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 is ITS used?

What traffic effects can be achieved through the use of ITS?
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1.1 Foreword

The overarching goal of the Swedish Road Administration is to create an accessible and balanced transport system with high-quality transport, safe traffic and a good environment – factors that play a decisive role in good regional development.

ITS is an important instrument to help us achieve these aims. With ITS solutions, we can contribute to more effective traffic planning and a better utilisation of the existing road network; at the same time the traffic environment is made safer and more environment-friendly.

Today, we have long and detailed experience of different ITS solutions in and outside Sweden. But how effective are ITS? What do we need to think about before deciding to implement an ITS solution? And how do we maintain and evaluate an ITS system?

This manual is aimed at traffic engineers and traffic planners at the Swedish Road Administration and at the municipal/regional level. The manual is intended to act as a knowledge-base and toolbox – not just for the implementation of ITS, but also as a support for making decisions on different ITS measures and for the maintenance and evaluation of existing ITS.

The manual contains a number of tangible examples of successful and well-documented initiatives within the ITS area where we have, by means of customised ITS, succeeded in resolving everything from acute traffic problems to the more comprehensive goals of traffic policies. In addition, this book contains valuable information on good, accessible ITS and checklists for different types of investment. All of this has been done in order to be able to inform the reader of every stage in the process; from needs analyses and planning via implementation and administration, to evaluation and development.

ITS-based systems and services are playing an increasingly more important role in our traffic environment. We hope that those of you working in traffic planning will, with the help of this manual, be able to contribute towards creating a better and safer traffic environment by means of ITS.

Peter Wessel
Unit Manager ITS, Swedish Road Administration
1.2 Introduction and purpose

The Swedish Road Administration has national responsibility for providing information on and furthering knowledge of intelligent transport systems, ITS. This manual is, along with other publications, intended to act as support for traffic engineers and traffic planners during the implementation of ITS measures.

The manual describes what ITS is, how ITS is used, and what effects can be achieved on the roads through the use of ITS.

The aim of the manual is to show ITS as a genuine alternative to physical measures in accordance with the principles of a four-stage process. The manual is intended to provide support in the choice of appropriate ITS measures. Thereby, it can also be considered an important tool to facilitate planning and the implementation of ITS measures.

The target-group to which this manual is aimed, consists primarily of traffic planners and traffic engineers at the local offices of the Swedish Road Administration, municipalities and other organisations of interest.

An ITS measure should be introduced when it is the most cost-effective means of solving a problem.

Traffic signals were the first form of ITS, however the development of modern day ITS really took off in the 90s.
1.3 Scope

The manual focuses on applications in the physical road environment, which are initiated by the road authorities (which in Sweden can be the Swedish Road Administration or a municipality depending of the road or area in question) and aimed at road-users. Roadside ITS applications include variable message and road signs, signals, and electronic systems for the purpose of:

- Providing information to road users
- Directing traffic
- Monitoring traffic

This handbook covers those ITS applications and services that are installed at the roadside and directed towards the road-user.
The manual has been designed in accordance with the four-stage process model that has been proposed for the implementation of ITS measures. Each stage of the process is described using a different colour; the colours are also used to separate the different sections of the manual.

The manual contains the following sections:

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<th>Section</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>The white section</strong></td>
<td>Provides an introductory description of the aim of the manual, what is meant by ITS and a summary of the implementation process for ITS.</td>
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<tr>
<td><strong>The blue section</strong></td>
<td>Corresponds to the needs analysis in the operational process. This describes the problems that ITS can solve from the perspective of the road authority and support for strategic plans and policy documents for ITS. In addition, suggestions are provided for identifying problems on the roads.</td>
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<tr>
<td><strong>The green section</strong></td>
<td>Corresponds to the implementation phase of the process. The greater part of this is a directory of the ITS and services that have currently been implemented in Sweden. For each ITS measure, the method of application, useful advice for implementation, what effect has been achieved in existing installations, and references to good examples, are provided. This section describes the elements involved in the planning and implementation phases of the operational process. It also covers procurement, installation and taking into operation.</td>
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<tr>
<td><strong>The orange section</strong></td>
<td>Corresponds to the administrative phase of the operational process. Administration covers operation and maintenance as well as customer support services. Good administration is crucial if the ITS measure is 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 in the physical traffic environment have the aim of increasing road safety and accessibility and/or improving the environment. According to the principles of the four-stage process\(^1,2\), a step by step method of application should be used when presenting proposed measures. ITS measures naturally belong in the first two steps:

**STEP 1.** Measures that could affect the demand for transport and the choice of transport mode.

**STEP 2.** Measures that provide more effective utilisation of the existing road network or vehicles.

### 2.1 ITS – A wide range of applications

Intelligent transport systems (ITS) aim to bring about changes in road-user behaviour in order to achieve improvements in the traffic system. The term ITS embraces all applications that use information technology (IT) or electronics in some form to create a service or dynamic function in a traffic or transport system. Another name for ITS is road informatics. In this handbook, the internationally recognised term ITS is chosen.

ITS has a wide range of applications that include vehicle-based driver support, communication between the roadside and vehicles, traffic management systems, information systems and electronic-payment systems. The use of ITS is increasing and, in Europe as in other parts of the world, widespread research and continual standardisation work is continuing. In this context, it should be noted that the European Commission has drawn up a common action plan for ITS in Europe that will result in an ITS directive in 2009. Information on the directive can be obtained via the European Commission’s website\(^3\).

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\(^1\) The Swedish Road Administrations contribution to town planning, Swedish Road Administration publication 1005:141.

\(^2\) The principles of the four-stage process for planning – used for sustainable measures in the transport system, the Swedish Association of Local Authorities and Regions

\(^3\) http://ec.europa.eu/transport/its/road/action_plan_en.htm
2.2 ITS from a life-cycle perspective

When implementing ITS measures, it is important to have a comprehensive perspective so that all factors contributing towards a successful implementation can be taken into account at the outset. This means that it is important to plan and budget for all aspects of the implementation as early as during the introductory phase of the project.

Technical systems are often viewed from a life-cycle perspective. This type of perspective is illustrated in the following model.

![Life-cycle model for the implementation of ITS](image)

*Figure 1. Life-cycle model for the implementation of ITS*

Once a need has been identified, the measure chosen is that which will have the greatest effect for the money invested. In order to carry out a cost-benefit assessment, all aspects of the ITS implementation are included, i.e. the investment in the system in addition to its implementation, operation, maintenance and evaluation.

Once the correct measure has been chosen, the ITS system is implemented. As a general rule, the implementation phase will continue until the system has been put into service.

After implementation, the administrative period will follow. Good administration and good procedures for operation and maintenance are often critical if the ITS measure is to be successful and have the desired effect.

The evaluation phase will come into effect a while after the system has been put into service. In order to ensure that the ITS measure has the desired effect and that there are benefits from these investments, the system and effect must be evaluated. If the system does not function or have the desired effect, then the measure should probably be removed so that the investment can be better utilised elsewhere.
2.3 Critical factors for success

Experience from the implementation of various ITS measures shows that there are great differences as regards both how great an effect they have and how well they are accepted by road-users. Each individual installation has its own specific local conditions that will also influence its expected functionality.

We have summarised some important success factors for good implementation of ITS measures below:

- The planning of measures should be **based on problems**. It is important to create a clear picture of what the problem is, what is causing the problem and what the consequences are for various road-users and social groups at an early stage.

- Apply **the right measure at the right location**. The planning of the measure should be based on local conditions.

- The aim of ITS is to influence the road-user’s behaviour. The measure must be **considered justifiable** in order for it to have an effect. If the road-user does not understand the relationship between the traffic conditions and the ITS system message that is conveyed, the message will not lead to the desired behavioural effect.

- **Information and support** for the implementation process is vital for a successful system. This means that it is important to create a mutual understanding between the road-user and locally interested parties.

- The planning of an ITS measure should be done from a **life-cycle perspective**, whereby not only the actual investment is taken into account, but also administration, operation, maintenance and evaluation. All costs and benefits throughout the entire life-cycle of an ITS measure should be taken into account. It may be difficult to calculate the benefits of a measure but all the potential effects should be listed as far as possible, even those that are not possible to quantify or assign a value to.

- The effects should be **sustainable over time**. The evaluation of the effects should verify whether the measure has solved the problem. Long-term effects should also be measured in order to guarantee sustainable effects. At the same time, a review of the need should be carried out in order to see whether the conditions have changed. If the need no longer remains or if there is no longer any effect, the system should be removed.

- Establish a long-term **commitment** from the road authority. A decisive factor for successful implementation is that those involved still believe in the measure once the project moves over to the administrative phase.
2.4 The implementation process – A summary

*ITS implementation is an iterative process with several sequential steps. The steps in the process are the same as during traditional planning, but the content of each step may vary in certain respects.*

ITS measures differ from physical measures in that they require electricity and sometimes also data-communication facilities. Furthermore, ITS equipment must sometimes be installed in a protected environment (moisture, temperature, security etc.). ITS equipment often has a limited service life, which is why the depreciation period and reinvestment should be taken into account during planning.

The implementation of ITS measures can be summarised in the following steps:

### 2.4.1 Initiation – Identifying the problem

Problems are brought to the attention of the local SRA office or municipal traffic department through opinions from the general public or via political initiatives. Before proposed measures are established, a clear picture should be generated of what the problem is, and what the consequences are, for the different road-users and social groups.

### 2.4.2 Needs analysis and the formulation of objectives

Through on-site observations and the gathering of documentary evidence such as traffic measurements, reported near-accidents, and contact with local interested parties, a needs list is created for each road-user group and social group. A description of the objectives should subsequently be drawn up to quantify the objectives and define a suitable measurement method.

### 2.4.3 Choosing a measure

On the basis of the needs list, a number of possible measures are proposed. The alternatives may include both ITS and physical measures. For each measure, an assessment of effects and costs is carried out.
Through a balanced assessment of the needs and the various alternative measures, a measure is chosen. A general rule is to select the measure providing the greatest effect for the financial investment made. But there may be local conditions or decisions on political direction that lead to departures from this rule.

2.4.5 Implementation

The implementation phase covers procurement, installation and bringing the ITS into operation. Good planning of all parts of the process – from procurement to administration and evaluation – are vital for determining how successful the implementation of the ITS measure will be. Support and information are equally important factors. Good support and transparency in the decision-making process are vital for internal acceptance, while clear information to the general public is vital for external acceptance.

2.4.6 Administration

ITS measures often embrace several types of systems that are dependent on each other. In order for the applied measure to be reliable, the systems must be available and function as intended. This requires good operational routines and adapted maintenance. The necessary customer support falls under administrative responsibility.

2.4.7 Evaluation

There are two key aspects that should be included in the evaluation of an ITS measure. The first concerns effect evaluation. Have we solved the problem? This evaluation can be carried out using a before-and-after measurement method and by measuring the long-term effects. The second aspect involves reviewing the need. Have external factors influenced whether the need still remains?
The Road to ITS – What problems can be solved?

What does the Swedish Road 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 Road Administration’s role and strategy for ITS

Work is being carried out to implement ITS both at the Swedish Road Administration and at the municipalities. By coordinating ITS activities within a national unit, the Swedish Road Administration wants to create a common platform and uniform focus on ITS. At the same time, the Swedish Road Administration has the aim of stimulating diversity and creative thinking by spreading knowledge and arousing interest in ITS out in the regions and municipalities.

In order to formulate a common strategy for ITS, the Swedish Road Administration has produced an “Detailed document on ITS”\(^1\) pointing out five ITS focus areas for the period 2008–2017:

1. **More effective and sustainable commuting to work**, which, from the perspective of the road authority means improved travel and traffic information services to increase accessibility to public transport and promote co-modal travel, where it is possible to switch between public transport and private travel, in areas that are attractive to commuters.

2. **More effective and more sustainable freight transport**, this mainly includes services for differentiated kilometre tax and information services for carriers.

3. **Improved road safety** from the perspective of the body maintaining the road mainly includes services for increased compliance with the applicable speed limits.

4. **Quality-assured traffic information** is about the road authority’s responsibility for ensuring more effective data collection and improved control systems for the provision of information.

5. **Reliable and effective working practices** are about the road authority’s role as a supplier of data and information.

In the same way as the Swedish Road Administration is responsible for the administration and maintenance of state roads, the Swedish municipalities are responsible for municipal roads and streets. Each municipality can formulate municipal policy documents, such as road safety programmes, Environmental programmes, etc. The Swedish Association of Local Authorities and Regions\(^2\) (SALAR) issues manuals and guidelines for the design of roads and road planning, often in cooperation with the Swedish Road Administration. Some examples are: “Vägar och Gators Utformning – VGU” [The Design of Roads and Streets], “Trafik för en Attraktiv Stad – TRAST” [Traffic for an Attractive Town] and “Exempelbanken” [The Catalogue of Examples].

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\(^2\) www.skl.se
3.1.1 Firmly establishing in rules and regulations

As is the case for many other traffic measures, ITS must adhere to the rules, regulations and statutes that apply. ITS is often about reinforcing and clarifying laws and regulations in order to get better adherence and compliance from road-users.

Variable road signs that provide a reminder of the speed limit are, for example, an effective way of making drivers more aware of the posted speed limit. ITS solutions can also be used to make drivers aware of pedestrian crossings, intersections, cycle crossings, roundabouts, areas where wild animals cross, bends in the road, work-vehicle crossing warnings, ghost drivers, school buses at bus stops and school children on the road.

When planning ITS, the Swedish Traffic Sign Regulations ("Vägmärkesförordningen") must be followed. A good rule of conduct is to inform the authority responsible3, or the latter’s representative, of an ITS that is being planned for implementation.

3 The authority responsible for the Traffic Sign Regulations at the present time is the Swedish Transport Agency.

3.2 The road authority perspective

The Swedish Road Administration’s five designated focus areas cover the transport policy goals of accessibility, road safety, the environment and transport quality. By identifying shortcomings or problems in road or traffic systems, various measures can be deployed. ITS aims to directly or indirectly influence road-user behaviour in order to achieve better compliance with the rules or distribution of traffic.

A description follows that describes the general focus areas together with suggestions regarding measures that can be applied to help resolve the problems and challenges faced by the Swedish Road Administration in accordance with their detailed document on ITS.

When a problem needs to be solved, the needs of all road-users and other parties of interest that are affected must be catered for as far as possible. The focus areas are described below from the perspectives of the different groups of road-users. Then a number of ITS measures that can be linked to
the respective focus area will be presented. These ITS measures are then presented in the directory section of the manual.

3.2.1 More effective and more sustainable commuting to work

More effective commuting to work has the aim of facilitating traffic and reducing the congestion in sections of road that are important for commuters.

- In the case of **motorists**, this involves influencing them and giving them incentives to walk, cycle or take public transport instead of taking the car. And for those choosing to take the car, this will involve reducing traffic queues and unnecessary searching for parking spaces, particularly on larger roads and in urban areas. This will also reduce the impact on the environment.

- In the case of **public transport**, this involves improving the accessibility and the punctuality of public transport and providing better information on departures and disruptions.

- For **pedestrians and cyclists**, this is about improving conditions so that these groups of road-users can move in the traffic environment in an effective and safe manner.

There is no single way of dealing with the challenges described and several measures may be required if the needs of all road-user groups are to be provided for.

Examples of ITS measures that could help make commuting to work more effective and sustainable are provided below.

The overview below refers to the effects that that the measure can be expected to provide. The effect of the measure on road safety, the environment and transport quality is illustrated graphically by describing the effect in accordance with four predetermined levels:

- ••• a very positive effect
- •• a fairly positive effect
- • little positive effect
- <blank> no effect demonstrated
THE ROAD TO ITS – WHAT PROBLEMS CAN BE SOLVED?

A detailed description of the measures and effects can be found in the directory section of the manual.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS measure</th>
<th>Effect on Road safety</th>
<th>Effect on The environment</th>
<th>Effect on Accessibility</th>
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3.2.2 More effective and more sustainable goods transport

In the Swedish Road Administration’s detailed document for the period, 2008–2017, the subject of more effective and more sustainable goods transport is discussed mainly from the perspective of differentiated kilometre tax and improved information services for carriers. The matter of what form the kilometre tax should take in Sweden is the subject of a national project⁴ that is financed by, among others, the Swedish Road Administration and is therefore not covered in this publication.

⁴ www.arena-ruc.com
In the case of measures aimed at improving information for carriers, it is the road authority’s responsibility to provide clear information on disruptions or a deterioration in traffic conditions to all road-users. In the event of road works or other temporary traffic diversions, information directed at carriers may be necessary in order to ensure a good level of accessibility.

Examples of ITS measures that are of current interest for more effective and more sustainable goods transport are:

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<th>Chapter</th>
<th>ITS measure</th>
<th>Effect on Road safety</th>
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<th>Availability Accessibility Safety</th>
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<td>Operator-controlled free-text information</td>
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<td>Information about temporary diversions/road works</td>
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<td>7.2</td>
<td>Monitoring and control of hazardous goods transport</td>
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### 3.2.3 Improved road safety

Improved road safety mainly involves creating increased compliance with speed limits and other traffic regulations among road-users. Speed is the single most important factor in road traffic accidents and is the factor that determines how serious the consequences of an accident will be. High speed and drivers that exceed the speed limit also generate a feeling of insecurity among unprotected road-users (pedestrians and cyclists) that travel on or alongside the road. Problems involving high speed and poor compliance with regulations are first and foremost found on country roads, larger carrier and through roads and major trunk roads leading towards the city.

- **For motorists**, improved traffic safety involves better compliance with rules and regulations. This means making the motorist aware of obstacles, disruptions and the speed limit, and involves monitoring speed limits to ensure compliance.
- **For pedestrians and cyclists**, improved traffic safety is about increasing security by making motorists more aware of their presence on or alongside the road.
- **For society**, increased traffic safety is consistent with fewer and less serious accidents, this reduces the cost to society for those who are killed or injured, at the same time it increases public confidence in the authority’s social responsibility.
Examples of ITS measures that aim to improve compliance with the speed limit include:

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<td>Vehicle-activated speed limit reminders</td>
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<td>Ghost driver warnings</td>
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<td>7.3</td>
<td>Tunnel monitoring and control</td>
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### 3.2.4 Quality-assured traffic information

The purpose of improving and quality-assuring traffic information is to strengthen and safeguard the data input sources used for traffic counts and dynamic measurement data that is be used for traffic planning purposes or conveyed to road-users. If the road authority (or contractor, where appropriate) is to make a decision regarding measures that will influence traffic and road-users, it is very important that this is based on correct information. This applies regardless of whether the information to the road-user is conveyed via variable message signs or via other channels.
If we look at the responsibilities of the road authority, there are two areas that are primarily affected. One of these is the quality assurance of input data sources and the other is the quality-assurance of the information conveyed to the road-user. Dynamic systems and dynamic information have two essential parameters that determine quality, namely time and place.

Quality-assured traffic information is important from several points of view:

- **For the motorist**, this is about credibility and reliance on the information being correct. Without confidence and reliability, the information will be of no value and the desired effect will not be achieved.

- **For those using public transport** this involves having confidence in departure and journey times for public transport. If there is a lack of confidence in public transport, the traveller may change to another transport mode.

- **For the road authority and the authorities**, the decision-making data for handling disruptions or changes in traffic conditions must be very reliable and very accessible. The information that is passed directly or indirectly to rescue services and the police should provide a correct and general picture of what has happened.

Most ITS measures covered by this manual are dependent on (or contribute towards) quality-assured traffic information. In other words, all ITS that are in some way activated by dynamic input are covered.

Some ITS measures that are dependent on quality-assured input are shown below.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS measure</th>
<th>Effect on</th>
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</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Queue-warning</td>
<td>Road safety</td>
<td>The environment</td>
<td>Accessibility</td>
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<tr>
<td>5.3</td>
<td>Weather warnings</td>
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<td>5.4</td>
<td>Operator-controlled free-text information</td>
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<td>5.4</td>
<td>Journey time information</td>
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<td>5.5</td>
<td>Information about temporary diversions/road works</td>
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<td>5.6</td>
<td>Vehicle-activated speed limit reminders</td>
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<tr>
<td>5.7</td>
<td>Vehicle-activated warning signs for pedestrians/cyclists</td>
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<tr>
<td>5.8</td>
<td>Ghost driver warnings</td>
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<tr>
<td>5.9</td>
<td>Dynamic parking information</td>
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<tr>
<td>5.10</td>
<td>Park and Ride information</td>
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<tr>
<td>5.11</td>
<td>Real-time public transport travel information</td>
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</tbody>
</table>
The system that is used today to provide input data for traffic information utilises: flow and speed information via pneumatic tube measurements and vehicle positions (floating car data); journey time information via video-camera systems; temperature information; road condition and wind information via climate stations; and, position data in real time from public transport vehicles (fleet control systems).

### 3.2.5 A reliable and effective way of working

A reliable and effective way of working involves, amongst other things, the road authority’s role as a supplier of data and information to external service providers and the public.

When designing and implementing ITS, rules and regulations, such as the Swedish Traffic Sign Regulations, must be applied. In order to ensure a mutual understanding with the authority responsible, the Swedish Transport Agency or the other exerciser of public authority should be informed of the planned ITS measures.

### 3.3 ITS versus physical measures – Examples

Traditionally, measures for solving problems on the roads consist of some form of physical measure. In many places, physical measures have already been implemented without having the desired effect, or there may be no room to implement physical measures that will remove the problem. In these cases, ITS is an option for making the roads more effective, safer and/or more sustainable.

An example of a problem that ITS can solve more effectively than physical measures is that of high speeds on roads that pass through smaller communities where pedestrians and cyclists often travel alongside and across such roads. A possible physical measure is to make the road narrower or to build speed-bumps. One possible ITS measure is to set up a sign that reminds drivers of the speed limit, or warning signs informing of pedestrians and cyclists.

Two examples are described below in which ITS measures have been shown to be more effective when compared with alternative physical measures.

#### 3.3.1 Excessive speeds through Våxtorp

An example that demonstrates how an ITS solution can have a greater effect on reducing speeds in Våxtorp, a small community along main road 24 between Laholm and Orkelljunga in Southern Sweden. The speed limit through the community is 50 km/h but was previously 70 km/h. There is a...
sparsely populated area with entrances and exits along the stretch of road. Both police and residents reported major problems with excessive speeds on the section of road in question.

One of the first physical measures was to narrow the road somewhat by means of an urban gateway with portable traffic islands (concrete foundation) and traffic dividers as well as markings on the road in order to indicate that it narrows. Traffic measurements before and after\(^5\) showed that average speeds reduced by 2–8 per cent, depending on the type of vehicle. The greatest impact recorded was for lorries with loads.

![Figure 3. Road markings and traffic islands, Våxtorp.](image)

As this measure did not have a sufficient impact on speed reduction, signs were erected to remind drivers of the speed limit in each direction. The concrete foundation was then removed. The sign is activated only when vehicles are driving too fast.

![Figure 4. Vehicle-activated speed limit reminders, Våxtorp](image)

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\(^5\) Evaluation of local ITS systems, SWECO 2007
The traffic measurements 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. Average speeds were reduced by between 11 and 16 per cent, mostly for heavy goods vehicles.

**Figure 5.** Average speed Våxtorp (2006 week 21), after narrowing and introducing traffic islands (2006 week 48) and after the ITS measure was introduced (2007 week 23)

### 3.3.2 Accessibility problems on Road 222, Värmdö

Road 222 between Mölnvik and Ålstäket in Värmdö outside Stockholm has had major accessibility problems that have resulted in lengthy queues, particularly during the summer when traffic increased from 18,000 to 28,000 vehicles per day. Queues form in the westbound direction towards Stockholm in the morning, and in the opposite direction in the afternoon.

*Reversible lane, Värmdö*
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 citybound traffic. In the afternoon, the middle lane is used for traffic heading in the eastbound direction.

Initially, the control method was manual. An automated ITS system was introduced in the autumn of 2008. This system uses mechanical barriers and variable displays that can be controlled and monitored remotely from the Traffic Management Centre – Trafik Stockholm.

Overall, the measure has had a positive effect on accessibility. The queues have disappeared and public transport has benefited. Only one in ten of those interviewed now complain about accessibility problems. In addition, the solution proved to be cost-effective. Building a four-lane road would have cost 140 million SEK, while the reversible lane solution cost only 20 million SEK.

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6 Evaluation of Reversible lane control on road 222. Swedish Road Administration, 2006:134
Directory of 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 applications are highlighted. Focus is given to applications in the physical road environment initiated by the road authority and aimed at road-users.

ITS applications at the roadside include variable messages and road signs, signals and electronic systems for the purpose of

- Providing information to road-users
- Directing traffic
- Monitoring traffic

The systems and services described include the following:

<table>
<thead>
<tr>
<th>Chapter</th>
<th>ITS and services</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Providing information to road-users</td>
</tr>
<tr>
<td>5.1</td>
<td>Queue-warning</td>
</tr>
<tr>
<td>5.2</td>
<td>Weather warnings</td>
</tr>
<tr>
<td>5.3</td>
<td>Operator-controlled free-text information</td>
</tr>
<tr>
<td>5.4</td>
<td>Journey time information</td>
</tr>
<tr>
<td>5.5</td>
<td>Information about temporary diversions/road works</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 warning signs for pedestrians/cyclists</td>
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<td>5.8</td>
<td>Ghost driver warning</td>
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<td>5.9</td>
<td>Dynamic parking information</td>
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<tr>
<td>5.10</td>
<td>Park and Ride information</td>
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<tr>
<td>5.11</td>
<td>Real-time public transport travel information</td>
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<tr>
<td>6</td>
<td>Directing traffic</td>
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<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>Variable speed limits</td>
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<td>6.5</td>
<td>Reversible lane control</td>
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<tr>
<td>6.6</td>
<td>Lane/motorway control</td>
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<tr>
<td>6.7</td>
<td>Road-user charging in urban areas</td>
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<tr>
<td>7</td>
<td>Monitoring traffic</td>
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<tr>
<td>7.1</td>
<td>Automatic speed surveillance</td>
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<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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</tbody>
</table>
Each system is described using the following headings:

<table>
<thead>
<tr>
<th>x.1</th>
<th>Application</th>
<th>Describes how the system functions together with other infrastructure.</th>
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</thead>
<tbody>
<tr>
<td>x.2</td>
<td>Effects</td>
<td>Describes the effects achieved by applications of the system in Sweden.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The system's effect on road safety, the environment and transport quality etc. are illustrated graphically and divided into four levels:</td>
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<tr>
<td></td>
<td></td>
<td>••• A very positive effect</td>
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<tr>
<td></td>
<td></td>
<td>•• A fairly positive effect</td>
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<tr>
<td></td>
<td></td>
<td>• Little positive effect</td>
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<tr>
<td></td>
<td></td>
<td>&lt;blank&gt; No effect demonstrated</td>
</tr>
<tr>
<td>x.3</td>
<td>Actors</td>
<td>Describes the actors that are involved in the implementation of an ITS service.</td>
</tr>
<tr>
<td>x.4</td>
<td>Good advice for implementation</td>
<td>Some advice and things to think about when implementing the ITS service are provided here.</td>
</tr>
<tr>
<td>x.5</td>
<td>See also</td>
<td>Here, reference is made to other systems that are connected to the system described.</td>
</tr>
</tbody>
</table>

Each chapter also contains references to good examples of actual implementations of the ITS system or service described.

## 4.1 Assessment of effect

The basic data for the assessments of effect carried out in this manual are based on a comparison of different evaluations in order to see whether the effects and attitudes point to any clear tendencies. The assessments of effect are therefore not an absolute truth; local conditions and special prerequisites for the effects of a system may have a considerable influence.

In certain cases, it is possible to point to some important fundamental rules and prerequisites to bear consider during implementation. This is described under each system chapter.

In order to provide an indication of an ITS effect and the level of effect that can be expected, a three-level scale is used for illustration purposes.

The effects are divided into:

- Road safety
- The environment
- Accessibility, availability and safety

The grading is performed as follows:

- ••• a very positive effect
- •• a fairly positive effect
- • little positive effect
- <blank> no effect demonstrated
An example follows below:

<table>
<thead>
<tr>
<th>Road safety</th>
<th>The environment</th>
<th>Accessibility</th>
<th>Availability</th>
<th>Safety</th>
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<tr>
<td>**</td>
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</table>

### 4.2 Costs

The costs of ITS measures vary a great deal, depending on the complexity and size of the system. The ITS measure may also be integrated with other measures, which makes it difficult to separate the ITS cost. When planning ITS, all costs should be calculated at an early stage. This is described in the manual’s section on planning.

Examples of cost factors include:

- Pilot studies that include the stocktaking of problems and a needs analysis
- Project management during the implementation phase
- Investment costs for equipment and software, mains connections, telephone and communication costs.
- Installation and the costs for bringing the ITS into operation (i.e. commissioning)
- Administrative costs (operation and maintenance)
- Reinvestment costs
- Evaluation costs

The publication, “Effects of Different Road Measurements”, by the Swedish Road Administration provides some examples of actual investment costs for different types of systems. Amongst other things, it is stated that annual operating costs vary between 5 and 10 per cent of the initial investment cost.

1 Effects of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
Providing information to road-users

What does better information for accessibility and safety actually mean?

What ITS measures can be used to provide information to road-users?

What effect can the measures provide?
Under the main heading, providing information to road-users, there is a single subheading and eleven ITS:

Road-user information via variable messages and road signs
- Queue-warning
- Weather warnings
- Operator-controlled free-text information
- Journey time information
- Information about temporary diversions/road works
- Vehicle-activated speed limit reminder
- Vehicle-activated warning signs 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 quickly form on roads with a great deal of traffic, such as major roads leading to and from the city during the rush hours or in other situations, e.g. during popular events. A high intensity of traffic combined with stressed motorists may result in pile ups with serious personal injuries and major delays to traffic as a result. On such roads, the introduction of a queue-warning system can improve safety.

Queue-warning systems require the measurement of traffic flows. This is done by recording vehicles’ speeds at different points along the road. Queue-warnings can be linked together with journey time information and recommendations for alternative routes via operator-controlled VMS. These are then examples of traffic management systems.1

5.1.1 Application

The primary purpose of a queue-warning system is to reduce the risk of rear-end collisions, which are common accident types on urban motorways. Motorists are warned of queues ahead and therefore have more time to adjust their speeds and prepare for a stop. Although some motorists may well be aware of areas that have a higher queue-risk, queue-warning systems have proved to be of great benefit.

5.1.2 Effects

Queue-warnings systems have an effect on the number of rear-end collisions and contribute to a less aggressive driving style. Other effects are, however, more difficult to demonstrate. An evaluation from Sweden’s second largest city, Gothenburg, has shown that queue-warnings systems contribute to calmer driving behaviour. There it has been shown, by means of floating car data, that the percentage of sudden braking (shorter than 300 m) is reduced from 75 per cent to 40 per cent; and also that the average braking distance at queues increased from 260 m to 420 m when the queue-warning system was activated.2

Although other variable message signs and individual free-text signs have an effect on rear-end collisions, MCS and queue-warning systems provide a quicker warning.3 In order to obtain better supporting evidence, the occurrence of rear-end collisions should also be studied on stretches of road only with other variable message signs and free-text signs.

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1 Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
2 Queue warning system on the E6, Gothenburg Report of traffic measurements. The Swedish National Road and Transport Research Institute note 39-2002
3 Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
5.1.3  Actors

In Sweden it is the road authorities (i.e. the Swedish Road Administration and/or municipalities) who are responsible for the implementation of queue-warning systems.

5.1.4  Good advice for implementation

It is important to bear in mind that variable message signs require regular maintenance in order to function. Administrative responsibility and the costs of operation and maintenance should be included at the planning stage.

5.1.5  See also

- Lane control on multi-lane roads (MCS – Motorway Control Systems)
- Tunnel monitoring and control
- Operator-controlled free-text information

5.1.6  Good examples: Queue-warning

In 2001, a queue-warning system was installed in the southbound direction on the E6 in Gothenburg, Sweden’s second largest city. The first section of the system was 3 km long; stretching from the Båckebol junction to the Ringó junction.

The stretch is equipped with seven queue-warning signs at intervals of 500–1,000 metres and detectors for measuring vehicle flows and speeds.

Traffic measurements carried out by the Swedish National Road and Transport Research Institute before and after the installation showed clear improvements in accessibility and reduced disruptions to traffic during peak hours. The number of rear-end collisions has halved and the number of those braking suddenly has reduced from 75 per cent to 40 per cent. Furthermore, personal injuries have reduced from 0.61 accidents a month to 0.24 accidents a month.

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

A factor that probably affected the results of the study in a positive direction was a new lane that was opened at the same time south of the Tingstad Tunnel. This makes it difficult to assess the extent to which the effect can be attributed to the queue-warning system.

5.2 Weather warnings

Severe weather conditions frequently occur in certain areas, e.g. on mountain roads in the border areas in Northern Sweden. In these areas, the roads are used by tourists and commercial drivers who sometimes lack local knowledge and knowledge regarding the unpredictability of the weather. Winter conditions and darkness prevail for half the year.

On these roads, it is easy to lose one’s bearings and drive off the road in some circumstances. For this reason, variable message signs for weather warnings have been set up on selected roads. Free-text messages can be displayed on these signs. Some examples of this type of information include: slippery road surfaces, snow obstructions and directives for driving in a convoy (including at which times). Based on this information, motorists can choose another route or wait to drive in a convoy.

Variable signs for weather warnings are administered from a traffic management centre. The traffic information centre is manned 24 hours a day and obtains information regarding prevailing weather conditions through SMHI – the Swedish Meteorological and Hydrological Institute), radar and satellite images, via the monitoring system VViS (the Swedish Road Administration’s weather information system), and from cameras.

5.2.1 Application

Together with other information channels such as ‘trafiken.nu’, SMS and radio, dynamic free-text signs for weather warnings provide a complete and current picture of the prevailing weather conditions. Based on this information the road-user gets better support for decisions regarding the remainder of the journey.

Weather warning systems are combined in some cases with physical measures such as road barriers that effectively prevent road-users entering sections of road that are dangerous for traffic.

5.2.2 Effects

Studies show that weather warning systems increase road safety and increase confidence among road-users.4

A study carried out by the Swedish Road Administration in 2004 has also shown that free-text messages provide more effective traffic information and greater obedience when compared to simpler warning systems. Flashing lights on mountain roads, for example, tend to be ignored by road-users.5

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4 The road user’s experience of variable and fixed message signs in Norbotten county, Eriksson, Swedish Road Administration, 2003
5 Gap analysis: Road E 10, Road information in severe weather situations between Svappavaara–Riksgränsen, Kiruna municipality, Johansson, Swedish Road Administration, 2004
5.2.3 Acts

This type of measure is the responsibility of the road authority. Physically closing-off roads is the responsibility of the operational contractor.

5.2.4 Good advice for implementation

If a weather warning system is established in the border area, it is important that the information is comprehensible to road-users from different countries. The greatest risk is actually for foreign road-users to miss information distributed via the other available communication channels, e.g. via the radio.

It is considered a good idea to coordinate information about closed mountain passages between Sweden and Norway, and any other countries in the region.

5.2.5 See also

- Variable speed limits

5.2.6 Good examples: Weather warnings

Along mountain roads, E10, E12 and road 95 in Northern Norrland in Sweden, the Swedish Road Administration has erected eight VMS (variable message signs) at strategic locations to inform road-users of closed roads. Car journeys over to Norway in heavy snow and severe weather can be made via the E10 border road. If the road is closed, an information sign is switched on in Svappavaara, Kiruna and Björkliden. If road 95 is closed, then an information sign is turned on outside Arjeplog and at the crossroads between road 625 and trunk road 95, (Laisvallsvägen).

In 2003, the Swedish Road Administration carried out an evaluation with a view to examining how information on weather warning signs along road E10 are received by road-users and what they think about this kind of message. The study shows that road-users’ experiences of signs are positive as regards appearance, location and message. They feel secure and appreciate information about closures. With the help of the signs, they can decide in time what action to take.

Sources: The road-user’s experience of variable and fixed message signs in Norbotten county, Eriksson, Swedish Road Administration, 2003.
Gap analysis: Road E 10, Road information in severe weather situations between Svappavaara–Riksgränsen, Kiruna municipality, Johansson, the Swedish Road Administration, 2004.
5.3 Operator-controlled free-text information

With operator-controlled free-text information, there is an opportunity to inform road-users dynamically about the prevailing weather conditions and unforeseen traffic events. In this way, the ability to maintain freely flowing traffic is improved. In addition, a valuable road-user service that reduces stress and provides better journey-planning opportunities is provided.

Operator controlled free-text information is primarily used for information on disruptions, queue-warnings, journey times and alternative choices of road. The system assumes that the road is equipped with variable message signs with free-text and systems for obtaining suitable traffic data.

5.3.1 Application

Information about disruptions by means of free-text VMS is typically used on motorways and larger roads, particularly those that carry a lot of traffic and are sensitive to disruptions. Information about disruptions that cause delays longer than 5 minutes is considered useful to display. Road-users are mostly interested in the consequences of the disruption rather than the cause. It can be a good idea to combine the text message with suitable graphic symbols.6

Although information on traffic disruptions is suitable for communicating via free-text, this should be complemented by a queue-warning system if

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6 Memo – Traffic management and Accessibility, Movea, 2009
there is a risk for queues to develop unexpectedly and suddenly on high-speed roads.

If journey times vary greatly and frequently, this type of information should also be distributed to road-users. Studies show that road-users are interested in finding alternative routes for their journey along with any information on journey times for such routes.7

5.3.2 Effects

Free-text messages have a great effect on accessibility as they can provide more exact information on a disruption, recommend alternative routes, and communicate journey-time information. How great the effect of the diversion will be depends primarily on the type of disruption, the wording of the message, what and how well-known the alternative routes are, how motorists perceive the traffic situation and what information they receive via other channels, particularly radio.

Road-users feel that their comfort is improved, and feel less stress and irritation, when better traffic information is provided.

Road safety is greatly dependent on speed. Changes in speed result from the messages on free-text signs and queue-warning systems. By reducing speeds over a longer section at the tail-end of queues, a positive effect on road safety can be achieved. A reduction of up to 10 per cent in the number of rear-end collisions has been recorded.

Operator controlled VMS signs have very little impact on the environment. Calculations for bigger events show that the beneficial impact on the environment may amount to 2–3 per cent of the total benefit.

5.3.3 Actors

The introduction of operator-controlled free-text information is the responsibility of the road authority, i.e. usually the Swedish Road Administration in Sweden.

5.3.4 Good advice for implementation

Studies have shown that free text information provides most benefit on roads that have high speeds and are prone to disruptions as a result of difficult weather or road conditions.

The wording of the free text message is of great importance with regard to the effect. It is important to describe the consequences of an event rather than describe the actual event itself. The message should be tangible and strongly worded. The benefit for the road-user is greater when words such as ‘accident’ are used, rather than weaker words such as ‘incident’.7

5.3.5 See also

• Queue-warning

7 Verification of the benefits of better traffic information, FASAN 2, Movea, 2007
5.3.6 Good examples: Operator-controlled free text information

Systems with variable message signs for automatic queue-warnings, diversions and information on road works have been installed on the E6 and E22, the northern approach roads to Malmö in Southern Sweden. Evaluations show that about 20 per cent of road-users pay heed to the message about queuing and recommendations to choose another named road. Similar results were achieved in the evaluation of a similar system in Gothenburg, Sweden’s second largest city.


5.4 Journey-time information

The recording of journey times is performed in cities in particular or in traffic systems that carry a lot of traffic in order to monitor and control the flow of traffic. The information is of interest to commuters, for example, in relation to accidents or queue development along a road.

The communicating of information about traffic situations and current journey times assumes that there is a system for the detection and measurement of flows and speeds in traffic. The calculation of journey times is based on data from detectors that are set out along specific routes.

One way of measuring journey times is to photograph vehicle number plates at several points and then add together the journey times for each section into a relevant journey time for a longer section. In this way, it is possible to identify deviations from expected journey times. The estimated journey time is shown via variable signs.
5.4.1 Application

Journey time information can serve several purposes. The service can provide information to road-users that can, with any luck, reduce their level of stress on the roads. The service can also contribute towards better accessibility as motorists can choose another route to take into account queues and incidents.

Studies show that road-users want information about accessibility as early as possible in order to be able to plan their journey. They also want the information via several channels to indicate that it is reliable. For this reason, traffic information can benefit from being communicated in parallel via variable message signs and traffic radio.

5.4.2 Effects

The aim of information about journey times is to create better accessibility for motorists and make traffic planning more effective for the road authority. Whether journey times on variable signs actually lead to a change in driving behaviour – and thereby improve road safety, provide better accessibility and reduce the impact on the environment – actually depends on how the system is implemented and whether there are alternative routes in the event of a traffic incident.

Swedish trials and measurements show that between 20 per cent and 30 per cent of motorists change their route as a result of a message about an incident.

Several studies show that information about journey times is popular with road-users, even if they do not change their behaviour.

5.4.3 Actors

The road authority is responsible for the implementation of journey-time information via variable messages and road signs. Communicating journey time information via other channels can be carried out externally using, for example, the media.

5.4.4 Good advice for implementation

When implementing a system for showing journey times, information should first be provided to road-users about what a journey-time message actually says. Experience shows that it is journey times in particular that road-users want, not deviations from journey times. It is also important that the information is reliable. The system should first be implemented on a limited scale and then followed up with traffic measurements and road-users’ reactions before extending it.

5.4.6 Good examples: Journey time information

In October 2006, a trial was started to provide information about journey times on the E4/E20 Södertälje road at Bredäng, south of Stockholm (interchange 152). Information about estimated journey

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6 Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
times was displayed on the signs every day between 7.00 and 9.00 AM during the trial period. The test was done for the road-users driving on the E4/E20 in the direction of Stockholm. Information was displayed about journey times to two of the bigger junctions on the motorway: the Nyboda interchange (155) and Nortull interchange at the Eugenia Tunnel (164).

Following the trial period, an evaluation was carried out that resulted in journey times being displayed permanently on the E4 in Stockholm from November 2007. The lesson was that the system provided a valuable improved service to road-users.

If you would like to find out more, contact the Swedish Road Administration, Stockholm Region.

5.5 Information about temporary diversions/road works

During work on multi-lane roads, road-workers are exposed to constant risks. Excessive speeds and carelessness on the part of road-users are important contributors to this risk. This results is regular incidents and accidents. Consequently, there is a need for safer and more effective methods for re-routing and reducing speeds at road-work sites.

5.5.1 Application

Mobile variable message signs are used to provide clear and correct information in connection with road works. It is well-known that dynamic signs are understood better than traditional plate signs by road-users. This has been the experience of a nationwide trial on variable speed limits.
Particularly dangerous tasks at road-works are opening and closing at the start of the day’s work. Traditionally, a risky visit to the road area is then necessary to set up the signs. With remote-controlled VMS signs, the dangerous element can be minimised while at the same time reducing work hours.

The use of vehicle-mounted signs with recommended maximum speeds is allowed in accordance with the new Swedish Traffic Sign Regulations that came into force in 2007.

5.5.2 Effects

It can be assumed that mobile variable message signs will have the same effect as fixed ones. In the ‘Work on the Roads’ project, the Swedish Road Administration studied the effects of different speed-reducing measures at road-work sites. This included speed-reminder signs that were activated by vehicles entering the area at excessive speeds. Speed-reminders, and other methods tested (including mobile road safety cameras), led to a reduction in average speeds and a reduced distribution of speeds before, at, and after, the road work site.

5.5.3 Actors

In Sweden, a number of trials have been carried out with mobile variable message signs. In these cases, it is the road authority, i.e. the Swedish Road Administration that has been responsible for the trials. As this concerns work environment matters, trade union parties have also been involved in the process.

5.5.4 Good advice for implementation

When implementing dynamic information on variable signs at road-work sites, other measures in addition to physical ones should be considered to reduce speed. Examples include the use of mobile road safety cameras and active speed bumps. With active speed bumps, only the vehicles that are being driven at excessive speeds are affected.

5.5.5 See also

- Automatic speed monitoring
- Vehicle-activated speed limit reminders

5.5.6 Good examples: Information about temporary diversions/road works

During road construction on the E18 in Västerås in central Sweden in 2007, eight mobile VMS signs for speed control were used. The aim was to be able to adjust speeds so that road workers would feel safe during the period of construction. The speed reductions were applied during working hours while higher speeds were allowed at weekends and during the night when there was no road-work activity.

In another Swedish Road Administration project, field studies were carried out with dynamic variable messages signs for road works on the E4 north of Stockholm (between Uppsala and Arlanda), the
E18 (between Arninge and Rosenkälla) and road 73 (at Jordbro). The aim of the project was to investigate whether variable message sign warnings at road-work sites could increase safety and create a better mental and physical working environment.

The trial was evaluated through road-user and road-worker surveys. 99 per cent of road-users felt that the signs were clear and easily understood and 78 per cent felt that the signs were more visible than traditional signs for road-works. 75 per cent of road-workers felt that the dynamic signs were better than traditional signs.


### 5.6 Vehicle-activated speed limit reminders

Speed-reminder signs are installed in order to resolve a local traffic problem at locations where traditional physical measures or ordinary sign layouts are not functioning or not cost-effective, or where ordinary sign layouts do not have the desired effect. These systems create awareness among road-users by simply being activated and illuminated when the current speed limit is exceeded.

Detectors (such as radar) measure the speeds of oncoming vehicles and activate a sign that informs speeding drivers of the current speed limit.

#### 5.6.1 Application

A common application for speed-reminder systems is that of improving road safety on roads that pass through small communities. In typical cases, the section of road is bordered by pavements and buildings on both sides. Alongside the road, there are schools and residential properties and unregulated pedestrian crossings at regular intervals. In addition, the view may be blocked. Unprotected road-users, such as children are exposed to risk when vehicle speeds exceed the statutory speed limits. One solution may then be to erect speed-reminder signs. These can be seen at a distance and give road-users time to adjust their speeds.

Another application is speed reduction on sections of road that are known accident black spots, for example, tight corners and situations with poor visibility.

#### 5.6.2 Effects

Speed-reminder signs increase compliance with the regulations and reduce speeds, e.g. in 30 km/h zones at schools. Studies have shown that average speeds are reduced by 10–15 per cent. Field surveys show that many people...
feel that road safety is increasing and that compliance with the speed limits is improved. People would like to see more of these systems on the roads.  

5.6.3 Actors

The measure is implemented by the road authorities. In Sweden, this is the local municipality and/or the Swedish Road Administration. It can also be beneficial to coordinate implementation with local actors such as schools and the police.

5.6.4 Good advice for implementation

Before a speed-reminder system is procured, a problem-assessment should be performed that involves traffic measurements, a gathering of opinions from the public, and an accident-analysis. Is there a real or perceived road safety problem, and are speed-reminder VMS signs a suitable measure?

After implementation, it is appropriate to carry out new traffic measurements. Did the measure have the desired effect? It may be beneficial to use information campaigns to provide information about the system’s functionality and purpose.

The system should be fine-tuned and adjusted directly after installation in order to increase road-users’ confidence in the system. If the sign is only active during certain periods, such as school days, it is also important that the timing settings for the sign are used and that they are correct. An advantage of dynamic displays compared to fixed signs is that it is possible to include the school calendar and thereby avoid speed reductions during holidays. If the measure is combined with automatic speed monitoring, an even greater speed-reduction effect can be obtained.

5.6.5 See also

• Vehicle-activated warning signs for pedestrians/cyclists
• Automatic speed monitoring

5.6.6 Good examples: Vehicle-activated speed limit reminders

In 2006, speed-reminder systems were installed in Björketorp, Växtorp and Bovallstrand in Western Sweden as part of the focus on local ITS. The systems were subsequently evaluated.

The results were generally positive and road-users demonstrated a good level of acceptance for the systems. In Bovallstrand, speeding decreased by as much as 56 per cent in the southbound direction after the system was installed. Engaging locally interested parties in the implementation process such as municipalities, the Swedish Road Administration and schools, proved to be an important factor for successfully establishing such a system. In interviews, 60 per cent of those interviewed stated that they believed the systems were contributing towards increased road safety. 84 per cent felt that the signs should remain and 75 per cent wanted more systems of this kind on the roads.

Source: Evaluation of local ITS, SWECO 2007
5.7 Vehicle activated warning sign for pedestrians/cyclists

Ordinarily, traffic signals detect approaching vehicles automatically, however, pedestrians and cyclists who want a green light often have to make their presence known by pressing a button at a pedestrian crossing. An active act – pressing on the button – is required to change the light to green.

There is a risk that pedestrians and cyclists will walk or cycle against the red light. Where there are pedestrian and cyclist signals in intensive traffic, there may also be safety problems as motorists almost always have a green light and the motorist quite simply fails to check whether the lights are red or green for pedestrians and cyclists.

An alternative to traditional signal control is to introduce a system that warns for pedestrians/cyclists. By equipping a pedestrian and/or cycle passage with movement-sensing detectors and warning signs, a safer junction can be achieved. When a road-user comes into the detection zone, a sign is activated automatically. The active time-period is predetermined and the sign is turned off when the period expires.

A battery-operated and cost effective variant of the pedestrian/cyclist warning is FIVÖ (Förstärkt Information vid Övergångsställen – Reinforced Road safety The environment Accessibility Availability Safety)
5.7.1  Application

At bus stops and schools, for example, the passage of crossing cyclists and pedestrians may, at times, be intensive. In combination with vehicle traffic, an unfavourable traffic situation may arise. Implementing a permanent reduction in speed is not always desirable if the purpose is only to reduce speeds when pedestrians or cyclists are in the area. In order to increase safety, a pedestrian and cyclist warning system can be built. As the system only has a warning function, pedestrians and cyclists are encouraged to continue their awareness of traffic.

5.7.2  Effects

Warning systems for pedestrians and cyclists have a positive effect on road safety because the signals are only activated when road-users are crossing. This makes the interplay between pedestrians and vehicular traffic easier. The risk of children forgetting to press for a green light, for example, is eliminated through automatic activation.

The delay for vehicular traffic is marginal, but leads to calmer driving at pedestrian crossings. The situation for pedestrians improves as a result of the greater respect given to the pedestrian crossing by vehicular traffic.

5.7.3  Actors

The measure is implemented by the road authority, which in Sweden is usually municipalities and the Swedish Road Administration. It can also be beneficial to coordinate implementation with local actors such as schools and the police. If implementation takes place at, for example, a bus stop, consultation can also take place with the head of public transport for the area.

5.7.4  Good advice for implementation

In order for unprotected road-users to feel safe, it is important that warning signs are reliable. For this reason, it is important that the functionality of the pedestrian and cyclist warning system is checked regularly. It would be reasonable to set out objectives for the display system and carry out studies of the effect in the long and short term. If the anticipated effect is not achieved, it is necessary to investigate the reasons why, and consider whether improvements could be made.

There is always a risk that the system will be activated unintentionally. Detection faults can occur as a result of weather conditions, birds and nearby people who do not intend to cross the road. If this occurs frequently, road-users may lose their confidence and respect for the system. In towns, the risk of detection errors can be greater than in rural areas due to the fact that there are more pedestrians in the urban environment.
5.7.5 See also

- Vehicle-activated speed limit reminders

5.7.6 Good examples: Pedestrian and cyclist warnings

Outside Skövde in Western Sweden, along road 49 (Hjovägen) towards Tibro, there is a company called Lichron that manufactures and sells machinery. Lichron Technical College is located next to the company. Many older school children take the bus to and from school. The bus stop is on road 49, which means that the school children need to cross this trunk road.

The speed limit is 70 km/h. In order to make motorists aware that there are pedestrians crossing the road and thereby increase road safety for pedestrians, two VMS signs were installed next to the bus stop. The signs are designed as warning signs for pedestrians. Movement at the bus stop and movement on the footpath towards the pedestrian crossing are detected. Parallel movements along the road are not detected.

An evaluation of the system, involving interviews, provided positive results. Almost half of the pupils interviewed felt that the environment around the pedestrian crossing had become safer. Motorists also responded that they had changed their driving behaviour and reduced speeds when driving past to a large extent. These findings indicate that the sign has had a positive effect. The majority of road-users wanted the sign to remain where it was. They also wanted to see more systems of this type on the roads. The bus drivers interviewed felt that the sign had contributed to an increase in road safety, and two out of three wanted the sign to remain.

At Svedmyraplan in Enskede in the south of Stockholm, a FIVÖ (Förstärkt Information vid Övergångsställe – Reinforced Information at Pedestrian Crossings) system was installed in 2007. This location was previously an accident blackspot due to the road width, which encouraged high speeds.

After the installation of the FIVÖ, observational studies were carried out by Stockholm’s traffic office to see how traffic had changed at the crossing. The conclusion was that pedestrians felt more secure due to the flashing signs at the crossing. Many pedestrians look up at the rows of lights to see that they have been activated before stepping out onto the crossing. Despite bolder behaviour, conflicts between pedestrians and motorists have reduced. When the signs are switched on for pedestrians to cross, the majority of pedestrians get a good response from motorists. They notice the signs and stop to allow pedestrians to cross to a greater extent than previously. Finally, it was also found that the crossing was visible from a greater distance than previously.

5.8 Ghost driver warning

Motorists who drive onto the motorway against the direction of traffic, referred to in Sweden as ghost drivers, are a serious problem. Taking a wrong turn such as this may lead to serious consequences as the result of frontal collisions that often lead to death. The serious consequences of such accidents often mean that they are covered by the media.

Overall, however, there are few accidents relating to driving against the flow of traffic compared with other types of accident. A study carried out by the Danish Road Administration showed that fewer than 0.5 per cent of accidents were due to motorists driving against the flow of traffic.

Traditional safety-improvement measures for driving against the flow of traffic include better signage, road markings and lane separation. Although these types of measures make it difficult to take a wrong turn, they do not make the oncoming traffic aware that a motorist is driving on the road against the flow of traffic. In this context, ITS can be an effective tool in reducing the risk of accidents.

5.8.1 Application

On the continent, ghost drivers are a familiar concept, the Danish Road Administration states that this problem is on the increase. This problem

10 Ghost Drivers – a Report, Danish Road Administration, Denmark 2008
has also been observed in Sweden. One of the most serious problems that can occur is when a driver enters the motorway via an exit road and, as a result, ends up driving against the flow of traffic. This is what Swedish and Danish ghost driver warning systems hope to prevent.

A fully developed system for dealing with ghost drivers may include the following elements:

- A detection system that registers driving against the flow of traffic.
- The driver of the ghost vehicle may be warned via, for example, LEDs on the roadway as well as other signage and audio signals.
- Information to other motorists will, as a general rule, require an alarm function that is triggered by a detector and alerts the Traffic Management Centre. From there, information can be passed to the police and SOS-Alarm. From there, traffic information can also be distributed via RDS/TMC and radio.
- Finally, the system may contain barriers for closing or opening exit roads.

5.8.2 Effects

Experience of this type of system is limited in Sweden. The first system has been recently set up in Varberg in the West of Sweden. In Denmark, several different systems have been implemented or are in the process of being implemented. Even in Denmark the experience is limited.

The reason is that this type of accident is relatively uncommon. It will therefore take time to gain experience of the system. It is clear, however, that for each serious accident the system can prevent, society will save considerable costs.

5.8.3 Actors

In Sweden, it is the Swedish Road Administration that is responsible for this type of measure.

5.8.4 Good advice for implementation

It is important that the road system is as self-explanatory as possible. Accidents may arise due to signs and road markings being unclear. On stretches that are particularly exposed to ghost driving, it is important that the geometry of the road also clarifies its functionality. This applies particularly to motorway ramps and motorway connector roads.

Preventative information can provide advice on how road-users should act if they encounter a ghost driver. In a critical situation, the seconds are precious and quick action can mean the difference between life and death.
5.8.6  **Good examples: Ghost drivers**

Sweden’s first system warning motorists of vehicles that drive against the flow of traffic is situated in Gunnestorp near Varberg in the West of Sweden. The reason this system was set up is because it is believed there are problems with ghost drivers at this location. Over the course of a year, three motorists have driven against the flow of traffic. One of them died.

The system is based on detectors on a 7-metre high mast, which sense when a vehicle is heading in the wrong direction. Flashing yellow warning lights are then activated further on in the road and warn the motorist. The message is further reinforced by warning roadway lights embedded in the road surface. Just a short time after the system was set up, the first ghost driver was filmed on video. The driver noticed the warnings and turned around.

At the Öresund Bridge connection between Sweden and Denmark, it is also possible to manage ghost drivers via the bridge’s traffic management and control system. For several years, there has been work in relation to the issue of motorists reversing or turning and driving against the flow of traffic. When the connection was opened, the fear of ghost drivers did not form part of the risk assessment that is always carried out as an active part of the safety work. Once ghost drivers were identified as a problem, initial efforts were made to improve the signage. At the same time, ongoing safety work focused on reducing the risk of this type of event occurring. In 2007, there were 68 incidents involving ghost drivers or cars reversing in the tunnel section of the connection.

In technical terms, the Öresund Bridge connection is equipped with a safety system that includes camera monitoring, dynamic signs, barrier systems and speed restrictions in the tunnel section. This system is monitored 24 hours a day by the traffic control centre that has the task of monitoring and preventing accidents as far as possible.

If a ghost driver is identified on the bridge or in the tunnel, the traffic centre at Lernacken near the Öresund Bridge can adopt several measures: speeds can be reduced, lanes closed and the police and, if necessary, emergency services can be notified. Broadcasts on Radio Malmöhus, DR P3 and DR P4 are interrupted and warnings go out to motorists.

*Sources: The Swedish Road Administration Region West, Öresund Bridge.*
5.9 Dynamic parking information

Motorists driving around looking for parking places may contribute towards a deterioration in road safety. The hunt for parking places may lead to traffic jams, queues and frustration as well as motorists not paying as much attention.

The percentage of traffic in cities that consists of vehicles looking for parking places in a limited city centre varies between 10 and 40 per cent.

Better information on different parking options leads to a simplification of the traffic situation for road-users looking for parking places. The effects are a reduction in vehicles searching for spaces, fewer queues at car parks and car parks being used more effectively. Fewer vehicles searching for spaces also leads to fewer emissions and has a positive effect on air quality.

Dynamic parking information systems are set up so that they can sense how many cars pass through the entrances and exits of car parks. This is done using detectors. Information on cars entering and exiting is then sent on to a central system for processing. From there, the information is sent to dynamic signs that display how many empty spaces are available, or whether the car park is full.

5.9.1 Application

The system is intended to show motorists where there are empty spaces in the city, but also to help them find the available spaces. The aim is to reduce the number of vehicles searching for spaces and make the traffic situation easier for road-users visiting the city centre. In addition, the system can be used to improve accessibility to the city centre and, in this way, increase the attractiveness of the city.

5.9.2 Effects

Dynamic parking information can lead to fewer drivers parking on kerbs, greater road safety and an improved environment. The system helps unfamiliar motorists feel more welcome to a new town or city. Another effect is that the system produces data that is of use in the local traffic planning process, through its ability to generate parking statistics.

5.9.3 Actors

At the decision-making stage, it is important to capture the views of all interested parties concerned with how a system should be implemented and designed. These interested parties may be car-park operators, politicians, road authorities, municipalities, owners of parking premises, local traders, and business and environmental interest groups.
5.9.4 Good advice for implementation

During implementation, a clear target scenario should be established with regard to what the system is intended to achieve. This target scenario should be based on experiences from the implementation of similar systems in other locations. When implementing a project, the actors responsible should monitor developments elsewhere in the world during the start-up phase, e.g. through study trips to other cities. In this way, an image and vision of how the system will be designed and what is to be achieved can be generated.

It is important to have a project organisation for implementation, where the representatives of all parties can monitor the project from conception to implementation and there they can have an influence over the implementation process.

Operation and maintenance should be planned and budgeted for at an early stage. In addition, the system should be constructed in a flexible manner so that it can be converted and expanded at a later stage. After a period of operation, it will be appropriate to evaluate and investigate the reliability of the system. Doing so will provide valuable feedback for operations managers. Dynamic parking information systems can also be developed in order to cover other media, such as the Internet, where information on the availability of spaces and suitable car parks can be distributed.

5.9.5 See also

- Park and Ride information

5.9.6 Good examples: Dynamic parking information

The parking management system, P-evenemang, in Sweden’s second largest city, Gothenburg, was commissioned in 2005. The system gives directions to major car parks for motorised visitors to events in central parts of the city. The aim is to reduce vehicles searching for spaces and achieve a better environment in the inner city. Motorists are informed of the event in the city even on approach roads via variable message signs. Once road-users have arrived in the city, they are met by dynamic parking signs with directions to suitable parking places. The signs show the number of free spaces and whether the car park is indoors or outdoors. The idea is to direct drivers to another car park if it is full. The aim is to reduce vehicles searching for spaces and achieve a better environment in the inner city. The system contributes to a better service for road-users and means that existing parking can be used more effectively.

Another purpose of the system is to increase the attractiveness of the city as a city for events, and provide event owners with the opportunity to profile and market the area and their events. The big events in Gothenburg should be an asset to the city and, at the same time, traffic in connection with these events should function as smoothly as possible. The municipality also issues traffic-related information about events on the website, Evenemangstrafiken.nu.

Interviews from the evaluation of the system demonstrate that event-arrangers and parking companies, as well as the Swedish Road Administration and Traffic Office in Gothenburg are satisfied with the system.
This is because the number of vehicles searching for parking spaces has been reduced, and because visitors are coming to the correct location and finding suitable parking within a particular area in the right time.

A survey among road-users shows that motorists coming to the city from some distance away for events are helped by parking information. Nine out of ten motorists think the signs are good. Those living in Gothenburg and the bordering municipalities believe that they save an average of 15 minutes thanks to the signs. For those living elsewhere in the region or further away, the corresponding figure is 19 minutes.

Source: Evaluation of P-evenemang, Swedish Road Administration, Region West and the Traffic Office Gothenburg, 2008.

### 5.10 Park and Ride information

Commuting by car has increased over the last few years and we now travel further and more frequently. This results in queues and an unfavourable impact on the environment. Measures aimed at making public transport and car-pooling easier could reduce these problems. Public transport can move people about with greater effectiveness in terms of space and energy. With Park and Ride information systems, the freedom of movement of the car can be combined with the cost effectiveness and environment friendliness of public transport.

Park and Ride information systems are not common in Sweden, but are used frequently abroad to provide, amongst other things, information about vacant parking spaces or the next train departure. Dynamic signs showing the number of vacant parking spaces can also be used to direct motorists between various nearby car-parks and for guidance within a large car park that is divided into sections.
5.10.1 Application

Park and Ride information systems make it possible for motorised road-users to park their vehicles and then continue their journey by bus or train. The motorist is informed of the current traffic situation and journey times by various transport modes via dynamic information on signs and is thereby given the opportunity to personally decide on the best alternative.

The amount of motor traffic is reduced, which can have a positive effect on the traffic situation, e.g. through a reduction in the demand for parking spaces in the city centre.

5.10.2 Effects

The experiences of Park and Ride systems in several British towns show that users appreciate the system. Studies show that approximately half of users exercise this option at least once a week.

A dynamic Park and Ride system in Fröttmaning, Munich reduced motor traffic on the road in question by 2 per cent, which meant 1,000 tonnes less carbon dioxide emissions per year. In addition, the users saved time. The journey is 30 per cent shorter than that for motorists during the rush hours.

A study of the effects of passenger information in the capital of Finland, Helsinki, estimates that the socio-economic benefit of road-users changing their mode of transport from cars to public transport will increase. It is estimated to reach 2,500 Euros per hour in 2025.

5.10.3 Actors

The introduction of Park and Ride and associated dynamic information systems is the responsibility of the road authority, usually the municipality, in cooperation with the head of the public transport organisation.

5.10.4 Good advice for implementation

A basic premise for Park and Ride is that there is a car park where motorists can park their cars when changing transport mode. The forms of public transport must also be separated from motor traffic so that they either have a separate lane or use an alternative route. Otherwise the public transport could end up with the same problems as the motor traffic. The best example of a successful implementation of Park and Ride is one where train traffic and motor traffic run parallel with each other (visual guidance); where there is a high service frequency during rush hours; and, where the train’s journey time is competitive in comparison with that of the car.

The location of information signs is important in order for the system to have an effect. Another measure that can stimulate the use of this type of service is if payment and the cost of parking are connected to the public transport ticket.

5.10.5 See also

- Dynamic parking information
5.10.6 Good examples: Park and Ride information

In connection with the building of the City Tunnel in Malmö in the South of Sweden, a new district is growing up at Hyllie in the southern part of the city. Housing, a shopping centre and places of work are being established between the town centre and the Öresund Bridge that connects Sweden and Denmark. A Park and Ride car park with room for more than 1 000 cars will be built (starting in 2009) and will be ready in 2011.

Due to its location at the newly established train station, motorists will be able to easily change their mode of transport when travelling on to Copenhagen and Kastrup airport, or the centre of Malmö.

Source: City of Malmö.

5.11 Real-time public transport travel information

Real-time travel information for public transport can be communicated via information display signs close to or at bus stops and train platforms. This information may consist of the current timetable, the expected time of arrival, delays, temporary changes or route-guidance.

A prerequisite for being able to communicate information about actual departure times is that there are technical systems keeping tabs on where the vehicles are, and how they are running. These systems must be able to perform forecasts for each respective vehicle that has an estimated departure-time from the stop; the system must also ensure that this information reaches travellers.

Better public transport information is one way to reinforce the competitiveness of public transport. As a result, it works together with other measures to contribute to an improved supply of public transport, which may, for example, involve rearranging routes or changes to the prices of tickets.

5.11.1 Application

Information is communicated to travellers via signage, monitors, dynamic signs or speakers at stops and within terminals. Information is provided on the next departure for various routes and on disruptions that have occurred. This allows the traveller to know what is happening, so that advice may be sought about alternative options. This information allows travellers to revise their journeys or to use the additional waiting time for something else.

Automatic announcements represent a measure that increases accessibility and the quality of travel on public transport for people with disabilities. This is in line with the policy guidelines that have been adopted by the Swedish Parliament for people with disabilities.
5.11.2 Effects

Travellers feel that traffic is functioning better if the information provided makes it possible to act in accordance with the current traffic situation. When waiting times are known, the passenger can carry out other activities. This makes the time spent waiting feel shorter. Studies indicate that travellers feel as if the waiting time is three times shorter when the estimated departure time is known in advance.

When major disruptions occur, travellers are informed of what has happened, what consequences this will have for their transport and when their transport is expected to function again. A more reliable system encourages more travellers to use public transport, and as a result it also contributes to a more sustainable form of travel.

5.11.3 Actors

Public transport stops are often situated on municipal land. For this reason, the municipality is an important actor when introducing a service. In addition, the heads of public transport and traffic companies should be involved in an implementation.

5.11.4 Good advice for implementation

It is important that passengers can rely on the information that is presented. Faith in the system is determined by the quality of the journey time information. It is also important that journey time data is worded in an instructional and clear manner. The passenger must be able to understand and recognise the information.

5.11.6 Good examples: Real-time public transport travel information

In the Gothenburg Region, Västrafik, who are the organisation responsible for public transport in the Västra Götaland region, has widely implemented dynamic information at stops and larger terminals. In Gothenburg, the information is communicated on signs and monitors via the ‘KomFram’ [Arrive] system. The target is for 650 stops, accounting for 90 per cent of all boarding, to have displays showing real time information by 2010.

This investment in expanding real time information has been particularly prioritised at major tram stops and along the routes of the mainline bus services. The equipment has been installed primarily at those stops that have more than 100 passengers boarding per day. This expansion will also include 200 stops where cost-effective battery-operated signs are to be installed. It is expected that these installations will be completed by 2010.

In a user survey carried out by Västrafik, nine out of ten passengers stated that they often or always looked at real-time displays. Nine out of ten also felt that the time-estimates were correct. In summary, passengers were satisfied with the information and did not feel a need for any further information.

Sources: Real time information for increased operational benefits, Traffic Report, 2009:1; Västrafik.
Managing traffic

How can traffic be managed through signal control?

What does the introduction of variable message signs actually involve?

What effect do traffic management measures have?
The “managing traffic” category has the following subheadings and ITS:

- **Traffic signal control**
  - Traffic signal control (independent, coordinated, adaptive)
  - Operation and maintenance of traffic signals
  - Public transport priority at traffic signals
- **Traffic control via variable message signs**
  - Variable speed limits (weather and traffic actuated)
  - Reversible lane control
  - Lane/motorway control
- **Traffic management – others**
  - Road user charging in urban areas

### 6.1 Traffic signal control
(independent, coordinated, adaptive)

*At the correct location, traffic signals are an effective means to improve road safety, accessibility and the effects on the environment. Despite the fact that many of the country’s more than two thousand traffic light controlled intersections are being rebuilt into roundabouts, traffic signals will continue to be used in the future.*

Traffic signal control may be either **independent** where each intersection’s signal system works completely in isolation of other systems, or **coordinated**, where the traffic signals are synchronised at several intersections. The aim is to reduce the total delay and number of stops in the area that is included in the coordinated system. Approximately 1,000 of Sweden’s traffic signal systems are part of a coordinated system. Coordination is mainly used in the urban environment. Coordinated signal systems can also be made **adaptive**, which means that the signals adapt to traffic in a more dynamic manner. This type of operation occurs in the three largest Swedish cities, Stockholm, Gothenburg and Malmö.

#### 6.1.1 Application

Traffic signals are introduced when the amount of traffic becomes so great that it cannot regulate itself in an efficient way. Signal control is particularly suitable at crossings where one approach has considerably more traffic than another. Points of conflict, where vehicular traffic makes it difficult for cyclists and pedestrians to cross the road, can also be controlled by signals. Signals are also used for the purpose of prioritising some vehicle categories, e.g. buses or emergency vehicles, or where it is necessary to control traffic in some other way.

Traffic signals are of great importance for pedestrians with disabilities and particularly for the safety and assurance of those with visual impairments.
Traffic lights also require a smaller area in terms of street space than roundabouts, for these reasons traffic lights are often a more frequently used form of control in the urban environment.

### 6.1.2 Effects

Independent traffic signals often work smoothly and effectively as they do not need to take account of the traffic situation at other crossings. By installing traffic signals at a suitable place, road safety is improved and can reduce the number of accidents by about 30 per cent at four-legged junctions. For three-legged junctions, the reduction in accidents attributable to traffic signals is about 15 per cent.¹

Coordinated signals, where a system of signals creates accessibility on a main road, can pose a major challenge to traffic engineers when it comes to designing for the needs of subordinate traffic flows. It is always important to have good supervision from traffic engineers as well as regular maintenance. Small improvements to the effectiveness of traffic signals provide major socio-economic gains through reductions in time, road safety and vehicle costs. Modern traffic signal control of the adaptive type in coordinated systems provides major financial savings for society in the form of shorter journey times, fewer queues, fewer stops and thereby fewer emissions and a reduction in the number of accidents. With improved coordination (e.g. with adaptive control), delays can be reduced by 10–20 per cent² or more, depending on the effectiveness of the existing coordination.

At crossings with a great deal of traffic, conflicts of interest may arise between groups of road-users. The implementation of traffic signals can then increase accessibility for certain groups of road-users, such as public transport or pedestrians. Traffic signals can also have a great impact on the local environment. The environmental impact of signals is related to the accessibility aspect; fewer stops at red lights lead to lower exhaust emissions.

### 6.1.3 Actors

Responsibility for implementation lies with the road authority, which in Sweden means the municipality in question or the Swedish Road Administration. In certain situations, coordination may be required, e.g. when an intersection controlled by signals affects both the municipality’s roads and those of the Swedish Road Administration.

### 6.1.4 Good advice for implementation

It is important to carry out a thorough acceptance inspection when commissioning traffic signals. This is particularly important as traffic signals are a safety device – i.e. the function of the signal system has a direct impact on road safety.

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¹ Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
² Memo – Traffic management and Accessibility, Movea, 2009
Operation and maintenance are very important in order for a positive effect to be achieved through the use of traffic signals (this will be dealt with in Section 6.2, Operation and maintenance of traffic signals).

### 6.1.5 See also

- Public transport priority at traffic signals
- Operation and maintenance of traffic signals

### 6.1.6 Good examples: Traffic signal control

Applying adaptive control to coordinated traffic signals can generate great socio-economic benefits. In brief, adaptive control is based on traffic signals adapting to the current traffic flow in a more dynamic fashion than is the case with traditional coordinated signals. This technology reduces queues and the number of vehicles that stop.

An example of this strategy can be found in the MATSIS project (Minskade CO$_2$-utsläpp genom Adaptiva TrafikSignalger I Stockholm [Reduced carbon dioxide emissions in Stockholm through adaptive traffic signals]). This project ran between 2004 and 2008. Improvements in six coordinated chains of signals were completed during this period. The measures have been most beneficial along Valhallavägen in the centre of Stockholm. Here it has been possible to save 850 tonnes of carbon dioxide per year, according to calculations. Great quantities of heavy vehicle traffic from the harbours no longer need to wait for lengthy periods of time at red lights, as was previously the case on central roads.

Overall, the computer simulations that have been carried out in the project show that it has been possible to reduce emissions by 2,900 tonnes of carbon dioxide per year, equivalent to 7 per cent, thanks to improved signal control. In addition, delays at the signals are reduced by 19 per cent. The total socio-economic benefit is estimated to be around 118 million SEK per year.

6.2 Operation and maintenance of traffic signals

When managing traffic signal systems, sufficient resources must be set aside for operation and maintenance. For financial reasons, there must always be an incentive for streamlining and rationalising operation and maintenance. The positive effects of traffic signals are dependent on sufficient attention being paid to these matters.

Continual operational measures and systematic maintenance are important. A lack of maintenance will lead to delays, greater vehicle costs, increases in the number of accidents, and increased exhaust emissions. Small yet inexpensive investments may lead to major socio-economic gains. This applies to both independent and coordinated traffic signals. Normally, the payback time for operational and maintenance measures for traffic signals is short (often less than a year – and sometimes days).[^3]

6.2.1 Application

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

**Preventive maintenance** includes fixing posts and signal housings with defects, cleaning lenses, adjusting acoustic signals, ensuring that detectors and buttons are functioning, fixing detector loops that are not well protected, etc. In Sweden, it is recommended that the majority of maintenance work is performed in accordance with the Operation and Maintenance Manual for Traffic Signals, published by the Swedish Road Administration.

**Correctional operational measures** include fixing broken detectors, posts that have been driven into, electronics failures and cable faults.

**Traffic engineering inspections** mean checking that the programming and functionality of the signalling equipment is gradually adapted so that it functions effectively and safely, even if external circumstances change. The circumstances that can change over time are traffic volumes, other traffic control measures, legislation, and the technical conditions for signal control.

6.2.2 Effects

Preventive and corrective maintenance is particularly important for accessibility, for example, for those with disabilities that depend on the buttons and lights working properly. It is also important for road safety. If a traffic signal flashes amber during periods of low traffic, it is estimated that the number of personal injuries will increase by about 50 per cent.[^4]

Systems that function well are important for business journeys and transportation in order to reduce queues and thereby also costs.

[^3]: Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
[^4]: Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
When it comes to the effects of improving signal control in socio-economic terms, the accessibility aspect is a dominating factor. The time and vehicle costs caused by delays in a normal Swedish coordinated traffic signal system are approximately 4 million SEK per year. In addition to this, the reduced costs of traffic accidents and environmental impact must also be considered. Together, these are approximately half as much.

Small, inexpensive investments provide major socio-economic gains. Normally, the payback period for operational maintenance measures for traffic signals is a short one, often less than a year. Based on studies of a number of intersections in Stockholm, fixing a broken detector can pay for itself in a day, (gain 2.5 million SEK per year, cost 7,000 SEK). Although many intersections are small, this measure is extremely profitable.

Changing a daily time setting at a crossing can have a repayment period of about one month (gain 0.5–1 SEK million per year, cost 50,000 SEK). This is based on a reduction of 10–20 per cent in delays.

As traffic conditions are continually changing, it is expected that the traffic signal system's programming will lose 1–5 per cent of its effectiveness each year. This means that even relatively frequent traffic engineering maintenance is profitable.

6.2.3 Actors

In Sweden, responsibility for implementation lies with the road authority, i.e. the municipality in question or the Swedish Road Administration.

6.2.4 Good advice for implementation

The operation and maintenance of traffic signals are often neglected and should be given more attention, given the socio-economic profitability associated with these measures.5

6.2.5 See also

- Traffic signal control
- Public transport priority at traffic signals

6.2.6 Good examples: Operation and maintenance of traffic signals

A new report provides examples of the great costs incurred by society as a result of badly maintained signals. The report estimates that about 1,000 of the country’s traffic signal systems have faulty detectors, which are costing 2.3 billion SEK per year in the form of delays in journey times, fuel and emissions.6

In contrast, Helsingborg is a city that regularly maintains its traffic signals throughout the city by regularly carrying out traffic engineering inspections. The signals are inspected and the programming is fine-tuned so that traffic flows improve. Part of this work also involves taking

5  Sweden needs better traffic signals, Swedish Road Administration, 2000:28
6  Better signal functions in the event of faulty detectors and buttons, Swedish Road Administration 2008:19
into account accident statistics for crossings with a view to improving road safety. Helsingborg could, therefore, be said to serve as a model with regard to traffic engineering maintenance.

Sources: The Swedish Road Administration, City of Helsingborg.

6.3 Public transport priority at traffic signals

It is very important that public transport functions efficiently in and outside urban areas. In order to avoid having more vehicles than the traffic system can cope with driving into town centres, it is essential that the public transport system encourages people to leave their car and take public transport instead. This can be achieved by making it easier for public transport to arrive at its destination on time. One way to improve accessibility for public transport is to give them priority at traffic signals.

Public transport is supported by real time systems with bus computers, radio communication, passenger information and traffic management. If these systems exist in a public transport fleet, there will often be good conditions for introducing prioritisation at a reasonable cost.

The actual bus prioritisation element of the public transport system is small, but is demanding with regard to speed, precision and reliability in the detection and radio communications systems.
6.3.1 Application

The attractiveness of public transport depends on, amongst other things, regularity, adherence to time tables and journey times. By prioritising public transport at intersections regulated by signals, the effectiveness and thereby also the attractiveness of public transport can be increased. Traditionally, the waiting time for buses at traffic signals is not negligible – buses have to queue at signals in the same way as other vehicles. But with traffic signal techniques, it is possible to influence the accessibility of public transport at both independent and coordinated signal controlled intersections.

Where it is not possible to restructure the road environment to favour public transport, e.g. with streets for buses only, prioritising public transport may be a suitable measure. A signal with a bus-prioritisation function may also resolve accessibility problems at crossings where the bus is coming from a side street and the main street is subject to heavy traffic.

Using the same equipment as that used in public transport vehicles, it is also possible to prioritise other categories of vehicles such as emergency vehicles or utility vehicles. This is being introduced, or is in the process of being introduced, in several areas in Sweden.

6.3.2 Effects

The main effect of prioritising public transport is that buses and trams arrive quicker and the number of stops is reduced. The distribution of journey times is also reduced, which leads to an improvement in regularity. Bus traffic is favoured ahead of motor traffic. As a bus has an average of 10–20 people onboard, while a car often has only one person, this form of travel is positive from several aspects.7

European evaluations show journey time gains of 5–15 per cent for bus traffic that is prioritised at traffic signals. In the best cases, a 40 per cent shorter delay for buses at traffic signals can be achieved. With frequent prioritisation, accessibility for cars may be affected negatively. There may also be a negative impact on accessibility for unprotected road-users, unless they are taken into consideration when planning the system.

The prioritisation of public transport vehicles can also be used to maintain a similar level of service with fewer vehicles, thanks to increased efficiency in connection with keeping vehicles moving to a greater extent.

6.3.3 Actors

The bodies concerned with this type of ITS functionality are those responsible for the upkeep or roads, heads of public transport and public transport contractors.

7 Let the buses through – How to effectively prioritise public transport at traffic signals. Swedish Road Administration, 2005:87
6.3.4 Good advice for implementation

Experience shows that it can be difficult to maintain the functionality of a prioritised traffic signal system. This is due to the complexity of the system due to the interplay between different detection systems, vehicle computers, roadside units and traffic signals. This complexity means that special demands are made with regard to monitoring, operation and trouble-shooting. As early as during the planning stage for system implementation, procedures should be set up by the responsible road authorities, heads of public transport and operational contractors. The organisations and staff involved must be motivated and the boundaries must be defined so that everyone knows who is responsible for each area.

Special focus should also be given to fine-tuning the system with regard to matters concerning radio coverage, waiting times and queues for other traffic, and adapting detector distances.8

6.3.5 See also

- Traffic signal control
- Public transport priority at traffic signals

6.3.6 Good examples: Prioritisation of public transport

Linköping is an example of a medium-sized Swedish town with well-functioning bus prioritisation. Buses are given priority over other traffic at 70 traffic signals. At the present time, city buses are prioritised, but this is being extended in order to cover certain regional bus lines. To ensure the quality of the system, the municipality has a regular schedule for checking that the roadside equipment is functioning correctly.9

Jönköping, another medium-sized Swedish town, introduced bus prioritisation in 1996. This system has been extended over time. In the town centre, buses are prioritised at 13 signals. They also have methods for ensuring that the system is functioning and that operational problems can be resolved. Complaints about faults that are received by the municipality go directly to the operational contractor’s emergency centre. The county traffic authority, municipality, and bus operators, also have joint progress meetings where operational issues can be raised.

In the city of Stockholm, a hundred or so buses are prioritised at a hundred different signalled intersections. The current system was introduced in 1998. Experience with the system has been good, which is why a major expansion of the system has been investigated in Greater Stockholm. A special peculiarity in Stockholm is that buses arriving too early in relation to the timetable are not prioritised. In this way, regularity and punctuality are improved. The risk of several buses “getting stuck together” and arriving in a convoy is thus reduced.


8 Better Bus Prioritisation, Swedish Road Administration, 2009
9 Better Bus Prioritisation, Swedish Road Administration, 2009
6.4 Variable speed limits

During the period, 2003–2008 the Swedish Road Administration carried out trials involving variable speed limits. Variable speed limits temporarily reduce the posted speed limit by means of variable road signs in the event of poor or risky weather conditions.

Variable speed limits generally provide a significantly better adaptation of speeds to the prevailing traffic situation than traditional speed signs. The effects are reinforced over time and the majority of road-users are very satisfied. The risk of accidents is reduced and the driving tempo becomes calmer. Accessibility is also improved slightly. The environmental impact is, however, very slight.

The first section of road with a variable speed limit was put into service (in Kyrkheddinge in southern Sweden) in October 2003. Since the Spring of 2008, all trial sections (a total of 20) have been in normal operation on the road network. In the Autumn of 2008, the section of the E18 in Västmanland in central Sweden was taken out of service when the motorway was opened. The speed messages displayed on the road signs are thereafter adapted on the basis of experience gained from the field trials.
The Swedish Road Administration feels that variable speed limits could be a suitable measure at about a hundred Swedish rural intersections in the period up to 2020.\(^{10}\)

### 6.4.1 Application

Trials with variable speed limits have been carried out at 20 locations in Sweden. Variable message signs, showing the maximum permitted speed, have been installed at these places. The speed limit is changed on the road signs when there is, for example, a risk that the road is slippery or that queues are forming, or where there are crossing vehicles or unprotected road-users on the road.

Speed limits may vary between 30 and 120 km/h. However, on individual sections, the variation is a maximum of 60 km/h. As a general rule, the “bright principle” is applied. This means that the road sign is only activated when weather conditions are worse than normal. If a road sign is not switched on, the speed limit sign immediately prior to the sign will apply.

The three application areas for variable speed limits are:

- Intersections with crossing and turning traffic
- Weather actuated roads with varying weather and/or road conditions, e.g. roads with side winds.
- Traffic actuated roads with varying traffic intensity – such as flows, speeds and queues, and also roads with pedestrians walking alongside or crossing.

### 6.4.2 Effects

According to Swedish evaluations, intersections can show speed reductions of up to 10 km/h and a reduced risk of accidents where this measure is applied. Where road conditions are difficult, the average speed can be reduced by 12–20 km/h, and compliance with the speed limit is improved.

In the event of difficult traffic situations and congestion, adjustment to lower speeds is handled in a more controlled fashion and the risk of sudden braking and rear-end collisions is reduced. At pedestrian actuated systems, variable speed limits lead to some reduction in the average speed.\(^{11}\)

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.

### 6.4.3 Actors

In Sweden, it is the road authorities – the Swedish Road Administration and/or a municipality – that is responsible for the implementation of variable speed limits. As variable speed limits have only been implemented in a trial at the present time, the Swedish Road Administration should be contacted for permission to apply this measure. It is important to establish

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\(^{10}\) Variable speed limits – a bright idea, Swedish Road Administration, 89193, 2008

\(^{11}\) Variable speed limits – a bright idea, Swedish Road Administration, 2008:77
a good partnership with the police as they have responsibility for monitoring speed compliance. In many cases, different interested parties may work towards, and bring pressure to bear on, a municipality or the Swedish Road Administration in order to introduce variable speed limits at schools, etc.

6.4.4 Good advice for implementation

The use of variable message signs is determined by the Swedish Traffic Sign Regulations and VGU ‘Vägar och Gators Utformning’ [the Design of Roads and Streets].

It is important to bear in mind that variable message signs require regular maintenance in order to function effectively. Administrative responsibility, and the costs of operation and maintenance, should be included at the planning stage.

6.4.5 See also

- Lane/motorway control
- Tunnel monitoring and control
- Traffic information via variable message signs

6.4.6 Good examples: Variable speed limits

On the E6 motorway between Skottorp and Heberg in Halland in the south-western part of Sweden, a trial variable speed system was commissioned for weather-actuated roads. This section is 55 km long and consists of eight subsections where the speed limit can be changed manually. There are a total of 38 variable speed signs along this section. The system is semi-automatic and is controlled from the Swedish Road Administration’s traffic management centre in Gothenburg. There, operators can make decisions to vary speed limits from between 60 and 120 km/h. To assist them, they have weather stations measuring temperatures, humidity, wind speeds and wind direction. The measurement values are processed in a weather model that alerts the Traffic Management Centre operators when threshold values are reached.

Traffic measurements since the introduction of the system show that speed adaptation has become significantly better. This applies particularly to private cars where there are low speed limits. A study by the Swedish Road Administration shows that the speeds are now 15–20 km/h lower in bad weather compared to a similar situation with traditional signage. In very severe road conditions (snow, ice and black ice), the speed limits on the signs are reduced to 80 km/h. This results in a calmer traffic rhythm. Calculations suggest that this measure has led to 40 per cent fewer deaths and serious injuries compared to the period before variable speed limits were introduced.

A survey of attitudes among motorists shows that the majority of road-users think that the system is good. The most common comment is that they feel that the traffic rhythm has become better. In addition, the majority of those asked stated that they felt the displayed speed was generally correspondent with the prevailing weather and road conditions. Once the trial had ended, the installation was made permanent in 2008.

Source: Variable speed limits – A bright idea, Swedish Road Administration, 2008:77
6.5 Reversible lane control

In many cases, problems arise when levels of traffic increase but the capacity of the road is limited and there is little or no possibility to build additional lanes. When this situation occurs, the road authority tries to find effective ways to improve accessibility.

Reversible lane control may be one solution that aims to improve accessibility. In city areas in particular, with major flows of traffic heading towards the city during morning hours and major flows of traffic leaving the city during the afternoon, reversible lane control may be an effective solution. Reversible lane control is almost always considered when there is a high level of traffic variation in different directions, usually in the morning and afternoon.

6.5.1 Application

A similar type of lane control is used for traffic control on 2+1 roads. The road has one lane per direction plus a lane that is alternately used by either direction of travel. When the direction of travel is changed on reversible lanes via variable message signs, safety increases for road-users and the road space is used more effectively.

6.5.2 Effects

Today, there is only one section of road in Sweden that has a reversible lane; this is in Värmdö outside Stockholm. The reversible road section is 1.5 km long. An evaluation study carried out on this road established a satisfactory level of functionality. The critical points have been the pedestrian crossings.
with traffic islands, where vehicles have managed to get on the wrong side of the road. Extensive road-user surveys have been carried out and speeds have been measured, both before and after implementation. Road-users affected by the reversible lane have been positive to its introduction; the exception being cyclists who have found things more difficult due to less space and fewer options for crossing the road. Accessibility has, however, greatly improved for motorists, although this has also led to higher vehicle speeds. There are now many people driving over and above the permitted 50 km/h speed limit.\textsuperscript{12}

6.5.3 Actors

It is the road authority that is responsible for the implementation of traffic control based on variable message signs. It is also advisable to consult the municipality, police and local interested parties.

6.5.4 Good advice for implementation

It is very important to think about how pedestrian and cycle traffic will be dealt with when introducing reversible lane control. Experience from the Värmdö implementation shows that there is a risk that accessibility will be reduced. It is also important to get all parties involved, i.e. private individuals, companies and organisations from the beginning of the project. This involves extensive work to provide suitable information.

The functionality of such a system should be controlled automatically as manual control entails great safety risks for road-personnel.


It is important to bear in mind that variable message signs require regular maintenance in order to function effectively. Administrative responsibility and the costs of operation and maintenance should be included at the planning stage.

6.5.5 See also

- Lane/motorway control
- Tunnel monitoring and control
- Traffic information via variable message signs

6.5.6 Good examples: Reversible lane control

Road 222 between Mölnvik and Ålstäket in Värmdö outside Stockholm has had major accessibility problems, particularly during the summer when traffic increases from 18,000 to 28,000 vehicles a day.

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

\textsuperscript{12} Evaluation of reversible lane control on Road 222 between Mölnvik and Ålstäket, Swedish Road Administration; 2006:134
As a solution to the acute traffic problem, the road was widened in 2006 and redesigned with three narrow lanes including a reversible lane in the middle.

In the morning when westbound traffic towards Stockholm is at its peak, the middle lane is used for traffic heading in to the city. In the afternoon when most traffic is heading away from town, the middle lane is allocated to the eastbound direction.

After starting out as a manual system, the reversible-lane control was made automatic in autumn 2008. This was achieved using mechanical barriers, variable signs and the ability to control and monitor the system remotely so that the driving direction in the middle lane can be controlled by the Traffic Management Centre – Trafik Stockholm.

Overall, the measure has had a favourable effect on accessibility. The queues that previously developed have disappeared and public transport has benefited. Only one in ten of those interviewed are now critical with regard to accessibility. In addition, the solution is cost-effective at a price of only 20 million SEK. Building a four-lane road would have cost 140 million SEK.

Source: Evaluation of a reversible lane on Road 222 between Malmö and Ålstäket, Swedish Road Administration; 2006:134.

6.6 Lane/motorway control

Lane control systems have been introduced on multi-lane roads around the world in order to increase the effectiveness, reliability, and safety of the road network as well as reducing its environmental impact. Using this system, one or more lanes can be closed on a section of road in the event of accidents and road-works. Speed control with recommended or prescribed speeds is often combined with lane control. This is referred to as an MCS (Motorway Control System).

At the present time, there are installations in Sweden’s two largest cities, Stockholm and Gothenburg.

The system is based on the speed and flow of vehicles. These variables are measured and recorded by roadway detectors. Detectors transfer measurement values to other equipment alongside the road. The data is then sent for further processing and analysis. Speeds are then regulated via lane signals that show recommended speeds in situations when speeds further downstream have fallen below certain predetermined thresholds, e.g. due to queues during periods of heavy traffic, or accidents or other obstacles on the road.

6.6.1 Application

Lane control is introduced in order to adapt the speed of traffic to the prevailing traffic conditions and to make it possible to close lanes without...
personnel needing to go out into the road. Lane signals are used to regulate the behaviour of road-users.

Together with speed control, lane control can provide road-users with information about prescribed speed limits, or recommendations regarding maximum speeds and lane restrictions. The aim is to maximise throughput on the road, avoid queues and maintain free-flowing traffic. Regulated lane control can be supplemented with variable message signs for warnings and information, e.g. queue-warnings and diversions using free-text information signs.

### 6.6.2 Effects

Lane control systems are widely used in European metropolitan areas. On the continent, journey time savings and increases in capacity are often around 5 to 10 per cent following the introduction of an MCS. No such effect has, however, been verified in Sweden.13

The authorities in different countries estimate that the introduction of such a system provides: a 25 per cent reduction in accidents; improved accessibility through more effective and quicker lane closures when closures are planned; and, reduced delays in connection with incidents.14

### 6.6.3 Actors

The roads that are suitable for motorway control systems are primarily major motorway routes and by-passes. The Swedish Road Administration is the organisation responsible for such systems. One reason for this is that MCS are one among the most expensive forms of ITS. Other important actors are the municipalities, and the police and rescue services.

### 6.6.4 Good advice for implementation

It has been shown that the meaning of the lane signals can be unclear to many road-users. When a new motorway control system is introduced, it is therefore important that well-planned information campaigns are executed in order to reduce the risk of the roadside information being misunderstood or ignored. Lane signals as a form of regulation are designed in Sweden in accordance with VGU for variable message signs.

### 6.6.5 See also

- Tunnel monitoring and control

### 6.6.6 Good examples: Lane/motorway control

The lane control system (MCS) on the E4 in Stockholm was introduced in 1996 and extended in 2004. An important function of this system is automatic incident detection, which helps to increase road safety and accessibility on this congested traffic route.

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14 Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
Speeds and traffic volumes are measured using detectors mounted over each lane. When incidents occur on the roads, new recommended speeds are automatically generated. These are displayed to approaching traffic on dynamic speed signs on gantries. The gantries are placed at intervals of 300 to 500 metres.

An evaluation has shown that an MCS can have a considerable positive effect on road safety. It contributes to reducing the distribution of speeds and calming traffic. As a result, overtaking accidents have almost disappeared. Furthermore, the number of accidents when changing lanes has been reduced by 50 per cent, the number of rear-end collisions has been reduced by 27 per cent, and the number of single-vehicle accidents has been reduced by 42 per cent since the system was installed.

Source: Evaluation of impacts of the motorway control system (MCS) in Stockholm, Nissan, Institute of Infrastructure, Traffic and Logistics Department, the Royal Institute of Technology, 2007.

6.7 Road-user charging in urban areas

Road-user charging in urban areas can be used to control traffic in a desired manner (to reduce congestion on the roads or to direct traffic away from sensitive environments). It is also used to generate funds that can finance other initiatives. Road-user charging is a tool that can be used in different ways, depending on the purpose of the system.

Under current legislation, road-user charging can only be levied on newly-built roads and bridges. Other forms of road charges are to be considered taxes and, as municipalities are only allowed to tax their own citizens, they must be levied as a state tax. During the Stockholm trial between 2005–2006,
congestion tax was managed by the Swedish Road Administration. The SRA were also responsible for the procurement and operation of the system. Once the trial was completed, the congestion tax system was made permanent in Stockholm, following a decision by the Swedish Parliament in 2007.

6.7.1 Application

Road user charging can help utilise road capacity more effectively and increase accessibility. The constant growth of traffic in towns leads to greater demands on streets and roads. The pressure becomes increasingly intense unless new roads are built. During rush hour traffic, major traffic routes reach their capacity limit, with queues as a result. The road transport system can be made more efficient through road-user charging by stimulating the use of public transport and car-pooling.

Other important effects are those related to reducing noise and, the emissions of greenhouse gases, carbon monoxides, and particles in urban areas that cause a great deal of negative environmental impact. Road-user charging can also be used, as it is in Norway, to generate income that can be used to finance e.g. infrastructure development.

6.7.2 Effects

Socio-economic benefits arise as a result of traffic being redistributed from congested roads at certain times, to other locations and other times. There is also some shift in peoples choice of transport mode. This is achieved by pricing road capacity in a manner that is fairer from a socio-economic perspective.

During the Stockholm trial, accessibility was improved and journey times were reduced significantly in and around the inner city. Particularly large reductions were found on larger approach 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; a road that was already susceptible to disruption. 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 great environmental impact. A reduction in transport mileage leads to reduced emissions and improved air quality in the cities where this measure has been implemented. The impact on health from the roads is thereby also improved. 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, noise and vibrations 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 is a large number of inhabitants, the reduction in particles in particular 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.\(^{15}\)

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\(^{15}\) Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
6.7.3 Actors

At the present time in Sweden, this type of measure can only be implemented by the Swedish Road Administration or another Government agency, even if this should take place in cooperation with local authorities such as municipalities or county/regional representatives. 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 imposition of the congestion tax in Stockholm involves a number of Swedish authorities and departments. The Swedish Road Administration continuously reports to the Ministry of Finance and the Ministry of Enterprise, Energy and Communications. The Swedish Tax Agency and County Administrative Court are responsible for reviews and appeals. The Swedish Enforcement Authority deals with the collection of congestion tax. The Swedish Road Administration’s Traffic Registry (‘Trafikregistret’) is also an important part of the organisation.

6.7.4 Good advice for implementation

Road user charging in urban areas is a very sensitive issue politically. Many systems that have been planned for the collection of charges (not just in Sweden) have come to a standstill due to problems relating to political acceptance and the influences of negative public opinion. For this reason, it is important that the introduction of such systems are supported locally by politicians and residents. The purpose of the road charges should be made clear, as well as the effects they are likely to bring about. The system must be designed in such a way that it is easy to use, and road-users must feel that they have something to gain from the system, e.g. in the form of reduced journey times.

From a socio-economic point of view, road-user charging can only be justified at those locations and times where and when there is congestion. This means that the measure is primarily relevant in cities during rush-hours. The introduction of congestion taxes in Stockholm and London demonstrate that such systems are likely to have a positive impact in similar environments with similar problems. How great this impact is will depend on how the tax is formulated and the availability of other travel alternatives.

6.7.6 Good examples: Road-user charging in urban areas

With a view to reducing congestion and improving the environment, the so-called ‘Stockholm trial’ with congestion tax was implemented together with increased public transport services and more parking spaces on major approach roads to Stockholm. Three main actors were involved, the City of Stockholm, AB Storstockholms Lokaltrafik (SL) and the Swedish Road Administration. The Stockholm trial began on 22 August 2005 with the aim of expanding public transport, and ended on 31 July 2006. The solution was then made permanent as the result of a decision by the Swedish Parliament.
The main aims of the Stockholm trial were to reduce traffic to and from the inner city by 10–15 per cent during the rush hours, and to increase overall accessibility for Stockholm traffic. It was also intended to reduce emissions of carbon dioxide, nitric oxides and particles. It was also hoped that residents would feel that the urban environment had improved.

The reduction in the flow of traffic was greater than expected and remained stable during the entire period, taking into account seasonal variations. Compared with the same period the year before, traffic on weekdays between 06.30 and 18.30 decreased by approximately 22 per cent; and, over the 24-hour period, vehicle journeys in and out of the inner city decreased by 19 per cent – equivalent to 100,000 journeys where 80,000 of these are made by private vehicles. These reductions have remained at roughly the same level since the trial was made permanent.

During the trial period, 40,000 more travellers used local public transport on an ordinary weekday, compared to the previous year. This represents an increase of 6 per cent. It is estimated that 4 per cent of this increase is a direct result of the Stockholm trial.

On the approaches to and from the inner city, the increase was more than 20,000 travellers over a 24-hour weekday period. This is equivalent to more than 45,000 journeys in, out, or through the inner city. Travel on the Stockholm underground system increased most, with 25,000 journeys per 24-hour weekday period, followed by bus transport, which increased by 16,000 journeys.

What systems can be used to monitor traffic?

What effect does automatic speed monitoring have?

What have our experiences of tunnel monitoring systems been?
The following ITS come under the main heading of monitoring traffic:

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

The latter two cover both monitoring and control, but the main purpose is regarded as monitoring and therefore they appear under this heading.

### 7.1 Automatic speed monitoring

*Deaths and personal injuries through road traffic accidents are a major public health problem. The Swedish Government’s long-term goal, expressed through Zero Vision in 1997, is that no one should be killed or seriously injured on the roads. Studies show that speed is a major contributory factor with regard to severity of road traffic accident outcomes.*

Unfortunately a significant proportion of Swedish road-users do not respect the posted speed limits. An automatic speed monitoring system provides a means of identifying vehicles that exceed the speed limit. The principle goal is not to generate revenue but to reduce the number of speed infringements in a cost-effective manner. Monitoring speed leads to both lower average speed and a reduction in the variation of vehicle speeds, which in turn leads to fewer deaths and injuries.

Speed cameras use radar to monitor the speed of approaching vehicles. If a passing vehicle exceeds the speed limit, the radar system triggers a camera which automatically takes a picture of the offending vehicle’s registration plate and the driver. The owner of the vehicle is identified through the Swedish Vehicle Licensing Agency and a fine is issued. Any passengers in the vehicle are removed from the photographic evidence.
7.1.1 Application

Automatic speed monitoring may be used to supplement police speed checks on roads that have known accident black spots or have high average speeds. Cameras have typically been mounted in fixed roadside cabinets or in special Police trailers.

At the end of 2008 there were 980 traffic cameras located along 2,630 km of roadway in Sweden. The cameras are connected directly to the police who are responsible for control and monitoring.1 Operating 24-hours a day and 365 days a year, it is estimated that the cameras save 15–20 lives annually.

During 2009, approximately 100 new road safety cameras will be introduced along 250 km of dangerous roadway.

Mobile road safety cameras are used to complement the existing fixed road safety cameras. These can be placed, for example, at road-works or outside schools.

The technology used in the road safety cameras can also be used to measure traffic flows and record the time and speed of passing vehicles. This information is used as supporting material in other road safety projects.

7.1.2 Effects

The road safety cameras that have been in use in Sweden have so far shown good results. The average speed on sections of road covered by cameras has been reduced by approximately 5 per cent and the number of speeding infringements has decreased by 20–30 per cent. Measurements carried out by the Swedish National Road and Transport Research Institute show that the number of fatalities on roads with cameras has been reduced by approximately 30 per cent and also that the number of those seriously injured has decreased by 20 per cent.2

There are also environmental reasons for monitoring road speeds. Road safety cameras contribute to a reduction in speeds which in turn lead to a reduction in carbon dioxide emissions, thereby benefitting the environment. Thanks to road safety cameras, it is estimated that the emissions of carbon dioxide can be reduced by as much as 20,000 tonnes annually.

7.1.3 Actors

The Swedish Road Administration and the Police share responsibility for managing the road safety camera system. The Road Administration is responsible for setting up, operating and maintaining the fixed cameras and for transferring data to the Police. The Police are responsible for deploying mobile road safety cameras. In addition the Police are responsible for deciding which cameras are active and for the prosecution of speeding offences recorded by the cameras.

A key part of the partnership is to make effective use of the camera network. To achieve this, the two organisations cooperate closely through a joint council.

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1 Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
2 Facts about road safety cameras; Swedish Road Administration; 89223, 2008
7.1.4 Good advice for implementation

Decisions regarding the introduction of Automatic Traffic Control (ATC) should be based on local conditions including: the incidence of speeding, traffic intensity and the frequency of accidents on the section of road in question.

7.1.6 Good examples: Automatic speed monitoring

In 2006, automatic speed monitoring cameras were installed on Road 50 in Bergslagen in Central Sweden (Road 50E, county boundary – Åsbro). This was the first section of road to have the new generation of road safety cameras. Ten units were installed over a 40 km section of road.

In order to evaluate the effects of the new cameras, studies were carried out before and after installation. The results were very positive and showed that average speeds on the section had been reduced by about 8 per cent. More significantly the proportion of vehicles exceeding the speed limit was reduced by approximately 40 per cent. Even the distribution of speeds (lowest to highest), was reduced.

Additionally these positive effects proved to be permanent over time. From May to November 2006, the reduction in speeds remained stable.


7.2 Monitoring and control of hazardous goods transport

There are relatively few accidents involving hazardous goods on the roads. Nevertheless any accident involving hazardous goods can potentially have serious consequences. However with the application of ITS systems such consequences, along with the risk of accidents occurring in the first place, can be mitigated.

The volume of hazardous goods on the Swedish road network is constantly increasing. That in combination with an ever more complex road traffic system has increased the need for monitoring, checking and controlling the transport of hazardous goods. Systems that enable the remote monitoring and control of hazardous goods transport can increase safety without limiting accessibility and thereby reduce the need for unnecessary paperwork.

The transport of hazardous goods represents a potential danger not only to users of the road network but even to people living in the vicinity of routes frequently used for hazardous goods transport. Systems must therefore be designed to protect third parties not actually on the road network.

A system for controlling the transport of hazardous goods should mitigate risk by providing transport operators with instructions about when and where goods may be safely transported.
Vehicles can be directed with different degrees of complexity, using everything from signs and manual monitoring to more automated systems. This may involve a local system operating independently (for example in a tunnel) or a central system (at a road traffic management centre) making decisions in real-time about what vehicles are allowed to travel on a given section of road.

### 7.2.1 Application

By combining different types of systems, emergency service centres and the emergency services can obtain real-time information about the position and type of hazardous goods on the road network. This information is invaluable in the event of an accident or incident, allowing the emergency services to arrive at the scene with the right equipment to tackle the situation at hand. The risk of terrorism has also raised the level of interest in monitoring hazardous goods and their whereabouts.

Work is currently ongoing to produce a web-based service that can provide information to a multitude of organisations (road authorities, emergency services and Police), to improve cooperation and coordination. This is done in an effort to reduce the consequences of an accident or incident involving hazardous goods.

### 7.2.2 Effects

These types of ITS measures can reduce the risk of accidents occurring and mitigate the consequences of accidents if they do occur. This applies both to society as whole as well as in specific environmentally sensitive areas.
Monitoring hazardous goods through ITS may also improve emergency service response times and their ability to deal more effectively with incidents involving hazardous goods.

The vast majority of incidents related to hazardous goods transport involve single vehicles. ITS systems can be used to specifically warn drivers transporting hazardous goods about prevailing road conditions or other potential dangers. Such systems can thereby contribute towards increased road safety for hazardous goods drivers and other road users.

7.2.3 Actors

Transport operators and the road authorities (both local and national) are responsible for the implementation of ITS systems related to the transport of hazardous goods. SOS Alarm has a key role to play in communicating information to the Police and emergency services. It is also vital that all the above mentioned bodies are involved in the design and implementation of services.

7.2.4 Good advice for implementation

Hazardous goods monitoring systems can usefully be regarded as additional functions to existing IT-based services already in use in the vehicle goods transport industry. This reduces some of the barriers for introducing such systems and makes them easier to “sell” to cost-conscious transport operators.

The control of hazardous goods is affected by the ADR provisions; i.e. European regulations that stipulate how hazardous good are to be classed, handled and transported. These regulations are in turn based on recommendations from the UN. ADR allows for the use of electronic data processing or the exchange of electronic data, either as a supplement to, or instead of, paper documentation.

The content of the ADR provisions is extensive and it would therefore be beneficial to simplify information management in conjunction with the implementation of a hazardous goods management system.

7.2.5 See also

- Tunnel monitoring and control
- Lane/motorway control

7.2.6 Good examples: Monitoring and control of hazardous goods transport

The development project, “Mobile IT for goods on the road” was started in 2007 by the Blekinge Institute of Technology, in cooperation with Sweco.

One of the aims of this project is to study how authority-related applications can be integrated with telematics applications connected to

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3 Effects Of Different Road Measurements, Cause and Effect 2008, Swedish Road Administration
4 European Agreement Concerning the International Carriage of Dangerous Goods by Road
heavy goods transport. Important areas covered by the project are safe transport with a focus on hazardous goods and demonstrating how mobile IT can streamline vehicle transportation of this type.

The needs of freight transportation on the roads will be reviewed and proposed solutions for achieving effectiveness, environmental targets and safe transport will be suggested.

Other projects, literature and interviews will form the basis for the development of concepts and analyses. The project will then develop a model in order to illustrate and validate a proposed concept. A prototype will be demonstrated at the World Congress on Intelligent Transport Systems – 2009.

There is an interest in monitoring hazardous goods at the Swedish Civil Contingencies Agency, Trafiken.nu in Stockholm and Gothenburg as well as the Swedish Road Administration. Through better control of the transport of hazardous goods, accidents can be prevented and any consequential damage can be limited.

The National Rescue Services Agency believes that telematics services are one of the few cost-effective ways of controlling hazardous goods.

Source: Mobile IT for goods on the road, Blekinge Institute of Technology, Sweco (Transport Telematics R&D Group Sweden).

### 7.3 Tunnel monitoring and control

The purpose of monitoring and control in road tunnels is to maintain a safe and effective flow of traffic, whilst at the same time minimising delays and the possibility for queues to develop during normal traffic conditions. Tunnel systems can also mitigate the consequences of accidents in tunnels.

Tunnel monitoring and safety issues have been on the agenda in Sweden since the early 90’s following an agreement between the major metropolitan centres on how to tackle traffic issues and problems in tunnels. The Swedish Road Administration has produced a general technical description for the construction and improvement of tunnels, Tunnel 2004. In this, the requirements for project planning, designing, constructing and improving tunnels are specified.

In order to manage incidents, there is equipment that is used for information and control in the tunnel, and on adjacent entrances and major approach roads. At the Traffic Management Centre, there are documented control strategies with instructions for incident management. Fire alarms, the control of fans, pumps and lighting, remote-controlled barriers, variable message/road signs and other variable road markings are also monitored and controlled from this centre.

### 7.3.1 Application

In Sweden, systems for monitoring and controlling traffic in tunnels are only appropriate for tunnel roads that carry large volumes of traffic. These
systems are controlled by the applicable regulations (Tunnel 2004 and EU directives) and are mainly appropriate in city areas.

Tunnels more than 500 metres long, which are covered by the EU directive (2004/54/EC), are regulated by a tunnel authority (the respective county administrative board). The body responsible for project planning and construction or operation on public roads is the Swedish Road Administration. On other roads and streets the municipality is responsible for these activities. Formally, it is the National Board of Housing, Building and Planning (‘Boverket’) that, in consultation with the Swedish Road Administration and the Swedish Rescue Services Agency (‘Räddningsverket’), issues regulations on the safety requirements that must be complied with by tunnels. Among the prescribed safety requirements named are: road markings, signs and information, monitoring systems, equipment for closing the tunnel, and parts of the communication system.

7.3.2 Effects

The possibility to close lane or section of tunnel in connection with incidents means that safety can also be improved for emergency services personnel and road-users. Tunnel traffic effectiveness is increased when lanes are closed in conjunction with road works. The time taken to establish a working area is also reduced. By adapting speeds to the prevailing traffic conditions, the capacity of the tunnel and road can be increased to some extent.

Quicker clearing of incidents with shorter blockage times and improved information about planned disruptions can lead to improved transport quality. Reductions in the severity outcomes of accidents can be expected as a result of earlier detection and also provides the possibility for faster emergency assistance responses.

7.3.3 Actors

Responsibility for the implementation of these measures rests with the road authority. In Sweden, it is mainly city tunnels with high traffic volumes that use extensive installations for tunnel monitoring and control. These systems incorporate queue-warning systems and lane control, due to the fact that they come under the EU directive and Tunnel 2004. Other actors involved in implementation are the rescue services and operational contractors.

7.3.4 Good advice for implementation

Tunnel control systems are a major investment and each control system must be adapted to the conditions that exist at a particular location. In areas with a great deal of traffic, tunnel systems can be integrated with motorway control systems.

7.3.5 See also

- Traffic control using variable message signs.
- Lane/motorway control
7.3.6 Good examples: Tunnel monitoring and control

In 2006, an exercise was carried out that included a trial evacuation of the Göta Tunnel in Gothenburg in Western Sweden. The trial was organised by Lund University in cooperation with the western regional office (‘Region Väst’) of the Swedish Road Administration. A total of 29 test subjects took part using their own cars. None of the subjects had been told in advance that they would have to evacuate the tunnel. Instead they had been told that they would be taking part in an exercise in which driving behaviours and technical installations would be tested.

The test subjects were allowed to drive into the Göta Tunnel, which was closed off to other traffic. Only one lane in the middle of the tunnel was open and the subjects were therefore forced to drive one after the other in a long queue. At transverse junction number 6, the subjects were stopped by a simulated accident, consisting of cars across the lane and artificial smoke. Two and a half minutes after the first car stopped, the evacuation alarm was activated. The alarm consisted of a spoken evacuation message and the activation of traffic information boards with the text, ‘Switch off your engine, Evacuate the tunnel’. Flashing green lights were also turned on at two emergency exits.

The test was documented by 15 video cameras mounted at roof level. Once the test subjects had evacuated the tunnel, they had to complete a questionnaire about the evacuation, the evacuation aids and other technical installations in the tunnel. In addition, four subjects were interviewed about their behaviour and their observations. The test subjects also took part in group discussions about the evacuation.

Several of the test subjects stated that the evacuation alarm was an important factor in their decision to leave their car. An audio signal made the road-users aware that something abnormal had occurred and made them look for further information. The text messages on the traffic information boards and flashing green lights at the emergency exits were also considered to be important by the test subjects.

Source: Evacuation test in the Göta Tunnel, Fire Technology Department, Lund University, 2007.
## Appendix 1 Effect matrix

<table>
<thead>
<tr>
<th>Estimation of effect:</th>
<th>Very positive effect</th>
<th>Fairly positive effect</th>
<th>Little positive effect</th>
<th>Calculated/estimated effect, not measured</th>
<th>No effect demonstrated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>•••</strong></td>
<td><strong>••</strong></td>
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</tbody>
</table>

### ROAD SAFETY

<table>
<thead>
<tr>
<th>Activity</th>
<th>TRAFFIC MANAGEMENT</th>
<th>TRAFFIC INFORMATION</th>
<th>MONITORING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents involving unprotected road-users</td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
<td><strong>•</strong></td>
</tr>
<tr>
<td>Single vehicle accidents</td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
<td><strong>•</strong></td>
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<tr>
<td>Accidents between vehicles on major roads (rear-end collisions)</td>
<td><strong>••</strong></td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
</tr>
<tr>
<td>Head-on collisions</td>
<td><strong>•</strong></td>
<td><strong>•</strong></td>
<td><strong>••</strong></td>
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<tr>
<td>Accidents involving crossing traffic</td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
<td></td>
</tr>
<tr>
<td>Accidents at road works and rescue work</td>
<td><strong>•</strong></td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
</tr>
<tr>
<td>Risks/consequences of hazardous goods transport</td>
<td></td>
<td></td>
<td><strong>•</strong></td>
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</tbody>
</table>

### THE ENVIRONMENT

<table>
<thead>
<tr>
<th>Activity</th>
<th>TRAFFIC MANAGEMENT</th>
<th>TRAFFIC INFORMATION</th>
<th>MONITORING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air quality and noise problems (particularly in and around urban areas)</td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
<td></td>
</tr>
<tr>
<td>Impact on the climate (CO₂, NOₓ, particles)</td>
<td><strong>••</strong></td>
<td><strong>••</strong></td>
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<tr>
<td>Increased use of land, encroachment etc. from road traffic</td>
<td><strong>•</strong></td>
<td><strong>••</strong></td>
<td></td>
</tr>
</tbody>
</table>

### ACCESSIBILITY

<table>
<thead>
<tr>
<th>Activity</th>
<th>TRAFFIC MANAGEMENT</th>
<th>TRAFFIC INFORMATION</th>
<th>MONITORING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility for pedestrians/cyclists</td>
<td></td>
<td></td>
<td><strong>•</strong></td>
</tr>
<tr>
<td>Problem of queuing on major roads</td>
<td><strong>••</strong></td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
</tr>
<tr>
<td>Queues/congestion in urban areas</td>
<td><strong>••</strong></td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
</tr>
</tbody>
</table>

### TRANSPORT QUALITY, MISCELLANEOUS

<table>
<thead>
<tr>
<th>Activity</th>
<th>TRAFFIC MANAGEMENT</th>
<th>TRAFFIC INFORMATION</th>
<th>MONITORING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td><strong>••</strong></td>
<td><strong>•</strong></td>
<td></td>
</tr>
<tr>
<td>Strengthening the competitiveness of public transport</td>
<td><strong>••</strong></td>
<td></td>
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</table>
Implementing ITS – Step-by-step instructions

What should we think about prior to implementing ITS measures?

How do we choose the right ITS measures?

How do we manage and follow up on the installation?
8.1 How is a problem on the roads identified?

When a measure is to be planned on the roads, the process is initiated through the identification of a problem. Through customer service and contact with the general public, views on difficult traffic conditions or dangerous roads, or other problems, can be brought to light.

There may also be recurrent incidents or accidents on a road or street. It may be that schools make initial contact about the difficulties children face in order to get to school. There may also be political decisions or initiatives or policy provisions that mean that a problem must be resolved.

Often a proposed solution follows a problem definition. The proposed solution is, however, often influenced by those who describe the problem and who therefore also initially define the needs. It is important to strive for an objective analysis of the problem during this phase.

- **What does the problem look like?** What characterises the problem: accessibility, road safety, the environment, transport quality, personal security?

- **Who is affected by the problem?** Is this motorists, public transport users, unprotected road-users or local interest groups?

- **Where and when does the problem arise?** Data and statistics.

- **What consequences does the problem have for different groups of road-users, the local environment, society?**

- **What could be causing the problem?**

The problem is illustrated from different perspectives through answers to these questions.
The result of a problem inventory is a written presentation of what form the problem takes, along with a possible causal connection.

8.2 The planning process

The planning of an ITS measure begins as soon as a problem has been identified and the need for a solution has gained support from the road authority.

The manual describes and lists important steps in the process, and provides good advice for implementation. The manual should act as a support and offer suggestions with regard to how the problem should be approached. It does not, however, pretend to be exhaustive with regard to methods for the planning and implementation of ITS measures.

The aim is to make it possible to use the manual for both simple and more complex measures with the ambition of offering a checklist rather than a detailed description of each section.

8.2.1 Steps in the planning process

A successful project begins with good planning. The implementation of an ITS measure should be carried out in project form. Administration, operation and maintenance can then take place through ordinary administration, or in project form.

The planning of an ITS measure is, in principle, no different to the planning of a physical measure. The Swedish Road Administration has published a large number of manuals and support documents for planning. There are, amongst other things, several documents describing how the principles of the four-stage process model can be used for planning purposes.1,2

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1 The principles of the four-stage process model in pilot studies (2006:122)
2 Countermeasure analysis according to the principles of the four-stage process model (Åtgärdsanalys enligt fyrestegsprincipen) (2002:72)
For the planning of measures from a long-term perspective, or for solutions that may cover several measures, overall planning should be carried out so that the benefits of coordination are achieved. Where the measures affect several interested parties, e.g. the Swedish Road Administration, a municipality and a county transport authority, joint planning involving all affected parties is recommended. The Swedish Road Administration has produced guidance for the joint planning of road informatics\(^3\) which should be used in these cases.

The steps that are involved in the planning process are described below. Depending on the complexity of the problem, the steps will vary as regards how far-reaching they are.

- **Initiation.** Includes start-up activities, such as drawing up the project specification, determining project managers and reference groups, contacting the interested parties involved, and the engagement of a consultant, where this is necessary. Who will make decisions on the choice of measures, and who will decide on financial matters, must also be established.

- **Preparation of an inventory and background analysis.** Covers the gathering of background facts such as: maps; local traffic regulations; incidents that have occurred; traffic measurements where appropriate; and the views of local residents, local organisations and authorities. National and/or local focus and policy documents should be identified. In order to create a good understanding of the situation, observations should be carried out at the problem location and should comprise of different perspectives. This is carried out in order to illustrate how motorists, public transport users and pedestrians/cyclists are affected. Video-filming and photographs of the traffic situation can act as important supporting material for future planning and implementation phases.

- **Needs analysis and description of objectives.** Once the problem has been identified and the consequences for the various interested parties that will be affected have been clarified, a structured needs analysis and description of objectives should be prepared. As the needs are different for different groups of road-users, the needs analysis should differentiate between the needs of:
  - Pedestrians and cyclists
  - Public transport users
  - Motorists
  - The local population and local activities
  - The needs of the authorities (and the road authority)

  The needs of the authorities may be formulated through decisions on political direction or local policy documents.

  The description of objectives should be carried out on the basis of every identified need. The goal should be measurable and the measurement method identified.

  **FOR EXAMPLE:**

  NEED: Road safety and the feeling of personal security need to be improved for pedestrians and cyclists travelling on the road in question, particularly at the pedestrian crossing.

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\(^3\) Guidance for joint planning of road informatics (2000:12)
OBJECTIVE: The average speed of vehicles should be reduced by 5 km/h and the proportion of those speeding reduced by 50 per cent. Personal security perceived by pedestrians and cyclists should increase by 50 per cent.

MEASUREMENT METHOD: Traffic measurements and field surveys.

• Choice of measure. Once there is a clear description of the objective, it is possible to analyse those potential measures that may resolve the problem. During this phase, this manual can be used for support, as can the Swedish Road Administration’s document concerning the effects of different road measurements for the road transport system from 2008. The ITS-division at the Swedish Road Administration and various ITS suppliers may also be useful contacts.

  – Think about whether there are several alternative solutions. The list of measures should include 2 to 5 potential measures that include both physical measures and ITS solutions. For each measure, an assessment of costs and effects must be carried out in order to see whether the objectives set will be achievable using the measure. Costs refer to estimates for the actual investment, operation and maintenance, evaluation, and various other project costs. Effects refer to how the measure will affect accessibility, road safety, the environment, and quality and security.

  – If, following the initial analysis, there are several alternatives that satisfy the objectives, a feasibility analysis should be performed. The most important tool here is a cost-benefit analysis. Non-quantifiable benefits should also be described. The publications mentioned above can also provide support for this part of the analysis.

  – A general rule is to select the measure that provides the greatest effect for the financial investment. Unquantifiable benefits or political directions may, however, weigh heavily when choosing a measure.

  – The result of the analysis should be summarised in an implementation plan (decision-making documentation), which consists of proposals for implementation, cost estimates, and a decision recommendation.

• Compile planning documents. Once a measure has been chosen, the detailed planning of procurement, installation, administration and evaluation can take place. See Section 8.3.2.
8.2.2 Planning documents

In order to ensure a life-cycle perspective in relation to the implementation of an ITS measure, planning should include all phases of the project. A number of planning documents have been identified below. These can either be formulated as independent documents or prepared collectively as a single planning document. The connection to this step in the implementation process is shown in the figure below.

![Figure 6. Planning documents at each stage of the implementation process](image)

In order to provide a sufficient level of support for implementation, the first versions of the planning documents should be prepared as early as the planning phase of the project. Several of the documents should thereafter be adjusted and updated once agreements have been entered into with different suppliers.

**Decision-making documentation for choosing a measure**

Before choosing a measure, there should be decision-making documentation containing details of cost estimates for investment, operation, maintenance, and evaluation, particularly with regard to the measure that is recommended. Costs can be described in a separate document. See below in the section on finance plans. The benefits (profitability) of the proposed measure should be described with sufficient precision to allow the decision on implementation to be made with greater ease.

When designing and implementing ITS, the applicable regulations, such as the Swedish Traffic Sign Regulations, should be applied. In order to ensure a mutual understanding with the responsible authority, the Swedish Transport Agency or other relevant exercisers of authority should be informed of the planned ITS measures.
The following items should be included in the decision-making documentation:

- Needs analysis for different groups of road-users
- Formulation of goals and targets
- Proposed measures with cost estimates and effect assessments
- Implementation analysis of the proposed measures
- Recommendations regarding the choice of measures

**Implementation plan**
In the implementation plan, detailed planning is carried out for all phases from procurement to installation, and taking the ITS into operation (i.e. commissioning). The plan should clearly state who is responsible for each phase, and what schedules apply. Document control and approval procedures should also be included. Documents included in the implementation plan are:

- **Specification of requirements**
  The procurement of technical systems and installation services must be put out to tender in accordance with the Swedish Public Procurement Act (LOU). A specification of requirements and tender documentation must be formulated in order to obtain bids from ITS suppliers. The most important elements of this are described in Chapter 5.4.2.

- **Finance plan**
  The finance plan should be as detailed as possible with regard to estimates of all costs (external and internal) in connection with the implementation of the ITS measure. The cost estimates should contain all elements from planning and procurement to installation, operation and maintenance, and also evaluation. It should be clear how the measure will be financed.

- **Management plan**
  The plan should describe how the ITS system will be operated and maintained and by whom. Other issues that should be described in the management plan are: How will customer support be dealt with? What contingencies will apply regarding the management of faults and repairs? At what intervals is maintenance expected to take place and how will system updates and adjustments be managed? It is assumed that the plan will be updated thereafter as required in cooperation with the chosen suppliers (for systems, installation services, and operation and maintenance services).

- **Evaluation plan**
  This plan should describe evaluation work, such as traffic measurements and field surveys, and state the dates and times for preliminary and follow-up measurements and those responsible for these activities. If an external party is engaged to carry out the evaluation, there must be cooperative work following the evaluation to update the plan accordingly. Suggested points that could feature in an evaluation template are described in Chapter 9.2.6.
8.2.3 Human-machine interaction and behavioural aspects of ITS

Human-machine interaction refers to how humans behave when they encounter machines and IT systems in their surroundings.

ITS are based on IT systems that communicate one or more messages that road-users are expected to understand and act in accordance with. As mentioned previously, ITS measures have the aim of trying to get the road-user to adapt his behaviour on the roads, which, in turn, has an impact at different levels (individual, societal etc).

Messages may be divided into the following three types:

- Guidance messages
- Warning messages
- Informational messages

The way in which people are affected by the message depends on whether it is understood, and how it is understood. If the road-user does not understand how a message should be interpreted and how he or she is expected to act, then it does not matter what message is given. Poorly designed ITS solutions or messages may even lead to the road-user unconsciously breaching traffic regulations and being fined. In a worst case scenario poor ITS designs and messages may also cause accidents.

The wording of the message should be clear and may consist of symbols combined with free-text.

An important prerequisite when designing ITS messages is to use the right message at the right place and right time. Road-users must be informed of the action they are expected to take.

Behavoural aspects related to traffic and road design represent an area that is attracting more and more interest. There are still, however, great gaps in the knowledge of road-users’ behaviours, which means that dangerous situations can arise. Continuing to focus on this subject and to conduct research in this area will hopefully lead to the individual and society deriving a greater benefit from the measures that are introduced.

8 Better Traffic Information, Fasan 2, Swedish Road Administration 2006:101
9 The Road, Technology and Man, Swedish Road Administration 2004:183
8.2.4 Summary of the planning process – checklist

The planning of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Planning stage</th>
<th>Ok*</th>
<th>Doc. approved**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there a clear (written) problem definition?</td>
<td></td>
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</tr>
<tr>
<td>Has an inspection been carried out at the location?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have the views of the affected parties (e.g. local environment) been obtained?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have maps/drawings, LTF, focus or policy documents been examined?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have needs analyses been carried out for various interested parties and groups of road-users?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a description of objectives been drawn up with defined objectives and measurement methods?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has decision-making documentation for the choice of measure been formulated?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the choice of measure been made?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a specification of requirements been drawn up?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a finance plan been drawn up?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a management plan been drawn up?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an evaluation plan been drawn up?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* This stage has been carried out or a document has been prepared (to be signed by the project manager).
** The document has been approved (to be signed by the project owner).
8.3 The implementation process

The implementation process begins with the decision to implement an ITS measure. The steps covered by implementation are:

- Preliminary investigation
- Procurement
- Placement and project planning
- Installation and verification
- Operations and information

8.3.1 Preliminary investigation

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

The aim of the preliminary investigation is to have a baseline measurement that can be compared to a subsequent measurement to see whether the system has had the desired effect. An example of a baseline measurement is provided below.

The preliminary investigation should embrace both traffic measurements and attitude surveys. How these are to be carried out will be described in the evaluation plan. A proposal for carrying out traffic measurements and attitude surveys is provided in Section 9.2 in relation to the Evaluation Process.

The result of the preliminary investigation should be checked against the description of goals. This is done in order to ensure that the factors measured in the investigation correspond to the goals that have been set for the expected effects.

EXAMPLE OF A BASELINE MEASUREMENT:
The result of the traffic measurement is that 40 per cent of road-users are exceeding the speed limit and that the average speed of those driving too fast is 62 km/h (where the permitted speed is 50 km/h). The objective is to reduce the percentage of those exceeding the speed limit to 10 per cent, and for the average speed of speeding vehicles to be reduced to 55 km/h. The attitude survey also shows that 70 per cent of pedestrians and cyclists feel that cars are driving too fast, while 30 per cent of motorists feel that they are driving too fast.
8.3.2 Procurement

The procurement of systems and services is among the most comprehensive and perhaps most difficult part of an implementation. Procurement will include both a specification of requirements and tender documentation. It may be of benefit to word the specification of requirements in such a way that it becomes function-oriented, so that functional requirements are prioritised ahead of technical ones. This will provide a great deal of scope for the supplier to suggest solutions.

The procurement of individual systems can be relatively expensive compared to purchasing several systems at the same time. It may, therefore, be a good idea to contact the ITS department at the Swedish Road Administration, or other local offices and municipalities in order to investigate what plans there may be for the introduction of similar ITS.

Procurement may be carried out in accordance with various models, such as:

- **System procurement** – the client is responsible for installation, bringing into operation (i.e. commissioning), and administration.

- **System and installation procurement** – the client takes over the system after installation and is responsible for administration.

- **Function procurement** – the client purchases and pays for a service and the supplier is responsible for the system, installation and administration, for a defined operational period.

As ITS measures embrace technical systems, there are some important parameters that should be included in a specification of requirements. This is in addition to the services that the system is expected to deliver. Depending on what type of procurement model is chosen, the tender documentation should specify requirements relating to:

- Availability – the proportion of operational running time for which the system will function
- Electricity and communications supply.
- The ability to make changes and add functions at a later date
- Training and documentation
- Installation instructions and criteria for the client’s approval of the installation
- Operation and maintenance assumptions
- Guarantees and financing
- Roles and responsibilities

The procurement exercise will result in a supplier being selected for the assignment. The agreement with the selected supplier should, as a minimum, include a specification of the points mentioned above.
8.3.3 Placement and project planning

A new inspection at the chosen location must be carried out in consultation with the supplier in order to determine where the equipment will be placed. Several factors will be decisive for placement and project planning:

- Critical points in the traffic environment where the problem is greatest, e.g. a specific crossing or accident prone stretch of the road.
- The distance between the critical point and the place where the equipment should be located in order to provide the desired effect
- Geography and visibility (free sight)
- Availability in relation to the supply of electricity and communications
- Any restrictions imposed by the land owner
- Any physical obstacles/difficulties for excavation work, the construction of portals or other constructions
- Definition of the message format and other time parameters
- Programming of control equipment
- Definition of message – The right message at the right location. The message conveyed should be clear and preferably use well-known and self-explanatory symbols. The behavioural aspects described in Section 8.2.3 must be taken into account.

Project planning is dealt with by the client or by the supplier on behalf of the client.
8.3.4 Installation and verification

The installation of the system is carried out by the supplier, contractor or both, depending on the procurement model. The ground work is often carried out by the road authority’s contractor. This can include excavation, the construction of physical gantries, the running of cables, etc. The supplier will be responsible for the installation and setting-up of technical roadside equipment and the central back-office system. Electrical and communications connections, and carrying out the necessary functional tests, are also the responsibility of the supplier.

The distribution of responsibilities between the parties responsible for the installation should be clarified in advance.

Once the installation has been carried out and approved by the installer, the client must also verify the installation. It is often the supplier who defines a verification procedure and who participates in the verification together with the client. In order to avoid misunderstandings, the verification procedure should be approved by the client before it is carried out. The criteria for approval of the installation (the verification) should be defined in the agreement with the supplier.

8.3.5 Operations and information

The most important part of the work involved in taking the system into operation, concerns providing information about the system to the parties concerned. Above all, road-users must be informed.

Information should be provided in good time in advance, preferably on several occasions and through several channels. A good way of distributing information to a large population is to advertise in newspapers. It is also possible to use radio and TV channels. Where possible, the media themselves can be approached to write about or feature a new ITS measure. There should also be information on the road authority’s website. For local residents and other local parties of interest, direct information sent via the post may be necessary. This can help to create a better understanding and feeling of security with regard to how road-users are expected to act and use the system.

Other interested parties, such as municipalities, the police and the emergency services must also be informed. Any existing customer services must receive adequate training and information in order to deal with questions from customers, before and after the operational phase.

The operator must have completed the necessary training programme and be available to deal with information about operations before the system is taken into operation.

Once road-users and other interested parties have been informed, and once customer services and the operator are in place, the system can be brought into service.
The responsibility for taking a system into operation and providing information should always rest with the road authority.

### 8.3.6 Summary of the implementation process – a checklist

The planning of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Implementation stage</th>
<th>Ok*</th>
<th>Doc. approved**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has a preliminary investigation (baseline measurement) been carried out?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do the factors measured in the preliminary investigation concur with those indicated in the description of objectives?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an agreement been entered into with the system supplier?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the placement of the equipment been decided upon?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has project planning been carried out for the system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a verification procedure for approval of the installation been produced?</td>
<td></td>
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</tr>
<tr>
<td>Has an agreement been entered into for the installation of the ITS measure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an agreement been entered into regarding the ground work, the installation of electricity and communications cables, and the physical construction?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has installation been carried out and approved?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has an agreement on operation and maintenance been entered into?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the necessary information been issued to road-users and other interested parties?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has customer support received the necessary training?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the management plan (including operation and maintenance) been adjusted in consultation with the chosen contractor? See the points in Chapter 6.1 in relation to the Management Process.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the system been brought into operation?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* This stage has been carried out or a document has been prepared (to be signed by the project manager).

** The document has been approved (to be signed by the project owner).
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)

Good management of the ITS solution is an important prerequisite for the measure to have the desired effect in both the short and long-term. All elements involved in managing the system are described in the management plan. Requirements for operation and maintenance, as well as support and contingencies, should be defined and form part of the agreement with those responsible for operations/support.

Management embraces several tasks:

- The day-to-day operation and management of the system. The more automated the system is, the less day-to-day management it requires. It is assumed that the system will have well-functioning procedures for the transfer of data, troubleshooting, storage and updating of data. In order for the operational manager to have the opportunity to monitor the system, daily system reports and alarms making manual troubleshooting possible should be generated.

- Handling customer questions and customer support. When questions arise, road-users and other parties concerned should have someone to contact to get an answer. How the customer support function is organised will depend on local conditions and what customer services already exist.

- The handling of failures, repairs and support. If the system, or parts of it, do not function, there must be a contingency for the replacement and repair of broken parts. The extent of this contingency will depend on how critical the system is to the traffic system, and the percentage of road-users that are affected.
• Periodic maintenance of the system. The need for preventive maintenance depends on how exposed the system is to wear and tear, and external influences. Certain systems need to be fine-tuned on a regular basis, or regularly need parts replaced or cleaned. A plan for preventive maintenance should be included in the management plan.

• The management of changes or system updates. If the system does not have the desired effect or needs to be supplemented with additional services, it should be possible to do this at a later point in time. The consequences for maintenance involving major system updates must also be dealt with. It is possible that signs may need to be reinforced, or that the system may need to be shut down to handle updates.

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

The management of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Management stage (operation and maintenance)</th>
<th>Ok*</th>
<th>Doc. approved**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are there clear procedures for operational tasks and the possibility to check these?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there clear instructions for customer support?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there procedures for troubleshooting, support and contingencies?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a plan for preventive maintenance?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a system for how the operation of the ITS system is to be managed in the event of system upgrades or changes?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Documentation of the system’s operational profile, i.e. the system’s operational period, set requirements for availability and how reliable the system needs to be. Establish an acceptance level with regard to potential operational disturbances.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* This stage has been carried out or a document has been prepared (to be signed by the project manager).
** The document has been approved (to be signed by the project owner).
9.2 The evaluation process

There is a subsequent phase in the implementation of ITS measures in order to evaluate whether the measure has had the desired effect – have we resolved the problem? During the planning phase, a description of objectives was prepared showing the effects the measure was expected to have. The description also defined methods to determine how the fulfilment of objectives could be measured.

The most important elements in the evaluation of ITS are:

- Preliminary investigation – baseline measurement
- Follow-up investigations
  - Measuring short-term effects
  - Measuring long-term effects

The preliminary investigation (baseline measurement) is described in Section 8.4. The follow-up investigation and measurement of long-term effects should be carried out in the same way as the preliminary investigation in order to be able to compare the results.

As ITS measures aim to influence road-user behaviour through guidance, warnings or informational messages, the evaluation that is carried out must measure whether road-users have actually been influenced, and to what extent. This must be done in relation to the targets that have previously been set. The main elements in an ITS evaluation are therefore traffic measurements and attitude surveys.

9.2.1 Traffic measurements

Traffic measurements should be carried out during both the preliminary and follow-up investigations. The type of traffic measurement that will need to be carried out will depend on what effects the investigation intends to measure.

Changes in journey times, speeds, flows, distances between vehicles, and numbers of vehicles are examples of parameters a traffic measurement will aim to investigate. Traffic measurements may, for example, be carried out by means of pneumatic-tube measurements, video cameras, laser guns, or through the use of GPS-positioning technologies.

The traffic measurement must be adapted to local conditions and related to the intended purpose of the ITS measure. The measurement point should be located as close as possible to the point where the effect is desired. The resolution of measurement data (time interval for sampling) should also be adapted to the measure.
9.2.2  **Attitude surveys**

Attitude surveys aim to survey how road-users perceive the ITS measure and whether they feel that their behaviour has been influenced or changed completely, and whether road safety has been improved. Attitude surveys are recommended even when establishing a baseline measurement, but it is primarily during the follow-up investigation that these should be carried out.

Attitude surveys can be carried out using questionnaires and field surveys that involve different groups of road-users affected by the system.

In order to survey the attitudes of motorists, the registration numbers of passing cars can be recorded, both during periods when the system is active, and when it is not active. Vehicle driver details can be cross-referenced from the Traffic Register using the registration numbers that have been recorded. Drivers can then be contacted by letter or telephone.

Surveys of other road-users can be carried out using questionnaires directed at residents in the immediate vicinity of schools and other local organisations and establishments.

Residents in the immediate area can often take the role of motorists, pedestrians, cyclists and public transport users. It is necessary to take this into account when wording questions.

The number or responses required in order to be able to ensure that the result is statistically sound will depend on how accurate the result needs to be. A general rule of thumb is that a minimum of 50 responses will be needed from each group that is to be compared, e.g. motorists, public transport users, pedestrians and cyclists, commuters, occasional travellers, women and men. The percentage of responses is often far greater from telephone interviews that it is from questionnaires (sent by letter). A large number of questionnaires should therefore be sent out in order that the number of responses from each group provides a sufficiently sound basis for analysis.

9.2.3  **Review of needs**

Part of the evaluation process involves an analysis of whether the identified need still remains. There may be external factors or events that change the prerequisites for traffic and road-user behaviour in the area concerned.

External factors need not be momentary – i.e. the conditions may change from one day to the next. There may also be incremental changes over long periods of time. For this reason, it is usual to carry out a review as part of the evaluation process. What the external factors actually are that influence the need for a countermeasure are difficult to determine, but examples of such factors include:

- Changes in local traffic regulations
- Road reconstruction or redesign, the road can be extended or its primary function can be changed (e.g. to a pedestrian precinct)
- The development of traffic is different to that expected
- Land is expropriated or used for other purposes
The review of needs must demonstrate whether external factors have led to a removal or increase in the need for ITS measures.

9.2.4 Reporting on the result of the evaluation

Making the results of evaluations available to decision-makers and officials is an important part of the process of increasing interest and knowledge on road-based ITS. By increasing knowledge about the effects different ITS solutions have, it is anticipated that the status of the entire ITS area will be heightened.

By disseminating the results of different evaluations, a broader and better general knowledge base is also created on the costs and benefits of different ITS solutions. This knowledge base is an important resource, not just for the project participants who are directly affected, but also for a wider audience of people and organisations that have an interest in ITS.

By gathering together experiences and evaluations from a great number of projects, better documentation is generated for decision-making relating to the type of measure that may be most appropriate in various situations, e.g. in order to resolve an acute traffic problem, or to achieve a long-term political objective for the traffic system.

To achieve greater understanding and use, it is important that the evaluation results are:

- Transparent
- Easily understood
- Able to be compared with other results
- Able to be transferred to other traffic environments/other conditions

9.2.5 Reporting template

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

- Problem definition
- Project description
- Evaluation plan
- Effects of the ITS project
- Transferability
### Problem definition

**Location:**

**Description of current traffic problems:**

### Project description

**Aim of the project (accessibility, transport effectiveness, safety, the environment and any eventual counteractions that may result, e.g. traffic and road-user):**

**Description of the ITS system and technology:**

### Evaluation plan

**Date of implementation, type of evaluation and methodology:**

**Objectives of the evaluation (technical, functional, financial and socio-economic objectives as well as objectives regarding effects):**

**Evaluation questions to be answered (posed by the main interested parties):**

**Evaluation area (describe the location of the system and associated equipment, including any inspection locations):**

**Anticipated effects to be investigated:**

**Evaluation methodology:**

> These points should be described before the project is implemented in order to facilitate a balanced illustration later.

### Effects of the ITS project

**Technical function (describe reliability and other measurements of how the technology has functioned):**

**Important results (describe the results in terms of effects, socio-economics and costs):**

**Report the statistical confidence levels of the project results:**

**Report to what extent it has been possible to respond to the various evaluation questions:**

**Overall assessment of the project results:**

### Transferability

**Describe local peculiarities that may have affected the project results. Try to perform an assessment of factors that could change the results if implemented in other locations.**
Summaries of ITS projects financed by the Swedish Road Administration should follow this template. All major projects with capital costs of more than 10 million SEK or evaluation costs of 0.5 million SEK must follow the template. This will facilitate the dissemination of knowledge via Swedish and international databases. Headings need not strictly follow the template. The key factor is that the content is included.

Not just those who are directly involved in the projects as participants but also other potential ITS users in other regions should be regarded as parties interested in an evaluation. In the case of the latter, it is important to find out how different systems and applications function, how much they cost in terms of investment and operation, and what effect they can be expected to have if they are applied at a particular location, or in another region with different conditions.

The reporting of results to this wider group of decision-makers will provide a basis for the assessment of the real effects of ITS investments in the long-term. Objective evaluation results obtained in this manner can be used to successfully build up a database of authentic costs and benefits. In turn, this will reinforce the body of knowledge at the road administration that intends to implement ITS in the future.

9.2.6 Summary of the evaluation process – a checklist

The evaluation of ITS should include the following elements:

<table>
<thead>
<tr>
<th>Evaluation stage</th>
<th>Ok*</th>
<th>Doc. approved**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has a plan been prepared for traffic measurements for baseline measurements and follow up investigations?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a plan been prepared for attitude surveys for baseline measurements and follow up investigations?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a baseline measurement been carried out (also part of the implementation process)?</td>
<td></td>
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</tr>
<tr>
<td>Have follow-up investigations been carried out?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a plan been prepared for long-term evaluation?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a measurement of long-term effects been carried out?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a plan been drawn up for reviewing the need? This can for example, cover the elements described under the Needs Analysis in section 8.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a review of the need been carried out?</td>
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<td></td>
</tr>
<tr>
<td>Has the review of the need led to changes, or the ITS system being removed?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* This stage has been carried out or a document has been prepared (to be signed by the project manager).
** The document has been approved (to be signed by the project owner).
BACKGROUND DOCUMENTS


Experiences of the effects of ITS in the Nordic countries, Movea 2007

Strategic plan 2008–2017, Swedish Road Administration 2007

Road informatics: A directory of systems and services [Väginformatik: katalog över system och tjänster], Swedish Road Administration 2005:115

Swedish Road Administration’s contribution to town planning [Vägverkets medverkan i samhälls- byggnadet], Swedish Road Administration publication 2005:141

The four-stage process model for planning – For sustainable measures in the transport system [Fyrstegsprincipen för planering – för hållbara åtgärder i transportsystemet], Swedish Association of Local Authorities and Regions

The four-stage process model in pilot studies [Fyrstegsprincipen i förstudier], Swedish Road Administration 2006:122

Analysis of measures in accordance with the four-stage process model [Åtgärdsanalys enligt fyrstegsprincipen], Swedish Road Administration 2002:72

Guidance for joint planning of road informatics [Handledning för gemensam planering av väginformatik], Swedish Road Administration 2000:12

Effects of different road measurements, Common assumptions [Effektsamband, Gemensamma förutsättningar], Swedish Road Administration 2008:9

Construction and improvements, Directory of effects [Nybryggad och förbättrande, Effektkatalog], Swedish Road Administration 2008:11

Operation and maintenance, Directory of effects [Drift och underhåll, Effektkatalog], Swedish Road Administration 2008:8

Sector information and the exercising of authority, Directory of effects [Sektorsuppgifter och myndighetsutövning, Effektkatalog], Swedish Road Administration 2008:12

The Road, technology and the human [Vägen, tekniken och människan], Swedish Road Administration 2004:183

References for each tool in the directory.

The details of some references may be missing. This may be because the information has been obtained through conversations with people or the fact that the reports, brochures etc. used as supporting evidence have not been published and cannot be ordered. This should not be interpreted as suggesting that there is no information, but rather that the information has not been suitably formalised e.g. as a report that is freely available.

PROVIDING INFORMATION TO ROAD-USERS

Queue-warnings


Weather warnings

Road-users’ experiences of variable and fixed message signs in Norbotten county [Trafikanters upplevelse av variabla och fasta meddelandeskytter i Norrbottens län], Eriksson, Swedish Road Administration 2003

Pilot study: Proposal for weather actuated roads in Region North [Förstudie: Förslag till väderstyrd väg i region norr], Swedish Road Administration 2002:159.

Gap analysis: Road E10, Road information in severe weather situations between Svappavaara – Riksgränsen, Kiruna municipality [Bristanalys: Väg E10, Väginformation vid svår vädersituation mellan Svappavaara – Riksgränsen, Kiruna kommun], Johansson, Swedish Road Administration 2004:3

Operator-controlled free text information

Verification of the benefits of better traffic information, FASAN 2, [Verifiering av nyttan av bättre trafikinformation, FASAN 2], Swedish Road Administration 2006:101

TRUT Project: “Road-user sacrifices and the benefits of traffic information” [Projekt TRUT: ”Trafikant- uppföringer och nyttan av trafikinformation”], Movea 2007

Memo – Traffic management and accessibility [PM – Trafikstyrning och Tillgänglighet], Movea 2007
Journey time information
TRUT Project: “Road-user sacrifices and the benefits of traffic information” [Projekt TRUT: ”Trafikant-uppförningar och nytta av trafikinformation”], Movea 2007

Information about temporary diversions/road works
Safer workplaces – Interim report for 2006 [Säkrare vägarbetsplatser – Delrapport för 2006], Swedish Road Administration 2007:64
Mobile gantries, Field trials on E4, E18 and road 73 [Mobil portal, Fältförsök på E4, E18 och väg 73], Salkert et al, Swedish Road Administration Production 2007

Vehicle-activated speed limit reminders
Evaluation of local ITS [Utvärdering lokala ITS-system], Sweco, 2007
Small-scale ITS: Evaluation of the effect of local VMS systems in urban areas [Småskalig ITS: Utvärdering av effekten av lokala VMS-system i tätort], Swedish National Road and Transport Research Institute, report 646, 2009

Vehicle-activated warning signs for pedestrians/cyclists
Traffic conflict study Enskedevägen, pedestrian crossing between Svedmyraplan and Herrhagsvägen [Trafikkonfliktstudie Enskedevägen, övergångsställe mellan Svedmyraplan och Herrhagsvägen], City of Stockholm Traffic Office, 2007
Evaluation of local ITS [Utvärdering lokala ITS-system], Swedish Road Administration Region West 2007

Ghost driver warnings
Ghost drivers – A report [Spøgelsesbilisme – Redeogelse], The Danish Road Administration, Denmark 2008

Dynamic parking information
Evaluation of P-evenemang (events parking) [Utvärdering P-evenemang], Swedish Road Administration Region West and the Traffic Office, Gothenburg, 2008
The parking management system in Helsingborg, Evaluation and improvement measures [Parkeringsledningssystemet i Helsingborg, Utvärdering och förbättringsåtgärder], Fredriksson, The Department of Technology and Society, Lund University, 2005

Real-time public transport travel information
Real time information for increased operational benefits [Realitidsinformation för ökad verksamhets-nytta], Traffic Report, 2009:1

DIRECTING TRAFFIC
Traffic signal control (independent, adaptive, coordinated)
Reduced carbon dioxide emissions in Stockholm through adaptive traffic signals [MATSIS – Minskade CO2-utsläpp genom Adaptiva Trafiksignaler I Stockholm], Movea 2008
Memo – Traffic management and accessibility [PM – Trafikstyrning och Tillgänglighet], Movea 2007

Operation and maintenance of traffic signals
Sweden needs better traffic signals [Sverige behöver bättre trafiksignaler], Swedish Road Administration 2000:28
GOOD traffic signals [BRA-trafiksignal], Swedish Road Administration 2003:60
Better signal functions in the event of faulty detectors and buttons [Bättre signalfunktion vid detektorfel och tryckknappsspel], Swedish Road Administration 2008:19

Public transport priority at traffic signals
RETT – A pilot project for improved regularity among bus services [RETT – ett pilotprojekt för bättre regulärhet i busstrafiken], SL 2003
Let the buses through – How to effectively prioritise public transport at traffic signals [Släpp fram bussarna – hur man effektivt prioriterar kollektivtrafik i trafiksignalen], Swedish Road Administration 2005:87
Prioritisation of bus traffic at traffic signals in Örebro – A pilot study [Prioritering av busstrafik i Örebrostrafiksignaler – en förstudie], Movea 2007
Bus prioritisation in the outer city – A pilot study [Bussprioritering i ytterstan – förstudie], SL 2008
Better Bus Prioritisation [Bättre Bussprioritering], Swedish Road Administration 2009 (working material)
Variable speed limits (weather and traffic actuated)
Variable speed limits – A bright idea – Report of results [Variabla hastigheter – en lysande idé – resultatrapport], Swedish Road Administration 2008:77

Reversible lane control
The design of roads and streets: Reversible lane control [Vägar och gators utformning: Reversibla körfält], Swedish Road Administration 2004:80
Evaluation of Reversible lane control on Road 222 [Utvärdering av reversibelt körfält på väg 222], Swedish Road Administration 2006:134

Lane/motorway control
Evaluation of impacts of the motorway control system (MCS) in Stockholm, Nissan, Institution for Infrastructure, Traffic and Logistics Department, the Royal Institute of Technology, 2007.
Memo – Traffic management and accessibility [PM – Trafikstyrning och tillgänglighet], Movea 2007

Road user charging in urban areas

MONITORING TRAFFIC

Automatic speed monitoring
Effects of automatic road safety control systems on safety [Effekter på trafiksäkerhet med automatisk trafiksäkerhetskontroll], Swedish Road Administration 2009:9

Facts about road safety cameras [Fakta om trafiksäkerhetskameror], Swedish Road Administration, 89223, 2008
Evaluation and analysis of road safety cameras – Road 50 E on the county border – Åsbro [Utvärdering och analys av trafiksäkerhetskameror – Riksväg 50 E länsgrens – Åsbro], Swedish Road Administration 2007:16

Monitoring and control of hazardous goods transport
Mobile IT for goods on the road [Mobil-IT för gods på väg], Blekinge Institute of Technology, Sweco (Transport Telematics R&D Group Sweden).

Tunnel monitoring and control
ATB Tunnel 2004, Swedish Road Administration 2004:124
Evacuation test in the Göta Tunnel [Utrymningsförsök i Götatunneln], Fire Technology Department, Lund University, Sweden 2007.