# EFFECTS OF WEATHER-CONTROLLED VARIABLE SPEED LIMITS ON INJURY ACCIDENTS

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## SUMMARY

A study was conducted on the impacts of weather-controlled variable speed limit systems on injury accidents. The high quality systems which based the control on automatic classification of road condition situations and which used fibre optic or LED signs decreased the injury accident risk in winter by 13% and in summer by 2%. For the other group of systems with manual control and electromechanical signs the safety was reduced. The length of the follow up periods was up to 12 years. The results were not statistically significant.

## INTRODUCTION

In Finland several road sections, totalling approximately 300 km, have been equipped with variable speed limits. The first individual variable speed limits were installed in the eighties. Since the early nineties also systems including several variable message signs (VMS) on a road section have been implemented. In Finland, most of these systems are weather-controlled. Eight such systems were included in this study.

The Finnish road authorities have adopted a policy to develop ITS applications gradually during experiments. According to this policy, VMS systems have been evaluated from different points of view. In the first phase, the user acceptance of the variable speed limits was studied by roadside interviews. The interview data concerning both motorway (1) and two-lane roads (2, 3) showed that users accepted the systems very well: 95% indicated the systems necessary, the speed limits were well recalled (86-95%) and controlling principles were accepted.

Effects of variable speed limits on driver behaviour were studied as well. Results showed that the VMS system on the E18 road affected driver behaviour according to the goals set for the systems (2, 3). During adverse road conditions the motorway VMS system decreased the mean speed and the standard deviation of speed (4). Variable speed limits were proved to be most effective when slipperiness was difficult to detect. Under good conditions, when higher speed limits were allowed the mean speed increased moderately (2, 3). Drivers seemed to obey the variable speed limits even more than the fixed speed limits. The findings highlighted the importance of the reliability and the error-free control and road authorities' responsibility in control policy. Results also indicated (5, 6) that the effectiveness of the variable speed limits was at least partially dependent on the sign type. Therefore, the use of fibre-optic signs was recommended for weather-controlled applications (7). The results were consistent with the results from central Europe. The results concerning fog warning VMS in the Netherlands showed that VMS contributed to safer driving behaviour in fog (8, 9). In Germany, it has been shown (10) that a VMS system including speed limits and warnings for fog and aquaplaning decreased the number of accidents by 20%.

In Finland, the VMS systems have been implemented gradually on relatively short road sections (fig 1). Now, when we had experience of several deployments during several years, a study on the impacts of the variable speed limits on injury accidents was conducted.

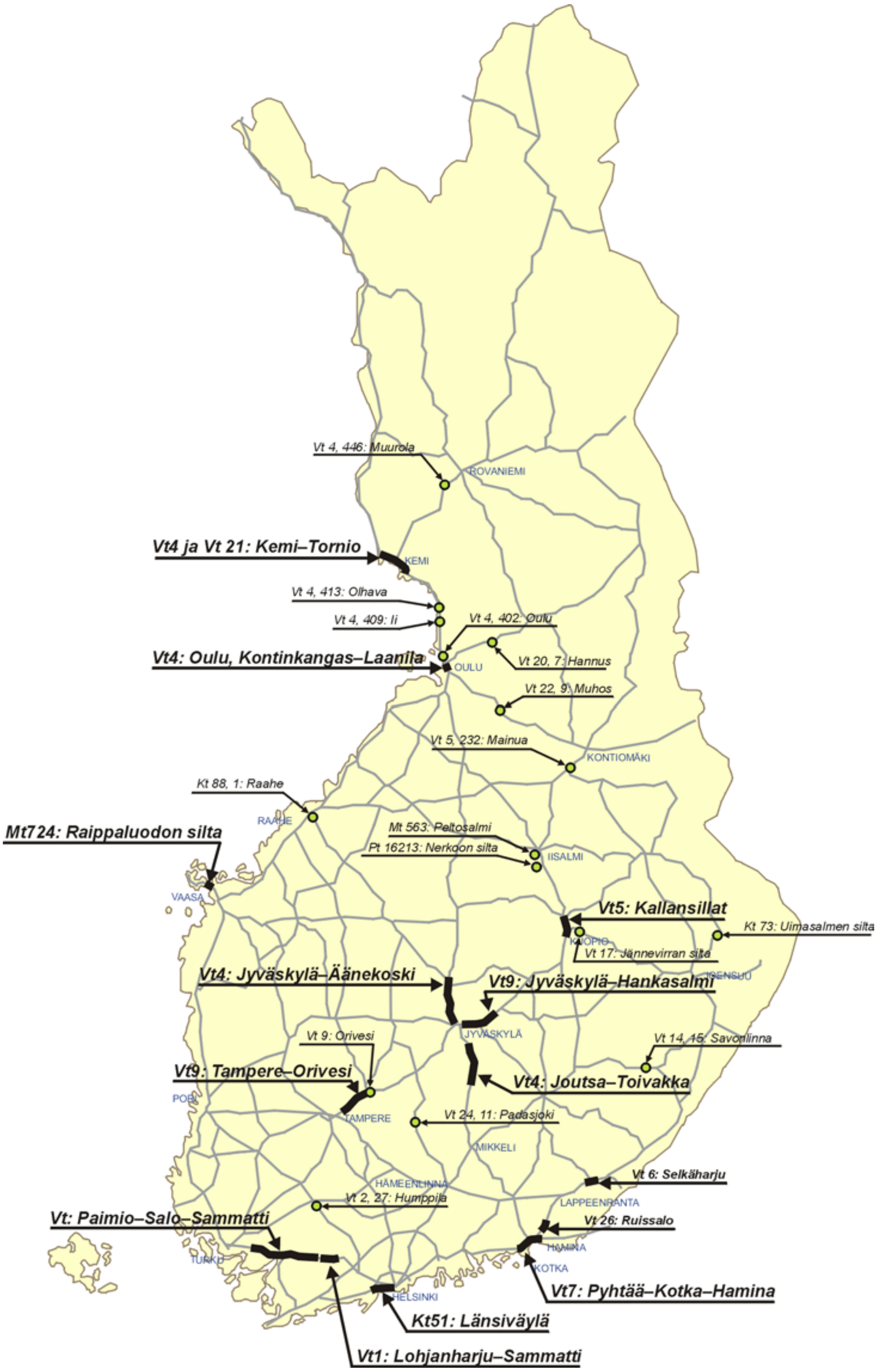


*Figure 1. Variable speed limits in Finland on pubic roads in 2003.*

# METHODS

## Description of systems

The evaluation study included eight variable speed limit systems controlled by weather and road condition data. The lengths of the equipped sections varied from 8 km to 41 km. Systems were implemented on two-lane roads. On this road type 80 km/h is usually the highest speed limit permitted in wintertime. Variable speed limit systems used three alternative limits: 100 km/h for good conditions, 80 km/h for moderate or normal conditions and 60 or 70 km/h for adverse conditions.

The data sources for the control of the VMS were automatic road weather stations, weather forecasts, road weather cameras and observations made by maintenance personnel. The automation rate of the control system varied. Some control systems provided continuous automatic categorisation of the weather and road condition corresponding to the alternative speed limits. This information either supported the manual control or the speed limits were changed automatically based to this classification.

The outlook of the signs varied depending whether the signs used LED / fibre optic or electromechanical techniques (Fig 2.). The legends of the electromechanical signs were black and the background yellow (as in fixed signs in Finland) while the LED and fibre optic signs had white legends on black background. In addition, the systems using LED or fibre optic signs included also other VMS like warning signs for slippery road.


*Figure 2. Schematic pictures of a LED/fibre optic and an electromechanical speed limit sign.*

## Design

The analysis was based on a comparison of the injury accident risk on the road sections before and after implementation of variable speed limits. The same types of roads with fixed speed limits were used to control the general trend in the injury accident risk. In the control data the fixed speed limits complied with the limits before the variable speed limit systems were implemented.

## Data collection

The data source for the injury data was the accident record made by the national police. The traffic volume data was based on the records of the automatic measurement stations maintained by the Finnish road administration. The injury risk was defined as number of injuries per 100 million vehicle kilometres.

The first VMS system in the analysis was implemented in 1992. The follow up period started from 1990 and ended to 2002. There was variation in the lengths of the before and after periods depending on when the variable speed limits were implemented. A total of 486 injury accidents in the before data and 281 injury accidents in the after data were included in the study.

## RESULTS

In the main analysis, eight VMS systems were divided into two groups, four deployments in each group. Speed limit systems in the group A (on the E18 road) used fibre optic or LED signs and based the control on automatic classification of road condition situations. These systems included variable slippery warning signs. Systems in the group B used electromechanical signs, and had neither automatic classification system for the control of the speed limits nor variable warning signs.

During the follow up period, the risk for injury accident decreased slightly in the control data. The risk for injury accident was highest for group A in winter before the implementation of the variable speed limits (table 1). This risk seemed to decrease after implementation.

*Table 1. Risks for injury accident in experimental and control data for group A (automatic classification, LED/fibre optic signs) and group B (no automatic classification, electromechanical signs).*

| Accident risk [accidents/100 mil. vehicle km) | | Winter | | Summer | |
|---|---|---|---|---|---|
| | | before | after | before | after |
| Group A | experimental | 16 | 12 | 10 | 9 |
| | control | 12 | 10 | 11 | 10 |
| Group B | experimental | 11 | 11 | 8 | 10 |
| | control | 12 | 11 | 11 | 10 |

The effects of the variable speed limit systems were computed by using the following formula:

$$100 \times \frac{(\text{accident risk}_{after,experiment} - \text{accident risk}_{before,experiment}) - (\text{accident risk}_{after,control} - \text{accident risk}_{before,control})}{\text{accident risk}_{before,experiment}}$$

The results showed that in the group A, the speed limit system seemed to decrease the injury accident risk. The weighted mean effect was -13% in winter and -2% in summer. For the group B the safety was reduced, the effect on injury accident risks being +8% in winter and +21% in summer. The weighted mean for all systems in the study showed that the variable speed limits seemed to decrease the risk for an injury accident in winter and increase the risk in summer.

Variation in the data was considerable in respect to the amount of injury accidents. Therefore, the results were not statistically significant.

## DISCUSSION AND CONCLUSIONS

This study investigated the effects of the variable weather-controlled speed limits on injury accident risk. Because variable speed limits were used for both to increase and decrease the speed of the traffic flow it was difficult to anticipate the safety effects of the system. The suggestive results showed that the high quality systems with elaborate control system seemed to decrease the injury accident risk especially in winter. The system seemed to improve traffic safety even though it was also used to improve the fluency of traffic flow. The positive effects are based first, on the efficient recognition of hazardous weather and road conditions, second, on the use of the variable slippery road signs to support the variable speed limit system, and third, on the moderate use of the highest speed limit (100 km/h). Without these qualities the variable speed limits seemed to reduce traffic safety.

The results highlighted the importance of the high quality of the variable speed limit systems. Previous research has shown that the lowest speed limits in VMS were used very seldom. Consequently, it is critical to automatically monitor and efficiently recognise hazardous conditions and provide the information to road users. In addition, the choice of sign technology may be important in addition to dynamic variable warnings.

In Finland, speed limits are lowered during wintertime on most two-lane roads. Variable speed limits make it possible to show higher speed limits under good conditions than fixed signs. With these high quality transport telematic systems, the aim to improve fluency of traffic flow seems possibly to parallel an improvement in traffic safety.

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