Can weather-related traffic management and information improve safety?

Risto Kulmala
VTT - Technical Research Centre of Finland
P.O.Box 1902, FIN-02044 VTT, Finland
Risto.Kulmala@vtt.fi

1. Introduction

Road safety has steadily improved in Finland during the last years except for accidents on wintry road conditions. The number of these accidents has remained the same during the last years. Ca. 25% of all fatal accidents occur on icy or snowy road surfaces, and an additional 15% in other adverse weather conditions.

The primary measure used to decrease accidents on icy and snowy roads is to improve the road surface conditions with the help of road maintenance actions (de-icing with salt, sanding, snow removal, etc.). Winter road maintenance usually applies the following procedure:

1. the personnel at the Road Weather Monitoring Centre (RWMC) starts to suspect of slipperiness on the basis of data from automatic weather monitoring stations, CCTV cameras or reports from neighbouring road offices
2. the on-duty person at the local road office is informed
3. the local road office checks the slipperiness on location
4. the local road office reports possible slipperiness and calls for maintenance actions
5. the road maintenance unit acts accordingly

This procedure is quite efficient but takes time. Time is critical as the accident risk in the hour preceding maintenance actions is estimated to be 12 times as high as it was twelve hours earlier (Öberg 1993). Hence, the Finnish National Road Administration (Finnra) especially aims to improve safety in the period from first indication at the RWMC to the start of maintenance actions on the road section by warning road users about the possible slipperiness.

The warning of road users should be useful as on slippery road surfaces only 14% of drivers estimate the road to be slippery, while more than 50% regarded the friction to be quite normal (Heinijoki 1994).

On average, drivers adapt their speeds to the road surface conditions. The mean speed on a slippery road surface is ca. 4 km/h lower than in good winter conditions, and the standard deviation of speeds is also lower due. This is due to the fact that the highest speeds decrease especially much compared to other speeds (Saastamoinen 1993). Theoretical calculations concerning stopping distances, however, have proven this adaptation to be insufficient in order to compensate for the reduced friction (Heinijoki 1994). In addition, Roine (1993) showed that in slippery conditions drivers have much smaller safety margins at curves than in good conditions.

Road surface conditions also affect headways. In south-western Finland, the percentage of headways shorter than 1.5 seconds is ca. 25% in slippery conditions compared to 39% in good winter conditions (Saastamoinen 1993).

The following chapters present the results of mainly Finnish studies on the use of traffic information and management systems in solving the afore-mentioned problems.

2. Importance and use of information

A telephone interview of Finnish car drivers was undertaken in 1996 to investigate user requirements for various traffic information systems (Penttinen, *et al.*, 1997). According to the study, The most popular sources of information were variable message signs (VMS), television, newspaper and radio. Road maps, road work maps, text television, RDS-TMC and information monitors at service stations were also considered important. The drivers showed least interest in Internet, GSM messages, as well as individual telephone service and fax service provided by the road administration. All information sources were estimated to be more important for infrequent than frequent trips. There were little differences between driver categories (i.e. sex, age, driving experience and area of residence). Nevertheless, the most experienced drivers wished to receive more on-the-road information (variable message signs, RDS-TMC and GSM messages). Men were more interested in RDS-TMC and GSM than women. Young drivers were more interested in GSM and CD-ROM-map than the others.

The drivers were asked to rate the importance of various information types. Weather and road surface information was regarded as the most important information type. Ca. 40% of the drivers regarded weather-related information important for their daily recurrent trips, and more than 50% for more seldomly made trips. In the wintertime, 42% of drivers obtained weather-related information for their daily recurrent trips, and even 59% for the more seldom trips (Penttinen, *et al.*, 1997).

Of the various weather-related information items, the drivers regarded most important the ones about current slipperiness, iciness, slush or snowing. The items ranked next were road surface forecasts, winter maintenance action reports, and fog. The least important items were road surface and air temperatures as well as rain (Penttinen, *et al.*, 1997).

The drivers reported that weather-related information mostly affects their manner of driving. Information affects to a smaller extent the time reserved for the trip and the choice of departure time. The least effect was reported for route and mode choice as well as whether the trip should be made at all (Penttinen, *et al.*, 1997).

This does not mean that the least effects were very small. For example, 16 - 18% of the drivers reported weather-related information to affect their decision about whether to make the trip or not. Interestingly but not surprisingly, elderly drivers reported more than twice as frequently as other drivers that their trip-making decisions are affected by weather-related information (Penttinen, *et al.*, 1997).

3. Information systems

Knowledge of the possible slipperiness or other weather problems is important to the drivers. Primarily, there are two types of technologies that can assist the drivers to acquire that knowledge. The driver can obtain the information 1) directly from his/her vehicle's own sensors or 2) from the road authority's in-vehicle or roadside sensors via an traffic information service.

The first case would seem to be better as it gives real-time information of the situation to the driver. Unfortunately a sufficiently reliable sensor system capable of continuous friction measurement is not yet available in the mass market. Various slip avoidance and ABS systems enable friction estimation, but usually in situations involving heavy braking, i.e. too late (Juhala 1994).

Hence, the dissemination of the road authority's weather information is currently the main instrument for increasing the drivers' knowledge of the weather conditions. The use of various information dissemination means is necessary in order to provide the information to as many road users as possible.

In Finland, pre-trip information services use radio, television, text-TV, telephone, internet, and information kiosks as communication means.

On-trip road weather information can also be distributed via a number of traffic and travel information services, e.g. RDS-TMC and GSM based services. In the case of local weather problems, the PROMISE GMS service utilises the Cell Broadcasting facility in GSM to broadcast weather warnings to only those cells in the cellular network suffering from the weather problem. One cell covers ca. 10 km of road length in the rural areas of Finland.

At points with exceptional road weather conditions and frequent weather-related problems, the use of VMS (Variable Message Signs) is feasible. In Finland, Finnra has initiated a systematic evaluation of the use of VMS in solving weather-related problems, starting with the comprehension of messages, development of the VMS control systems and algorithms, and ending with actual impact evaluation of pilot implementations.

Hirvenoja (1994) studied the comprehension of various weather messages with the help of interviews. A large majority of drivers understood the "slippery road" pictogram including a snow flake symbol (Figure 1) correctly, and the pictogram had also the highest user acceptance for implementation. The drivers had great difficulties in interpreting correctly friction coefficients, whereas headway recommendations such as in Figure 2 were understood quite well (Hirvenoja, 1994).

Figure 1. Slippery road VMS.

Figure 2. Headway recommendation.

The slippery road VMS display (on/off) as well as the following distance recommendation also depends on the road surface condition classification by the RWMC. In addition, the headway recommendation depends on vehicle type and the speed of the vehicle. The following distance recommendation was actually the estimated stopping distance with an additional one second reaction time, and 1.5 seconds for lorries taking into account the brake delays (Rämä, *et al.*, 1996).

Rämä, *et al.* (1996) studied the effects of slippery road warning VMS (as in Figure 1) on driving behaviour. The signs were found to decrease driving mean speeds by 1 - 2 km/h, and the effects could be detected as far as 14 km after the sign.

The dynamic headway recommendation also decreased driving speeds by ca. 1 km/h, and in addition decreased the percentage of short headways by ca. 25%. More than 80% of the drivers understood the VMS messages correctly (Rämä, *et al.*, 1996) after the addition of a supplemental sign with the text "recommendation" below the sign. The effects of the sign on short headways were about half higher before the additional sign was installed, indicating that some drivers might interpret the sign to be linked with automatic police surveillance.

In addition to the effects on speed and headway, the signs might have other impacts on driver behaviour. Consequently, a combined roadside and telephone interview was undertaken to investigate other potential responses to these signs (Luoma, *et al.*, 1997).

The results suggested that these variable message signs have many other impacts than can be measured in terms of speed and headway. The most essential effects deal with the direction of attention to find cues showing potential hazards, testing the slipperiness, and careful passing behaviour. On the other hand, the results suggest that the driving speed and headway are also the most essential variables which many other variables correlate with (Luoma, *et al.*, 1997).

The automatic fog-warning system on the M25 motorways in England displays the "Fog" legend on roadside matrix signals. The assessment of this system showed that the net mean vehicle speed reduction was ca. 3 km/h, when the signals were switched on as a result of the formation of fog (Cooper and Sawyer, 1993).

4. Traffic management and control systems

A German study (Balz & Zhu 1994) on the effects of a fog warning system employing VMS and variable speed limits found the accidents after the implementation of the system to decrease by 30% on the study section. Accidents in fog had decreased 85%. The number of accidents had also decreased on other motor ways in the same area by 10% in the same period, while the number of accidents in fog had decreased by 64%. Hence, the effect of the weather warning system was a ca. 20% reduction in the number of accidents. The speeds had decreased by ca. 10%.

A Dutch fog warning system included text warning ("fog") and dynamic speed limit VMS signs on a motorway. The evaluation of this system showed a positive effect on driving behaviour. The system reduced speeds in fog by 8 to 10 km/h, although in extremely dense fog (visibility less than 35 m), the system had an adverse effect on speed. This was due to the too high lowest possible speed limit display in the VMS (60 km/h). A more uniform speed behaviour was obtained on the entire carriageway due to the introduction of the system. All effects pointed towards safer behaviour and reduced accident risks (Hogema, *et al.*, 1996).

A Finnish weather controlled motorway section is equipped with variable speed limit signs and warning VMS (Pilli-Sihvola, 1996). The effects of the system were evaluated by Rämä (1997). In the wintertime, the change from 100 km/h to 80 km/h decreased the mean speed of cars outside platoons by 3.4 km/h, in addition to the average mean speed reduction of 6.3 km/h caused by the adverse road surface conditions. The corresponding effect was 2.5 km/h for all cars in addition to the effect of the adverse conditions (-6.3 km/h). If there was no rain or the rain was insignificant, the effect was ca. 2 km/h more i.e. 4.6 km/h. The proportion of these conditions was approximately 95% of all "adverse" conditions. When the road condition was such that the slippery road warning was displayed the speed reduction was 1.8 km/h for cars outside platoons in addition to the -9.3 km/h "weather effect" (Rämä 1997).

In the summertime, the change from 120 km/h to 100 km/h decreased the mean speed of cars outside platoons by 5.2 km/h, and the change from 120 km/h to 80 km/h by 8 km/h in addition to the average decrease in the mean speed caused by the adverse conditions (-2.0 km/h and -6.1 km/h, respectively). (Rämä 1997)

A very interesting result deals with the speed distributions. The lower speed limits on the test section decreased especially the highest speeds, and consequently the speed variance was reduced. In the control sections, however, adverse road conditions resulted in increased speed variance despite the mean speed reduction. A more detailed analysis of the distributions showed that this was caused by the fact that the highest speeds almost did not decrease at all whereas the lowest speeds decreased considerably. The most cautious of the drivers are most affected by the conditions, but some drivers are not affected at all. The latter perhaps regard the speed limit (permanent on the control section) as a "social norm" or speed recommendation valid in all conditions. (Rämä 1997)

The comparison of the displayed speed limit and manual observations of the weather and road conditions indicated that too high speed limits were applied in 26% of the cases. The speed limits displayed were seldom too low. There were even rare cases, when the speeds on the control section were lower than on the study section (very snowy winter conditions, speed limits displayed on test section 80 km/h). The speed limit of 80 km/h was evidently too high for these exceptional conditions. (Rämä 1997)

Currently, dynamic speed adaptation systems are being developed for cars, e.g. in Sweden. These systems employ a speed limiter which automatically sets the maximum speed according to the static speed limit and the prevailing dynamic conditions. This could be developed to automatically react to the road weather conditions. When approaching a curve on a slippery road, e.g., the system would set the maximum speed so low that the driver should be able to drive safely along the road through the curve without losing control of the vehicle. Such a system would require heavy investments in roadside equipment, although a less ambitious system based on satellite positioning, digital maps and dynamic wireless information services could be a feasible solution. The system would be very effective in improving safety. User acceptance problems can be expected, although the first experiments with test vehicles employing a speed limiting device have indicated a surprisingly high user acceptance (Almquist and Nygård, 1997).

5. Can the systems improve safety?

Knowledge about the current weather and road surface conditions is clearly not enough to reduce the accident risks in adverse conditions to their level in good conditions despite the optimistic expectations of those who plan and implement weather-related information systems. Accident risks on adverse conditions are many times as high as in good conditions, but the speed effects of information systems are only in the magnitude of 1 - 3 km/h. This speed reduction corresponds to an accident risk reduction of at most 10% (Ranta & Kallberg 1996).

Studies have shown weather-related information to also affect other safety-related factors such as headways, attention, alertness, passing decisions etc. These effects do not, however, eliminate the risk difference between adverse and good weather and road surface conditions.

The more substantial effects of traffic control systems indicate that drivers seem to require clear instructions to “correct” behaviour in the form of e.g. speed recommendations. The impact evaluations of traffic management and control systems indicate that the accident reductions due to these systems are ca. 10 - 30%. The efficiency of these systems is closely linked to the operation of the control system, as an efficient system responds quickly and accurately to the conditions and does not give too high speed recommendations in any circumstances. Too high speed recommendations will result in increased accident risks.

The most efficient means probably involve "forcing" the behaviour to the safe limits with the help of in-vehicle control devices, but these will not be easily accepted by the drivers.

Hence, the answer to the question of the title is "Yes". Traffic management and information can improve road safety. Much research effort has , however, still to be undertaken with regard to affecting driving behaviour before the accident risks in adverse conditions will be of similar magnitude as those in good conditions. The Finnish National Road Administration is currently continuing such research within the scope of the Euroregional VIKING action supported by the TEN-T grants of the European Community.

Acknowledgements

The paper is based on a number of studies commissioned by the Finnish National Road Administration (Finnra).

References

Almquist, S. and Nygård, M. Lund 1997. "Demonstrationsförsök med dynamisk hastighetsanpassning i tätort." Vägverket, Program för Väginformatik, Lägesrapport 1997-01-10.

Balz, W. and Zhu, J. Stuttgart 1994. "Nebelwarnsystem A8 Hohenstadt - Riedheim. Wirkungsanalyse". Landesamt für Strassenwesen, Baden-Württenberg & PTV Consult GmbH.

Cooper, B. R. and Sawyer, H. E. Crowthorne 1993. "Assessment of M25 automatic fog-warning system - Final report". TRL Project report 16. Crowthorne. 11 p.

Heinijoki, H. Helsinki 1994. "Kelin kokemisen, rengaskunnon ja rengastyypin vaikutus nopeuskäyttäytymiseen". Tielaitoksen selvityksiä 19. 99 p. ISBN 951-47-9098-7

Hirvenoja, E. Helsinki 1994. "Comprehension of variable message signs for road conditions". Finnra Reports 62/1994.

Hogema, J. H., van der Horst, R. and van Nifterick, W. 1996. "Evaluation of an automatic fog-warning system". Traffic Engineering + Control, November 1996. pp. 629 - 632.

Juhala, M. Helsinki 1994. "Esiselvitys automaattisesta liukkauden havaitsemisesta liikenteessä". Tielaitos, Liikenteen hallinta -projekti. Tielaitoksen selvityksiä 63/1994. 52 p.

Ranta, S. and Kallberg, V-P. Helsinki 1996. "Ajonopeuden liikenneturvallisuusvaikutuksia koskevien tilastollisten tutkimustenn analyysi [Analysis of statistical studies of the effects of speed on safety]." Finnish National Road Administration, Finnra studies 2/1996. 91 p. + app. 12 p. TIEL 320 0020.

Luoma, J., Rämä, P., Penttinen, M. and Harjula, V. "Driver responses to variable road condition signs." Proceedings of the Conference on International Cooperation on Theories and Concepts in Traffic Safety, Lund, Sweden, November 5-7, 1997, in press.

Penttinen, M., Luoma, J. and Rämä, P. "Information needs of Finnish drivers." Proceedings of the 4th World Congress on Intelligent Transport Systems, Berlin, October 5-10, 1997, in press.

Pilli-Sihvola, Y. Birmingham 1996. "Weather-related traffic management - E18 Finnish test area". In: SIRWEC 8th International Road Weather Conference, April 17 - 19, University of Birmingham - UK, Proceedings. SIRWEC & Vaisala. Pp. 161 - 170.

Roine, M. Helsinki 1993. "Kuljettajakäyttäytyminen kaarre- ja jonoajossa." Tielaitoksen selvityksiä 87. 34 p. ISBN 951-47-8771-4.

Rämä, P., Kulmala, R. and Heinonen, M. Helsinki 1996. "Muuttuvien kelivaroitusmerkkien vaikutus ajonopeuksiin, aikaväleihin ja kuljettajien käsityksiin". Helsinki, Tielaitos, keskushallinto. Tielaitoksen selvityksiä 1/1996. 77 p.

Rämä, P. "Effects of weather controlled traffic management system on driver behaviour." Proceedings of the 4th World Congress on Intelligent Transport Systems, Berlin, October 5-10, 1997, in press.

Saastamoinen, K. Helsinki 1993. ”Kelin vaikutus ajokäyttäytymiseen ja liikennevirran ominaisuuksiin”. Tielaitoksen selvityksiä 80. 48 p. ISBN 951-47-8139-2.

Öberg G. 1993. ”Traffic on ice and snow”. Nordic Road & Transport Research No. 3/1993. pp. 32 - 33.