (signed project owner).
The system in operation – Maintenance, evaluation and follow-up

- How do we look after and maintain the ITS system?
- How do we deal with updates and changes to the system?
- What do we do if the system is out of service?
9.1 The management process (operation and maintenance)

Effective maintenance of the ITS system is necessary in order to ensure that the short and long term benefits of the chosen measure are achieved. All aspects of maintenance are described in the maintenance plan. Requirements for operation and maintenance as well as support and readiness shall be defined and included in contracts with operations and support people.

Administration encompasses several tasks:

- **Daily operation and maintenance of the system.** It is a precondition that the system has functioning routines for data transfer, error handling, data storage and updating of data. For the operator to be able to monitor the system it should generate daily reports and have alarm systems that make manual error handling possible.

- **Handling customer inquiries and customer support.** When questions arise, road users and other concerned parties have someone to contact to get answers. How this customer support is organized will depend on local conditions and which customer services already exist.

- **Managing errors, repairs and support.** If the system or parts of it, are not working, there must be contingencies for replacement and repair of broken parts. The extent of readiness depends on how critical the system is within the traffic system, and how many road users are affected by it.
**Periodic maintenance of the system.** The need for preventive maintenance depends on how vulnerable the system is to wear and external influences. Certain systems need regular tuning or have parts that need replacing or cleaning. A plan for preventive maintenance should be part of the administration plan.

**Management of modifications or system updates.** If the system does not have the desired effect or needs to be supplemented by additional services, this should be possible to do after implementation. Implications for operation during major system updates must be managed. Perhaps enhanced signage or a shutdown of the system is required to handle updates.

### 9.1.1 Summary of the administration process – a checklist

Administration of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Arbetssätt förvaltning (drift &amp; underhåll)</th>
<th>OK*</th>
<th>Doc. approved**</th>
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</thead>
<tbody>
<tr>
<td>Are there clear routines for operational tasks and the possibility of control?</td>
<td></td>
<td></td>
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<tr>
<td>Are there clear instructions for customer support?</td>
<td></td>
<td></td>
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<tr>
<td>Are there routines for error handling, support and readiness?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a plan for preventive maintenance?</td>
<td></td>
<td></td>
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<tr>
<td>Is there a plan for how the operation of the ITS system will be managed during system upgrades or modifications?</td>
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</tr>
<tr>
<td>Documentation of the system’s operational profile, i.e. the system’s operational life, fixed requirements for availability and how reliable the system ought to be. Determining the level of acceptance with regard to prospective disruptions.</td>
<td></td>
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</tbody>
</table>

* The moment has been executed or document produced (signed project leader).
** The document has been approved (signed project owner).
9.2 The evaluation process

A key part of any ITS implementation is a robust evaluation process to assess whether a measure has had the desired effect – has the problem been solved? In the planning phase, a description of goals should have been produced for the intended measure. The description of goals also defines a method for how the achievement of those goals will be measured.

The most important points in the evaluation of ITS are:

- Preliminary investigation – baseline-measurement.
- Post administration investigation
  - measurement of short-term effects
  - measurement of long-term effects.

The preliminary investigation (baseline-measurement) is described in Section 8.3.1. Post administration investigations and measurement of long-term effects should be performed in the same way as the preliminary investigation, for results to be comparable.

Since ITS measures aim to influence road user behaviour through guidance, warning or informational messages, the evaluation must measure whether road users were affected, and to what degree, relative to the stated aims. The main elements of an ITS evaluation are therefore traffic measurements and attitude surveys.

9.2.1 Traffic measurements

Traffic measurements should be conducted in both the preliminary and post administration investigations. The type of traffic measurement which need to be performed depend on what effects the investigation aims to measure.

Changes in journey times, speeds, flows, distance between vehicles and number of vehicles are examples of parameters that a traffic measurement can aim to investigate. Traffic measurements can be performed using tube counters, video cameras, laser guns or the use of positional information through GPS.

Traffic measurements must be adapted to local conditions and to the purpose of the ITS measure. The measuring point should be located as close as possible to the point where the measure is expected to be most effective. The resolution of the measurement data (time interval) should also be adapted to the measure.

9.2.2 Attitude surveys

Attitude surveys aim to investigate how road users perceive the ITS measure, and if they feel that they have altered their behaviour; has road safety been improved, for example. Attitude surveys are also recommended at zero-measurement, but it is mainly during the post implementation investigation that attitude surveys should be conducted.

Implementation can be assessed through questionnaires and interview surveys with road user groups affected by the system.
Through the collection of vehicle licence plate numbers, motorists passing the location of the ITS measure can be contacted by email or telephone to canvass their attitudes towards the new system.

Investigation of other road users can be achieved through questionnaires to residents in the area, schools and other local activities.

Residents in the area affected can often act both as motorists, pedestrians, cyclists and public transport users. This should be considered during the formulation of questions.

The number of respondents required to ensure a statistically valid assessment depends on how accurate the results should be. A general rule of thumb is that at least 50 responses are needed from each group: motorists, public transport users, pedestrians and cyclists, commuters and infrequent travellers, men and women. The response rate is often much higher with telephone interviews than with questionnaires (letter). A large number of questionnaires should therefore be sent out, so that the number of responses from each group constitutes a sufficiently secure foundation.

**9.2.3 Review of needs**

An analysis of whether the need remains is also a key part of the evaluation. There may be external factors or events that modify the conditions for how traffic behaves in that particular area.

External factors are not necessarily momentary; when conditions change from one day to another. They may also include slow, gradual changes. It is therefore natural that a review is part of the evaluation. It is difficult to say exactly what external factors affect the need for a measure, but examples of factors are:

- Local traffic regulation changes.
- The road is rebuilt, expanded or changed to another function (e.g., a pedestrian road).
- Traffic development takes place in a different way than expected.
- The land is developed or used for other purposes.
- Political decisions affecting traffic development or prioritized objectives.
- Operating costs are too high or another solution is more cost-effective.

A review of needs will show whether external factors have caused the need for ITS measures to disappear or grow.
9.2.4 Reporting evaluation results

Making the results from evaluations available to decision makers and administrators is an important part in the process of increasing interest and knowledge of ITS in traffic. With increased knowledge of what the effects of various ITS solutions may be, the status of the entire ITS field is enhanced.

Through circulating the results of various evaluations, a wider and more general knowledge about the benefits and costs of different types of ITS solutions is created. This knowledge base is an important asset not only to those directly involved in projects but also to a wider group of ITS stakeholders.

By collecting expertise and evaluations from a large number of projects, a better basis for decision-making is created, concerning the type of measures that may be best in different situations, to solve a pressing traffic problem or to meet a longer-term transport policy objective.

For broader understanding and use, it is important that the results from evaluations are:

- Transparent
- Easy to comprehend.
- Possible to compare with other results.
- Possible to apply to other traffic environments/other conditions.

9.2.5 Reporting template

The following evaluation aspects should be included when reporting results from an evaluation:

- Problem definition.
- Project definition.
- Evaluation plan.
- Effects of ITS project.
- Transferability

A proposal for a reporting template is shown on the next page.
**Problem definition**

<table>
<thead>
<tr>
<th>Location:</th>
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<table>
<thead>
<tr>
<th>Description of current traffic problem:</th>
</tr>
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</table>

**Project description**

<table>
<thead>
<tr>
<th>Project goals (Accessibility, transport efficiency, safety, environment and any counteraction of segregation):</th>
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</table>

<table>
<thead>
<tr>
<th>Description of ITS system and technology:</th>
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</table>

**Evaluation plan**

<table>
<thead>
<tr>
<th>Time of implementation, type of evaluation and method:</th>
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<table>
<thead>
<tr>
<th>Evaluation goals (technical, functional, financial and socio-economic goals and expected effect):</th>
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</table>

<table>
<thead>
<tr>
<th>Evaluation questions that shall be answered (set by major stakeholders):</th>
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<table>
<thead>
<tr>
<th>Evaluation area (describe the location of the system and associated equipment including prospective control points):</th>
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</table>

<table>
<thead>
<tr>
<th>Expected effects that should be investigated:</th>
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<table>
<thead>
<tr>
<th>Evaluation Methodology:</th>
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</table>

*These points shall be described before the project is implemented in order to facilitate its all-around illumination afterwards.*

**Effects of the ITS project**

<table>
<thead>
<tr>
<th>Technical function (describe reliability and other measurements of how the technology functioned):</th>
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<table>
<thead>
<tr>
<th>Important results (describe results regarding the effects; socio-economics and costs):</th>
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</table>

<table>
<thead>
<tr>
<th>Accounting for statistical certainty in the project results:</th>
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</table>

<table>
<thead>
<tr>
<th>Accounting for the degree to which the different evaluation questions could be answered:</th>
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</table>

<table>
<thead>
<tr>
<th>Overall assessment of the project results:</th>
</tr>
</thead>
</table>

**Transferbility**

<table>
<thead>
<tr>
<th>Describe the local characteristics which have likely affected the project results. Try to make an assessment of the factors that can change the results when introduced in other locations.</th>
</tr>
</thead>
</table>
Summaries of ITS projects funded by the Swedish Transport Administration should follow this template. It will facilitate knowledge sharing through Swedish and international databases. Headings do not need to follow the template strictly. The main thing is that the content is the same.

It is not just those directly involved as participants in projects that should be seen as stakeholders in the evaluation, but also potential users of ITS in other regions. For the latter, it is important to know how the various systems and applications work, how much they cost in investment and operation and the effects they are expected to yield if applied to a location or region under different conditions.

Reporting of results for this broader group of decision makers provides a basis for assessing the real long-term effects of ITS investments. Objective evaluation results obtained in this way can be used to gradually build up a database of reliable costs and benefits.

This will in turn strengthen the body of knowledge for road maintenance authorities who wish to implement ITS in the future.

### 9.2.6 Summary of the evaluation process – a checklist

Evaluation of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Working element evaluation</th>
<th>OK*</th>
<th>Doc. approved**</th>
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</thead>
<tbody>
<tr>
<td>Has a plan for traffic measurements of the zero-measurement and post implementation investigation been prepared?</td>
<td></td>
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<tr>
<td>Has a plan for attitude surveys of zero-measurement and post implementation investigation been prepared?</td>
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</tr>
<tr>
<td>Has a zero-measurement been conducted? (also included in the implementation process)</td>
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<tr>
<td>Has a post implementation investigation been conducted?</td>
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<tr>
<td>Has a plan for long-term evaluation been prepared?</td>
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<tr>
<td>Has a measurement of long-term effects been conducted?</td>
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<tr>
<td>Has a plan for a review of needs been prepared? This can, for example, include the elements described in the Needs Analysis in Chapter 8.2.</td>
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</tr>
<tr>
<td>Has a review of needs been carried out?</td>
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<td></td>
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<tr>
<td>Has the review of needs led to modifications or removal of the ITS system?</td>
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</tr>
</tbody>
</table>

* The moment has been executed or document produced (signed project leader).
** The document has been approved (signed project owner).
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