WINTER MAINTENANCE AND TRAFFIC SAFETY

Mikko Malmivuo, Otto Kärki, Tapani Mäkinen
Technical Research Centre of Finland (VTT)
Lämpömiehenkuja 2 C, 02150 Espoo, Finland
TEL. +358-9-456 5978/ FAX +358-9-464 850

1. Introduction

The object of this study was to analyze Finnish wintertime safety from the point of view of winter maintenance. The idea was to update certain existing key studies on traffic safety, while examining the link between winter maintenance and traffic safety from a broad new range of perspectives. The study was divided into five sections:

- Overall statistical analysis of wintertime accidents
- In-depth study of fatal meeting and run-off-road accidents in winter road conditions
- Safety analysis based on the maintenance classification of roads
- Study of possibilities for improved road condition monitoring
- Review of studies on the effects of road conditions and winter maintenance on driver behavior

This paper describes the results considered most interesting from an international point of view. The study revealed that the effects of winter maintenance and winter road conditions on traffic safety are far from unambiguous.

2. Wintertime Traffic Safety In Finland

Finland prepares for wintertime traffic safety basically in three ways:

1. Cars and vans must have winter tires at least from the beginning of December to the end of February.
2. The speed limit on motorways is lowered from 120 km/h to 100 km/h (75 mph -> 62 mph) and on almost all Class I highways from 100 km/h to 80 km/h (62 mph -> 50 mph) from the beginning of October to the end of March.
3. Maintenance teams carry out winter maintenance (snow plowing, salting and sanding) based on the maintenance class of the road.

Despite the fact that the accident risk in winter road conditions is much higher than in the summer road conditions, the personal injury accident and the fatality risk in wintertime (October - March) in Finland is at same level as in summertime (April - September) (table 1). This is because dry, snowless and iceless ‘summer-like’ road conditions often occur in winter. The degree of risk in summer-like road conditions during the winter is in fact much lower than in “real” summer road conditions. Wintertime safety in Finland seemed to be better in the 1996-99 review period than in 1991-95, which was reported in an earlier study [Malmivuo & Peltola 1997]

It is also worth noting that the risk of damage-only accidents is much higher in winter than in summer. Very likely the lower speeds and softening effects of snow ensure that most of the damage is limited to the vehicle.

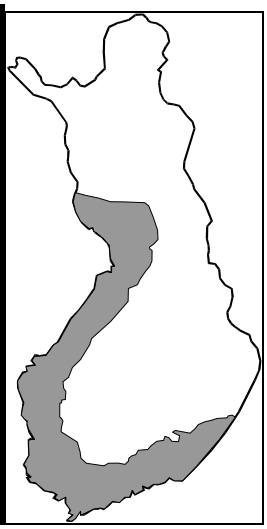
Table 1. Risk of accident, personal injury accident and traffic fatality in different ADT (ADT = Average Daily Traffic) classes in 1996-99 compared to 1991-95 (risk = number of accidents or fatalities/ 100 million vehicle km). Wintertime is from October to March and summertime from April to September.

	Wintertime 1996-99	*Wintertime 1991-95*	Summertime 1996-99	*Summertime 1991-95*
All accidents				
daily traffic < 1500 veh.	66.8	*71.2*	50.5	*55.5*
daily traffic 1500 -6000	63.6	*64.9*	44.1	*46*
daily traffic > 6000	37.9	*33.8*	27.6	*24.4*
All	54.9	*56.4*	39.7	*41.5*
Personal injury accidents				
daily traffic < 1500 veh.	12.6	*14.6*	14.7	*16.7*
daily traffic 1500 -6000	12.3	*14.8*	12.4	*13.9*
daily traffic > 6000	9.5	*11.7*	7.9	*9*
All	**11.3**	*13.7*	**11.3**	*13.1*
Fatalities				
daily traffic < 1500 veh.	1.1	*1.4*	1.3	*1.5*
daily traffic 1500 -6000	1.3	*1.8*	1.2	*1.5*
daily traffic > 6000	0.9	*1.1*	0.9	*0.8*
All	**1.1**	*1.4*	**1.1**	*1.3*

Certain previous studies have shown that sudden winter road conditions are much more dangerous than steady coverage of ice and snow on the road surface [Brüde & Larsson 1980]. This is especially true in the coastal area of Finland, where temperature fluctuations near zero degrees Celsius are more common than inland and create a less homogeneous ice and snow coverage with more surprises. As table 2 shows, the personal injury accident risk and fatality risk were previously (1991-95) exceptionally high in winter, especially on busy roads (daily traffic over 6000 vehicles/day).

Table 2. Wintertime risks compared to summertime risks in coastal and inland areas in different ADT classes in 1996-99 compared to 1991-95. Wintertime is from October to March and summertime from April to September. The coastal area on the map is shown in gray.

	1996-99 Winter risk/ summer risk		1991-95 Winter risk/ summer risk	
	Coast	Inland	*Coast*	*Inland*
All accidents				
daily traffic < 1500 veh.	1.33	1.31	*1.26*	*1.29*
daily traffic 1500 -6000	1.45	1.43	*1.42*	*1.40*
daily traffic > 6000	1.36	1.41	*1.41*	*1.35*
All	1.39	1.38	*1.37*	*1.35*
Personal injury accidents				
daily traffic < 1500 veh.	0.83	0.88	*0.87*	*0.88*
daily traffic 1500 -6000	1.00	0.98	*1.09*	*1.04*
daily traffic > 6000	**1.23**	1.12	***1.35***	*1.17*
All	1.02	0.97	*1.09*	*1.00*
Fatalities				
daily traffic < 1500 veh.	0.78	0.89	*0.85*	*0.95*
daily traffic 1500 -6000	1.21	0.93	*1.22*	*1.23*
daily traffic > 6000	**1.02**	0.90	***1.56***	*1.07*
All	1.03	0.91	*1.10*	*1.09*



One of the most interesting findings in this study emerged when daily personal injury accident numbers were compared for winter and summer periods. According to figure 1, the numbers are surprisingly similar for both seasons. At first glance this seems odd. Everyone living in Finland hears

or reads several times each winter how slippery icy or snowy weather has caused dozens of run-off-road accidents. As figure 1 demonstrates, however, these slippery days not increase the number of daily personal injury accidents more than summertime. Most likely the comparison in figure 1 would be closer to our expectations if limited to damage-only accidents.

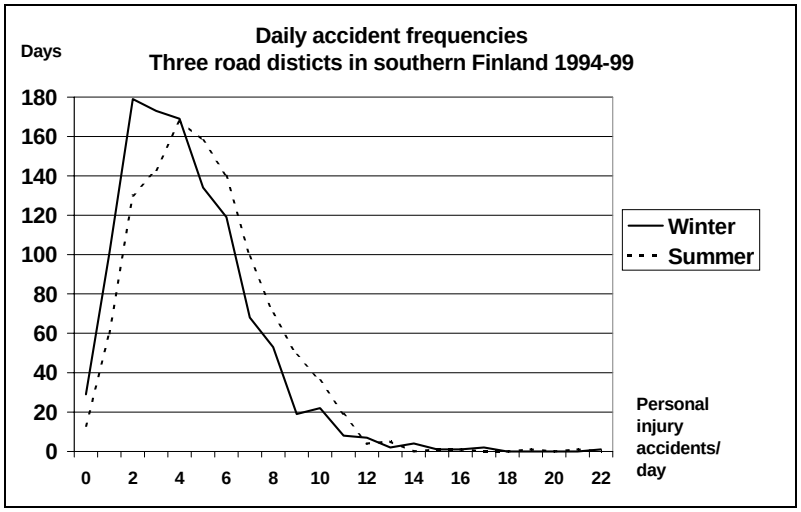


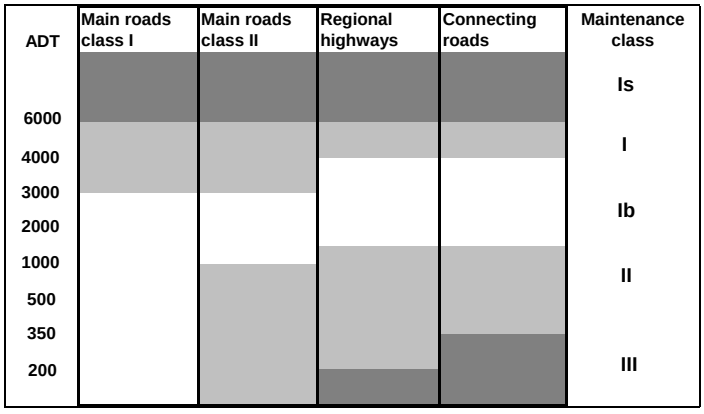
Figure 1. Comparison of daily personal injury accident numbers in wintertime (October - March) and summertime (April - September) in three road districts in southern Finland 1994-1999.

3. Winter Maintenance Categories

Winter maintenance in Finland is based on maintenance classification, which in turn is based on road class and traffic volume (table 3) as follows:

- Is - Road kept mainly bare. During long very cold periods surface may be partly icy.
- I - Road kept mainly bare, but possible narrow stripes of packed snow or ice between vehicle paths and lanes. Compromises at night.
- Ib - Snowy surface during part of the winter. Road should be maintained mainly without salt.
- II - Mainly snowy surface. Sand added on intersections and hills, and in critical conditions on the whole network.
- III - snowy surface, sand added only during extreme conditions

Table 3. Maintenance classification in Finland based on road classification and traffic volume



The wintertime safety of different maintenance classes has been carefully monitored in order to adjust the classification wherever needed. Figure 2 compares summertime and wintertime safety in the upper road class. Winter maintenance enhancement can be expected to improve safety on road sections with a much higher accident density in winter than in summer. As figure 2 shows, however, there are no such sections on class I main roads.

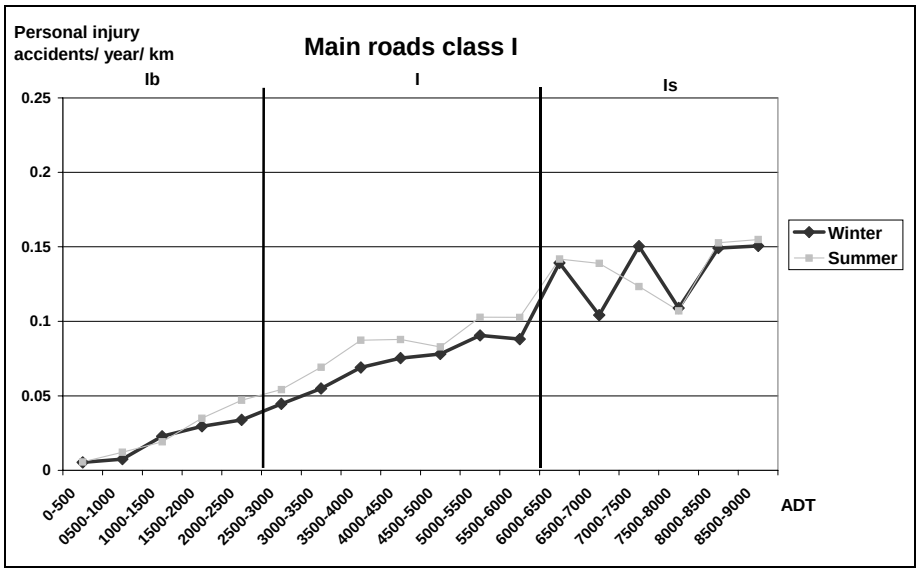


Figure 2. Personal injury accident density in winter and summer on class I main roads by maintenance class. In Finland, wintertime is from October to March and summertime from April to September. Averages are for the period 1994-99.

4. Special Characteristics Of Fatal Meeting And Run-off-road Accidents In Winter Road Conditions

In Finland fatal traffic accidents are analyzed much more carefully than accidents causing less severe injuries. The Fatal Accident Investigation Board, which includes medical and technical experts, carries out a detailed examination program creating a broad range of data for every fatal accident [Hantula 1992]. Consequently it is possible to select for study only those accidents in which the winter road condition was one reason for the accident

In this study we used Fatal Accident Investigation Board data to study carefully the two most typical winter road condition accident types, meeting accidents and run-off-road accidents, for the period 1997-99. Analyzing only accidents in which the winter road condition was one of the causes revealed the following:

- 64% (meeting accidents) and 72% (run-off-road accidents) of drivers causing the accident used defective tires. Groove depth was below the legal measurement of 3 mm (1/8 inch) in about 20% of vehicles.
- Between 21% (meeting accident) and 33% (run-off-road accidents) of drivers causing the accident exceeded the speed limit.
- Use of a safety belt would certainly or probably have saved 34% of meeting accident and 17% of run-off-road accident victims. (In Finland wearing a safety belt is mandatory and fines are imposed for non-compliance.)

All these figures reveal that improved traffic enforcement can have as good or even better an impact on traffic safety than using the same amount of money to enhance winter maintenance. The friction

between the tire and the road surface is dependent on both the condition of the road and the condition of the tires.

Ice (36% of cases) and slush (23% of cases) were the most dominant road conditions during fatal meeting accidents in winter road conditions (table 4). From the winter maintenance point of view, one of the main problems is that 47% of fatal meeting accidents occurred during snowfall (snow or wet snow). Typically the whole maintenance fleet is on the road during heavy snowfalls, and the only way to improve the ever-changing road conditions is to invest in new equipment. An other problem is, that there is very little a maintenance operator can do about problems arising from restricted visibility caused by precipitation

However, some observations based on Fatal Accident Investigation Board data indicate that safety could also be improved by better maintenance. According to this study, road conditions at the accident location were exceptionally slippery in 21% of fatal meeting accidents and in 39% of run-off-road accidents during winter road conditions. In these cases local slipperiness was usually caused by micro-scale climate changes, e.g. warm or cold air from the sea or lakes near the shore or on bridges, or a sharp border between sunlight and shadow. Micro-climatic changes of this type should be more closely monitored by the maintenance operator. One sector with the highest potential for improvement is road condition monitoring techniques.

5. Problems With Road Condition Monitoring

In Finland, road condition monitoring is based on the road weather station network. There are 273 road weather stations on the main roads, with an average distance between stations of 30 km (19 miles). The stations measure local air and road surface temperature, humidity, rainfall, electrical conductivity of the road surface (indicating the amount of salt) etc. Unfortunately, there are no detectors that can directly identify the slipperiness of a road surface. This has to be estimated from individual censor observations, a procedure which is still fallible. Road condition status should not therefore be under the sole purview of road weather stations

Friction measurement devices in road maintenance vehicles are not restricted to a certain spot on the road, and they do measure slipperiness directly. However, they cannot be everywhere all the time. Therefore even extensive mobile friction measurement cannot be relied upon to reveal quickly enough where and when a road surface is starting to get slippery.

A third information source is weather cameras, which provide easily interpretable information directly to so called road condition centres, but they are still few in number. Modern technology has not yet been able to monitor road conditions so completely as to eliminate the value of information from local citizens and local weather forecasts.

6. The Relation Between Winter Road Conditions And Safety

The question about the impact of winter maintenance on traffic safety is complicated by the fact that drivers tend to adapt their behavior and speed according to the road surface conditions. On slippery roads drivers reduce their speed, but unfortunately this is not sufficient to compensate for the increased risk caused by slipperiness. In the following studies four important areas are reviewed:

- Drivers' ability to estimate the slipperiness of the road
- The effects of winter road conditions on driving speeds
- The effects of speed on traffic safety
- The effect of winter road conditions on traffic safety

In 1994, as part of a major Finnish "Road traffic in winter" research scheme an interview-based survey was carried out on the ability of drivers to estimate the slipperiness of the road [Heinijoki 1994]. One key result was that the probability of drivers heavily overestimating the condition of the road on sections where the surface appeared bare was 2.5 times higher than on sections where the

surface was wholly or partially covered with snow. From the winter maintenance point of view, this means that in some cases snow plowing and removal can in fact make slipperiness more difficult to detect.

Under the same research scheme it was estimated based on automatic speed measurement station data that speeds fell by 0...3 km/h (0...2 mph) in good winter road conditions, 3...6 km/h (2...4 mph) in fairly slippery conditions and 4...7 km/h (2... 4 mph) in very slippery conditions [Saastamoinen 1993]. In 1998 the Swedish National Road and Transport Research Institute (VTI) reported that the speed decreasing effect of snowy and icy road conditions can be as much as 9...16 km/h (6...10 mph) compared with good conditions [Nilsson & Obrenovis 1998]. In 1991-94 Norwegian researchers carried out a very extensive study that observed driving speeds four times a day over three winters on 25 road sections in Norway (table 5) [Vaa et al. 1995]. According to the study the speed decreasing effects of winter road conditions varies from 4,2 km/h (wet road and snowy weather) up to 11.7 km/h (ice and rain).

The effect of speed on traffic safety has been estimated in numerous studies. On average, a 1 km/h decrease of the average speed decreases the amount of persomal injury accidents by 2 to 3 percent. The effect on fatal accidents is double [Ranta & Kallberg].

In Finland, data from road weather stations is not sufficient or reliable enough to indicate vehicle mileage in different road conditions. Nor are police reports reliable enough to describe the road condition at the accident location. According to Finnish studies the risk of personal injury accident in icy road conditions is 10...20 times higher than in bare and dry conditions [Malmivuo & Peltola 1996]. According to the Norwegian study, injury accident risk on icy roads was approximately 4.5 times as high as on bare roads (table 4) [Evensen 1996].

Table 4. Risk of personal injury accident in different road conditions. [Evensen 1996]. ([1] = uncertain value)

	Personal injury accidents/ 1 000 000 vehicle km
Dry and bare road, winter	0.12
Wet and bare road, winter	0.16
Slush	0.18[1]
Loose snow	0.30
Ice	0.53
Hoarfrost	0.53
Hard snow	0.31
Bare tracks	0.12[1]
Slippery tracks	0.30[1]
Dry and bare road, summer	0.14
Wet and bare road, summer	0.18

Exactly how winter maintenance changes road conditions seems important. If it removes black, transparent ice which is hard to detect from behind the steering wheel, maintenance may correct erroneous speed adaptation. However, if it removes the snow coverage without increasing friction, increased speeds may at least partially cancel out the intended safety benefits.

As a final example of the relation between weather and road safety, the Weather Index offers one way to examine the effects of weather. In Finland the Weather Index is used to assess the cost of winter maintenance in different months. It is an auxiliary mean in cost negotiations between the road administrator and the operator. The index describes the weather with a range of parameters (e.g. depth of rainfall, amount of freezing on roads etc.). The long-term average for a given month is 100. Index

115, for example, indicates that maintenance is estimated to be 15% more costly than average. As figure 3 shows, the weather in wintertime does not actually describe how difficult road conditions will be for the road user after winter maintenance operations.

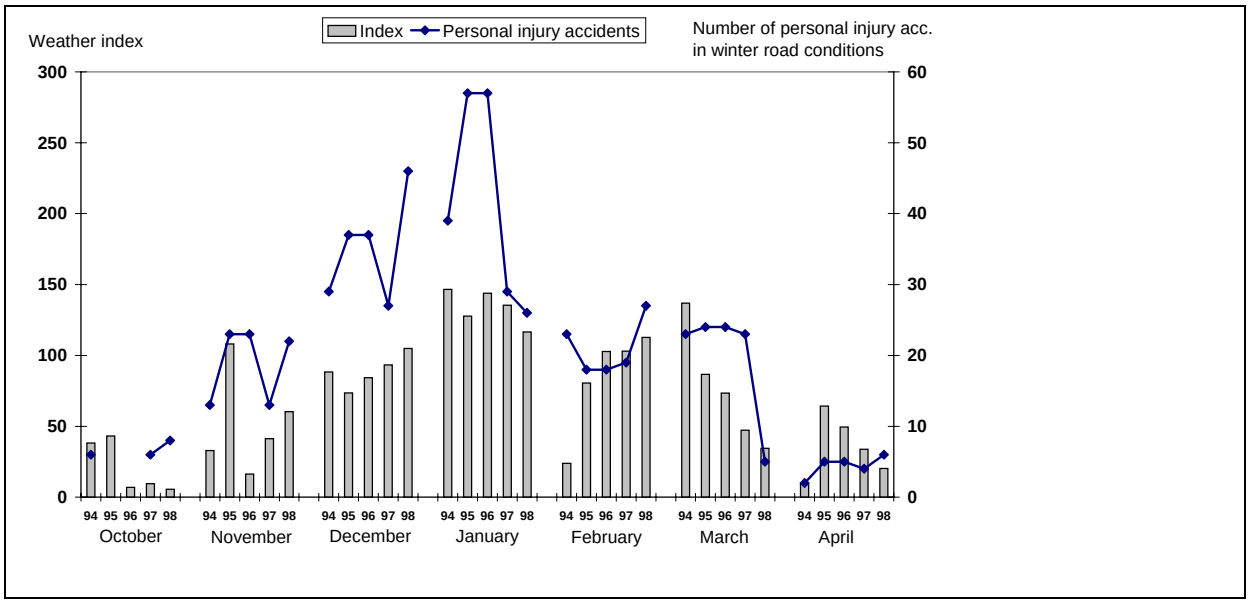


Figure 3. Weather index and personal injury accidents in Helsinki road district 1994-98

7. Conclusions

This study revealed that the effects of winter maintenance on traffic safety are not unambiguous. The effects of winter maintenance and winter road conditions should be studied from many perspectives and possible extra financing and enhancement of winter maintenance, at least in Finland, should be carefully designed.

In summary, several observations indicate that winter road maintenance enhancement is worthwhile in Finland:

- The risks of winter road conditions are manifold compared with summer road conditions
- Road conditions at the accident location were exceptionally slippery in 21% of fatal meeting accidents and 39% of fatal run-off-road accidents (where the winter road condition was one cause of the accident)

On the other hand, several factors indicated that the enhancement of winter maintenance should be designed carefully before it is applied in Finland:

- Nowadays, personal injury and fatality risks in wintertime are at the same level as in summertime
- Enhancement of traffic enforcement (especially monitoring defective tires and overspeed) can be more effective than enhancement of winter maintenance from a safety point of view
- Drivers decrease their speeds in slippery-looking conditions by 4...7 km/h, which is as big an effect as a speed limit decrease in normal conditions of 20 km/h
- Daily personal injury accident amounts in the summer and in the winter are identical

8. Acknowledgments

This study was financed by the Finnish Road Administration. Many thanks to supervisor Anne Leppänen (M.Sc.Tech.) whose wide experience, helpful comments and open-mindedness towards new approaches made this study possible. I should also like to thank Olli Penttinen (M.Sc.Tech) of the Road Administration and Senior Research Scientist Tapani Mäkinen of the Technical Research Centre

of Finland, whose passionate interest in the subject supported me in many ways. My colleague, Research Scientist Otto Kärki also gave much of his valuable time in carefully analyzing the Fatal Accident Investigation Board data.

9. References

Brüde Ulf & Larsson Jörgen 1980: Wintertime interrelationships between weather, road conditions and road accidents. Statistical description and analysis. VTI rapport 210.

Evensen Ragnar 1996: Veg-grepsprosjektet, konsekvenser av enkle strategier (in Norwegian), Delsprosjekt 5.15. Statens vegvesen, Intern rapport nr. 1918.

Hantula Lasse 1992: Development of a case study method of road accidents in Finland. Journal of traffic medicine. 1992 20(1) pp 27-35.

Heinijoki Heikki 1994: Influence of the type and condition of tyres and drivers' perceptions of road condition on driving speed (in Finnish). Finnra reports 19/1994. ISBN 0788-3722.

Malmivuo Mikko & Peltola Harri 1997: Traffic safety at wintertime (in Finnish). Finnra reports 6/1997. ISBN 951-726-317-1.

Nilsson Göran & Obrenovic Alexander 1998: Seasonal Speed limits. VTI rapport 435 A.

Ranta Susanna & Kallberg Veli-Pekka 1996: Analysis of statistical studies of the effects of peed of safety. VTT Research Report 362.

Saastamoinen Kimmo 1993: Effect of road conditions on driving behaviour and properties of the traffic flow (In Finnish). FinnRA reports 80/1993. ISBN 951-726-8139-2.

Vaa Torgeir, Sakshaug Kristian, Resen-Fellie Ole Peter 1995, Road salting and traffic safety, the effect of road salting on accidents and driving speed. Conference paper.