

THE ROLE OF SEASONAL SPEED LIMITS IN SPEED MANAGEMENT

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BACKGROUND

In many northern countries accident risks are higher in winter than in summer (1). To tackle the problem winter maintenance has been intensified and systems developed to help drivers. However, safety benefits may be partly lost because drivers are tempted to travel faster in these improved conditions.

Speed limits have been very effective in reducing accidents. Fixed speed limits at all times are probably most effective in good road conditions and slightly less so in adverse ones. In some cases, however, speed limits can encourage excessive speeds if they do not match prevailing conditions. This is also true – perhaps even more so – of variable speed limits.

In 1997 a joint 2-year experiment was launched by the Ministry of Transport and Communications and the Finnish National Road Administration, in which speed limits would be changed according to the season of the year. Speed limits would be raised in summer and lowered in winter. Following good experience with the latter, coverage of lower wintertime speed limits was gradually extended. Higher speed limits in summer have not been used since the experiment. The effects of lower speed limits in winter both during and after the experiment will be presented to discuss the role of seasonal speed limits in speed management.

LOWER WINTERTIME SPEED LIMIT EXPERIMENT 1987–1989

Method

The effects of seasonally changing speed limits were evaluated using similar pairs of road sections randomly selected as experimental and control roads for the first winter. During the second winter the experimental and control roads were exchanged. Data was collected before and after the changes in speed limits. During the experiment comprehensive data was obtained on speeds, accidents and drivers' opinions.

Experimental Design

A total of 4,000 road kilometres with a 100 km/h speed limit were selected based on the need to reduce speed limits. There were 147 pairs of similar road sections, totalling 294 sections. Their average length was 13.5 km and average annual daily traffic (AADT) 2,400

vehicles per day. The roads were two-lane secondary roads with an average roadway width of 7.0 metres and hard shoulder width of 0.7 metres.

Based on the accident analysis the speed limits were lowered for 4 months. The experiment was done as a before-after study with control road sections, enabling variations of weather, amount of traffic etc. to be eliminated from the analysis.

Similar road sections were paired and the implementation order of lower speed limits within each pair (roads A and B) was selected randomly. One road in each pair (road A) was assigned a lower speed limit during the first winter, the other receiving it instead during the second (B, see Table 1). Road sections were only selected where there were no alternative routes nearby with constantly low or high speed limits.

In addition, all speed limits of 120 km/h on all motorways were reduced to 100 km/h during both winters. The results of that reduction are not covered here, as no control roads were used because of the small sample size (120 kilometres).

TABLE 1. Speed limit on experimental roads by winter (A and B refers to road section in each pair)

	Winters (November to February)		
	Before experiment	1987-1988	1988-1989
Road A ^{a)}	100 km/h	80 km/h	100 km/h
Road B ^{a)}	100 km/h	100 km/h	80 km/h

^{a)}A refers to the road section in each pair randomly selected to receive a lower speed limit during the first winter. B received the lower speed limit instead in the second winter; A did not.

Data Collection

Speed Measurements

Speeds were measured unobtrusively by radar at 24 given spots each month (2). In all, 140,000 vehicles were covered. Measurements were started 1 month before the introduction of lower wintertime speed limits and ended 2 years later. Measurements in each place were done on the same weekday at the same time of day. Each measurement aimed to cover the speed of at least 100 vehicles and lasted 0.5 to 2.5 hours.

Accident and Exposure Data

Accident data were received routinely from the police. At least 640 accidents (140 injury accidents) occurred on experimental and control roads every winter. Traffic mileage was received from periodical traffic counts, which were complemented by average traffic variation factors to evaluate accident rates and variations. Weather information was received from the Meteorological Office.

Driver Interviews

Drivers on experimental and control roads were interviewed during both winters (3), totalling more than 1,600 at eight locations. Drivers were randomly selected from those passing the interview point, stopped by police and interviewed, if they agreed, by road authorities personnel. All drivers were first asked whether they would be prepared to answer a few questions lasting no more than a couple of minutes. Only very few said they were too busy.

Drivers were asked some general questions and for their opinions on speed limits and changing them. Some questions also related to the specific road they had just been driving on and the speed limit assigned to it. Some background information was also asked.

Effects on Speeds (2)

Reducing the 100 km/h speed limit to 80 km/h during winter decreased the average speed of all measured vehicles by 3.8 km/h ($p < 0.001$, Figure 1). The average speed was further reduced by 3.3 km/h due to weather and road condition-related factors. Reducing the speed limit had no significant effect on speeds of vehicles other than cars. Lower speed limits cut the average speed of cars by 5.2 km/h.

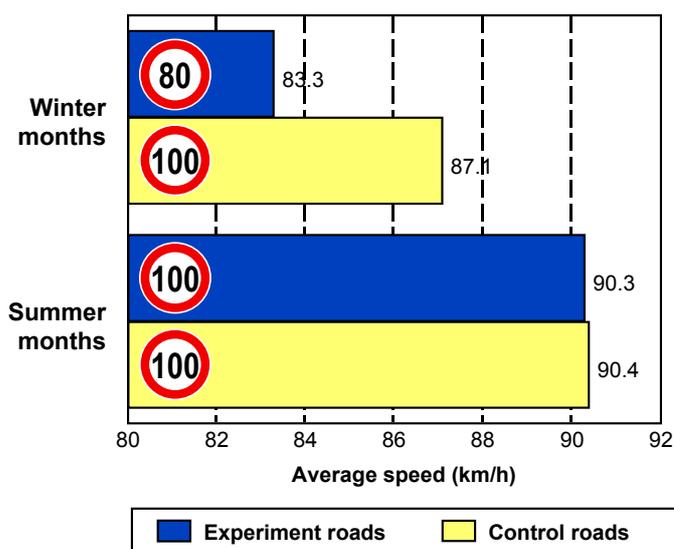


FIGURE 1. Average speed of all vehicles on experimental and control roads by season, in the lower wintertime speed limit experiment of 1987–1989. Round signs show the actual speed limit. During summer months the speed did not differ significantly but during winter months the difference was significant ($p < 0.001$). Sample size 567 separate measurements each including at least around 100 individual speed observations.

The lower speed limit had the greatest effect on the highest speeds recorded, and served to narrow the gap between the lowest and highest vehicle speeds (Figure 2). Speeds of the fastest vehicles (V_{85}) were reduced by as much as 5.7 km/h and those of the slowest vehicles (V_{15}) by 2.2 km/h compared with the 3.8 km/h reduction in mean speeds.

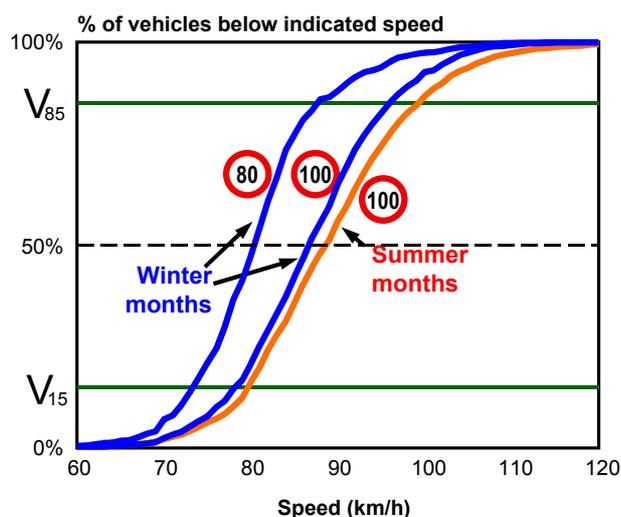


FIGURE 2. Example of cumulative speed distributions on one of 24 measurement points during different phases of the experiment. Here, winter means November to February and summer May to September as these months have relatively equal mean speeds. V_{15} and V_{85} indicate speeds exceeded by 15 and 85 per cent of drivers. Sample size for the different curves varies between 964 and 2731 individual speed observations. Each curve is based on speed data from at least four separate measurements.

Using Generalised Linear Modelling Techniques (GLIM) (4) speed models were developed to learn more about speed behaviour in winter. Models were made for average monthly mean speeds as well as for V_{85} and V_{15} speeds and speed variance.

The following conclusions were drawn from the model describing the monthly variation of average speeds at different measuring points ($N = 567$, $R^2 = 0.79$):

- The higher the vehicle speed prior to the change in limit, the greater is the reduction observed with the lower limit ($t = -13.9$).
- In addition to the speed limit, other factors affecting vehicle speed include slippery road surfaces, which cut speeds by an average of 2.5 km ($t = -8.0$).
- Snow, sleet or heavy rain reduce speeds on average by 1.0 km/h ($t = -2.8$).
- Even a gradual change in speed over time could be detected, the average speed having increased by 1.0 km/h over the 2 year period ($t = 6.1$).
- There were clear differences in speed between different months, but all winter months showed fairly similar speeds. The only exception was November, where speeds were slightly higher than in January (+0.9 km/h, $t = 2.2$)

Effects on Accidents (1)

The number of accidents during both experiment winters was higher than during the two preceding winters, both on experimental and control roads (Figure 3). The probable reason is the increase of traffic volumes and the general increasing accident trend during those years. The weather conditions were not very different from preceding years (1).

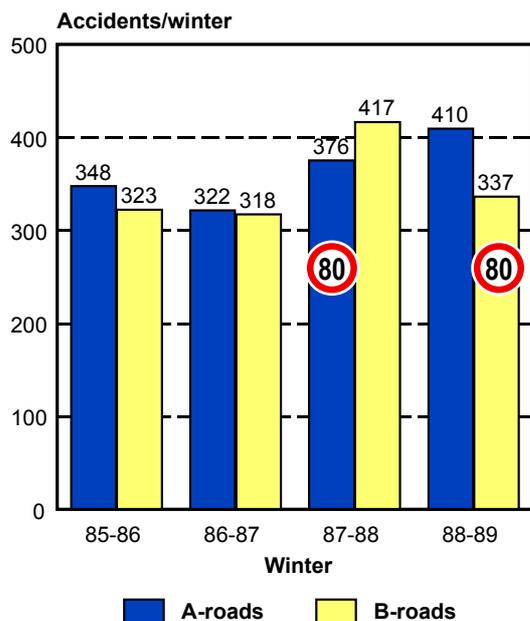


FIGURE 3. Number of accidents on roads with lower speed limits during the first winter (A roads) and second winter (B roads) in the lower wintertime speed limit experiment of 1987 - 1989. Round signs indicate 80 km/h speed limits; otherwise the speed limit was 100 km/h.

The number of accidents on experimental roads was, however, lower than on control roads. Based on our calculations the most probable effect of reducing 100 km/h speed limits to 80 km/h during winter months was evaluated to be a 14% reduction. The 95 per cent confidence interval of the effect was a 5... 22% reduction. No statistically significant effect was detected in the number of injury accidents (the most probable effect was an 11% reduction in number of injury accidents).

To learn more about the differences in traffic safety effect of lower wintertime speed limits, possible changes in different conditions were studied using maximum likelihood techniques. A general conclusion is that the reduction of accidents is often greater in good conditions (asphalt, width of roadway more than 7 metres, hard shoulder at least 1 metre, low hilliness, low curvature, road links between crossings, good visibility, small number of private roads and high number of public roads joining the road, AADT more than 3,000 vehicles/day and amount of goods vehicles above 12 per cent, Table 2).

TABLE 2. Accident changes in conditions where the most probable effect of lower wintertime speed limits significantly differed from zero in the 1987-1989 experiment.

Conditions	Most probable effects of lower wintertime speed limits on all accidents	
	Most probable accident reduction, %	95 per cent confidence interval
Asphalt pavement	15%	5–23%
Roadway wider than 7 m	26%	9–40%
Hard shoulder more than 1 m	23%	10–34%
Hilliness less than 15 metres/km	18%	8–27%
Curvature less than 20 gon/km	13%	1–23%
460 metre visibility on more than 50% of the road	14%	3–25%
Road links (between junctions)	13%	1–23%
At least 3 public road junctions/10 km	23%	9–35%
Less than 5 private road junctions/km	17%	6–26%
AADT more than 3 000 vehicles/day	24%	13–33%
Proportion of goods vehicles above 12%	18%	4–29%

A GLIM model (4) was created to describe variations of monthly numbers of accidents on each of the road sections during winter months. The following conclusions were drawn from the model (N = 6,228, 79% of systematic variation explained):

- The accident risk (accidents/traffic mileage) more than doubled when the proportion of goods vehicles increased from 5% to 27% (usually around 12%); 5% and 27% were the lowest and highest observed values (t-value 6.1).
- The accident risk more than doubled when the hilliness increased from 1 to 35 metres per kilometre. The accident rate increased especially on wide roads (t-values 8.0 and 8.3).
- The accident risk increased by more than 50% when the number of adverse weather days in a month increased from 2 to 31. Adverse weather days were defined as days when the highest daily temperature is between –5 and +5 degrees Celsius (t-value 5.9).
- In 1989 (two winter months) the accident rate was 30% less than in preceding years because of changes in accident recording procedures. It was concluded that this change did not affect the analyses (t-value 4.7).
- In February the accident rate was 20% smaller (t-value 3.8) and in December 15% greater than in January (t-value 3.0).
- On roads with an AADT of at least 3,000 vehicles/day the lower wintertime speed limit decreased the accident risk by 20% (t-value 3.0). On roads with less traffic the effect was not statistically significant (decreased 7%, t-value 1.1).

Drivers' Opinions (3)

Three drivers out of four said they were in favour of season-specific speed limits. The most common reason for not supporting changes in speed limits seemed to be a resistance to all kinds of speed limits. A clear majority of all drivers interviewed were satisfied with the speed limit in force on the stretch of the road where they were interviewed.

In the experiment, speed limits were lowered at the end of October and returned to normal at the beginning of March. The majority of respondents accepted the dates selected for changing of the speed limits, together with the limits actually changed. Some drivers in fact suggested shifting the date for increasing the limits later into the spring.

More than four out of five drivers correctly remembered the posted speed limit on the road they were travelling on. Drivers recalled better an 80 km/h speed limit (96%) than a 100 km/h limit (75%). They also remembered an unchanged speed limit slightly better than one that changed according to the time of year.

FOLLOW-UP OF THE EFFECTS

Following the 2-year experiment the system of lower wintertime speed limits was gradually extended because of the good results of the experiment. In 1997 a follow-up study of the lower wintertime speed limits was finalised (5). Although the experimental design with random selection of treated locations and control roads was no longer in place, some comparisons could be made fairly reliably.

In 1989 and 1991, more than 2,000 and 5,000 road kilometres respectively were added to the wintertime speed limit system for the first time. This made it possible to compare their speed and accident records with records from roads still outside the system. Although the selection of roads into the system is probably biased, the data is much more extensive now, and conclusions can be drawn based on a larger number of injury accidents and greater quantity of speed data from automatic speed measurement points on the Finnish road network.

Only road sections that had not been extensively improved during the observation period and whose accident records could be tracked reliably were used for the comparison.

Follow-up of Speeds

Speeds on the Finnish road network are monitored based on data from more than 200 automatic measuring stations that determine the speed and type of each passing vehicle. For the comparison, data was taken from the following measuring points:

- Three semi-motorway points with a fixed 100 km/h speed limit
- 11 two-lane road measurement points with a fixed 100 km/h speed limit
- 23 two-lane road measurement points with a 100 km/h speed limit during summer and an 80 km/h limit during winter months.

The following conclusions were drawn: (Figure 4):

- Average speeds have increased slightly, but this may be due partly to different measurement methods and measuring times (whole day compared to daytime).

- The difference in average speeds between summer and winter months on roads with lower wintertime speed limits was about 7.3 km/h in 1996 compared with 7.0 km/h during the experiment. It seems that the effect of lower wintertime speed limits still exists on these roads.
- The difference in average speeds between summer and winter months on semi-motorways was only 3.1 km/h in 1996, compared with 5.9 km/h on other fixed 100 km/h roads. The respective speed difference in the 1987-1989 experiment was 3.3 km/h (measured on non semi-motorways only).

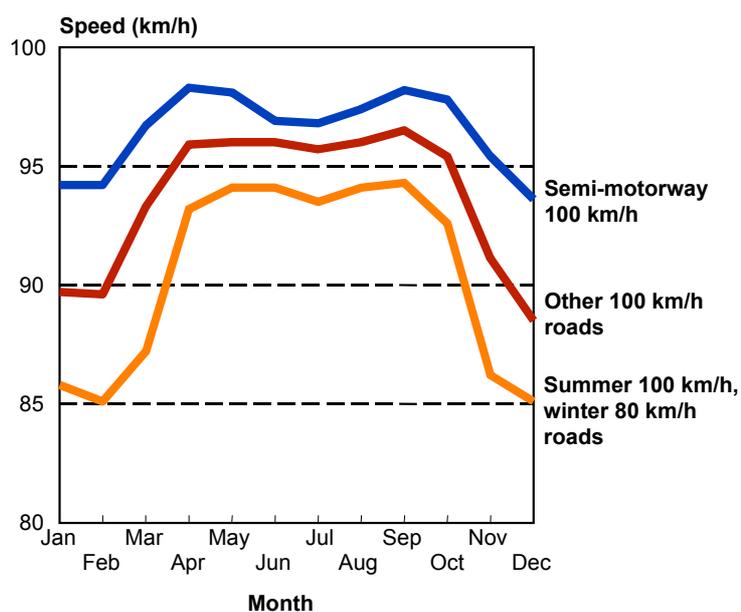


FIGURE 4. Variation of average monthly speed on different kinds of roads with a 100 km/h speed limit at least in summer. Lines are based on continuous measurements of speeds of all vehicles at several measurement points in 1996.

Follow up of Accidents

There are two sets of roads whose speed limit has been lowered at a specific time, along with their control roads. In 1989 about 2,000 km of roads were assigned a wintertime speed limit. The problem with this data set is the very short before period. This could not be made longer if we wished to avoid inaccuracies from errors at accident locations, which could not be reliably checked from before 1987. The other data set contains more than 5,000 km of roads whose speed limit was lowered for the first time in 1991.

Actually both sets of roads may have had lower speed limits on some parts during the 1987-1989 experiment, but they were not omitted from the analysis so as to include as big a road network as possible in the comparison. In principle this could cause slight underestimation of the safety effect of lower wintertime speed limits, because there may have been some lower limits in the before period as well. The bias cannot be very large, and is probably greater in the 1989 set than in the 1991 set.

Injury accident risks in the 1991 set clearly decreased on 'experimental' roads but increased slightly on 'control' roads. In the 1989 set, accident risks decreased both on 'experimental' and on 'control' roads – more on the former (Table 3 and Figure 5). Different development of accident risks in different sets could be caused by the different periods (in Finland, overall safety on roads started to improve after 1989).

TABLE 3. Average number of injury accidents and fatalities per winter (November to February) on wintertime speed limit roads and roads used as controls (roads with a year-round 100 km/h speed limit) before and after the introduction of wintertime speed limits. There are two sets of roads: those on which wintertime speed limits were introduced in 1991, and those on which they were introduced in 1989.

	Wintertime speed limits introduced			
	in 1991		in 1989	
	Before (4 winters)	After (5 winters)	Before (2 winters)	After (7 winters)
INJURY ACCIDENTS				
Winter limit roads	121.5	91.2	103.0	72.3
Constant 100 km/h	28.0	30.4	31.5	28.7
FATALITIES				
Winter limit roads	19.8	16.4	19.0	12.3
Constant 100 km/h	4.8	6.8	4.0	6.4

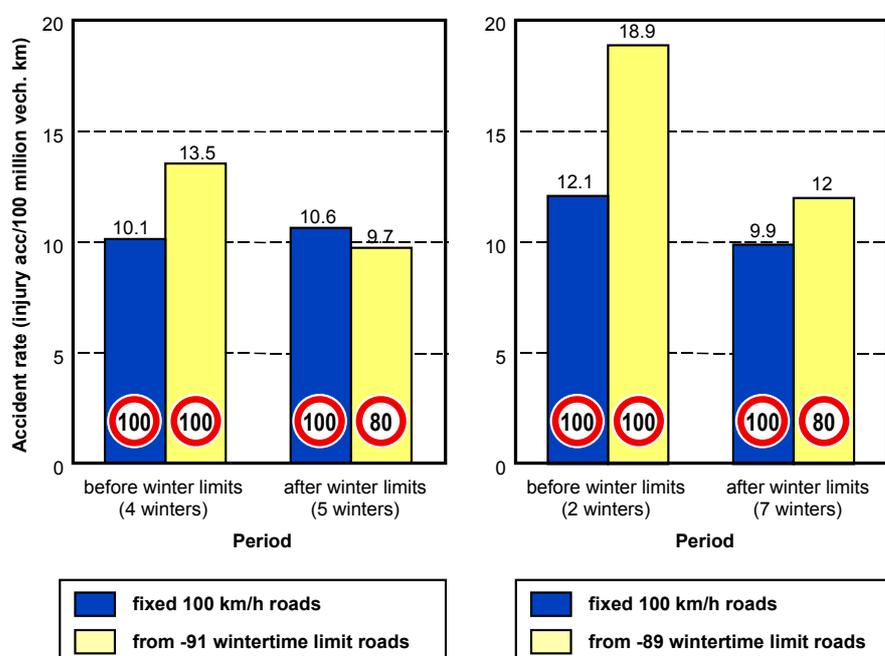


FIGURE 5. Accident risk during winter months on roads where lower wintertime speed limits were introduced in 1991 and 1989 respectively and their control roads (speed fixed at 100 km/h).

The most probable effect of lower wintertime speed limits was calculated separately for the 1991 and 1989 road sets, and the combined result was calculated using Meta-analysis (6). The results regarding injury accidents were as follows:

Roads:	Effect of lower wintertime speed limits on injury accidents	95% confidence interval
1989 set	-24%	-47...-2%
1991 set	-32%	-49...-13%
Together	-28%	-41...-11%

In conclusion, from the follow-up studies it would seem that the safety effects have been even greater than those observed in the 1987-1989 experiment. However, there may be a regression-to-the-mean effect influencing these results.

ACCIDENT DEVELOPMENT UP TO DATE

The latest accident risk calculations suggest that the positive safety effect caused by the lower wintertime speed limits at the end on 1980's can be seen even on the fatality risk of all the public roads in Finland. These even if the lower speed limits are only used on main road network (Figure 6).

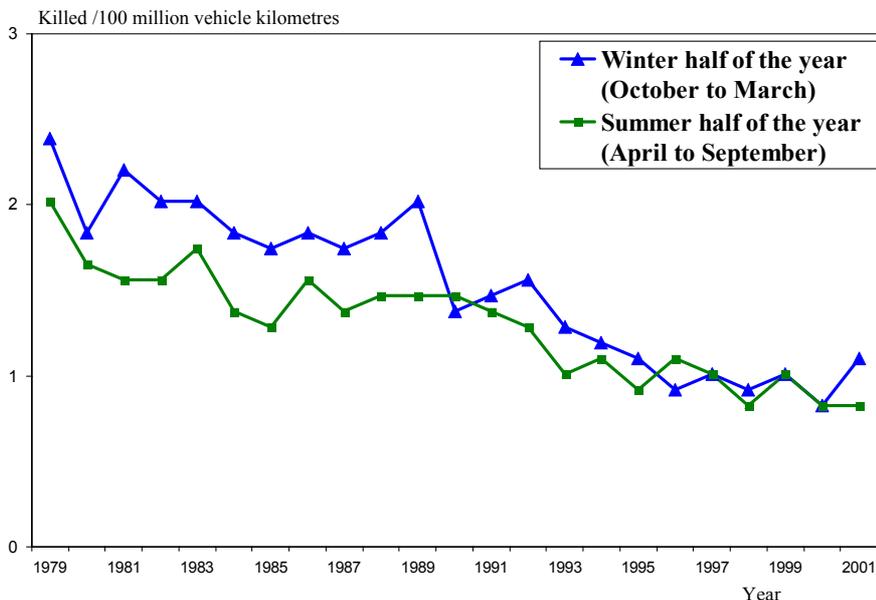


FIGURE 6. Fatality risk on all public roads in Finland in 1979 - 2001 (killed /100 million motor vehicle kilometres).

TABLE 4. Proportion of accidents and fatalities during winter months on Finnish non-motorway main roads having a 100 km/h speed limit during summer months according to the speed limit during winter months (November - February) in 1997-2001.

	Number of injury accidents		Proportion of
	Winter months	Whole year	winter months, %
Injury accidents			
During winter months the speed limit 100 km/h:			
Was reduced to 80 km/h	761	2419	31,5
Remained to 100 km/h	207	616	33,6
Variable speed limit *)	32	80	40,0
Fatalities			
During winter months the speed limit 100 km/h:			
Was reduced to 80 km/h	126	368	34,2
Remained to 100 km/h	31	84	36,9
Variable speed limit *)	11	14	78,6

*) Variable speed limit based on conditions. Maximum speed limit 100 km/h.

During last few years also variable speed limits have been used on some main road sections in Finland. Usually it means a 100 km/h speed limit when the conditions are considered to be good (no heavy rain, snowing or especially slippery road surface) and a 80 km/h speed limit when the conditions are not so good. Based on the quite small amount of data, rather many accidents during winter months have occurred on the main road sections having variable speed limits (Table 4). The proportion of accidents and fatalities during winter months is higher on variable speed limits than on 80 km/h roads (1-tailed $p=0,07$ and $p=0,001$). Respective proportion of winter month fatalities on variable speed limits is also higher than on 100 km/h roads (2-tailed $p=0,007$). Other differences in the proportion of winter month accidents in Table 4 are not statistically significant. Further analysis using before-after comparisons is needed to verify if the high proportion of accidents during winter months on road section having variable speed limits is caused by the variable speed limits. Maybe the variable speed limits have been installed on road section that already before that had a high proportion of accidents during winter months.

DISCUSSION AND CONCLUSIONS

In a country with great seasonal variations like Finland, changing speed limits according to the time of year is one way of enhancing the safety effects of speed limits. It is generally accepted that speeds need to be adjusted according to prevailing conditions. Seasonally changing speed limits are a simple way of supporting drivers' speed adaptation, which seems otherwise inadequate to maintaining a good safety level throughout the year.

The question of seasonally changing speed limits is an acute one, because technical solutions to more dynamic speed adaptation are still very expensive and need further study before they can be extensively implemented. Seasonally changing speed limits are now being considered and tested also in other northern countries.

Despite its limited extent, the 2-year scientific experiment in 1987-1989 produced a significant safety benefit. The number of accidents decreased on roads where speed limits

had been reduced. Especially good was the result in fairly good conditions – where speed changes were greatest.

Analysis of the data from the years after the experiment (1989–1996) shows that the effects of expanding the measure have been very positive. The latest study suggests as much as a 28% reduction of injury accidents on the large part of road network now covered by the system. A study based on fatal accidents by a special accident investigation board (7), and studies based on measured speed changes (5, 8) all support the idea of increased safety effects due to extensive introduction of wintertime speed limits. It should be mentioned, however, that the follow-up study did not have as reliable an experimental design as the actual experiment.

The difference in average speeds between summer and winter months on semi-motorways were only 3.1 km/h in 1996, compared with 5.9 km/h on other fixed 100 km/h roads. The respective speed difference in the 1987-1989 experiment was 3.3 km/h (measured on non semi-motorways only). This suggests that reduction of most 100 km/h speed limits could even reduce speeds on the remaining 100 km/h speed limits. This effect cannot be seen on semi-motorway speeds. The phenomenon requires further study and could be caused by drivers taking better account than before of increased risks in winter. A similar effect could be induced by drivers getting used to the lower speeds imposed during winter months.

Changes in driving speeds on roads other than those where speed limits have been changed could be a similar effect to that observed on US highways when speed limits were increased – in that case higher speed limits on some roads seemed to increase speeds on nearby roads as well (9).

Drivers have supported the idea of changing speed limits according to the time of year. They have also accepted surprisingly well the lower speed limits imposed in wintertime. It seems that drivers are ready to adapt their behaviour once they know and understand the reason for it.

Some drivers suggested shifting the date for increasing speed limits later into the spring. This is not supported by variations in accident risks, which show the autumn months in fact to be riskier than the spring months. Obviously drivers were not aware of this. Such information could be better exploited to motivate safer driving behaviour, especially during dark autumn nights.

There has been also some opposition to lowering wintertime speed limits. After publication of the results (1) some criticism was levelled at the analysis and reporting of the results. This is why a review analysis of the accident data was published almost 10 years after the original report. The analysis (10) confirms the findings and conclusions of the original report (1).

Lower wintertime speed limits have a good safety effect, as they seem to have a positive effect even on most roads with a fixed 100 km/h speed limit. There is still concern as to speed and safety in wintertime on semi-motorways (wide two-lane roads with at grade junctions and high speeds), on which safety has otherwise also been poor. These roads seem to experience numerous head-on collisions with very severe consequences, and their winter safety record has worsened compared to all other road types.

The first experiences from changing speed limits according to weather and road conditions have not given very positive indications on safety effects. They need to be further studied. The use of speed limits lower than 80 km/h should also be considered. Also the conditions leading to a reduction of speed limit should be carefully considered.

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