POTENTIAL OF WINTER MAINTENANCE FOR TRAFFIC SAFETY IN FINLAND

O. KÄRKI
Centre for Economic Development, Transport and the Environment for South Ostrobothnia, Vaasa, Finland
OTTO.KARKI@ELY-KESKUS.FI

ABSTRACT

Fatalities in wintertime traffic have fallen by roughly 70% in Finland since 1990, thanks to improved winter service management and other steps taken by road authorities. The fatality risk has been approximately the same in winter and summer for over 10 years. In the early 1990s the fatality risk in wintertime traffic was about 20% higher than in summertime. Several factors underlie this positive trend, among them the development of winter maintenance, wintertime speed limits, automated speed enforcement, road weather information systems and vehicle technology. A positive trend in wintertime safety has emerged despite reduction of salting in road maintenance throughout the 1990s and 2000s.

This paper presents an analysis of long-term accident data. The results were compared with speeds and traffic mileage in wintertime in Finland. In addition to road maintenance classes different road types were considered with a science-based safety evaluation tool.

There is still room for potential in achieving better results in wintertime safety in Finland; although the number of fatalities on state roads in winter is currently under 100 per year, it was estimated that quality management in winter maintenance could cut the figures by three fatalities and 50 injury accidents per year.

KEYWORDS

WINTER MAINTENANCE, TRAFFIC SAFETY

1. INTRODUCTION

The prevailing national goal in Finland is to reduce the annual number of road accident fatalities from the current 250 to 125 in 2020. Although the traffic safety trend has been positive, losses to public health and the socio-economy resulting from inadequate traffic safety are still huge. The better traffic safety gets, the more expensive it becomes to improve safety by constructing roads. There is an ongoing effort to find effective means to improve safety.

There are over 78 000 km of state roads in Finland. Winter maintenance is classified into five main quality categories (Figure 1). The current winter maintenance policy emphasises roads with high traffic volume (AADT>15000/day). Roughly 25% of mileage is driven on these roads; there is no more time given to achieve the required friction value of 0.30 once snowfall has ended. Currently the level of service in winter maintenance is the same both day and night on all main roads in Finland. This is planned to continue by contract renewal until 2015 on all state roads. The length of the existing maintenance contracts in Finland is 5 or 7 years.

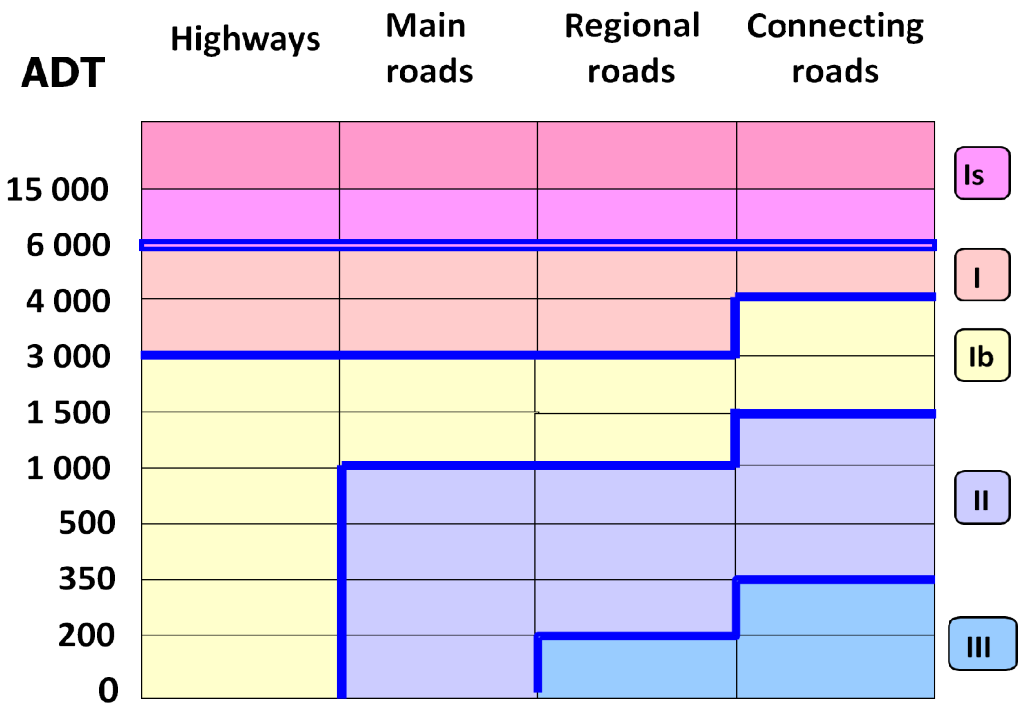

Figure 1 - Rough division of the road network into winter maintenance classes [7]

Previous research has shown that the level of winter maintenance does not correlate linearly with traffic safety. Current estimates of the effects of raising the level of winter maintenance on accidents vary. In Finland a higher winter maintenance class means, in calculations, a 2% cut in injury accidents. This corresponds roughly to a 5% cut in accidents in wintertime and a 7–35% cut in accidents on wintry roads. In practice the level of winter maintenance should be raised over a sufficiently long distance to gain safety benefits. According to quality tracking of winter maintenance in Finland, only 20% of mileage between 1 December and 31 March is driven in clearly wintry driving conditions (Table 1 and Figure 2).

Table 1 - Road conditions (%) between 1 December and 31 March in Finland [7].

Maintenance class	Bare	Looks bare	Broad ruts on packed snow	Narrow ruts on packed snow	Packed snow	Irregular packed snow	Snow	Slush	Total
IS	68	16	13	0,4	1	0,1	2	0,5	100
I	54	16	22	2	3	0,2	2	0,6	100
Ib	30	9	26	13	17	1	3	0,5	100
II	15	3	7	10	54	6	4	0,3	100
III	10	1	2	2	73	7	5	0,4	100

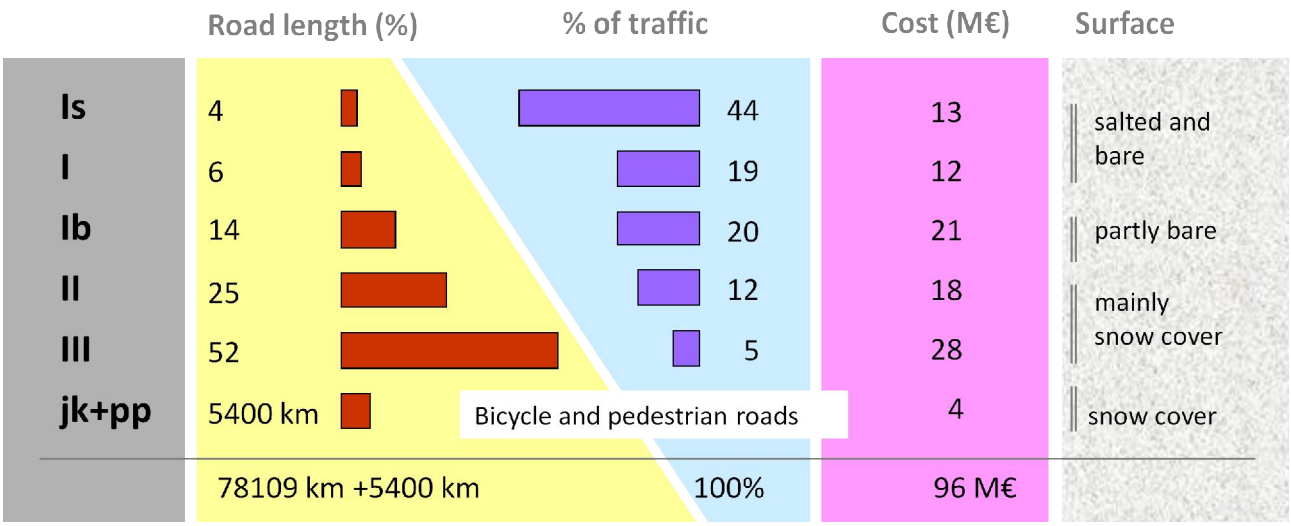

Figure 2 - Road length, mileage and cost by winter maintenance classes in Finland [9]

Practice has shown that the accident cut achieved by raising the level of winter maintenance is not always as pronounced as calculations indicate. One reason is assumed to be higher speed levels in better road conditions. There is also some evidence that the gap between clients' quality requirements and the quality produced by contractors has grown. The predictability of road conditions, especially friction, is essential to traffic safety in winter. However, customer satisfaction is good on main roads and satisfactory on regional and connecting roads.

2. WINTERTIME TRAFFIC SAFETY MILESTONES SINCE 1980

Salt usage in winter maintenance peaked in Finland in 1990. At the time, the amount of fatalities in road traffic had begun to rise again and it did not seem very effective to avoid serious accidents by salting even more. There was a clear need to find complementary means to improve traffic safety in winter. Wintertime speed limit pilots were started in 1987 and the speed limits became established practice in the early 1990s. Daily winter maintenance on state roads was mainly carried out in-house by public transport authorities. The level of wintertime safety research was high and a falling trend in accidents began to take shape, especially in winter.

Winter maintenance methods were improved throughout the 1980s and 1990s. Road weather information systems developed rapidly, and in the early 2000s there were some 300 road weather stations and 250 weather cameras nationwide, enabling a reduction of salt use. The current numbers are 376 and 460 respectively. Speed limits are reduced on 9000 km of road for approximately 5 months each winter: to 80 km/h on two-lane roads and to 100 km/h on motorways. Wintertime speed limits are calculated to save 12–13 lives each year in Finland, and to cut fatality rates by as much as 49% on roads where wintertime speed limits are in use [4].

A client-producer model started to take shape among the state road authorities in 1998. Three years later the Finnish Road Administration was founded and maintenance gradually opened up to competition. By 2004, maintenance of state roads was contracted entirely. Before the arrival of open competition there were some concerns about quality and its effects on traffic safety. However, these have been good given the money spent on maintenance.

In the early 1990s the fatality risk in wintertime traffic was still about 20% higher than in summertime. By the end of the decade the fatality risk was approximately the same in winter and summer. This ratio has not changed much since then but the total fatality risk has decreased (Figure 3). Several factors underlie this positive trend, among them the development of winter maintenance, wintertime speed limits, automated speed enforcement, road weather information systems, and vehicle technology.

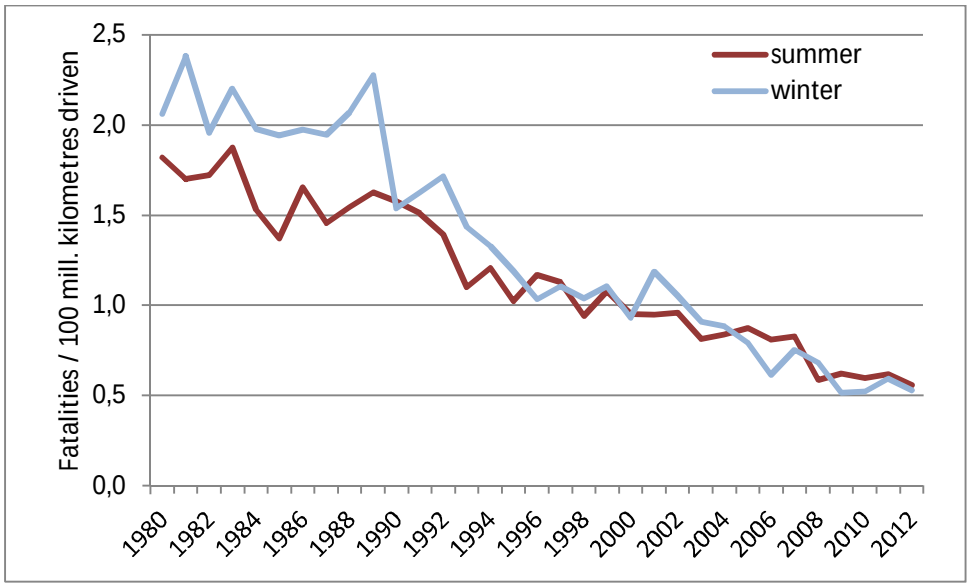

Figure 3 - Fatality risk in traffic in winter and summer 1980 - 2012 in Finland [9]

Injury accident risk in winter and in summer has been almost on the same level for over 30 years (Figure 4). Consequently, the severity of accidents has decreased more in winter.

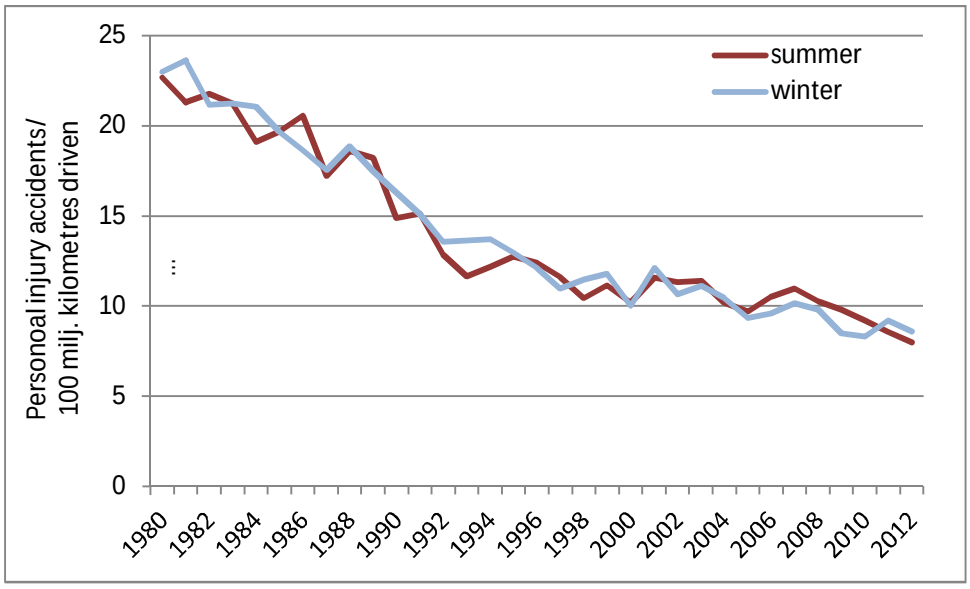

Figure 4 - Injury accident risk in traffic in winter and summer 1980 - 2012 in Finland [9]

The most serious road traffic accident in Finland occurred in March 2004, when 23 young people lost their lives in slippery road conditions in the middle of the night in a head-on collision between a bus and a wood truck. Seven steps were taken immediately by the road authorities following the accident. The quality requirement at night was raised over 2300 kilometres of road to the same level as in daytime and weather information was

improved. Summertime speed limits were no longer allowed on roads with AADT>3000 and no separation between lanes. Among other things, automated speed enforcement was also increased. In the 2000s most traffic safety benefits were gained by automated speed enforcement, which has had an even better influence on safety in winter than in summer. Automated speed enforcement saves 27 lives each year in Finland [5]. Vehicle technology, such as ESC, has also improved safety in wintertime traffic during this time. Added to this is a decrease in the amount of inadequate tyres in traffic flow in winter [8]. The average age of vehicles, 10.6 years, is still one of the oldest in Europe. Thus, there is still room to improve safety without highly developed ITS solutions also.

3. METHODS

The study began with a literature review, followed by in-depth analysis of traffic safety in wintertime in Finland. The statistics of the traffic accident investigative committee were mainly used in the latter [1, 3, 4, 9].

Accident analysis was done with accident data from 1997–2008. The results were compared with the mileage of all traffic on main roads and of heavy vehicles. Previous estimates of mileage in wintry road conditions were employed. A comparison was also made with fatalities and injury accidents and speeds for every hour of the day. Safety on weekdays was also analysed.

Current accident risks and densities were calculated with the safety evaluation tool TARVA used for state roads in Finland. TARVA combines information from accident records and accident prediction models. It combines the accident history of the past 5 years and the average accident risks in various road and traffic environments. Traffic environments in TARVA are formed from road groups that have a pretty low variation in accident rates [6], (Figure 5).

In addition to winter maintenance classes, various road types and traffic volumes were analysed. Accident reduction potential was calculated from the current number of accidents on the road network in wintertime. The share of accidents in wintertime on various road groups was calculated. The reduction potential of winter maintenance and quality assurance was estimated to be 4.4% on main roads and high-class roads, and 2.2% on regional and connecting roads, of accidents during the winter period (1st October - 31st March). This estimate was compared with previous in-depth analysis of fatalities in wintertime traffic to ensure reliability of the analysis. The severity of accidents was estimated from the relation between fatalities and injury accidents.

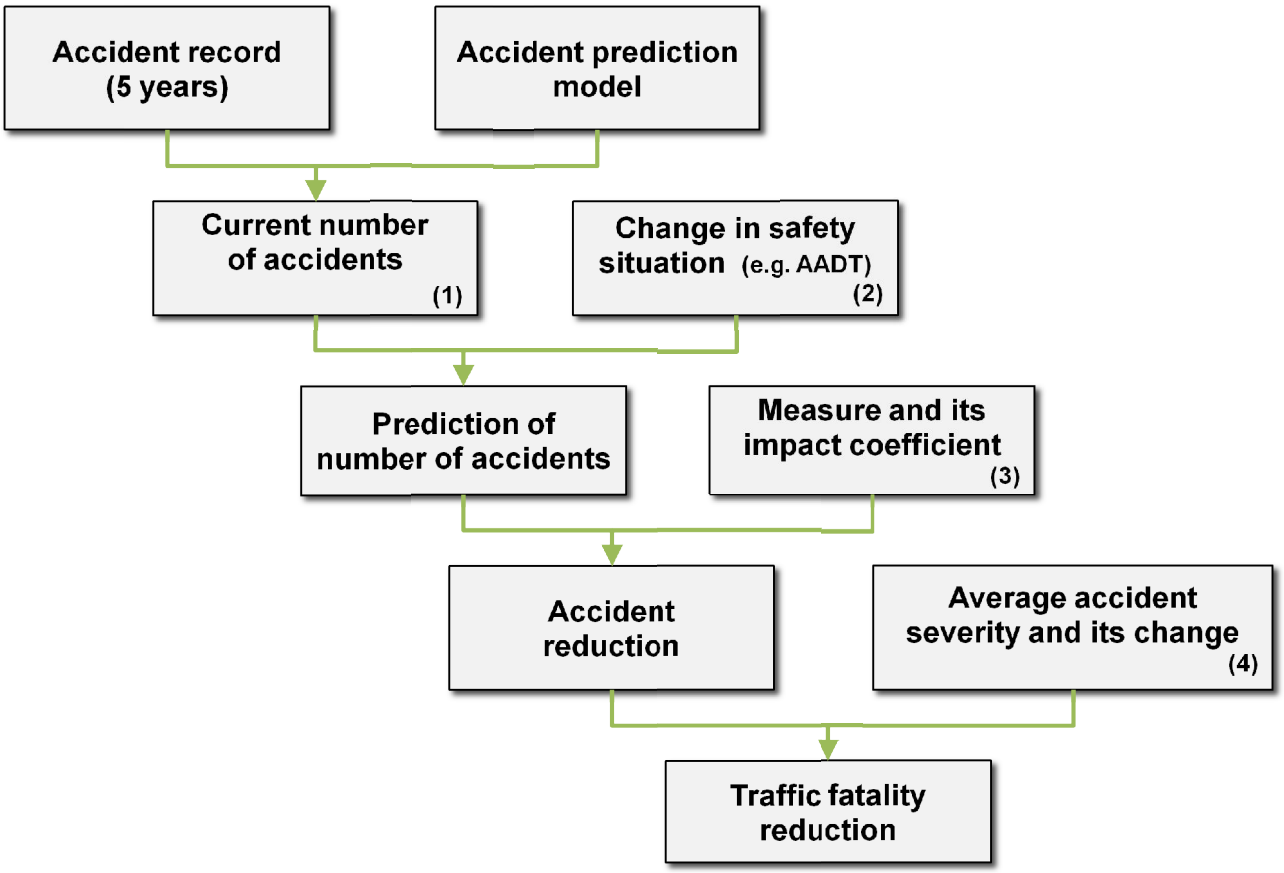

Figure 5 - Evaluation of traffic safety effects of improved winter maintenance by TARVA [6]

4. RESULTS

4.1 In-depth analysis

In-depth analysis of fatalities from head-on accidents in 2002–2004 was done to explore the potential of winter maintenance on traffic safety and cost effectiveness of winter maintenance. The results showed that roughly 15 fatalities a year from head-on accidents can be affected by winter maintenance. It was estimated that other risk factors than weather or driving conditions explained 40% of those. Winter maintenance classes Is, I and Ib had the highest traffic safety potential. By estimating that 50% of remaining accidents could be avoided, three lives a year could be saved from head-on accidents by a higher winter maintenance level [1]. That means 5–6 lives could be saved when considering all the accident classes on state roads. The total amount of fatalities has fallen since then.

There are usually many risk factors involved in serious accidents. However, in serious accidents in wintertime, human factors still often play an important role. One factor that slightly raises the traffic safety potential of action by road authorities in winter over summer is that in winter accidents, a single strongly contributing risk-factor like alcohol or speeding is less likely. However, the difference between strong risk-factors in fatal accidents in summer and winter is not that big, amounting to 5–11% or up to 16% on regional and connecting roads. If speeding were ignored in this analysis, there would be a bigger difference between winter and summer because of wintertime speed limits. On the other hand, strong risk-taking seems to be more common in fatalities on motorways in winter, at least when considering compliance with speed limits [3, 4, 9], (Figure 6).

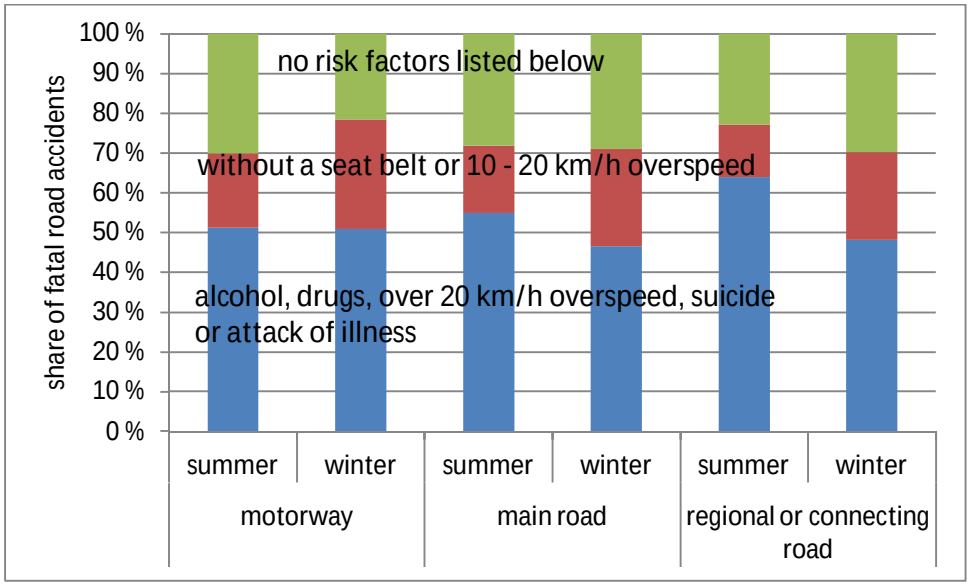

Figure 6 - Strong risk factors in fatal accidents on state roads in 2002 - 2011 [9]

Considering the quality measures of road authorities and consultants, an important finding is that strong risk-taking is much more often involved in fatal accidents in the evenings, at night and at weekends. Accordingly, fatality risk in traffic during non-office hours is much higher. However, strong risk factors are involved in fatal accidents during non-office hours more often in summer [9]. Therefore, there is more potential to have an effect on accidents by means of action by the road authorities in winter, (Figure 7).

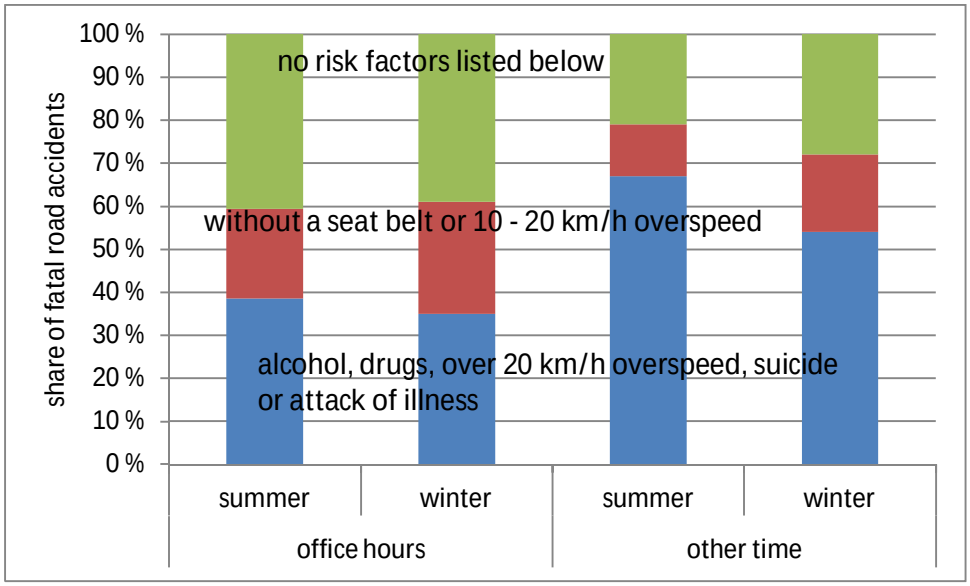

Figure 7 - Strong risk factors in fatal accidents during office hours and non office hours [9]

According to the statistics of the traffic accident investigative committee, usually based on police information, roughly 60% of fatalities in head-on accidents during the winter period from October to March occur when the road surface is icy or snowy [1]. The share of the driving mileage in icy or snowy conditions over the same period is 10–15%. This means a highly increased accident risk in those weather conditions.

4.2 Accident analysis

In Finland, roughly 65% of fatalities on state roads in winter occur on main roads (including high-class roads like motorways). Around 60% of those are from head-on or overtake accidents (Figure 8). The percentage of head-on accidents or overtake accidents of fatalities on two-lane main roads is about 70% in winter. Among the worst road types in terms of serious accidents are motor traffic roads with no barrier between the lanes [2].

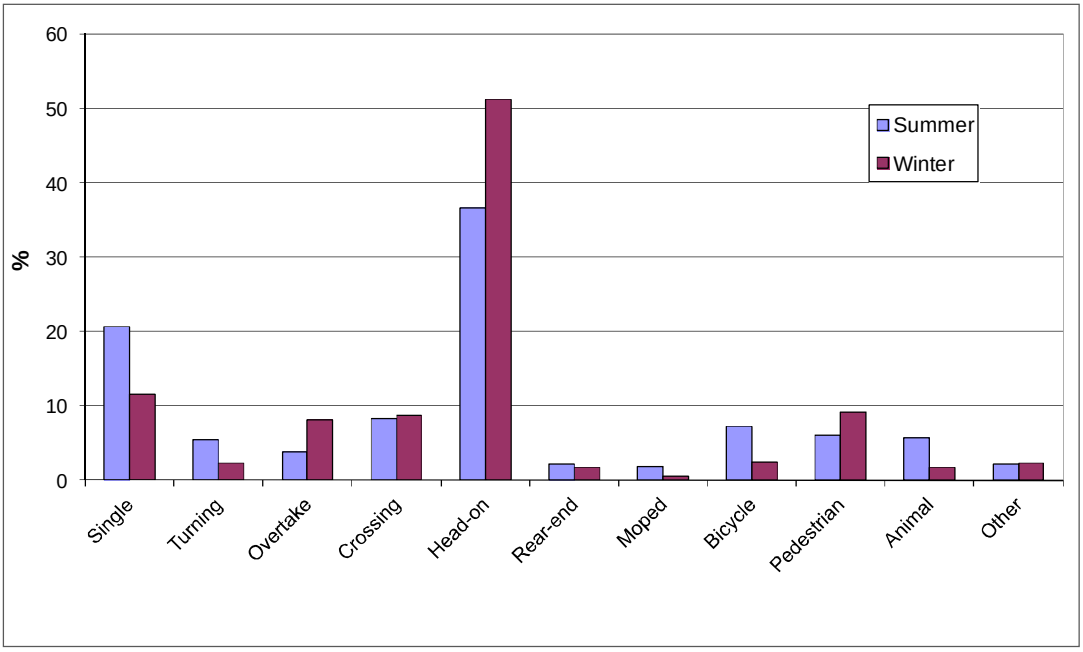

Figure 8 - Accident classes of fatalities on main roads in Finland in 1997–2008 (N=1016), [2]

Interesting findings have emerged from accident statistics for 1997–2008. Injury accidents have a strong correlation with traffic volume. It seems also that the fatality risk in wintertime traffic has some correlation with average speed and the amount of heavy vehicles in the traffic flow. The fatality risk during night-time hours is 3–4 times higher than the average fatality risk in wintertime traffic. Increased average speed and darkness are strong risk factors at night (Figure 9). Despite the positive effects of road weather information systems, it is clear that drivers do not adapt their driving and speeding behaviour enough to existing road conditions. The highest fatality risks were found on Monday, Friday, Saturday and Sunday [2].

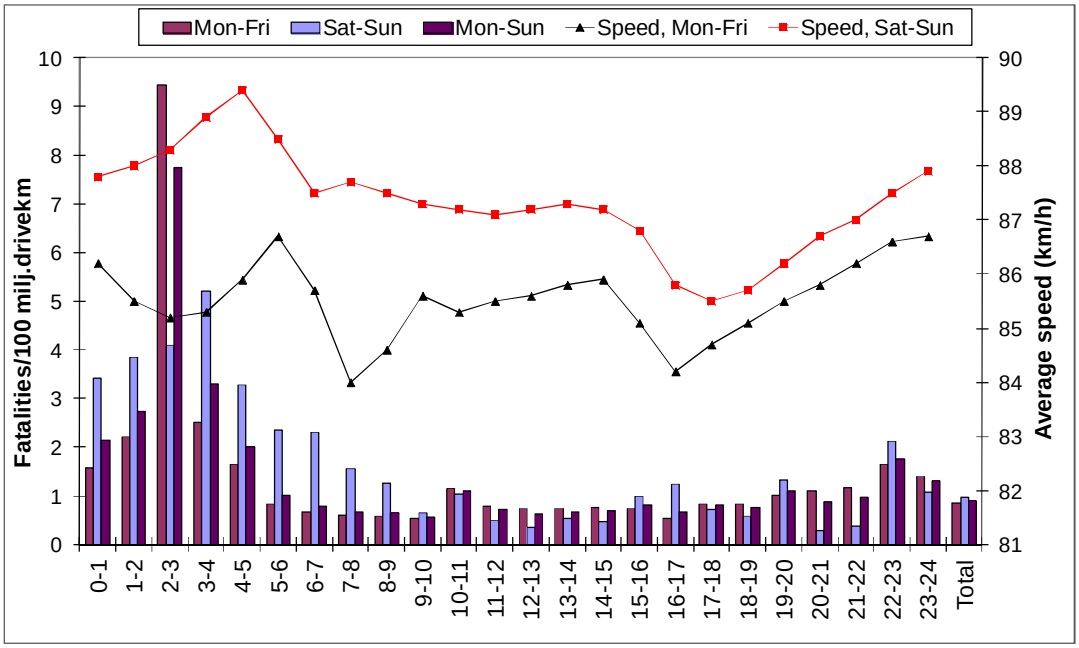

Figure 9 - Fatality risk and average speed hourly on Finnish main roads in 1997–2008 (N=1016), [2]

4.3 Accident reduction potential

Accident risks decrease when the winter maintenance class is higher. However, other factors than winter maintenance affect the risk level more. When comparing risks in wintertime to those of every month of the year, wintertime risks tend to be higher in high winter maintenance classes (Table 2). On roads with low winter maintenance class, strong risk taking in summer highly increases the overall risk. The risk figures show that there is still significant potential to improve safety in wintertime, especially in winter maintenance classes Is and I. This potential used to be much higher, but actions like wintertime speed limits and automated speed enforcement have claimed most of the potential.

Table 2 - Safety related information on Finnish public roads in 2008–2012 by winter maintenance class [2, 9]

Winter maintenance class	Road length (km)	Fatalities				Injury accidents			
		N/year	Risk[1]	Density[2]	Winterrisk[3]	N/year	Risk[1]	Density[2]	Winterrisk[3]
Is	3274	59	0.37	1.80	+6%	848	5.4	26	+8%
I	4547	45	0.65	0.99	+13%	564	8.2	12	0%
Ib	10606	47	0.64	0.44	+4%	790	10.7	7	0%
II	19340	41	0.90	0.21	-5%	621	13.6	3	-3%
III	40342	16	0.82	0.04	-34%	319	16.5	1	-23%
Total	78109	208	0.57	0.27	-3%	3142	8.6	4	-2%

[1] Fatalities (killed people) or injury accidents per 100 million vehicle km
[2] Fatalities or injury accidents per 100 road km, year
[3] Risk 1st October - 31st March compared to yearly risk

Serious accidents and risks need to be analysed also by road type to understand what is really the effect of road type and the effect of winter maintenance on safety. The best estimations of the present safety situation on roads can be done with science-based safety evaluation tools like TARVA. It was found that most of the safety potential for fatalities in

wintertime traffic lies on main roads with no barrier between the lanes and high traffic volume. By comparison, the greatest potential for injury accidents lies on motorways and other dual carriageways. It has been observed that wintertime speed limits significantly reduce the severity of accidents on motorways. On other dual carriageways, wintertime speed limits are not usually applied. On rural main roads, the severity of accidents partly depends on whether the roads are camera enforced or not. On urban roads, higher risks in summer partly depend on the amount of pedestrians and bicycles in traffic. A remarkable potential of winter maintenance for traffic safety exists on main roads and high-class roads (Table 3).

Table 3 - Safety related information on Finnish public roads in 2008 - 2012 by main road group [2, 6, 9]

			Fatalities				**Injury accidents**			
Road group	Road length (km)	AADT (veh/day)	N/year	Risk[1]	Density[2]	Winter-risk[3]	N/year	Risk[1]	Density[2]	Winter-risk[3]
High-class roads										
Motorway	780	23583	10.2	0.15	1.31	-14%	212	3.2	27	8%
Other 2 carriageways	484	18455	4.8	0.15	0.99	8%	222	6.8	46	9%
Semi-motorway[4]	101	10497	4.4	1.14	4.38	8%	16	4.1	16	15%
Rural main roads										
wide[5]	2185	5402	32.2	0.75	1.47	10%	254	5.9	12	1%
narrow	8276	2170	47.2	0.72	0.57	7%	454	6.9	5	2%
Rural minor roads										
wide[5]	1146	2966	7.6	0.61	0.66	-17%	110	8.9	10	1%
narrow	56689	321	52.2	0.79	0.09	-15%	856	12.9	2	-10%
Urban roads										
Urban sign	2423	2527	12.8	0.57	0.53	-9%	413	18.5	17	-4%
Main road, dense[6]	1397	5260	18.2	0.68	1.30	1%	249	9.3	18	1%
Minor road, dense[6]	4632	1533	18	0.69	0.39	-17%	357	13.8	8	-5%
Total	78113	1284	207.6	0.57	0.27	-3%	3142	8.6	4	-2%

[1] Fatalities (killed people) or injury accidents per 100 million vehicle km
[2] Fatalities or injury accidents per 100 road km, year
[3] Risk 1st October - 31st March compared to yearly risk
[4] Driving directions not separated on semi-motorways
[5] On main roads wide refers to roads with a pavement width of at least 9.5 m, on minor roads at least 8.0 m
[6] Dense refers to statistically defined dense population next to the road (at least 200 people within 200 m from each other

The greatest potential to improve traffic safety by means of winter maintenance was found on rural main roads. Most lives can be saved on roads with one carriageway and a big traffic volume. However, remarkable potential remains on motorways and other dual carriageways for reducing injury accidents. It was estimated that the realistic potential of winter maintenance and client enforcement is double on main roads and high-class roads compared to minor roads (Table 4).

Table 4 - Accident reduction potential of winter maintenance on Finnish public roads by main road group [2, 6, 9]

Road group	Road length (km)	Fatalities				Injury accidents			
		N/year	N/winter[1]	%/winter[2]	Reduction potential[3]	N/year	N/winter[1]	%/winter[2]	Reduction potential[3]
High-class roads									
Motorway	780	10.2	3.9	38	0.17	212	103	49	4.5
Other 2 carriageways	484	4.8	2.3	48	0.10	222	109	49	4.8
Semi-motorway[4]	101	4.4	2.1	47	0.09	16	8	52	0.4
Rural main roads									
wide[5]	2185	32.2	15.9	50	0.70	254	115	45	5.1
narrow	8276	47.2	22.8	48	1.00	454	208	46	9.2
Rural minor roads									
wide[5]	1146	7.6	2.9	38	0.06	110	50	46	1.1
narrow	56689	52.2	20.3	39	0.45	856	346	40	7.6
Urban roads									
Urban sign	2423	12.8	5.2	41	0.23	413	179	43	7.9
Main road, dense[6]	1397	18.2	8.4	46	0.37	249	113	46	5.0
Minor road, dense[6]	4632	18	6.9	38	0.15	357	153	43	3.4
Total	78113	207.6	90.9	44	3.33	3142	1389	44	48.9

[1] Fatalities (killed people) or injury accidents 1st October - 31st March years 2008 - 2012 (wintertime)
[2] Estimation from long term accident statistics
[3] Reduction potential is estimated to be 4.4% of wintertime accidents on high-class and main roads, 2.2% on minor roads
[4] Driving directions not separated on semi-motorways
[5] On main roads wide refers to roads with a pavement width of at least 9.5 m, on minor roads at least 8.0 m
[6] Dense refers to statistically defined dense population next to the road (at least 200 people within 200 m from each other

5. CONCLUSIONS AND DISCUSSION

In Finland, the trend in winter traffic safety has long been positive for a number of reasons. Wintertime speed limits alone save 12–13 lives each year, and along with automated speed enforcement, saves also 12–13 lives in winter period, have claimed much of the available room for improvement of winter maintenance in terms of traffic safety. Tyre-related fatal accidents are more common in winter than summer [4, 5, 8]. Every further life saved by winter maintenance becomes a more difficult and expensive task. Nonetheless, the predictability and reliability of winter maintenance must be at such a high level that even inexperienced drivers and those driving on inadequate tyres can manage in varying weather conditions. The remaining potential of winter maintenance is so remarkable that it cannot be ignored when aiming at ambitious traffic safety goals. It should be noted that the positive safety trend has continued in Finland despite cutbacks in salting. Effective road weather information systems have enabled the optimisation of salt use.

This paper attempts to make a realistic estimation of the accident reduction potential of winter maintenance and its quality control. The results reveal on which road groups the greatest safety potential exists. Analysing safety only in respect of various winter

maintenance classes does not give enough answers to traffic safety problems in winter. It is vital to analyse various road types and consider roads with separated driving directions. Different roads should be maintained better when optimising the effects on saved lives and injury accidents. By improving winter maintenance on fewer than 10% of the roads, over 50% of traffic will enjoy positive safety effects. In-depth analyses increase our understanding of risk factors causing the accidents.

In Finland, the quality requirements of winter maintenance have been the same for both nighttime and daytime maintenance since 2009 on all main roads. This policy should reduce the highest weather and visibility risks for traffic safety. Unfortunately, more often there seem to be other strong risk factors contributing to accidents during non-office hours. However, in-depth analysis may give too narrow a view of accidents which could be affected by road authorities. Sometimes weather and road conditions may be a crucial factor even if the driver is speeding or under the influence of alcohol. It is also easier to ignore a client's quality requirements at night. There are only a limited amount of spot checks. Modern real-time monitoring systems reduce to some extent the risk of ignoring quality requirements. However, practice has shown that the more quality requirements are tightened, the more the gap widens between ordered and produced quality - especially if no time is given to implement the required quality. It is also possible that the safety benefits of better winter maintenance are partly lost by higher speeds. This phenomenon is more common at weekends. The speeding problem is effectively tackled on many main roads with camera enforcement.

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