Relations between Road Weather, Road Maintenance and Traffic Accidents

Canada paper on accidents in snow

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Introduction

A large part of all road transports are affected by the seasonal variations in the climate. In areas where road surface temperature sinks below 0°C during winter time, the effect for the road user can be very dangerous driving conditions, and may cause large delays in traffic. These hazardous road conditions are best described with type of road slipperiness, e.g. rime or snow. In Europe and North America, much maintenance work is done by the national road administrations to improve winter-time road conditions and thereby increasing the trafficability and decreasing the accident rate.

Historically, the main purpose for winter road maintenance has been to keep roads trafficable by improving road surface friction and removing snow deep enough to hindrance the traffic (Hubendick, 1973). The increased performance of the winter maintenance actions have gradually lead to that road users seldom encounters slippery road conditions. At the same time, this have meant that road-users no longer are prepared for rapid changes in road condition. The modern road user only slightly adjust the speed of their vehicle to the prevailing road conditions even if the hazard is clearly visible, such as heavy snowfall (Öberg et al, 1991). Due to this behaviour, winter road maintenance is today also considered as a measure of safety even if the right measure ought to be speed adjustment in combination with proper maintenance action.

A study relating accident risk to maintenance (Sävenhed, 1995) based the study on two winter seasons, which included a total of 941 accidents that happened within 12 hours before and

after maintenance action. The accident risk is defined as the number of accidents per million axle-pair kilometres. The accident risk will be higher when bad road conditions are more rare, e.g. it will be higher in southern Sweden than in the northern parts because of the more severe winters when people are more used to bad road conditions. Normally there is a higher accident risk night-time than during the day, as a result of low visibility. When snow starts falling, more accidents happen at first, but after a while the risk stabilises as people get used to the new road conditions.

This is a initial study and the objectives are therefore quite broad. In the study we want to address questions such as:
Which type of slippery road conditions may normally develop, and during which weather conditions? At which of these conditions are winter maintenance taken action? The accidents that do happen in the area, do they suggest any improvements in the RWiS (Road Weather information System)?

Types of slippery road conditions

In this study, the definition of a slippery road condition has been: occasions when the road surface friction coefficient may decrease to less than 0.25. This definition includes most of the occasions when water freezes onto the road surface or when the road surface is covered with snow (Hubendick, 1973; Öberg et al, 1991). This is also the lowest value of the friction coefficient for, what the Swedish National Road Administration (SNRA) classify as, satisfactory friction (Vägverket, 1996).

A systematisation and valuation of slipperiness on roads based on a theoretical discussion was presented by Lindqvist (1979). Totally, 24 different types of slipperiness and the associated weather conditions were described. Because some of the situations are rare, Lindqvist also weighted the situations with respect to occurrence of slipperiness, duration and spatial distribution. The result was seven types of slipperiness, in ranking order:

1. Coating of ice, formed from a water cover, including melt water that freezes.

2. Hoarfrost due to radiative cooling.

3.Coating of ice, formed by compacted snow.

4. Loose snow at precipitation.

5. Snow compacted by traffic.

6. Hoarfrost during a period with increasing temperature but on a still cold road surface.

7. Coating of ice, formed from supercooled rainwater.

All seven are a result of either precipitation or sublimation of water vapour.

In this study, the initial list of 24 different types defined in Lindqvist (1979) has been modified by removing some rare occasions and dividing the rest into two different groups, primary and secondary types of road slipperiness. The new list includes 16 types of slipperiness which all, theoretically, fulfil the friction coefficient criteria. These types are presented in Table I.

Table I. Types of road slipperiness that can be detected from meteorological observations (modified after Lindqvist, 1979)

Primary types of slipperiness	**Precipitation**	**Weather description**	**Secondary types of slipperiness**	**Precipitation**	**Weather and influence from other factors**
1. Rainwater freezing at a cold surface	Rain	A period of low temperatures preceding the event	13. Snow packed by traffic	Snow	Recent or ongoing snowfall. Traffic
2. Supercooled rainwater	Rain	Various	14. Modd	snow	Recent or ongoing snowfall. Salt
3. Direct snowfall	Snow	Snowfall Tair < 0°C	15. Refreezing slush	Snow	Recent or ongoing snowfall. To large saltcontent
4. Drifting snow	Snow	Recent or ongoing snowfall, Strong winds	16. Refreezing water on the surface	No	Saltsolution
5. Melting snow at air temperature above 0°C	Snow	Heavy snowfall Tair > 0°C			
6. melting snow at air temperature below 0°C	Snow	Heavy snowfall Tair < 0°C			
7.Watercover which freezes	No	Clear weather following a rainy period			
8. Fog-water freezing at a cold surface	No	Fog and moderate winds			

Table I continuing

Primary types of slipperiness	Precipitation	Weather description	Secondary types of slipperiness	Precipitation	Weather and influence from other factors
9. Freezing dew	No	Clear and calm weather			
10. Hoar-frost due to radiative cooling	No	Clear and calm weather			
11. Hoar-frost due to advection	No	Moderate winds			
12. Hoar-frost during a period with increasing temperature but still cold road surface	No	Morning heating of air temperature			

The primary types of slipperiness are directly related to the occurring road weather. The development of secondary types of slipperiness are instead a combination of weather, traffic and maintenance activity. The secondary types 15, refreezing slush, and 16, refreezing water on the surface, may be very problematic when they develop.

Winter road maintenance

The personnel responsible for road maintenance must have meteorological information, with high temporal and spatial resolution, on the road conditions in their area. To get this information, a Road Weather Information System (RWIS) is used. A description of the British RWIS can be found in Thornes, 1991. The Swedish National Road Administration have around 700 field station in their system. These field stations are equipped with sensors measuring air temperature, relative humidity, road surface temperature, precipitation, wind speed and wind direction. In the system it is also possible to get information about meteorological conditions, from satellite images and weather radar, and weather forecasts.

The criteria for when an maintenance action should take place is, in Sweden, different for different road categories. The largest roads, highways, have the highest priority and should always be free from ice and snow, while in some areas roads will get "winter road standard" meaning that only larger amounts of snow is removed. In this study only larger roads with

highest priority, classified as A1 and A2 roads, are considered. These roads also have diurnal restrictions for maintenance. The maintenance activity may have a longer responding time during the night, between 23:00h to 06:00h, but the roads should be cleared before peak hours, normally before and after working hours. In this study each day has been divided into four periods, based on sunset and sunrise in the area of concern since the net radiation is an important factor affecting the daily variation of the road surface temperature.

Morning	from 04:00h to 10.00h
Day	from 10.00h to 14:00h
Evening	from 14.00h to 22:00h
Night	from 22:00h to 04:00h

The diurnal distribution of maintenance activities, in an area in southern Sweden, during the winter season of 1995-96 are shown in Figure1. Winter road maintenance is most frequent in the morning hours, in one morning of three maintenance action is taken place. On the other hand, maintenance is performed only one night of seven. this agrees with the maintenance specification mentioned above.

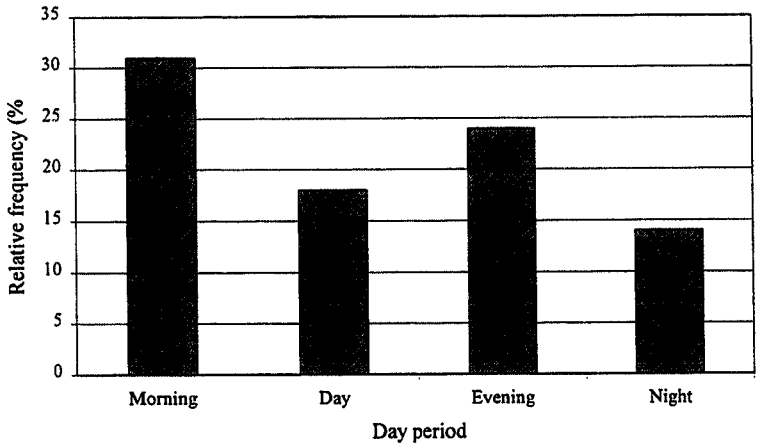

Figure 1. The diurnal distribution of maintenance activities. Based on totally 182 days from the winter season of 1995-96

Following the systematisation of types of slipperiness according to Table I, types of slipperiness that were reported in the maintenace reports were investigated. The reasons for maintenance actions during February 1996, as it were noted in the maintenance reports, are presented in Figure 2.

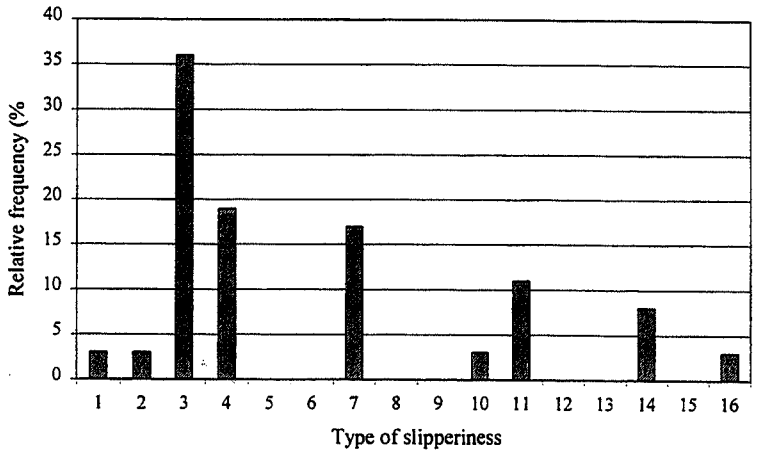

Figure 2 Type of slipperiness reported in maintenance reports, February 1996. Totally 36 periods of maintenance activity.

Figure 2 shows that during this month most action were taken due to snowfall (3) and the, with this, associated snowdrift (4). Totally, 65% of the maintenance action were performed during periods associated with precipitation. Circa 90% of the occasions were primary types of slipperiness and only 10% were secondary types of slipperiness.

Observations at RWIS-stations in the area

Data from February 1996 was chosen because this was the first month when precipitation was measured with OpticEye (Enator Telub Ab, Sweden). This instrument measures not only the amount of precipitation but also type, e.g. rain, snow or sleet. This information, in combination with the ordinary variables, "occasions with slippery road conditions" were defined from the RWIS-data set. The distribution of these occasions is presented in Figure 3.

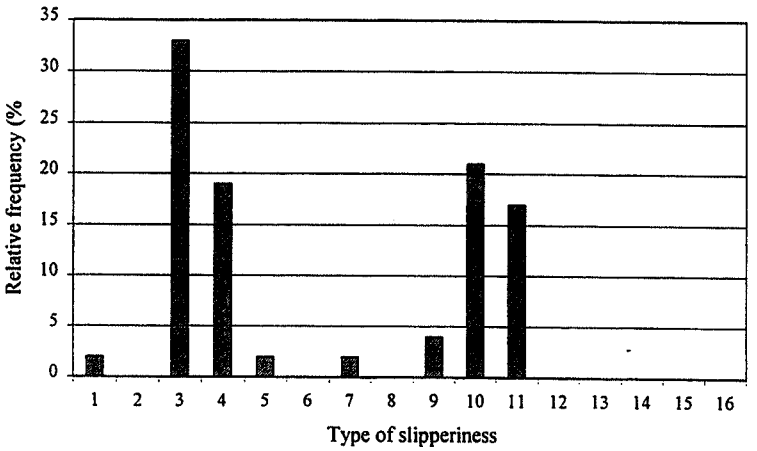

Figure 3 Type of slipperiness recorded in RWiS data set, February 1996. Totally 52 periods.

As in the maintenance reports, the most common type of slipperiness in RWiS data was snowfall. The second most frequent type of slipperiness was hoar frost due to radiation. It must be kept in mind, that an indication of sublimation is built on the theoretical relation between dewpoint temperature, road surface temperature and sublimation. This is not yet tested quantitatively, meaning that it is clearly a source of false alarms.

Neither of the secondary types of slipperiness are observed, as such information is not available from the RWiS.

Traffic accidents

The relation between road weather, road maintenance and road accidents are not so clear and should not be so. Any clear relation between road weather and road accidents indicates that there is a need for improvements in the safety measurements. Figure 4 present the frequency of slippery roads in the RWiS-data set, the reported maintenance activities and police reported traffic accidents in February, 1996.

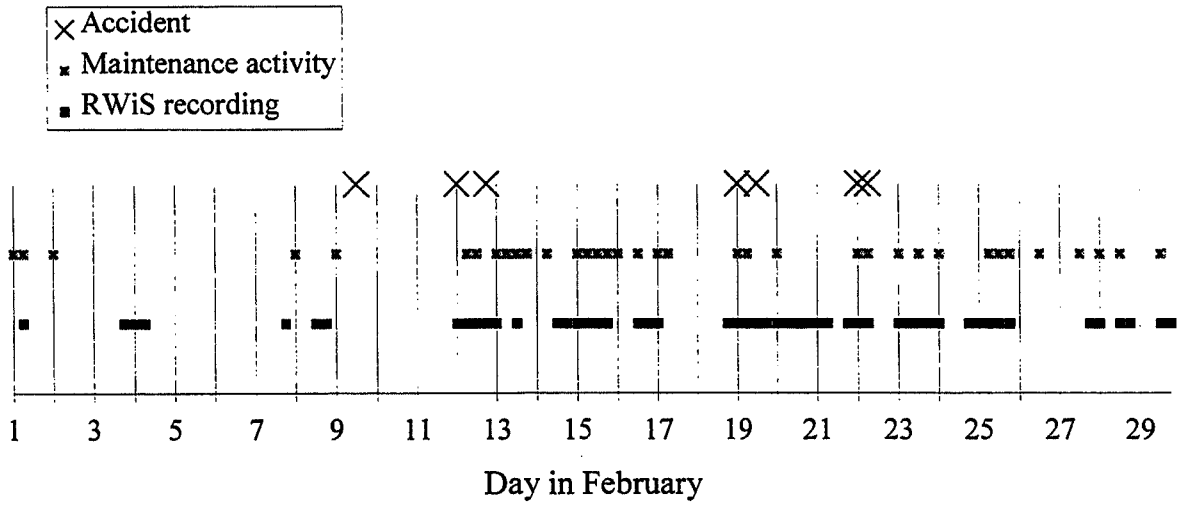

Figure 4 Periods with slippery road conditions according to RWiS recordings and periods of maintenance activities and police reported traffic accidents in the area.

From a visual interpretation of the information in Figure 4 it may seem that there has been more occasions of slippery road conditions than there has been maintenance actions. Once again one must remember that RWiS observations are more like an indication of the prevailing road conditions rather than the true conditions, as long as there is no information about the road surface. The maintenance reports are still the most reliable information because of the drivers on-site observation. Most of the traffic accidents though, did occur in between maintenance actions.

Traffic accidents reported in the area were compared with RWiS information from the time of the accident. The purpose of this was to see if there are any trends towards some specific type of road slipperiness. The result is presented in Figure 5.

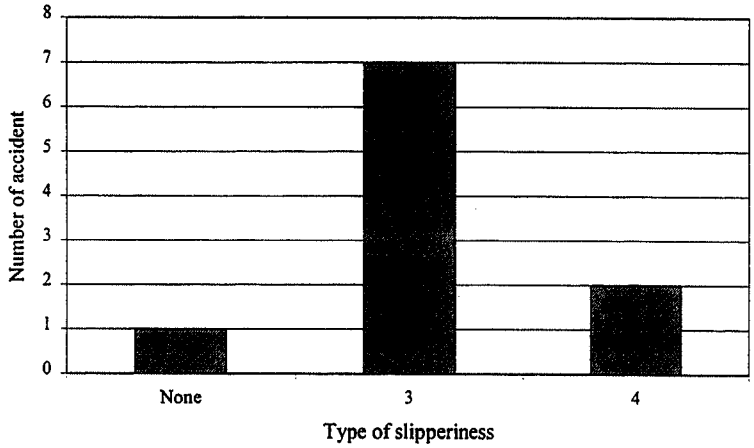

Figure 5 Type of slippery road conditions, based on RWiS data, at occasions with traffic accidents. Totally 10 accidents.

Out of ten accidents nine occurred during periods with snow on the road surface. This must be categorised as a not very hazardous condition as it is clearly visible. The risk for the road-user can be decreased by reducing the speed of the vehicle. The result indicate that the road-user does not associate the prevailing weather conditions with problematic or hazardous road conditions.

Discussion

The result from this initial study, agrees with the result of Öberg et al, 1991. Even if the hazard is clearly visible, the road-user does not adjust their speed. It also agrees with

Sävenhed (1995), that most traffic accidents occurs during snowfall. Even though there is a larger number of periods with slippery road conditions recorded in the RWiS-data than in the maintenance reports, Figure 5 indicates that the maintenance personnel have performed their work very well.

The result in this study fits quite well the seven different types of slipperiness on roads that were the result of the weighting in Lindqvist (1979). One difference could be that the most important type of slipperiness in February 1996, judging from frequency and the number of traffic accident reported in this study, should be direct snowfall (3).

There is clearly a need for more information about the road surface condition. Approximately 50% of the occasions are periods when water freezes onto the surface. It is very hard to estimate this from the ordinary set of observed variables. This is probably the reason why there is a larger number of periods recorded in the RWiS data set than periods when maintenance actions have taken place.

For what purpose should winter maintenance take place? Is it to keep roads trafficable or is it a measure of road safety? One must remember that the word trafficable also includes the travel time from one location to another. Industrial transports often have very tight schedules and therefore speed adjustment as an argument for safety will always have a limit. A limit that probably will be higher than the proper speed limit during the worst conditions.

Conclusion

The most frequent types of slipperiness on road according to the RWiS data in February 1996 were snowfall and hoar-frost. These two were associated with weather events such as snowfall and radiative cooling of the road surface.

The winter maintenance action where mostly taken during periods of snowfall and drifting snow, but also when there was of risk for water covering the road surface to freeze. This water-cover could be the same as hoar frost.

Most of the police reported traffic accidents in February 1996 did occur during periods with snowfall, which also was detected at the RWiS-stations. Therefore do these accidents not suggest any changes in the RWiS.

The result also indicates that it is important to present information from the RWIS about prevailing road conditions to the road-users. Preferably together with speed recommendations, when not all of the road user associate bad weather with low surface friction.

This study will continue with a larger dataset covering several winter seasons.

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