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Intelligent Speed Adaptation (ISA)

Results of large-scale trials in Borlänge, Lidköping, Lund and Umeå during the period 1999-2002.

Title: Intelligent Speed Adaptation (ISA), Results of large-scale trials in Borlänge, Lidköping, Lund and Umeå during the period 1999-2002

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Main contents: During the period 1999-2002 the Swedish National Road Administration conducted a comprehensive road information project which included a large-scale trial involving Intelligent Speed Adaptation in urban areas. Several thousand vehicles have been equipped with voluntary, supportive and informative systems to help keep drivers from exceeding the speed limit. The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities. Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems.

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The submitted report documents the background, implementation and the results of the comparative evaluation of the individual systems, which were made centrally by the Swedish National Road Administration. The report is designed to provide information and guidance for the continued consideration of a possible introduction of a speed adaptation system on a large-scale.

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Preface

During the period 1999-2002 the Swedish National Road Administration conducted a comprehensive road information project which included a large-scale trial involving Intelligent Speed Adaptation in urban areas. Several thousand vehicles have been equipped with voluntary, supportive and informative systems to help keep drivers from exceeding the speed limit. The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities. Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems.

1999 saw the planning of how the trial would be implemented and evaluated and in 2000 the systems started being installed in the vehicles. Most of the actual field trials were carried out in 2001. All the data from the trials were compiled and analysed during 2002. At the same time numerous experiences for discussion of the continued introduction have been collected.

The submitted report documents the background, implementation and the results of the comparative evaluation of the individual systems, which were made centrally by the Swedish National Road Administration. The report is designed to provide information and guidance for the continued consideration of a possible introduction of a speed adaptation system on a large-scale.

We would like to thank all the participating municipalities, automotive industry and companies as well as all private persons and haulage companies that contributed with vehicles, answering questionnaires and good development ideas.

Torbjörn Biding

Project manager, ISA project

Abstract

Between 1999-2002 the Swedish National Road Administration conducted a large-scale trial involving *Intelligent Speed Adaptation* (ISA) in urban areas. Several thousand vehicles were equipped with voluntary, supportive and informative systems to help keep drivers from exceeding the speed limit. Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems.

The aim of the trial, which was conducted jointly by the Swedish National Road Administration and four Swedish municipalities, was to learn more about:

- driver attitudes and how they use the systems
- the impact on road safety and the environment
- the integration of the systems in vehicles
- the prospects for Intelligent Transport Systems (ITS) on a large scale.

The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities.

1999 saw the planning of how the trial would be implemented and evaluated, and in 2000 the systems started being installed in the vehicles. Most of the actual field trial was carried out in 2001, when up to 5 000 vehicles, driven by over 10 000 drivers were out in traffic. This means that there are many people who can testify first-hand about what it is like to drive using an ISA system. Numerous surveys and interviews were conducted throughout the trial period. All the data collected trial was compiled and analysed in 2002. At the same time, invaluable experience was gained from which to continue discussing the future introduction of ISA on the market.

The main findings were:

- Better road safety without increasing travel time
- If everyone had ISA, there could be 20% fewer road injuries in urban areas
- High acceptance of ISA, and after the trial most test drivers were of the opinion that ISA should be compulsory in urban areas
- ISA vehicles were found to have a positive influence on surrounding traffic
- Minor differences between the systems, with an average speed reduction of 3-4 km/h on stretches between intersections
- The systems must be improved to become more attractive.

Based on the experience from the Swedish ISA project as regards implementation, evaluation, technology, information and the dialogue on the issues involved in a market introduction, the following recommendations can be made as input in the continuation of this dialogue.

- The results from the project are clearly positive from a road safety point of view and do not appear to have any essential negative side effects. We therefore strongly recommend that the public and private sectors work in partnership to launch the system on the market as soon as possible.

- The Swedish National Road Administration should immediately start drawing up regulations that ISA systems be standard in future vehicles (either as compulsory by law, or through voluntary agreement with the automotive industry). These regulations should be fully drawn up by no later than 2005. In the negotiations with the automotive industry, a decision should be made that the regulations would apply from a specific year (like somewhere between 2008 and 2010) which would give the automotive industry a reasonable amount of time to develop and install ISA systems as a standard feature.
- The Swedish National Road Administration should set a good example by having ISA systems installed in its own vehicle fleet by 2005.
- In conjunction with this, the speed limit system and surveillance policies must be revised with a view to the new potential provided by ITS.

Summary

The largest ISA trial in the world

During the period 1999-2002 the Swedish National Road Administration conducted a large-scale trial involving *Intelligent Speed Adaptation* (ISA) in urban areas. The designation ISA is initially an international designation and stands for "Intelligent Speed Adaptation". Several thousand vehicles have been equipped with voluntary, supportive and informative systems to help keep drivers from exceeding the speed limit. Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems.

The aim of the trial, which was conducted jointly with four Swedish municipalities, was to learn more about:

- driver attitudes and usage
- impact on road safety and the environment
- integration of the systems in vehicles
- prerequisites for road informatics on a large-scale.

The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities.

The Government and the Swedish National Road Administration generally consider it important to ascertain how and whether road informatic solutions can be used above all to improve road safety. ISA is primarily an application for towns, as well as residential areas and other sensitive environments where speed bumps are commonly used. Naturally it should also be possible to use the speed adaptation system for roads other than 30 and 50 km/hour roads, but in the trial interest was focused on urban areas, where no spontaneous development is currently in progress via vehicle development. The speed adaptation systems can be informative or supportive. Informative can, for example, be in the form of an audio signal while supportive can take the shape of an accelerator resistance when the speed limit is exceeded.

1999 saw the planning of how the trial would be implemented and evaluated and in 2000 the systems started being installed in the vehicles. Most of the actual field trials were carried out in 2001, when at most some 5000 vehicles were on the roads, these were driven by more than 10000 drivers. This resulted in the ISA trial becoming the largest in world so far. Consequently, many persons can testify how it is to drive with ISA. Numerous measurements and interviews have been made during the trial period. All the data from the trial were compiled and analysed during 2002. At the same time numerous experiences for discussion of the continued introduction have been collected.

The submitted report documents the background, implementation and the results of the comparative evaluation of the individual systems, which were made centrally by the Swedish National Road Administration. The report is designed to provide information and guidance for the continued consideration of a possible introduction of a speed adaptation system on a large-scale.

Three ISA models have been tested

Umeå, Borlänge, Lund and Lidköping make up the trial towns in the large-scale Intelligent Speed Adaptation (ISA) trial. The project has been financed and co-ordinated nationally by the Swedish National Road Administration and the practical trial period ran over an eighteen-month period from August 2000 to December 2001. In total the Swedish National Road Administration has invested over SEK 75 million in the project.

Different systems and technical solutions have been tested at the different trial sites. In Umeå a *warning system* was tested where the driver received a warning signal (audio and visual) when the legal speed limit was exceeded. The system in Umeå from hereon in will be designated **warning ISA**.

In Borlänge a system was tested that used audio and visual *warnings* for breaches of the speed limit and in addition a display *informed* the driver about the existing speed limit on the road in question. This system from hereon in will be called **informative ISA**.

In Lund a system was tested that supported the driver's speed adaptation through an *"active accelerator"*, which means when the driver has reached the legal speed limit a counter pressure is applied to the accelerator. A display was also used in Lund to show the legal speed limit. This system hereon in will be called **active accelerator** or abbreviated as active gas. In Lidköping both informative and active accelerator systems were tested.

In total approximately 5000 trial vehicles were included in the ISA trial. The majority, some 4000, have been based in Umeå. The remainder were distributed between Borlänge, Lund and Lidköping. Different functions have been tested in different towns:

- Borlänge: 400 vehicles with the informative system.
- Lund: 290 vehicles with active accelerator.
- Lidköping: 150 vehicles with the informative system and 130 with active accelerator.
- Umeå: 4000 vehicles with the warning system.

It should be added that in Borlänge (and Lund) each vehicle that participated in the trial has been logged[1] during the entire trial period. Logging was necessary in order to analyse how the vehicle has been driven during the trial and made up an important part of the evaluation. The drivers in Borlänge were aware of this. Furthermore, it was pointed out to publicly paid commercial road users that logged data may be used for the follow-up of conditions during procurement. One condition is that the vehicle should observe the speed limits in force. In this way the system has, in a certain context, been recording commercial traffic in Borlänge. In time the experiences of this will be used to develop forms for quality assurance of transport services with regard to safety.

The trial should be seen as an important core in a program for ISA that encompasses several parallel activities. Accordingly, the ISA project has contributed towards a discussion about the design of a future intelligent speed adaptation system parallel with the trial. This includes, among others, the need of incentives, legal aspects, liability issues, standardisation and the possibility of internationalisation. It has also been important to co-operate internationally in order to be able to introduce standardised solutions.

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1 Automatic registration of speed and position.

Important functions for ISA

The function aimed for with "Intelligent Speed Adaptation" is to *give the driver support in adapting speed*. In the implemented trial support has concerned helping the driver not to exceed the statutory speed limit, however in the future, ISA may become more intelligent and then consider, for example, the weather, road conditions and other circumstances.

The ISA system has the following basic functions:

- Calculates an appropriate highest speed (for the time and place where the vehicle is located).
- Measures the speed of the vehicle.
- Supports the driver in speed adaptation.

These functions have been implemented in different ways at the trial sites, and using different types of systems manufactured by several different companies:

ISA town (manufacturer)	**Positioning**	**Communication with vehicle**	**Support to the driver**
Umeå (Hogia)	Transponder, compass, speed sensor	Transmitters on lampposts Transmitters not on-line connected to a central system.	Does not show speed limit Diode+audio when exceeded.
Borlänge (Itinerary)	GPS, compass, speed sensor, map matching	GSM	Display shows speed limit. Diode+audio when exceeded.
Borlänge (Invexor)	GPS, map matching	GSM	Display shows speed limit. Diode+audio when exceeded, or vibration in the accelerator
Lund (IMITA/Itinerary)	GPS, compass, speed sensor, map matching	No.	Display shows speed limit. Accelerator resistance when exceeded.
Lidköping warning (Itinerary)	GPS, compass, speed sensor, map matching	No.	Display shows speed limit. Diode+audio when exceeded.
Lidköping supportive (IMITA/Itinerary)	GPS, compass, speed sensor, map matching	No.	Display shows speed limit. Accelerator resistance when exceeded.

Results

The main results of the trial are briefly presented below. In chapter 4 the results are presented in more detail and with explanations. In general it can be said that the expected positive effects were confirmed and even reinforced, while the results are mixed with regard to the non-effects or negative effects. For example, the drivers felt that they had become better drivers when using ISA at the same time as there is a tendency to become either more active or passive with ISA in the vehicle.

Improved road safety without increasing travelling time

All in all the evaluation shows that it is reasonable to believe that road safety has improved significantly by using ISA. If everyone had ISA, there could be 20% fewer road injuries in urban areas.

The average speed on stretches of road has clearly fallen with ISA. The ISA vehicles drive more homogeneously and with less spread of speed, which probably increases safety even more. Pedestrian awareness has increased.

Entry speeds into intersections (at the beginning of the braking process) have also fallen with ISA, more than half the effect towards the centre of the stretch. Even the lowest speed in the middle of the intersection has fallen for three-legged intersections (not four-legged intersections and roundabouts).

Travelling times in urban areas remain unchanged despite lower driving speeds in specific areas. The explanation is because there is less stopping and fewer braking situations with ISA. In this ways delays in queue situations and at intersections are reduced, and in doing so the average travelling time is not affected. Road-users experience travelling times as unchanged or marginally longer. Measurements for active gas indicate that travelling times are even marginally shorter.

Acceptance of ISA is high

A clear majority of drivers believed that you should keep to the speed limit on 30 and 50 km/hour roads.

Acceptance of ISA in urban areas is extremely high. Even higher than the level for seat belts before legislation was introduced. Around 35% used seat belts before it became statutory. When legislation was introduced usage increased to about 80%.

There is a belief of becoming a better driver when using ISA. Around two in three wanted to keep the system if it was free, while around one in three could even consider paying a limited amount. One in ten in Lund used the system voluntarily outside of the test area. (The speed limit was then set manually.)

Test drivers sufficiently representative

The recruitment group represented quite well the average driver. Those who chose to take part were somewhat more positive to the trial then those who chose not to take part, which is quite natural. Support of ISA was particularly appreciated on 30 and 50 roads and in vulnerable/dangerous road environments. In Umeå the fleet of vehicles represented - 4000 vehicles - as much as 10% of vehicle kilometres travelled, which means the result ought to be sufficiently representative in order to draw sustainable conclusions. It was primarily due to technical reasons that persons could not take part in the trial. Women are however underrepresented among the test drivers, as they generally driver older models than men.

The test drivers thought it was easier to keep the speed limit when using ISA. It was an advantage to see the speed limit on a display. 70-80% considered the basic concept of ISA to be good, even if the technology (GPS-coverage, movement of the active accelerator) has not been completely reliable during the trials.

Problems and difficulties have interfered with the trials, yet in the evaluation the drivers have, to a certain degree, been able to distinguish between the equipment in the trials and the technology itself. In all probability the opinions would have been even better without the problems, especially for active gas. Active gas caused the most trouble (sometimes, frequently or very often 37% in Lund, 46% Lidköping) followed by informative (41% in Borlänge, 14% in Lidköping) and least warning (5% in Umeå).

ISA-vehicles influence other road users

The result in Umeå indicates that other road users were also affected by ISA. This means that large effects can also be attained even with a smaller amount of ISA vehicles on the road.
ISA may prove to be the best idea yet together with policing to solve road safety problems on 50 roads in urban areas. This is where most personal injuries occur and acceptance for alternative physical measures, for example, road bumps is low.

Small differences between systems

Effects on speed differ very little between the systems. The driving speed fell on stretches by up to 3-4 km/hour for each of the systems. The difference between the systems for the entire road system at 30-50 km/hour, which is the main focus of the trial, only amounted however to 0.3-0.4 km/hour. The reason being, among others, that the audio signal in the warning system was experienced as so irritating that attempts were made to avoid it. In general this resulted in the same speed reduction as for active accelerator. Consequently, the choice of system should also be based on other criteria, such as cost, operating reliability and user points of view.

Warning and informative systems were preferred in advance by most people among the general public and among those recruited. Only around half as many considered active gas to seem suitable. A distinctive trait after the trial was that the test drivers thought that the system they tested was the most effective in order to increase road safety. Order of preference straight off for all test drivers is: warning, informative, active gas, nevertheless, the differences are small! The parallel driving simulator study shows that the drivers have fixed perceptions about which system is preferable. Therefore it may be advisable to develop a system where the user can select between an active or passive system.

You must accelerate a little more with warning/informative, somewhat less with active gas. You feel a little more "in the way" with warning, still a little more with informative and the most with active gas. You look more at the speedometer with warning, a little less with active gas. Glancing at the speedometer fell for everyone in time.

Attention to speed signs increased a little for warning, which has no display. It was unchanged for informative and it fell slightly for active gas.

Fuel consumption is believed to have dropped a little for informative, but only marginally for warning and active gas. According to the test drivers' own assessments, speed fell in the trial areas: on all stretches (30, 50, 70 km/hour). The experienced reduction was greatest for active gas, approximately 2 km/hour. The least effect for warning (10-20% lower), but this is still in the same magnitude. Measurements support that the driving speed fell by 1-2 km/hour, while travelling times including stops remained unchanged.

The system must be improved to become more attractive

ISA is perceived to be effective for the purpose, but the equipment is not so pleasing with regard to its design, etc. The possibility for the user to adjust the audio signal is one wish. Fewer than 20% have often or quite often wanted to switch off the audio.

Driving pleasure is unchanged for warning and informative systems, but fell a little for active gas.

Drivers have noticed that the warning is given a few km/hour over the speed limit on their own speedometers. Greater demands should be made on speedometers in cars showing the correct speed when using ISA (or that ISA replaces the speedometer).

Subsidies or other incentives (lower insurance premiums, etc) may be necessary to stimulate voluntary acquisition.

Issues concerning the introduction of ISA!

When you are the only one using ISA you feel more in the way. According to the drivers it therefore important in the long term that ISA is introduced for everyone!

Many believe that the introduction of ISA should be statutory for special groups (new driving licence holders, notorious speeding offenders and drink-drivers).

The state and municipalities can take the lead by equipping their own fleets of vehicles and through making demands on ISA for publicly procured transport services.

Commercial and company car drivers were generally negative to the trial and the introduction of ISA. Equipment has been sabotaged during the trial. The negative attitude of commercial drivers must be influenced through dialogue with the drivers as well as employers and by looking over stressful working conditions.

Technology in ISA trial

The **voluntary, supportive** and **informative** systems evaluated in the four local projects had the aim of helping the driver to not exceed the statutory speed limit. In the future ISA can be developed into a more intelligent system that can be used, for example, dynamically or in connection with different weather and road conditions.

A speed adaptation system ought to be capable of carry out the following basic functions in order to give the driver effective support (also compare figure 7.1):

- Calculate an appropriate highest speed for the time and place where the vehicle is located.
- Measure the speed of the vehicle.
- Support the driver in speed adaptation.

Calculation of an appropriate highest speed

In order for the ISA system to be able to calculate an appropriate highest speed (here the legal speed limit) it must know the time and position of the vehicle and what speed limits apply at different locations and possibly times. This requires:

- A “positioning system” that tracks the position of the vehicle

- A map (database) with the legal speed limits
- Software that matches the positions on the map and finds the legal speed limit at the location and time in question.

These tasks can be carried out in several different ways, which gives some principal technical guidance in the creation of an ISA system.

Choice of the positioning system

The positioning system normally consists of components in the vehicle that receive signals which are transmitted from a reference transmitter and calculates the position of the vehicle relative to these. In addition, the position must be supplemented with information from sensors that measure the speed, direction, etc. of the vehicle. Here there are two main paths to follow:

- Construct your own network of reference transmitters in the area in question.
- Use an existing positioning system (GPS for example).

To construct your own network of reference transmitters can be done, for example, by using microwave technology (transponder technology). This technology was used in the trial in Umeå where 200 transmitters were installed. To build up this infrastructure is very expensive, which is why this technology is more suitable when a large number of vehicles are to be positioned within a limited area, which was the case in the Umeå trial where 4000 vehicles participated. The advantages of this technology are the possibilities of good and stable precision in positioning, independent of other systems and cheaper vehicle equipment. The expensive investment in infrastructure and road installations can be avoided by using an existing positioning system instead.

GPS (Global Position System), the America system for satellite positioning, gives a precision of approximately 10 metres in positioning and can also measure speed. The primary disadvantage is that the positioning system only works when the vehicle equipment has free visibility towards at least 3 satellites, which limits the coverage and precision in urban areas, tunnels, etc. However, it is possible to minimise this problem through supplementing the vehicle equipment with sensors that measure speed and direction, and in doing so can navigate brief periods without satellite coverage. In addition to this even map-matching is usually used, which, among others, “snaps” the position to the closest road. However, with these supplements the actual vehicle computer becomes more expensive than corresponding transponder technology.

GPS was considered to be the available positioning system that best suited the objective of the project in Borlänge, Umeå and Lund.

Conveying the map (database) with speed limits to the vehicle

The problem in communicating a map with the legal speed limits to the vehicle include:

- the speed map is located centrally and must be conveyed to all vehicles
- speed limits change, which means the speed map needs to be updated in all vehicles
- the speed map can be too large for the small vehicle computers
- the speed map can be too large to transfer using "ordinary telecommunications"

As the primary objective of the ISA trial was to evaluate the effect on road safety and the attitudes of the drivers, and not to solve problems concerning the technical infrastructure, these problems

were avoided by defining so small trial areas that the map could be stored on the vehicle computers and by limiting map updating procedures or handling this manually.

With the transponder technology used in Umeå, each transmitter transferred a very local map that included legal speed limits up until the next transmitter. This system permitted changes to the speed limits as long as the road system did not change. In Lund and Lidköping the entire map was installed into the vehicle computer memory. Updates could only be applied by visiting the depot. In Borlänge the possibility of transferring and updating maps via GSM existed, to avoid visiting the depot.

Measure the speed of the vehicle

Here one of two main methods could be chosen:

- Use the vehicle's existing system.
- Measure the speed by using the positioning system.

In the Umeå system the vehicle's existing system for measuring speed was used, by connecting into a pulse encoder, which on most vehicles is the input data to the speedometer and kilometre counter. Calibration was necessary during installation in order to give good accuracy. This measurement method reacted quickly to changes in speed and gave consistent speed data, but also consistent measurement error if the system was incorrectly calibrated, for example, after changing to other tyres. One practical problem was that older vehicles did not have an electronic pulse encoder and that speed pulses on newer vehicles were only accessible via the vehicle's CAN bus, which in some cases was encrypted. This problem was sidestepped in the Umeå trial by eliminating such vehicles during recruitment.

In the GPS based system in Borlänge only speed data from the vehicle's GPS was used. This measurement method gave a slight delayed effect and no or inferior speed data with bad satellite coverage. On the other hand, the occurrence of measurement errors was equally spread upwards and downwards around the correct speed and in doing so gave a very good average value. Measuring the driving speed with GPS required no connection to the vehicle (besides the power supply) or adaptation to different vehicle models.

In the GPS based systems, which were based on navigators and which were used in Borlänge, Lidköping and Lund, both the speed pulse and speed data from GPS were used. This allowed extremely accurate speed measurement. In most cases the ISA system gave a better speed measurement than that presented on many of the vehicles' speedometers.

Support to the driver

With basic data in the form of the legal speed limit and the vehicle speed all that remained was a comparison of these and then to inform and support the driver. The methods used up until now for information to the driver in an ISA context (individually or together) are the following:

- show the legal speed limit on the display.
- indicate on the display, using a diode or lamp that the speed is too high.
- indicate using an audio signal that the speed is too high.
- indicate via feedback in accelerator that the speed is too high.

- make it difficult for the vehicle to exceed the speed limit in question.
- prevent the vehicle from exceeding the speed limit in question.

All methods except from the last named were tested within the ISA trial. See the compilation earlier in table 3:1. More details about the technology in the ISA trial can be found in chapter 5.

The information in the ISA project

The purpose of detailed work concerning information issues has been to create good co-ordinated communications, within the project as well with the surrounding world and contribute towards making the implementation of the project more efficient. For ISA, where attention from the media and press has been immense, well planned work within information and communications has been a success factor in the project. By starting the information work from the outset of the project the public relations officers have been involved and shaped the project. By employing this working method it's been possible to place emphasis on the individual instead of the technology, which is not unusual for ITS projects. Information has been used to generate knowledge and influence attitudes. The challenge has been to create a good climate for research in ISA and highlight the potential possibilities without simultaneously influencing the test drivers.

Media strategy

A separate media strategy has been developed to manage contact with the media in an efficient and consistent manner. The content of the strategy corresponds well with the content in the information plan, but documents details in contacts with the media. The starting point for the ISA project has been the earlier assumption that only by using voluntary systems is it possible to get a market and an acceptance for ISA. It has been important to try and maintain a neutral debate in Sweden. The aim of the project has been to strive after good handling in the media through:

- allowing many of the test drivers to express themselves, willingly both positive and negative about ISA to convey a wider perspective,
- work actively with demonstration drives,
- provide continuously information to the media
- promote the benefits of ISA
- keep a broad group of journalists informed and a limited group of journalists well informed about ISA.

In order to create a clear profile for the project it was decided that the project manager for the ISA project should first and foremost keep contact with media. If major events happened during the course of the project press conferences could come into question and when the project had anything of interest to convey press releases would be sent out. Large-scale test runs would be used to create a greater understanding of ISA.

The project introduced ISA through the values prestige and soft values. ISA should be treated as a trademark charged with these values. Nationally the message was aimed at the benefits of ISA; that the project was the largest of its kind in the world and that usage is voluntary (unlike other enforced systems).

Project site

A project site was developed and launched on the Internet to facilitate internal communications. This has had the task to act as a knowledge base for the project, where information could be downloaded and uploaded.

An external project site, www.vv.see/isa, was also developed on the website of the Swedish National Road Administration. Information about the project's background and the latest events taking place in the project were distributed via the Internet. All material distributed from national project is also available via the web site. There are also links to the websites of the four trial sites. More details about the information in the ISA project are set out in chapter 6.

How can ISA be introduced on to the market?

Experiences from the ISA trial

The results clearly indicate that ISA makes a positive contribution towards road safety. They confirm previous experiences from smaller trials in Eslöv and Umeå regarding user acceptance and effects on the traffic. Feared negative effects have been exaggerated, but ergonomics need to be improved.

The speed measurements in Umeå and results from vehicle logs in Lund and Borlänge show undoubtedly that the average speed fell for vehicles equipped with ISA. Furthermore, the spread of speed was less. The higher the average speed the greater the reduction in speed provided that the prior average speed is over or close to the speed limit in question. The only sure difference between the systems is that the effect on the spread of speed is less for informative and warning systems than for active gas. The reductions in average speed are of the same magnitude.

ISA's design and function has caused problems, but one trusts the system. The greatest problems have been with active gas, which in the tested version, among others, affected the driving characteristics of some vehicles when accelerating. This has probably affected the drivers in their evaluation of the technology and function. These deficiencies must be corrected before an introduction.
Many have complained about the audio signal on warning respective informative ISA and this has been accentuated during the trial period. A softer tone was requested. Even the visual signal has caused some problems and many found it difficult to see the speed reading on the display when the sun was on it.

One idea with ISA is that the driver is warned when the speed limit is reached and thereby does not need to look at the speedometer or speed signs as much as without ISA. For active gas 40% of drivers said that they looked less at the speedometer and signs. For informative ISA there is no great difference while drivers with warning ISA looked a little more than usual. About half of the drivers with warning ISA increased their attention to both the speedometer and speed signs.
As the warning system has no display this is a reasonable reaction.

More drivers with warning and informative systems considered that they needed to accelerator and brake more than earlier while it was the opposite for active gas drivers. A probable explanation is that the function in active gas automatically adjusts the speed once the speed limit is reached while drivers with informative and warning ISA must carry out an active action (lift off the accelerator and possibly brake). The results also show that with active gas you attempt to reach the maximum

permitted speed where possible. In other words, acceleration is always a little stronger when you accelerate than without ISA. This probably also applies for informative and warning systems too.

Even if a specific increase can be noted for some factors with regard to mental strain it does not seem to have a negative effect on driving to any appreciable extent. This standpoint is supported by there being a clear opinion that ISA does not demand attention from other, more important things while driving.

The trials show that the test drivers are predominantly positive to the system despite the technical and functional deficiencies that the systems have been marred by. If ISA should make a wide scale break through it is still important that the equipment has been ergonomically tested, works without problems and is reliable. As the will to pay is low it is also important that the spread with a voluntary introduction is stimulated by subsidies or other incentives.

You can interpret the results that active gas has somewhat greater effects on exceeding the speed limit and in doing so safety. However, acceptance is greater for the warning and informative systems. Functional difficulties have certainly contributed towards this more than the effect on the speed for active gas. In order to gain high acceptance in an introductory phase it is important to offer the possibility for the driver to choose between different functional models. Preferably these should be combined in an integrated system. It seems to be initially easier to accept the warning and informative systems. Eventually many feel that the audio signal is annoying and wish to replace it with a more unobtrusive warning. Active gas or another similar system may then be preferable.

Introduction from a technical perspective

If there is a will to introduce ISA on a large-scale, the technology exists. Distinct boundaries ought to be drawn between the role of the authorities and industry. The authorities ought to answer for providing a comprehensive and updated road database with speed limits and let industry produce the requisite vehicle equipment. The difficulties of communicating legal speed limits to large fleets of vehicles should not be underestimated. Especially if this speed information in the future should be dynamically adapted to current circumstances and be legally valid. The choice of what level of speed support can be considered suitable is not limited by the available technology. Everything from discrete informative systems to more actively supportive or vehicle affecting are already fully feasible.

Introduction from an automotive industry perspective

In order for an ISA system to be sufficiently attractive, have a high acceptance level and high observance, dynamic speed limits should be introduced. Dynamic speeds increase the drivers' understanding for speed limits and also make it more meaningful to have support in the vehicle to help observe the speed limits.

The market can be aided by support such as tax relief or lower insurance premiums. This will probably be necessary for, e.g. a GPS based ISA system to be possible around 2008 at a reasonable price for the user. It should also be reasonable as the benefit for society with this kind of system will initially be greater than for the individual.

System harmonisation, at least within Europe, is necessary in order to get the automotive industry involved in the technical development and hold down costs for the system.

Introduction from a community perspective

Against the background of the ISA trial results society ought to support the introduction of voluntary, supportive and informative ISA systems on a large-scale. Speed adaptation systems are expected to contribute towards increased road safety and a reduced number of fatalities and injuries on our roads.

In order to support and facilitate the introduction of ISA during the period 2002-2008 society ought to take the following steps:

- The Swedish National Road Administration provides all interested parties with information and knowledge from the implemented ISA trial. This includes recommendations about project planning, information and marketing (support), costs, technical equipment, operation and maintenance, etc.
- The Swedish National Road Administration speeds up via regional NVDB[2]-co-ordinate the development of NVDB in the geographical areas where speed adaptation systems are requested.
- the Swedish National Road Administration co-ordinates with procurement applications for ISA systems to simplify the co-ordination of orders. Prices can be reduced with larger orders. Orders can also be divided among different suppliers as it is of interest to both the Swedish National Road Administration and the automotive industry and its customers to have several manufacturers on the market. Procurement material/technical specification of requirements to be provided by the Swedish National Road Administration.
- The Swedish National Road Administration furnishes recommendations for how many installations of speed adaptation systems ought to be made based on experiences from the ISA trial. Recommendations to be drawn up in co-operation with the vehicle department and the contracted installation engineers within the ISA project.
- The Swedish National Road Administration fits its internal fleet of vehicles with a speed adaptation system.
- With the procurement of transport services for the Swedish National Road Administration speed adaptation systems should be requested. The Swedish National Road Administration also acts so that other parties follow suit.
- The Swedish National Road Administration, together with the Swedish Ministry for Industry, Employment and Communications, investigates the possibilities of government subsidies for vehicles equipped with speed adaptation systems.

Recommendations guided by the Swedish ISA project

Guided by experiences from the Swedish ISA project - implementation, evaluation, technology, information and participation from the automotive industry the following recommendations can be given ahead of continued discussions about the introduction on the market.

a) The project results are clearly positive from a road safety point of view and do not seem to have any significant negative side effects. We therefore strongly recommend society and the automotive industry in collaboration to work for the quickest possible introduction.

b) A majority of test drivers consider that an ISA system should be standard in future vehicles. The Swedish National Road Administration should immediately initiate that regulations

[2] National Road Database (NVDB)

(statutory or voluntary agreement with the automotive industry) are drawn up about the ISA system being a standard feature in future vehicles. The regulations should be completed by 2005 at the latest. In negotiations with the automotive industry a decision should be made regarding a fixed year from when the regulations should start to apply; this should give the automotive industry reasonable time to develop and install the ISA system as standard (for example, some time between 2008-2010).

c) Companies that can demonstrate a serious interest in developing and offering an ISA system on the aftermarket ought to be given support from the government through VINNOVA, etc in order to stimulate the emergence of well developed technologies for after-sales installation of systems during the period 2003-2015.

d) Possibilities ought to be created to install ISA nationally or within limited areas for fleets of vehicles through a reliable and continuously updated speed database being in existence by 2005 at the latest.

e) The Swedish National Road Administration should take the lead by installing ISA in its own fleet of vehicles by 2005 at the latest. Government and municipal authorities ought to be encouraged to install ISA in their own fleets. Demands on the presence of speed adaptation systems ought to be made with the procurement of public transport services by 2008 at the latest.

f) Subsidies or other incentives ought to be introduced during the period 2003-2010 to stimulate the use of ISA on the private market too. A study of the effects of different incentives should be started immediately.

g) Sweden ought to act for an international introduction of speed adaptation systems primarily within the EU. This should take place through the distribution of knowledge about the ISA system's effects and acceptance as well as to strive for international agreement on HMI, standards, etc. Demands should also be made on improved accuracy of speedometers in vehicles.

h) The speed limitation system and supervision policy should be reviewed in parallel with regard to the new conditions that road informatics give. Questions about the technology to keep the legal speed limits and which limits are applicable should, if possible, be kept apart.

A possible introductory scenario

Guided by the recommendations the following introductory process is conceivable:

2002-2004

- Negotiations in progress between the government and industry about regulations for ISA in new vehicles.

- Government subsidies introduced for those installing ISA voluntarily

- The Swedish National Road Administration starts the installation of ISA in all its own vehicles and demands this in association with the procurement of transport services.

- VINNOVA, etc, financiers support companies that develop and sell ISA systems on the aftermarket.

- Work to enter speed limits in the national road database to be intensified.

- Introduction of dynamic speed limits

- Increased co-operation between the authorities and the automotive industry in Europe.

2005-2009

- In 2005 the government presents new regulations for ISA as standard in new vehicles

- Function and reliability for after sales installed systems has improved due to government support

- Earlier during the period, ISA has been installed in 5% of older vehicles with the help of the actions of the Swedish National Road Administration and other authorities in connection with the procurement of transport services.

- Penetration has increased by up to 35% as private persons more and more request ISA by the end of the period

- Standardisation is in progress within the automotive industry so that ISA will work throughout Europe

2010-2014

- Co-operation between the government and the automotive industry has resulted in 2010 becoming the date that ISA becomes compulsory as standard in all new vehicles

- ISA has been installed in 60% of all vehicles

- Increased demand and greater manufacturing batches result in so low costs that ISA no longer needs government subsidies.

- ISA is a matter of course and an opinion has been created, on a voluntary basis, for regulations about compulsory usage.

2015-2019

- More than 80% of all vehicles have ISA systems and as early as 2015 a decision is made, completely undramatically, that the use of ISA becomes compulsory in Sweden. Several countries within the EU simultaneously make the same decision.

- The availability of a well updated road database in Sweden and in larger parts of Europe has resulted in a large number of telematic services such as traffic information, navigation, and a number of "mayday" functions etc., being connected with the ISA-system.

2020-2024

- Expansion of the mobile data communications has come so far that in principle 100% of the European road network is covered.

- In Sweden and most parts of Europe the Road Administrations have established traffic information centres (TIC) that have the task of continuously updating all vehicles on the road with essential guidance, traffic information and any restrictions.

2025-2030

- All vehicles according to law must be connected to a TIC

- At the end of the period the Swedish National Road Administration and other Road Administrations successively dismantle all road signs as all essential information is displayed to the driver by means of the vehicle used for the journey or for the transport services.

Reports included in the ISA project

The reports included in the national reporting of the ISA project are listed below. Further reports can be found in the local project reports in Borlänge (Right Speed), Lidköping (ISA in Lidköping), Lund (Lunda-ISA) and Umeå (Smart Speed).

FINAL REPORT, THE ISA PROJECT

Intelligent Speed Adaptation (ISA)
Results of large-scale trials in Borlänge, Lidköping, Lund and Umeå during the period 1999-2002. The Swedish National Road Administration, Aug 2002 (Submitted report VV Publication 2002:89)

FINAL REPORTS, SUB-PROJECT

ISA Evaluation - effects
Final report for the sub-project traffic effects - analysis of traffic measurements. The Swedish National Road Administration and VTI, Aug 2002. VV Publication 2002:98

ISA Evaluation - user aspects
National final report. The Swedish National Road Administration and Movea, Aug 2002. VV Publication 2002:97

Intelligent Speed Adaptation (ISA)
Result of driving simulator test. Volvo, Oct 2001. Volvo Engineering report ER-520077.

ISA Technical report
Final report for the sub-project technology. The Swedish National Road Administration and SWECO Position, Aug 2002.

ISA Information
Final report for the sub-project information. The Swedish National Road Administration, Aug 2002.

FINAL REPORTS, TRIAL SITES

Right Speed - Summary of the ISA project in Borlänge
Comprehensive description of the contents in other interim reports and the presentation and generic discussion of the most important results. The Swedish National Road Administration and Borlänge municipality, Aug 2002.VV Publication 2002:92.

ISA in Lidköping - Summary of the ISA project in Lidköping
Reporting to the Swedish National Road Administration and information to our test drivers. The Swedish National Road Administration and Lidköping municipality, Aug 2002. VV Publication 2002:93

Lunda-ISA - Summary of the ISA project in Lund
Effects of active accelerator in urban areas. Report 15. Generic report. The Swedish National Road Administration and Lund municipality, Aug 2002. VV Publication 2002:94

Smart speed - Summary of the ISA project in Umeå
The Swedish National Road Administration and Umeå municipality, Aug 2002. VV Publication 2002:95

The reports can be obtained from: Vägverket, Butiken, SE-781 87 Borlänge, Sweden telephone: +46 243-755 00, fax: +46 243-755 50, e-mail: vagverket.butiken@vv.se

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1. Introduction

During the period 1999-2002 the Swedish National Road Administration conducted a large-scale trial involving *Intelligent Speed Adaptation* (ISA) in urban areas. The designation ISA is initially an international designation and stands for "Intelligent Speed Adaptation". Several thousand vehicles have been equipped with voluntary, supportive and informative systems to help keep drivers from exceeding the speed limit. Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems.

The aim of the trial, which was conducted jointly with four Swedish municipalities, was to learn more about:

- ·driver attitudes and usage
- ·impact on road safety and the environment
- ·integration of the systems in vehicles
- prerequisites for road informatics on a large-scale.

The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities.

The Government and the Swedish National Road Administration generally consider it important to ascertain how and whether road informatic solutions can be used above all to improve road safety. Some of the most important road safety problems are: too high speeds, tiredness/alcohol, bad states of the roads/weathers, heavy traffic, junctions and meetings between cars and unprotected road-users. Examples of road information ideas that can contribute towards solutions to these problems are dynamic speed adaptation, seat belt reminders, alcohol locks, tiredness detectors, friction meters, adaptive automatic speed control, communications between vehicle and traffic signals and pedestrian detectors.

ISA is primarily an application for towns, as well as residential areas and other sensitive environments where speed bumps are commonly used. Naturally it should also be possible to use the speed adaptation system for roads other than 30 and 50 km/hour roads, but in the begin interest was focused on urban areas, where no spontaneous development is currently in progress via vehicle development. The speed adaptation systems can be informative or supportive. Informative can, for example, be in the form of an audio signal while supportive can take the shape of an accelerator resistance when the speed limit is exceeded. The system can be anything from adaptable signs at the edge of the road that measure the speed of individual vehicles to automatic setting of appropriate speeds with regard to prevailing road and traffic conditions.

1999 saw the planning of how the trial would be implemented and evaluated and in 2000 the systems started being installed in the vehicles. Most of the actual field trials were carried out in 2001 when at most some 5000 vehicles were on the roads, these were driven by more than 10000 drivers. Consequently many persons can testify how it is to drive with ISA. Numerous measurements and interviews have been made during the trial period. All the data from the trials were compiled and analysed during 2002. At the same time numerous experiences for discussion of the continued introduction have been collected.

The submitted report documents the background, implementation and the results of the comparative evaluation of the individual systems which were made centrally by the Swedish National Road Administration. The report is designed to provide information and guidance for the continued consideration of a possible introduction of a speed adaptation system on a large-scale.

2. Background and purpose

2.1 Previous ISA trials and pilot studies

Sweden has been a pioneer within ISA. The Lund Institute of Technology has run research within the ISA field since the beginning of the Eighties. A smaller trial with ISA was carried out in Eslöv in 1996. At the same time a trial was made in Umeå with 100 trial vehicles. Both trials proved to be very successful. In 1997-98 the Swedish Association of Local Authorities run a project in Borlänge to prove ISA as a method to quality assure municipal transport services. 20 trial vehicles participated.

The successful small scale ISA projects made up a part of the background to the government decision that the Swedish National Road Administration should implement "Large-scale trials with Intelligent speed adaptation", which was later renamed "ISA - Intelligent Speed Adaptation". The project has been in progress since 1999 and was completed with reporting in 2002.

Pilot studies of ISA in the form of a government commission during 1997-98[3,4] recommended voluntary support systems that road users were encouraged to use in order to get help to drive safely and at a more even tempo. In an initial stage support to keep static speed limits of 30 and 50 km/hour was given priority. In a later stage it would be ideal to reconsider the current static speed limits and introduce more differentiated speed limits, which the new technologies permit. Trials with dynamic speed limits have been in progress during 2001. It is also necessary in the long term to study supplementary technical solutions that provide improved communications between conflicting vehicles and between vehicles and unprotected road users so that the number of risk situations at intersections is reduced.

2.2 The purpose and objectives in the long and short term

In the long term it's a question of:

...finding cost effective road informatic solutions that increase road safety through improved adaptation of the speed to prevailing road and traffic conditions.

The objective can, easily expressed, said to be to reduce the speed heavily in critical situations such as: bad state of roads, collisions from behind, passage through urban area intersections and at zebra crossings without accessibility being generally affected too much.

Previous studies (TRICS+[5], TOSCA[6], MASTER[7] and the government commission) has shown that there is great potential in speed adaptation systems to improve road safety, but it is unsure how such systems are better than other options if you weigh in system costs and the impact on the environment,

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3 The Swedish National Road Administration (1997) Conditions for and effects of implementing a large-scale trial with speed adaptation systems. Part 1.

4 The Swedish National Road Administration (1998) Government commission on speed adaptation systems. Report part 2.

5 The Swedish National Road Administration (1995). TRICS+ to reach the zero vision.

6 Lind G. (1996) Test-site-Oriented Scenario Assessment. KFB report 1996:13.

7 Várhelyi, and Mäkinen, T (1998). Evaluation of in-car speed limiters. MASTER.

accessibility and transport costs. A practical pilot trial must be implemented as a first step in the introduction to get experience whether the potential effects can also be achieved in reality.

Intelligent speed adaptation is defined as follows:

> ... processes that partly monitor the relation between the actual speed of a vehicle and a suitable speed, partly to act correctively when this relation is incorrect.

In the definition above it is important to clearly state what *suitable* means, for example, highest permitted speed, highest recommended speed, recommended speed in the present conditions (state of the road, visibility, routing, unprotected road users, etc.). In the large-scale trials *suitable* has meant the highest permitted speed, that's to say the same as today's system with fixed signs. Furthermore, the function to keep the speed should be seen independent of the technology. Correction can take place through automatic speed limiters as well as through the driver's own action when, for example, a signal sounds due to speeding.

Three main objectives were formulated with the implementation of the large-scale trial at the start of 1999[8]:

- provide knowledge about obstacles for and possibilities of a general introduction
- provide knowledge about the effects on road safety, environmental impact, accessibility and transport services costs
- act as a catalyst for the creation of a market for speed adaptation systems

In 1998 there was so much experience from different field trials that parts in the large speed adaptation system concept was mature enough to be tested on a larger scale. This does not mean that all parts were considered or assumed to be fully developed. A great deal of development was still needed as well as field trials in order for different technologies to be produced and used. An investment in speed adaptation ought to be seen as a step towards introducing road informatic solutions as a supplement to traditional solutions to different problems in the traffic. A pilot scheme of this nature is therefore expected to have effects far in excess of the actual trial. For this reason it was understood that it would be difficult to isolate the effects of the actual road informatics. However, it is important that knowledge surrounding the indicators that can be measured is built up and the effects are made clear. The four municipalities that were selected for the implementation of the trials were Borlänge, Lidköping, Lund and Umeå.

To implement the trials simultaneously in four municipalities has given many advantages:

- Several functions and technical solutions could be tested
- Several different traffic environments and sizes of town could be tested
- Different organisational solutions could be tested
- Different amounts of equipped vehicles could be studied
- More knowledge about introductory problems and challenges obtained
- Different geographical conditions could be tested

8 The Swedish National Road Administration (1998) Government commission on speed adaptation systems. Report part 2.

- Different types of transport services and driver categories could be tested

- Co-operation and experience gains obtained as the trials did not need to be started at the same time

The large-scale trial is an important phase in a strategy to achieve a major introduction of speed adaptation systems. The idea was for the introduction to start locally, based on each trial municipality's specific conditions, to then spread to other local, regional, national and international processes. In three of the four participating municipalities there was already an embryo of a market for the new technology before the trials. A key party in this is the municipal organisation.

Basic conditions for the introduction of speed adaptation systems in urban areas were considered to be:

- User requirement is central - we should not use enforced methods

- The system must solve urgent problems both from a user and community point of view

- The trial must be based on local commitment and local needs, i.e. that the municipality considers speed to be a problem and is willing to give this priority.

- Voluntary and informative system are those currently requested, the system is only a *support* to the driver, *responsibility* to keep speed limits remains with the driver

- Authorities and operators run the area and demand systems for quality assurance of community paid transport services. For these transport services it is the market, the collective consumer, that forces development of suitable tools

- The administrations must support the infrastructure for a future system for speed adaptation

- The automotive and electronic industries develop and sell systems in the vehicles

- Standardisation and harmonisation issues ought to be conducted separately for the area; in which Swedish solutions should be promoted

- Clear role division between authorities, operators of infrastructure and industry are important

The government's direct influence of the local market ought to be limited to, besides supporting variety, primarily contributions with technical know-how and standardisation work, look after technical legal matters as well as contribute with venture capital and bear responsibility for quality assurance and evaluation. The government should concentrate on evaluating the trial and distribute good and bad experiences to other local, regional, national and international parties.

The most important aim was, with regard to the overall objective for speed adaptation, to propose to the government an ISA system for introduction, guided by the large scale trials. This meant that the trials should help us to:

... find an feasible voluntary solution which gives significant increase in road safety, bring about moderate side effects and is at least as cost efficient as traditional road safety measures.

The proposed system can be one of the tested systems, a combination of these, a system in a modified form or a completely new system with other properties. It is a question of bringing together the objective in order to achieve marked road safety improvements with the aim of achieving acceptance and voluntariness. The aim to achieve marked road safety improvements means that speed adaptation

should first and foremost take place at intersections, interaction with unprotected road users and for road users with the highest driving speeds. The aim of obtaining high acceptance means that speed adaptation ought to influence average accessibility as little as possible.

As a first step on the way towards an introduction of speed adaptation systems for urban environments a large-scale trial needed to be implemented. The trial should serve as a stimulant and make up the start of a longer introductory process. Earlier trial results in the area pointed towards acceptance, understanding and not least, a certain will to pay for the system. The following framework for the evaluation describes the objective and what was expected to be achieved with the trial.

The main motive for large-scale trials with *Intelligent Speed Adaptation*:

- Problem with driving speeds in urban areas being too high, which results in accidents primarily serious consequences of accidents
- Contribute to the introduction and long term development of dynamic speed adaptation which fits in well in a master strategy in order to achieve a zero vision
- Systems that support speed adaptation in urban areas are ranked highly in studies and show very good acceptance and a certain will to pay in the trials in Eslöv and Umeå
- Trial participants said that they changed their behaviours (calmer, improved interplay, safer) with support in the car, which was verified by measurements in the form of conflict studies in Eslöv

The purpose in the form of knowledge enhancing elements during the implementation of the trial.

- Provide knowledge about obstacles for and possibilities of a general introduction
- Act as a catalyst for the creation of a market for speed adaptation systems
- Build up knowledge about different road user categories' views of the ISA concept and what is demanded (incentives, etc.) to increase usage and thereby strengthen the safety effects
- Develop the view of speed adaptation systems as a part of an integrated road informatics environment
- Study in detail the responsibility relationship between orderers and service providers and/or product suppliers (really road operators and the automotive industry) before a major introduction after 2001.
- Develop awareness around road safety and know-how concerning the road safety effects of speed adaptation systems
- Build up Swedish expertise and develop new techniques of potential industrial importance
- Develop know-how concerning environmental impact from applied speed adaptation (noise, exhaust fumes, etc.)
- Establish how accessibility is affected
- Study transport costs

3. Implementation

3.1 ISA trial

Umeå, Borlänge, Lund and Lidköping make up the trial towns in the large-scale Intelligent Speed Adaptation (ISA) trial. The project has been financed and co-ordinated nationally by the Swedish National Road Administration and the practical trial period ran over an eighteen-month period from August 2000 to December 2001. In total the Swedish National Road Administration has invested over SEK 75 million in the project.

Different systems and technical solutions have been tested at the different trial sites. In Umeå a *warning system* was tested where the driver received a warning signal (audio and visual) when the legal speed limit was exceeded. The system in Umeå from hereon in will be designated **warning ISA**.

In Borlänge a system was tested that with audio and visual *warnings* for breaches of the speed limit and in addition a display *informed* the driver about the existing speed limit on the road in question. This system from hereon in will be called **informative ISA**.

In Lund a system was tested that supported the driver's speed adaptation through an *"active accelerator"*, which means when the driver has reached the legal speed limit a counter pressure is applied to the accelerator. A display was also used in Lund to show the legal speed limit. This system is called **active accelerator** or abbreviated active gas. In Lidköping both informative and active gas were tested.

In total approximately 5000 trial vehicles were included in the ISA trial. The majority, about 4000, have been based in Umeå. The remainder were distributed between Borlänge, Lund and Lidköping. Different functions have been tested in different towns:

- Borlänge: 400 vehicles with the informative system.
- Lund: 290 vehicles with active accelerator.
- Lidköping: 150 vehicles with the informative system, 130 with active accelerator.
- Umeå: 4000 vehicles with the warning system.

It should be added that in Borlänge (and Lund) each vehicle that participated in the trial has been logged.[9] during the entire trial period. Logging was necessary in order to analyse how the vehicle has been driven during the trial and made up an important part of the evaluation. The drivers in Borlänge were aware of this. Furthermore, it was pointed out to publicly paid commercial traffic that logged data may be used for the follow-up of conditions during procurement. One condition is that the vehicle should observe the speed limits in force. In this way the system has, in a certain context, been recording commercial traffic in Borlänge. In time the experiences of this will be used to develop forms for quality assurance of transport services with regard to safety.

It is important to emphasis that the actual trial in itself is not synonymous with starting a comprehensive introduction process. The trial should be seen as an important core in a program for ISA that encompasses several parallel activities. Accordingly, the ISA project has contributed towards a discussion about the design of a future intelligent speed adaptation system parallel with the trial. This includes, among others, the need of incentives, legal aspects, liability issues, standardisation and the possibility of internationalisation. It has also been important to co-operate internationally in order to be able to introduce standardised solutions.

9 Automatic registration of speed and position.

3.2 System overview

The function aimed for with "Intelligent Speed Adaptation" is to *give the driver support in adapting speed*. In the implemented trial support has concerned helping the driver not to exceed the statutory speed limit, however in the future, ISA may become more intelligent and then consider, for example, the weather, road conditions and other circumstances.

The ISA system has the following basic functions:

- Calculates an appropriate highest speed (for the time and place where the vehicle is located).
- Measures the speed of the vehicle.
- Supports the driver in speed adaptation.

These functions have been implemented in different ways at the trial sites, and using different types of systems manufactured by several different companies:

Table 3:1 Overview of systems and functions tested at the different trial sites

ISA town (manufacturer)	**Positioning**	**Communication with vehicle**	**Support to the driver**
Umeå (Hogia)	Transponder, compass, speed sensor	Transmitters on lampposts Transmitters not on-line connected to a central system.	Does not show speed limit Diode+audio when exceeded.
Borlänge (Itinerary)	GPS, compass, speed sensor, map matching	GSM	Display shows speed limit. Diode+audio when exceeded.
Borlänge (Invexor)	GPS, map matching	GSM	Display shows speed limit. Diode+audio when exceeded, or vibration in the accelerator
Lund (IMITA/Itinerary)	GPS, compass, speed sensor, map matching	No.	Display shows speed limit. Accelerator resistance when exceeded.
Lidköping warning (Itinerary)	GPS, compass, speed sensor, map matching	No.	Display shows speed limit. Diode+audio when exceeded.
Lidköping supportive (IMITA/Itinerary)	GPS, compass, speed sensor, map matching	No.	Display shows speed limit. Accelerator resistance when exceeded.

The design of the driver interface for the three warning system models is shown in the figure below.

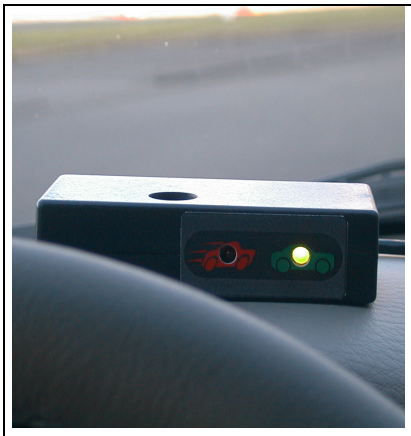		
Warning system "Speed Checker", Umeå	*Warning system "Itinerary", Borlänge*	*Warning system "Invexor", Borlänge*

Figure 3:1 System design for the warning system

An overview of different system components for active gas is shown in the figure below. More about the technology is evident in chapter 5.

System overview, Active gas (Lund/Lidköping)

Figure 3:2 System design for active gas

3.3 ISA - project organisation

The Swedish National Road Administration has since the end of the Eighties implemented a large number of development and demonstration trials within the field of road informatics. Projects have been carried out in close co-operation with industry, universities/researchers and municipalities. Experience from the trials is that as long as responsibility rests with the principal, in this case the Swedish National Road Administration, then implementation and the organisation work well. It has not worked as well when a successful trial in a later stage is to be implemented under the responsibility of the concerned parties' ordinary line organisation. It is obvious that the parties' organisation, which bears responsibility for development, does not succeed in transferring all the knowledge generated, via among others field trials, to the line organisation. Experience also clearly shows that persons that have participated during the development phase, seldom or never, participate when the new activity is to be established.

Traditionally an organisation is always drawn with the responsible orderer at the top, to then, via a number of downward steps, finally land on the lap of those implementing the work. Each step that passes downwards also means that the responsibility is successively diluted. Those carrying out the work, and who find themselves at the bottom of the hierarchy, perceive their responsibility to be small. "You can always guarantee that some one else will tell you what to do". With the experience in hand that key personnel can disappear by the implementation phase, it was decided that the ISA project should reverse the project hierarchical organisation.

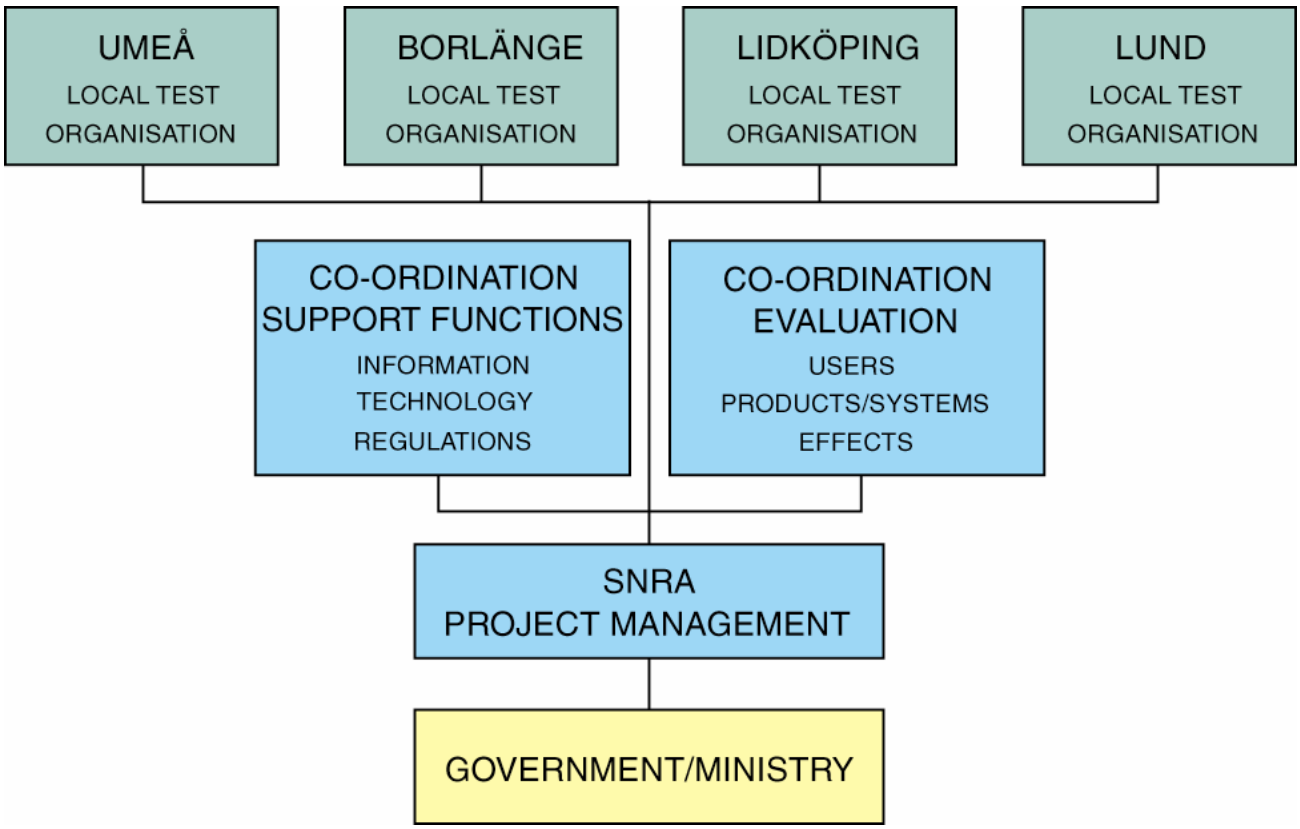

Figure 3:3 Organisation for the national ISA project

In order to highlight that responsibility for the ISA project trials out in the individual municipalities rested with the municipalities, an organisation was created with these at the top of the hierarchy. The idea was to create a "supportive" organisation where the Employer (Government) and the co-ordinating organisation (The Swedish National Road Administration) should act as a support for municipalities when the work should be implemented.

As previously mentioned the Swedish National Road Administration has for many years built up expertise within the road informatics field. The knowledge was offered to the municipalities via two, within the framework for the ISA project, separate sub-projects, *Co-ordination evaluation* and *Co-ordination technology/information*. The two sub-projects were manned with experts that for many years have participated in the Swedish National Road Administration's development and demonstration trials. The task of the experts was to train and guide the four municipalities' project participants during the implementation of the ISA project.

The responsibility of the two sub-projects was to also:

— ensure that the national evaluation was carried out so it was possible to compare the trials in the four municipalities.

— ensure that the technical specifications were co-ordinated to facilitate procurement of the requisite ISA systems for the trial

— produce a common communications strategy and common information material.

Work within the project was co-ordinated through a co-ordination group with the following make-up:

ISA-Umeå
Project chief: Bo Svanholm, Umeå Municipality
Project manager: Mattias Wärnhjelm, Umeå Municipality (up to 2000) and Jonas Sundberg, Sweco (from 2000)
(Local trial organisation Umeå)

ISA-Borlänge
Project chief and project manager: Håkan Bergeå, Borlänge municipality
(Local trial organisation Borlänge)

ISA-Lidköping
Project chief: Dan-Eric Sjögren, Lidköping municipality
Project manager: Tom Dahlstedt, Lidköping municipality
(Local trial organisation Lidköping)

ISA-Lund
Project chief: Göran Eriksson, Lund municipality
Project manager: Göran Haglund up to 2001 and Päivi Elmkvist from 2001, Lund municipality
(Local trial organisation Lund)

ISA Nationally - The Swedish National Road Administration
Philip Gustafsson, The Swedish National Road Administration (coordinating support functions) up to 1999
Anneli Johansson, The Swedish National Road Administration (information officer) up to 2000
Malin Theorin, The Swedish National Road Administration (information officer) from 2000
Stefan Myhrberg, SWECO Position (technical chief)
Gunnar Lind, Transek (co-ordination evaluation, editing of the final report)
Anders Lindkvist, Movea (responsible for views of users)

Karin André, Volvo (responsible for product/system views)
Arne Carlsson, VTI (responsible for traffic effects)
Torbjörn Biding, The Swedish National Road Administration (project manager)

ISA Expert group
The project has also had the support of an expert group, who provided standpoints about implementation, evaluation and introductory problems during the trial period. The group consisted of:
Lars Darin / Björn Stafbom, the Swedish Ministry for Industry, Employment and Communications
Christer Hydén, LTH
Lars Lind, Volvo
Hans-Erik Pettersson, VTI
Christopher Patten, The Swedish National Road Administration VIV
Roger Johansson/ Peter Larsson /Anders Lie, The Swedish National Road Administration ROP
Bengt Skagersjö, the Swedish Association of Local Authorities
Gunnar Lind, Transek
Kalle Bång, KTH
Elsa Rosenblad, CTH

3.4 The local ISA project

Right Speed – Borlänge

In Borlänge the local project was divided up into the following parts: Information activities, Physical measures, Geographic database, Equipment and technology, Measuring and evaluation as well as Road traffic surveys. The municipality engaged TransportCentrum within the Teknikdalen institution to lead the project in collaboration with TFK (Institute for transport research).

Voluntary private test drivers took part in the trial, as well as drivers of commercial vehicles. Dialogues with commercial drivers were handled by the company, which in turn received information from the project management.

The success factors in the project are considered to be, among others, the following:

- The project group had extensive media contacts, which gave a positive picture in the media and that contributed to the project being received positively

- The project has worked with information in a consistent and professional manner and in doing so has been able to have a good dialogue with everyone involved.

- The organisation has had a clear allocation of responsibility and regular meetings with detailed minutes.

- Readiness for problems has been good, which meant problems that did occur were solved efficiently.

Experiences from the project are also the following:

- Dialogues with commercial drivers ought to be managed in the same way as for private drivers, i.e. direct contact so that more comprehensive background and motives are collected for the project.

- With regard to the evaluation, basic conditions need to be defined earlier without forgoing the need of making adjustments while the project is in progress.

- Information work is extremely important in projects of the size and character of the ISA project.

- Complex technologies demand respect and should be handled accordingly.

In Borlänge they are continuing to work with the project VITSA (further development of ITS usage) where half of the ISA test drivers are participating. Under the VITSA umbrella and with access to vehicle fleets and an analysis database they are hoping to attract more projects within the field of IT in road traffic.

ISA in Lidköping

In Lidköping the municipality's Technical committee has borne responsibility for the project and the Highways department has implemented the work. A reference team, consisting of the co-operate group which existed within the project "Lidköping - A spear head for the Zero vision" has been utilised. The municipality engaged the following consultants as support in the project group: Vägverket Konsult within information, SKOP for the evaluation and Sweco for technology.

Work within the project has been characterised by a close co-operation with a short decision-making process and distinctive limits of responsibility. The project group was manned with skilled employees and a strong project manager. Personal chemistry in the project group and relations between the municipality, the Swedish National Road Administration, suppliers and others within the project has been good.

Test drivers have been private and commercial motorists.

The success factors in the project are considered to be, among others, the following:

- The organisation has been basic and small and the decision-making process has been short.

- A close, personal contact with the test drivers has created good relations, which has meant that operating disturbances could be handled extremely well.

- Clear information has also contributed to difficulties that have arisen within the project being met with understanding.

Experiences from the project are the following:

- Communication is important and the method of handling information to citizens is something the municipality will use in other contexts.

- Procurement of the technical equipment could of benefited from central co-ordination.

- Projects with several local sub-projects can benefit from more developed powers to control the evaluation centrally. In this way questionnaires and questions can be co-ordinated and in that give broader data for conclusions.

At the initiative of the municipality, Lidköping municipality continues to co-operate with the Swedish National Road Administration concerning ISA. Road safety in general is of interest to the municipality.

Lunda – ISA

Lund municipality, Technical administration, was the principal for the local project. The organisation consisted of a local authority officer with responsibility for finances, a project manager and a project co-ordinator. The project included a large amount of research work and the Lund Institute of Technology

was engaged for this. Work has been characterised by co-operation where suppliers, the municipality and LTH have co-operated closely. Trivector System AB has acted as a technical consultant.

The trial was implemented using private drivers as well as company cars.

The success factors in the project are considered to be, among others, the following:

- The project organisation as well as the make-up of the test drivers has consisted of people with a large interest in technology and curiosity.

- The municipality has for a long period co-operated with the Regional hospital and LTH and in this way built up a good knowledge of accidents and their effects from a Road administration point of view.

- The municipality has a deep insight that changes in the physical road environment are not always the best idea from a cost or accessibility point of view.

- The local project has had an extremely qualified evaluation side.

Experiences from the project are the following:

- In hindsight the municipality would have benefited from being stronger in "new technology" at start of the project. It was difficult to communicate the system requirements, etc.

- A public relations officer was not employed and media contacts and co-ordination with the national project information group were handled by the project manager/project co-ordinator. On certain occasions there has been a want and with future trials another organisation would be considered.

- Time schedules should be realistic, primarily at the starting phase of the project. Readiness for the exchange of resources is also needed when the time schedule extends over several years.

- It has been positive that the different municipalities have been able to evaluate the different technologies, but the total project could have benefited from greater co-ordination of the evaluation.

- The organisation around the technology would benefit from being stronger and being supported centrally.

- The municipality also thinks that it has been valuable to evaluate stretches with higher speeds.

Within the Lund municipality co-operation is in progress with the Swedish National Road Administration, Region Skåne, and municipalities in south west Skåne within road informatics where together they have looked at controlling and developing/optimising road traffic control systems. The municipality is continuing with the future introduction of ISA in municipal transport services and has also applied for project means to continue with active supportive systems. Lund hopes that the trial sites take responsibility to operate and keep ISA issues alive.

Smart speed – Umeå

The project owner for the local project was Umeå municipality through the technical office. The municipality provided its own personnel for important functions within the project management, installation of roadside equipment, road traffic measurements and the supervision of system operations.

The transport research unit at Umeå University, TRUM, answered for recruitment and user surveys. Hogia Persontrafiksystem supplied the system and SWECO VBB provided project planning and assisted with project management support during all the phases of the trial. The local project has consisted of committed employees with well defined areas of responsibility.
Voluntary private test drivers took part in the trial, as well as drivers of municipal owned vehicles and commercial vehicles.

The success factors in the project are considered to be, among others, the following:

- Marketing efforts and information have been an important part in the work and contributed to the project affecting 10000-15000 persons in one way or another.
- Interest for projects within road safety has been immense from the municipality and its inhabitants.
- A good and clear project description.

Experiences from the project are the following:

- There is a large amount of statistical data from field trials that can be used in future projects.
- Experiences in combination with large interest in road safety from the municipality can be used in future campaigns.
- When several sub-projects co-operate this is facilitated by the synchronisation and joint planning of the time schedules.

The municipality will continue to work with IT in road traffic. Camera and speed supervision are of current interest.

Common experiences

Information and dialogue with concerned parties was mentioned by all four local projects as a large success factor in the project.

All the municipalities thought it was positive to co-operate with the other municipalities. Through the exchange they have learnt from each other and benefited partly from mistakes, but also from the success concept. Co-operation between some of the municipalities in the work with the specification of requirements, procurement and database development were mentioned as concrete examples.

4. Evaluation

4.1 Important starting-points

The purpose of the evaluation is primarily that with sufficient safety establish whether the road traffic situation through speed adaptation has changed so that the tested solutions can be considered to give significant road safety effects and be reasonably cost effective. This demands the effects on road safety, environmental impact, accessibility and transport costs to be analysed.

Based on results from earlier studies and what has been said in connection with the government commission the most significant for the ISA project can be said to be:

- to achieve large-scaleness
- to spread knowledge of ISA - contribute to factual discussions
- to confirm positive effects
  - large speed reductions and reduced spread of speed with free driving conditions
  - smoothing braking process at roundabouts, intersections and curves
  - greater time gaps between vehicles in the speed interval 30-50 km/hour
  - increased acceptance after testing the ISA system
- to identify a lack of or negative effects
  - no changes in turning speeds or when it concerns giving way to pedestrians
  - no self-experienced improvement with the ISA system
  - lower entry speeds can be traced 30 metres or further from intersections
  - drivers can be a little more passive with the ISA system

Large-scaleness has been achieved in Umeå, where over 4000 vehicles have participated in the trial. The spread of knowledge has been achieved through trials in four sites with the possibility for the general public, journalists and other interested parties to test vehicles. Positive and any negative effects have been studied through questionnaires and road traffic studies.

Pilot trials are directed at urban areas, where acceptance of speed limits and lower speeds in risk situations are greatest. The type situations that are particularly problematic when driving in *urban areas*, are intersection manoeuvres and adaptation of speed with the presence of pedestrians and cyclists. The tested ISA systems that adapt the speed to the legal speed limit can first and foremost be expected to give a damping effect on distances, but there is a hope that the lower speed shall also spread to intersections with a greater tendency to give way as a result.

4.2 Main results

The main results of the trial are briefly presented below. Later in the chapter the results are presented in more detail and with explanations. In general it can be said that the expected positive effects were confirmed and even reinforced, while the results are mixed with regard to the non effects or negative effects. For example, the drivers felt that they had become better drivers when using ISA at the same time as there is a tendency to become either a more active or passive with ISA in the vehicle.

Improved road safety without increasing travelling time

All in all the evaluation shows that it is reasonable to believe that road safety has improved significantly by using ISA. If everyone had ISA, there could be 20% fewer road injuries in urban areas.

The average speed on stretches has clearly fallen with ISA. The ISA vehicles drive more homogeneously and with less spread of speed, which probably increases safety even more. Pedestrian awareness has increased.

Entry speeds into intersections (at the beginning of the braking process) have also fallen with ISA, more than half the effect towards the centre of the stretch. Even the lowest speed in the middle of the intersection has fallen for three-legged intersections (not four-legged intersections and roundabouts).

Travelling times in urban areas remain unchanged despite lower driving speeds in specific areas. The explanation is because there is less stopping and fewer braking situations with ISA. In this way, delays in queue situations and at intersections are reduced, so the average travelling time is not affected. Road-users experience travelling times as unchanged or marginally longer. Measurements for active gas indicate that travelling times are even marginally shorter.

Acceptance of ISA is high

A clear majority of drivers believed that you keep to the speed limit on 30 and 50 km/hour roads.

Acceptance of ISA in urban areas is extremely high. Even higher than the level for seat belts before legislation was introduced. Around 35% used seat belts before it became statutory. When legislation was introduced usage increased to about 80%.

There is a belief of becoming a better driver when using ISA. Around two in three wanted to keep the system if it was free, while around one in three could even consider paying a limited amount. One in ten in Lund used the system voluntarily outside of the test area. (The speed limit was then set manually.)

Test drivers sufficiently representative

The recruitment group represented the average driver quite well. Those who chose to take part were somewhat more positive to the trial then those who chose not to take part, which is quite natural. Support of ISA was particularly appreciated on 30 and 50 roads and in vulnerable/dangerous road environments. In Umeå the fleet of vehicles represented - 4000 vehicles - as much as 10% of vehicle kilometre travelled, which means the result ought to be sufficiently representative in order to draw sustainable conclusions. It was primarily due to technical reasons that persons could not take part in the trial. Women are however underrepresented among the test drivers, as they generally driver older models than men.

The test drivers thought it was easier to keep the speed limit when using ISA. It was an advantage to see the speed limit on a display. 70-80% considered the basic concept of ISA to be good, even if the technology (GPS-coverage, movement among the active accelerator) has not been completely reliable during the trials.

Problems and difficulties have interfered with the trials, yet in the evaluation the drivers have, to a certain degree, be able to distinguish between the equipment in the trials and the technology itself. In all probability the opinions would have been even better without the problems, especially for active gas. Active gas caused the most trouble (sometimes, frequently or very often 37% in Lund, 46% Lidköping) followed by informative (41% in Borlänge, 14% in Lidköping) and least warning (5% in Umeå).

ISA-vehicles influence other road users

The results in Umeå indicate that other road users were also affected by ISA. This means that large effects can also be attained even with a smaller amount of ISA vehicles on the road.

ISA may prove to be the best idea yet together with policing to solve road safety problems on 50 roads in urban areas. This is where most personal injuries occur and acceptance for alternative physical measures, for example, road bumps is low.

Small differences between systems

Effects on speed differ very little between the systems. The driving speed fell on routes by up to 3-4 km/hour for each of the systems. The difference between the systems for the entire road system at 30-50 km/hour, which is the main focus of the trial, only amounted however to 0.3-0.4 km/hour. The reason being, among others, that the audio signal in the warning system was experienced as so irritating that attempts were made to avoid it. In general this resulted in the same speed reduction as for active accelerator. Consequently, the choice of system should also be based on other criteria, such as cost, operating reliability and user points of view.

Warning and informative systems were preferred in advance by most people among the general public and among those recruited. Only around half as many considered active gas to seem suitable.

A distinctive trait after the trial was that the test drivers thought that the system they tested was the most effective in order to increase road safety. Order of preference straight off for all test drivers is: warning, informative, active gas, nevertheless, the differences are small! The parallel driving simulator study shows that the drivers have fixed perceptions about which system is preferable. Therefore it may be advisable to develop a system where the user can select between an active or passive system.

You must accelerate a little more with warning/informative, somewhat less with active gas. You feel a little more "in the way" with warning, still a little more with informative and the most with active gas. You look more at the speedometer with warning, a little less with active gas. Glancing at the speedometer fell for everyone in time.

Attention to speed signs increased a little for warning, which has no display. It was unchanged for informative and it fell slightly for active gas.

Fuel consumption is believed to have dropped a little for informative, but only marginally for warning and active gas. According to the test drivers' own assessments the speed has dropped in the trial area: for all stretches of road (30, 50, 70 km/hour). The experienced reduction was greatest for active gas, approximately 2 km/hour. The least effect for warning (10-20% lower), but this is still in the same magnitude. Measurements support that the driving speed fell by 1-2 km/hour, while travelling times including stops remained unchanged.

The system must be improved to become more attractive

ISA is perceived to be effective for the purpose, but the equipment is not so pleasing with regard to its design, etc. The possibility for the user to adjust the audio signal is one wish. Fewer than 20% have often or quite often wanted to switch off the audio.

Driving pleasure is unchanged for warning and informative systems, but fell a little for active gas.

Drivers have noticed that the warning is given a few km/hour over the speed limit on their own speedometers. Greater demands should be made on speedometers in cars showing the correct speed when using ISA (or that ISA replaces the speedometer).

Subsidies or other incentives (lower insurance premiums, etc) may be necessary to stimulate voluntary acquisition.

Issues concerning the introduction of ISA!

When you are the only one using ISA you feel more in the way. According to the drivers it therefore important in the long term that ISA is introduced for everyone!

Many believe that the introduction of ISA should be statutory for special groups (new driving licence holders, notorious speeding offenders and drink-drivers).

The state and municipalities can take the lead by equipping their own fleets of vehicles and through making demands on ISA for publicly procured transport services.
Commercial and company car drivers are generally negative to the trial and the introduction of ISA. Equipment has been sabotaged during the trial. The negative attitude of commercial drivers must be influenced through dialogue with drivers as well as employers and by looking over stressful working conditions.

4.3 Methodology

Conditions

Evaluation of the large-scale ISA trial has started from experiences from earlier smaller trials in Eslöv and Umeå. Twenty of more hypotheses on the effects of ISA have been formulated with the guidance of these trials and have been prioritised in the national evaluation. In the smaller trials good experiences concerning the effects of ISA were received, which is why much of the evaluation has been concentrated to the users' acceptance of the system and how the user interface has been perceived. At the same time we know that acceptance tends to be higher for systems that do not affect the driver as much and therefore have limited road safety effects. Consequently, it is a question of finding a suitable balance between high acceptance and greater effects with the starting-point that the system should be voluntary and supportive. Evaluation has therefore also been designed to examine how large the road traffic effects are that the different systems give both on average and locally at critical points in the road traffic system.

The organisation of the ISA trials has meant that the trial sites have been given great freedom to structure the trials and evaluation themselves. The reason for this has been the Swedish National Road Administration has primarily concentrated on the objective of gaining large user acceptance. The large-scale trial is an important phase in a strategy to achieve a major introduction of speed adaptation systems. The introduction is thought to start locally, under each trial municipality's specific conditions, to then spread to other regions and nations. The dialogue with citizens has therefore been an important starting point. Information about speed adaptation has therefore been distributed to all citizens during the trials, not only to the test drivers. This has naturally affected the results and should be seen as a part in the process to be evaluated.

Co-ordination of the evaluations of the four trial sites has the intention of giving sufficient results for an assessment of the hypotheses that have been prioritised in the national evaluation. It was realised at an early stage due to budget reasons that the implementation of all types of investigations at all sites was not possible. Co-ordination has therefore tried to ensure that the evaluation of the four trial sites together meant that all prioritised hypotheses were investigated. In addition, we have tried to bring about that as many comparisons between systems as possible could be made. Besides the national evaluation, a number of further studies were made locally at the different trial sites based on local interests. The results of these studies are evident from the final reports of the trial sites.

Expectations of a general introduction of speed adaptation

According to a compilation in 1998[10] large positive effects had been established in earlier trials with speed adaptation in vehicles. Large speed reductions and reduced spread of speed with free driving conditions. The speed process and speed adaptation at roundabouts, intersections and curves had been smoother. In addition, acceptance had increased among the test drivers after having tested speed limiters. For this reason a large number of questionnaires are included in the evaluation of the ISA trials to investigate acceptance before, during and after the trial.
With an evaluation of the large-scale trials it has been important to confirm the positive effects reached in earlier small scale trials, to identify any negative safety effects and to establish expected 'exposure effects' from the trial vehicles to the surrounding vehicles and from road stretches to intersections. In Umeå with 4000 vehicles, which represented 5-15% of the road traffic work on different types of roads, it has been possible to study the “exposure effects”.

Accident development in urban areas has been studied through the comparison of accident figures in 1996-98 with the following three year period 1999-2001. Accidents reported by the police in the National Road Administration's accident database VITS have been extracted. Resulting in all accidents with motor vehicles occurring in **urban areas** being included, on both national and municipal roads.

10 Várhelyi, A. and Mäkinen, T (1998). Evaluation of in-car speed limiters. MASTER.

An urban area is defined as a community with at least 200 inhabitants and a maximum distance of 200 m between properties. This means that the material also comprises all accidents in smaller urban areas in rural districts. These smaller urban areas have in general one or more national roads as thoroughfares which have a speed limit of 50 or 70 km/hour.

In 1996-98 police reported that 22580 personal injury accidents occurred with motor vehicles in urban areas. The number of seriously injured and fatalities (DSS) in these accidents was 4803 (24770 minor injuries) Table 4:1 below shows the apportionment as a percentage of speed limits to the number of personal injury accidents and the number of DSS. The table also presents the apportionment at intersections and road stretches.

Table 4:1 ***Apportionment as a percentage for speed limits to personal injury accidents and the number of DSS in the years 1996-98 (accidents with motor vehicles).***

Speed limit (km/hour)	**Personal injury accident**			**Number of fatalities and seriously injured**		
	Intersection	**Stretch of road**	**Total**	**Intersection**	**Stretch of road**	**Total**
30	0.9%	0.5%	1.4%	0.9%	0.5%	1.4%
50	58%	22%	80%	53%	23%	77%
70	8.7%	5.4%	14%	9.4%	7.9%	17%
90	0.5%	0.5%	1.0%	0.9%	1.2%	2.0%
No data	2.0%	1.5%	3.5%	1.5%	1.2%	2.7%
Sum	70%	30%	100%	66%	34%	100%

As is evident from the table 80% of the personal injury accidents occur on 50 roads and nearly 60% at intersections on 50 roads. Around 15% of the personal injury accidents occur on 70 roads. The share on 30 roads is low, about 1.5%. In total 70% of accidents occur at intersections and 30% on stretches of road.

The serious injury consequences in the form of the number or fatalities or seriously injured are spread approximately as the number of accidents, with 70 roads having a slightly higher share and 50 roads slightly lower compared with the number of accidents In total intersections answered for just over 65% of the number of seriously injured and fatalities and stretches of road for approx. 35% Accordingly, the dominant road safety problem in urban areas is **intersection manoeuvres and to a certain degree 50 roads**.

The corresponding analysis divided by type of accident shows that bicycle/moped accidents and intersecting paths dominate at intersections. These represent 40% of the personal injury accidents. Next come turn offs and pedestrians at intersections with 17% combined. On stretches of road the dominant type of accidents are single and collisions from behind followed by pedestrians.
These three types of accident answer for approx. 20% of the total number. Note that the share of pedestrian accidents is nearly as large on stretches of road as at intersections.

Table 4:2 ***Apportionment as a percentage for type of accident to personal injury accidents and the number of DSS in the years 1996-98 (accidents with motor vehicles).***

Type of accident	Personal injury accident			Number of fatalities and seriously injured		
	Intersection	Stretch of road	Total	Intersection	Stretch of road	Total
Single	4.4%	6.7%	11%	5.5%	11%	16%
Meeting+overtaking	0.9%	3.1%	4.0%	0.9%	5.5%	6.5%
Collision from behind	5.5%	6.6%	12%	2.3%	2.6%	5.0%
Turning	10%	0.1%	10%	6.6%	0.1%	6.7%
Intersecting	18%	0.1%	18%	15%	0.1%	15%
Bicycle/moped	23%	3.8%	26%	23%	3.7%	26%
Pedestrian	7.0%	5.8%	13%	11%	8.4%	19%
Diverse+game	2.2%	3.8%	6.1%	1.7%	3.1%	4.8%
Sum	70%	30%	100%	66%	34%	100%

Bicycle/moped and pedestrian accidents answer for approx. 45% of the number of fatalities and serious injured, of which nearly 35%-units at intersections. Accordingly, over half of the number of DSS in intersection accidents is from accidents with unprotected road users. Thus it is clear that the dominant road safety problem in urban areas is **intersection accidents followed by single accidents and unprotected road users on stretches of road.**

As the average speed in urban areas on average is low due to delays at intersections it is important instead to assume that it is **individual high driving speeds in critical situations** that have **the greatest significance for danger/safety**. ISA is an application that primarily can be expected on stretches of road, where driving speeds are high and speed limits are frequently exceeded. However, from the report it is evident that about two thirds of the personal injury accidents occur at intersections. Accordingly, from a road safety point of view, it is desirable that the ISA function gives consequential effects with intersection behaviour. In the evaluation logging of the driving process has therefore been carried out for informative systems in Borlänge and for active gas in Lund. This is used to closely study entry speeds, braking process and turning speeds at intersections.

Methods used in the evaluation

Based on previous trials a number of hypotheses were formulated in the project's introduction, these were to be especially studied in the large-scale trials and be included in the national evaluation. These hypotheses have been governing for the structure of the evaluation.

Road traffic effects

The table gives an overview over which forms of measurements were used to test the hypotheses. The hypotheses indicate that measurements concerning road traffic effects ought to comprise:

- average speed and spread of speed with free driving conditions
- driving process including entry and turning speeds at roundabouts and intersections
- occurrence of driving against red lights
- time gaps and vehicle queues

- inclination to stop at zebra crossings
- effects of travelling time, fuel consumption and exhaust emissions

Legend for the designations in the table:

Logging Registration in the vehicle of time, acceleration, speed, position, speed limit with 0.2 sec (Lund), 1.0 or 10 sec (Borlänge) interval.
Interaction Video recording at fixed site. Interplay car driver - unprotected road user

ISA system	**Warning**	**Informative**	**Informative**	**Active accelerator**
Area / district	Umeå	Borlänge	Lidköping	Lund
Average speed for free vehicles	Point speed measurements before/after			
Time gaps and length of queues	Point speed measurements before/after	Not studied		Passenger studies
Driving process at intersections and roundabouts	Attitude studies with driver and conflict studies	Logging of vehicles with/without activated equipment	Attitude studies with drivers	Attitude studies with drivers, interaction studies and logging of vehicles
Entry speed at intersections	Point speed measurements before/after 10 m before the intersection	Logging of vehicles with/without activated equipment	Not studied.	Logging of vehicles with/without activated equipment
Turning speeds at intersections	Not studied.	Logging of vehicles with/without activated equipment	Not studied.	Logging of vehicles with/without activated equipment
Driving against red lights	Not studied.	Not studied.	Not studied.	Especially before/after study of share that drive against red.
Stop at zebra crossings	Not studied.	Not studied.	Not studied.	Special interaction study between road-users and passenger study.
Other effects (travelling time, fuel and exhaust fumes)	Not studied.	Logging of vehicles with/without activated equipment	Not studied.	Logging of vehicles with/without activated equipment

Logging has taken place during a pre-period without activated ISA equipment (approx. 1 month) and during a post-period (remainder of the trial period) with activated equipment. Time, position and speed were obtained from each vehicle as basic data. The driving process can be extracted from the logged material for certain selected places of interest (roundabouts and intersections).

Comparisons between systems were made more difficult by the arrangement of the trials being at four different sites. In Umeå there have been a large number of the equipped vehicles that can give macro effects in speed, time gaps and length of queues, mapped through road traffic measurements. However, the result of these measurements must be "extrapolated" to apply solely for the equipped vehicles in order to compare with the other systems.

In Borlänge and Lund the most important results have been obtained from logging of equipped vehicles, which means road traffic data solely from equipped vehicles. This makes it easy to compare the informative system with active accelerator. However, when these two systems are to be compared with the warning system it becomes more complicated. The comparison must then be made using extrapolated data as set out above. However, the hypothesis is the difference between with and without a display is marginal.

User

The hypotheses indicate that questions ought to be asked in questionnaires within the following areas:

- need of speed adaptation and design of driver support
- ISA's effect on the driving style
- the driver's conceived safety and unprotected road user's safety
- mental strain and concentration on driving
- long term behaviour and attitude changes while the trial is in progress

In the table it is noted how the different user aspects have been evaluated for the different technical main solutions.

Legend for the designations in the table:

Zero	the general public's attitudes in the trial sites early in the project
Zero control	the general public's attitudes in other areas (entire country) early in the project (especially financing)
Recruitment	measuring in connection with recruitment of drivers (even those who do not accept)
Pre	the attitudes of test drivers including commercial drivers before the system was used
Under	attitudes of the test drivers including commercial drivers (panel's) at different stages of the trial as follows:
One month	attitudes of the test drivers (panel's) after one month of test driving
Middle	attitudes of the test drivers (panel's) after half of the trial period (only Umeå)
Post	attitudes of the test drivers (panel's) after the completed trial (in the final phase)
End trial	attitudes of the general public in the trial sites in the final phase/after the completed
Final control	attitudes of the general public in other areas (entire country) after the completed trials (implemented with special financing after the ISA project has been completed)
Unprotected	Special investigation with unprotected road users or general public (residents)
Passenger	Observer(s) travel with a selection of test drivers on a planned route. Even special with instrumentation in the car.
Conflict	Studies of conflict situations primarily at intersections
Focus	Group discussions/in depth interviews according to special schedule

ISA system	**Warning**	**Informative**	**Informative**	**Active accelerator**	**Active accelerator**
Area / district	Umeå	Borlänge	Lidköping		Lund
Need of and attitudes to speed adaptation	Zero, zero control, under, end, final inspection, focus, conflict	Zero, zero control, under, end, final inspection, focus	Zero, zero control, under, end, final inspection, focus		Zero, zero control, under, end, final inspection, focus, interaction, passenger
Design of driver support	Under, focus	Under, focus	Under, focus		Under, focus
Notion about ISA's effect	Under, focus	Under, focus, logging	Under, focus		Under, focus, logging, passenger
Safety and road safety	(Zero and end), under, focus, unprotected, conflict	(Zero and end), under, focus, unprotected	(Zero and end), under, focus		(Zero and end), under, focus, unprotected, interaction, passenger
Mental strain	Under	Under	Under		Under, passenger
Concentration on driving	Under	Under	Under		Under, passenger
Long term attitude and behavioural changes	Zero, zero control, under, end, final inspection, focus	Zero, zero control, under, end, final inspection, focus, logging	Zero, zero control, under, end, final inspection, focus		Zero, zero control, under, end, final inspection, focus, logging

The size of the trial has given good possibilities to analyse the material based on the variations under the conditions that applied. On the other hand it has been significantly more difficult to generalize the results as the selection, to a certain degree, has been controlled by the conditions that co-vary with attitudes to speed adaptation system. Different control possibilities, among others, discontinuance analysis have been used to examine the representativeness.

Product/System

The hypotheses indicate that the following issues ought to be highlighted:

- the system's functionality and intelligibility
- will to pay for different ISA systems
- ideas for the development of the technology

Opinions about the product/system have been included as a part of a user questionnaire that was distributed. In addition, the user interface and other implementation issues have been discussed in parallel with the trials in a separate expert group which has been linked to the project. Volvo has also implemented a separate study in its driving simulator in order to provide further aspects concerning the user interface among a future ISA function.

ISA system	**Warning**	**Informative**	**Informative**	**Active accelerator**	**Active accelerator**
Area / district	Umeå	Borlänge	Lidköping		Lund
Ideas about functionality	Under, focus				
Ideas about intelligibility	Under, focus				
Will to pay	Before, under, end				
Development ideas	Under, focus and driving simulator study.				
Implementation issues	Experiences from the trial sites and discussions in the expert groups in parallel with the trial.				

In order to evaluate the functionality in the best possible way a proposal has been made for the design of the system, which is both separate and in some cases common to the trial sites. This is so it is possible in the evaluation to assess what are functionally related results and what is design related. As a user it is however difficult to distinguish between the function and the design.

4.4 Conditions and differences between the trial sites

Trial sites

Four trial sites have taken part in the trial, Umeå, Borlänge, Lidköping and Lund. The sites have unique properties and prerequisites that affect the possibility of comparing the results
The structure of the population, travelling, the design of the infrastructure, local information campaigns, etc can colour the test drivers' and other respondents' answers to the questions in polls.
Below follows a concise summary of some of the characteristic features for the trial sites:

Umeå

Umeå is a medium-size town (105,000 inhabitants in the municipality) with a university, a young population and relatively high number of cyclists despite the geographical location with darkness and cold during the winter. The number of cars per capita is low, but a great deal of traffic crosses through the town of which a large number are heavy goods vehicles. Road safety is prioritised and there is a current programme to give a calmer and safer traffic tempo. Bumps, chicanes, etc. have been introduced. There is a large number of 30 roads and 30 zones bypassing sensitive sections. Road safety is discussed regularly. Umeå residents are familiar with ISA from an earlier pilot trial.

Borlänge

Borlänge has around 50,000 inhabitants. It is a young municipality with college, state road administration, modern companies and some heavy traditional industries. There are a relatively high number of cyclists on a well developed cycle path system. The road system is of a high class without capacity problems despite relatively high traffic rate. There are areas and stretches of road with a 30 limit. Comparatively high number of cars per capita. ISA is not completely unfamiliar after a minor ISA trial with taxis.

Lidköping

Lidköping is the smallest of the trial sites with just below 40,000 inhabitants. It is not a student town as are the other trial sites, rather a diversified industrial town. Lidköping is a pilot municipality for zero vision, and road safety including ISA has had a lot of space in the local press. The town has a high number of cars per capita, nevertheless still a degree of cyclists. Reported speed calming measures have been introduced.

Lund

Lund is a typical university town with around 75,000 inhabitants. The town is highly characterised by student life with a low number of cars per capita, many cyclists and other unprotected road users. There is a very old town centre with a 30 limit throughout. Campaigns for improved road safety and environment have made the inhabitants aware of the traffic and its consequences. The earlier plot trial in Eslöv with active accelerator has also been reported in the press in Lund.

The role of the trial sites

The trial sites have slightly different roles, which should be taken into consideration when analysing the results.

Umeå

Umeå is the trial site that has definitely had the most participants with close to 4000 equipped vehicles. Here mass effects were primarily aimed for as the ISA vehicle can influence other traffic in lowering its speed and rhythm. Effects on the average traffic can be expected to be traced here. The large number of participants and also the variations in the user studies are special. In Umeå the simplest system was tested, the warning system which is relatively inexpensive and therefore can be introduced on a large scale. Umeå's ISA system was known locally as the "speed checker". The driver received a warning sound and visual signal when the legal speed limit was exceeded.

Borlänge

In Borlänge an alternative technology was used for the informative system. The system consisted of a display that displayed the current speed limit. The driver was notified using an audio and visual signal when the speed limit was exceeded. The audio signal was repeated if the speed violation continued. Two makes were tested. The vehicles in Borlänge were logged, which gave the possibility of comparing the logged behaviour with regard to speed and the acceleration/retardation processes with the data in the questionnaires and interviews.

Lidköping

In Lidköping both informative system according to the Borlänge model and active gas according to the model using in Lund were tested. The role of Lidköping has been to examine the differences in attitudes among drivers who have tested both systems. One complication for the evaluation in Lidköping has been that the trial is a part of the zero vision project. This project embraces several parallel activities that can have an effect on the project result. Here a project journal has been kept to keep control of these external factors. This has been used to record changes with regard to the introduction of 30 zones, new roads, new speed limits, new laws, etc.

Lund

In Lund the trial has been implemented using the active supportive system a.k.a. active gas. The system means the driver perceives a resistance in accelerator when the legal speed limit is reached. A display shows which speed limit applies. The user can bypass the system by pressing down hard on the pedal. For "the same price" the driver receives a speed control system that can be used outside of the trial site. These systems are relatively expensive which is why the number has been restricted. In Lund several different special studies were being made. As in Borlänge the vehicles were logged.

Recruitment

Recruitment is important for the possibility of generalizing the results. From an ideal point of view, the group of test drivers ought to make up a complete image of all vehicle drivers. In practice this is not possible, among others, due to the technical demands on the vehicle in order for ISA to work as well as the selection principle of voluntary participation (with some exception regarding commercial drivers).

An early limitation was that vehicles manufactured before 1988 could not be considered due to the lack of an electronic pulse encoder for the speedometer. Later it came to light that the ISA system did not work well in a number of the newer models from some vehicle manufacturers due to numerous different reasons (varies depending on the type of system). This could be a question of problems caused by magnetic fields generated by fans, wipers or that the active supportive system caused changes to the vehicle's performance. There were also practical problems with accessibility in connection with installation. The limitations above meant the nearly half of the vehicle park was excluded from the possibility of being used in the trial. Owners to older vehicles are generally younger and frequently women more than average and have lower incomes. This as well as whether this category of vehicle driver has another attitude to speed and road safety has been closely studied through a discontinuance analysis.

Private test drivers take part due to their own interest. A certain bias could be feared as those who applied are basically positive and/or curious about either ISA in generally or the system on offer. The recruitment procedure for private test drivers has varied between the trial sites.

In Umeå recruitment basis was made up of a random selection among owners of vehicles within the municipality that the speed adaptation system was adjudged to work satisfactorily in. Later the recruitment basis was expanded over a greater geographical area and that even car owners that had changed to newer vehicles during the last year were included. These were contacted by post and telephone and offered the chance to participate. Those who declined received resulting questions about their motives behind not participating. The recruitment basis in Borlänge with regard to private drivers was made up of registered vehicle owners in the municipality. Even here supplements were made to fill the quota with private drivers.

In Lidköping recruitment of private test drivers was carried out according to marketing in connection with special arrangements and with information. Interested drivers could apply. In addition, to get a reasonable spread bearing in mind age, sex, vehicle type, car usage, etc. a random selection of inhabitants in the municipality were asked about their interest in being included in the trial. Due to the limitations of using active gas in all cars even directed recruitment was used. For those indicating their interest there was a possibility to choose which type of ISA system they wanted to try. The choice of system was also affected to a certain degree by the supportive system (active gas) also working as a constant speed control outside of the test area. This extra bonus was judged not to have such a great effect on the evaluation.

In Lund introduction letters, information brochures and questionnaires were sent out to randomly selected car owners from the car register. The ambition was to group the test drivers in 16 cells bearing in mind sex, age and attitude towards ISA. However, the received replies did not fill all the cells, especially for young drivers and older, female drivers. Therefore a supplementary dispatch was sent out aimed at these groups. A discontinuance analysis was carried out to find out why people did not want to take part in the trials or wanted to leave the trial after starting.

Drivers of municipal owned vehicles and commercial vehicles also took part in the trials. These were not recruited personally but through direct contact with the operative management at respective administrations/haulage companies. Accordingly, the drivers did not choose to participate themselves. Consequently, a comparison with private drivers would be of interest, but as the commercial drivers did not want to answer the questionnaires to the same degree as the voluntary recruited private drivers the data was insufficient.

4.5 Who became test drivers?

In total some 22,500 persons were contacted at the four trial sites. The response varied immensely between the trial sites, mainly due to which contact method was used. In Umeå, where contact was made via the telephone and then recruitment forms where sent out, a response was received from 86%. Even in Lidköping, where direct contact was primarily used, the response was high, 80%. In Lund 61% responded and in Borlänge 38%. In these towns information material and forms as well as reminders were sent out to those selected per post.

Two of three asked (61-71%) were not interested in participating in the trial. The motives as to why they did not wish to participate varied immensely. A large number stated that they do not drive in urban areas very often, that they nevertheless drove carefully and that they did not have time. One fifth of those declining were more critical to ISA and the trial. They want to decide how they drove, referred to the feeling of being supervised or that they did not want damage or have more gadgets in the car.

Of those who initially applied many withdrew before the trial started or once it had started. There were many reasons for this. They had changed their mind, changed car or found technical problems in connection with installation or during the preliminary test-driving. The latter is probably an explanation as to why so many gave up in Lidköping and Lund compared to the other trial sites as the problems with active gas were greater than for both of the other types of system.

Table 4:3 Some background data about the private drivers contacted during recruitment.

	Number/share %				No. of men %				Average age			
Trial site	U	B	Li	Lu	U	B	Li	Lu	U	B	Li	Lu
Total number contacted	13852	3000	1830	3875								
Total no. responses	11971	1143	1453	1607								
Share response	86	38	80	61								
Of those responding: Not interested	61	66	71	61	79	64	79	62	48	52	50	49
Interested but did not participate (withdrew)	14	17	20	23	79	67	79	64	49	51	51	49
Interested, participated as test driver	26	17	9	16	81	69	78	67	55	52	55	49

The share of men dominates in the recruitment selection, especially in Umeå and Lidköping (81 resp 78%). In Borlänge the share of men amounted to 69% in the test driver group and 67% in Lund. Data from Borlänge and Lund corresponded well with the amount of male car owners for the entire country, which is 68% [11]. Accordingly, women are underrepresented in the group from the recruitment basis that became test drivers in Umeå and Lidköping.

The average age of the test drivers from the recruitment selection is 55 years old in Umeå and Lidköping, 52 in Borlänge and 49 in Lund. The average age among those not interested in Umeå and

11 Vehicles at the turn of the year 2000/2001. SIKA SSM 01:6

Lidköping are about 5 years younger, for the other sites it's unchanged. An explanation to the age difference and the over representation of men could be that women and young persons to a greater degree than men and older drivers own and drive older cars, which for technical reasons cannot be used as test vehicles.

In order to compensate for the imbalance with regard to sex and age in Lidköping so-called co-drivers were also included in the evaluation. This meant that all family members that drove the family's ISA car answered the questions in the study. This increased the share of women on average to 35% and the age difference was levelled out.

Those interested in participating were generally more positive to the current ISA systems than those who did not want to participate. This is evident from figure 4:1 which shows the size of the share of respective interested (of which some became test drivers) and not interested but who thought the system seemed good (quite or very good). The general public (selection of the population) answered to the stronger question as to whether they could be interested in purchasing ISA. Their opinions are also inserted in the figure.

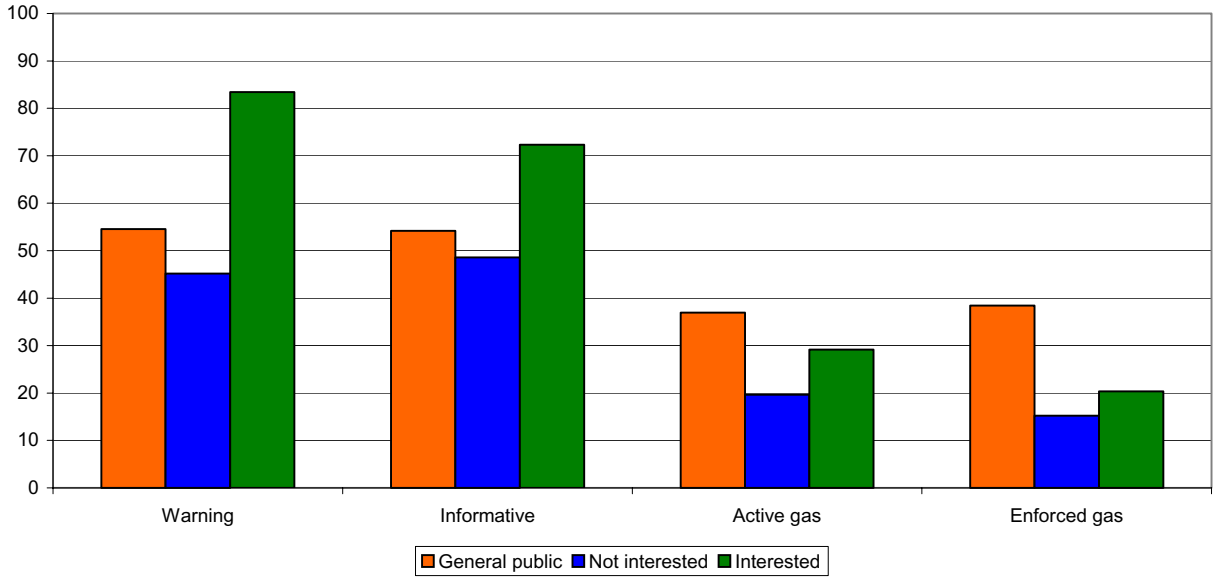

Figure 4:1 Share of different groups (all trial sites) that though it would be good or quite good to have different ISA systems (the public: interested in acquiring ISA without actually testing it)

Opinions differed considerably between trial sites. In Umeå the warning system received the most supporters of those interested. Followed by the informative system while active gas and enforced gas in Umeå only had 20% of supporters. The same pattern was noticed in Borlänge while those interested in Lund and Lidköping gave the informative system the most votes, followed by the warning system but active gas also had many supporters (60%). Nearly half of those not interested in participating considered the warning system respective informative system to be good or quite good and a few less among the general public could consider acquiring these systems. About 20% are interested in active gas.

Earlier trials in Umeå and Eslöv and the local information in connection with these trials have probably affected the answers as well as the concise wording of the question.

Conclusions about representativity

The recruited test drivers quite well represent the average car driver even if the majority of those asked, for different reasons, did not participate. The test drivers are road safety conscious, realize that they need support to lower their speed and are thereby somewhat more motivated to test the technology than drivers in general. However, the differences are not greater than that behavioural and attitude changes registered can be said to be typical for the majority of car drivers.

4.6 How has ISA affected traffic and safety?

General arrangement

The field trials and evaluation plans have been arranged so that it should be possible to answer the hypotheses made on the effects of an ISA system. Below a review is made of the expected effects with an introduction as the result of the evaluation[12]. The report tries to answer the questions around the hypotheses 1-8 below in section 4.9.

Road environments

The effects of an ISA system are naturally different for different types of roads and speed limits. Therefore, in the evaluation of road traffic effects, a classification of road environments has been used based on the two factors above and the type of area. The division according to road type follows the functional division used in ARGUS[13]:

- centre zone, 30 km/hour
- local road, central, 30 resp 50 km/hour
- local road, suburbs, 30 resp 50 km/hour
- service road, 30 resp 50 km/hour
- industrial road, 50 km/hour
- main road, 30, 50 resp 70 km/hour
- approach/thoroughfare 2-lanes, 50 resp 70 km/hour
- approach/thoroughfare 4-lanes, 50 resp 70 km/hour
- crossing zone, 30-50 km/hour resp 50-70 km/hour

The centre zone means that a larger interrelated road system where all roads have a 30 km/hour throughout the day or in the daytime. Meeting places in the centre zone only exist in Lund and Borlänge.

The measurement section named crossing zone only exists in Umeå. This involves a measurement section on a link where the speed limit changes at the subsequent intersection and a new limit applies on the next link in the direction of travel.

In each trial site an inventory has been made of appropriate measurement sections and a number of ultimate measurement points for speed measurements have been selected. In Borlänge and Lund these measurement sections are also used for more detailed reporting and analysis of data from the logged ISA vehicles.

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12 The main part of the results is presented here. Further details can be found in "Final report for the sub-project road traffic effects - analysis of road traffic measurements" (Linköping 2002-07-05).

13 ARGUS-Handbook with general advice about the design and standard of roads. The Swedish National Road Administration and the Swedish Association of Local Authorities. 1987.

Traffic situation at the four trial sites

For **Lund** it can be said that average speeds are relatively low and problems with high average speeds cannot be observed. Instead it is speed violations that are the greatest problem. Only 30 roads have speeds that clearly exceed the speed limit and where the amount of speed violation is high at certain points in the road system. On 30 roads the share of speed violation is 65-70% at the measurement section in the middle of links and average speeds here clearly exceed 30 km/h. Measured in vehicle kilometres travelled across the entire system violation dropped to just over 30%.

Even on roads designated as 50 km/h the average speeds lies above the designated speed on some measurement sections and the share of violation lies at 40-45%. On some stretches of road, primarily the large approach roads with double lanes, the share of violation is about 60%.

Consequently, the analysis of measurements shows that Lund, despite a great deal of work, still has problems with high speeds. Those stretches of road where problems with high speeds are at their worst are the roads where the design does not correspond with the speed designations and unprotected road user's road safety demands on low speeds. Thus it is not the average speeds that are the problem for the road traffic situation in Lund, but the 5-10% of vehicles that drive the fastest.

The conclusion of the data analysis for **Lidköping**, exactly as for Lund, can be said to be that average speeds are relatively low and problems with high average speeds cannot be observed. Only on 30 roads are there average speeds that clearly exceed the speed limit and where the share of violation is high, 65-70%. 50 roads generally have relatively moderate speeds with violation under 40-45%. The highest speeds (85-percentile) lie here at 60-70 km/h. There are no measurements for approaches/thoroughfares. With regard to speeds on roads in Lidköping, the municipality does not consider it to be problem-free just because the average speed is low or under the designated speed. Also here it is the share that drives the fastest that is the problem.

Conclusions for **Borlänge** can be summaries as high average speeds occur only on the best road system, namely four lane approaches. Here the average speed lies above the speed limit and the share of violation is high 70-80%. The highest speeds in the form of 85-percentile lie 17-18 km/h above the speed limit. In addition, there is a main road with a 30 km/hour limit with a high share of violation. Common 50 roads generally have moderate speeds with average speeds under 50 km/hour and the share of violation is below approx. 50%. 85-percentile lies at the highest at 68 km/h.

The conclusion of the data from **Umeå** can be said to be that average speeds are relatively low and problems with high average speeds cannot be observed. Only on isolated 30 roads are there average speeds that clearly exceed the speed limit and where the share of violation is high, 65-85%, and the highest speeds lie at just over 50 km/h. 50 roads generally have moderate speeds with average speeds around 50 km/hour and the share of violation is below approx 55-60%. The highest speeds in the form of 85-percentile lie in the interval 57-63 km/h. This applies to 50 roads on the main road system; the local road system has clearly lower speeds. There are no measurements on approaches/thoroughfares. For 70 roads on the main road system an average speed of around 70 km/hour applies and violations of approx 50%.

Accordingly, the average speeds are moderate on most of the roads at the trial sites. It is primarily the occurrence of **isolated vehicles with high-speed violations** that are the problem. The level of speed violations varies from just under 35% on 30 roads down to 12% on 110 roads according to the logged measurements in Lund and Borlänge which cover the entire trial area, see table 4:4 below.

Has the average and maximum speeds of free vehicles been lowered with ISA?

Calmer crossings, improved adaptation to legal speed limits with ISA are expected to give positive safety effects. The effect on the driving speed has primarily been measured through the logging of

vehicles in Borlänge and Lund. Furthermore, the occurrence of 'exposure effects' in Umeå has been studied through road traffic measurements. This has been supplemented with questions partly to test drivers in association with attitude measurements, and partly to other road traffic groups with the final measurements.

Occurrence of speed violations - log data

The average speeds at the trial sites normally lie under the speed limit. Therefore speed problems are primarily linked to specific risk situations and to speed violations. Basic data has been collected through logging to study the development of the share of speed violations.

Table 4:4 Speed violations for logged vehicles in Lund and Borlänge, entire trial area, for a pre-period and two post-periods.

Variable	**Pre-period Not activated**	**Difference, post-period 1**	**Difference, post-period 2**
Lund - active gas			
Share vehicle kilometres travelled above speed limit: at 30 km/hour	33.7%	-14.1%	-6.9%
at 50 km/hour	28.2%	-15.0%	-12.8%
at 70 km/hour	35.9%	-18.1%	-13.6%
Borlänge - informative			
Share vehicle kilometres travelled above speed limit: at 30 km/hour	33.8%	-9.6%	-3.4%
at 50 km/hour	31.1%	-16.4%	-11.8%
at 70 km/hour	21.4%	-13.0%	-9.4%
at 90 km/hour	25.1%	-16.7%	-11.4%
at 110 km/hour	12.4%	-9.5%	-7.4%

The share of vehicle kilometres travelled above the legal speed limit in Lund has dropped by 14-18 percentage points in post-period 1, but then increased a little in post-period 2. The reduction after this period is 7-13 percentage points with the least effect at 30 km/hour.

In Borlänge the speed violations have dropped by 10-16 percentage points in post-period 1, which is marginally lower than in Lund. However, in post-period 2 an increase in the share above the legal speed limit was noted. The reduction after this period is 3-12 percentage points with the least effect at 30 km/hour and greatest at 50 km/hour.

The share of vehicle kilometres travelled above the legal speed limit has obviously dropped significantly. This probably occurs first and foremost in free vehicle conditions[14] why the effect on the driving speed is low. The effect seems to be at its greatest on 50 and 70 roads, where personal injury accidents are concentrated. The reduced number of speed violations with that ought to have contributed to increase road safety. However, one concern is the effect drops off in post-period 2. Clearly the drivers gradually adapt so that they drive as close to the limit as possible. This results in the share of violations increasing once again, but speeding is probably in these cases only marginal.

14 Here free vehicle conditions refer to unobstructed vehicles with a time gap to the vehicle in front of at least 5 seconds.

A comparison between systems shows that the speed violations drop slightly more with active gas, but the differences are small. Maybe it's possible to say that active gas is more effective at 30 km/hour, where many find it difficult to keep the statutory speed limit.

Average speeds - log data

In Lund and Borlänge each ISA equipped vehicle has been logged during journeys within the trial area. Logging was done one month before the equipment was activated and then with activated equipment during the remaining trial period. Accordingly, the log data has consistently been divided into **non-activated** equipment and **activated** equipment, that's to say a before and after comparison. In turn the after material has been analysed in two periods. An initial first period which, for each vehicle, is approximately the first month after activation. Then about one month has been selected at the end of the trial period in order to examine any long-term effects.

Table 4:5 Average driving speed for logged vehicles in Lund and Borlänge, entire trial area, for one pre-period and two post-periods.

Variable	**Pre-period Not activated**	**Difference, post period 1**	**Difference, post period 2**
Lund - active gas			
Driving speed at 30 km/hour	21.9	-0.8	-0.2
Driving speed at 50 km/hour	36.4	-1.1	-1.2
Driving speed at 70 km/hour	58.7	-2.0	-2.0
Borlänge - informative			
Driving speed at 30 km/hour	25.3	-0.6	-0.6
Driving speed at 50 km/hour	38.7	-1.5	-1.5
Driving speed at 70 km/hour	58.7	-2.8	-3.0
Driving speed at 90 km/hour	84.4	-2.5	-3.4
Driving speed at 110 km/hour	97.3	-1.1	n.a.

The driving speed (when the vehicle is moving) in Lund has fallen marginally at the end of the trial period at 30 km/hour, but a little more at 50 and 70 km/hour, 1.2-2.0 km/hour.

In Borlänge the driving speed has fallen by 0.6 km/hour at 30 km/hour, but a little more at 50 and 70 km/hour, 1.5-3.0 km/hour. The effect at these three speed limits is strikingly similar to that in Lund. At 90 km/hour the driving speed has fallen by approx. 3 km/hour and at 110 km/hour by a few km/hour. The value for post-period 2 is not applicable due to a speed reduction to 90 km/hour during the period.

To sum up it can be said that the effect on the average driving speeds by ISA is clear but small, which is feasible as these are, to high degree, a function of the traffic flow and road design. In addition, the average speeds are already when starting low and well under legal speed limits.

A comparison between systems perhaps surprisingly shows that the informative system in Borlänge had a greater effect on the driving speed. Due to difficulties in maintaining the speed exactly the system first warns at 2 km/hour above the speed limit, which ought to mean higher average speeds. The difference at 30-50 km/hour, which is the main focus of the trial, only amounted however to 0.3-0.4 km/hour.

Differences between road types - log data

The average point speed for logged vehicles has been calculated in the measurement sections where speed measurements were made. This has been done for both pre and post situations. Table 4:6 below shows the measured average speeds from logged data. The measurement section lies a little different in Lund and Borlänge, which is why road types have not been included. Data from post-period 2 in Borlänge is unsafe, which is why period 1 has been reported instead.'

Table 4:6 Logged data in Lund and Borlänge at measurement sections for one pre-period and post period 2.

	Lund - active gas		*Borlänge - informative*	
Road type	**Pre-period not activated**	**Post-period 2 activated**	**Pre-period not activated**	**Post-period 1 activated**
Centre zone 30	26.3	+0.1	21.6	-0.4
Local road 30			21.2	+2,6
Local road 50/30			26.1	-2.5
Service 30	32.2	-2.3		
Service 50			35.0	-2.8
Industrial road 50			39.2	-2.3
Main road 30	31.5	-1.2		
Main road 50	46.4	-1.9	44.6	-2.2
Main road 70			52.9	-3.0
Approach 50 2-lanes	50.0	-4.1		
Approach 50 4-lanes	51.3	-2.3	49.2	-3.0
Approach 70 2-lanes	60.3	-0.2		
Approach 70 4-lanes	57.3	0.0	73.6	-2.4

Supplementary analyses made in Lund for other approaches with 70 km/hour have shown that speed reductions have also occurred there, which corresponds better with table 4:5. In summing up it can be said that during the post periods the average speed for the trial vehicles has fallen by 2-3 km/hour on service roads, main roads and approaches. For local roads there are both speed increases and decreases. There the effect of ISA is uncertain. Differences between different types of roads are small and uncertain.

The spread of speed and maximum speeds - examples from log data

The results above for average speeds and speed violations in Lund show the spread of speed has reduced within the group that tested ISA. Data for logged vehicles in individual measurement sections can be summarised by: the higher the original average speed the greater the speed reduction provided that the average speed is above or close to the legal speed limit in the pre-situation. The speed reduction in post-period 2 varies from 5 km/hour on 70 roads down to 1 km/hour on 50 roads with mixed traffic.
For the standard deviation the results show a reduction by about 40% on 70 roads and approaches at 50 km/hour. For other 50 roads and 30 roads the reduction in standard deviation is somewhat less, approx 30-35%.

This means the reduction in speed for the 85-percentile[15] on approaches at 50 km/hour is approx. 3 km/hour higher than the average value on these roads (in total approx. 6-7 km/hour on approaches for the 85-percentile) and approx. 3.5 km/hour greater on 70 roads. For the 15-percentile on approaches 50 km/hour the net effect becomes a little increase in speed by 0-1 km/hour.

The reduction in the spread of speed is significantly lower with the informative system in Borlänge compared with Lund which tested active accelerator. The difference is feasible as you are not forced down to the speed limit using the informative system as you are with active gas, which gives space for individual differences and with that a greater spread of speed. A reasonable estimation is that the standard deviation drops by 20-25% with the system used in Borlänge. This means that the 85-percentile for 50 roads falls by 1.5 km/hour more than the average value (in total approx. 3.5-4 km/hour) and by approx. 2 km/hour more on 70 roads. For the 15-percentile the net effect remains at an unchanged level on 50 roads or a small reduction by 0.5 km/hour.

The effect of the ISA-systems is illustrated in figure 4:2 below. The figure shows a frequency chart which is representative for an approach or fair main road at 50 km/hour. The average speed without ISA is 55 km/hour and the standard deviation 8 km/hour. The curve applies for free vehicles or with a limited share of obstructed vehicles (maximum 40%).

The ISA system reduces the average speed down to 50.0 km/hour, but also the spread of speed. For active gas the standard deviation is 5.0 km/hour and for the informative system 6.4 km/hour. This means a reduction by 38 respective 20%.

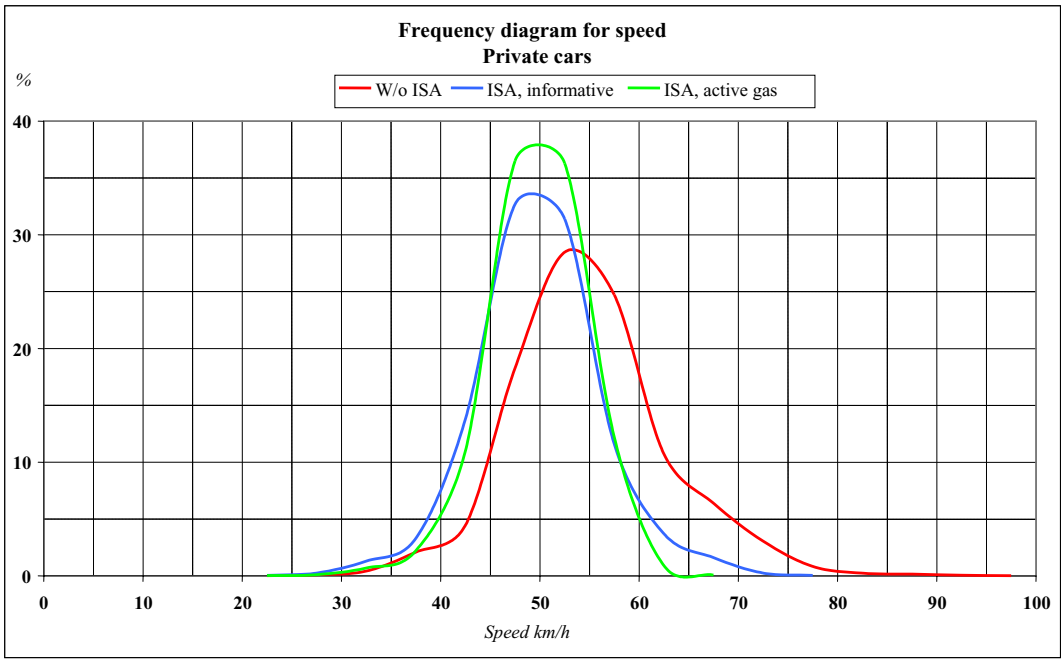

Figure 4:2 Frequency chart speed for non ISA-vehicles and two ISA systems.

The figure clearly shows a speed reduction and the reduced spread, which results in a greater reduction for the 85-percentile than for the median speed. The "crowding" of speeds towards the interval 40-55 km/hour is especially prominent. The share of vehicles that precisely maintain 50 km/hour has increased by 8 respective 13 percentage points compared with non-ISA vehicles.

15 The speed that 85% of vehicles keep under and consequently that is exceeded by 15%.

As mentioned above the figures apply for a good road design with a high degree of free vehicles. With poorer road types and a great degree of obstructed vehicles the ISA effect becomes smaller.

Exposure effects - traffic measurements

Measurements of average speeds were made in 1999 before the trial and in 2000-01 when the trial had started in Umeå. The metering arrangement in Umeå meant only measurements in one direction in the middle of a road link. In addition, measurements were made at a point 10 m before a subsequent intersection in all measurement sections. This arrangement allowed speed reductions before the intersection to be studied.

Below data is reported from the measurement section with a constant speed limit throughout the entire day, where the ISA vehicles' effect on other traffic can be expected to be at its greatest. This applies to roads with 30, 50 and 70 limits. The measurement sections outside of the trial area, seven in total with one per road type, are reported to the right in the figure.

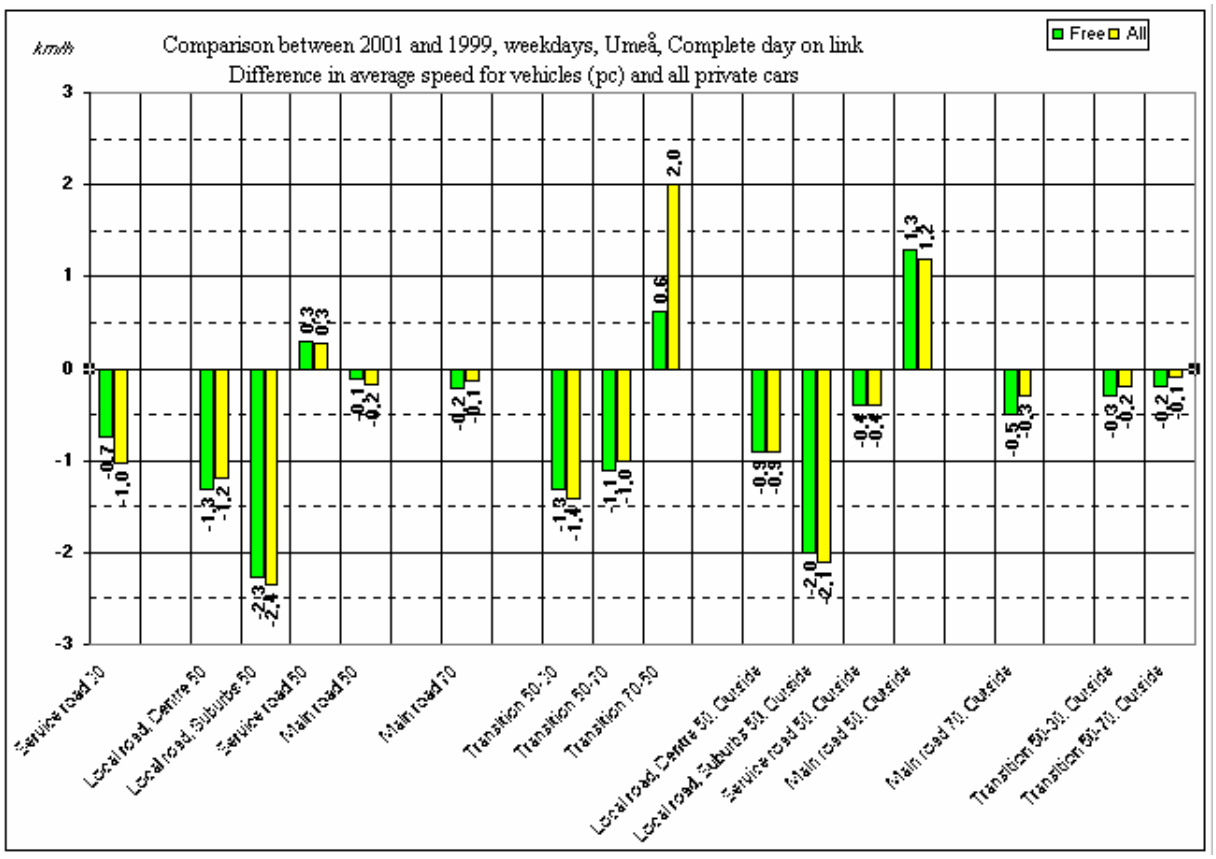

Figure 4:3 ***The difference in average speed (km/hour) for private cars per road environment in Umeå throughout the day between autumn 1999 and autumn 2001, free vehicles and all private cars in the county***

The following comments can be made about the figure above:

- Two sections on 30 service roads have a reduction by 0.7 km/hour. For the 2000 to 2001 the reduction is 0.5 km/hour.

- Prominent reduction of the driving speed on local roads with 50 km/hour and 50-30 transitions (9 measurement sections) by 1.3-2.3 km/hour. The reduction during the last year on local roads is however only 0.3-0.4 km/hour.

- On other 50 roads there is both a little reduction and a little increase. Here the changes have been small during both years.

- On 70 roads there is a reduction by 0.2 km/hour on main roads, but on 70-50 transitions there is an increase by 0.6 km/hour.
- For five sections outside of the trial area a reduction is observed by 0.2-0.9 km/hour. One section of the main road has an increase by 1.3 km/hour. The seventh measurement section outside of the control area (local road suburb) is not comparable. The number of vehicles during 2001 is approx. 40% higher than previous years due to diversions.

- The standard deviation has increased a little on all types of roads except main road 70 km/hour and transition stretches.

A corresponding comparison has been made for the average speed of those private cars that **exceed** the speed limit. In this connection both increases and decreases in the violation speed were noted, but at the most by 0.5 km/hour. This applies to inside as well as outside the trial area. If you consider 2000 to 2001 it is predominantly small increases within the trial area.

The above data indicates a small yet systematic lowering of the average speed between the years 1999 and 2001, but with the main focus on the first year. An investigation of the maximum speeds indicates that the effect on the 85-percentile is somewhat smaller than on the average speed for free vehicles, which can appear surprising. But this is an effect of the increasing spread of speed. Low and medium speeds have decreased more than the highest speeds. Among the highest speeds there are probably no ISA vehicles and furthermore interaction with ISA vehicles is small.

A certain lowering of speed can also be seen in the measurement section located 10 m before an intersection, which is of the same size as for a link. Figure 4:4 below shows data for the measurement section 10 m before an intersection. The result should be compared with figure 4:3.

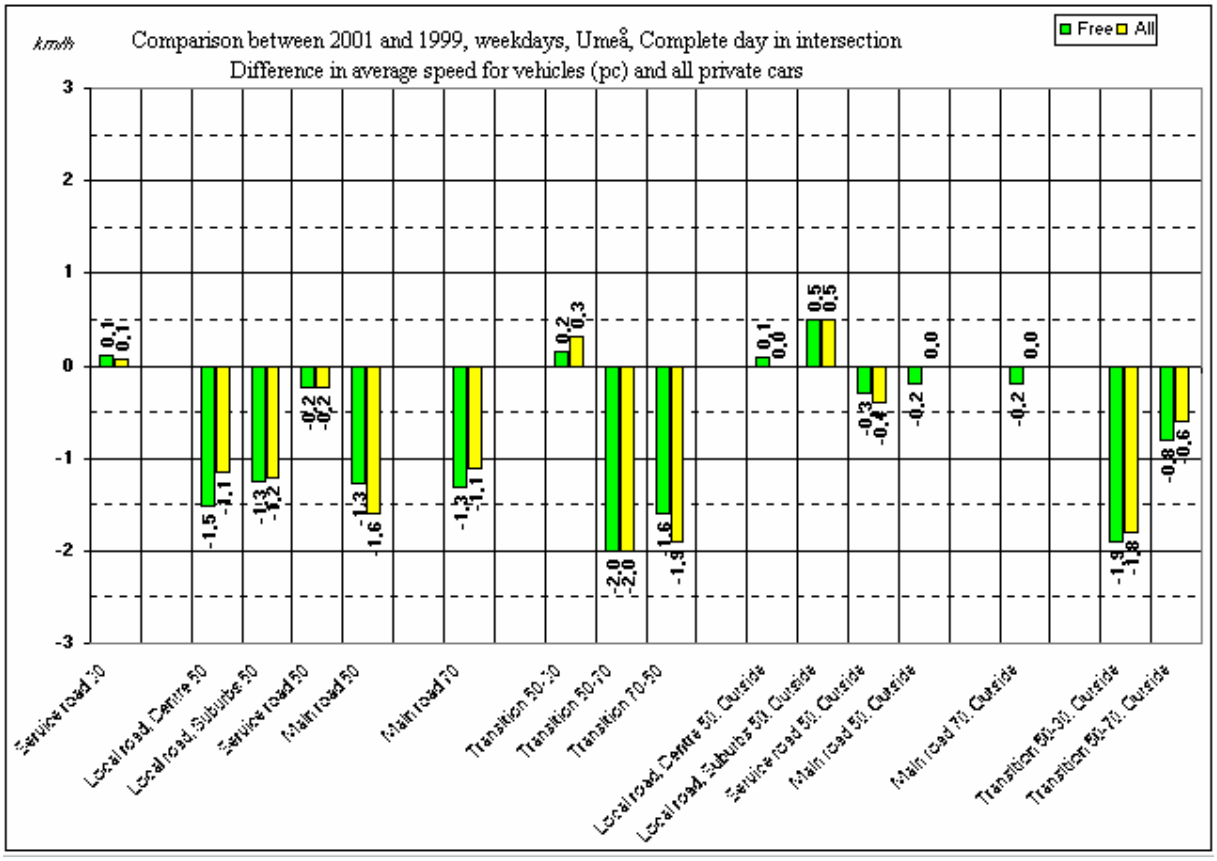

Figure 4:4 ***The difference in average speed (km/hour) for private cars per road environment in Umeå throughout the day between autumn 1999 and autumn 2001, free vehicles and all private cars at the intersection***

As is evident from the figure above there is a clear and distinctive lowering for all 50 and 70 roads except for three sections of 50-30 transitions. The reductions vary between 0.2 and 2.0 km/hour depending on the type of road. Outside of the trial area there is an increase as well as a decrease in the average speed, but under 0.5 km/hour except for two sections on transition stretches that have great reductions.

Accordingly, the reduction in average speed at an intersection is insignificantly lower than for a link on 50 roads, but the lowering is more equally divided over both years. For link the entire reduction is during the first year with unchanged or a minor reduction during the second year. On 70 roads at intersections a certain lowering was observed which was not found on links.

All in all for all measurement sections in Umeå a small yet systematic reduction of the average speed for free vehicles on links can be established. However, this does not apply for 70-roads on the main road system where the average speed remains unchanged at about 70 km/hour with a violation of approx 50%. For 30-roads the effect lies at 0.3-0.9 km/hour with the greatest reduction on the local road system. The reduction in the 85-percentile on 30 roads is approx. 0.2 km/hour greater than for the average speed. For 50-roads the reduction is the same size, 0.6-0.9 km/hour on links, but here the reduction for the 85-percentile is smaller. This means that the spread of speed has become somewhat greater. The standard deviation has on 50 roads increased by 0.3 km/hour. This increased spread is however fully according to expectations. If a small share of 5-10% of the vehicles lowers their speed significantly and the others maintain their speed the result for the entire population is an increased spread of speed.

For measurement sections at intersections marginal effects have been observed on 30 roads. Here the reduction of the average speed is less than or equal to 0.3 km/hour. However, on 50 roads the reduction is only slightly lower than for links and on 70 roads there is a reduction at intersections that cannot be seen on links.

These effects on links and at intersections can very depending on a reduced speed from the 4-15% of ISA vehicles that were in the traffic during the autumn of 2000 and throughout 2001. It is possible to make a theoretical calculation of the average speed for ISA vehicles using the data that has been produced from the measurements and which is reported above under the **condition** that the non ISA equipped vehicles have **the same average speed during 1999 and 2001**. On 50 roads the average share of free vehicles is approx. 70% and the share of ISA vehicles in 2001 is 7%. It is reasonable to presuppose that the share of free vehicles is higher for ISA vehicles, say that the share of free vehicles is 80-100% among ISA vehicles. This then gives a share of the free vehicles of 8-10% that are ISA equipped. Using the average speed and standard deviation among free vehicles entered in 1999 and 2001 as a guide a reasonable estimation can be made of the speed reduction for ISA-vehicles.
The following results were obtained for road links where the interval depends on the share of ISA vehicles as set out above.

- For 50 roads a speed reduction of 2.5-3.0 km/hour among ISA-vehicles.
- For 50 roads plus transitions a speed reduction of 4.0-5.0 km/hour among ISA-vehicles.

The results above must be used with a degree of caution, as it is not probable that non-ISA vehicles had the same speed during both of the years. A feasible assessment is to say that the speed reduction for ISA vehicles is on average 3-4 km/hour on 50 roads.

Yet the speed reduction could be due to a general trend in the traffic, regionally and nationally.
When compared to measurements in urban areas between 2001 and 1999 by the Swedish National Road Administration the following data is obtain for the average speed of private cars:

- An increase for the entire country by 0.1 km/hour for main routes with 50 km/hour
- An increase for the entire country by 0.1 km/hour on B-routes

- A reduction in Region North by 1.0 km/hour on main routes with 50 km/hour
- An increase in Region North by 3.4 km/hour on B-routes

In Region North it is only on main 50 routes that a reduction has been noted while it is a large increase of B-routes. However, these changes are not significant because of a large variation between the different measurement points in the Swedish National Road Administration's measurements. What further supports the hypothesis that ISA vehicles in Umeå have had an effect is the fact that neither is there a clear tendency to a speed reduction in measurement sections with 50 and 70 outside of the trial area.

Conclusions - maximum and average speeds

Speed violations have fallen sharply with ISA. The effect is at its greatest on 50 and 70 roads where personal injury accidents are concentrated. With that the reduced number of speed violations ought to have contributed to increase road safety. A comparison between systems shows that the speed violations drop slightly more with active gas, but the differences are small.

Road traffic measurements in Umeå point towards a small yet systematic reduction in the average and maximum speeds (the 85-percentile), which can be derived to the ISA trial. This shows that spreading effects occur even with the approximately 10% of ISA vehicles that were involved for the trials in Umeå.

How has the driving process and speeds at roundabouts and intersections been affected?

At intersections the speed level is expected to drop, which results in the number of occasions vehicles are involved in conflicts dropping. For vehicles involved in conflict situations the reaction time increases due to the lower entry speed and with that any consequences will be less serious. Logging together with conflict and passenger studies have contributed towards illustrating the issue

Driving process - log data

Speed development approx. 80 m before an intersection on main roads has been studied. An **average speed profile** for incoming vehicles before an intersection has been calculated for all ISA equipped private cars. From this speed profile the lowest point speed (minimum speed) and the highest point speed (maximum speed) before an intersection have been decided. Calculations as above have also been made for a pre-period and two post-periods.

Figure 4:5 below shows a measured driving process from Lund where the max. and min. speeds are highlighted.

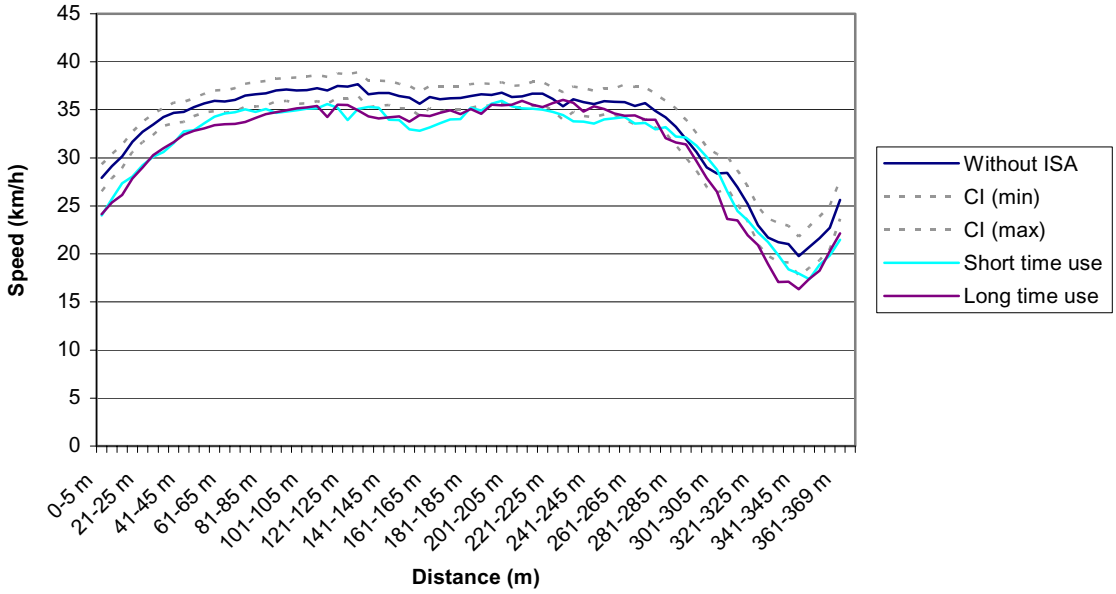

Figure 4:5 Example of the average speed profiles among test drivers without and with active accelerator on a main road, 50 km/hour, mixed traffic.

Calculations are made for two different types of intersection, three-legged intersections and four-legged intersections, for vehicles driving straight ahead on the main road towards the stop or give way obligated secondary road. In addition, the equivalent has been done for an incoming direction on the main road with a roundabout. The data is present below for Lund. The same tendencies can be found in the data from Borlänge.

Figure 4:6 below shows data for three-legged intersections (T-intersections) where the secondary road has a give way obligation. The figure shows the max. and min. speed for incoming vehicles on the main road (driving straight ahead). Data is available for five T-intersections and two directions per intersection. For each direction data is reported for the pre-period with non-activated equipment and two post-periods with activated equipment. Intersection T3 only has data for the min. speed in orientation west.

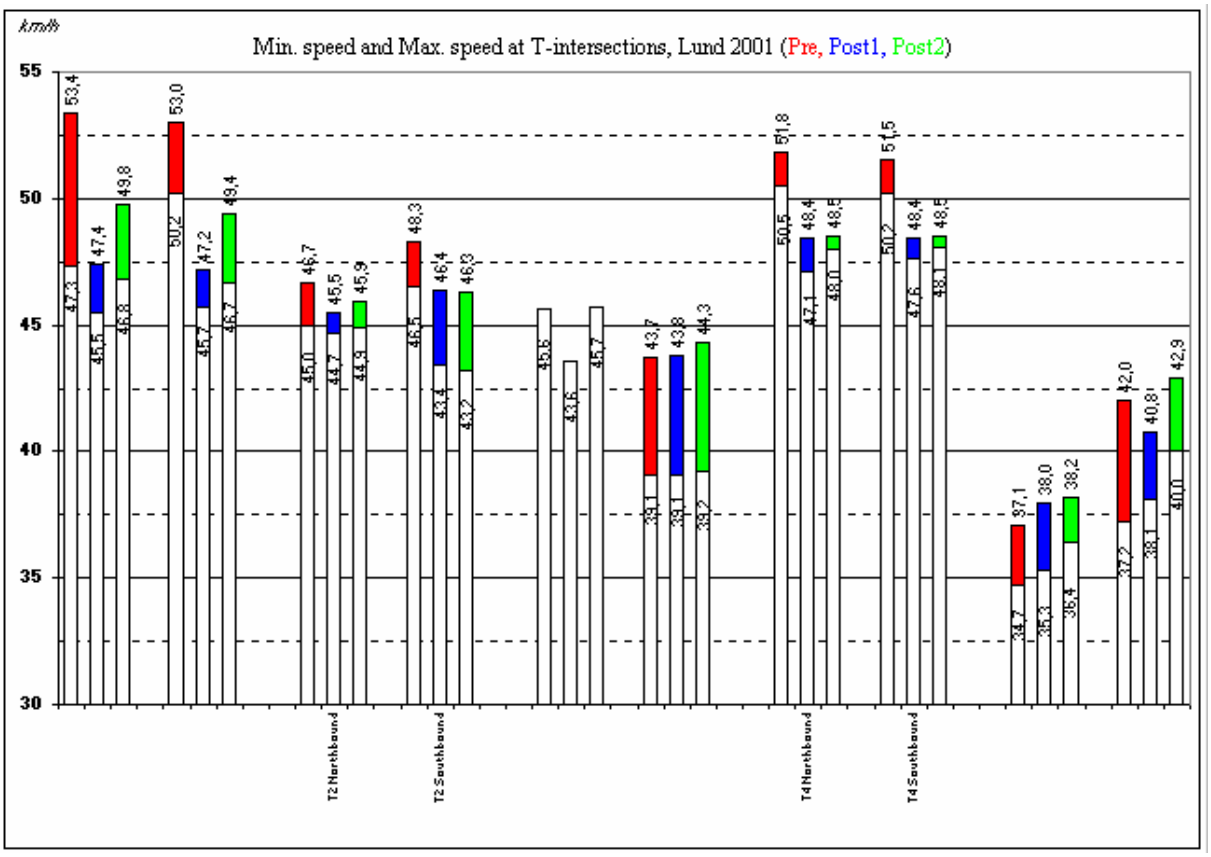

Figure 4:6 Max. and min. speed (km/hour) on arrival on the main road to T-intersections

In the figure it is evident that intersection T5 differs from the others through a generally low speed level and a small increase in speed in the post-periods. The remaining four have a speed level around or above 40 km/hour. For these four distinct reductions can be observed in the post-periods. It generally applies that speeds once again rise a little in post-period 2, but the main effect remains.

For these four T-intersections with eight directions (seven for maximum speed) t-tests have been carried out in pairs for max. respective min. speeds before the intersection. The following results have been obtained:

- For maximum speed a reduction in post-period 2 with an average of 2.2 km/h, from 49.8 km/hour to 47.6 km/hour, significant value (level 99%).

- For the minimum speed a reduction in post-period 2 with an average of 1.5 km/h, from 46.8 km/hour to 45.3 km/hour, significant value (level 95%).

In summarising it can be said that ISA contributes to lowering the arrival speed on main roads before T-intersections with approx. 2 km/hour. The reduction is roughly as large as for main roads with 50 km/hour and the speed level before the intersection is also the same as for the main road.
At intersections with low arrival speeds no effect was obtained.

Figure 4:7 below shows data in the same way for four-legged intersections where the secondary road has a give way obligation. Data is available for three intersections and two directions per intersection.

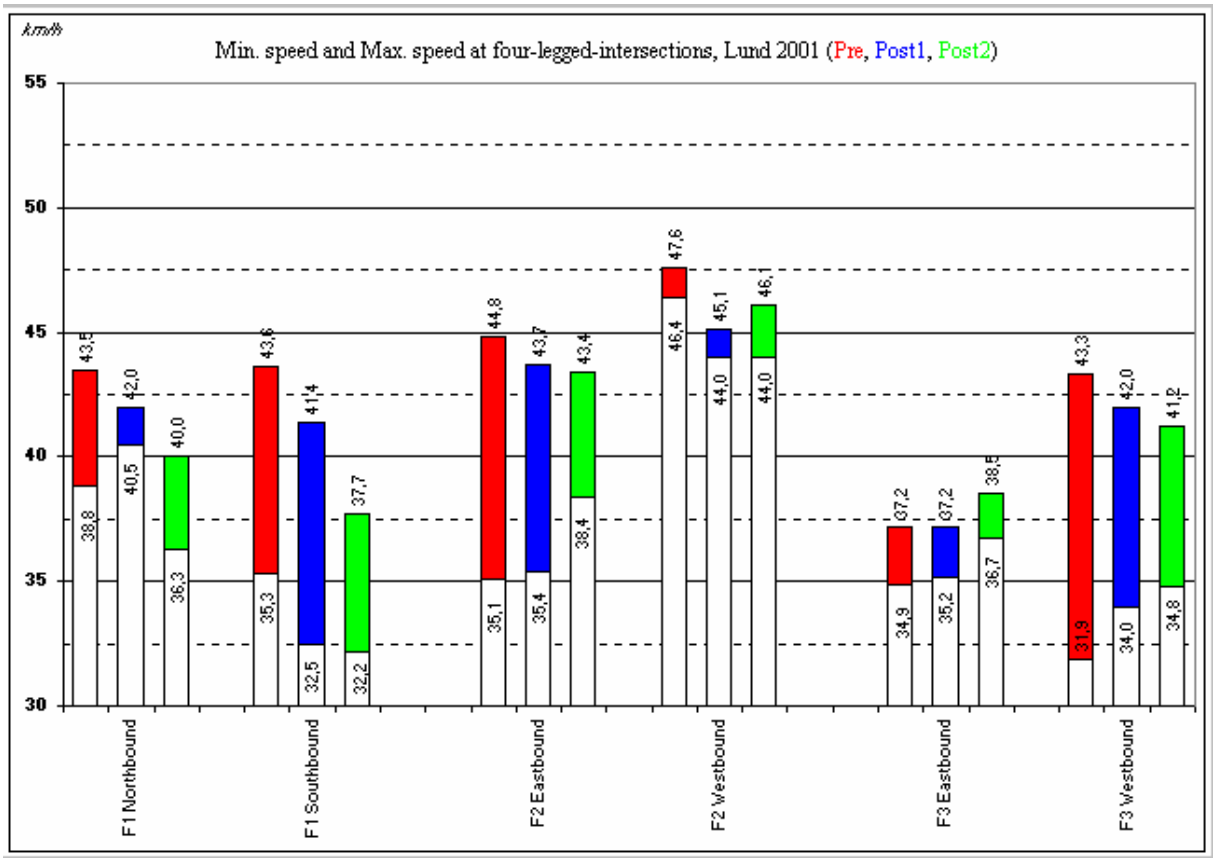

Figure 4:7 ***Max. and min. speed (km/hour) on arrival on the main road to four-legged intersections***

From the figure it is evident that the speed level is generally lower than for three-legged intersections and the difference between max. and min. is considerably greater. The speeds were between 32 and 45 km/hour. But there still seems to be a small speed reduction in the post-periods. The following results were obtained for three intersections with six directions:

- For maximum speed a reduction in post-period 2 with an average of 2.1 km/h, from 43.3 km/hour to 41.2 km/hour, significant value (level 95%).

- For min. speed there is no remaining reduction in post-period 2.

In summary it can be said that only the highest speed (max. level) at the beginning of the arrival process is affected by the ISA equipment and the speed reduction is approx. 1.5-2 km/hour. The reduction in maximum speed is approximately the same size as for roads with mixed traffic (main or service roads). Everything points towards the changed behaviour on links continuing up until the braking process before the intersection. With four-legged intersection the braking distance is relatively large and no ISA effect is obtained precisely before the intersection. On the other hand, with three-legged intersections the braking distance is smaller and there is a lasting effect of the ISA system through the intersection.

Finally in figure 4:8 data is shown for roundabouts with a give way obligation for incoming traffic on the main road. Data is available for four roundabouts on 50 roads with single lane circulation, two roundabouts on 50 roads with two-lane circulation and a roundabout on a 70 road with two-lane circulation.

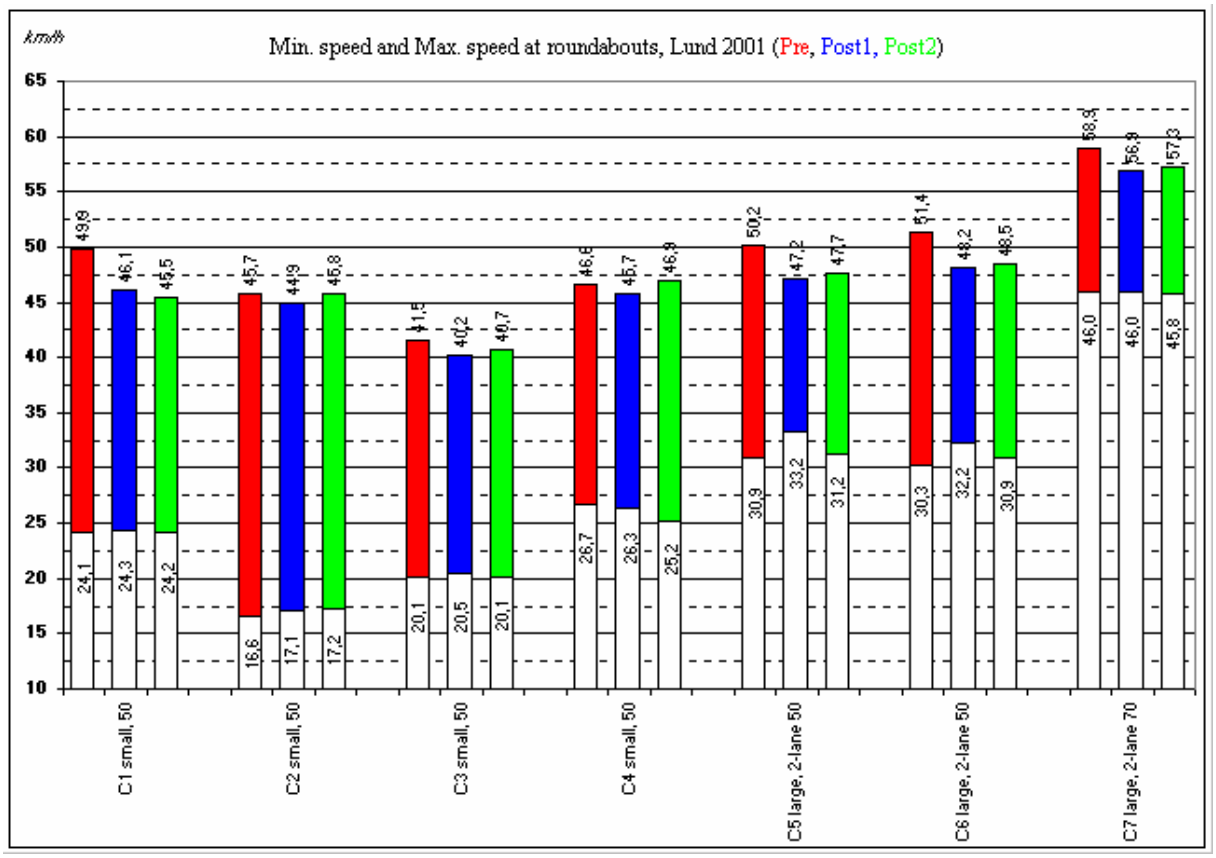

Figure 4:8 Max- and min speed (km/hour) on arrival on the main road to the roundabout.

It is evident from the figure that the difference between max. and min. speeds show a marked increase than for normal intersections. But this is natural as obligation to give way prevails for incoming traffic. The speed level for the min. speed is a little higher for large roundabouts compared with small single lane roundabouts. Position C7 on the 70 road has a much higher speed level for both min. and max. speeds. At this position the max. speed in the post-periods has dropped by 1.6-2.0 km/hour, the same as for the four-legged intersections above.

Data from the six roundabouts on 50 roads have been tested with paired t-tests. The following results were obtained for these six:

- For maximum speed a reduction in post-period 2 with an average of 1.7 km/h, from 47.6 km/hour to 45.9 km/hour, significant value (level 95%).

- For the min. speed an unchanged speed was noted in post-period 2. The average min. speed is 24.8 km/hour both in the pre-period and in post-period 2.

In summary it can be said that it is only the max. level of the incoming speed that is affected by ISA equipment, exactly as for four-legged intersections, and this effect is also approx. 2 km/hour before the roundabouts. The reduction is somewhat lower than that obtained for the main road with 50 km/hour. Even here it seems as if the changed behaviour on the link follows continues to just before the roundabout, where braking starts. After this there are no ISA effects when the vehicle comes down to speed levels of 25-35 km/hour on 50 roads.

If you compare the data from Umeå above, you see the reduction there is only slightly lower on 50 roads approx. 10 m before the intersection. This indicates that the effects of ISA drop off and disappear in the interval 0-25 m before an intersection.

Conclusions - intersection speeds

The arrival process before intersections and roundabouts has been influenced by ISA up until 50-80 metres before the intersection point. The effect is just as large as on links. When you come down into low speeds of 25-30 km/hour on 50 roads in the actual intersection no ISA effects can be shown. In T-intersections, where speeds are usually higher, even the min. speed is affected on main roads in the same way as for max. speed.

Has the turning speed in intersections been affected by ISA?

Logging of vehicles gives the opportunity to study the turning process through intersections. Private cars that made a right turn respective left turn **from the main road** at the selected intersections were studied. At each intersection an average speed profile was calculated for each turning movement, right respective left turn from the main road. The lowest speed (min. speed) in this speed profile was calculated. This was performed for all private cars for a pre-period and two post-periods.

Table 4:7 shows the data for five intersections in Lund, three three-legged intersections and two four-legged intersections. Each row corresponds to an intersection and with right respective left turns from the main road. The number of vehicles is small for intersection T4 and here there are no observations for post-period 2. For intersection F1 the number of left turns is small in R1 and right turns in R2.

Table 4:7 Min. speed (km/hour) when turning from the main road in T-intersections and four-legged intersections

	Min. speed km/hour		
Intersection type, turning movement	**Pre-period**	**Post 1**	**Post 2**
T3 three-legged, give way right turn	25.1	+0.1	+0.2
left turn	20.0	-1.0	-2.3
T4 three-legged, give way right turn	17.0	-2.8	-
left turn	17.1	+1.2	-
T5 three-legged, give way right turn	19.1	-0.4	+0.9
left turn	20.1	-2.8	-2.7
F1 four-legged, stop right turn R1	24.8	+3.3	+0.3
right turn R2	15.3	+4.3	-1.9
left turn R1	5.9	+9.0	-3.9
left turn R2	24.3	+2.2	+0.0
F3 four-legged, stop right turn R1	19.3	-0.5	-3.5
left turn R2	13.9	+2.2	+0.6

As is evident from the table there are no clear tendencies. The lowest speed (min. speed when turning) can be seen to marginally fall in three-legged intersections but increase in four-legged intersections. Statistical tests give no significant differences. If intersection T4 and two movements in F1, both with small quantities, are removed from the result the min. speed is increased by 0.4 km/hour in post-period 1 and deceases by 0.8 km/hour in post-period 2.

Conclusion

The measured minimum speeds in intersections lie on the level 20-30 km/hour when turning from the main road. No difference in the turning speed with ISA can be shown in either Lund or in Borlänge with an activated ISA system. There seems to be a clear conclusion that at speed levels of 30-35 km/hour and

lower on 50 roads no ISA effects are obtained, exactly as with roundabouts and four-legged intersections.

Have time gaps between vehicles and queue forming been affected by ISA?

According to the small trials in the MASTER project, a tendency is obtained towards increased time gaps when driving in vehicle queues. This is of interest as it can have a great impact on road safety. The time gaps were therefore measured in the ISA trial by calculating the average time distance from the point speed measurements in Umeå for obstructed vehicles (vehicles in a queue situation).

Time gaps - log data

The time gap between two vehicles is defined in a predetermined road section as the time difference between the front car's rear bumper and the rear car's front bumper, see figure 4:9. If the measurement is made with axle sensors the time is measured between the front car's rear wheel and the rear car's front wheel, which is evident from the mentioned figure. This measurement ought to be called the axle time gap, and it is this measurement that is used when processing speed data. Five (5) seconds is used here as the limit between obstructed and free vehicles.

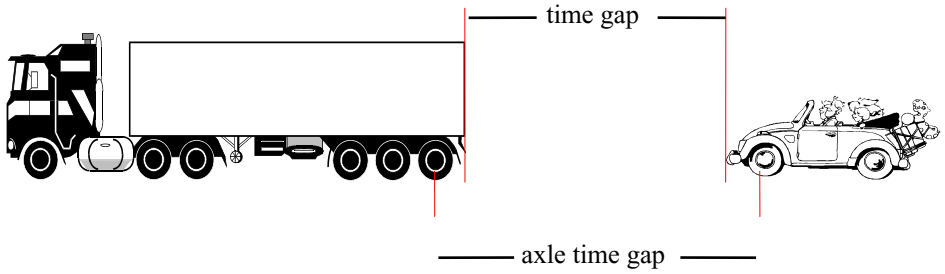

Figure 4:9 Difference between time gap and axle time gap

Increased time gaps in vehicle queues ought to reduce the risk of collisions. An interesting question is whether "dangerous" time gaps in vehicle queues have changed when ISA vehicles have been in the traffic. Consequently, the analysis has been made in Umeå and Lund using vehicles with short time gaps. In Umeå where all the vehicles are included, no tendencies towards a change in the time gap in vehicle queues could be observed. However, with the limited quantity of ISA vehicles in the traffic of 5-15% that there is in Umeå, it is not possible to discover minor changes among these vehicles.

In Lund passenger studies have been made where the driver's behaviour is studied in specially equipped vehicles while travelling along a predetermined route. Each test driver drove along a 33 km test route. The driver's following distance is registered five times per second. The differences between ISA and non-ISA vehicles are small (smaller than 0.1 sec) and as well it was not possible in Lund to observe any specific differences. With the study of the shortest time gaps (less than three seconds) the difference was even smaller.

Accordingly, no sign of a change in keeping distances in queues with ISA equipment could be established.

Queue forming - point speed measurements

Earlier it was established that the spread of speed (measured as a standard deviation) has increased a little for 50 roads but fallen for 70 roads. For 30 roads the spread of speed remains unchanged. You can ask whether this change in spread of speed has resulted in increased traffic queue lengths. To this end the average queue length has been calculated for each measurement section in Umeå (as the number of free vehicles divided by the total number). The result is that no noticeable changes in the average queue length could be traced on 30, 50 or 70 roads.

Conclusions - time gaps and queue forming

From the measurements in Umeå no signs of change to the time gap in vehicle queues could be established. Neither could any signs of increased queue lengths be traced. Neither in Lund with the passenger studies was it possible to establish any changes in distance keeping in queues with ISA equipment.

Are you better or worse at stopping at red lights with ISA?

A calmer driving style is expected with ISA, which is presumed to result in a decline in driving against red lights at intersections controlled by traffic lights. Studies of driving against red lights at intersections controlled by traffic lights was carried out as a before and after study in Lund. Vehicles that arrived after the green/amber change and during the red phase were registered manually by an observer in the field and the number driving against red lights were calculated.

In total for all ten approach roads in Lund an increase was obtained for the amount of vehicles driving against red from 1.0% in 2000 to 1.9% in the autumn of 2001, an increase of 0.9 percentage points. The number of ISA vehicles observed on the approach roads during the measurements was only **one** vehicle, which makes it meaningless to perform a comparative analysis between ISA vehicles and non-equipped vehicles.

Conclusion - driving against red lights

No system effect with regard to driving against red lights can be shown with the small number of ISA vehicles (230) in Lund. However, a general tendency was that the amount driving against red lights had increased independent of whether you use ISA or not. An increase was observed also in the control site of Helsingborg.

Do you take pedestrians more or less into consideration with ISA?

Interplay between pedestrian and motorist - interaction study

According to passenger observations in Lund[16] ISA (active gas) has had a significantly positive effect on the interplay with pedestrians in urban areas if you group a number negative and positive behaviours. Even give way behaviour, including giving way at zebra crossings shows a slight positive effect.

In Lund[17] even a separate interaction study was carried out where zebra crossings were video taped and analysed. The willingness to give way at zebra crossings between pedestrians and ISA equipped cars respective other cars was studied. No difference could be noted here. The ISA drivers did not give way to pedestrians more frequently despite their lower speed. Inversely this means that the drivers of the ISA cars did not compensate in these situations because they could not driver faster than the speed limit. On the other hand, drivers of ISA equipped town buses displayed a tendency (not significant) not to give way at the studied zebra crossings as often as other bus drivers. This can indicate that the bus drivers, which have a tough time table to follow, try to compensate for not being able to break the speed limits by driving a little faster in low speed situations.

16 Hjämdahl, Magnus; The effects of active accelerator on driver behaviour. Results from passenger observations. Sub-report 4 LundaISA

17 Draskoczy, Ashouri; Interplay between road users after the introduction of large-scale use of active accelerator, Sub-report 8 LundaISA, December 2001

Incidents with pedestrians and cyclists - conflict studies

Conflict studies were carried out at six intersections in Umeå. The locations were selected where the risk of accidents was judged to be greatest and where the introduction of speed adaptation was expected to lower the risk of accidents. The criteria in order to make the conflict study were that the intersections should not be rebuilt and that there is a relatively large flow of cars and unprotected road users at the locations. Six locations were chosen by the Umeå municipality, three intersections and three zebra crossings on a stretch of road. Of the three intersections two were controlled by traffic lights.

The registration of conflicts was done with the help of three conflict observers, who were trained by the Lund Institute of Technology. The pre-study was carried out in October 1999 and the post study in October 2001. The weather in October 1999 was cold and without rain. The weather in October 2001 was a little warmer compared with the pre-study, but with steady rain, which may have affected the results.

The number of conflicts, which also comprised car-car-conflicts reduced sharply during the post study. The following results were obtained:

- The number of conflicts in total fell by 68%
- The number of serious conflicts fell by 54%
- The number of serious conflicts with unprotected road users also fell by 54%.

The pre-study was dominated by car-bicycle-conflicts (46% of the total number of serious conflicts), while in the post study there was a more even distribution of conflicts with cars, bicycles and pedestrians. The reason for the large amount of bicycle conflicts in the pre-study can be explained by the fact that one of the locations was situated in the middle of the university area (Petrus Lestadius väg) and many students cycle there. That a reduction then occurred in the post study may be due to the weather as many people chose not to cycle in the rain.

Conclusions - considerations to pedestrians

The observation study in Lund indicates that the behaviour to give way is not affected by active gas. However, there is a tendency towards compensation behaviour by bus drivers, which may be due to the bus drivers' stressful work situation. The conflict study in Umeå indicates that the number of serious conflicts drops sharply with warning ISA. Even if special conditions such as the weather and the subjectivity of the observers can play a part it seems that a clear improvement has taken place.

How is road safety affected by ISA?

Evaluation of the road safety effect based on accident statistics (Umeå)

In Umeå with a relatively large number of equipped vehicles during the trial period there are conditions for a general effect on road safety to occur. A follow up of the number of persons injured in traffic has been made during the two years between 1998-99 and compared with the year 2000-2001 when the ISA trial was in progress. For 1998-99 the hospital reported accidents were used, these were processed in the municipality's accident database. For the year 2000-01 the Swedish National Road Administration co--operation project Strada was used where extracts were made from hospital reportted accidents. This means that the statistics for the years 1998-99 can deviated a little from 2000-01.

The analysis shows that in the trial area (north of the river) the number of injured (including fatalities) had reduced during the year 2000-2001 from 555 to 543, a completely random change

For the years 1999-2001, when the ISA project was in progress in Umeå, the number of personal injury accidents in urban areas in Sweden increased by 3.0% compared with the previous three-year period.

But the number of serious injured or fatalities has increased by a full 7.3%. This means that the serious consequences have increased more than the number of accidents.

Consequently, the number of injured and fatalities remains unchanged in the trial area in Umeå compared with a 7% increase noted for the country as a whole. The results indicate that the warning ISA in Umeå has contributed to improve road safety.

Evaluation of the road safety effect based on speed changes

As evident and significant speed reductions can be observed in the measurement data, the question arises which total effects can this bring about for road safety in respective districts. As the average speed in urban areas is low, bearing in mind delays at intersections, we choose instead to start from the individually measured driving speeds.

Umeå - warning system

In Umeå the point speeds have been measured at approx. 50 measurement sections, which can be used to see how much the risk for personal injury accidents has decreased. According to the accepted model (power model) the risk with speed decreases to the power of three.

A lowering of the speed on 50 roads from 60 km/h down to the speed limit 50 km/h reduces the risk of personal injury to 58% of the original or by approximately 42% as set out in the following calculation:

$$50^3 / 60^3 = 125000 / 216000 = 0.58$$

Therefore the speed of the individual vehicle has been raised to the power of three for each measurement section and the total result has been calculated. In this context heavy vehicles have been weighted with 1.6 factor as in urban areas each heavy vehicle on average has 1.6 axle pairs and the risk of an accident is expressed as the number of accidents per axle pair kilometre. The individual speeds in cubic have been added and finally the "cubic total" has been divided by the number of vehicles. The average value mirrors the risk of personal injury accidents in the measurement section in question (called the safety measurement).

A comparison between the years 1999 and 2001 in this safety measurement has been made by studying the percentage change between both years. A reduction of the safety measurement means in this connection a reduced risk for personal injury accidents. The results for links are summarised in the table below **at 5-15% ISA** in different road environments (mostly local roads):

Table 4:8 Risk reduction according to the power model for different road types in Umeå

	Umeå - warning **Risk change**	
Road type	**Links**	**10 m before an intersection**
Local road 30	-5%	+1%
Local road 50	-7%	-4%
Service 30	-2%	-2%
Service 50	+1%	unchanged
Transition 50/30	-3%	+2%
Transition 50/70	-3%	-6%
Transition 70/50	+4%	-6%
Main road 30	-2%	-2%
Main road 50	unchanged	-4%
Main road 70	-0.5%	+5%

All in all for all measurement sections in Umeå, both Smart Speed with 30 limits and the entire day, a systematic drop in the risk of accidents on links can be established, which however does not apply for 70 roads. For 30 roads the effect lies at 2-5% with the greatest reduction on the local road system. For 50 roads the reduction in accident risk is 3% on links. The fall in the accident risk is however somewhat smaller at intersections than for links, especially on 30 roads.

Borlänge - informative system

In Borlänge there is data from logged vehicles that forms the basis for a calculation of the changed accident risks in road traffic. These data state the changes in average speed and standard deviation for trial vehicles.

In order to apply the power model completely requires data for individual vehicles. However if you take normally distributed speeds, the power model can be used approximately for just the average value if the coefficient of variation is presumed to be constant. A normal value for the coefficient of variation is approx. 0.14-0.15 on 50 and 70 roads and approx. 0.2 for 30 roads. This means that the coefficient of variation contributes with approx. 6% of total risk measurement on 50 and 70 roads and 12% for 30 roads. Accordingly, it is feasible to calculate the average value and standard deviation in the measured distributions for the calculation using the power model. This means a higher value for the accident risk than the usual power model, where consideration is only taken to the average value.

For the measurement section with 50 km/hour on links a reduction of 18% in the risk measurement on 50-roads is then obtained. With approx. 2% of ISA vehicles, the risk of personal injury accidents should fall by approx. 0.35% on 50-roads in Borlänge during the trial period.

In order to secure the average risk reduction for the entire trial area the measured driving speed for respective speed limits in the table 4:5 can be used. The following values for the risk reduction are obtained, which **then only refer to the ISA vehicles**, not all traffic.

90 km/hour	**70 km/hour**	**50 km/hour**	**30 km/hour**
11%	15%	12%	10%

Lund - active gas

In Lund the standard deviation for logged vehicles has been reduced by approx. 40% for 70 roads and approaches with 50 km/hour. For other 50 roads and 30 roads the reduction in standard deviation is somewhat less, approx 30-35%. The values are greater than in Borlänge, which is feasible as active gas forces down speeds under the speed limit in a more pronounced way. For the average speed is can be noted, seen for all the log data, an average reduction by 7.5% for 70 roads and 50 approaches while the reduction is approx. 4% for common 50 roads and approx. 5.5% for 30 roads.

When consideration is taken to the heavily reduced spread, a total risk reduction is obtained calculated in per cent for **ISA-vehicles** in Lund.

70 km/hour	50 km/hour approaches	50 km/hour main road	50 km/hour mixed traffic	30 km/hour
24%	22%	14%	11%	20%

As the share of ISA vehicles was 1-2% the values in the table should be multiplied by approx. 0.015 in order to obtain the true risk reduction during the actual trial for respective types of road. However, this is of course a max. value measured in the middle of the stretch of road where the speed reduction for ISA vehicles is at its greatest. In order to secure the average risk reduction for the **entire trial area** the driving speeds in the table 4:5 can be used. The following values are then obtained for the risk reduction for ISA vehicles with active gas in Lund.

70 km/hour	50 km/hour	30 km/hour
13%	12%	11%

Thus the reduction in the risk for personal injury accidents will be roughly the same in all road environments, 11-13%. Note that the values for 70 and 30 roads are approximately half of the max. values, but the value for 50 roads is about the same as for main road and mixed traffic in the first calculation.

Conclusion - estimated overall road safety potential

The following studies can be used to estimate the overall road safety effect of the different ISA systems:

- analysis of accident statistics (Umeå)
- "exposure effects" on the remaining traffic (Umeå)
- influence on the average speed and spread of speed
- dampening of the maximum speed and speed violations
- influence on arrival and turning speeds at intersections and roundabouts
- influence on driving against red at intersections
- influence on the number of serious conflicts
- influence on the consideration taken to pedestrians and cyclists

Data from Lund and Borlänge points towards the amount of speed violations falling with ISA. The effect seems to be greater on 50 and 70 roads than on 30 roads. However, data from Umeå indicates the effect being greater on 30 than on 70 roads. This may be due to the number of ISA vehicles is greater on the local road system, where there is not so much through traffic. The theoretical calculations of the informative system in Borlänge points towards a risk reduction of 15% for 70 roads and 10-12% for other types of road. The equivalent calculation in Lund for active gas shows a risk reduction of 11-13%, about the same for all types of roads. The values for the informative system in Borlänge and active gas

in Lund are accordingly of the same magnitude. IT is not possible with that to say that one system should be better than the other. If you then add the effects of improved consideration to pedestrians **the risk reduction for both ISA systems can be estimated to be around 15-20%**.

With a total appraisal of all the studies everything points towards road safety improving in Umeå during the trial period with ISA vehicles, which amounted to 5-15% of the number of private cars, with the largest amount on the local road system. The number of injuries is unchanged against a 7 per cent increase for the country as a whole. The results of the conflict studies indicate a clear reduction in the number of conflicts in road traffic, both for mutual conflicts between vehicles and conflicts with unprotected road users. The result shows that the warning system in Umeå, cautiously calculated, has reduced personal injuries in urban areas by around 3%. If you add to this the number of serious conflicts has fallen, the improvement can be estimated to lie in the interval 3-4%. Calculated proportionally on solely ISA vehicles this should mean a risk reduction of 30-40%, i.e. a higher value than for equivalent systems in Borlänge, but this figure ought to be adjusted downwards as the initial per cent values probably contributes more than the last. Both the accident analysis and the speed measurements indicate however that spread effects occur in Umeå. In all probability the **spread effects** to the other traffic have **contributed to a further substantial risk reduction** over and above that applying to ISA vehicles alone.

The measurements show that the effect of ISA is greater on links than at and in the vicinity of intersections. The greater majority of personal injury accidents with unprotected road users occur at intersections on the main road systems. Therefore the road safety effect of ISA equipment is generally smaller for unprotected road users than for motorists. Conflict studies and passenger studies however indicate distinct improvements even at intersections.

All in all it is reasonable to believe that road safety has improved significantly by using ISA.
If everyone had ISA the number of road injuries could be at least 20% and in best case up towards 25% **fewer in urban areas.** In the long term it is also possible to develop the system. Primarily it is then the occurrence of dangerous time gaps between vehicles that should be emphasised.

Are travelling times and the environment impaired by ISA?

Travelling times - log data in Lund

Log data gives the possibility to study the effects on the total travelling time. The total travel time and the total travel distance for all logged vehicles have been calculated within the trial area. The quota between travel distance and travel time is an excellent estimate for the average speed of all vehicle kilometres travelled within the trial area and with that a measurement of the change in travelling times between a pre and post-period.

In table 4:9 the average travel speed for the entire trial area is presented. The average travel speed involves the total vehicle kilometres travelled (driven road lengths) divided by the total travelling time (including stops) for all trial vehicles that are private cars. The equivalent calculation for driving speed (see table 4:5) involves times being deducted when the vehicle stops.

The pre-period represents the month before the equipment was activated. Post-period 1 is the first month post after activation and post-period 2 represents weeks 39-44 in 2001.

Table 4:9 Logged data in Lund, entire trial area, for one pre-period and two post-periods.

Variable	**Pre-period Not activated**	**Post-period 1 Activated**	**Post-period 2 Activated**
Travel speed at 30 km/hour	17.9	+0.3	+0.9
Travel speed at 50 km/hour	31.5	-0.1	-0.3
Travel speed at 70 km/hour	54.5	-0.3	-0.7
Travel speed in total	34.2	+0.1	+0.2

The travel speed remains mainly unchanged between the pre- and post-periods. Only a marginal reduction is noted at 70 km/hour. In total the travel speed has even increased marginally, which in turn means that travelling times on average have fallen a little. This result may seem somewhat surprising.

In total the driving speed fell by approx. 1 km/hour in Lund according to table 4:5. This means that in the post situation the stop time in queues and the like has been swapped with time in motion, but at a slightly lower speed. This could be interpreted as less aggressive driving behaviour, where one attempts to minimise the risk of sudden stops and utilize the permitted speed when the opportunity presents itself. As is evident from figure 4:10, speed is reduced over the stretch of road, but this is compensated for by faster acceleration after braking at intersections. Consequently, travelling times in urban areas with ISA remain mainly unchanged.

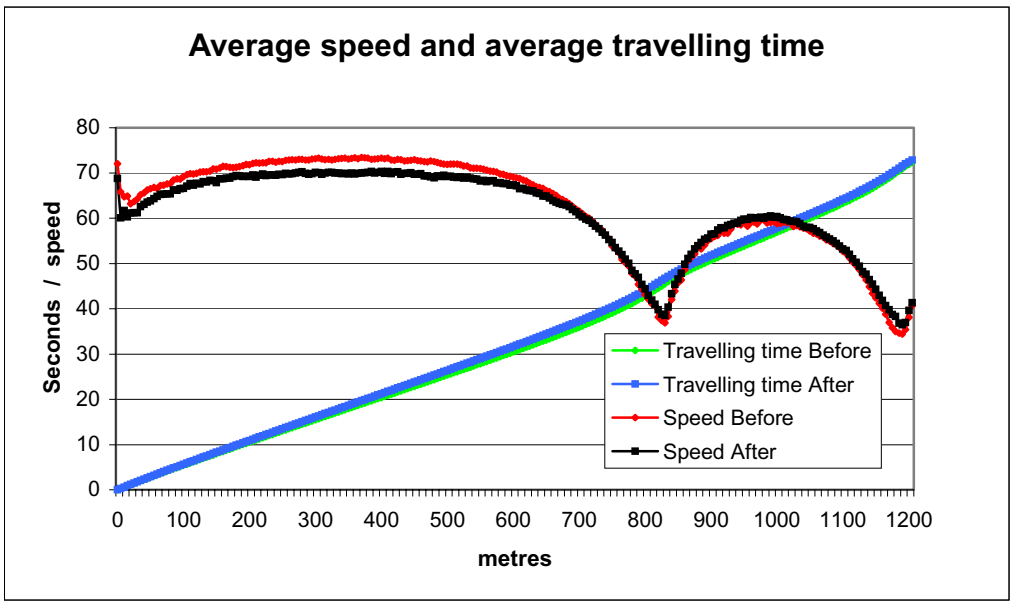

Figure 4:10 Example of the driving process on links and at intersection without and with ISA

In summary it can be said that the effects of ISA are moderate on travel and driving speeds in average, which is feasible as these to a high degree are a function of the traffic flow and road design. Nevertheless, the amount of vehicle kilometres travelled above the legal speed limit and the highest speeds have dropped significantly.

Effects of fuel consumption and emissions

The calculation of fuel consumption and exhaust emissions performed in Lund for each logged driving process on the different types of roads. The exhaust emissions calculated are CO, NO_x and HC and refer to active gas. A VTI developed exhaust calculation program VETO was used for the calculations. The

amount of fuel and exhaust fumes per car and driven km are calculated for each studied driving process. The average value for all driving process per road type is then calculated. The emission factors that the VETO model uses are valid within a limited speed interval (0-60 km/hour) and acceleration interval (-1.5 to +1.5 m/s^2) and apply for a petrol-powered typical car (Volvo 940).

The calculation of fuel consumption and emissions was made for a pre-period with non-activated equipment and a post-period which ran over the entire trial period. The following results were obtained with regard to fuel consumption with the comparison between non-activated and activated vehicles:

- For all types of roads combined the calculated fuel consumption on average per vehicle had fallen by 0.021 l/10 km (from 1.115 to 1.094 l/10 km) in the post-period. This is a reduction of 2% and it is significant on the level 95%.

- Calculated per road type there is a reduction for each road type except approaches with 70 km/hour. Here a small increase of 0.8% was noted. For the other types of road the reduction was 0.5-3.5% and the largest reduction was on main road mixed traffic 50 km/hour. The reduction for individual road types is not significant except for main road mixed traffic with 50 km/hour.

The conclusion is that the average speed reduction in the post-period even affects fuel consumption but on a small scale. The largest is the fuel reduction on roads with mixed traffic. Here the reduction in speed is smaller than on approaches, but drivers probably have a calmer driving style with less acceleration and deceleration, which results in a great reduction in fuel consumption.

The following results have been obtained regarding emissions of nitrogen oxides, NO_x, with the comparison of the pre- and post-periods:

- For all types of roads combined the calculated emissions on average per vehicle had fallen by 0.020 g/km (from 0.258 to 0.238 g/km) in the post-period. This is a reduction of 8%.

- Calculated per road type there is a reduction for all road types by 6-8%. However, for four lane approaches a reduction of 15% was noted. The reduction is significant for types of road except approaches with 70 km/hour.

As is evident from the above, the average reduction in emissions of nitrogen oxides as a percentage is greater than the reduction in fuel. This means that in addition to the speed reduction in the post-period even a calmer driving style with less speed variation and less acceleration and deceleration is used. It appears as stop times in queues but subsequent acceleration is exchanged with periods of driving at low speed. The result from the emission studies confirms the results above where travel speed is unchanged but the driving speed has fallen.

The average driving distance in urban areas for private cars is approx. 5500 km per year. If the results above from Lund are representative this means that an ISA equipped vehicle reduces its emissions of nitrogen oxides by 0.11 kg per year. This corresponds to emissions from approx. 430 km of driving in urban areas by one vehicle.

The emission of hydrocarbons, HC, fell as a percentage by approximately the same amount as nitrogen oxides, but the absolute amount was less, only approx. 0.0015 g/km on average. This means an annual reduction of approx. 8 grams per vehicle.

Conclusions - travelling time and emissions

Many have feared increased travelling times using ISA. In urban areas however a large part of the travelling time consists of delays in queues and stopping at intersections. Theoretical calculations with unchanged driving behaviour indicate an extension of the travelling time by a few per cent. The drivers

of ISA cars seem to have adapted their behaviour however, through smoother braking, shot stops and faster acceleration so that the feared extended travelling times have not occurred in practice. This driving style, which is similar to the one taught for eco-driving, also contributes towards lower exhaust emissions. The results apply for active gas, but ought to apply to a certain degree to the other ISA systems. In figure 4:12 below it can be seen that this result is confirmed by the drivers' own experiences.

4.7 What do the users think?

General format

The purpose of the national user evaluations is to demonstrate the users' reactions to traffic safety and experiences of using the tested intelligent speed adaptation systems. The questionnaires have been formulated so that it is possible to answer the hypotheses 9-16 below in section 4.9. This is achieved by compilations and comparisons of follow-ups and evaluations of the trial sites with respect to

- attitudes to traffic safety and speed
- experiences of the tested ISA system
- acceptance and willingness to pay for such systems
- performance and behaviour when using ISA

An important part of the national evaluation is highlighting similarities between the different ISA systems and trial sites. To be able to generalise and evaluate the trials sites' results, the aim has been to ensure that the format for the activities to be carried out is similar and that the content is comparable.

Documentation and coordination for comparable evaluation

The measurements with respect to the user that have formed the basis of the national evaluation have comprised

A. Questionnaires to the general public at the trial sites (before and after the trials). Control measurements were made with special financing for a nationwide selection prior to the trials (1997), whereby a number of questions were later tied in with the ISA questionnaires. These control measurements were repeated towards the end of 2002, whereby the effects of both the ISA trials and the debate around ISA are made evident.

B. Questionnaires/interviews in connection with recruitment of test drivers. In total, around 15000 people at the four trial sites have taken part.

C. Questionnaires/interviews with test drivers or a selection of test drivers (panel). Measurements have been made at different stages of the trial period including identifying changes over the course of time. These are
   - pre-measurements prior to the trials starting/the system has been activated in the vehicle
   - first month measurements when the driver has had the system working for around a month
   - middle measurement (Umeå only) when around half of the trial period has been completed
   - final measurement at the end of the trials

D. Focus groups/in-depth interviews with different groups of test drivers and other participants (private drivers, commercial drivers, mechanics, drivers that have tested two systems etc.)

Results from special studies, experiments and other local evaluation activities act as support to the evaluation.

E. Logging of behaviour (speed, changes in speed etc.) in Borlänge and Lund

F. Interaction studies (interaction between road-users), passenger observations, workload measurements in cars with instruments, diary (Lund)

G. Questionnaires/interviews with unprotected road-users (Lund and Umeå)

An important part of the national evaluation is highlighting similarities between the different ISA systems and trial sites. To be able to generalise and evaluate the trials sites' results, the aim has therefore been, as far as possible, to carry out the evaluations in a similar way with comparable content.

To ensure comparability, common study templates for each measuring occasion have been formulated. These contain information with uniform design that is of interest to the national evaluation. Each trial site has then applied the templates with adaptations to the tested ISA system and trial site-specific conditions. The templates have been expanded to include additional questions in line with local wishes.

The information gathered is put in relation to appropriate reference levels. The references have been presented in different ways. Performance and behaviour is measured in a pre/post situation or connected/disconnected system. In addition, we have a number of comparable control measurements carried out at another site or with a nationwide selection as control group. Questions on the test drivers' attitudes to the tested ISA system are put in relation to corresponding experiences without the system.

Measurements have been repeated in order to identify changes over the course of time. Two measurements concerning the attitudes of the general public have been made both before and after a completed trial. The test drivers' perceptions have been noted before, during and after the trial in order to identify expectations, first impressions and opinions following an extended period of use.

Is support required in order to observe speed limits?

Previous studies illustrate that the driver considers that ISA does not need to be constantly connected, but that support in connection with dangerous situations and other special conditions is good. The evaluation in the MASTER project shows that urban areas, poor vision, pedestrian crossings and slippery road surfaces are those areas where ISA is most justified.

Is it easy or difficult observing speed limits?

Both the general public and the test drivers are agreed in their opinions of suitable speed limits in different environments. The 30 km/hr limit generally in urban areas is often considered to be too low. Men are more inclined to have this opinion than women and it is more common among the middle-aged than younger or older drivers. This attitude has been growing among the general public as time progresses. Most people consider 50 km/hr is fitting in urban areas while 70 km/hr is considered too high. In residential areas, a speed limit of 30 km/hr is somewhat more justifiable but even this figure is considered to be a little too low. However, the 30-limit outside schools and day-care centres is appropriate, and here there is widespread agreement irrespective of gender and age.

The acceptance for a 70 km/hr general speed limit on highways is low, whereas 90 km/hr is considered to be appropriate, with a limit of 110 km/hr on motorways.

A considerable proportion of the motorists questioned agreed totally or partially with the statement that they found it difficult observing the speed limits in urban areas. Certain differences between the trial sites are evident which may be due to different formulations of the question. Proportionately more motorists in Borlänge than at other trial sites agreed with the statement. Those who have registered their interest in ISA consider as a group that they find it more difficult observing the speed limit than those who are not interested. The general public has least problems observing the speed limit (see figure 4:11). This information is corroborated by the fact that those who are interested in ISA, compared to

those who are not interested, are often more inclined to exceed the applicable speed limit by 10 km/hr or more.

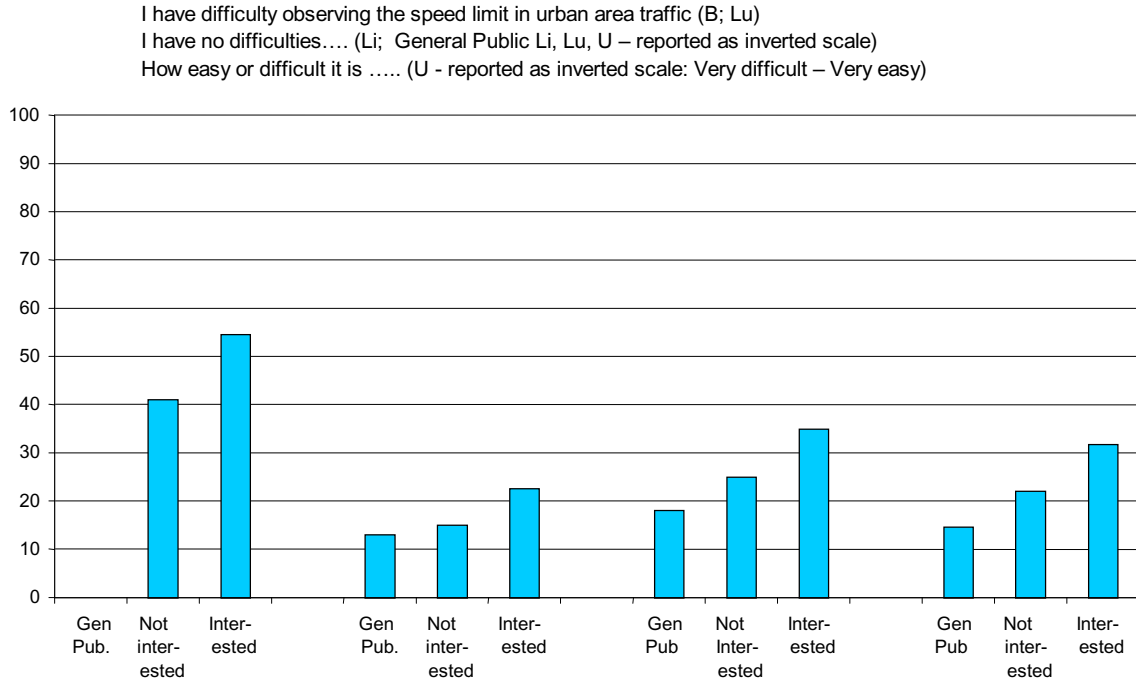

Figure 4:11 Difficulty observing the speed limits in urban areas?

Three of four motorists think it is a moral obligation to observe the speed limit in urban areas. Among the participating commercial drivers, only about 65% have this opinion. Furthermore, there is a small intimation that those who are interested in ISA have a somewhat higher moral standing as regards this issue than those who are not interested.

Even though the morality level is relatively high, more than half of the test drivers admit to sometimes, often or very often consciously driving too fast on major roads when there is not much traffic. In Lund, 72 % have admitted to this. Most motorists (75 - 85%) exceed the speed limit sometimes or often when overtaking in order to get past as quickly as possible.

The attitude towards adaptability in traffic has a similar pattern. 20 - 40 % agree with the statement that the traffic rhythm often requires driving faster than the applicable speed limit. Bus drivers can be grouped at the lower level (the time table determines buses' movements in regular traffic) while other commercial drivers generally belong to the upper level. A marginally greater proportion of those who are interested in ISA compared to those who are not interested in ISA agreed with the statement. This can be interpreted as those that are interested in ISA are more motivated to test the technology because they realise that they have difficulties observing speed limits, they are hopeful of rectifying this situation and that ISA could be the tool to realise this ambition.

Where, when and for whom would ISA be most justified?

The test drivers' assessment following a completed trial of how justified ISA is in different traffic environments and for different road user groups is another way of illustrating the need. In general, a somewhat larger proportion of test drivers in Lidköping (both informed ISA and active gas) compared to other trial sites state that ISA is justifiable (see figure 4:11 below).

ISA is needed primarily in 30-environments where 80% of test drivers consider that it is justified, particularly outside schools and day-care centres where 90% hold this opinion. On 50-stretches in urban areas and residential areas fewer consider it justifiable, in particular the proportion who consider it very justified reduces considerably (to 30-55%). Outside of day-care centres and schools in 50-environments, however, it is almost as justified as it is in 30-environments. For higher speed limits the proportion drops to 50-60% and is even lower for highway traffic.

50-75% of test drivers (the level varies between trial sites) consider that it is very or quite justified with ISA during the day time in urban areas and specifically during rush-hour traffic. About an equally large proportion consider that ISA is justified in poor weather conditions and where there are road works (rain, fog and slippery surfaces) but the proportion who consider that it is very justified is somewhat higher. Considerably fewer (30 – 50%) consider that ISA is justified during periods of low traffic, even in the evenings and at night.

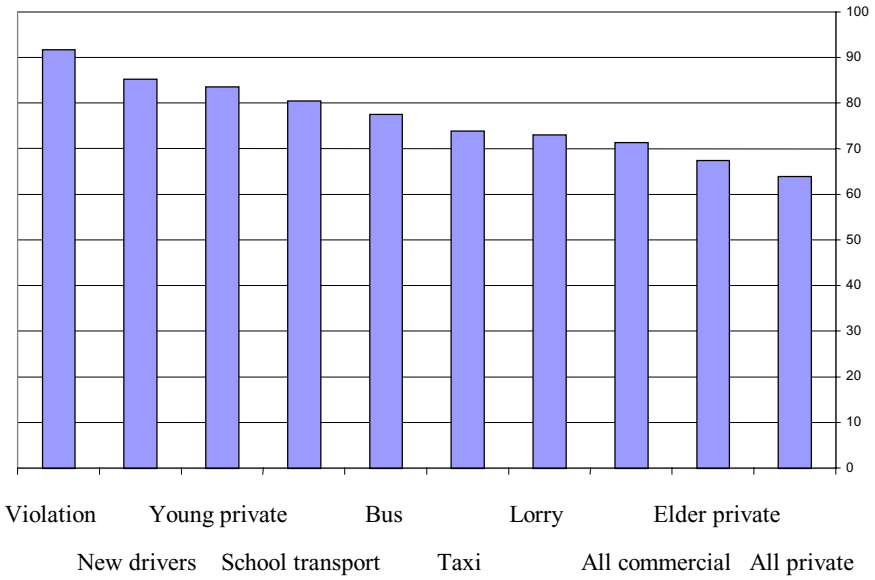

Figure 4:12 Is ISA justifiable for different driver categories?

Motorists who repeatedly drive over the limit are most in need of ISA according to the test drivers. 90 – 95% consider that ISA is justified for these. Justification for other driver categories is shown in the figure. A large proportion also consider that is justified for new driving license holders and young motorists. Then come groups with commercial drivers headed by school transport drivers. However, Umeå's test drivers do not consider it as justified for bus and school transport drivers as other sites. Test drivers in Lund are generally 5-15% lower in their assessment ratings. One reason could be that test drivers in Lund are not completely happy with their system as drivers in other trial areas are partly due to technical problems.

Conclusion – need of support

One conclusion is that those who are interested in participating consider that it is more difficult for them to observe the speed limits than others and that there is a intimation that this group have higher traffic morals. This may be correct but could also be an expression for greater self-insight or the influence of being offered the chance of participating as test driver.

With regard to the view of the needs of others, it is the view that ISA is most justified for notorious speeding offenders, drunk-drivers, for other traffic violators and for new car drivers.

Is ISA more effective than other measures?

What do drivers think about the effects of ISA on speeding?

The test drivers' own perception is that ISA has had its greatest effect on 30-stretches. The exception is Borlänge drivers who consider that the effect is best on 50-stretches. Then the effect drops the higher the speed limit is, but it is judged to be perceivable in all speed limit classes. Those drivers who drive with active gas note the best effects. On 30-stretches the drivers perceive that this effect is reinforced during the course of the trials, whilst a certain marginal reduction is noted for other speed intervals. See figure 4:13 (refers to urban areas). It is striking that the differences are negligible between the expectation prior to and the perception after the trial.

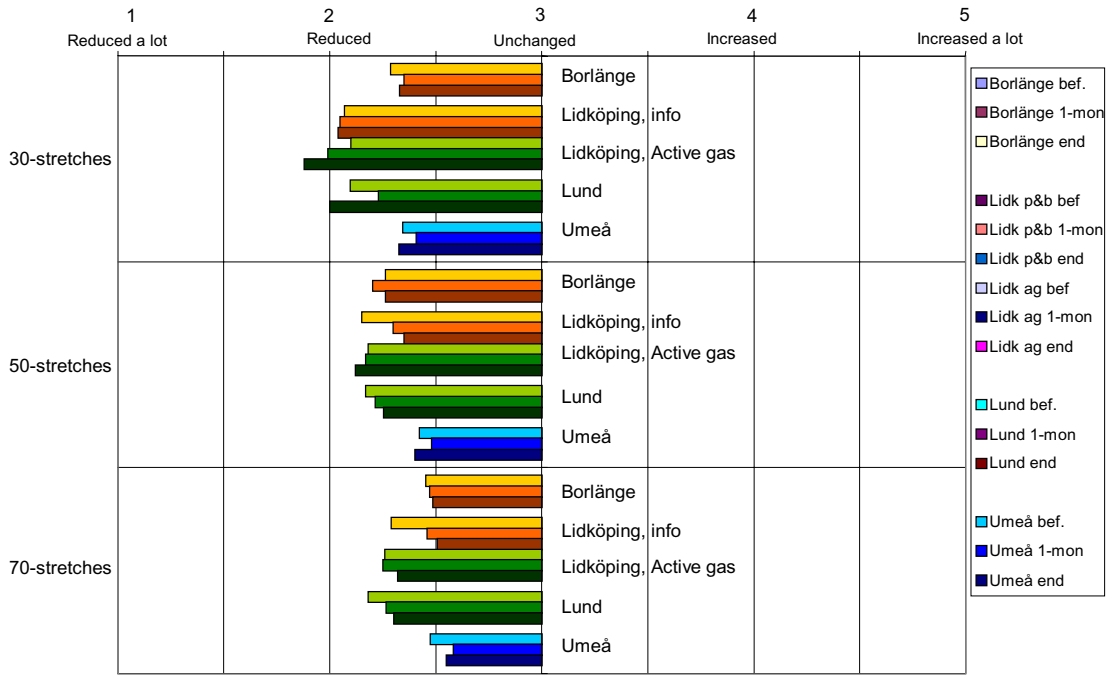

Figure 4:13 Does the driver perceive that speed reduces using ISA?

The results can be compared with measured results in tables 4:4 and 4:5. The speed reductions are great in all environments, but greater at 50 and 70 than for 30 km/hr stretches. This might be interpreted as that drivers consider it most important with speed reductions for 30 km/hr and therefore perceive the effect most evident there. However, in Borlänge the greatest effect has been reported at 50 km/hr and not at 30 km/hr.

A relatively large proportion of the test drivers are influenced in their selection of speed intervals by what they believe other motorists think. This also applies when driving with ISA. Around 25-30 % cannot avoid taking into account what others think and 50-70 % consider that they are more “in the way” for other motorists. Social pressure is quite a major factor here.

Test drivers assess that journey times are unchanged or have been negligibly increased using ISA. Those driving with the warning system in Umeå agree with this to a somewhat lesser degree than others. Only a minority of test drivers (up to 4.5 %) say that they often or sometimes have selected an alternative route to avoid areas that have a 30 km/hr limit. Lidköping is an exception, where 6-12% say that they have selected an alternative route.

A clear, positive effect is that a large proportion of drivers (70-90 %) consider the risk of getting caught for speeding within the trial sites has reduced a lot or quite a lot.

What do drivers think of ISA compared to other measures?

On several occasions the test drivers have answered the question on what they think about the various measures for increasing the observance of speed limits. A corresponding question has also been put to the general public. The test drivers are very much in agreement with the general public.

Test drivers	**The general public**
Increased police surveillance	Increased police surveillance
ISA	Mini roundabouts
Mini roundabouts	**ISA**
Raised pedestrian crossings	Raised pedestrian crossings
Surveillance cameras	Surveillance cameras
Flower boxes	Flower boxes
Speed bumps	Speed bumps

ISA is consequently high on the list not only with the test drivers but also with the general public. Speed bumps are particularly unpopular in Umeå (where there are a particularly large number of bumps). On the other hand, a study in Umeå[18] shows that unprotected road users want improved traffic safety primarily by having more and better-maintained pedestrian and cycle paths, followed by traffic education for children and more policemen. ISA (warning system) is in 8th place for this group.

Conclusions

The drivers perceive that speeds have reduced somewhat using ISA for all speed intervals. Both the test drivers and the general public think that ISA is better than, for example, speed bumps and raised pedestrian crossings. The test drivers also think that ISA is better than mini roundabouts for reducing speeding violations.

Does the driver perceive that traffic safety has improved with ISA?

Traffic safety is influenced by the driver's attitude to safety, the ability to drive the vehicle and the conditions that could disrupt the possibilities of carrying out the driving task.

In Lund, 23% of the participants report that they have been involved in accidents (including less serious ones) over the last three years, but this figure is only 9 - 13 % of the drivers at other trial sites. 55 - 75 % of accidents have occurred in urban areas. Among the general public, 10 - 13% (Lund 10%) report that they have been involved in an accident in the last three years. The test drivers do not therefore differ from the general public with regard to accident involvement, with the exception of Lund. Around 35% also consider that they have difficulty observing the speed limit in urban areas. A tendency for the reduction of occurrence of accidents from pre to post measurements is evident among the test drivers in Borlänge and Umeå but not at the other sites. This tendency concurs with the conflict studies carried out in Umeå 1999 and 2001.

The ISA-trials, as with other initiatives (vision zero activities), have helped put traffic safety in focus from a general point of view at the trial sites and with the test drivers. Between 80 and 90 % of both the test drivers and the general public concur that there is a strong connection between speed and the risk of accident. Of the test drivers, 40-60% considered that ISA would contribute towards increasing their own traffic safety prior to the trials. This proportion drops by 25% after the first month, and then rises again to around 40%.

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18 Lundholm, Garvill, Marell, Westin; Unprotected road users' attitude to traffic safety and risks in traffic. Transport Research Unit, Umeå University 2001:01

A rather small proportion (8- 14%) considers that ISA draws attention away from more important things when driving, but for most people this is no problem. Around 30 % of the drivers in Borlänge and Lund, and 20 % at the other trial sites consider that their irritation in traffic increases quite a lot or a lot when using ISA in the car than compared to not using it. In addition, this proportion has increased over the course of time. The reason for this irritation may be due to both technical problems and defects in the functionality of ISA.

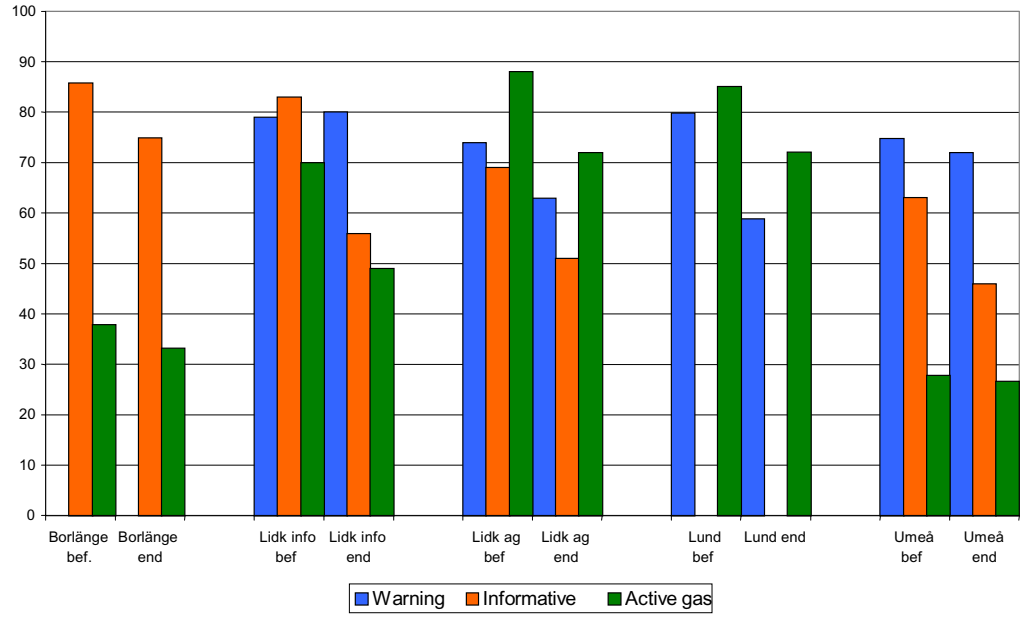

Figure 4:14 The proportion of test drivers at each trial site that consider the types of system are effective or very effective for increasing traffic safety

The views on ISA's effectiveness for increasing traffic safety provide a certain input to the assessment of acceptance. The proportion of drivers who consider that the systems are very or quite effective drops by between 5 and 20%, with one exception, from the measurement before the start of the trials to the end of trials. This applies both for the systems that have been tested by the drivers themselves as for other ISA-systems. However, it should be noted that the systems tested by the drivers themselves have most advocates, with the exception of the informative system users of ISA in Lidköping.

Conclusion – perceived safety

The majority of the drivers perceive that the system they have tested is effective for improving safety. In Umeå and Borlänge, they are sceptical towards active gas, which has not been tested.

Is more or less consideration taken to unprotected road users using ISA?

According to previous studies, motorists' inclination to give way to pedestrians and cyclists remains the same. A special study in Umeå[19] shows that more than half of unprotected road users consider that motorists and car drivers often or very often drive dangerously close to pedestrians and cyclists. Interviews carried out in Lund and Helsingborg[20] prior to and after the activation of ISA showed no

19 Lundholm, Garvill, Marell, Westin; Unprotected road users' attitude to traffic safety and risks in traffic, Transport Research Unit, Umeå University 2001:01.

20 Risser, Kaufmann; Interview with pedestrians on possible effects of ISA on unprotected road users, Progress report 7. LundaISA.

signs of communication between drivers of cars equipped with ISA and pedestrians being negatively affected.

Almost every third test driver (note 18% in Borlänge) considers, on the contrary, that his or her attention towards pedestrians has increased quite a lot or very much. In Lund, 43 % of the test drivers consider that the interaction between motorists and cyclists /pedestrians has become more considerate, while 7% think that it has become less considerate

Conclusion – consideration towards pedestrians

The conclusion is that ISA, in the opinion of the test drivers, provides an increase in attention towards unprotected road users. This has also been expressed by actual deeds, which has been shown by observations from Lund. The expected compensatory behaviour of not stopping at pedestrian crossings to make up for lost time has not been evident, except perhaps for stressed bus drivers.

Is it more or less troublesome driving with ISA?

Using questionnaires, test drivers have stated their own perceptions of the mental burden. The basis for this has been the RTLX method (Raw Task Load Index [21]), although using a simplified methodology and scale.

The results are illustrated in figure 4:15. The aspects include different mental and physical demands. No change was evident with regard to stress, whilst the pressures of time were somewhat more noticeable. A more evident indication is that the drivers using ISA feel more in the way for other motorists than those without ISA. This applies to a somewhat higher degree for drivers of active gas and informative system than warning system. A lesser proportion of test drivers (15-30%) perceive that irritation in traffic has increased, but there are also those who think the opposite (13%).

The problem of frustration is somewhat greater. This concurs with previous results from the MASTER project, which reports a statistically significant rise in the level of frustration. One difference between the systems can be noted with respect to strain. At the beginning of the test period, many perceived ISA as taxing. At the end of the trial, this is not as evident, but nevertheless 40% of the test drivers in Lund and 34% of the test drivers in Lidköping who drive with active gas stated that it was somewhat or much more taxing while 20-30% at these sites think the opposite. A reduction in strain was more the case towards the end of the test period for other systems. On the other hand, a predominant proportion of active gas drivers think that ISA requires less attention in traffic while drivers who drive with other systems think the opposite, particularly the drivers in Borlänge.

The feeling of being monitored or checked was evident for all systems. Between 23 and 32 % of the drivers think that this feeling has increased. There is no major difference here between systems or sites despite that logging during the trial only occurred in Lund and Borlänge.

The feeling of safety has been strengthened but partly at the cost of perceived freedom. The pleasure of driving has dropped for those driving with active gas and particularly in Lund where 40% think that it has dropped quite a lot or a lot. For other ISA-systems there is no difference. In Borlänge and Lund, where test vehicles were logged, half of the drivers prior to the trials thought they would feel that they were being monitored, but this share dropped during the course of the trials to about 30 %. In Umeå and Lidköping, where there was no logging the corresponding proportion was around 35-40% prior to, and 25% after, the implementation of the trials. An exaggerated apprehension was also evident here.

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21 Byers, J. C., Bittner, A. C. Jr., Hill, S.G., 1989: Traditional and raw task load index (TLX) correlations: Are Paired comparisons necessary? Advances in Industrial Ergonomics and Safety I, pp 481-485.

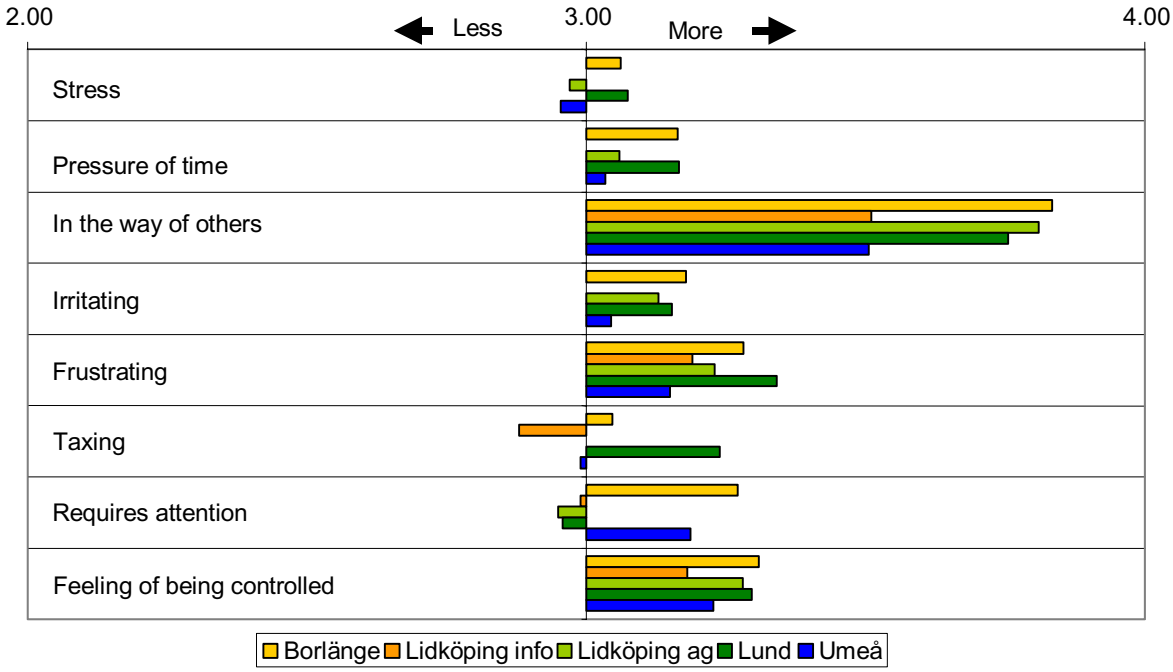

Figure 4:15 Self-reported change in mental burden for test drivers at the end of the trials

To the general question of whether it was considered that ISA drew attention away from more important things when driving, a clear majority answered that this was not the case. In Borlänge, only 7% concur completely or for the most part with this statement. The corresponding figure for Lidköping is 9% of the drivers with informative system and 12% of the drivers with active gas, in Lund 14% and in Umeå 8%, i.e. a somewhat larger share among active gas drivers than drivers using other systems.

It has not been more taxing driving with ISA, although possibly with active gas. For active gas, the small problems that have arisen for the operability and performance of some participants' vehicles are suspected of having an influence. The fact that a large proportion of test drivers often feel in the way for other motorists may have caused mental strain for some drivers. Some drivers have been irritated and frustrated with ISA and many have experienced a feeling of being monitored. The small negative change in mental burden that can be noted for certain factors has dropped during the course of the trial and the positive change has been strengthened.

Conclusion – mental burden

The conclusion is that the drivers do not feel more stressed. The overwhelming perception is that ISA does not draw attention from other, more important things when driving.

Do you become a better or worse driver using ISA?

ISA is expected to facilitate the task of driving by the system simplifying speed controls. The test drivers have reported their impressions and perceptions on whether driving the vehicle in different respects has changed using ISA.

One hypothesis is that drivers with ISA in the car look less often at the speedometer than those without ISA equipment, which should provide opportunities for increased attention to traffic and better interaction with other road users. Of those driving with the warning system in Umeå and informative system in Borlänge, a predominant number look to a greater degree at the speedometer. However, this share has dropped over the course of the trial. On the other hand, those driving with active gas number

more than those who look less at the speedometer. A probable explanation for this is that, at the beginning, drivers are inclined to check the speedometer when the equipment is turned on and off. This need is less when driving with active gas. As drivers familiarise themselves with ISA, the need to look at the speedometer drops.

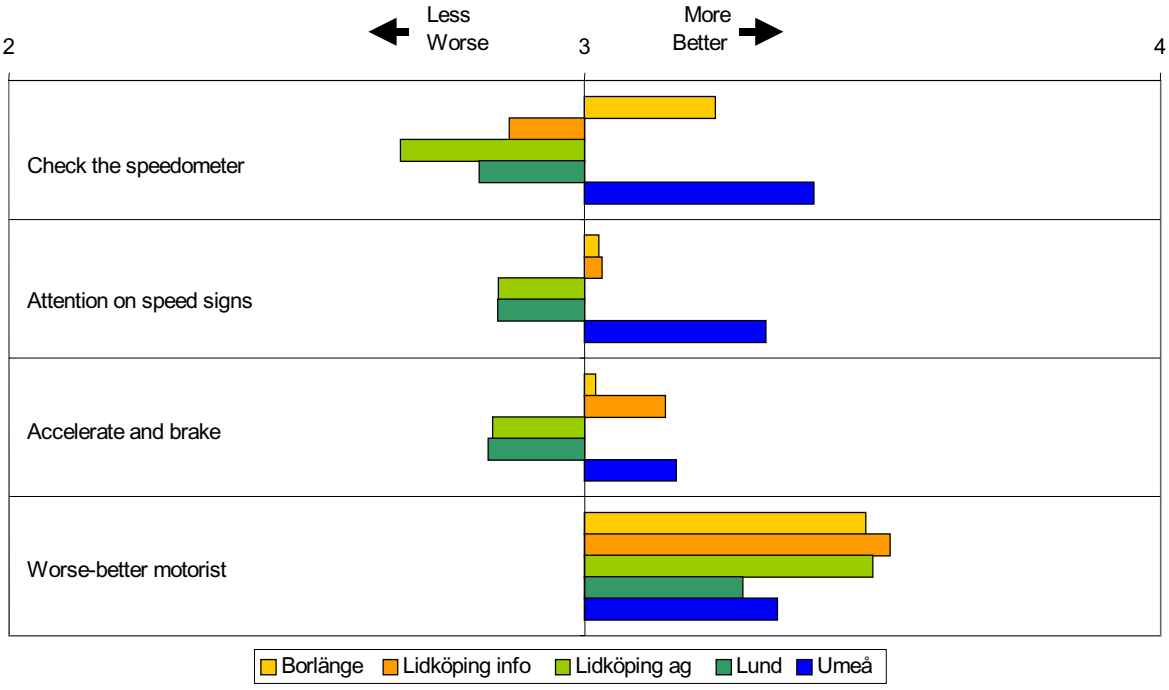

Figure 4:16 perception of change of certain driving tasks (final measurement)

The pattern is almost the same for the attention paid to speed signs. The majority of Umeå drivers (44%) have become more attentive to signs, while the figure for active gas drivers who think that attention paid to signs has dropped is 40%. The difference is equal for the informative system as a whole.

Several drivers of the warning and informative systems reported that they accelerate and brake to a greater degree than previously, while a predominant share of active gas drivers, on the other hand, claim that they do not need to accelerate and brake to the same degree as those without the system.

There is a clear perception from the drivers that they have become better car drivers as a result of ISA. Around half of those driving with the informative system (46 and 54%) consider that they have become somewhat or much better car drivers after the trials, 46 and 36 % of those driving with active gas share this perception and the figure is 34 % for those driving with the warning system. An increasing number had this perception during the course of the trial. Accustomisation has been positive in this respect.

An overwhelming majority consider that it has become easier or much more easy to observe the speed limits using ISA. Table 4:10 shows the number of the test drivers who share this opinion after completion of the trial. With the exception of the informative system (Borlänge deviates) most test drivers consider that ISA facilitates the chances of observing 30 km/hr, then 50 and 70.

Between 80 and 98% of the test drivers expected that it would be easier to observe speed limits using ISA before the trials commenced. The proportion that thought that this was correct after one month was 15 - 20% lower while a small revival was noted in connection with the final measurements.
The pattern is similar for different speed limits, and even between the sites, however, this is most

evident at 30 km/hr. It should also be noted that proportionately more consider that active gas makes it easier to observe the speed limits than the other ISA systems, after the completion of the trials.

Table 4:10 Share of test drivers who consider it is easier or much easier to observe speed limits in the final phase of the trial (%)

	Informative	Active gas	Warning
30 km/hr	74	85	75
50 km/hr	76	81	71
70 km/hr	64	73	62

The results mean that the high expectations are not fully met after a short period of use, but the impression improved gradually the more the technology was used. This concurs well with the expectations for the amount of time required for adaptation to the technology. The change is illustrated in figure 4:17 with respect to 50 km/hr.

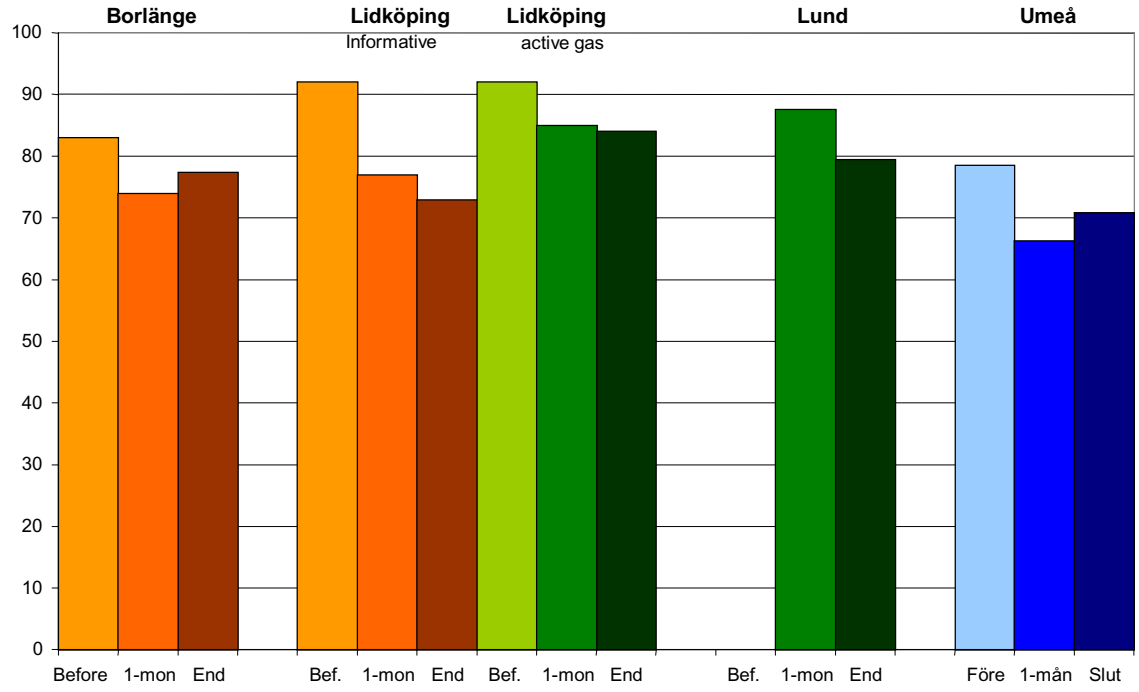

Figure 4:17 Change of perception, during the trial, that it is easier or much easier to observe the speed limit at 50 km/hr with ISA (share of test drivers in %)

Conclusion – perceived driving ability

The conclusion on the change over the course of time is that several factors with respect to driver tasks changed positively during the trial. Drivers looked increasingly less at the speedometer during the trial, especially with active gas, which indicates that drivers trusted ISA to an increasing degree. The same thing applies generally for speed signs. The change in the extent of particular driving phases (accelerating - braking), which for the warning and informative ISA systems was perceived to have increased at the beginning, were not as evident after a period of use. The drivers adapt.

How has the behaviour and the attitudes of the drivers changed over the course of the trial?

The test drivers changed attitudes and behaviour over the year the trials have been in full swing have been measured. This has been done partly through repeated questionnaires and interviews, before, immediately after start, during and after the completed trial, supplemented with focus group discussions, partly through passenger studies, logging and to a certain extent conflict studies. The results show that adaptation also continues after drivers have tested the equipment for a whole year. Therefore, the results could be different after a further year's driving with ISA.

The expectations on the equipment have been excessive in certain respects. This has lead to a certain disappointment being evident in the first month measurements, which is reflected in poor value judgements. However, the drivers have progressively embraced the benefits of ISA, and apart from some disadvantages, which are apparent in that the value judgements in several cases improve again in the final measurements after around one year.

In a corresponding way, an adaptation process can be traced in the measurement results. Speed reductions are primarily greater after one month than after one year. The ISA equipment initially makes an intrusion into the familiar driving style. Driving speed is reduced principally under free driving conditions where speed violations have been usual, followed by an adjustment of driving style so that the allowed speed level is utilised wherever possible. You approach the upper limit whilst at the same time try to avoid braking and stopping unless it is necessary. This results in ISA's influence on journey times being minimised.

Ergonomical deficiencies, for example, all the more intensive sound signals are difficult to get accustomed to, which is shown in the following section. Irritation increases hear over the course of the trial.

4.8 How can the ISA system be improved?

The aim of the international evaluation of product aspects is to be clear about how the system should be designed and developed for integration with other equipment in the car. The report is based on the hypotheses 17-20 at the end of the chapter. The answers have been received by collecting experiences from the trial sites, driving simulation studies and expert discussions with respect to:

- attitudes to functionality and intelligibility
- inclination to pay
- development ideas
- implementation issues

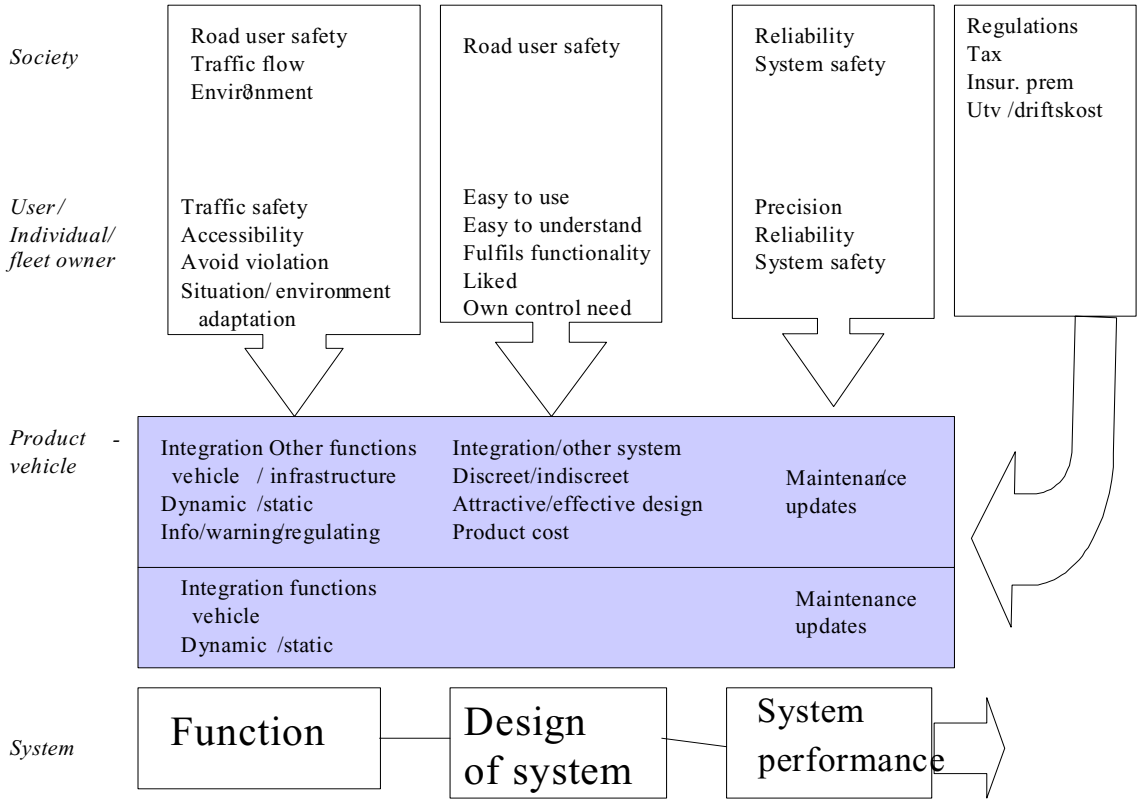

Figure 4:18 Outline diagram of factors influencing the product

Figure 4:18 shows an overview of society/fleet owner/user demands on an ISA system's functionality, design and performance, and that which is important to consider in the vehicle and for the infrastructure. For example, the user puts demands on the system being easy to use, easy to understand and that it answers to the user's control requirements. This results in the producer deliberating about how the system should be integrated with other systems and how the warning signal should be designed in order to achieve appropriate discretion.

How has the equipment performed during the trial period?

The ISA systems used have been developed and produced as a part of the project. There was not enough time to try out and long-term test these prototypes to the extent required and normally done ahead of a market launch. Operational problems have therefore arisen, particularly for the more technically complicated active gas system. For example, 35% of the drivers in Lund report that they often or very often have had problem with the accelerator pedal's depressed position. In Umeå, only a few percent have reported that they have often had technical problems while 7-15 % of those who have driven with the informative system mention this.

The systems include different functions that influence the perception of driver support:

Table 4:11 System functions of significance with respect to driver support

ISA system Function	Warning (Umeå)	Informative with appl. speed limit (Borlänge, Lidköping)	Active gas with kick-down (Lidköping, Lund)
Sound signal	X	X	
Light signal	X	X	
Display (screen)		X	X
Resistance in gas			X
Manual setting of speed (outside of trial site)			X
Placement	X	X	X

The functions are not directly comparable. The signals are not designed in the same way in the different systems. The sound signals are, for example, more intensive in Umeå's warning system than in the informative system with display. In addition, two makes of the informative system are used in Borlänge where signals and displays have different designs. The display used in connection with active gas also differs from other types.

Sound signal

Many affected test drivers perceive the sound signal in the warning and informative systems to be noisy. The proportion of the private test drivers that often or quite often wanted to switch off the signal has gradually increased over the course of the trial to almost 20% (see figure 4:18). Among commercial drivers (incl taxi and bus) the figure is significantly higher (38 % in Umeå and 69 % in Lidköping). 10 % of the private test drivers report that passengers have often or very often complained about the noise. This is particularly evident in Borlänge among the younger age group (18-29 years), where 37 % report this.

Every fourth private test drivers who have driven with warning or informative ISA system state that they often or very often would like to change the sound. A softer tone is desired. 25-40% think that the signal should increase in strength, and even more (30-50%) think that the sound signal should peep quicker the more the speed limit is exceeded. Only a marginally smaller share (0-3 %) consider that it is often or very often a problem listening to ISA's warning signal due to traffic noises, noise from the engine, fan noise, mobile telephone use, radio on, or children in the car.

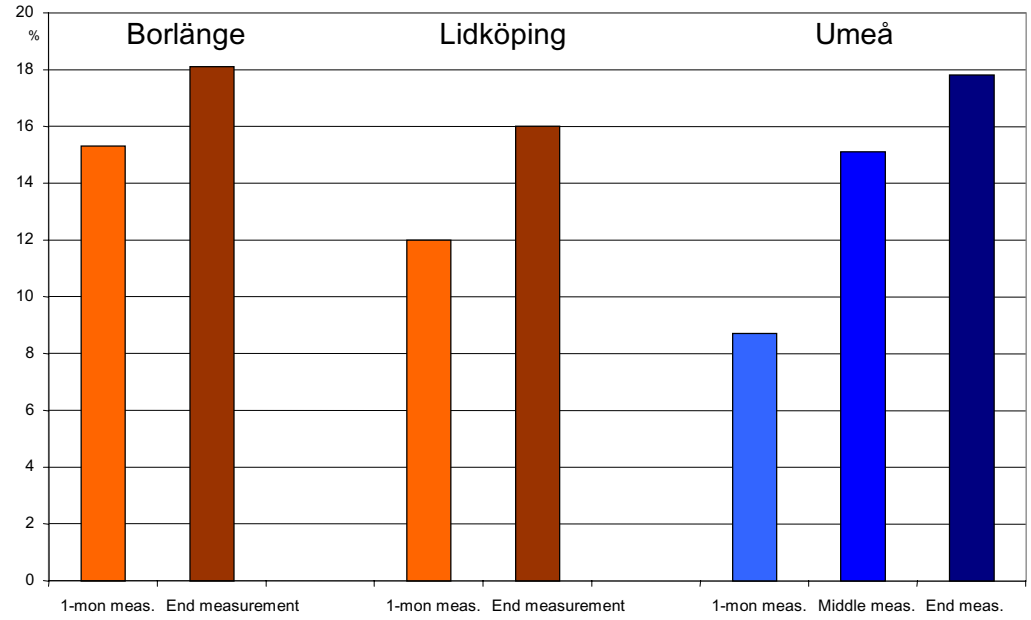

Figure 4:19 Share of private test drivers who often or quite often would like to switch off the signal

Light signal

The light signal has not caused as many problems as the sound signal. However, 10-20 % of the users of informative ISA report that it has very often or often been a problem to see the green and red signals when the sun shines directly on the apparatus. The figure for light signals on the warning system is lower. During other light conditions (not direct sunlight, cloudy, darkness etc) only a few percent have had problems seeing the light signals.

Display

Direct sunlight also makes it very difficult to see the vehicle speed on the display. For informative ISA, 9 % in Lidköping and 20% in Borlänge report that they have very often or often had this problem. For active gas, the share is higher, 25% in Lidköping and 45% in Lund. In cloudy weather, only a few percent experience problems seeing the display. A smaller share (around 10 %) has had problems due to sight impairment or other such problems.

The accelerator pedal's resistance

Of the private drivers who drive with active gas, 12 % in Lidköping and 18% in Lund reported that they quite often or often would like to reduce the strength of the resistance to the accelerator pedal, whilst practically nobody wanted to do the opposite.

Reliability

The ISA systems tested are developed and produced within the framework of the project. They have not been fully tested and have therefore been afflicted with a number of technical problems, which particularly applies to active gas and, to a certain extent, to the informative system. 46 % of the test drivers in Lidköping consider that active gas has been troublesome (sometimes, often or always) and 37 % in Lund (some have even left the trial due to technical problems). In Borlänge, 41% of drivers share this view about the informative system, but the figure is only 14% in Lidköping. The warning ISA system has been most problem-free, only 5 % in Umeå consider it to be troublesome. The technical problems at the beginning of the trials were numerous in the diary notes of the trial personnel in Lund.

One interpretation is that these problems were so extensive that they may have affected the prospects for a balanced and factual assessment of active gas, and even resulted in several test subjects abandoning the trials. It also came to light during the in-depth interviews that technical problems had affected the assessment of acceptance.

A number of error functions or deficiencies in the precision have been reported. For example, 25% of those who have driven the warning ISA system reported that the warning sometimes, often or always comes too late. 55% of those who have driven the informative ISA system have this perception, and around 70% of those who have driven with active gas. The change is marginal during the trial period.

Viewpoints on how ISA affects the different driving situations are most evident for active gas which is of course connected to the vehicle's propulsion system. The greatest problem has been the changes in the car's characteristics due to the delays in the reactions during accelerator depression. Around 60% experienced sometimes, often or always problems during start/accelerator depression following one month's test-driving. Towards the end of the test period, the proportion had reduced in Lidköping but increased further in Lund. Accelerating under the speed limit caused problems for around 40% in the beginning, and even more (47%) experienced this problem at the end of the test period. Overtaking caused problems for 20-30% which then fell to 15-20% at the end of the trials.

Despite the problems with technology and operability, the test drivers have confidence in the systems. The proportion who has a lot or complete confidence in the ISA systems is greatest for the informative ISA system (80-90%), followed by active gas and finally warning ISA. For all systems, apart from warning ISA and active gas in Lund, this perception has been strengthened during the course of the test period (see figure 4:20).

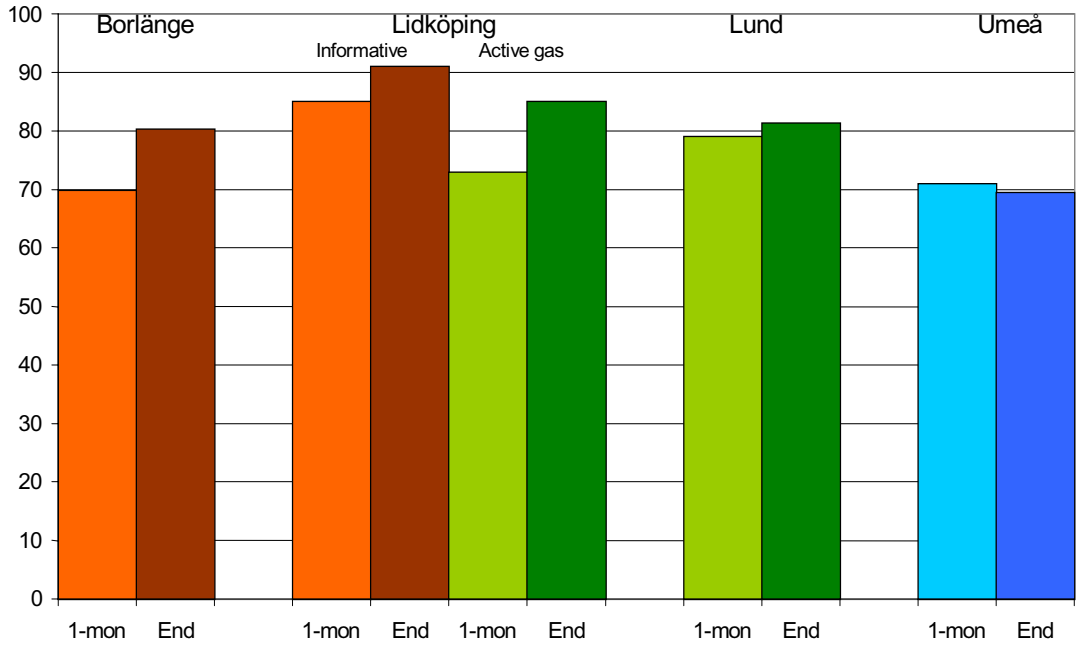

Figure 4:20 Share of test drivers who have a lot or complete confidence in ISA

Conclusion – the function of the equipment

The negative experience of the ergonomic deficiencies such as the intensive sound signal is impossible to get accustomed to. Those wanting to switch of the sound signal often or quite often increased from 13 to 17% for informative ISA, and from 9 to 18% for warning ISA. Other technical and functional deficiencies which were not corrected were continued to be perceived as negative, for example, slow

reaction time when depressing the accelerator using active gas. One conclusion of this is that the equipment to be tested in the future or that is to be introduced onto the market must be ergonomically tested, work perfectly and be reliable.

The drivers have confidence in ISA and this perception has been strengthened during the test period in Borlänge and Lidköping while it remains at a high level for the other sites.

What is the general impression of ISA?

Applicability and attractiveness

To examine the test drivers' attitudes towards ISA, a procedure based on the Dutch method is used[22]. The test drivers were asked to mark their perception for a number of questions relating to applicability and attractiveness. The opposites to the questions, for example bad – good are specified in the end points on a seven point scale. The answers submitted in connection with the final measurements have been analysed for each trial site, which included help from factor analyses. In this context, six question pairs were formulated describing attractiveness (or satisfaction) and applicability (or usefulness). These are:

For attractiveness: *unpleasant – pleasant, irritating – soothing, uncomfortable – comfortable*

For applicability: *ineffective – effective, unclear – clear confusing – informative*

The neutral position is four on both scales. All driver categories give a relatively high grade for applicability (average value 5.7). Commercial drivers (service vehicles, buses and other commercial drivers) grade applicability somewhat lower than the others. Views on attractiveness are more spread (average value 4.0). Commercial drivers and private drivers in both of the youngest age classes stated that attractiveness was insufficient. The drivers who were originally negative to the ISA systems also shared this opinion, while those who originally were positive to ISA, along with older drivers, are more positive.

When breaking down the different systems, minor shifts and changes become apparent but the main trait remains. Accordingly, the level of applicability is a few tenths higher on the scale for the warning system compared to the other two systems. Furthermore, differences exist between genders which is not shown in the figure. More women think that the warning system is more attractive than men do, while the opposite is true for the other systems, even though the difference is negligible.

Overall perception

The drivers' assessment of whether ISA is good or bad provides an indication of the overall perception of the system. A clear majority think that ISA is good! This applies most of all for those who have driven with the warning and informative systems, with a somewhat smaller share for active gas. A clear majority of those who were negative to all ISA systems in the beginning think that the system works well. See figure 4:21 which shows the share in percent of the test drivers who answered positively (5, 6 and 7) and negatively (1, 2 and 3) on the seven point scale. The difference between the different driver categories follows the same pattern as for applicability and attractiveness above.

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22 van der Laan, Heino, de Ward; A simple procedure for the assessment of acceptance of Advanced Transport Telematics. Transportation Research, Part C. Vol 5, No. 1 pp 1-10. 1997

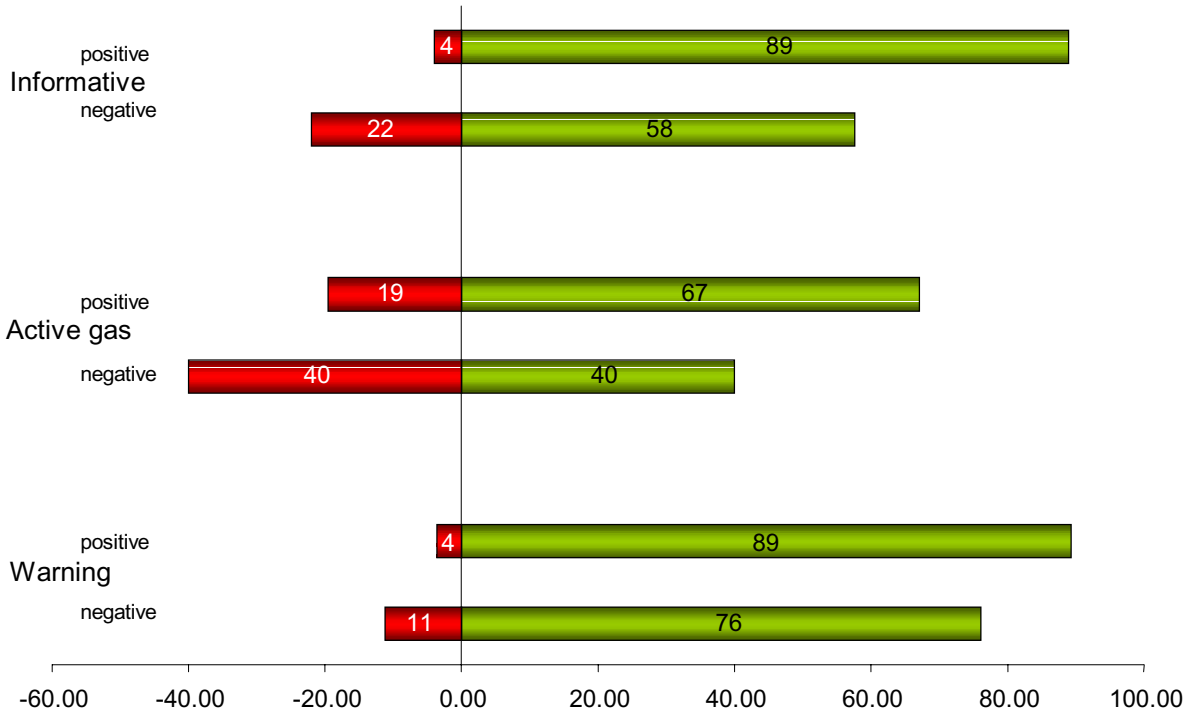


Figure 4:21 The test drivers' perception on whether ISA has been good or bad broken down by their original opinion to ISA

The acceptance of ISA has been strengthened by a majority of the test drivers, after the trials, who consider that ISA should be compulsory in urban areas (Borlänge 60%, Lidköping info 64%, Lidköping active gas 60%, Lund 45% and Umeå 55%). Almost 40% (Lund 30%) think that it should be applicable by law. A large proportion (around 40%) think that ISA should even be compulsory in highway traffic.

Interest for keeping ISA

Many of the drivers who have participated in the trial using ISA equipment would like to keep the equipment after completion of the trial. A little over 60 %, of those who have tested warning and informative ISA are interested, whilst the share is lower for those who have tested active gas (49% in Lidköping and 36% in Lund). Following the completion of the trial, the number wishing to keep the system is a little lower than after one month's operation (see figure 4:22).

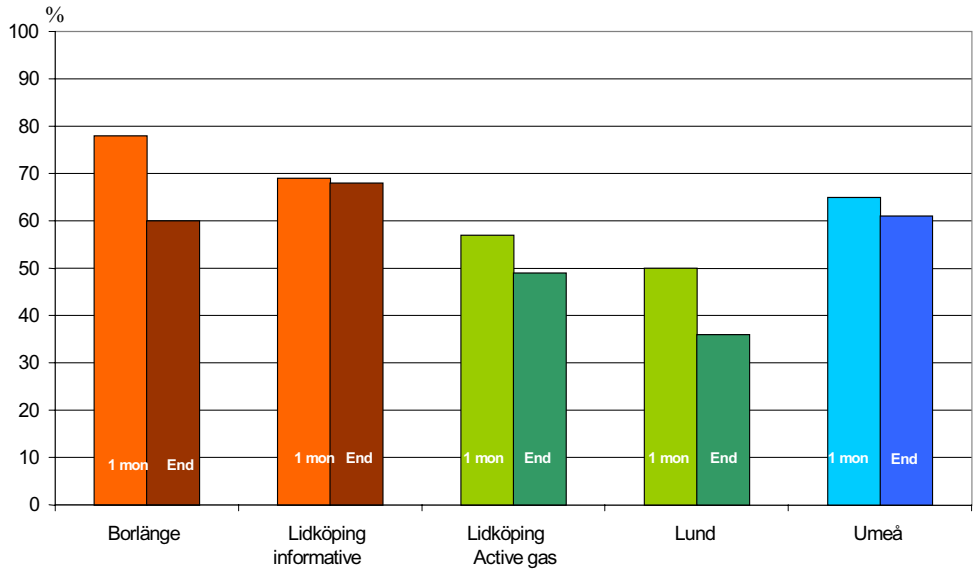


Figure 4:22 The share of test drivers who would like to keep the ISA equipment after one month and following completion of the test period

Conclusion – overall impression

A clear majority of the test drivers give ISA a good overall total judgement. This judgement is supported by a majority of the test drivers, after the trials, having the opinion that ISA should be compulsory in urban areas. On the other hand, drivers, particularly younger drivers and commercial drivers, to a great degree, feel that ISA is not so attractive. Almost two out of three test drivers wanted to keep their warning or informative ISA after the trials. The number is somewhat fewer for active gas.

What are drivers prepared to pay for the ISA system?

The willingness to pay out of the drivers' own pockets to keep their ISA equipment varies a lot between the four trial sites and for the different systems. For those driving with the informative system and are willing to pay for it, the figure is around 50%, marginally more in Lidköping than in Borlänge.
34% of those who have driven with warning and, on average, an equally large proportion of those who have driven with active gas (Lidköping 40% and Lund 29%) are willing to pay.

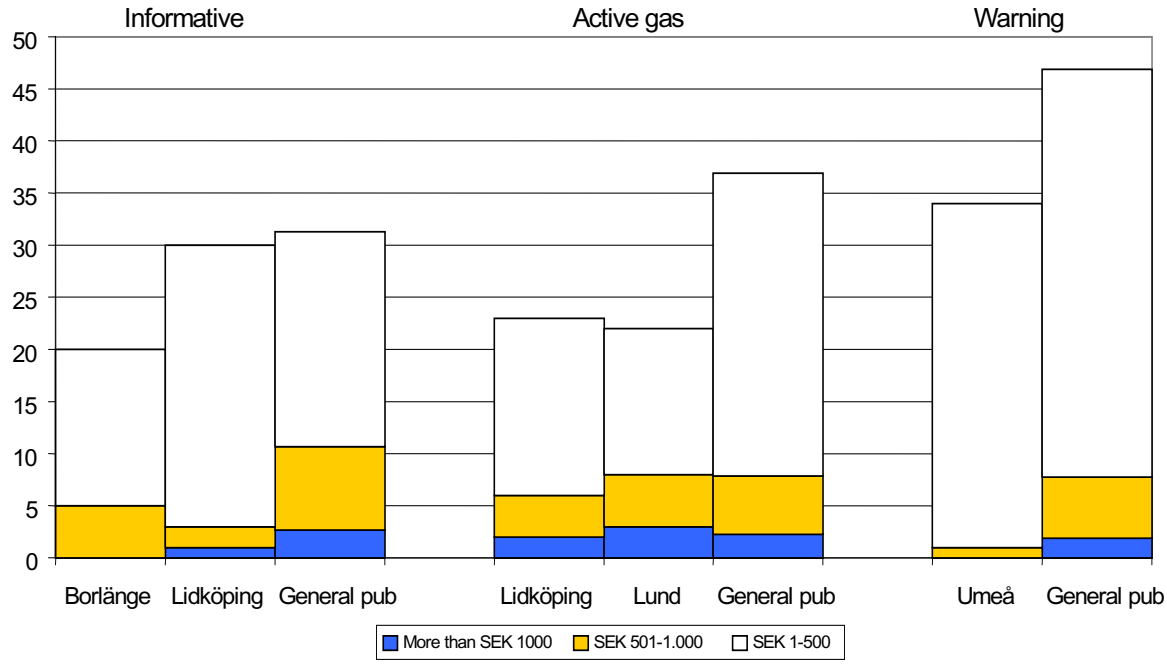


Figure 4:23 ***Share of test drivers who are prepared to pay to keep ISA shown in a range of price classes. The figure also includes what the general public was prepared to pay for the various systems***

How much are drivers willing to pay?

Only a small minority are prepared to pay more than SEK 500 in order to keep their ISA equipment following the final measurements. For warning systems the figure is 1%, for informative 3-5%, and for active gas 6-7%. Before the trials started, significantly more people were prepared to pay above SEK 500. This was particularly evident in Lidköping where almost a third of the test drivers, irrespective of type of system, were prepared to pay above SEK 500. Practically nobody was prepared to pay more than SEK 1000, 2-3% of the test drivers who drove with active gas, under 1% of drivers using informative and none of those who drove with warning. See figure 4:23 which also includes the general public's perception of what they were prepared to pay for each described type of system (from measurements in Umeå, Lund and Borlänge).

For those test drivers who are prepared to pay something, the average sum (the median) is SEK 150 for warning ISA, SEK 400 for informative ISA and SEK 500 for active gas. When the average sum of what drivers were willing to pay is calculated for all test drivers - both the group that are prepared to pay and those who are not - the median is SEK 0 for all systems. This means that those who are not prepared to pay dominate the figures.

How much will ISA cost on the market?

Views on how much ISA equipment is going to raise the price for new cars or how much it will cost to equip older cars varies substantially between the trial sites. It is important to bear in mind that the equipment tested has been very different at the four sites, and the technical level has varied from site to site. Nevertheless, it should be observed that the difference between the sites is greater with regard to what ISA should cost on the market than when in concerns the individual's will to pay. 30% of those who think that ISA should be paid for in Lund think that a new car could cost over SEK 1000 extra, and 70% that a car could be at least SEK 500 more expensive. In Umeå, only 10% think that the car could be SEK 500 more expensive. The results are illustrated in figure 4:24

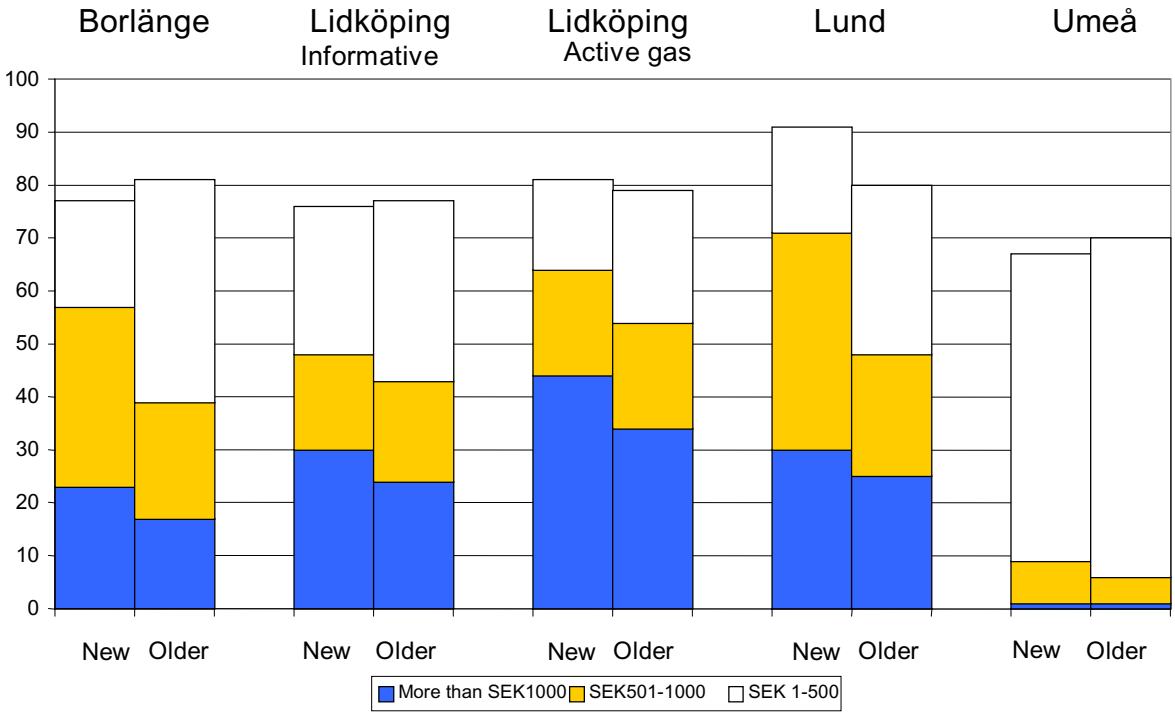


Figure 4:24 Rise in the price of a new car and price for equipping older cars with ISA. Share of test drivers per price class

If the test drivers who think that ISA should be paid for are included, the average price for ISA equipment for a new car and for equipping an older car is as follows:

Warning system		
New car	SEK 100	
Older car	SEK 100	
Informative system		
New car	SEK 750	Borlänge SEK 1000, Lidköping SEK 500
Older car	SEK 500	Borlänge SEK 500, Lidköping SEK 500
Active gas		
New car	SEK 1000	Lidköping SEK 1000; Lund SEK 1000
Older car	SEK 750	Lidköping SEK 1000; Lund SEK 500

The average values are higher if you only take into account those who think ISA should be paid for. For these test drivers, the warning system could cost SEK 300, informative system SEK 1000 and active gas SEK 1250.

The figures in the table do not show the market potential but only what the test drivers think is an acceptable level. However, this gives an indication that the willingness to pay is low despite that many would like to keep the system after the field trials are completed. If ISA is to be introduced to the wider public, the low willingness to pay must be taken into consideration. Some form of subsidy or other incentive may therefore be necessary.

What business concepts have evolved during the course of the trials?

Implementing a system like ISA (irrespective of specific design) involves being subject to a number of influencing factors which have been broken down here by function, design and performance. Function refers to what the system is to achieve, i.e. to adapt the speed of the vehicle; design is the specific design of the function that is made up of, for example, proposed pedal with resistance, display, etc. System

performance refers to how the system is able to communicate with the functions for each instance but also over the course of time. The ambition of the field trials has primarily been to evaluate society's and the individual's perception of the system. More on development concepts is reported in the final chapter where the implementation is discussed based on the perspectives of the technology involved, the automotive industry and society in general.

Concepts from the field trial

Questionnaires have been taken during and after the test period in connection with the user studies. What would be worth changing?

A number of deficiencies in the precision have been reported. The systems do not always react when they should. Many drivers report that the warning system often comes on too late. The precision needs to be checked out and improved.

The functionality has caused some irritation. Many drivers have complained about the sound signal for warning and informative ISA, and this has been accentuated during the trial period. Practically every fifth driver with these systems has often wanted to switch off the signal. A softer tone is desired.
The light signal has also caused problems, and it has been difficult for many drivers to see the speed information in the display window with the sun shining directly on it. Both the sound and light signals need to be improved.

A group of experts has been appointed to discuss the technical development parallel with the trials. What additional developments to ISA technology can be expected? The discussion suggests that it is probable that the technology for enabling ISA in future cars will be in place. This makes the system less expensive and easier to integrate with other support features.

Concepts from the driving simulator tests

If the production and design of the product in the vehicle is to be handled and sold by the automotive industry, consideration must be taken to a number of different factors, for example, integration into own product, operability of the system, the product in the infrastructure, the users' wishes and capacity, maintenance of the system and business opportunities. Some of the more important factors include the obvious fact that the design should allow for safe use, but also that it stimulates the drivers to use it, and that the system is integrated into the vehicle in a satisfactory manner. The system designs may be active (the system intervenes in the function of the vehicle) or passive (the system informs the driver) and discrete (only the driver is made aware) or indiscrete (all passengers receive the message).

As part of the process of investigating further concepts for design of the system in the vehicle a little closer, a driving simulation test[23] has been carried out at Volvo with 18 test subjects recruited internally at Volvo. Two different types of system design were tested:

- *passive, discrete* system with short vibration in the seat which informed the driver that the speed limit had been exceeded and a display which let the driver know what the speed limit was

- *active, discrete* system with “dead” accelerator pedal where acceleration was “cut” when the applicable speed limit was exceeded. This could be avoided by “kick-down”. The system is similar to that tested in Lidköping and Lund.

23 Intelligent Speed Adaptation (ISA). Volvo Engineering report ER-520077

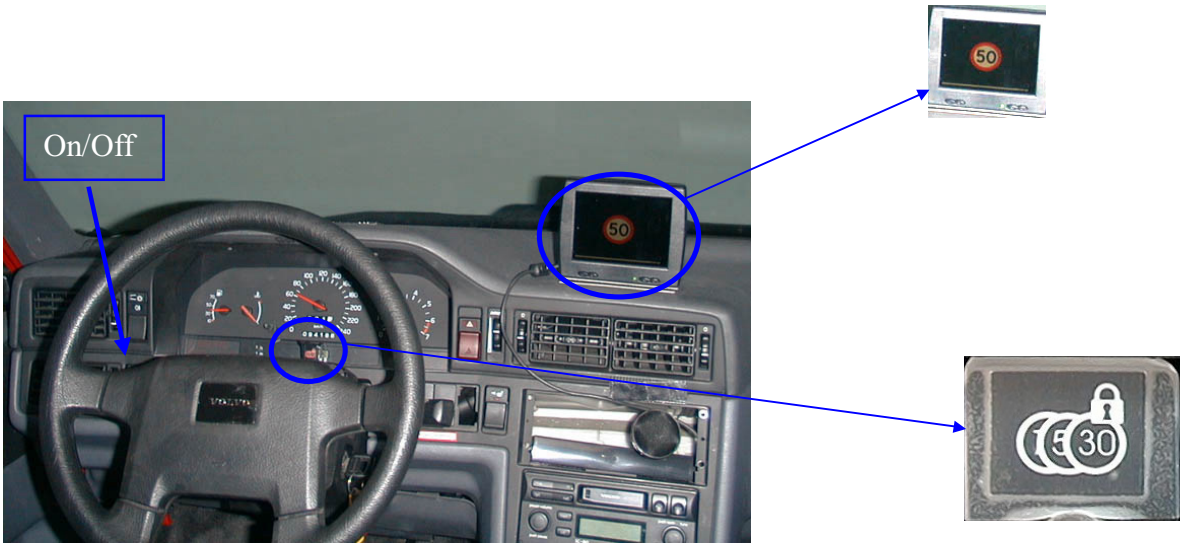


Figure 4:25 Passive system with vibration in the seat

The passive system had the innovation of the vibration in the seat, i.e. if the driver exceeded the speed limit, the seat vibrated for a short moment (2 seconds) at a frequency of 200 MHz. In addition, a display was present showing the applicable speed limit (see below). If the driver exceeded the speed limit, the applicable speed limit flashed on the display until the driver had slowed to the displayed speed. An activation button was also included with this option, along with an indicator showing the status of the system.

All 18 test subjects drove for 15 minutes with each system in varying sequences. The traffic situations included speed limits of 30 km/hr, 50 km/hr and 70 km/hr, traffic lights, overtaking, etc. intersections with traffic lights and other road users were included in the distance driven in the simulator. The test drivers were encouraged to drive as they normally would in traffic. If they judged that the driving situation called for the system to be deactivated, this was permitted, but they were encouraged to reactivate the system as soon as possible. After the driving, the trial subjects were asked a number of questions relating to the operability and the specific design of the system.

The overall average speed during the tests was 58 km/hr with the dead pedal system and 56 km/hr with the vibration in the seat system. It may have been expected that the average speed could possibly have been higher with a passive system, but this was not the case.

The majority (12) preferred the dead-pedal system ahead of the vibration in the seat. Those preferring the dead-pedal system preferred the active system, i.e. the system intervenes if the driver drove too quickly. However, if the vibration in the seat method was preferred, a system that intervenes was **not** wanted; a passive system (5) was preferred. Only 2 of 18 reported that they did not want any of the systems.

It should, however, be pointed out that a number of those preferring the dead-pedal system (2 of 12) did not follow the system. The same applies for the vibration in the seat system, i.e. of those preferring the system, a number did not follow the system (3 of 5). The majority (15 of 18) held the opinion that it **must** be possible to deactivate the system whenever necessary.

Both systems were described as somewhat frustrating but nevertheless helpful. The systems were not regarded as distracting. Some drivers reported that they would use an ISA system if they had it in their

own car. Others stated that they would use the system under certain specific conditions (e.g. that they could add or remove parts of the tested system).

Most held the opinion that such a system was very good for reducing speed on the roads. They had a number of suggestions for improvements to the systems, the numbers in brackets specify the number suggesting each modification. Everyone had improvements for the system they preferred. Nobody specified modifications/improvements for both systems.

The active system (dead accelerator pedal):

- More resistance to the accelerator pedal when the motor is cut (6)
- Add information on applicable speed limit (as in the passive system) (6)

The passive system (vibration in the seat)

- The possibility of setting the frequency of the vibration (2).
- More aggressive vibration that fades progressively (1)
- Possibility of replacing the vibration with a sound warning or flashing light (1)

The study shows that many drivers were prepared to embrace an intelligent speed adaptation system. However, there are differences when asked which systems the drivers were prepared to use. Those preferring an active system were **not** prepared to use a passive system and vice versa. The general opinion was that it was of the utmost importance that all cars operated with such a system, otherwise traffic flow would be disjointed.

Conclusion - development concepts

If ISA is to achieve a major breakthrough, it is important that the equipment is ergonomically tested, works problem-free and is reliable.

A system ought to be developed whereby the user can select between an active and a passive system. It should also be designed in such a way that it feels perfectly natural to follow the system. In the long term it is important to integrate the system with other driving support systems, cruise control, collision warning systems etc. Properly integrated systems provide for comfortable driving and a tangible feeling of safety and mental well-being for the driver.

4.9 Answers to hypotheses and questions concerning ISA

Using previous trials, twenty hypotheses were formulated in the user and effect groups, which were to be particularly studied in the large-scale trials and be included in the comparable evaluation. In addition, a number of other aspects have been assessed locally at the separate trial sites. The conclusions have been outlined earlier in the chapter. The assembled hypotheses and the answers we were given from the trials are reported below.

Traffic effects:

1. Average speed and speed distribution under free driving conditions. A more balanced way of driving using ISA, better adjusted to applicable speed limits is expected to result in positive safety effects.

   The trials confirm that both average speeds and speed distribution reduce using ISA. In addition the proportion of speeding violations and conflicts has reduced. On the whole, traffic safety effects are therefore greater than most other comparable measures taken in urban areas.

2. Driving process and speed adaptation at roundabouts and intersections At intersections, the speed level is expected to drop, which will lead to the number of occasions where vehicles are involved in conflicts reducing. For vehicles involved in conflict situations, the reaction time is increased due to the lower entry speed, which means the consequences will be less serious.

   The trials do not show that speed levels are influenced at the intersections themselves where the average speed is already low when exiting. One exception is T-junctions, where the average speed is higher. Lower speeds can also be tracked here on primary roads at the junction itself. The trials confirm, however, that the number of serious conflicts reduce using ISA.

3. Approach speed in distance intervals 0-80 m before intersection. A more balance driving style using ISA also means lower approach speeds to the intersections.

   The trials confirm that the approach process is influenced, but the effect of ISA diminishes and is gone at the 0-25 m interval before the intersection.

4. Turning speed at the intersection. A more balanced driving style allows for more time at intersections and lower turning speeds when interacting with other road users.

   ISA has no detectable effect with regard to turning speeds, which are already low when exiting

5. Time gaps and vehicle queues at the 30-70 km/hr speed interval. Time gaps between vehicles in queues are expected to increase, while time gaps between queues (columns) run the risk of being reduced. The latter may give rise to problems for pedestrians finding acceptable time gaps.

   Trials indicate that the ability to keep distances in dangerous situations is improved using ISA, but this result is uncertain. An indication that queue lengths were influenced was not detected.

6. The inclination to stop at a red light at signal-controlled intersections. The share of drivers driving through a red light in connection with signal-controlled intersections reduced.

   This could not be detected in the limited studies carried out in the trials.

7. The inclination to stop at pedestrian crossings. The share of drivers who stop at both signal-controlled or non-signal controlled pedestrian crossings will increase.

   The trials cannot clearly confirm that the inclination to stop has increased, when the results suggest the opposite. For example, there is a tendency for bus drivers in Lund to stop less. On the other hand, consideration to pedestrians in risk situations has increased in Umeå, where the share of serious conflicts has dropped and in Lund where interaction has improved.

8. Other effects (journey times, fuel consumption and exhaust emissions). Journey times, fuel consumption and exhaust emissions will not be affected in any significant way by using ISA.

   Trials show that at least active gas and probably even the other ISA systems do not lead to an increase in journey times in urban areas. Fuel consumption and exhaust emissions are not negatively affected either, on the contrary the opposite. The drivers have skilfully adapted to the system so that the feared negative effects have not arisen in reality.

The user
:

9. Needs of and attitudes to speed adaptation. The driver thinks that support in connection with dangerous situations (according to results from previous studies) is needed to a greater extent than for other general speed adaptation systems (continually connected in urban areas).

The trials confirm the view that support is needed and is considered greatest (over 75% of respondents to the questionnaire) for 30-environments, outside schools and day-care centres, during rush-hour traffic, poor weather conditions and for special groups such as notorious speeding offenders.

10. Design of driver support. The road user will probably be informed, but not controlled (by enforced system).

    The question has been expanded to include mentioning the compulsory presence of the equipment in the car and its compulsory use. The trials show that the driver wants by and large to be informed, but also that support is greater than expected for making it applicable by law.

11. Perception on ISA's influence on driving style. Not before the driver has tested the system can he or she get a feeling for, and create an impression of, how the technology might influence the individual. It could be about driving in a more balanced way and an increased feeling of being secure of not being caught for speeding.

    The trials show that driving style is influenced by ISA. ISA focuses on speed adaptation and drivers pay more attention to speed signs and unprotected road users. Three of four perceive that the risk of being caught for speeding has reduced a lot or quite a lot.

12. Driver safety. The individual's fears about the risks of using ISA are exaggerated. Traffic safety consciousness may instead increase for those that have tested the system

    The trials confirm that the fears associated with ISA are exaggerated. The drivers also perceive that their own safety, and attention paid to speed signs, for example, has increased.

13. Unprotected road user safety. The unprotected road users perceive a greater sense of safety when the speed of vehicle traffic is more uniform and predictable.

    More studies, for example, passenger and conflict studies suggest that pedestrian safety has increased, even though interviews with pedestrians show that they themselves have not noticed any difference.

14. Mental burden. Using ISA in the car is expected to reduce the mental burden.

    The trials show that drivers do not feel stressed, and that ISA does not draw attention away from more important things. The predominant feeling of irritation is, however, that drivers feel "in the way of others".

15. Concentrating on the task of driving. Using ISA in the car means drivers look less at the speedometer, which provides room for increased attention towards the traffic.

    The trials confirm that drivers look less at the speedometer, especially with active gas, and dedicate more attention on traffic the more ISA is used.

16. Long-term attitude and behaviour changes. The compulsion for certain drivers to exceed the speed limit will be moderated, which will result in an increase in traffic safety.

    The trials show that the compulsion to exceed the speed limit is replaced by the compulsion to utilise the applicable speed limit wherever possible.

The product/system:

17. Perceptions on functionality. The user's expectations towards the technology are difficult to assess because few people know or understand what the system is capable of. This is an information problem

.

The drivers had a realistic view of the equipment. The drivers have confidence in ISA and this remains unchanged or has been strengthened during the course of the trials. Apparent technical deficiencies have drawn criticism.

18. Perception on intelligibility. The picture of how the system operates should agree with how it operates it reality. Information submitted must be consistent, i.e. it must agree with the information gathered in other ways. This means that when the drivers pass by a sign with speed limits, the system in the vehicle should be activated, not before or after.

    Every fourth test driver experiences problems with the precision of speed information. Questions have also arisen due to faulty information from the speedometers which can amount to 15 km/hr. The trials confirm that different systems must be coordinated so as not to confuse motorists.

19. The willingness to pay for separate ISA systems. The willingness to pay is greater for active gas than for the warning system, but increases greatly if the system can be combined with different forms of benefit or warranty.

    The trials confirm that the willingness to pay is somewhat greater for active gas. However, overall the willingness to pay is low. Whether this willingness increases in combination with other measures has not been investigated.

20. Technical development. It is probable that the technology for enabling ISA in future cars will be in place. This makes the system less expensive and easier to integrate with other support features.

    This is supported by discussions in the expert group, but has not been able to be investigated in detail during the trials.

5. Technology

5.1 Available technology

The purpose of the **voluntary, supportive** and **informative** systems that were evaluated through the four local projects was to help drivers avoid exceeding the legal speed limit. In the future, ISA will be developed into a more intelligent system which can be used, for example, dynamically or in connection with varying weather and traffic conditions

Basic features in the ISA system

A speed adaptation system should be capable of carrying out basic features in order to provide the driver with effective support (compare also figure 7.1):

- Calculate the appropriate highest speed (for the time and place the vehicle is currently in). In this trial in line with the applicable speed limit.
- Measure the vehicle's speed.
- Support the driver in adapting the speed.

Calculation of appropriate top speed

In order for the ISA system to calculate the appropriate top speed (in this case the applicable speed limit), it must know the time and place of the vehicle, and the speed limits that apply for the various places and wherever possible the times. The following is therefore required:

- A "positioning system" which tracks the location of the vehicle
- A map (database) with applicable speed limits
- Software that matches the position on the map, and finds the applicable speed limit for the current time and place.

These tasks can be carried out in several different ways, which means there are some important technical path selections in the creation of an ISA system.

Selection of positioning system

The positioning system usually consists of components in the vehicle that receive signals that are transmitted from reference transmitters, and calculate the vehicle's position relative to these. In addition, the position must have additional information from sensors that measure the speed and direction of the vehicle. Here there are two main paths to take:

- Build a separate network of reference transmitters in the relevant area.
- Use existing positioning systems (e.g. GPS).

Building a separate network of reference transmitters could be achieved through, for example, using microwave technology (transponder technology). This technology has been used in the trials in Umeå where 200 transmitters were located. Building up this infrastructure is very expensive, which is why this technology is best suited when a large number of vehicles are to be positioned within a limited area, which was the case in the Umeå trials where 4000 vehicles participated. The advantage of this technology is the possibility of a reliable, stable precision for the positioning, independent of other systems and less expensive vehicle units. By using an existing positioning system instead means that expensive investment in a separate infrastructure and installations at street level is avoided.

GPS (Global Positioning System), USA's system for satellite positioning, gives a precision of around 10 m when positioning and can also measure speed. The main disadvantage is that the positioning only works when the vehicle equipment has an unobstructed view of at least three satellites, which limits coverage and precision in urban areas and tunnels etc. However, this problem can be minimised by adding sensors to the vehicle equipment that measure speed and direction, and thereby can navigate for shorter periods without satellite coverage. In addition to this map-matching is also usually used which "snaps" the position to the nearest road. With these additions the vehicle computer will, however, be more expensive than corresponding transponder technology.

GPS was considered to be the best available positioning system and suited the purpose of the project in Borlänge, Umeå and Lund.

Communication of the map (database) with speed limits to the vehicles

The problem communicating a map with applicable speed limits is because:

- the speed map is centrally localised and must be communicated to all vehicles
- speed limits are changed, which means that the speed map is updated for all vehicles
- the speed map may be to large to be housed in small vehicle computers
- the speed map may be too large to be transmitted via "normal telecommunications".

Because the primary purpose of the ISA trials was to evaluate the effects of traffic safety and the attitudes of drivers, and not to solve the problems concerning technical infrastructure, these problems were by-passed by defining small enough trial areas for them to be housed in the vehicle computers, and that updating of the maps was limited and handled manually.

Using the transponder technology used in Umeå a very local map was transmitted from each transmitter which contained the applicable speed limits up to the next transmitter. The system thereby made changes to speed limits possible, as long as the road network itself was not altered . In Lund and Lidköping the entire map was loaded into the vehicle computer memory. Updating was only possible by visiting the depot. The option for transmitting maps via GSM, to avoid depot visits, was available in Borlänge.

Measure the vehicle's speed

One of two main principles could be selected here:

- Use the vehicle's existing speedometer.
- Measure the speed with help from the positioning system.

For Umeå's system, the vehicle's existing speedometer was used, by connecting to a pulse sensor, which for most vehicles is input data to the speedometer and mileage counter. To achieve reliable accuracy, calibration was required at installation. This measurement method was quick to react in detecting changes in speed and provided consistent speed information, but also consistent measurement errors if the system was incorrectly calibrated, for example, following a change of tires. In addition, a practical problem was that elder vehicles lacked an electronic pulse sensor, and that the speed pulse in really new cars is only accessible via the car's CAN bus, which in certain cases is encrypted. This problem was avoided in the Umeå trials by such vehicles being screened out during recruiting.

For the GPS based system in Borlänge, only the speed information from the vehicle's GPS was used. This measurement method provided a somewhat delayed effect and no or poor speed information where satellite coverage was poor. On the other hand, measurement errors were evenly spread up and down around the correct speed and thereby gave an extremely good average value. Measurement of the speed using GPS required no connection to the vehicle (over and above the power supply) or adaptation to different vehicle models.

For the GPS based systems based on navigators, used in Borlänge, Lidköping and Lund, both the speed pulse and speed information from GPS were used, thereby allowing extremely accurate speed measurement. In most cases, the ISA systems provided a better speed measurement than that displayed by many of the vehicles' speedometers.

Support to the driver

With basic data in the form of applicable speed limits and vehicle speed, all that remains is a comparison of these and then to inform and support the driver. The methods used so far for providing information to the driver for ISA systems (individually or together) are as follows:

- show applicable speed limits on the display.
- indicate on the display, using LED or lamp that the speed is too high.
- indicate using a sound signal that the speed is too high.
- indicate via feedback from the accelerator pedal that the speed is too high.
- hamper the vehicle from exceeding the current speed limit.
- prevent the vehicle from exceeding the current speed limit.

All methods apart from the last-mentioned were tested in the ISA trials. See summary previously in table 3:1.

Additional features for trials and research

Because the ISA project was a trial, certain systems were fitted with additional features whose purpose was to facilitate the evaluation of the project. In Borlänge and Lund, the vehicle equipment was fitted with features for *logging of driving data*. The purpose of this was to allow the evaluation of when, where and how speed violations took place, with or without the ISA system.

A practical difficulty with this was how the log files were to be retrieved from hundreds of trial vehicles. In Borlänge, this was solved by using functions for GSM connection to all trial vehicles. In Lund the log files were retrieved from the system during depot visits. To be able to analyse the log files, special software was written in both Borlänge and Lund. Read more about logging and analyses in the reports from each site.

5.2 Technical coordination

Level of coordination

Generally in the ISA project, each municipality has been able to formulate the project itself as regards selection of technology, suppliers, collection of data, evaluations etc., under the proviso that the needs of a comparable evaluation of each system is accommodated for.

With regard to the technology, coordination has been made through a special technical coordinator and by means of national liaison meetings. Part of the coordination that has taken place in some technically related areas is described below. At each site's local project organisation there has also been a resource available with responsibility for technology.

Technical procurement

Procurement of equipment for field trials of this size is quite a complicated process, especially as complete systems with the requested features have not been developed for series production. Procurement of equipment for the field trials was coordinated between the trial sites who had selected similar technical solutions:

- Borlänge and Lidköping: coordinated procurement for the warning system
- Lund and Lidköping: coordinated procurement for the supportive system

Umeå was alone on having selected transponder technology and therefore could not coordinate procurement with other ISA sites to any great degree. However, feedback was exchanged between all trial sites with regard to procurement procedures, technical specifications etc.

Map format

Production of both digital maps and trial equipment was facilitated by the formulation of a common specification. This is also used to describe the interface in the procurement documents. The format is used by Borlänge, Lidköping and Lund. Umeå's speed map was adapted instead directly to the current transponder solution.

Mapinfo Interchange Format (MIF), consisting of MIF file and MID file, was used as exchange format as it is open and text based and thereby can be read and interpreted by all potential suppliers.

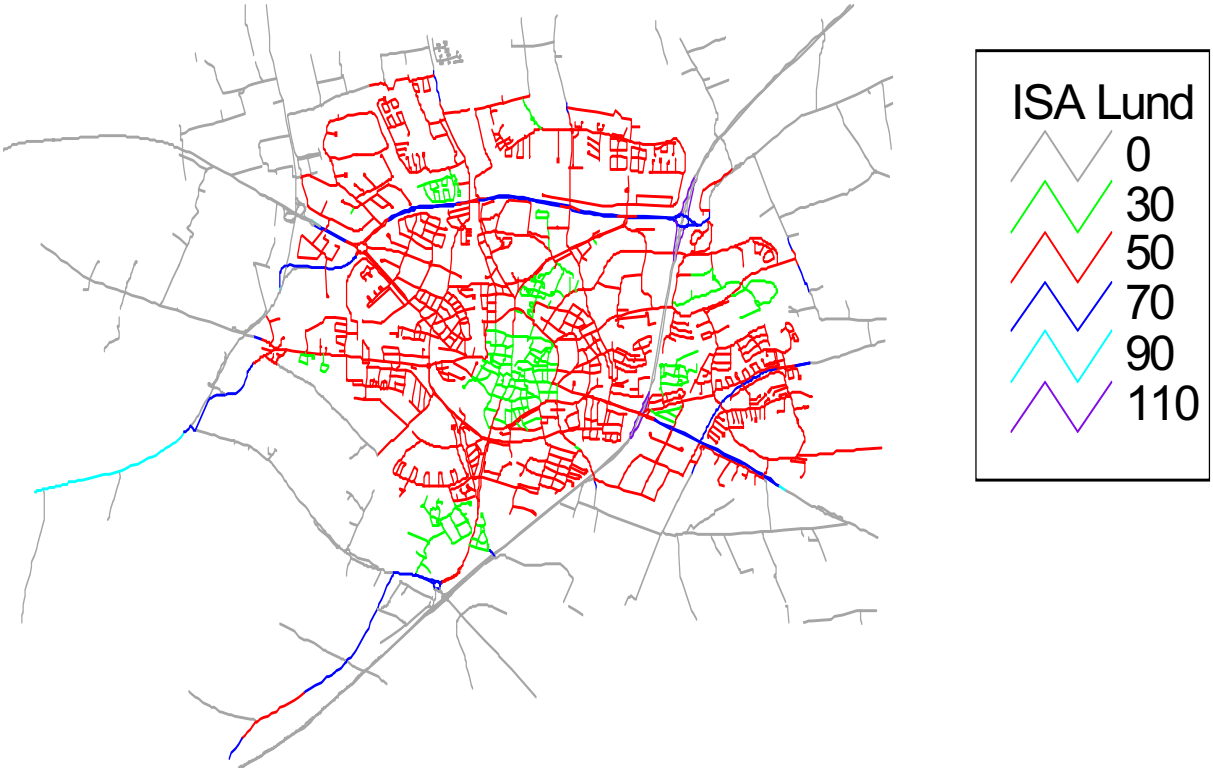


Figure 5:1 ISA map of Lund

The links in the speed maps were broken when a new speed limit started to apply. A number of attributes were associated with each link with the speed limit being one of these. A number of other attributes were added to facilitate the handling of different speeds in different directions, and at different times of the day or night (by schools), different times of the year (by schools and for winter reductions), and for assisting with navigation as well as for specifying how logging was to be done.

In Borlänge the aim was to use both data and format from NVDB (Swedish National Road Database). However, this project was in a very early phase which meant this could only be done to a limited extent.

Log file format

In Borlänge and Lund the position and speed of the vehicles were logged into the vehicle equipment on a continuous basis along with a number of additional parameters. Because the trial sites had different requirements for logging, there was no direct coordination of the log file format. Borlänge's log file format was adapted for the warning system, for transmission via GSM and to suit the relevant analysis tool. The log file format in Lund was adapted to suit the active supportive system and also to allow detailed studies of, for example, acceleration. A path selection with regard to logging was whether to associate the log data to geographical position (x,y) or to the position on the road link (link no, m). In Borlänge, they decided to associate the log data to road link to make evaluation easier, while Lund selected to associate log data to geographical position, which helps with the actual logging itself.

No logging was carried out in Lidköping and Umeå.

Warning signals, margins etc.

General discussions on how the warning signals in the warning systems should sound took place at an early stage in the project, but because each trial site procured technology based on individual needs, common requirements for sound signals were never established. Corresponding discussions took place

regarding at what speed (in relation to the speed limit) the warning signals should be emitted. The main alternatives were:

- Before the speed limit was reached (allowing time to brake or stop accelerating).
- “Exactly” when the speed limit was reached.
- A few km/hr over the speed limit (with consideration to the technical error margins in the speedometer and shortcomings in the driver's driving ability, so that warnings were never given “unnecessarily”).

The decision was taken that the warning and informative systems, as far as possible, were to give a warning at 2 km/hr over the applicable speed limit. However, for active gas the support was to be introduced exactly when the speed limit had been reached.

Inspection

The ISA project requested, via official letter to the Swedish National Road Administration's Vehicle Standards Division, inspection exemption for each vehicle's installation. The Swedish National Road Administration decided that the warning system did not need any exemption because the equipment could be placed on an equal footing to car stereos or navigation systems. Accordingly, these vehicles did not need to be inspected following the installation of the ISA system. On the other hand, it was decided that the supportive systems in Lund and Lidköping were to be inspected following installation. In addition, the Swedish National Testing Institute carried out extensive tests on the active gas system.

Other coordination

Other technical questions that were partially coordinated between the sites included:

- Placement of the display in the vehicle.
- Contracts between the project and vehicle owners/trial participants.
- Claims policy
- Installation instructions for connection to the speed pulse sensor for different vehicle types.

5.3 Trial equipment

A brief description of the trial equipment used in the project is given below. A more detailed description is given in the appendices for each trial site.

Borlänge

Following problems with supplier delays and defective functionality, the technical procurement for 400 vehicle computers and accompanying servers in Borlänge were supplied from two separate manufacturers. Overall, “the ISA system” in Borlänge has consisted of components as shown in the figure below.

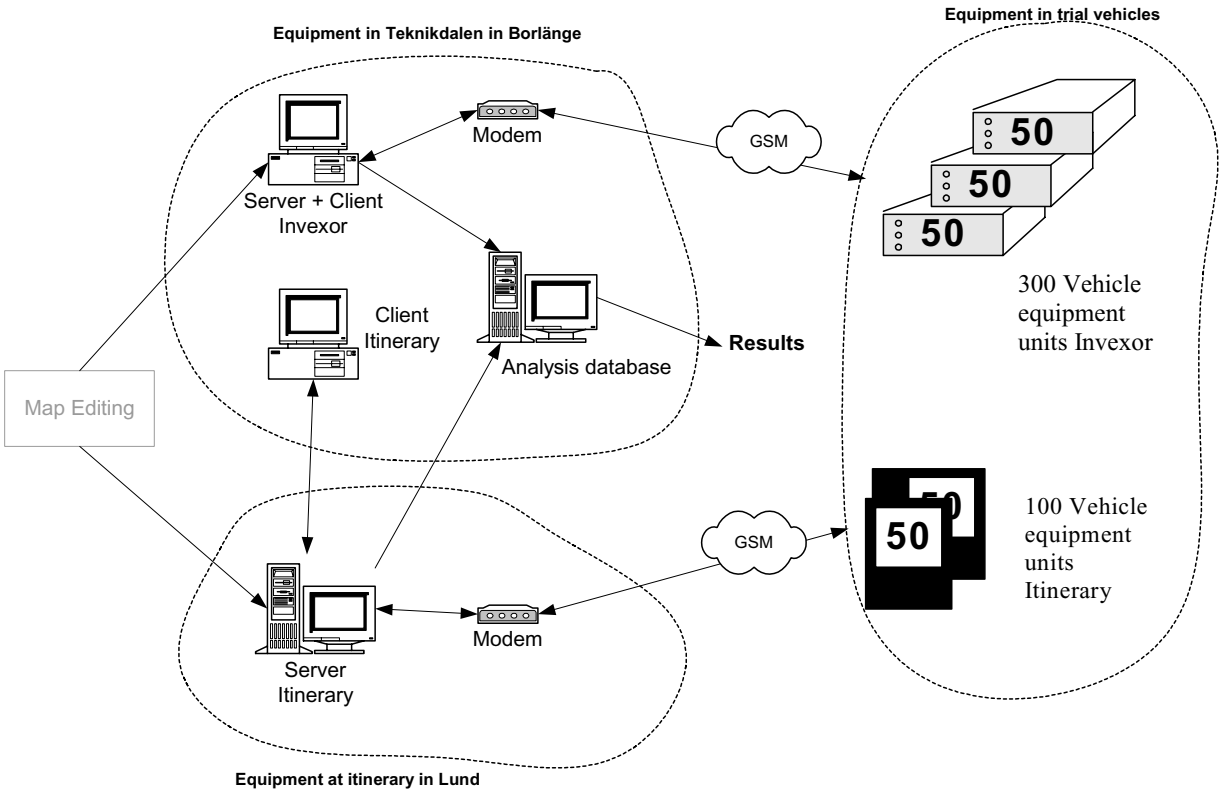


Figure 5:2 Equipment used in Right Speed in Borlänge

The Umeå company Invexor AB supplied 300 vehicle computers and server equipment. 10 of the vehicle units were fitted with "Vibra" later in the project, which is a type of vibrating unit which was attached to the accelerator pedal to emit warnings when the speed limit is exceeded.

The GPS antenna was built into the vehicle unit. A 12 V, GSM modem, PC connection, external GPS antenna and external units (e.g. vibrating accelerator pedal) were attached to the rear side. To improve reception conditions,, precision and performance, certain trial vehicles were fitted with external GPS antennas.

All trial vehicles in Borlänge were equipped with GSM modems for communication with the server and external GSM antennas.

Figure 5:3 Complete vehicle system "Invexor" prior to installation

Invexor's vehicle unit was only fitted with GPS sensors, and therefore had unreliable or even no precision in the areas with poor GPS conditions, e.g. large cities with tall buildings, narrow streets, tunnels etc.

Servers and communications

Invexor's server application, the Windows program Traxu, is used for calling the vehicle in order to:

- Change configuration
- Retrieve log files
- Send new maps
- Update software in the vehicle units

The server application also had the option of receiving calls from vehicle units that wanted to upload their log files. Vehicle units could also be connected via cable to submit log files.

Itinerary

100 vehicle units and server equipment were supplied by Itinerary Systems AB in Lund. The design of the vehicle unit is shown in the middle of figure 3:1.

Vehicle unit

Itinerary' vehicle unit was based on an in-house developed hardware system specially designed for vehicle computers, and an in-house real time operative system adapted for navigation applications. The vehicle computer had GPS, electronic compass and connection to the vehicle's speed pulse and the vehicle's reverse gear indicator. In this way, dead reckoning was made possible as an additional feature to GPS positioning.

The vehicle equipment consisted of a display, a computer unit, GSM telephone and cabling as well as external antennas for GPS and GSM. The display had the option of showing 3 red 7-segment figures. In addition, there were three LEDs: red, amber and green.

Because of the Itinerary vehicle unit's dead reckoning and map matching features, better precision was achieved in the areas with poor GPS conditions. However, the current version is adapted to suit the prevailing conditions before SA interference for GPS was removed.

Figure 5:4 Complete vehicle system "Itinerary" prior to installation

Servers and communications

Server functionality was divided up into a client (Windows) and a server (Linux) which were connected via a network (TCP/IP). Using the server application, the vehicle could call up to:

- Change configuration
- Retrieve log files
- Send new maps
- Update software in the vehicle units

The server application also had the option of receiving calls from vehicle units that wanted to upload their log files.

Lund

For Lunda-ISA, 290 sets of vehicle and depot equipment were supplied from Imita AB in Lund. The sub supplier for navigators was Itinerary Systems AB.

Vehicle equipment

All vehicle equipment in Lund was for active supportive system.

The vehicle's geographical position was continuously determined with help from GPS data and a combination of the features dead reckoning and map matching, algorithms in the positioning unit. The vehicle's instantaneous actual speed is registered continuously with the help of a connection to the vehicle's existing speed sensor or with an additionally mounted pulse sensor.

When the vehicle's speed has reached the applicable speed limit, an inert/resistance function in the accelerator pedal is activated, clearly indicating to the driver that continuing to travel at the current speed is not desirable if the vehicle is to be kept within the legal limit. The function is based on comparisons of current speed and valid speed limit which are obtained from the digital map.

Wherever necessary, for example in an emergency situation, the driver is to have the option of using kick-down of the accelerator pedal in order to drive over the speed limit for a particular site. This requirement was a pre-condition from the Swedish National Road Administration National Project Management in allowing this intervening speed adaptation system to be used in the LundaISA trial.

The applicable speed limit was shown for the driver on a display mounted on the instrument panel. Travel data from the vehicle's driving, position, speed, time, use of kick-down etc, was registered and stored in a log file.

Servers and communications

The vehicle units were loaded with information (digital map with speed limits and control parameters) and emptied of log files through a cable connection to an external PC or via other communication systems.

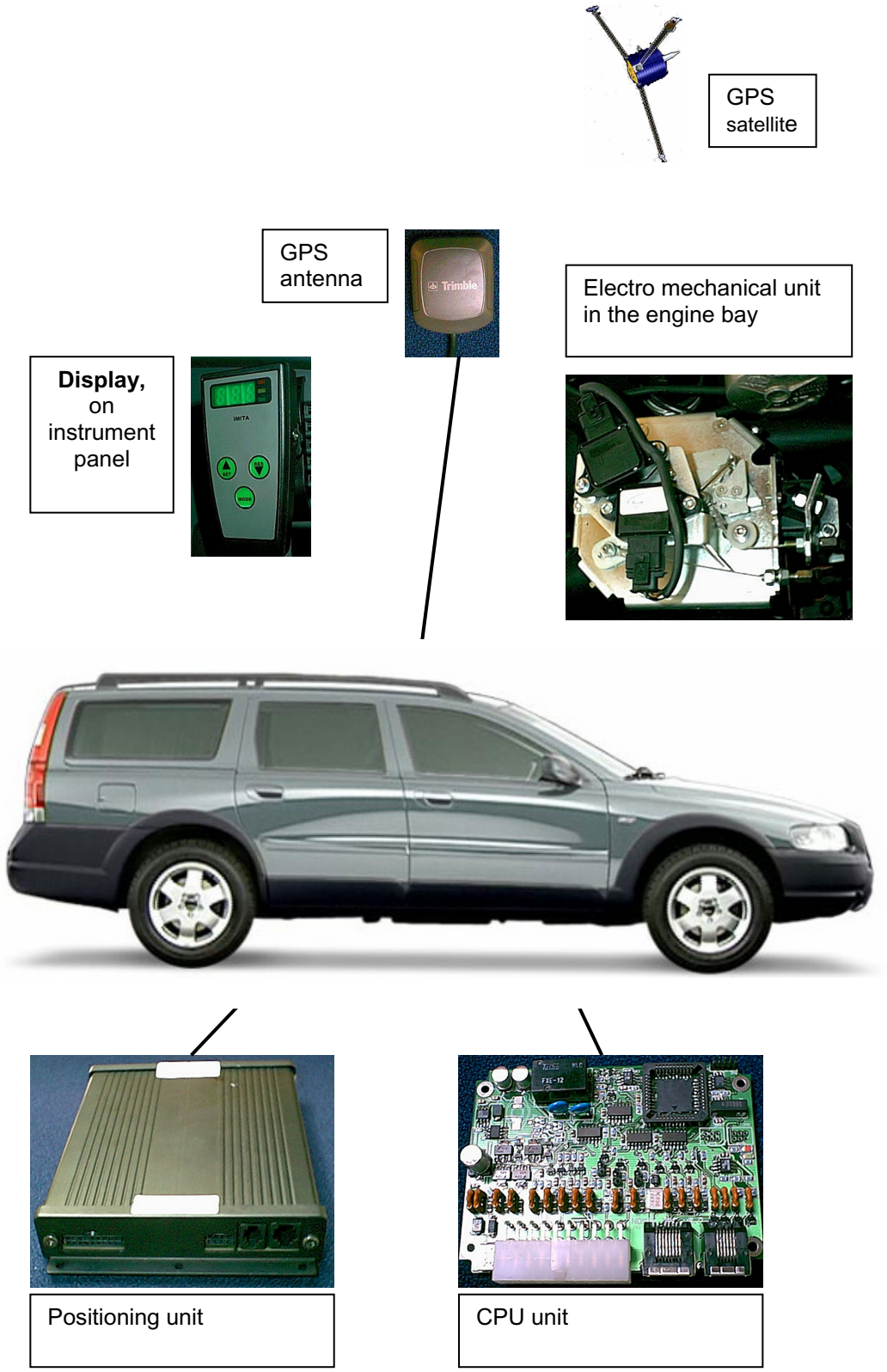


Figure 5:5 Vehicle system "Imita"

Lidköping

280 trial equipment units were procured, 150 with warning ISA system (“peep & flash”) and 130 with supportive ISA system, “active gas”. The supplier of supportive systems was Imita AB in Lund and the warning systems and sub supplier of navigators to supporting systems was Itinerary Systems AB.

Warning ISA – “Peep & Flash”

Vehicle equipment

A display showed the current speed limit in the trial area. If the speed limit was exceeded, a red LED was lit on the display and a sound signal was activated. The car operated normally outside of the trial area.

Systems and communications

Itinerary Systems developed a hardware and software platform, “Navigator”, which was installed in the car. The main area of use was to provide the driver with direction instructions via a voice and/or visually on the display, but for the ISA project the software was modified to provide information on applicable speed limit.

The hardware in the Navigator contained processors, memory, GPS receiver and interface for other types of sensor. The ISA application compiled sensor data and calculated the current position with help of map matching. When the position was determined, the permitted speed for the current road was read and sent via a serial interface to a display (warning ISA) or to the active gas (supportive system ISA). The driver's behaviour could then be registered and stored in the Navigator to be analysed, studied and evaluated later. Using this system, the effects of the supportive and warning ISA equipment in Lund and Borlänge were studied. This logging function was not utilised in Lidköping.

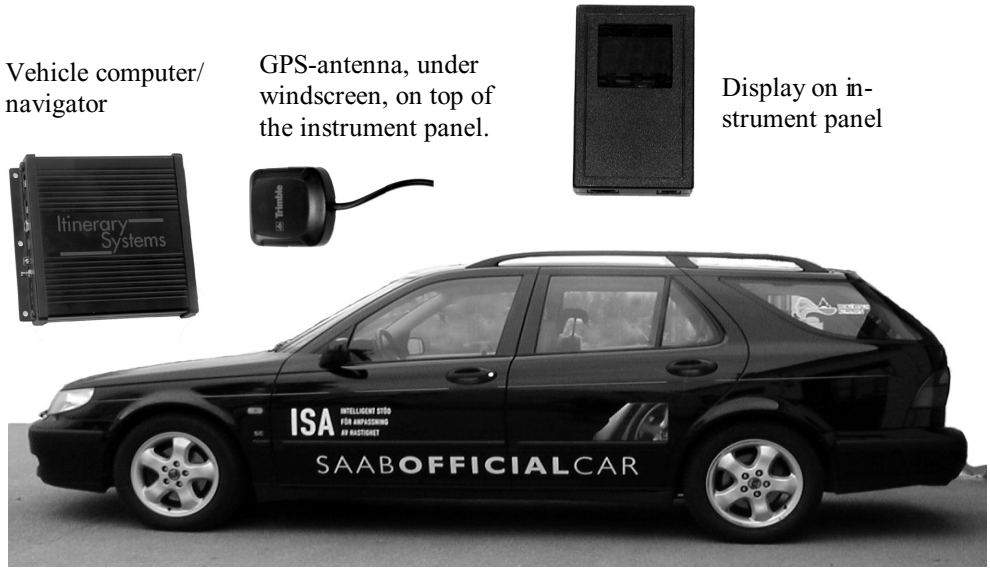


Figure 5:6 Warning system in Lidköping (Itinerary)

Supportive ISA – Active gas

Vehicle equipment

The equipment as specified above was supplemented with an electronically controlled servo, which was installed in the engine bay between the accelerator pedal and the fuel injection system. The "peep & flash" feature was omitted. The current speed limit in the trial area was shown on a display. When driving at the maximum permitted speed, the driver felt resistance in the accelerator pedal. The kick-down option (violation) was available. Outside of the trial area the car operated normally unless the driver chose to utilise any of the two bonus effects the electronics in the active gas system had to offer, i.e.

- cruise control, where the driver could determine the speed via buttons on the display, or
- the ISA feature where the driver himself set the permitted speed limit via buttons on the display.

None of these selections were possible within the trial area.

Figure 5:7 Warning system in Lidköping (Imita/Itinerary)

Umeå

4000 "Speed Checkers " were delivered by Hogia. The design is shown to the left in figure 3:1. The technical system used to achieve the required functional solution consisted of the sub-systems vehicle equipment (Speed Checker), communications link between vehicle and roadside, roadside equipment, central system and calibration system.

Vehicle equipment,

The main function of the system, i.e. to inform and warn the driver that a speed violation is in progress from inside the vehicle, was achieved using a special vehicle unit called *Speed Checker*. The speed checker was installed on the instrument panel or on the inside of the windscreen. When a speed violation occurred, signals in the form of light and sound were emitted to the driver.

Information on applicable restrictions was received from information packages from roadside transmitters. The vehicle equipment for the trial was connected to the vehicle in two ways, firstly the vehicle battery was used for power supply, and secondly the speed of the vehicle was supplied via a connection to the vehicle's pulse sensor for Speed Checker.

Systems and communications

Information to the Speed Checker was made up of a number of "packages" which described the attributes for a number of directions. The "information package" consisted of applicable regulations/information (e.g.. *max 50 km/hr),* distance and direction of travel to an activation point, (e.g.. *if 50 m in an easterly direction*) and distance to cover with period of validity (e.g. *following 500 metres*).

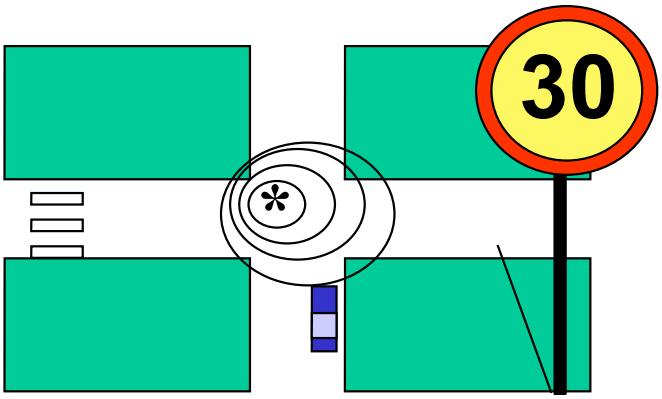


Figure 5:8 Information package to Speed Checker

A "simpler" frequency around 418 MHz was used for communication, which meant that equipment costs could be kept down. The selection of communication interface did not impact on the functionality of the trial, but it was intended exclusively for the research project. The selected communications link allowed two-way communication between the vehicle and roadside. However, the Speed Checker installed in the vehicle was not equipped to transmit return signals. Two-way communication was used, however, for setting the parameters of the roadside equipment.

The task of the central system was to define the functionality of the system and transmit control instructions to the transmitter located in the road network, and was constructed as a PC application with outgoing from a digital road network description. In a database in the central system (located in a portable computer) the current attributes for each transmitter in the system were defined. This means that the Trial Management Team always had the possibility of surveying the logic of the system as well as analysing different solution options.

Setting the parameters was done using a portable computer linked to a special vehicle-based transmitter module. The trial car drove to the transmitter that was to have its parameters set/changed, and the current information was transferred to the transmitter via the communications module. The process was fully automatic, and no physical measures were necessary for the roadside equipment.

5.4 Experiences

Borlänge

Selection of technical solution and functions

From an early stage, the Right Speed project had a clear direction for the profile of the project using technology which not only was to meet the requirements of the project, but also was to provide feedback on how the ISA system could work technically in a large-scale environment. This meant that the following basic demands were required of the system:

- Updating the speed map in a simple way.
- Continuous logging of vehicle speeds.
- Retrieving the logged data in a simple way.
- Evaluation of the logged data in a rational way.

These basic requirements together with the size of the trial area suggested a solution using GPS based vehicle computers and communications using a central operations station. This is described as the preferable system architecture in the requirement specification, which also includes descriptions of the features rather than the technology.

During the development phase, and the major delays that affected the project, there was a feeling that the project requirements were too great for the functions of the system. Logging and communications were untried disciplines in this context. We were subsequently able to report that thanks to these features, unique evaluation material was obtained.

The question should also be asked whether additional features would have helped the implementation of the trials or provide extra impetus to it. In retrospect it would have been better to have a more “automatic” monitoring system of the trial vehicles' status, as well as amount and quality of received log data. The selection of logging all driving data to enable accurate evaluation, placed great demands on the equipment and the organisation and increased the technical risks involved with the project, as this technology had not been tested before. Otherwise, the selection of GPS in combination with a digital map and GSM proved to be correct, as this technology is in line with how future sharp ISA systems could be constructed.

Procurement

The challenge of procurement was how to purchase a system that did not yet exist, but preferably from someone who had done it before! The greatest interest for prequalification, and that three serious thoroughly-prepared tenders were eventually received, must be regarded as successful for such specialised procurement with such high requirements. For evaluation purposes it was relatively easy selecting a supplier (Itinerary) where all had sound technical solutions, but the price difference was very large.

Delivered equipment

The substantial delays in the development and delivery of the ordered equipment not only meant delays in the project, but also that the project had to devote a lot of time and work testing prototypes along with replanning installations etc. It was probably the correct decision to allow in an alternative supplier (Invexor) at this stage, as things were very uncertain as to whether Itinerary were capable of delivery usable equipment before the project was over. This eventually resulted in the project having two types of ISA system, built to the same functional specifications.

Both systems included the majority of the requested features, but they also had, unfortunately, a number of teething problems and defects which resulted in much more work for the project. Generally, both systems fulfilled the functional basic requirements: to display speed limits for the driver and to log driving data.

Installations

Delays in deliveries of the equipment resulted in difficulties rebooking installations. Otherwise the installations themselves were completed relatively trouble-free. It was much easier for participating private drivers finding the time for the installation than it was for participating companies.

After-sales installation of ISA equipment for interested private individuals is perfectly feasible, probably even at a large-scale. However, full-scale after-sales installation in "all" vehicles requires a strategy similar to that used in Umeå, where installation took place in connection with car inspection.

Operation experiences

Teething problems with the supplied vehicle equipment resulted in several visits to the garage. Flaws in functions and reliability of the GSM communication system resulted in extra work getting in the log files, and also a certain absence of log data. Overall, operational costs acquiring and interpreting log data have been much greater than expected. Updating maps has also required more work and taken a longer time than expected, both with regards to production of a new speed map, and distribution (via GSM) to the trial vehicles.

In principle, the navigation and display of the speed limit worked properly. The fact that the map had some flaws, and that GPS navigation without extra sensors does not provide 100% coverage, was known in advance of the inception of the trials. The project was forced to install vehicle equipment which was not fully tested, which resulted in problems for both trial subjects and for the project.

Apart from this, it was the GSM communication, used for transmitting map updates and log data, that caused most problems from an operations perspective. Sabotage of equipment, which occurred primarily at some of the participating bus companies, also caused some problems.

Lund

Technical solution and function

Implementation of the speed adaptation trial LundaISA provided considerable feedback on the implications of an R&D activity. Using the positive results from previous pilot projects pertaining to speed adaptation where significantly less complicated technology was used, the hopes were to create a reliable ISA system for large-scale use using development resources. The criteria involved developing an industrial product, ISA equipment, which met the high technological and quality requirements which were necessary for use in actual traffic. In addition, the product should be capable of being used in a variety of car models on the market.

In retrospect, it should be said that ambitions were somewhat optimistic when taking deadlines, budgets and manufacturing capacity into consideration.

Procurement

The Swedish National Road Administration has initiated, and had overall responsibility for, the ISA project while the four trial sites had operative responsibility for its implementation. The Swedish National Road Administration's role has been to have overall responsibility for project management, responsibility for central information and provide technical support and coordinate evaluations

concerning the trials. Different activity groups were created at the start of the project, and have been in touch with the trial sites covering a variety of issues.

Activities in the Technology Group, which was to act as support and discussion partner for the trial sites' local organisations, had an important mission in negotiating with the Swedish National Road Administration's Vehicle Standards Division, the Swedish Motor Vehicle Inspection Company and the different suppliers.

Installations

Despite time restrictions on the development work on the functionality of the speed adaptation, the active gas with feedback to the driver, and the positioning function with speed limit information, the project could be carried out with a sufficiently large number of trial subjects and for a long enough period of time to be regarded as being large-scale and having long-term effects. The target of equipping 300 vehicles and allowing these to be driven for six to twelve months was not achieved until the third and final year of the project, 2001, which resulted in the evaluation being partly delayed.

Development work

Over the course of the project, the ISA variants that the trial sites have used have been continuously developed. This work has been hard and extensive, and has sometimes interfered with project planning and delayed the trial period. A positive factor is the experience gained by the suppliers over the entire project who have listened to user reactions and continually improved their products and installations.

For the active gas ISA system, which has been the main feature for LundaISA, development work has meant that Imita AB can now offer the market significantly better functionality which also includes a digital map and GPS support. For continued development of the active gas concept, more knowledge about the regulations pertaining to accelerator depression in the car is required. Incentives should be in place for a collaboration with the automotive industry to this end so that a feature for speed adaptation can be built in to vehicles at the manufacturing stage.

Future development work should also include efforts to simplify the construction and installation of the ISA system so that continued promotion of the concept is possible. A breakthrough for the concept is naturally very cost-sensitive, and a lot of attention should be paid to reducing manufacturing and installation costs.

Lidköping

Navigator

The same navigator has been used for both systems. Accuracy has been perceived as being very good for speed measurement, and as a rule good enough when changing speed limit (reaction time when passing signs) in urban area environments. The ability to “hit” speed signs becomes noticeably worse when travelling along long, straight stretches of road, reaction is often delayed and the spread is great for repeated instances of driving on the same stretch. In addition, when turning off from such long straight stretches, the navigator often mixes up turnings that are close to each other.

This problem may also arise when distinguishing between closely spaced streets with different speed limits. This has been “solved” by removing some of these problem roads from the map. The navigator starts when the ignition in the car is activated. The time, before the navigator starts to display the permitted speed and indicate any possible violation, varies substantially. Following short “stops by the pavement edge” the time is brief (under 30 seconds). When the car has stood still for long periods, times over 5 minutes have been noted.

Warning ISA

The warning signals have been the same for all the equipment types with respect to character and sound/light strength. However, the perception of these signals has varied greatly, because the location of the display has varied between the different car models. In certain cases the display has ended up close to the driver's range of vision and/or ears, and far away in other instances. Together with the noise level, which varies between different cars, this has meant that the drivers' perception of the suitability of the signals has varied.

The most common fault with the warning ISA is that the system stops peeping during speed violations. This fault has been remedied by replacing the navigator.

Another fault, which appeared early during the trial period, was that ISA indicated a violation during very low speeds. This was fixed by reinstalling and modifying the software.

Supportive ISA

Indication for the active gas has been calibrated during installation, in order to be consistent with the speedometer. This should not have be done when bearing in mind that one of the purposes of the trial was to compare the two systems, the outcome instead was that the drivers perceived that ISA and the car's speedometer corresponded to each other.

Indication of speed violation consists of light upwards pressure on the accelerator pedal, which then becomes sluggish when continued depression of the pedal is attempted. The pressure and the sluggishness have been adapted during installation to suit the car model and, in certain instances, the driver. It has not been possible to make all test cars uniform in this respect.

The construction of the mechanical unit ("servo") means that when the pressure is applied, a reaction is created in the unit's throttle arm, which in certain cars results in a short admission of petrol and acceleration, and the speed limit thereby exceeded. This short jerk often creates a feeling of uncertainty for the driver, and the problem has not been completely resolved through adjustments.

The most common remark pertaining to the active gas system has been its insensitivity. The equipment's ability to transmit pedal activity accurately to the throttle in the car engine, has been perceived as being inadequate, and has cause a lot of irritation among the test drivers. Many call-backs to the garage have been caused by the drivers being unhappy with the adjustment and calibration of the system in these respects.

All car owners with active gas have sometimes, or often visited the garage on their own initiative to adjust their system. It was discovered at an early stage that some drivers had experienced that the accelerator had jammed or even that "the car accelerated by itself". All installation was suspended and all cars with installed equipment were recalled and the problem corrected.

Umeå

Scope

The trial has provided very valuable feedback with regard to the technical solution used and more general feedback of attempting to implement such a technical system in an existing vehicle fleet on a large scale. The first objective for the trial was to install Speed Checkers in around 10000 vehicles. This number was then halved for the final project planning due to a reduced budget.

However, over the course of the project it was discovered that the initial objective of 10000 vehicles could never have been achieved even if there was sufficient funds in the budget as large series require technology that is autonomous and insensitive. Permanent electrical installation would also be required.

That the new target of 5000 installed Speed Checkers was not met either (the final number of installed Speed Checkers amounted to a little under 4000), depended primarily on the trial suffering a larger loss of test drivers than was expected due to technical problems during installation.

The greatest of these technical problems concerned the effects of magnetic fields in the vehicle. The compass/direction sensor, which is sensitive to magnetic fields, was produced as an additional feature after the contract was signed.

Other reasons for the set targets not being met included certain car models being excluded from the original selection which resulted in a larger proportion of the selected cars needing to be recruited. In addition, many people who initially said they were interested in having a Speed Checker installed left the trial before installing.

Not included in the calculations is the fact that around 10 percent of those who were summoned for inspection did not come at the agreed time, which caused a much greater loss of vehicles who were booked for installation than expected.

Another factor influencing the final number of cars with Speed Checker installed, was that some drivers with Speed Checkers changed car during the course of the trial. In these cases the Speed Checkers have been dismounted from the old cars (unless the owner wished to keep them), but it was not always possible to reinstall these units in new cars.

The trials have been very useful for gaining experience and knowledge, for example, through working on a solution to the problem of magnetism and assembly in different car models. The technology and equipment used in the trials cannot be used in all car models. This is partly due to the Speed Checker being more difficult to install in certain cars, and partly to the direction sensor not working in models where the magnetic field was too strong. This means it appears today that a number of cars cannot be fitted with Speed Checkers if the system is used on a large scale. However, the question is if the number of equipped cars is nevertheless sufficient for a “domino effect” to occur.

System

It can be reported that the system had good operational reliability during the trial period. The system has not been troubled by transmitter problems to any great extent. One improvement with regard to construction and design of these is the weather protection for the network components which in some cases took in water and were thereby rendered inoperable.

The problems that did arise were more concerned with the vehicle units. Problems with magnetism arose, but also problems with delayed reactions of Speed Checker warnings when comparing to the speedometer display. Following a report from the system supplier, Hogia, explaining that the problem was due to the cars' speedometers displaying a speed that was too high in relation to the actual speed , the decision was taken to introduce a buffer of +2 km/hr before the Speed Checker was to react. In so doing the Speed Checker would warn at the same time as the car's speedometer indicated that the driver was driving over the permitted speed limit.

The creation of the sound in the Speed Checker can be discussed as it was given as the primary reason for trial participants wanting to conclude the trial prematurely. (However, it should be pointed out that the number actually leaving the trial was not great because of this.) The sound was also one of the reasons why it was so difficult recruiting trial subjects after a number of vehicles had a Speed checker installed. This was probably due to many of those who had not had a Speed Checker installed knowing somebody who had. These had talked about the sound, and warned others about installing the equipment in the car.

When comparing the technology used in the Umeå project, and the GPS controlled system of the type used in Borlänge, there are similarities. In Borlänge the system is based on the vehicle carrying a digital map of the road network with speed limits incorporated. This works out the applicable speed limit through navigational fix using GPS. The system used in Umeå is based on roadside transmitters and simpler vehicle equipment.

Because the system used in Umeå is developed using angular conditions and the functions this entails, the information obtained by the Speed Checker from the transmitters is similar to a local digital map. With this method of thinking, the system in Umeå can be perceived as being cheaper, as information included in the digital map is available, without the need for investments in the map.

Implementation

The decision to equip the test vehicles in connection with inspection and by specially trained personnel at the Swedish Motor Vehicle Inspection Company has proved to be an extremely good solution for such an extensive trial project as this. Despite many subjects leaving before it was time for installation, the experienced gained from the installation of Speed Checkers in connection with inspection of the vehicle nevertheless provides the best outcome regarding the number of people wanting to participate in the trial and coming at the agreed time. That people interested in the project left before an appointment was given for installation, can be solved by reducing the amount of time between the offer of installation and actually carrying it out. In so doing the risk is reduced for the people involved losing interest.

By employing the “drop-in” principle for installation of the ISA equipment, the level of service increased for both new installations and for cars where the Speed Checker needed to be checked for different reasons.

Deviations from the time schedule during the project period depended primarily on the delayed deliveries of the transmitter equipment. In addition, the project did not get the frequency permit for radio communication before the middle of September 1999, which meant that contracts, prototypes, tests, etc were delayed somewhat.

The major loss of vehicles caused by magnetic interference and installation problems in certain car models also contributed to delays and a fewer number of installed vehicles compared to target. The result was that start of operations for the complete system was a little over 8 months late.

Joint conclusions

Selection of technical solution and features

As the Swedish National Road Administration decided to stimulate a number of system solutions, every trial site could select the features to be included in their ISA system themselves. All trial sites based their selections on what they assumed the aim of the trials was from the aspect of evaluation, and specified their required features in the system accordingly. The tender was then to propose technical solutions for these features. However, the exception from this principle was made with respect to the positioning method, where Umeå wanted a system with transmitters and transponders, and other sites requested digital map together with GPS.

As regards the logging of driving data carried out in Borlänge and Lund, it could possibly be said in retrospect that the ambition was too high, bearing in mind this was a new science, and that there were no operational systems to refer to. All in all, freedom in selecting technology and features was allowed, which resulted in certain difficulties coordinating the evaluation. On the other hand, several alternative technologies were tested in this way and the technical risk was spread over several suppliers, which reduced the risk for the project as a whole ending up in a crisis due to technical problems.

Procurement

The systems the project wanted to purchase were not stock items and had to be developed. Large established suppliers of navigation and communication systems were deterred by the limited volume requested and the high demands of adapting to the needs of the project. The interest was great, however, from smaller innovative companies in the branch.

Delivered equipment

All trial sites had problems with supplies of trial equipment, both with respect to the equipment's functionality and delivery deadlines. This meant not only delays to the project, but also that the project had to devote a lot of time and work testing prototypes along with replanning installations etc.

The delivered systems finally received the majority of the requested functionality, but also, unfortunately, a number of teething problems and defects which in turn lead to a lot of extra work for the project and problems for electricians and trial subjects. However, all trial sites eventually succeeded in fitting out the trial vehicles virtually as planned, which means that over 5000 trial subjects were able to test different variations of ISA.

Installations

Apart from the problems with rebooking installations caused by the delays in deliveries, the actual installations were carried out relatively problem-free. It proved to be much easier for participating private drivers to find the time for the installation than it was for participating companies.

After-sales installation of ISA equipment for interested private individuals is perfectly feasible, probably even at a large-scale. However, full-scale after-sales installation in “all” vehicles requires a strategy similar to that used in Umeå, where installation took place in connection with car inspection.

Operations and maintenance

In Borlänge, Lund and Lidköping, teething problems with the delivered vehicle equipment resulted in many visits to the garage. Most problems could, however, be corrected. Umeå's equipment was more dependable in service.

The supportive systems in Lund and Lidköping also had certain defects which meant that the vehicle's driving characteristics were even affected when driving under applicable speed limits, which included the occurrence of a feeling of delay or insensitivity when depressing the accelerator in many trial vehicles. However, at the end of the project the suppliers of the active system could present a new system where these problems appeared to have been solved. Unfortunately, the trial subjects did not have the time for installation, which undoubtedly influenced the trial subject's perception on the active system negatively.

Overall, operational costs acquiring and interpreting log data have been much greater than expected. Updating maps has also required more work and taken a longer time than expected, both with regard to production of a new speed map, and distribution (manually or via GSM) to the trial vehicles. Sabotage of equipment, which occurred primarily at some of the participating bus companies in Borlänge, caused problems and added costs
.
In principle, the navigation and display of the speed limit worked properly. The fact that the maps had some flaws, and that GPS navigation without extra sensors does not provide 100% coverage, was known in advance of the inception of the trials.

Other conclusions

The existing speedometers in the trial vehicles (as in other vehicles) do not measure and display the speed as well as in the installed ISA systems. Many vehicles display higher speeds up to 15 km/hr too high.

6. Information

The purpose of the detailed work associated with information issues has been to create well-coordinated communications, both within the project and the world outside as well as helping to make the implementation of the project more effective. For ISA, where attention from the media and press has been great, the careful planning of work involving information and communications has been a success factor for the project. By starting information work early in the initial stages of the project, public relations officers have been involved in the format of the project. By working in this way focus has been on the individual instead of on the technology, which is not unusual for ITS projects. Information has been used to generate knowledge and influence attitudes. The challenge has been to create a good climate for researching ISA and highlighting the potential possibilities, without influencing the test drivers at the same time.

6.1 Organisation and cooperation

Information work has been carried out partly at a local level through Public Relations Officers who have been included in the four towns' project organisations, and partly at a national level through the Swedish National Road Administration's Information Coordinator. The five Public Relations Officers have made up a work group in the Information sub project. In addition, the Coordinator has been included in the Project Management Group, and has therefore been able to ensure that communications and information has been discussed and coordinated throughout the length of the project.

The Public Relations Officers created a network at the start of the project. The purpose of the network was to gain a general perspective of the project, and to support each other through utilising each other's experiences and knowledge. Each Public Relations Officer had responsibility for information at his site while the Sub Project Manager for Information had responsibility for general information as well as the long-term perspective.

An information strategy was created at the start of the project. During the course of the project, this strategy has been built on and modified based on experiences from project members. Using this strategy, work in the municipalities and at a national level has been standardised. Guidelines included in the strategy have made up a strong base in the ISA project, and ensured that a uniform and clear message has been communicated and that everyone in the project is speaking “the same language”.

6.2 Target groups and information channels

At the start of the project, a number of clear and strategically important target groups were defined. In connection with this identification, it was also determined that information should be disseminated via both established and new contact channels. Firstly, the objective was for the target groups to know what ISA was all about, secondly that they should be aware of ISA functionality, and thirdly, that the target groups understood the benefits and possibilities associated with ISA. The target groups for the project have been the general public, researchers, the automotive industry, organisations and media. At a national level, the test drivers in the project have been included in the general public group. However, in the local project, the test drivers have been an importantly identified own target group separate from the general public.

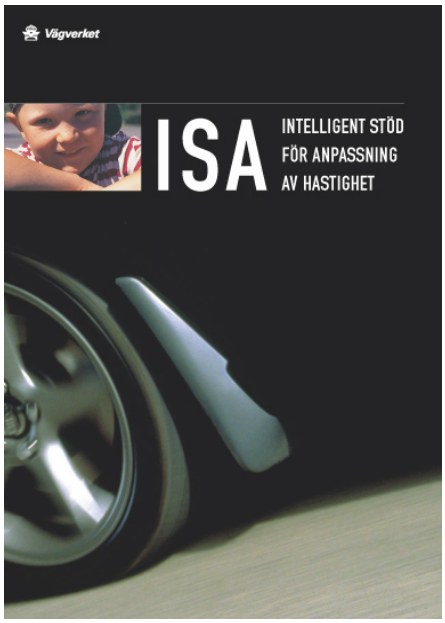
Using the target groups as a starting point, the type of message to be disseminated was analysed, along with the contact channels that were to be used. The objective was to spread the right message to the right group and that these messages should be formulated so that the groups could utilise the information in the required way.

Experiences from previous studies carried out by the Swedish National Road Administration and others have shown that women in general have been more interested in traffic safety (soft values) than men, while men were more interested in the technology and mechanics (hard values). Because ISA was primarily perceived as a traffic safety project, work was therefore mainly focussed on information to women. The project assessed that it would be tactically wrong to focus on women due to the fact that men, to a greater extent, are registered as owners and moreover take the decisions regarding the equipment in the family's car. To encourage men's interest in the information on ISA, it was important to give ISA a high status. The project achieved this by using the hard values when communicating in writing, verbally or graphically.

All information concerning ISA was based on the above-mentioned concepts. The language used for communicating was easy to understand and direct, and would not require any previous knowledge on ISA. The messages were formulated in a homogeneous way so that the recipients would experience a feeling of recognition.

It was important to identify positive value words both for the project and the target groups. A behavioural scientist was introduced to this work, and when value words were established, it was decided that these should be used to create a uniform profile for the project. The value words used were:

children, research, support, information, intelligent, large-scale, traffic safety, security, new technology, environmental consciousness, international interest, cooperation and knowledge.



The words were used as a base in the messages communicated, and incorporated into all material the project sent out.

The main objective in communicating to the general public was to arouse interest in ISA, and that the general public were able to create an understanding and opinion on the system. The media became the primary information channel for this purpose early on in the project.

Starting in 1999, newsletters have been sent out 4 times a year. Information has been distributed to a selection of people within the target groups, and to people who have registered an interest in receiving the information. The newsletters have been sent via e-mail and by printed material. The mailing list has gradually grown during the course of the project.

Information on ISA to organisations and researchers has mainly been disseminated via seminars and through information material.

6.3 Guidelines for information work

A large-scale trial arouses the interest of the media, particularly at those sites where the trials are being carried out, but also domestically and internationally. The media are in these cases a major information disseminator. The interest in ISA was expected to be extra large in the initial stages and in connection with the publication of the results. The project was also the largest project to have been carried out within the field of speed adaptation.

The media interest in ISA was great even before the start of the project. An early article analysis illustrated that ISA was perceived as a surveillance, controlling and enforcing system on the driver. This erroneous image of the Swedish ISA project needed to be corrected so that the media's perception did not influence the test drivers. To a certain extent, the automotive industry also had a negative attitude ahead of the start of the project. Their negative attitude was based on experiences concerning the previous small-scale project that was carried out using an enforcing ISA system. The debate was dominated by views that ISA could be dangerous for traffic safety in overtaking situations. By using voluntary, supportive and informative ISA systems and emphasising the benefits of these systems, the views of the automotive industry could be changed, and interest and acceptance in the project could be built up.

Information strategy

During the planning phase of the project, work was commenced on building up a base for coordinating information in the project. An information strategy was created, and using this as a base, annual information plans were formulated. This strategy has been a living document that was revised through information plans if the need arose. Yearly reviews of these plans have been carried out through article analyses.

Information plans

The information strategy was broken down into targets through annual information plans. The plans described activities and time schedules in a more detailed way which would allow the possibility of review. The objective of the information plans was to create a platform for the information work, and create a uniform image of the project. As part of this work, a joint graphics profile and templates for communications and handling press messages were created. It was also decided in the information plans that a newsletter should be published during the project, and that all information material should be produced in both Swedish and English.

Media strategy

A separate media strategy was developed to be able to handle contacts with the media in an effective and consistent manner. The content of the strategy matched well with the content in the information plan, but also reports in detail contacts with the media. The reference point for the ISA project has been the previous assumption that only a voluntary system is possible for the acceptance of ISA in the marketplace. The important thing has been to maintain a neutral debate in Sweden. The objectives of the project have been to work for a positive handling in the media by:

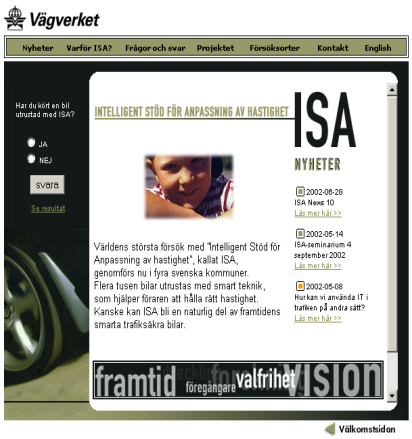
- allowing many test drivers to express themselves, preferably both in a positive and negative way about ISA in order to communicate a wider perspective,
- working actively with driving demonstrations,
- providing information to the media on a continuous basis,
- communicating the benefits of ISA,
- keeping a wide cross-section of journalists informed, and a closer-knit group of journalists well informed about ISA.

It was decided that the Project Manager in the ISA project should be the main contact with the media in order to create a clear profile for the project. If major events occurred during the project, press conferences would be of immediate interest and consequently press messages with items of interest would be distributed. To create a better understanding for ISA, test-driving was used to a great extent.

The project launched ISA focussing on the values of prestige and soft values. ISA was to be handled as a brand name loaded with these values. Nationally, the messages were focussed on the benefits of ISA, that the project was the biggest of its kind in the world, and that use was voluntary (as opposed to other enforcing systems).

Project site

A project site was developed and established on the Internet to assist internal communications. This has had the task of being a knowledge bank for the project, where information could be uploaded and downloaded.



An external project site, www.vv.se/isa, was also developed in connection with the Swedish National Road Administration's website. Via the Internet, information on the background of the project and what is currently ongoing is circulated. All material distributed from the national project is also available on the website. The site also has links to the four trial sites' web sites.

6.4 The local information project

Borlänge

In 1998 certain preparatory information work was carried out, whose principle task involved selling the project internally, i.e. within the organisations that participated. The local Project Manager conducted information meetings with the Management for Dalatrafik and transport companies in the Borlänge municipality. The meetings addressed issues concerning the participating companies in the project, and discussed any points of view that the affected drivers might have. Larger information meetings were planned, and the importance of supplying advance information to trade union organisations was emphasised by the project team.

At the information meetings, which were conducted in January, 1999, the purpose of Borlänge's participation in the trial was stressed, which was to develop traffic safety work in the municipality, and the ambition of becoming a development centre for road informatics. The project would then result in new development opportunities in traffic safety and the ITS area.

The local project, Right Speed, in Borlänge published a project brochure with information on the project and its organisation.

In 2000 and 2001, information was also distributed about the status and progress of the project via issue 8 of the newsletter. Both the newsletter and other information material was also available via the website www.rattfart.com.

Visitors could even borrow an information video on ISA via the website.

Lund

The trial in Lund chose an open yet low profile regarding outgoing information, to avoid test drivers being influenced. No active measures were taken to create publicity. For this reason, a Public Relations Officer was not hired; contacts with the media and liaison with the national project's information group were handled by the Project Manager/Project Coordinator instead. This has proven to be a handicap on certain occasions, and for future trials a different organisation should be considered. However, approaches from the mass media have always been dealt with positively, and members of the project have taken part in interviews, filming and test-driving.

In connection with the technical authority's organisation for traffic issues, the general public has been invited to test drive ISA vehicles on two occasions. The reference group, interested companies and naturally the media and visitors have always been afforded the opportunity of test-driving ISA vehicles.

Brochures have been available, partly for the national trial and partly for LundaISA. The LundaISA project also distributed information on the project and contacts on the Internet via Lund municipality's website *www.lund.se/kommuninformation /04_ kommunens forvaltningar/tekniska_forvaltningen /ISA*. Information has also been available at Lund Institute of Technology's website.

In order to inform general high-street garages about ISA equipment, 14 different garages were visited personally.

A test driver evening was organised in April, 2002 as thanks for all those who had participated in the LundaISA field trial. During the evening, preliminary results were presented and discussed, and the test drivers and project members socialised over dinner. The opportunity of discussing the trial with suppliers, the municipality and researchers was appreciated by many.

Lidköping

The purpose of the information activities in Lidköping was to create a positive attitude to ISA among the residents of Lidköping municipality, and get them in a positive frame of mind to participate in the trial. The purpose was also to create a clear and coherent image of the results of the project and create the conditions for a positive dialogue with the different target groups with regard to the advancement and future of the project.

During recruitment, evening meetings were organised in smaller groups for potential test drivers. The information was extensive both about the trial and the technical equipment. The presentation meant that test drivers had the opportunity of getting to know the trial management team and test drive ISA cars before deciding on whether to join.

Information has been distributed to test drivers at the start of the field trial via recruitment brochures, film commercials, personal visits, information sheets during installation, the newsletter “Just between test drivers” and test driver's own club page at the projects website *www.lidkoping.se/isa*. The newsletter was published roughly every other month starting in 1999.

Umeå

Around 25 % of car owners in the urban areas of Umeå were canvassed for recruitment. Commercial drivers were a priority group in the Smart Speed trial because of their great exposure to the road network compared to private motorists. Efforts to get out information were made via two sub campaigns; an information campaign aimed at the general public, followed by a recruitment campaign with around 20000 candidates as target group.

Getting the information out to the different target groups involved communication channels such as radio, TV, direct advertising or adverts in the daily press. The information campaign with the selected candidates as target group used direct advertising, TV and radio advertising. For the mass media it was appropriate to use seminars, newsletters and letters sent to the editor as channels for information dissemination.

The main information efforts were made in 1999 and 2000, when recruitment of trial subjects and the expansion of roadside equipment was implemented. Minimal efforts were required after this as regards information dissemination. However, during the final phase of the project it was necessary to distribute the trial results among the relevant parties.

Responsible authorities for Smart Speed were Umeå Municipality, Umeå University, the Swedish Motor Vehicle Inspection Company and the Swedish National Road Administration. Together they have sent out all information material over the trial period. Individual information efforts had different combinations of originators which clearly reflected the responsible authority's role in the trial. The local Public Relations Officer was responsible for the content and design of the information material, as well as the selection of sending authority. The Public Relations Officer was also responsible

for a Q&A forum for dealing with questions concerning Smart Speed which was available for the media, general public and trial participants.

The Umeå project also used the Internet as an information medium. Via the website www.smartfart.umea.sethe visito were informed about the technology and the project.

Potential test drivers registered their interest for participati in the project on the website.

Local information sheets on the project's Speed Checker ai installation are available via the website with a letter from the head of the municipality headed “Why we would like you to be a test driver”.

6.5 Information to test drivers

The challenge in the recruitment process was to find a representative cross-section of road users, not just with respect to age, gender and private/commercial driver, but also to represent a range of positive, neutral and negative attitudes to the ISA concept.

Experience from previous large-scale projects showed a large loss of test drivers during the duration of the project. Additionally, installations contributed to costs in the form of loss of time and petrol money for the test drivers, which would cause a loss of recruited subjects. Furthermore, the test drivers were to attend information meetings and complete a number of questionnaires which would cause more loss of time. It was important to discuss these gestures which the test drivers that completed the evaluation made, and compensate the drivers in some way if at all possible. The ISA project did not have the possibility of paying the test drivers financially, but project members emphasised their gratitude when communicating with the test drivers.

The Public Relations Officers in the trial towns had a crucial role in the recruitment process, because they handled communications with the general public. It was important that this was handled at a local level so as to understand and satisfy local needs and viewpoints from the test drivers in the best possible way. The project's Information Manager handled coordination of communications with the test drivers at a national level.

The objective of the project was to have 6000 equipped cars and it succeeded in recruiting that many, but for technical and practical reasons, it was only possible to install the ISA system in 5000 cars.

The test drivers became an important transmitter of information to the general public. By informing the test drivers about ISA, the message of the project was spread out in an effective way. One calculation made was based on the average household in Sweden consisting of 2.1 people. Via 5000 test drivers, the project would be exposed to 10500 people who could learn about the system and its features. For the next step, it was assumed that each person would communicate information on the project to around 20 friends and acquaintances; simply put the drivers alone would convey the message to 100000 people. Keeping the test drivers well informed was therefore an extremely powerful means for achieving the objectives with regard to dissemination of information about the project.

6.6 Training and education of project members

At the start of the project, possible problems which could arise over the course of the project were discussed. Project members realised the importance of being well prepared to deal with various situations, for example, contacts with the media and crisis management. The preparations and coherent

information were regarded as success factors. Coordination of information in critical situations was seen as vitally important, and the image of the project risked being confused or erroneous without it. If an ISA car were to be involved in an accident, for example, coordination and preparatory measures would be of the utmost importance. In such critical situations the information structure must be clear and well established. Against this background, the project team decided to put great emphasis on preparations, training and education.

Media training

In January 1999, a 2-day course in media communications was held. The course included both theory and practical media training. Through education, Project Managers and Public Relations Officers gained knowledge on the journalistic way of working, and could thereby handle contacts with the media in a better way. The project team was welded together, language among project members was standardised and concepts, value words and project fundamentals were established during the training period. In December 2000 supplementary training in media communications was held to refresh skills.

Crisis communications

A crisis communications plan was drawn up. The plan specified the flow of information, who was to communicate the information, where it was to be distributed and the channels that were to be used. In April 2000, Project Managers and Public Relations Officers were trained by being exposed to practical cases of a disaster situation. The exercise was formulated by the Swedish National Road Administration Western Region's Safety Officer and the ISA project's Public Relations Officers.

6.7 Experiences

Media's view of ISA

The purpose of the media strategy project was to communicate a message which was as neutral as possible, whilst disseminating information on the project so that the general public were able to form their own opinions about ISA. Media coverage concerning ISA has been monitored during the course of the project. To review how the information strategy in the project has worked, article analysis was used as a tool. The analyses were made by an external company, and with help of these analyses, the project received feedback on whether the messages had reached their target, and whether the information given out by the project had been reflected in the media. The review also provided confirmation of whether something had been misinterpreted, or if there was a tendency to angle the articles in any way. The article analyses were made at the end of each year starting in 1999. The analyses served partly as a review of how the project's message had been communicated and perceived, but also as a yard stick for how the project had progressed in the development process. During the analysis work, the project team realised that journalists' angling when reporting along with their perception of ISA were often linked if they had test driven the system themselves. The significance of the demonstrations and test-driving increased during the course of the project and was an extremely powerful way of spreading information about ISA.

The aim of the Information sub project in 1999 was to spread information about the inception of a large-scale project in Sweden and what it was all about. The purpose was that the general public, particularly in the project towns, should gain knowledge about ISA, and a large number of people were to have the chance of testing the system. The articles published throughout the year were clearly positive in their attitude towards the project. The messages were objective and factual, often focussed on the technology and in particular it was the active gas system that aroused most interest. Coverage was totally free from criticism or speculation of the type “Big brother is watching you” and instead communicated a message of ISA being a positive contribution to increasing road safety. The conclusion from the article analysis in 1999 was to continue with the same strategy, and be attentive to the debate surrounding integrity.

The year 2000 was to see 6000 test drivers recruited. This meant that an increasing number of people would have opinions on the project. In addition, the test drivers would have support for their opinions

after they had tested ISA. The aim of the project was to spread information about ongoing activities, and to create the conditions for bringing the opinions of the test drivers to light. In so doing, the image of ISA was expanded and more voices had the chance of being heard. The article analysis demonstrated a homogeneous image, and also that the articles were once again characterised by positive attitudes and technology aspects, but they also included behavioural issues and interviews with project participants. The press often highlighted the benefits of using ISA and talked about how speeds could be regulated and how road bumps and other obstacles in traffic could be replaced, and about positive environmental effects and less noise emission. The main negative aspect that was highlighted was the cost factor. The conclusion of the analysis for the year 2000 was that information from the Project Management was relatively sparse and homogeneous over the year. The Information sub-project deemed that the project had succeeded in getting out the right message to a much better degree than was previously the case.

In 2001 a new image of ISA was portrayed, namely that installing the system in the car would not be especially expensive. The features also reflected a positive debate growing among politicians and the automotive industry in Europe. When the positive preliminary results were presented, the articles were focussed to a great extent on the evaluation and the results. Several articles referred to specific events over the year, such as the MHF (The Union Of Temperance Drivers Of Sweden) conference in Tylösand, Minister of Industry and Commerce - Björn Rosengren's comments about cruise control, and the EU meeting on traffic safety in Trollhättan. Significantly more articles focussed on the project participant's experiences of the test systems.

In 1999 and 2000, the press coverage was principally characterised by a discussion on enforcement when comparing to 2001, where the focus on free-will with respect to the implementation of the systems was more evident. The media portrays an image of high speeds being one of the principle causes of serious accidents, and that ISA is one way of avoiding these. Several of the problems that were highlighted in previous years such as costs, the feeling of being monitored, resistance from the automotive industry and the fear of electronic systems in traffic, were played down by presenting the facts. ISA was described in several articles as something which would be standard equipment in future cars. The conclusions from the work with information in the year 2001 was that the project reached out with its message and successfully created a positive debate on ISA. The project team considered that they had succeeded, for the most part, in getting out the message when comparing to previous years, due to a more strategic approach to information management.

The automotive industry's view of ISA

As previously mentioned, the automotive industry, at the inception of the project, had a negative attitude to speed adaptation. These views were based on experiences from previous small-scale projects, and the debate that had prevailed on speed adaptation concerned the safety risks involved if the system was to be enforced. The integration problem was also a contributory factor to this negative point of view. Converting the automotive industry's attitude to a positive stance was imperative for the ISA project. Following careful consideration, it was decided that the Swedish ISA project was only going to include voluntary and supportive systems. On the initiative of the Swedish National Road Administration, the active gas system was fitted with a “kick-down” function, which could be used by the driver (if the situation required it) in emergency situations. Consequently, Volvo decided to participate in the evaluation of the product and the system. The participation of the automotive industry was not only significant for the project group, but it also created interest in, and a status for ISA.
Saab took part with five cars with ISA installed for the demonstration of the “vision zero stretch” in Trollhättan. The demonstrational visualised how ISA could contribute to realising the vision of “zero killed or seriously injured in traffic,” and improve safety on the roads.

The automotive industry's changed attitudes together with the choice of using a voluntary, supportive system were important preconditions for the information process, as two of the aims of the project were to spread information and gain acceptance for the system. The work had been of a more difficult character if an enforced system had been used. ISA as a concept is based on the car drivers accepting the

system, and regarding an installation as increasing safety and, to a certain extent, comfort in the car. It was important for the project to allow test drivers to test the system and thereby create a demand for the ISA product. Linking the automotive industry to the project, meant customer needs could be communicated. If the market should then prove to be large enough, a product could be introduced on the market.

7. How can ISA be introduced on the market?

The large-scale ISA-trial has been in progress in Sweden since 1999. The trial is the largest of its kind in the world with respect to using IT systems for speed adaptation. The trial has been carried out at four sites in the country and was completed in August 2002. The experiences and conclusions that might contribute to the continued discussions on whether ISA should be implemented In Sweden and in Europe as a whole are detailed below.

7.1 Experiences from the ISA trial

The results point unequivocally to ISA being a positive feature for traffic safety. They confirm previous results from minor trials in Eslöv and Umeå regarding user acceptance and traffic effects. The fear of negative effects has been exaggerated, but the ergonomics need to be improved.

Speed measurements in Umeå and the results from vehicle logging in Lund and Borlänge illustrate irrefutably that average speed levels dropped for vehicles fitted with ISA equipment. In addition speed spread was less. The higher the average speed the greater the speed reduction provided that the pervious average speed is above or close to the current speed limit. The only tangible difference between the systems is that the effect on speed spread is less for informative and warning systems than for active gas. The reduction of average speeds is around the same amount.

The design and functionality of ISA has caused problems, but drivers have confidence in the system. The greatest problem arose with the active gas system, which in the tested version affected a number of vehicles' driving characteristics when accelerating. This has probably influenced the drivers in their assessment of the technology and functionality. These flaws must be corrected before any implementation of the system.

Many drivers have complained about the sound signal for warning and informative ISA, and this has been accentuated during the trial period. A softer tone is desired. The light signal has also caused problems, and it has been difficult for many drivers to see the speed information in the display window with the sun shining directly on it.

One concept of ISA is that the driver is informed when the speed limit has been reached and does not need to check the speedometer or speed signs to the same extent, as was previously the case without ISA. For active gas, 40% of drivers report that they check both the speedometer and signs to a lesser extent. For informative ISA there is no great difference, whilst with warning ISA, drivers check somewhat more than previously instead. Around half of the drivers with warning ISA increase their attention on the speedometer and speed signs. Because the warning system lacks a display, this is a reasonable response.
Several drivers with warning and informative systems reported accelerating and braking more often than before, while the opposite was the case with active gas drivers. A probable explanation is that the active gas system automatically makes a speed adjustment when the speed limit has been reached, while the drivers with informative and warning ISA were actively forced to take action (reducing acceleration or maybe braking). The results also show using active gas drivers attempt to utilise the maximum permitted speed wherever possible. Acceleration is consequently somewhat greater when accelerating than without ISA. This probably also applies for the informative and warning systems.

Even though a certain increase can be noted for a number of factors with respect to mental burden, it seems that these do not affect driving negatively to any notable degree. This point of view was substantiated by the overwhelming perception that ISA does not draw attention from other, more important things when driving.

Despite the technical and functional flaws the systems have been inflicted with, the trials demonstrate that the test drivers are overwhelmingly positive to the systems. If ISA is to achieve a major breakthrough, it is nevertheless important that the equipment is ergonomically tested, works problem-free and is reliable. Because the will to pay is weak, it is also important that the promoting a voluntary introduction is stimulated through subsidies and other incentives.

The results could be interpreted as active gas having a somewhat greater effect on speed violations and thereby safety. The acceptance is however greater for the warning and informative systems. Functional problems have probably contributed to this more than the influence on speed of active gas. To establish a high level of acceptance in the introduction phase, it is probably important to provide the possibility for the drivers to choose between the different functional variations. Preferably these should be built into an integrated system. It appears easier accepting the warning and informative systems in the beginning. After a while, many experience the sound signal as irritating, and want to replace it with a more discreet warning. Active gas or another system variation would be preferable in this case.

7.2 Implementation from a technical perspective

The future appearance of ISA technology depends greatly on the features that will be most requested by authorities, car drivers and others. There will probably be a requirement for technology that ensures both the vehicle and drivers are constantly aware of applicable speed limits, and additionally that the drivers receive support when adjusting speed.

Based on the technical experiences from the ISA project. the following prioritised development areas can be identified:

1. Road database with speed limits
2. Communications with vehicle
3. Vehicle equipment

Work on the NVDB (Swedish National Road Database) has been ongoing for several years, which in the long term will be applicable base data for roads and accompanying attributes (including speed limits). However, for this to be fully comprehensive and updated, all the municipalities in the country need to earmark resources for digitising their road data, and keeping it updated. At present there is insufficient impetus in this process, which is why there is currently a feeling of uncertainty as to when NVDB will be fully comprehensive and completely updated with regard to speed limits. This must be changed to allow the conditions for the implementation of ISA throughout the country.

Borlänge is the only trial site that has tested wireless communication in vehicles, and *communication* has been a bottleneck in the system in this case. If sharp ISA is to be capable of working on a large scale, technology must be available that allow stable two-way communication for larger vehicle fleets. Ongoing investments in the infrastructure for telecommunications (primarily for 3G) suggest the basis for this will be in place within 3-5 years.

Vehicle equipment developed as prototypes in the trial project has worked satisfactorily, following running-in and adjustments. However, a lot of extra work remains before this equipment can be accepted technically for large-scale implementation, something that must be done primarily by industrial partners as well as from an active commitment from authorities. The automotive industry has assessed that the ISA system, in the form used for the trial project, cannot be offered as standard before 2008. There are companies today that can already offer simpler forms of speed information via PDA's.

These increasingly more common “electronic diaries” (PDA) are equipped, to a great extent, with digital maps and GPS receivers. These units can be used as simple ISA systems in “the pocket” or in any vehicle.

New features

The above line of reasoning pertaining to the required technical development is based on current ISA systems, i.e. to support motorists when adapting the speed to the applicable speed limit. However, new features in the pipeline will be putting additional demands on the technology.

Dynamic speed limits, adapted to the weather, traffic situations and other circumstances, is such a feature that can be expected to be introduced to some degree. Naturally, this not only puts demands on the technology but also on the speed limit legislation. Studies and trials in this field have begun.

There are many other features that can be considered related to ISA, as they build on providing drivers with information and support for the purpose of increasing traffic safety. Many of these features could divide the technical infrastructure behind ISA, and it is therefore important to be aware of this before designing any new systems. These include: traffic information, navigation systems, weather information and other driver support in addition to speed adaptation (e.g. other traffic regulations).

Implementation aspects

Post-installing ISA equipment in the majority of Sweden's vehicle fleets is a gigantic and probably impossible logistic operation. The automotive industry has, as previously mentioned, deemed that ISA systems can be on the market as an option in 2008 at the earliest. It should also be added that the parties responsible for producing the digital road database (NVDB) assess that the speed limits will not be entered in the database for all roads before 2005 at the earliest.

All in all, it is highly probable that the authorities will be responsible for providing coverage and updated databases of road networks and their speed limits, and industry (the automotive industry, navigation and telecommunications) will provide the various products that communicate speed information, under the proviso that someone is prepared to pay for them.

The following figure summarises which parts of the necessary technology and infrastructure for large-scale ISA which can be assessed as being in place (green circles) and what is still in need of developments (red figures):

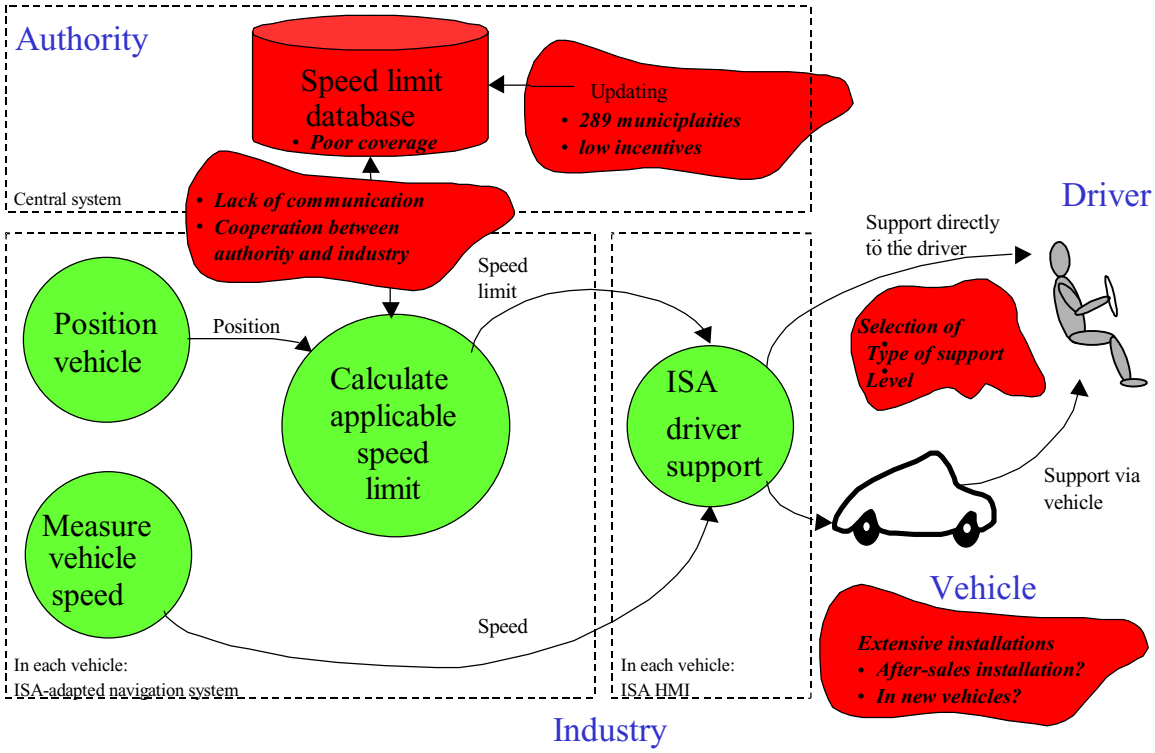


Figure 7:1 Status for the functions in large-scale ISA.

Conclusion from a technical perspective

If the will exists to implement ISA on a large scale, the technology is available. Clear boundaries should be established between the role of the authorities and industry. The authorities should be responsible for providing a fully comprehensive and updated road database with speed limits, and allow industry to produce the necessary vehicle equipment. Difficulties in communicating the applicable speed limits to large vehicle fleets should not be underestimated. Particularly if this speed information is to be both dynamically adapted to the applicable circumstances and legally binding in the future. The selection of speed support that may be regarded as appropriate is not restricted by the available technology. Everything from a discreet informative system to a more actively supportive or vehicle impacting system is already perfectly feasible today.

7.3 Implementation from the perspective of the automotive industry

System design and areas of responsibility

System design has two scenarios;

A Infrastructure with “beacons” and simpler receivers in the vehicle
B More complex systems in the vehicle (GPS) and fully updated map database

	Technical development responsibility	Costs for technical development	Responsibility for maintaining information flow	Responsibility for technical development
A	Principally authorities, small for automotive industry/users	Principally in infrastructure, small for automotive industry/users	Authorities	Authorities, small for automotive industry
B	Principally automotive industry/users	Automotive industry directly, users indirectly, possibly authorities in the form of tax exemption etc.	Authorities (map databases)	Principally automotive industry

The system solution selected depends, to a great degree, on the coverage ambition, which in turn depends on the required effects from the aspect of traffic safety and acceptance/benefit to the users. System solution A is more effective for smaller geographical areas, urban areas or other selected stretches (e.g. 30 limits outside schools). System solution B enables coverage of greater areas restricted by GPS coverage and updating of map databases.

Traffic safety

There are obvious connections between speed and traffic safety. The implications are greater during poor road, weather and reduced visibility conditions. The level of driver safety awareness could be increased only if a system like ISA is present. The trial illustrates that interest for observing the statutory speeds limit is high, particularly at lower speeds and definitely at “sensitive” places such as schools, etc.

An ISA system supports maintaining the speed limit, and in the best case a lower average speed is obtained for vehicles than would otherwise be the case. The drivers in the trial believed that ISA would be more effective at lower speeds, and they were sceptical towards ISA at 70 limits.

At lower speeds the risk for personal injury in the vehicle is relatively low while for unprotected road users it is higher. At higher speeds the risk for personal injury in the vehicle is therefore higher because more single-vehicle accidents occur at these speeds. On the other hand, the risk is lower for unprotected road users because accidents occur less frequently between vehicles and road users on stretches at these speeds. Intersection accidents are, however, more frequent. The greatest risk in this context is the distance (gaps) that occurs between vehicles.

The greatest risk for pedestrians is probably when the gap between vehicles is between 2-5 seconds. Gaps under 2 seconds are easy to judge as being too small, and over 5 seconds the gap is generally speaking large enough for safe passage. There are at present systems that are sold, known as ACC (Autonomous Cruise Control) where drivers regulate the gap to the vehicle in front. This regulation takes place by the vehicle automatically braking when the gap reaches the set minimum value. The development work has demonstrated that the drivers accept distances between 1-2 seconds. Greater distances (compare to the Swedish adopted three second rule) mean that other vehicles will force their way into the gap, and is so doing create an uncertain situation in dense traffic. Accordingly, this rule is mainly appropriate for avoiding situations involving high-speed collisions from behind in rural areas.

The action that would probably increase safety for unprotected road users most is, therefore, a system that can regulate the gap to the vehicle in front so that it is not between the critical range of 2 and

5 seconds at low speeds. Another measure, which would raise the level of traffic safety considerably, is convincing motorists who drive well above the legal speed limit to adjust their speed.

In order to achieve a high initial effect, it has been suggested that the Government and the municipality should take precedent in their procurement of transport services and demand that vehicles are equipped with some form of ISA system. It can be discussed what real effects this would have on traffic safety bearing in mind that acceptance among commercial drivers for the ISA system was low during the trials. Not having voluntarily selected to have a speed information/warning system in the vehicle probably does not encourage the inclination to observe the information/warning.

Acceptance for ISA systems and willingness to pay

Acceptance depends greatly on the price to the user. A high price puts demands on the usefulness of the functionality to the user - value for money. If the price can be estimated more in terms of direct benefits to the user, the willingness to pay obviously increases.

If ISA were to be statutory, or command a low price from the perspective of the user, acceptance would probably be on a parity with police surveillance according to studies. Police surveillance and ISA were compared to other speed reduction measures, e.g. “speed bumps”, flower boxes and mini-roundabouts.

If a GPS based ISA system is to be sold without connection to another system, the price will be high for the user which will lead to a low level of acceptance. Some form of incentive will then be necessary. If a GPS based ISA system can be sold together with another system (e.g. Navigation system), a higher price can probably be charged directly to the user, but with the result of achieving a poor overall effect due to fewer systems being sold.

Many users in the trial think that an ISA system should be compulsory for everyone. Only one in three can consider paying something for the system. The willingness to pay made evident by the results is very low at around SEK 300 for the “warning” system and around SEK 1000 for “active gas”.

The difference in this level of willingness to pay for the systems may be due to the opinion that a more integrated system in the vehicle, and which also takes a more “active” role, is more complex and therefore can justifiably command a higher price.

The acceptance for speed adjustment among the general public and specifically for the ISA system would probably be greater if speed limits were dynamic (i.e. adapted for prevailing conditions e.g. weather, time of the day or night, road works). There was also a high acceptance level for ISA as support for certain driver groups, e.g. notorious speeding offenders, drink drivers and drivers who have just passed their test.

Commercial drivers in the trial reported having a very low acceptance level for ISA. The majority did not have the option of deciding to have the system in their vehicle, and were initially negative to this type of speed adjustment system. The often stressed pace of work is probably a factor here.

Proposition strategies for ISA systems

One condition for an effective implementation, and thereby an acceptable price to the customer, is harmonising the selection of system (“beacon” based or GPS/map database). The optimum scenario is this happening in the same way on a global basis; in Europe it is a necessity. If the automotive industry is forced to develop a number of different technical solutions due to different systems being adopted throughout Europe, the development costs and, accordingly, the price to the customer will be high.

In the case of a “beacon” based system becoming a reality, the above-mentioned prices could be reasonable (around SEK 300 for “warning” system and around SEK 1000 for “active gas”). In the case

of a GPS/map database system being selected, these prices are far away from being realistic without subsidies or other incentives.

If an ISA system is to be integrated into the vehicle (e.g. via the pedals or instruments) a development time of around 5-6 years is required. If the system is to be in the form of an "add-on" system, a shorter time of around 2-3 years is required. Selling a GPS based ISA system in conjunction with another system also requiring GPS (e.g. navigation) is one solution but the price is still too high for these and the volumes too low. However, it is probable that the volumes for navigation systems will increase over the coming 5 years, and in 2008 be around 20%, although still at a relatively high price.

A first step could be to introduce a display for speed limits in the existing navigation display. This would take around 1-2 years to implement, and would still require a GPS/Navigation system in the vehicle and a map database with updates from the authorities.

Possible interface in the vehicle

The system could be discreet or indiscreet (only drivers receive the information/warning or everyone in the vehicle receives the warning). The system could be informative/warning where the driver is the first to actively take the decision on whether to observe the information/warning and take action. It could also be "actively supportive" where the system informs/warns by practically proposing and implementing an action for the driver in the form of resistance in the accelerator pedal, for example. However, in the latter case it is important that the driver, for safety reasons, can take an active decision not to observe the system's "recommendation" at any time, but has the option of taking complete control of the speed regulation.

A system like the "informative"/"warning" system used in the trials, uses the two senses that are most occupied whilst driving the vehicle for its communication needs, hearing and sight, which is a clear disadvantage. The automotive industry is working a great deal in avoiding burdening these senses further. However, this type of system seems to have a high acceptance level (despite certain comments about irritation). This could be due to a feeling of not being directly "influential" on the vehicle's operation.

A system like "active gas" is a "natural" interface because it communicates directly to the part of the body that is carrying out the activity (the accelerator foot). However, studies show that this might cause a certain worry about a feeling of losing control. But it probably has to do with that it is an "actively supportive system" in itself, i.e. it does not wait for activity from the driver first.

In simulator studies another form of "actively supportive pedal" was tested. The accelerator pedal "died" and speed was not increased irrespective of pedal position (although this feature can be by-passed using "kick-down"). This had good test results. A vibration warning in the seat was tested in simulator studies. The vibration was considered as good together with discreet information, but this type of warning was "rather obtrusive" on the body, and drivers preferred to regulate the strength themselves.

Reactions to "active gas" and "dead accelerator pedal" a similar to the reactions to "informative" /"warning" systems and "vibration in the seat". To sum up it could perhaps be stated that direct "interventions" in the task of driving is effective, not as irritating as first feared, but it might create a certain feeling of uncertainty. With respect to the warnings/info where the driver is first to take an active decision, effectiveness is probably a little less, irritation caused by the warning greater, but without the tendency to feeling uncertain. Irritation is based on the fact that a flashing light, peeping sound and repeated vibrations in the seat contributes to stress (which of course is meant to achieve an effect).
It is understood that stress leads to irritation. The correct sound characteristics in a system like the informative/warning system is, in any case, important for optimising the warning effect and amount of irritation. The option of adjusting the sound volume is probably needed as well.

Display of the speed limit, both for the purpose of giving a warning or information, and as general information, if the warning is not to be shown, is always good. This was shown both for the trial sites and in simulator tests.

The system solution selected in the vehicle will depend on the costs of development, possible price to the customer and user benefits and user-friendliness.

Conclusions - from an automotive industry perspective

In order for an ISA system to be sufficiently attractive, have a high level of acceptance and achieve high observance, dynamic speed limits should be introduced. Dynamic speeds increase the driver's understanding for the speed limit, and also make it more meaningful having support in observing the speed limit in the vehicle.

The market can benefit from support such as tax exemption or reduced insurance premiums. This will probably be necessary for a GPS based ISA system if it is to be available around 2008 at a reasonable price to the user. This should be reasonable because the benefits to society of such a system as this will initially be greater than for the private individual.

System harmonising, in Europe at least, is necessary to get the automotive industry onside in developing the technology and keeping the costs for the system down.

7.4 Implementation from the perspective of society

Using the evaluation it can be verified that drivers in general appreciate receiving information of applicable speed limits in the vehicle. A large number of speeding offences are committed involuntarily due to the driver not realising or paying attention to the applicable speed limit.

Increased interest in ISA

As a result of the great mass media interest in ISA and clear indications of positive results from the trials, several other municipalities and authorities have now approached the Swedish National Road Administration and shown interest in fitting the vehicles in their various departments with ISA equipment.

To be able to satisfy these enquiries in a consistent and structured fashion, a short-term strategy has been drawn up for implementing ISA over the period 2002-2008. The primary reason for a short-term strategy being established up until 2008, is due to the automotive industry currently talking about ISA in terms of it being an option in future vehicles, but that this was not probable until 2008 at the earliest.

The manufacturing base for future car models has already been produced several years in advance. This means there is a “gap” between the now concluded ISA trial in 2002 and the target year 2008. To hasten the implementation process of ISA up until 2008, measures are needed to be taken to build up a market. The Swedish National Road Administration will play an important part in these measures.

The discussion surrounding a long-term implementation strategy is progressing in conjunction with authorities and the automotive industry on a European level (Speed Alert and PROSPER). Accordingly, it is of the utmost importance that implementation of ISA systems on a short-term national basis takes place in line with the planned subject matter of these discussions.

Previous reference points for introduction of ISA on the market

When summarising the reference points in the ISA trial for introducing ISA onto a market, it can be stated that the systems should be *voluntary, informative and supportive*. The driver should have total control over the vehicle at all times.

It is important to work together with the automotive industry. The ISA trial has succeeded in capturing the interest of the automotive industry, something which previous trials with speed informative systems, to a certain extent, failed to do. Volvo participates actively in the project, and SAAB has equipped five cars with active gas, which has been demonstrated on the vision zero stretch at Trollhättan over a one year period.

It is important to commence work as soon as possible on dynamic speed limits, because this will provide impetus for using and increasing the benefits of the ISA system. It is probable that dynamic speed limits will increase the credibility for speed limits and consequently the drivers' observance of them.
The automotive industry sees the development of dynamic speed limits adapted to prevailing road conditions, the road type and the traffic situation as very positive.

A fully functioning ISA system requires a national road database with speed limits. An international collaboration is necessary to implement ISA on a large scale.

Test-driving and demonstrations of ISA have great value for marketing the systems. The Swedish trial is a good example of this.

What do the test drivers want?

It can be deduced from the evaluation that the system is probably too expensive. This has been evaluated using questionnaires on the test drivers in the four trial municipalities. It probably requires less expensive systems if it is to be attractive for vehicle owners to purchase. A plausible development is that ISA will be included as a service in a larger package of in-vehicle services that the automotive industry will be offering.

The drivers would like to see ISA as standard in future vehicles, and think it should be compulsory in urban areas, and that statutory installation is reasonable, both for the informative and actively supportive systems. A first step would be to see it installed for speed offenders and new drivers. The driver decides himself how the system is to be utilised.

The drivers also think it is correct to place demands on safer transport which include keeping the applicable speed limits. This applies to transportation paid for publicly, e.g. school transport, bus traffic, elderly people and ambulance services.

In order for ISA to be able to handle voluntary implementation on the private market, subsidies will probably be required for a long period as ISA provides greater benefits to society as a whole than to the private individual. The likelihood is that a figure of SEK 1000 for ISA as an option on the aftermarket is necessary. A more attractive design is probably also required. Before the system becomes statutory, it should be at the driver's discretion how it is used. Usage very much depends on at what level speed surveillance will be in the future.

Strategy for implementation of ISA in the short term (2002-2008)

To satisfy the enquiries that are now being received from interested parties, the need for an implementation strategy in the short term has arisen. As previously mentioned, such a strategy refers to the period up until the time ISA equipment is a standard option in all new cars. In short, the strategy is based on the following points:

- create the technical conditions for ISA through access to digital speed information.
- begin with ISA in urban areas where acceptance is greatest
- wait before implementing ISA in rural areas until automatic speed surveillance has been built out
- have quality assurance of public transportation at the forefront

- subsidise ISA on the private market during the introduction period
- responsibility for observing applicable speed limits remaining with the driver

That ISA is not yet available as standard equipment means that the ISA system will be post-installed in the vehicle in the beginning. There are currently three suppliers of ISA system, all of which are small to medium-sized companies. All of these companies are capable of delivering equipment and can ensure its operation and maintenance. An ISA system currently costs between about SEK 5000 and SEK 20000 each. The price of the equipment could be reduced significantly for larger coordinated orders.

The evaluation reveals that ISA is assessed to result in an improvement of traffic safety by around 20% in urban areas. It is plausible that the corresponding effects would also be the case in rural areas.
A car driver drives on average around 15000 km annually, and on average is involved in 1 accident per million vehicle-km at a cost to society of around SEK 1 million[24]. This gives SEK 1 million per million vehicle-km, i.e. SEK 1/vehicle-km. If ISA is assumed to reduce the consequences of accidents by 20%, it is worth subsidising ISA by SEK 0.2/vehicle-km, i.e. SEK 3000 annually. It is therefore reasonable to subsidise installation of ISA in cars by at least SEK 5000 during an introduction period which would give a repayment period of around 1.5 years. It is also important that the equipment is checked as part of the annual vehicle inspection.

In the long term, the ISA systems that are introduced into vehicles will be loaded with all speed limits in the road network. In a shorter perspective, it is possible to only include speed limits for certain road sections in the ISA system.

When implementing ISA with a GPS based system, a digital map is used. The most important data volumes in this map are the description of the road network and information on applicable speed limits. This basic data should be taken from NVDB (Swedish National Road Database). The justification for this is that the NVDB concept allows for a common structure for data throughout Sweden, as well as allowing data to be updated over time.

The status for NVDB is that since 2002, a nationwide description of the road network is available. However, this road network is not always complete, as it needs to be updated with newly built roads. With respect to speed limits, information on signed speed limits for all state-owned roads is included, and other road networks will be added gradually. For the municipal road network, this will take place in connection with the review by LTF (Local Traffic Association) which will have been completed by 2005 at the latest.

A problem that was sometimes noted concerning speed data, was that differences can occur in the position specification as regards the applicable speed limit and sign location. NVDB has assumed that these should concur and, in connection with the LTF review for the municipalities, this will also be reviewed for quality.

Conclusions - from a society perspective

Taking the ISA trial's results into consideration, society in general should support the implementation of voluntary, supportive and informative ISA systems on a large scale. The speed informative system is expected to contribute to increased traffic safety, and a reduction in the number of killed and injured on the roads.

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24 The value originates from basic data for SAMKALK, which is a spreadsheet application for calculating the effects of infrastructure investments.

In supporting and assisting the implementation of ISA, society should take the following actions:

- The Swedish National Road Administration should provide all interested parties with information and the knowledge gained from the implemented ISA trial. This includes recommendations on project planning, information and marketing (establishment), costs, technical equipment, operations and maintenance etc.

- The Swedish National Road Administration should speed up the development of NVDB in the geographical areas where speed informative systems are in demand, with the help of regional NVDB Coordinators.

- The Swedish National Road Administration coordinates the procurement of ISA systems for all enquiries, to facilitate the ordering process. The price may be reduced for larger orders. Orders can also be allocated to different suppliers, as it is of interest both for the Swedish National Road Administration and the automotive industry and its customers to have several manufacturers on the market. A procurement procedure/technical specification is to be provided by the Swedish National Road Administration.

- The Swedish National Road Administration should provide recommendations for how installation of speed informative system should be conducted based on experiences from the ISA trial. Recommendations should be worked out in conjunction with the Vehicle Standards department, and contracted mechanics in the ISA project.

- The Swedish National Road Administration should equip their internal vehicle fleet with the speed informative system.

- For procurement with the Swedish National Road Administration regarding transport, speed informative systems should be requested. The Swedish National Road Administration should also work to encourage other parties to do likewise.

- The Swedish National Road Administration should investigate together with the Swedish Ministry for Industry, Employment and Communications the possibility of state subsidies for vehicles equipped with speed informative system.

7.5 Recommendations resulting from the Swedish ISA project

Utilising the experiences from the Swedish ISA project – implementation, evaluation, technology, information and participation from the automotive industry, the following recommendations can be given for the continued discussion on its introduction on the market.

a) The project results are clearly positive from a traffic safety perspective, and they do not show any obvious negative side effects. We therefore highly recommend that society and the automotive industry work together to implement ISA as soon as possible.

b) A majority of the test drivers consider that the ISA system should be standard in future vehicles. The Swedish National Road Administration should immediately initiate that regulations (legally binding or voluntary agreements with the automotive industry) are drawn up pertaining to the ISA system being standard in future vehicles. These regulations should be formulated by 2005 at the latest. In negotiations with the automotive industry, decision shall be taken that the regulations are to apply from a stipulated year which would give the automotive industry reasonable time to develop and install the ISA system as standard (for example some time between 2008 and 2010).

c) Companies that are able to show serious interest in developing and offering the ISA system on the after-market should receive support from the state through VINNOVA (Swedish Agency for Innovation Systems) and others so as to stimulate the emergence of fully developed technology for post-installed systems during the period 2003-2015.

d) Opportunities should be generated for installing ISA nationally, or in limited areas for vehicle fleets, by a reliable and continually updated speeds database being available by 2005 at the latest.

e) The Swedish National Road Administration should show an example by installing ISA in their own vehicle fleet by 2005 at the latest. State and municipal authorities should encourage the installation of ISA in their own fleets. Requirements for the presence of speed informative systems should be specified as part of the procurement process for public transportation by at the latest.

f) Subsidies or other incentives should be introduced during the years 2003-2010 to stimulate the use of ISA on the private market. Studies on the effects of these incentives should be started immediately.

g) Sweden should work towards implementing speed informative system on an international basis, primarily within the EU. This should be achieved by spreading knowledge on the effects of ISA systems and its acceptance, and to work for international agreements on HMI, standards etc. Requirements should also be specified for the vehicle speedometers being more accurate than currently is the case.

h) The speed limitation system and surveillance policy should also be reviewed at the same time, with consideration taken to the new conditions that road informatics provides. The issue of the methods used to keep the applicable speed limits, and the limits that are appropriate should, wherever possible, be kept apart.

A conceivable implementation scenario

Based on these recommendations, the following introduction schedule is conceivable:

2002-2004

- Negotiations continue between the Government and industry concerning the regulations for ISA in new vehicles.
- State subsidies for those installing ISA voluntarily are introduced
- The Swedish National Road Administration begins installing ISA in all of their vehicles, and has it as a requirement in their procurement process for transportation.
- VINNOVA and other financiers support companies that develop and market ISA systems on the after-market.
- Work on entering speed limits in the national road database is intensified
- Introduction of dynamic speed limits
- Increased cooperation between the authorities and the automotive industry in Europe.

2005-2009

- In 2005 the Government presents new regulations for ISA as a standard in new vehicles
- Functionality and reliability of post-installed systems has been improved with the help of state subsidies
- Early in the period, ISA has been installed in 5 % of older vehicles with the help of the Swedish National Road Administration and other authorities acting in connection with the procurement of transportation.
- At the end of the period, penetration has increased by up to 35 % due to the increasing demands for ISA from private individuals
- Standardisation continues within the automotive industry to enable ISA to work throughout Europe

2010-2014

- The collaboration between the Government and the automotive industry has resulted in 2010 being stipulated as the year for ISA becoming compulsory as standard in all new vehicles
- ISA has been installed in 60 % of all vehicles
- Increased demand and larger manufacturing series result in lower costs, and the need for state subsidy for ISA is removed.
- Having ISA becomes a matter of course and opinions have turned voluntarily towards regulations for compulsory use.

2015-2019

- More than 80% of all vehicles have the ISA system and as early as 2015 the decision is taken, without objection, to make ISA compulsory in Sweden. At the same time, a number of countries in the EU take the same decision.
- Access to a fully updated road database in Sweden, and in large parts of Europe, has resulted in a large number of telematics services such as traffic information, navigation, a number of. “mayday” functions etc, being linked with ISA systems.

2020-2024

- The rolling out of the mobile data communication network has reached a point where, in principle, 100% of the European road network is covered.
- In Sweden and large parts of Europe, road maintenance bodies have established traffic information centres (TIC) whose task is to update all vehicles on the roads with the necessary route guides, traffic information and any possible restrictions on a continual basis.

2025-2030

- Stipulations are in place for all vehicles to be connected to a TIC
- At the end of the period, the Swedish National Road Administration and other road maintenance bodies gradually dismantle road signs as all necessary information is displayed for the driver with the help of the vehicle being used for the journey or for transportation.

Additional R&D needs for support of ISA in the future

In conclusion, some suggestions are given for additional R&D projects that could support the implementation of ISA in Sweden and Europe.

a) Dynamic ISA

ISA provides greater possibilities for varying speeds, in time and space, which contributes to increased acceptance. The effects and technology for dynamic ISA need to be studied.

b) ISA outside of urban areas

The ISA trial has been focussed on urban areas. The effects and acceptance in rural areas will, in all probability be different, and needs to be studied in more detail.

c) 30/50 streets

Intersections with different speed limits for approaching and exiting have been included in the trial. Using ISA it is easier to let the intersection have 30 km/hr while the stretches have 50 km/hr. The effects, technology and acceptance associated with this should be investigated.

d) ISA in urban area intersections

The effects of ISA are lower in urban area intersections than on road stretches. Additional road informatics at intersections needs to be developed focussing on the problems of unprotected road users.

e) Integration in the vehicle

The user interface for ISA needs to be improved, so that applicability and attractiveness are increased. The effects on functionality and behaviour should be investigated.

f) Speedometer demands

As discussed previously, faulty information from current speedometer can amount to 15 km/hr. It therefore needs to be investigated how greater demands can be put on speedometers and how this can be coordinated internationally. One solution is for the ISA system to replace the current speedometer entirely.

g) Formulation and effects of incentives

Incentives can give impetus to ISA development. The effects of different incentives for the installation and use of ISA should be studied.

h) Alternative ISA solutions such as PDA

Alternative technical solutions can be considered for ISA. For example, the digital map could be obtained via pocket computers, referred to as PDA terminals. The effects and costs for alternative solutions should be studied.

i) Review of speed limits

Acceptance for ISA depends on attitudes to the applicable speed limits. General zones with 30 km/hr in urban areas and 70-stretches of road in rural areas have a low level of acceptance. A review of speed limits with reference to the new technology should therefore be made when considering the acceptance level and effects.

j) Camera surveillance

Speed surveillance could have a decisive role for the implementation of ISA. Drivers report that the most important benefit of using ISA is that speeding fines are naturally avoided. The correlation between camera surveillance and the effects of ISA should therefore be investigated.

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