

A statistical forecast model for road surface friction

Pulp Friction pilot

Introduction

Slippery road conditions increase traffic incident risk. Conventional road weather models have been developed to forecast parameters like road surface temperature and road condition. Such forecasts are useful tools in the hands of operational meteorologists in the process of producing road weather warnings, e.g. if the road weather is expected to be normal, bad or very bad. Also, road maintenance authorities use road weather forecasts extensively in the planning of their road maintenance activities.

Friction means the grip between car tires and road surface. In cases of dry and clear road the value of friction is typically around 0.8. Water, snow and especially ice reduce friction, and under very slippery situations the friction can be as low as 0.1. The connection between the description of road surface and friction values are presented in Figure 1. The definitions have been made by the Finnish Transport Agency.

Friction	0,00 – 0,14	0,15 – 0,19	0,20 – 0,24	0,25 – 0,29	0,30 – 0,44	0,45 – 1,00
Description of the road surface	Wet ice	Icy	Packed snow	Rough ice/ packed snow	Clear and wet	Clear and dry
Slipperiness classification	Very slippery	Slippery	Fair winter condition	Good winter condition	Good road condition	Good road condition
Road weather index	Very bad road weather	Bad road weather		Normal road weather		

Figure 1: Road weather classification made by Finnish Transport Agency.

The friction model presented here was developed by performing a statistical analysis of road weather observations measured with the Vaisala DSC111 sensors (Figure 2a) which measure the thickness of water/snow/ice layer on the surface optically and produce an

estimate of prevailing friction. There are presently more than 110 road weather stations along the Finnish road network equipped with the DSC111 sensor (Figure 2b).

Road maintenance activities, especially salting and gritting, improve the grip. Unfortunately, the information of road maintenance operations that have been carried out can not be covered by the road weather model because such data are not available at the moment. The condition of car tires and the road pavement may have significant impacts on friction but they are not covered in this application.

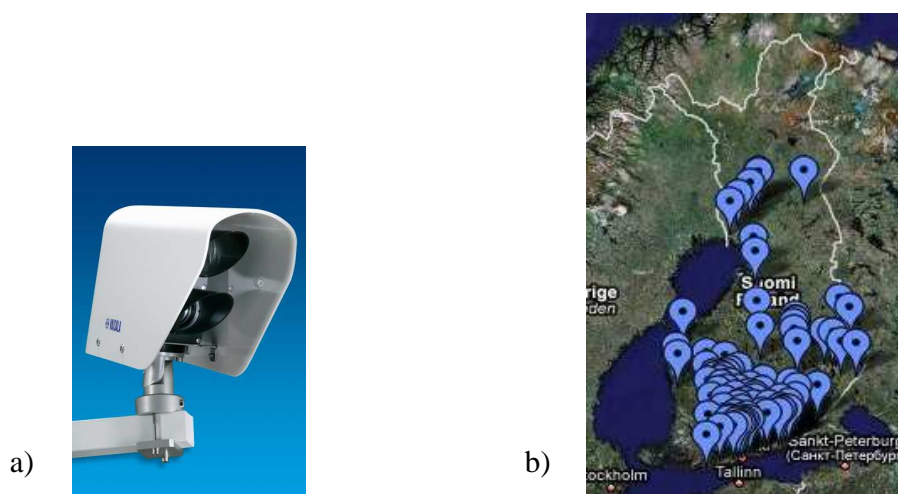


Figure 2: Vaisala DSC111 sensor (a) and locations of road weather stations with DSC111 sensors (b).

Friction model development

The friction model was developed by completing a statistical correlation analysis using road weather observations from some 20 stations equipped with Vaisala DSC111 sensors. Data were collected during winters 2007-2008, 2008-2009 and 2009-2010. The main undertaking was to define correlations between observed friction and other road weather parameters.

Observations are typically made every ten minutes at the road weather stations. The available data amounts are hence quite large and different kinds of winter time weather situations were covered. Winters 2007-2008 and 2008-2009 included occasional snow and ice but also warmer periods were encountered with water on the road surfaces and temperatures above zero degrees. Winter 2009-2010 was much colder with higher amount of snow.

Figure 3a presents a distribution of observed friction and the amount of snow and ice on the road surface at Anjala point (located in south eastern part Finland) in winter 2007-2008. The friction values decrease when the snow and ice amount increases although the distribution is quite wide. In cases of high amounts of snow and/or ice the measured friction is always low. Figure 3b shows the measured friction as a function of thickness of water on the surface. The distribution is quite narrow and the measured minimum value for friction is seen at around 0.5 in cases high amounts of water on the surface. Also a small temperature dependency was observed when there was ice or snow on the surface, but in cases of water there was no temperature dependency or it was very small.

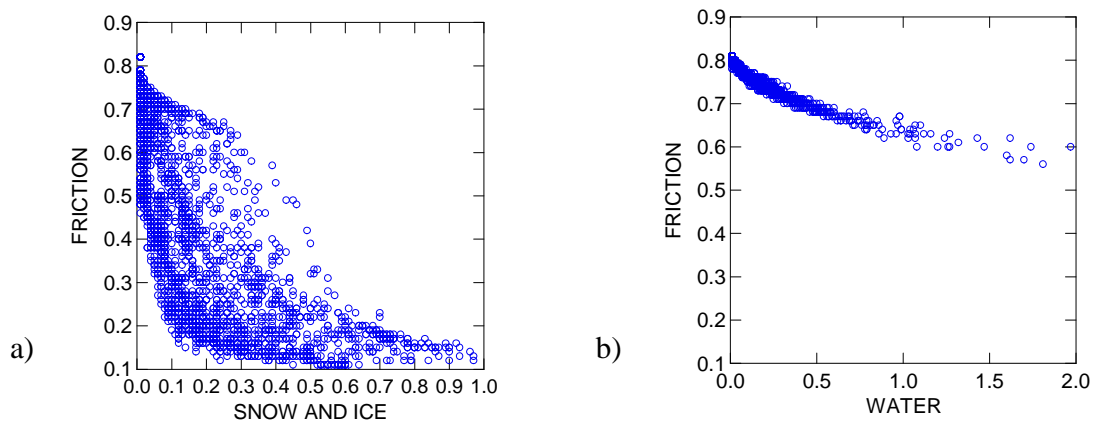


Figure 3: Anjala 2007-2008. Observed friction with ice and/or snow on the surface (a) and same for water (b). Snow and ice amounts are in equivalent mm.

Individual formulae were developed for (a) icy and/or snowy roads, (b) wet roads, and (c) clear roads. For icy and/or snowy roads, friction is a function of the thickness of ice and snow on the road and, including a small temperature dependency. For wet roads, the formula is a function of the thickness of water layer, only, and for dry and clear road surfaces, friction is a constant 0.82. This value represents the default maximum value of friction as measured by the DSC111 instrument. The resulting formulae are given below:

$$\text{Friction} = \begin{cases} A \times f(\text{Snow_mm}, \text{Ice_mm}) + B \times T_{\text{road}} + C & \Leftrightarrow \text{Snow_mm} + \text{Ice_mm} > 0 \\ D \times f(\text{Water_mm}) + E & \Leftrightarrow \text{Snow_mm} + \text{Ice_mm} = 0, \text{Water_mm} > 0 \\ 0.82 & \Leftrightarrow \text{Snow_mm} + \text{Ice_mm} = 0, \text{Water_mm} = 0 \end{cases}$$

All the required parameters of the friction formulae (Snow_mm, Ice_mm, Water_mm and T_road) are output parameters of FMI's road weather forecast model, so the model can produce friction forecast based on the given relationship.

Figures 4a and 4b present the capability of the derived statistical relationship (based on winter 2007-2008 data) to simulate the logic behind the DSC111 instrument utilizing an independent dataset from winter 2008-2009. Modeled (FC, x-axis) data was calculated using the observed thickness of ice/snow/water and the road surface temperature. Coefficients A-E in the formulae vary slightly for individual stations. The distributions shown here present Anjala results which look quite promising with relatively high correlation values as can be seen from the figures.

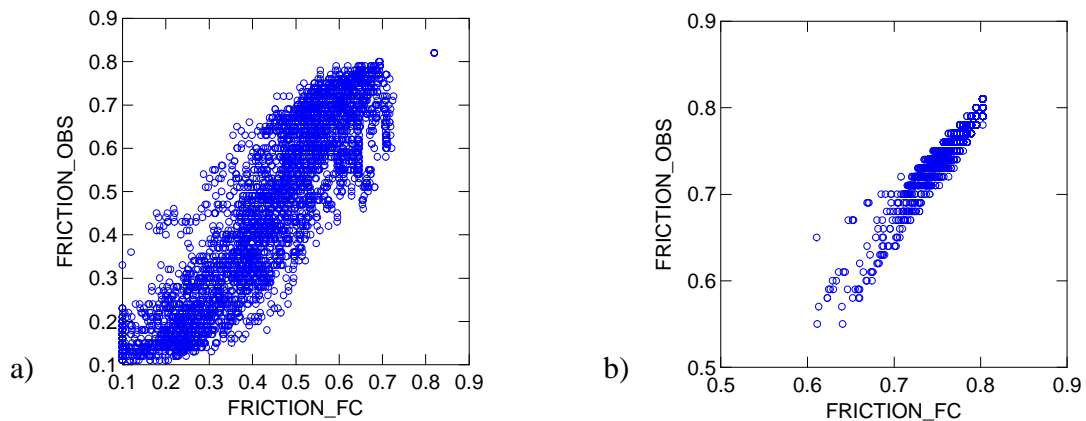


Figure 4: Anjala 2008-2009: Observed (OBS) and modeled friction (FC) in case of icy and/or snowy roads, correlation 0.89 (a). Same for water (b), correlation 0.97.

Operational friction model

The derived friction model is linked to FMI's present operational road weather forecast model. The model is tailored to run for point locations having DSC111 sensors installed (see Figure 2b). As of winter 2009-10 the number of stations is about 110. The model is being run operationally once an hour, and the model results are visualized in a format shown in Figure 5. The visualization can be seen at the site <http://pilot.roadidea.eu/friction/> and the service is provided together with Roadidea partners FMI, Destia and Demis. All of the locations have presently the same formula and same coefficients.

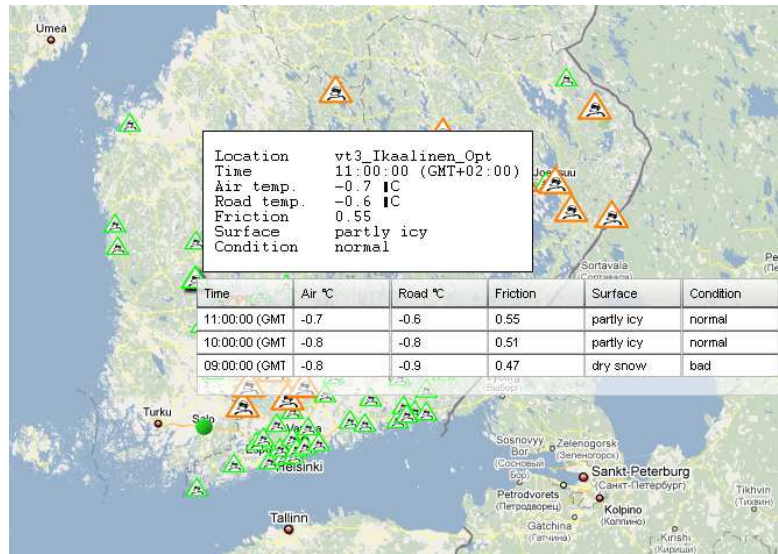


Figure 5: Forecasted friction and other road weather parameters presented in the Google maps ROADIDEA application. It is based on close collaboration between ROADIDEA partners FMI, Destia and Demis.

Another application is a mobile phone service which is presenting information of observed and forecasted road weather, figure 6. Also, photos taken by the nearest road weather cameras are presented. The service locates the user so the nearest road weather information can be seen via the service.

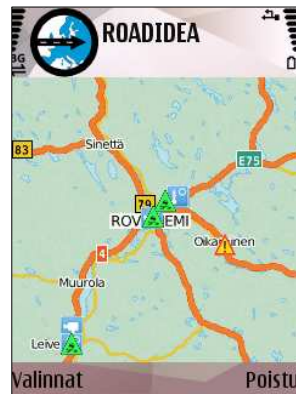


Figure 6: Mobile phone application presenting friction and other road weather forecasts.

The friction model produces quite good results when the road surface becomes icy. The observed friction decreases rapidly like does the modeled one. However, the modeled friction remains in many cases for too long at low values, whereas the observed friction starts to increase. This is most probably due to the road maintenance activities. Salting and snow plowing operations are carried out to get rid of existing snow and/or ice on the surface to have a better grip

One of the major bottlenecks in the friction modeling is how to tackle the road maintenance activities – or the lack of information of road maintenance activities that are being carried out. Information of salting and snow plowing operations cannot be covered by FMI's road weather model because the data are not available. Salting and snow plowing improve the road conditions. Friction becomes better and snow amounts on the roads reduce and, moreover, the freezing temperature changes because of usage of salt. For such reasons the road weather model forecasts quite often too bad road conditions and too low friction values.

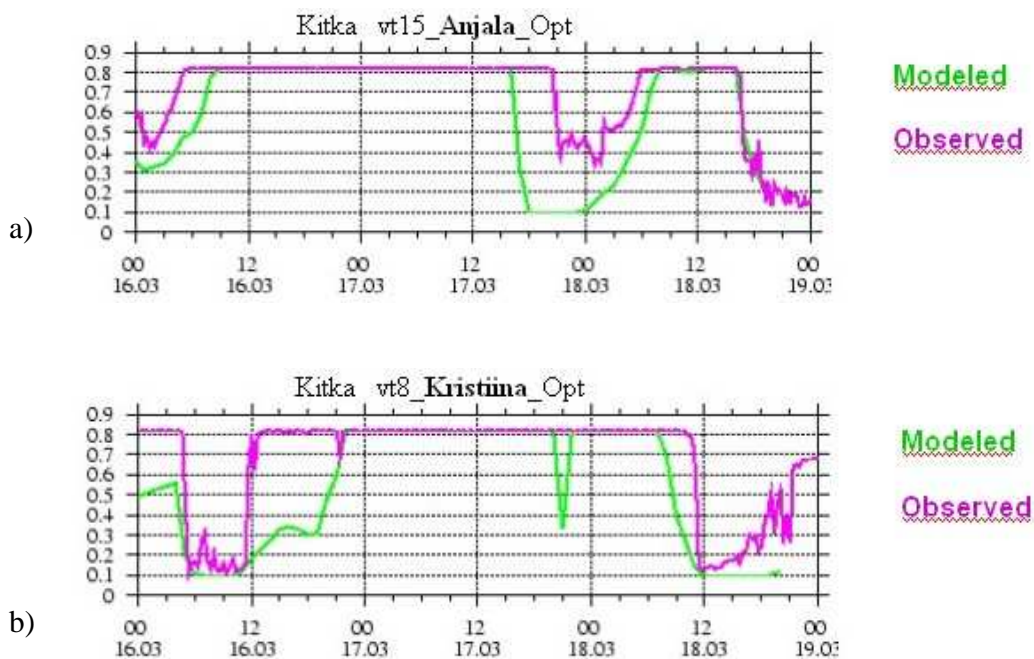


Figure 7: Examples of modeled vs. observed friction.

A further problem with the friction model is that the road weather model has usually too big storages for water/snow/ice/frost. When these storage terms of the model are too high the eventual friction values become too low. Therefore, the friction formulas must be further developed and/or the wearing of the storages must be adjusted.

Figure 7 presents two examples of the friction forecast model. In Figure 7a the modeled friction is too low because the model produces too much ice and/or snow and also because the road maintenance activities are not included. The calculated friction remains for a long time at a low level, whereas the observed friction reaches a better grip much more rapidly. Figure 7b shows a situation where the modeled friction follows the observations quite nicely.

Conclusions and future scenarios

The friction model is a new tool for road weather forecasting. The results and output of the friction model can be used by meteorologists and road maintenance authorities. Also, there

is available a mobile phone product for drivers. However, the presented bottlenecks must be solved in order to have useful forecasts. The worst of the bottlenecks is the lack of information about road maintenance activities. FMI's road weather model quite generally includes too high amounts of ice/snow/water leading too low values of forecasted friction, but this problem can probably be solved by developing the wearing effects of the amount of ice/snow/water within the model.

An idea to further develop the friction model is to generate own formulae for all individual calculation points, because there are large areal differences in road conditions in the country. Roads of the southern parts of Finland are usually kept free of snow, if possible, whereas in the northern parts of the country roads are quite generally covered by ice and snow. Individual formulae could take into account localized microclimatic features. Also, instead of deterministic forecasts it would be possible to develop probabilistic friction/slipperiness forecasts based on the developed friction model.