CLASSIFICATION OF ROAD SLIPPERINESS

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ABSTRACT

A method for classification of different types of slipperiness on roads in Sweden is presented together with two examples of applications based on the method. As a number of different types of slipperiness may develop on roads in winter, each due to a specific combination of meteorological variables, road maintenance work can be a complicated task. By using the slipperiness classification it is possible to survey road conditions in different areas and between different years to optimise winter road maintenance. The classification is performed with an expert system using meteorological data from the Swedish Road Weather Information System as input. The road condition is classified as either good or as one out of ten different types of slipperiness on roads. Examples of new applications based on this method are: I) Maps with road slipperiness distributions in Sweden. These maps increase the understanding of the problem and can be used as decision support when making traffic safety policies. II) Evaluations of relations between traffic accidents on slippery roads and winter road maintenance. As the most important purpose with winter road maintenance is to prevent traffic accidents on slippery roads, it is important to continuously evaluate the work to keep it as optimal as possible. An evaluation study performed in a southern part of Sweden showed that traffic accident rates are different for different types of road slipperiness.

INTRODUCTION

In Europe and North America, much winter road maintenance (WRM) work is done by the national road administrations to improve wintertime road conditions and thereby keeping up the traffic flow and decreasing the accident rate. The personnel responsible for road maintenance continuously monitor the meteorological conditions along roads in their area. The information is derived from a Road Weather Information System (RWIS), which has a high temporal and spatial resolution. The Swedish National Road Administration has more than 600 field stations equipped with sensors measuring several meteorological variables. The number of different types of slipperiness that may develop on roads in winter makes great demands upon not only the RWIS but also the ability to interpret the information. With a standardised slipperiness classification it is possible to objectively analyse RWIS information and survey the distribution of road slipperiness conditions in a region. A climatological description of road conditions increases knowledge of the problem and further improves the winter road maintenance.

There have been studies that climatologically described the road climate variations in an area (Cornford & Thornes, 1996). However, to our knowledge no operational classification of types of slipperiness on roads is currently available to compare road conditions in different areas or between different years. Several different climatological indices, e.g. Hulme (Hulme, 1982), COST (Voldborg & Knudsen, 1988) or GAB (Gustavsson, 1996), have been developed but they all describe the road climate in such a way that the need for winter road maintenance can be assessed from monthly or seasonally averaged meteorological data (Gustavsson, 1996). The GAB index, however, provides a classification of road conditions to describe the severity of a winter, using RWIS observations, but the criteria for the classification are the same as those for winter road maintenance and it is not therefore an exclusively climatological description of a season (Gustavsson & Bogren, 1994). Therefore, it is not possible to use those indices to investigate which type of road condition is most common in an area.

This paper presents a method for classification of winter road slipperiness. The classification method is constructed as a computerised rule-based expert system, which classifies RWIS-data into non-hazardous road conditions or a specific type of slipperiness on roads. Two applications based on the slipperiness classification are also presented.

METHODS

The WRM personnel have access to meteorological information about the road conditions in their area with high temporal and spatial resolution from a RWIS. In the Swedish RWIS a large number of field stations are situated at road sides, each equipped with sensors measuring air temperature (T_{air}), relative humidity (Rh) and road surface temperature (T_{road}). Observations are made every 30 minutes and the data is collected and stored in a central archive. Some stations also observe precipitation (P), wind speed (U) and wind direction. The dewpoint temperature (T_{dew}) is automatically derived from T_{air} and Rh.

From the RWIS observations, the road condition at the field station is classified as either not slippery or as one out of ten types of slipperiness. The classification is performed with a computerised, knowledge-based expert system. The different types of slipperiness are presented in Table 1, together with variables necessary for the classification.

Table 1: Ten different types of slipperiness on roads and the variables necessary for the classification.

Type of slipperiness	*Precipitation*	*Variables*
1. Rain or sleet on a frozen road surface.	Yes	P T_{air} T_{road}
2. Snowfall on a frozen road surface.	Yes	P T_{air} T_{road}
3. Snowfall or sleet on a warm road surface.	Yes	P T_{air} T_{road}
4. Snowfall together with hoar-frost	Yes	P T_{air} T_{road} T_{dew}
5. Hoar-frost and low visibility	No	T_{road} T_{dew} Rh
6. Freezing dew followed by hoar-frost	No	T_{road} T_{dew}
7. Strong formation of hoar-frost	No	T_{road} T_{dew} Rh U
8. Weak formation of hoar-frost	No	T_{road} T_{dew} Rh U
9. Drifting snow	Yes	P T_{air} Rh U
10.Watercover which freezes	Yes	P T_{air} T_{dew} T_{road} Rh

Six of the types are due to precipitation and the other four are due to sublimation. These two processes are responsible for the transportation of water to the road surface. Frozen water is crucial, as it is the media that reduces road friction to such a degree that the condition can be classified as slippery. Norrman (1999a) further describes the construction of the classification model.

The first four types of slipperiness in Table 1 are a result of precipitation. The different types of slipperiness that develop during occasions with precipitation are identified in combination with the other variables. On occasions with slipperiness type 4, water is transported towards the surface by two different processes, precipitation and sublimation. Snow sticks to the road surface and the ice cover will increase rapidly. The formation of hoarfrost is often associated with low visibility, due to high relative humidity. This can be classified as a specific type of slipperiness, as the low visibility may increase the traffic hazard. The low visibility criterion is based on measurements conducted by Ruppert & Schlup (1998). They found that when *Rh* is greater than 95%, visibility is reduced to less than 500 m. Another situation is when dewfall onto the road surface has preceded the hoarfrost event. When the road-surface temperature drops below 0°C, the already wet surface freezes and the hoarfrost further increases the ice cover. Heavy sublimation of hoarfrost may occur when there is a large downward flux of water vapour. If the water vapour flux were small, there would be only weak sublimation. To distinguish between heavy and weak formation of hoarfrost a wind criteria is used (Monteith & Unsworth, 1990).

For some situations it is important to study the previous weather conditions. Lindqvist (1979) presented two such types of slipperiness: snowdrift and when water cover on the road surface freezes as T_{road} falls below 0°C. Snowdrift occurs when winds are strong and when there is snow with drifting potential in the surroundings. The criteria for this type of slipperiness are vague; the snow has to be dry enough and the wind has to be strong enough. The criteria used in the classification are the same as those used by the road authorities when deciding if there is a need for maintenance activity. When water cover on the road freezes as T_{road} drops below 0°C, the water source is generally residual water from earlier rainfall or dewfall. This type of slipperiness uses criteria developed for the GAB-index (Gustavsson & Bogren, 1994).

TWO EXAMPLES OF APPLICATION BASED ON THE SLIPPERINESS CLASSIFICATION

Temporal and spatial distribution of road slipperiness

The distribution of hours with road slipperiness in southern Sweden has been investigated (Norrman, 1999b). In the study, number of observations with slipperiness at each RWIS field station was summed together as monthly totals to investigate the temporal and spatial distribution. The study utilised the average data from two winter periods, from November until April, 1996-97 and 1997-98. The interpolated distribution of the monthly values of hours with road slipperiness is presented in Figure 2.

In November the coastal areas and the most southern part have less then 60 hours of road slipperiness due to the maritime influence from the west. The number of hours with road slipperiness increases with both latitude and elevation. Elevated areas are located south of the lakes and in northwest, the southern parts of the Scandes. The influence from these two variables results in a border between the northern elevated part of Sweden and the southern part of Sweden. December has the largest variation with latitude. During December the inland has more than 240 hours with road slipperiness compared to 120 hours at the coast. In January no area has less than 120 hours of road slipperiness, which means more than 4 hours per day on an average. In February the distribution is patchy. The border between the northern and southern part of Sweden is also visible this month. February has the strongest positive trend with elevation of all the months. This is one reason to the patchy distribution. The number of hours with slipperiness drops substantially in March. Only the highest elevated area in the north has more than 120 hours with slipperiness. The distribution in the Southwest clearly show the influence warm south westerlies. Finally, in April most of Southern Sweden has less then 60 hours, 2 hours per day.

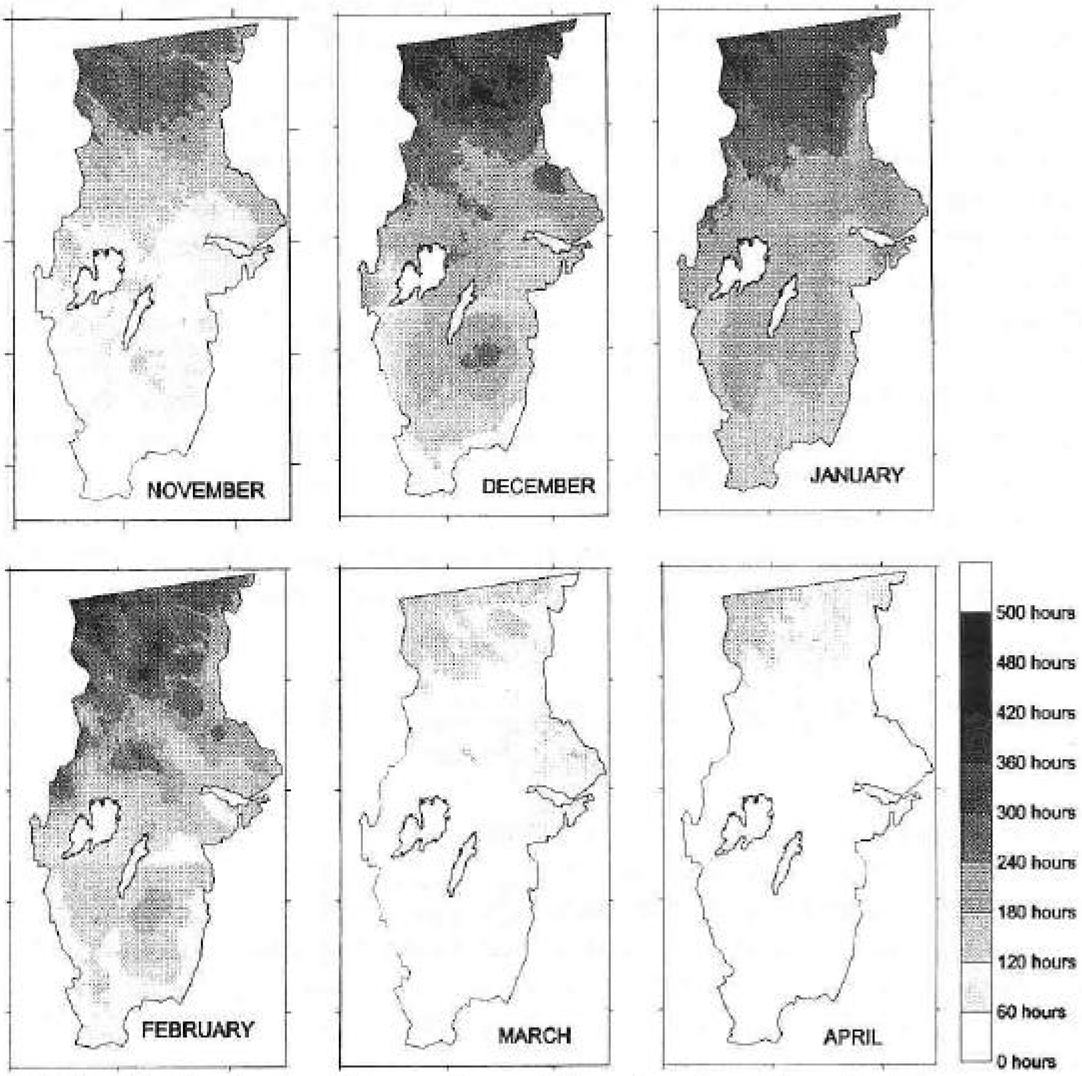

Figure 1: Monthly distribution of hours with road slipperiness in southern Sweden.

Traffic accidents due to slipperiness

An important purpose with winter road maintenance is to take measures against road slipperiness to prevent traffic accidents. In this section, a method for evaluating relations between road slipperiness, traffic accidents and winter road maintenance is presented (Norrman, et al., 1999). The evaluation reveals which type of slippery road condition that has the highest accident rate. The distribution of traffic accidents on the ten types of slipperiness was investigated by matching the classified RWIS data set with the time of traffic accidents for each separate area. The accident rate, A_{rate}, for each type of road slipperiness was derived from the number of hours for each type and the number of traffic accidents. If one assumes that all accidents during a month, A_m, are evenly distributed events not affected by different road conditions, the average number of accidents per hour is A_m/h_m, where h_m is the number of hours in that month. From this ratio an expected number of accidents could be calculated, for each specific type of slipperiness, when the duration of slippery conditions is known. To find the accident rate for a specific type of slipperiness, $A_{rate,\ t}$, the number of accidents on occasions with that type of slipperiness is divided with the expected number of accidents. The ratio, $A_{rate,\ t}$, was calculated for all types during three different winters in a Swedish county. If the ratio was 1, the number of traffic accidents that occurred during that type was the same as the expected number of accidents. If the accident rate was larger than 1, more traffic accidents had occurred than expected if evenly distributed. Largest number of traffic accidents occurred during precipitation (snow) on a frozen road surface (type 2), and precipitation (rain/sleet) on a frozen road surface (type 1), see Table 2.

Table 2: Accidents distribution and accident rate during on each type of slipperiness. For description of the different types of slipperiness see table 1.

Type of slipperiness	*Accident distribution (%)*	*Accident rate*	*Type of slipperiness*	*Accident distribution (%)*	*Accident rate*
Type 1	13	11.6	Type 6	2	3.2
Type 2	36	6.1	Type 7	12	2.5
Type 3	6	3.4	Type 8	11	4.5
Type 4	6	6.4	Type 9	5	1.5
Type 5	8	1.5	Type 10	1	2.6

Slipperiness due to type 1 had the highest accident rate, which indicates that these are hazardous occasions. The second most hazardous road condition was when snowfall and frost formation occurs at the same time, type 4. The data in Table 2 are based on a total of 234 accidents of which 85 occurred when road conditions were classified as slippery.

DISCUSSION

By using the classification it is possible to get a quantitative and elaborate measure of road slipperiness. With the classified data it is possible to investigate the temporal and spatial distributions and also to relate road slipperiness to other transport problem such as accidents.

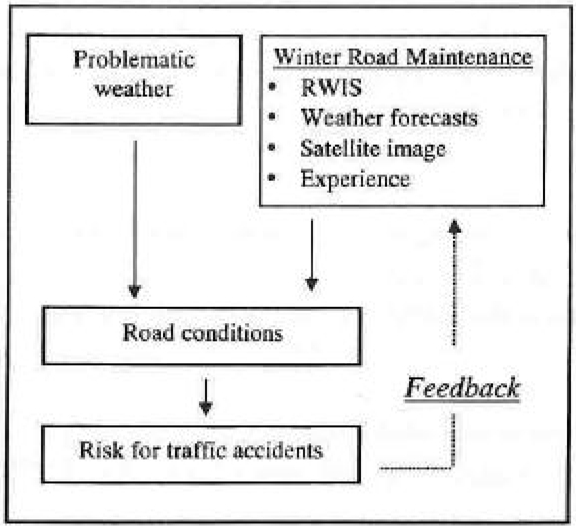

Figure 2: Flow chart showing the impact from weather on road conditions. Winter road maintenance is performed to improve the road conditions. By analysing traffic accidents and road conditions, the WRM receives feedback concerning their work.

The aim for these studies is to increase the knowledge about road slipperiness and how it affects road transportation. In Figure 2, a flow chart show how knowledge about road slipperiness can be implemented in the WRM.

In the flow chart, the weather affects the road condition and road slipperiness may develop. During such an occasion the risk for traffic accidents increases. By performing WRM the road conditions are improved and the number of hours with slippery roads is reduced. The feedback give information about how well the aim with for the WRM, no accidents due to road slipperiness, have been achieved for different types of road slipperiness. Examples of other evaluations in which this method can be used are: the effect of speed reduction instead of winter road maintenance or traffic flow instead of traffic accidents. This is possible as long as the road condition is classified with the standardised set of slipperiness types.

This paper also demonstrates the benefits of applying a standardised road slipperiness classification in all kinds of sources for road safety information: RWIS, traffic accident reports and WRM reports. With a standardised and objective classification of the road conditions and digitally stored data, all evaluations are easily conducted. With more knowledge of the relations between road slipperiness and traffic accidents the safety strategies can be improved. Examples of other measures to increase traffic safety during occasions with slippery roads could be to: Present information about the prevailing road condition to increase the public awareness of the situation or a temporary speed reduction in the area according to the prevailing situation. Introducing a system for presenting information to drivers is of course nothing that can be done in one working area alone, due to the large costs for build up of the system. By investigating which types of slipperiness that is most problematic and where they are most frequent, areas where an information system will be most needed can be identified.

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