



Variable speed – in a nutshell

Extended summary



EXTENDED SUMMARY

Variable speed in a nutshell

Variable Speed Limit (VSL) trials were begun in 2003 and are pursued at twenty places with road crossing control, pedestrian control, weather control and traffic control. Some important lessons emerged:

- VSL at crossings resulted in speed reductions of 5 - 15 km/h. VSL may be suitable at a relatively high primary flow and side-road traffic of 20 – 30%. Around 150 crossings may be candidates for VSL in the rural network
- Pedestrian-controlled VSL gives rise to some speed adaptation and reduced speed variation. Pedestrians are predominantly positive
- Weather-controlled VSL gives extra encouragement to reduce the speed under difficult road conditions
- Traffic-controlled VSL gives a smoother flow and less sudden braking in traffic tailbacks. On one stretch of road, better mobility and high safety improvement were obtained, whereas the effects are limited on another stretch.
- Motorist acceptance is high for all applications.
- The principle is advocated that VSL signs should be lit up only under impaired conditions.
- The judicial process needs to be simplified, so that VSL regulation can be decided by the Road Administration.
- Less costly solutions can be achieved. Change the procurement procedure, stimulate the market, use technology with local control and logging, and develop technical innovations for energy supply outside built-up areas.
- The methodology for road condition detecting and VSL control needs to be automated
- Try VSL in combination with speed monitoring and increased information

The Swedish Road Administration has been running trials since 2003 on Variable Speed Limits (VSL), now at twenty places in the country. Variable speed limit means that the speed limit is temporarily lowered by means of adjustable, luminous road signs when impaired or more risky conditions prevail.

One of the objectives is to show whether and how VSL can contribute to better speed adaptation in a cost-effective manner. The trials are pursued in four types of applications, namely systems that are controlled by:

- crossing and turning traffic at road crossings, including bus exits.
- pedestrians along the road or crossing the road
- weather conditions, principally road conditions and wind
- traffic intensity (flows, speeds and tailbacks)

Passage and presence detectors are provided at the crossings in order to record vehicles. Pedestrians are detected by movement detectors (microwave detectors). Weather-controlled stretches of road are provided with weather stations (Road Weather Information System) that record temperature, precipitation, wind, surface status, etc. A weather model uses information for calculating the road conditions for the relevant stretch of road. This, together with the appraisal by the road traffic supervisor, serves as a basis for displaying the relevant speed limit. On traffic-controlled stretches of road, speed limit control is based principally on the traffic flow and the speed of the vehicles. At crossings, pedestrian-controlled and traffic-controlled systems, speed indication takes place automatically. The weather-controlled stretches of road are controlled manually, but indication is partially automated on certain stretches.

A special task in the project has been to investigate the conditions for simplifying the design and management of VSL at various stages of the procurement and operating phases, with the aim of minimizing the costs. Some shortcomings occurred in the introductory procurements of the project, but these have been corrected on later procurements. By the purchaser taking into account the experience gained, while the market for this type of systems is growing, a larger number of players will hopefully emerge on the Swedish market. In future requirement specifications, consideration should be given to using functional requirements for opening up to alternative solutions and products. It is important for the purchaser organization to maintain sufficient knowledge and avoid handing over functional responsibility to the contractor, so that a dependence situation will not arise. In numerous technology areas, technical development should contribute to better and more cost-effective systems. Examples of such areas are:

- better optical properties of LED-based signs
- mobile communications for control
- new power supply alternatives and lower energy demands

Trials have been run on the basis of the Ordinance (2002:713) on trial activities with varying highest permissible speed. On the basis of this ordinance, the Swedish Road Administration has issued regulations for each individual trial stretch of road. Certain difficulties have then arisen in specifying stringently what the various control criteria involve. For continued variable speed activities, the regulation process must be simplified. It should be possible for the authority that is responsible for road maintenance in a particular area to decide on the regulation. The whole regulation system in the area needs to be revised so that it will also be able to handle other types of varying speeds, such as time-differentiated indication and variable 30 km/h signs on buses.

In order to be able shed light on targets and expectations and give answers to questions concerning effects, attitudes and profitability, an evaluation programme has been run with the following main activities:

- Measurement and analysis of traffic data (traffic counting, and speed, accessibility and interaction studies)
- Attitude measurements (enquiries and interviews)

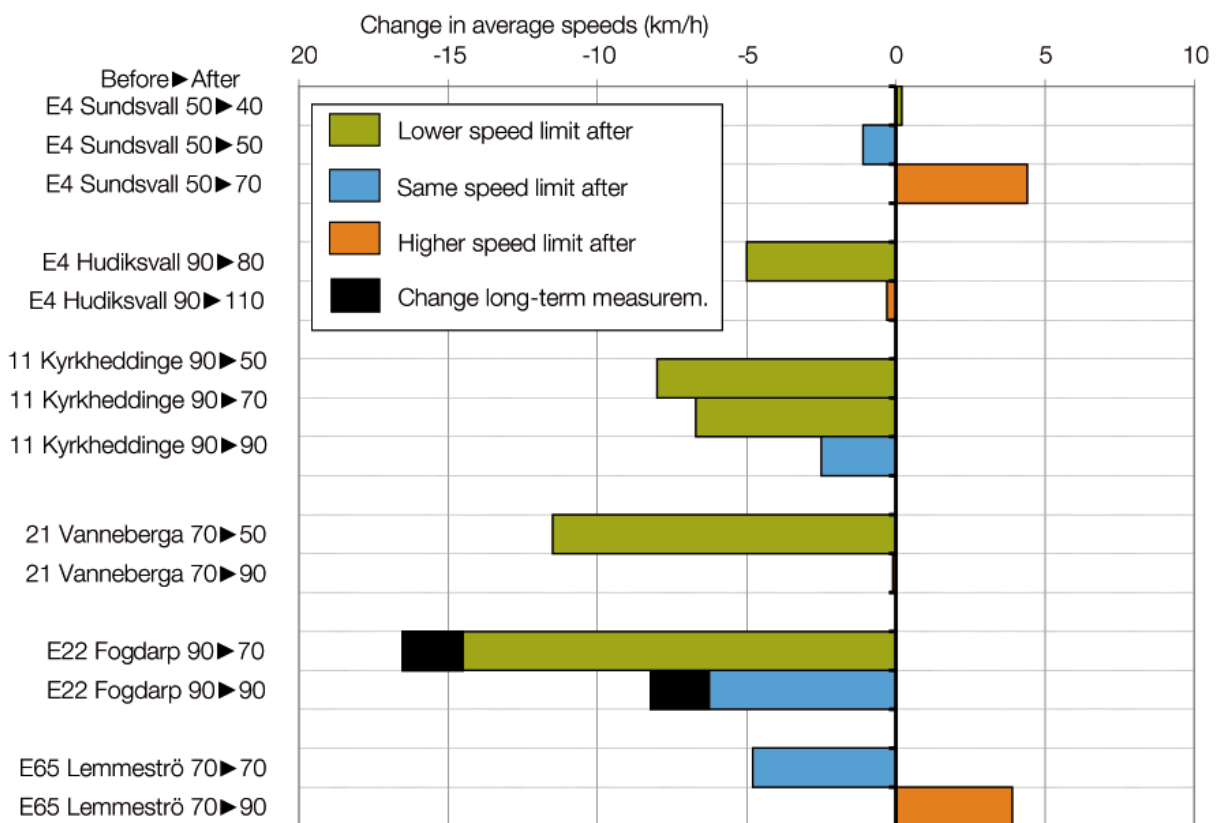
- Follow-up and analysis of operating data
- National economy calculations (including valuations of road safety, accessibility and environmental effects)
- Outside world studies (international experience, etc.)

The measurements of traffic data have been made in the form of studies before and after implementation at equivalent times of the year, after the VSL system has been in operation for at least four months.

An ambitious reliability target has been set up at the beginning of the VSL project. The equipment must give trouble-free technical performance during 99.5% of the time, which corresponds to accepted total stoppages of 45 hours per year. Another availability yardstick is also used for weather-controlled objects, i.e. during which the "right speed limit" (according to the prevailing conditions/regulations) has been displayed on the VSL during the periods when impaired conditions prevailed. The target should be that the functional availability should amount to at least 80% for weather-controlled objects.

Crossing control

The chart below shows the speed levels that resulted in various VSL indications at crossings. The results show that VSL gives different speed reductions depending on the speed limit at the outset, the magnitude of the speed limit reduction and the traffic conditions on site. At lower speed limits with VSL compared to



earlier permanently displayed speed limits (the green bar in the chart), high speed reductions occurred (with the exception of the pedestrian crossing in Sundsvall). The highest reduction is in the Fogdarp system, where the speed reduction was almost 15 km/h on the first after-implementation measurement. One year later, the reduction was a further 2 km/h, which demonstrates that the system produces sustainable effects. With the same speed limit displayed with the VSL as previously with a permanent road sign (blue bar), the average speed at all crossings dropped by 1 – 7 km/h. With an increase in the speed limit (VSL sign switched off, red bar) in relation to the earlier permanent road sign, no increase occurred at two of the crossings. The results also show that VSL contributes to improved driver awareness of dangerous crossings.

Those who drive fastest (85 percentile) have also lowered their speed, but not by as much as the average value.

The reduced speed levels produce positive road safety effects. Calculations for some of the crossings (Hudiksvall and Fogdarp) indicate that the number of fatalities and seriously injured persons should be reduced by 15 – 40%. The accessibility and environmental effects are marginal but are predominantly positive.

The performance of the technology and organization was better than expected. The total availability achieved for the crossings studied was 99.8 %.

Motorists are very positive to VSL at crossings. The greatest positive effect was perceived by those who turned from a side road onto a main road – a manoeuvre that was also considered to be most problematic before the introduction of VSL. The study also shows that motorists have generally been better at keeping to the speed limit and that VSL has a good effect on observance.

However, in spite of the good effects, it is difficult to achieve profitability due to the costs. The most profitable system was at Fogdarp (benefit about 3 times the cost). Vanneberga is also considered to be profitable, whereas the Hudiksvall system is on the verge of being profitable under the calculation conditions and the design of the trial systems. However, a simpler design may possibly halve the investment and the operating costs, and the profitability will then increase by 30%.

Strategy for VSL crossings

Application principally in rural crossings:

- VSL should be given consideration when traffic on the main road amounts to between 8000 and 14000 vehicles/24 h and the side road traffic amounts to 20 – 30%. VSL may be justified also with other traffic flows in situations such as if visibility is limited or there are other road safety reasons.
- At a relatively high volume of traffic on the main road (>10 000 vehicles/24 h), but with a smaller proportion of traffic on the side road (< about 10 %), it should be possible to use dynamic warning signs ("crossing traffic" road sign in the form of a Variable Message Sign), together with a permanent local speed road sign.

- If the proportion of traffic on the side road is higher (> about 35 - 40 %), consideration may be given to a local, permanent speed limit road sign. In this case, crossing and turning vehicles from the side road would be so common that the speed limit should always be lowered in the vicinity of the crossing. However, if the main flow is high, this method may be inadequate from the safety aspect, and consideration should then be given to rebuilding the crossing. Either a roundabout or a dual-level crossing may then be necessary.

If several situations activate a warning or speed limit sign, an additional board/special information board should be used with a message giving the reason for the speed reduction/warning. For crossing applications, the reasons may be, for instance, crossing or turning vehicles, buses at the bus stop close to the crossing, pedestrians on a pedestrian crossing, etc.

Pedestrian control

Experience from pedestrian-controlled VSL varies somewhat. The recommended speed of 30 km/h along a school street, activated at the beginning and end of the school day (Alvik), has caused an average speed reduction of about 10 km/h compared to the earlier permanent speed limit sign of 50 km/h. The results are strengthened by pedestrians perceiving the traffic situation as having become better for them and, above all, for children who use the stretch of road during school hours, although the problem remains at other times.

Regulatory variable speed limits at crossings and other pedestrian passages may result in lowered speeds, but the magnitude is dependent on circumstances on site and how the system is used at road crossings, bus stops, etc. Observance of lower speed limits is often poor. However, measurements show that the speed variation may drop, which is positive from the road safety aspect.

Pedestrians and residents interviewed are generally pleased with the VSL systems. However, many (about half, depending on the actual system) consider that motorists do not lower their speed sufficiently and that they therefore do not feel an increased sense of security.

Strategy for pedestrian-controlled systems

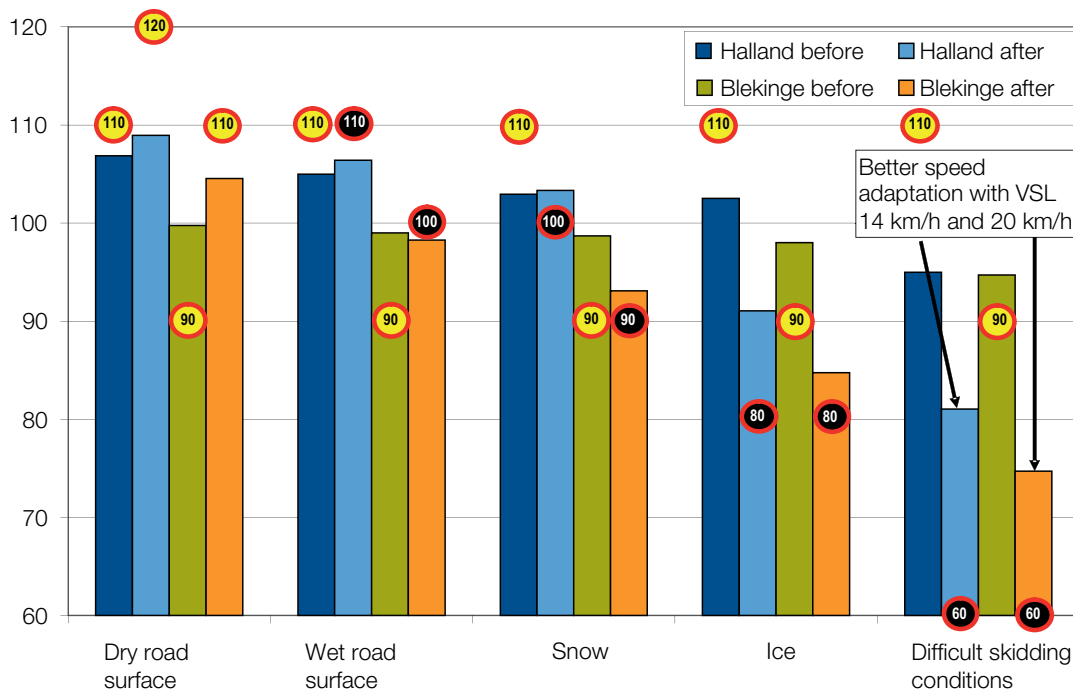
VSL can be applied if the place for the crossing is dangerous from the traffic aspect, e.g. due to shortcomings in speed adaptation, if pedestrians, parents, etc. feel insecurity when walking along the road or crossing it, or if the place has inadequate existing devices for crossing. However, VSL cannot be of such a design and have such performance that pedestrians are lulled into a false sense of security and rely on the motorists always reducing their speed. Neither must VSL be used to justify shortcomings in traffic separation. Further source information is needed before clear recommendations can be given concerning pedestrian-controlled VSL.

Weather control

In weather-controlled systems, the highest permissible speed (that applies under good weather and road conditions) has been raised by 10 or 20 km/h. This has resulted in only a minor increase in average speed (2 – 4 km/h). An additional small speed increase was recorded in conjunction with long-term measurements but, on the other hand, motorists lower their speed further under poor road conditions. Observance of the highest permissible speed limit has thus been improved.

Motorists adapt their speed much better to different road conditions with VSL than without. Under difficult conditions (ice and serious icy conditions), the average speed dropped by 12 – 20 km/h below the speed to which the motorist spontaneously lowers under the prevailing condition in trial objects on the E6 in Halland and E22 in Blekinge. The speed adaptation is shown in the figure below.

The conclusion is that the VSL system has fairly limited significance to speed adaptation when the road conditions are good (dry road) or moderately difficult (wet road surface). On the other hand, under difficult or very difficult conditions, the VSL system provides extra stimulus for the motorists to lower their speed. They have particularly great need for support under hoar-frost or black ice conditions that are not visible with the naked eye.



Calculations of road safety effects show that E6 Halland has not experienced any change in the total number of accidents, whereas the number of fatalities and serious injuries according to the calculation models increased by about 4%. This presupposes that the system shows the right speed during 80% of the time when impaired conditions prevail. The situation is roughly the same on E22 Blekinge. However, follow-up of the number of actually injured and killed persons on E6 Halland during the 2.5 years before and after the introduction of VSL

shows a reduction of about 40%, which indicates a higher safety potential than calculated.

In Blekinge, the trend appears to be an increase in the actual number of accidents, which can be assumed to be due to a greater increase in the highest speed limit, and the fact that the system performance was periodically defective during the trial period. However, the follow-up period is far too short for drawing reliable conclusions.

The effects on accessibility and environment are very small. The time used has dropped by just over 1%, whereas the emission levels have increased by 0.6 – 2%. These effects are due principally to the increase in the highest permissible speed limit.

Weather-controlled variable speeds are perceived as positive by most motorists, mainly in Halland but also in Blekinge. Most also consider that the speed displayed often agrees with the weather and road conditions that actually prevail, although around one third do not agree. The fact that many perceive that the message displayed is incorrect indicates that it is important to ensure that the speed limit displayed actually agrees with the actual conditions, if respect is to be maintained.

The technical performance of the weather-controlled systems was reasonable. However, the Blekinge system and, to a certain extent, also the Öland Bridge system have experienced communication problems that were difficult to solve, but were later identified. Due to the problems, the technical availability in Blekinge was around 60%. The technical availability of the Halland system was high. The manual handling has also caused problems. This applies to matters such as verification of alarms for deterioration in road conditions and difficulties in indicating correctly the five different speed levels. A process is in progress for automating control (including new surface sensors and fewer speed levels). A step in this direction was taken for the system on the Öland Bridge, which has been partially automated.

The national economy calculation shows that the benefit/cost ratio for Halland is 1.6 times the cost. The investment in Halland is thus profitable, provided that the right speed is shown for 80% of the time. On the other hand, this reliability level is insufficient for the investment in Blekinge to be profitable (benefit/cost ratio of +0.8). A sensitivity analysis shows that the availability at the right speed under poor road conditions must be 92% if the same profitability is to be achieved as that generally obtained for weather-controlled stretches of road in Finland. An analysis of alternatives for Blekinge shows that merely raising the speed limit from 90 to 110 km/h leads to serious negative safety consequences. However, merely the introduction of VSL when the speed limit is 110 km/h would be very profitable.

Strategy for weather control

Weather-controlled VSL may be suitable for motorways, expressways and dual-carriageway roads if:

- this stretch of road is prone to accidents with a high proportion of accidents related to difficult and troublesome road conditions
- speed adaptation is poor under troublesome and difficult road conditions
- the stretch of road has varying climatic conditions that can give rise to treacherous likelihood of skidding (not always noticed by motorists)
- the stretch of road has local road condition variations (bridges, dips, shadowed sections, etc.)

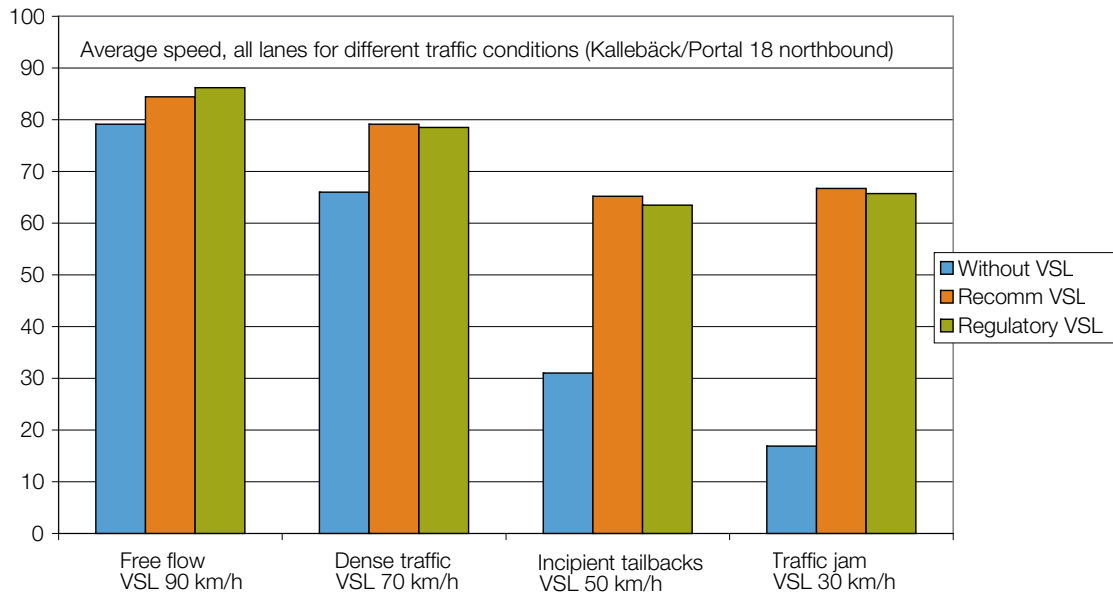
The introduction of VSL offers opportunities for increasing the highest permissible speed limit under good road conditions (basically dry summer road conditions) with a maximum of 10 km/h above the normal speed level that the stretch of road should have according to general valuation, even taking into account the new speed limits. For weather control, three speed levels are considered to be sufficient. Efforts should be made to have automated indication by employing reliable sensors that can detect all weather and road condition types and that can also record the effects of adopted road maintenance measures. The information shall be automatically processed and shall lead to quick adaptation of the displayed speed limit. Faster and more reliable road condition detection also enables suitable road maintenance measures (skid avoidance, also for preventive purposes) to be adopted earlier.

Traffic-controlled systems

The relative speeds between vehicles and between the traffic in different lanes are important for road safety on motorways. Wide variations make the flows unstable and contribute to the occurrence of sudden tailbacks and rear-end accidents. The proportion of rear-end accidents on the Möln dal stretch of road is 75%. It is therefore important to homogenize the vehicle speeds, which can be achieved by gradually reduced speed limits.

On the Möln dal stretch of road in a direction towards Gothenburg, the difference in speed between lanes was reduced after the introduction of VSL, which is beneficial from the road safety aspect. The risk of traffic jams, with impaired capacity and lower speeds, is reduced. The figure below shows how the average speed changes under different traffic conditions without VSL, compared with the recommended and specified speed limits at a sensitive point on the Möln dal stretch of road.

The speed has been increased and is 65 km/h on average in tailbacks, having earlier been 20 – 30 km/h. The total time when the speeds are below the theoretical capacity speed for traffic jams has been reduced, which is a sign that the traffic flows more smoothly and that delays have been reduced. The differences between recommended and regulatory speeds are very small. Corresponding information from the Tingstad Tunnel points in the same direction.



The speeds on the E18 Norrtälje Road have dropped throughout at free flow and in dense traffic by a few km/h after the introduction of VSL. At incipient tailbacks and developed jams, the difference is very small. There are two clear bottlenecks on the stretch of road on which tailbacks occur in morning traffic.

The VSL system covers only part of the northern bottleneck, i.e. tailbacks have already occurred where the first VSL signs are located. The mobility there does not appear to have been improved. On the other hand, the situation seems to be less difficult in the southern bottleneck. Measurements indicate that VSL control should begin further north on the stretch of road.

With the speed increase obtained in Mölndal, the environmental costs increase by 7%. The speeds have dropped on the Norrtälje Road, which suggests marginally positive environmental effects.

Road safety is affected by the highest permissible speed being raised (Mölndal and E18 Norrtälje Road) and by the introduction of VSL in busy traffic and the risk of tailbacks. A theoretical calculation for Mölndal shows that the risk of personal injury accidents in free flow increases by 18% if consideration is given only to the change in average speed. However, the information is contradicted by studies abroad and by actual accidents. Statistics indicate that the personal injury ratio has dropped by 20%. The result indicates that the relative speed is of very great importance on stretches of road with a large proportion of rear-end accidents.

The acceptance of variable speed in traffic-controlled systems is very high. Two out of three motorists consider that variable speed system is good or very good, and the respect for variable speed limit is high. The principal reason for this is that the system provides good information on the traffic situation and what can be expected further ahead, i.e. it helps by providing a good lead time.

The Mölndal system is expected to have very good profitability.

Strategy for traffic control

Traffic-controlled VSL is best suited on:

- motorways or multi-carriageway roads with high traffic intensity
- stretches of road with a normal speed of 90 km/h or higher (positive effects can be obtained also at lower normal speeds)
- stretches of road with relatively high flows and recurrent bottleneck problems
- stretches of road with a large number of accidents and relatively numerous rear-end accidents
- stretches of road with frequently recurrent dramatic speed reductions.

Stretches of road on which traffic-controlled VSL may be suitable are mainly in city regions and on traffic-intensive and sensitive stretches such as bridges, etc.

Variable speed limits appear to be an appropriate means for dealing with congestion and incipient tailbacks, where the speeds are likely to suddenly drop due to tailbacks. In fully developed tailbacks, the system is not equally effective. A reasonable strategy can therefore be to find out where sudden speed reductions often occur and tailbacks arise on the large highways, and to install VSL on a limited stretch of road. Where tailbacks develop, a simpler tailback warning system, e.g. luminous road sign with tailback warning symbol, can be used. However, the handling of VSL on traffic-controlled stretches of road is complicated, and the strategies must therefore be developed further.

The VSL concept needs to be developed further

It is important to improve the VSL technique in order to achieve high stability and reliability, while also cutting costs. Peripheral equipment must also be developed in order to improve efficiency and availability. On the basis of the experience that the trials have produced, it may be advisable to

- develop further the methods for optimizing VSL control for different applications
- develop principles for the displayed variable speed levels in accordance with the new speed limit system
- develop models and sensors for automatic road condition detection and VSL control
- work towards simplifying the legal process by Road Administration's decisions
- study and test VSL in new application areas and/or environments, such as light/darkness/ fog, alignment (tight curves, steep hills), for environmental reasons (noise, particles)
- test VSL in combination with speed monitoring and increased information
- work towards cost reduction – improve the energy supply and efficiency, stimulate the market/competition, simplify regulations (decision order, legislation, suitable Swedish Road Administration regulations/applications), increase the automation.

Contact

Information about "Trial with variable speed limits" is also available at www.vv.se/variabelhastighet

You can also contact:

Project leader

Lars-Olof Landerfors

Phone: +46 70 528 88 46

E-mail: lars-olof.landerfors@vv.se

Evaluation Coordinator

Anders Lindkvist

Phone: +46 70 830 38 00

E-mail: anders.lindkvist@movea.se

Vägverket
Swedish Road Administration
SE-781 87 Borlänge
www.vv.se vagverket@vv.se

Phone: +46 771 119 119. Textphone: +46 243 750 90. Fax: +46 243 758 25.

