EFFECTS OF WEATHER-CONTROLLED VARIABLE MESSAGE SIGNING IN FINLAND

– CASE HIGHWAY 1 (E18)

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SUMMARY

This study was designed to investigate the effects of variable speed limits and variable message signs controlled according to weather and road surface conditions on traffic flow in the wintertime and the acceptance of the system. The results clearly indicate that the system can be used in increasing traffic safety in poor winter conditions by decreasing driving speeds and lengthening headways and, on the other hand, in increasing traffic flow in good conditions by raising driving speeds. The driver acceptability of the system was high.

INTRODUCTION

Poor road surface conditions cause traffic safety problems and the accident rate has been shown in many studies to be higher during slippery than during bare road surface conditions (1). The main human errors leading to increased risk in winter are drivers' poor ability to recognise and to adapt their behaviour to adverse weather conditions (2).

Since the beginning of the 1990's, the Finnish Road Administration (Finnra) has developed a variable traffic control system based on weather and road surface conditions as well as other factors affecting traffic in order to enable drivers to better adjust their speed according to the conditions. Another aim was to create a more flexible speed limit system than the fixed winter speed limits.

The first step in developing a variable traffic control system was to improve road weather monitoring to enable the traffic control systems to react to changing weather and road surface conditions. The systematic development of variable traffic control systems was officially kicked off in 1998 within the E18 telematics R&D project in Finland. Earlier, transport telematics had mainly been utilised in individual services (3).

The strategy of the Finnish Road Administration is to develop traffic control systems in stages on the basis of pilot systems and their impact assessments. The main aim of the systems is to

improve traffic safety in poor road conditions by lowering the speed limit, but variable traffic control is also used to increase traffic flow in good road conditions.

THE AIM OF THE STUDY

The aim of the study (4) was to assess the impacts of a weather and road surface condition – controlled variable traffic control system with fibre-optic signs on traffic flow on the single-carriageway highway 1 in winter conditions. The acceptability of the control system also had to be assessed.

Another objective was to get information that could be compared with the results of earlier studies to draw up more universal assessments of the impacts of weather and road surface condition –controlled traffic control systems.

DESCRIPTION OF THE SYSTEM

The VMS system is located on a 37 km long single-carriageway highway 1 (E 18) in southern Finland. The system contains 22 variable fibre-optic speed limit signs as well as four variable message signs. The speed limits used are 60 kmph, 80 kmph and 100 kmph. Maximum speed limit used during dark was 80 kmph, but this policy has been changed since the study.

The variable message signs can display the warnings ”slippery", "road works" and ”danger”. The LED signs beneath the warning signs display texts about the current driving conditions. The combinations of message texts and warning signs have been preplanned. Figure 1 shows examples of the types of variable message signs used at the research site.

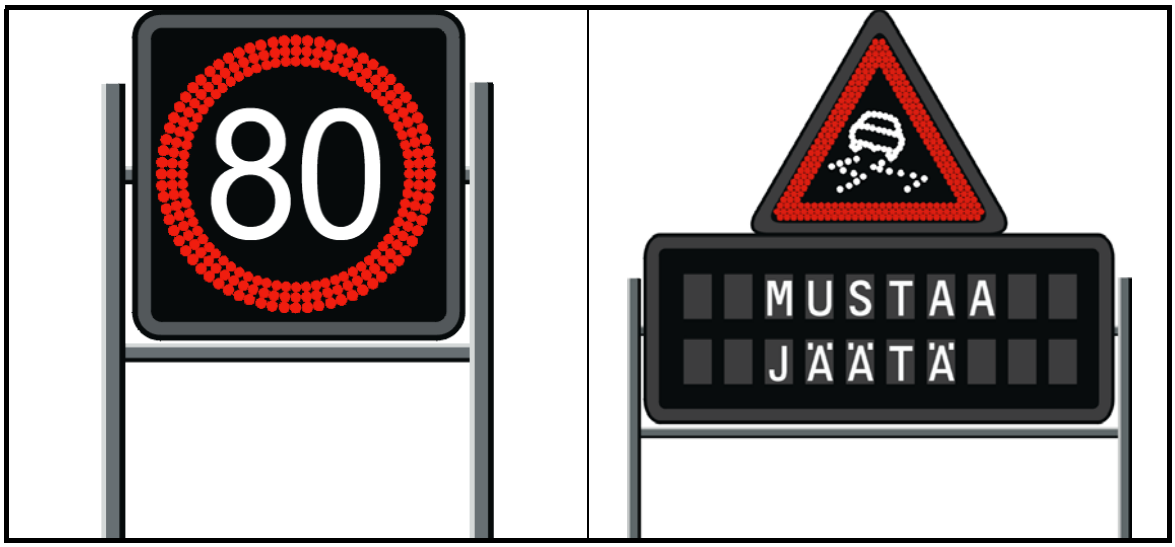


Figure 1. Examples of the variable traffic signs used in the study (speed limit 80 kmph, warning sign "slippery road" and message "BLACK ICE").

Variable traffic signs are mostly adapted according to the weather and road surface conditions, but they can also adapt to other traffic variables (e.g. road works, accidents). The duty manager controls the signs according to the Traffic Management Centre’s control principles

and the weather and road surface condition data received at the Centre. The system being studied did not automatically create control recommendations for the variable message signs.

The duty manager receives weather and road surface condition data from the road weather information system as well as the Finnish Road Enterprise and Finnish Meteorological Institute's Road Weather Centre, the road authorities, the police, road users, weather radar images and weather forecasts. The road weather information system at the research site consisted of nine road weather stations and four road weather cameras. The cameras are used to assess both the road surface condition and visibility. Road weather station data is recorded every 15 minutes to an hour, depending on the weather and road surface conditions. In winter (the time of the study), data is recorded every 20 minutes on average.

The variable speed limit signs are divided into three groups. They can be controlled individually or in groups. The control of the variable warning signs and text signs varies depending on the current traffic and weather status. The objective is to provide safe and flexible traffic control in any and all conditions. The duty manager at the Traffic Management Centre controls the signs via a radio modem system.

EVALUATION METHOD

Study design and schedule

The effects of variable message signing on traffic flow were studied in situations when the "slippery road" warning was used, and in situations when there was no special hazard to warn road users about. The study was based on a before-and-after and test sample-control sample design. The "before" period was 10.12.1998 - 16.2.1999 and the "after" period was 10.12.1999 - 16.2.2000. The system began operating in late February 1999.

Before the variable traffic control system was introduced, the winter speed limits were 80kmph on both the test and control road sections. The control road section was also located on highway 1, about 20 kilometres west of the test road section. During the study, highway 1 had no variable message signs in the direction of Helsinki before the test road section, but in the direction of Turku the variable message signs began about 15 km before the first variable speed limit sign of the test road section.

The effects of the system on driving speeds were studied in both directions: to Helsinki and to Turku. The study of headways focused in the direction towards Helsinki (main direction of the study). The effects were examined at three points in both directions on the test road section. The closest variable speed limit signs were located 0,8-2,7 km and variable message signs 0,8-2,9 km before the measurement points on the lane to Helsinki. The closest variable speed limit signs were located 0,8-4,2 km and variable message signs 9,2-18,8 km before the measurement points on the lane to Turku.

Data collection

Traffic data was collected at three points on the test road section and at one point on the control road section using loop detectors in pavement. Data was collected about the behaviour of individual vehicles as they moved through these points.

Road weather data was collected at two road weather stations on the test road section and at one station on the control road section. The data was used in a road weather classification system that followed the traffic control system control principles and consisted of three categories: poor road surface conditions, normal road surface conditions and good road surface conditions. There were very few situations with extremely poor road surface conditions recorded, so these situations were left out of the study.

Information on how long each sign was on, which speed limits and hazard warnings were used, and what texts were displayed on the LED signs were recorded in the status files (sign display logs) of the variable message signs. A new line of data was recorded into the sign display log whenever the sign display changed.

The driver roadside interviews were conducted between 9.30 a.m. and 4.30 p.m. on two weekdays in late February and early March 2000, a little over a year after the system had been introduced. The people interviewed were car and van drivers. The rest stop on the test road section where the interviews were conducted was located about 3 km after the nearest variable speed limit sign, while the nearest variable message sign and LED sign were located about 10 km away. Vehicles were picked for the interview at random as space freed up on the rest stop.

Impact assessment

Speed and headway distributions

The effects of variable message signs on traffic flow were assessed on the basis of vehicle speed and headway distributions in different message display situations. The effects of variable message signs on mean speeds and the standard deviation of the speeds were assessed using cars and vans that were ”free” and not in platoons. The definition of ”free” is that the time interval between the vehicle and the one in front of it is more than 5 seconds.

The headway assessments were carried out using all vehicles driving in platoons (time intervals between vehicles are 5 seconds or less). The assessment focused on changes in short headways (shorter than one second).

Statistical assessments

The statistical significance of the effects of the variable traffic control system on the mean speed of ”free” cars and vans was assessed using the t-test, while the significance of the effect on the standard deviation of the driving speeds was assessed using the F-test. The statistical significance of the effects of the traffic control system on the short headways (under 1 s) of vehicles in platoons and on the answers to the driver interviews were assessed using the χ^2-test.

The limit of a statistically significant difference in both tests is the risk level 0,05. The risk level means the probability that a significant difference or dependence could be a coincidence. Statistical assessments of the results concerning traffic flow took into consideration the effects of general trends by taking into account the changes at the control point (before-after).

RESULTS

Use of variable message signs

During the study, the variable speed limit of 80 kmph was used 94–96 % of the time, while100 kmph was used 4 % and 60 kmph was used only 0,3 % of the time. According to an earlier study (5), use of the lowest speed limit of 60 kmph was also very rare (less than 1 %) on the automatically weather-controlled highway 7.

Effects on mean speed

The effects of the system on the speed of ”free” cars and vans were significantly greater than the effects of the road surface conditions during the ”before” period. During the ”after” period, the greatest difference between mean speeds in different traffic control situations was on average about 10 kmph, while the effects of the road surface conditions during the ”before” period averaged about 2 kmph at maximum.

Highway 1 had variable message signs for about 15 km before the test road section began in the direction of Turku, while there were no variable message signs before the test road in the direction of Helsinki. This did not seem to have any effect on the results, as the variable traffic control system had a similar impact on driving speeds in both directions.

The distance between the ”slippery road” warning and the measurement point locations did not appear to have much impact on the speeds of ”free” cars during poor road surface conditions, but did have an impact on the short headways between vehicles in platoons.

The variable sign of 60 kmph combined with the ”slippery road” warning decreased mean speeds. The effect was greater during normal road surface conditions (2,8…4,2 kmph) than during poor ones (2,5 kpmh). If there was no ”slippery road” warning displayed, the 60 kmph speed limit alone caused a 1,8 kmph decrease in mean speeds in normal road surface conditions. The effect was not as great as the combined effect of the speed limit and ”slippery road” warning.

The variable sign of 80 kmph combined with the ”slippery road” warning also decreased mean speeds. The worse the road surface conditions were, the greater the effect was. The effect was 1,5...1,8 kmph during poor road surface conditions and 0,2...0,5 kmph during normal ones. The 80 kmph variable speed limit alone increased mean speeds in comparison with the speeds recorded when a fixed 80 kmph winter speed limit was used. The worse the road surface conditions were, the greater the effect was. The effect was 2,3...2,6 kmph during poor road surface conditions.

The variable sign of 100 kmph clearly increased mean speeds. The effect was greater during normal road surface conditions (6.6...6,9 kmph) than during good ones (5,9...6,1 kmph).

Figure 2 presents a summary of the effects of the variable traffic control system on the mean speeds of ”free” (outside the platoons) cars and vans in different situations.

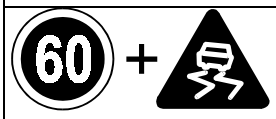
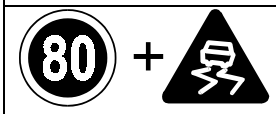
Test road	Control road	Road condition	Effects in winter Mean speed
		Poor	- 2,5 kmph
		Normal	- 2,8...4,2 kmph
		Poor	- 1,5...1,8 kmph
		Normal	- 0,2...0,5 kmph
		Poor	+ 2,3...2,6 kmph
		Normal	+ 1,5...1,8 kmph
		Good	+ 0,0...0,6 kmph
			
		Normal	+ 6,6...6,9 kmph
		Good	+ 5,9...6,1 kmph

Figure 2. The effects of the variable traffic control system on the mean speeds of "free" cars and vans in wintertime when different messages are displayed (the headways between vehicles over 5 s).

Effects on close following

The study examined the effects of the variable traffic control system especially on short headways of less than one second between vehicles in platoons. The headways between vehicles in platoons were dependent on the road surface conditions. The better the road surface conditions, the shorter the headways. As road surface conditions improved, driving speeds increased and there was a greater number of short vehicle headways.

When the 60 kmph speed limit and "slippery road" warning were used in the direction of Helsinki (the main direction examined in the study), the number of short headways decreased by about 18 % during poor road surface conditions and by 6 % during normal ones. Use of the "slippery road" warning also decreased the number of short headways when the 80 kmph speed limit was in use. Short headways decreased by about 20 % during poor road surface conditions, and by 14 % during normal ones.

Findings above correspond with those of the highway 7 study (5), where the "slippery road" warning sign was located 0.6 km from the measurement point. The distances between the "slippery road" warnings and the measurement point locations were significantly longer (9 - 19 km) in the direction of Turku than they were in the direction of Helsinki (1- 3 km), and their impact on the number of short headways was also significantly smaller.

Use of the 80 kmph speed limit alone decreased the number of short headways during good road surface conditions. But the number of short headways increased during normal and poor road surface conditions, which in turn increased the accident risk, especially during poor road surface conditions.

Raising the speed limit to 100 kmph significantly increased the relative share of short headways between vehicles in platoons during both normal and good road surface conditions, thus increasing accident risk, especially during normal road surface conditions. These detrimental

effects on traffic safety corresponded with the results from highway 7 (5) during normal road surface conditions.

Figure 3 presents a summary of the effects of the variable traffic control system on the short headways of less than one second between vehicles in platoons in different control situations.

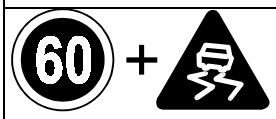
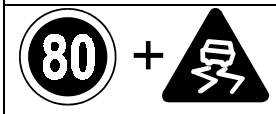
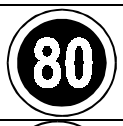
Test road	Control road	Road condition	Effects in winter Headways
		Poor	- 18 %
		Normal	- 6 %
		Poor	- 20 %
		Normal	- 14 %
		Poor	+ 8 %
		Normal	+ 6 %
		Good	- 6 %
			
		Normal	+ 60 %
		Good	+ 31 %

Figure 3. The effects of the variable traffic control system on the percentage of short headways (under 1 s) between vehicles in platoons when different messages are displayed.

Interviews of drivers

96 % of drivers considered variable speed limits necessary and 92 % considered speed limits correctly set. The system was mostly said to improve traffic safety or fluency, and the speed limits were thought to correspond with the current road and weather conditions. Interviews conducted on highway 7 (5) and on highway 9 (6) yielded similar results.

2/3 of drivers considered the appropriate speed limit for good winter road surface conditions in the dark to be 80 kmph. 30 % of drivers believed the appropriate speed limit would be 100 kmph. Most of these were drivers who made a significant amount of trips in a year. Drivers on highway 1 were more in favour of a lower speed limit than those on highway 9 (5). The poor geometry of highway 1 may be the reason for this difference.

86 % of drivers remembered the speed limit correctly (the interview site was 3 km away from the last speed limit sign). The percentage is greater than the one on highway 9, where 80 % of drivers correctly recalled the speed limit (2 km away from the last speed limit sign). On highway 9 the speed limit was displayed using electromechanical signs that are similar in appearance to the traditional fixed speed limit signs. Drivers have been found to recall speed limits displayed on fibre-optic signs better than those on electromechanical signs also during previous studies (7).

41 % of drivers could recall the combination of the hazard warning ”slippery road” and the LED text AQUAPLANING. The low number of correct recalls is most likely partly caused by the long distance (10 km) between the interview site and the message sign.

CONCLUSIONS AND RECOMMENDATIONS

The variable traffic control system affected speeds clearly more than road surface conditions did before the implementation of the system. The system functions according to the specified goals when used properly. It helps improve traffic safety in poor winter conditions (e.g. icy, slushy, snowy) and increase the speed of traffic flow in good winter conditions. Drivers accept the variable speed limits and trust their correctness. This sets high standards for the control principles and reliability of the system.

The ”slippery road” warning sign has a positive impact on traffic safety in poor winter conditions. The combination of a variable 60 kmph speed limit and a slippery road warning sign increased traffic safety by lowering the mean speed of ”free” cars and by increasing headways between cars in platoons. The 60 kmph speed limit should be used more frequently in poor conditions

The ”slippery road” warning decreased mean speeds and increased headways between cars in platoons also when the 80kmph speed limit was in use. This indicates that the use of variable message signs improves traffic safety and that drivers trust that these signs display appropriate messages. However, the positive impact of the ”slippery road” warning on headways in platoons was diminished the further the vehicles travelled from the warning sign. Since the ”slippery road” sign is meant to warn drivers about localised road conditions, the locations and density of the variable hazard warning sign grid could be further amended on the basis of the findings of this study. While the ”slippery road” warning is primarily local, variable speed limits apply to longer road sections.

Raising the speed limit from 80 kmph to 100 kmph significantly increased mean speeds and the amount of short headways for vehicles in platoons. The standard deviation of driving speeds also increased. The effects were greater during normal road surface conditions than during good ones. The use of the 100 kmph speed limit to increase fluency calls for good weather and road surface conditions.

To decrease the number of too short headways, the LED signs could be used to remind drivers about keeping a safe following distance even during good road surface conditions, if there is no significant other information that needs to be displayed.

The effects of the variable message signs were similar in the directions of both Helsinki and Turku, indicating that the variable message signs located ahead of the test road section on the lane to Turku had no effect.

The effects of the signs on highway 1 that were controlled by a duty manager were similar to the effects of the signs on highway 7 that were automatically controlled according to weather and road weather data. The proper functioning of both traffic control systems requires a highly-developed system for the provision of reliable, up-to-date road weather data to base traffic control decisions on.

The road weather station network should be dense enough, and the stations and their sensors should be reliable. Information from the road weather stations can be supplemented with images from road weather cameras and weather radar as well as weather and road weather forecasts. Control recommendations made by a system based on reliable road weather data would

most likely support the duty manager's control decisions, especially in poor road surface conditions.

The implementation process of traffic control systems should always include the later calibration of the system to ensure that the system will function properly in real conditions. Traffic Management Centres should be prepared for having to adjust the control parameters of the systems many times before they will be correctly calibrated.

The technical properties and traffic control principles of traffic control systems and their background systems will continue to be developed in Finland to ensure better functioning and correct control decisions. Things to be studied and developed are e.g. standardised control principles, speed limits during darkness, the effects of 60 kmph speed limits without additional signs and the location and frequency of the signs.

The development will follow the following successful strategy:
- implement control systems to solve existing problems and needs,
- assess the effects and development needs of the systems, and
- utilise these findings at other sites and in the further development of systems.

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