Correlation between floating car data and road weather information implemented for winter road maintenance follow-up by monitoring the road friction

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ABSTRACT

Winter road maintenance is essential for a functioning road network in regions experiencing long periods of winter. A lot of research is spent in the area of optimising winter road maintenance by searching for new sources of information. One possible source of information, which is soon to be implemented in Sweden for winter road maintenance follow-up, is floating car data (FCD) obtained from connected vehicles regarding road friction. This publication shows promising results of combining diverse sources of information regarding road friction, road weather and road maintenance operations for winter road maintenance follow-up before, during and after a snowfall.

Keywords: Winter Road Maintenance, Floating Car Data, FCD, Connected Vehicles, Road Friction, Road Weather Information System, RWIS, Mobile Reporting of Ploughing, MIP.

INTRODUCTION

Winter road maintenance is crucial for transportation in regions experiencing long winters with cold temperatures and ice- and snow-covered roads (*1, 2*). The digitisation of winter road maintenance has developed fast during the last few years, which is essential when the fleet of road vehicles going toward being fully autonomous (*3, 4*). To follow up on road weather, multiple authors have investigated the potential implementation of floating car data (FCD) to gain knowledge about current road conditions (*5, 6*) and to bridge the gap between road weather information system (RWIS) stations (*7, 8*). Recent research has shown promising numbers of coverage and reliability regarding the use of FCD from connected vehicles for winter road friction follow-up (*9, 10*). But questions remain about how the FCD could be interpreted together with information regarding maintenance operations, which would enable monitoring the road friction before, during and after an operation, independent of ongoing precipitation.

BACKGROUND & DATA SOURCES

Since 2018, the Swedish Transport Administration has procured FCD regarding road friction collected from connected vehicles in the project Digital Vinter. The aim of Digital Vinter is to investigate how FCD could be implemented for winter road maintenance follow-up instead of the methods used in Sweden today. The two most common methods in recent years have been the Corlaba, generating spot-wise measurements, and the ViaFriction or similar systems, generating continuous measurements. Both methods are force-based and estimate the tire slip, but they are both dependent on dedicated vehicles performing the measurements which makes it impossible to fully cover the road network in Sweden.

The FCD used in Digital Vinter is delivered by Volvo Cars and NIRA Dynamics, which both use information already implemented for other purposes such as vehicle-to-vehicle (V2V) communication. The friction measurements are based on information from systems such as the anti-lock brake system (ABS) and the advanced driver-assistance systems (ADAS). As for the traditional methods mentioned above, the friction measurements using FCD are force-based calculating tire slip, both in the longitudinal and lateral direction.

Besides FCD, the available sources of data used for this analysis are information from an RWIS station and the mobile reporting of ploughing (MIP) system. There are more than 800 RWIS stations along the 100,000 km of public roads in Sweden, and these stations generate information about current road and air temperature, wind speed, precipitation amount and type, humidity, and dew point, and for some stations estimation of the road friction. The MIP system collects data describing the type of maintenance operations carried out, including location and time. The maintenance operations which would be registered in the MIP system are ploughing, salting or ice removal. The RWIS stations and the MIP system is owned and operated by the Swedish Transport Administration.

RESULTS & DISCUSSION

Presented in the results is an analysis regarding the correlation between information gathered using FCD, RWIS and MIP for the potential implementation of FCD for winter road maintenance follow-up. The analysis is done for a stretch at Europe Road 4 (E4) located in northern Sweden along the coastline between the towns of Piteå and Töre, where the larger city of Luleå is in the middle. The total stretch is 95 km long and the directions of driving are wire separated, for at least half of the stretch there are two lanes in each direction. The analysis is done for 18 days in December 2022, and the closest RWIS station is in Ersnäs, close to Luleå. This part of Sweden experiences 150 days of snow in a normal year (*11*).

Combining data in this way gives a lot of information and knowledge of the road surface characteristics. During these 18 days, there is a difference in the daily average road friction as shown in Figure 1 (a). The drop in road friction is mostly correlated to the snow which is shown in Figure 1 (b), there is some snowfall for most of the days, but during the 8-11, 13 and 18 of December the precipitation goes above 20 mm. Looking at the temperature in Figure 1 (c), it is seen that after the 11 of December, there is a drop in the air temperature from -5°C to -15°C. This affects the road friction and the maintenance operation which was conducted, see Figure 1 (d), which shows the distance driven by maintenance operators per day.

Taking an average value for a full day is a bit rough, therefore in Figure 2 a close-up of December 6-9 is shown at hourly level. The layout of Figure 2 is the same as for Figure 1, with the friction, precipitation, air, road surface and dew point temperature and the length driven by the road operators. But in this figure, the data are presented hourly. Notable is that when the data is presented hourly, hours without FCD could be distinguished night-time, this is due to the lack of vehicles using the road for these hours. This lack of data has been discussed earlier (*10*), and is considered not to be too much of a problem since the planning of road maintenance often is done when the traffic is most intense, namely when we have the largest volumes of FCD.

In Figure 2 it is clear that the increase in snowfall causes a decrease in road friction while at the same time increasing the need for road maintenance operations. This is especially seen during the daytime of December 8. But when the data is divided into daily averages it is not completely obvious that the maintenance operations, Figure 2 (d), immediately increase road friction, Figure 2 (a). For example, after the snowfall when the air temperature, Figure 2 (c), is close to zero at noon on 6 December, the road friction decreases for a few hours after the precipitation has ended, Figure 2 (b), even if there are ongoing maintenance operations, Figure 2 (d). But after the snowfall during the daytime of December 7, the maintenance operations seem to immediately reverse the drop in road friction, Figure 2 (a). The main difference between December 6 and December 7 is the temperature, Figure 2 (c), which could imply that the difference in the behaviour of the road friction induced by the maintenance operation could be the use of salt as a deicer.

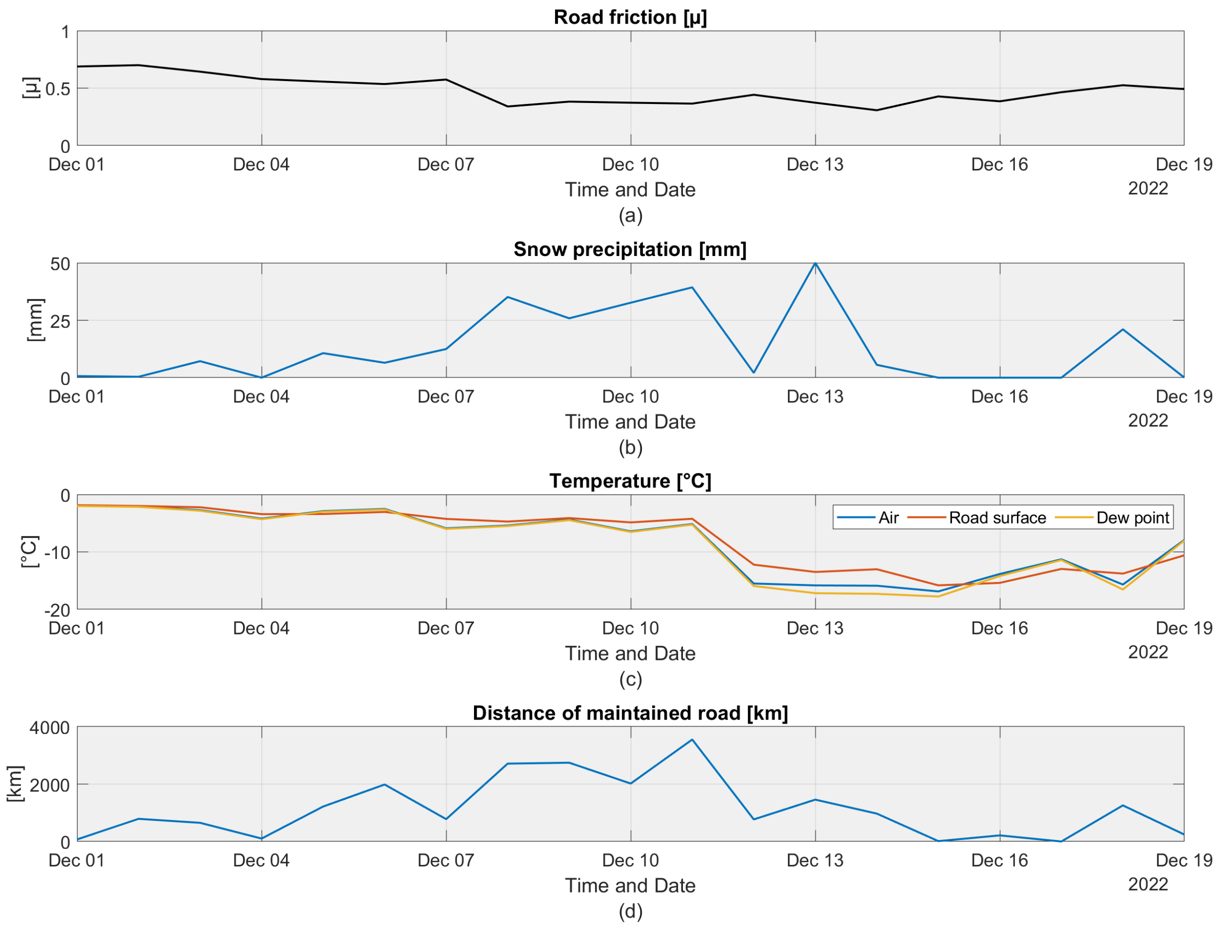

FIGURE 1 Daily data for the stretch of E4, 1-18 of December 2022. a) The average daily road friction (FCD), b) snow precipitation (RWIS, Ersnäs), c) air, road surface and dew point temperature (RWIS, Ersnäs), d) the daily distance of maintained road in kilometres (MIP).

CONCLUSIONS

In this publication, we combine data from diverse sources connected to winter road maintenance, FCD regarding road friction, RWIS regarding road weather and MIP which reports the winter maintenance operations done on a specific road. By combining the different data types, it is possible to follow the development of road friction before, during and after a snowfall, and see the effects of winter road maintenance when monitoring the road friction in combination with road weather information. In this case, we only analysed data for a few days during December 2022. But when implementing this type of data, it will be possible to apply self-learning algorithms looking into the efficiency and potential optimisation of winter road maintenance. Which most certainly will be beneficial both for the environment and for increased road safety.

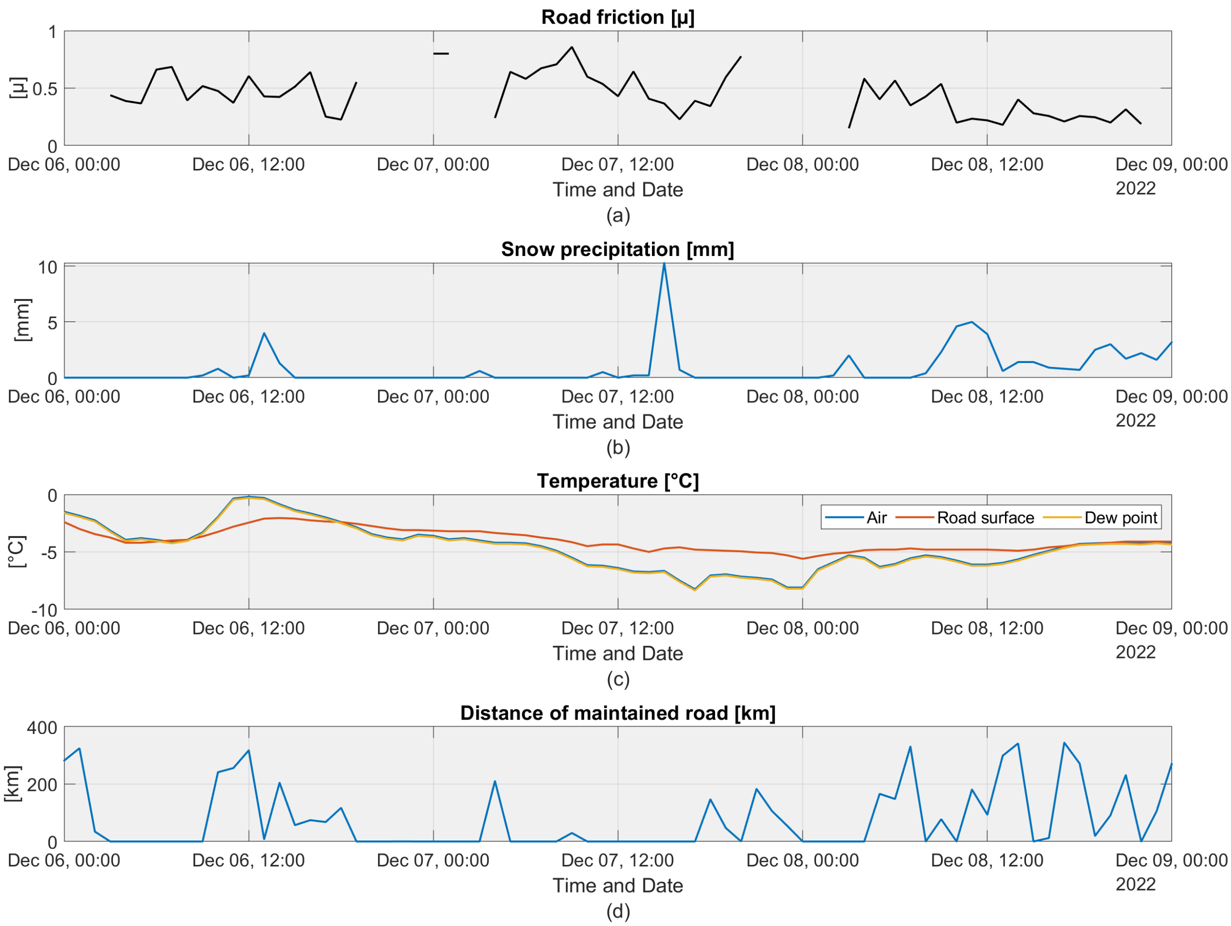

FIGURE 2 Hourly data for the stretch of E4, 6-8 of December 2022. a) The average hourly road friction (FCD), b) precipitation (RWIS, Ersnäs), c) air, road surface and dew point temperature (RWIS, Ersnäs), d) the hourly distance of maintained road in kilometres (MIP).

REFERENCES

1. Norrman, J., M. Eriksson, and S. Lindquist, Relationships between road slipperiness, traffic accident risk and winter road maintenance activity. *Climate Research*, Vol. 15, 2000, pp. 185–193.
2. Kilpeläinen, M. and H. Summala, Effects of weather and weather forecasts on driver behaviour. *Transportation Research Part F*, Vol. 10, 2007, pp. 288–299.
3. Litman, T., Autonomous Vehicle Implementation Predictions - Implications for Transport Planning. *Victoria Transport Policy Institute*, 2020, pp. 1–45.
4. Ødegård, I. and A. Klein-Paste, Do We Need a Change in Road Winter Maintenance to Accommodate for Automated Vehicles? A State-of-the-Art Literature Review Considering Automated Vehicle Technology's Usage of Road Infrastructure During Winter. *National Academy of Science: Transportation Research Board*, Vol. 2675, No. 10, 2021.
5. Ye, Z., X. Shi, C. Strong, and R. Larson, Vehicle-based sensor technologies for winter highway operations. *IET Intelligent Transport Systems*, Vol. 6, No. 3, 2012, pp. 336–345.
6. Casselgren, J. and U. Bodin, Reusable road condition information system for traffic safety

and targeted maintenance. *IET Intelligent Transport Systems*, Vol. 11, No. 1, 2017, pp. 230–238.

7. Odelius, J., S. Famurewa, L. Forslöf, J. Casselgren, and H. Konttaniemi, Industrial internet applications for efficient road winter maintenance. *Journal of Quality in Maintenance Engineering*, Vol. 23, No. 3, 2017, pp. 355–367.
8. Hu, Y., E. Almkvist, T. Gustavsson, and J. Bogren, Modeling Road Surface Temperature from Air Temperature and Geographical Parameters—Implication for the Application of Floating Car Data in a Road Weather Forecast Model. *Journal of Applied Meteorology and Climatology*, Vol. 58, No. 1, 2019, pp. 1023–1038.
9. Sollén, S. and J. Casselgren, Large-scale implementation of floating car data monitoring road friction. *IET Intelligent Transport Systems*, Vol. 1-13, 2021.
10. Sollén, S., Monitoring Winter Road Friction using Floating Car Data. *Licentiate Thesis - Luleå University of Technology*, 2022.
11. SMHI, *Normalt antal dygn med snötäcke per år.*, 2023-01-02, `https://www.smhi.se/data/meteorologi/sno/normalt-antal-dygn-med-snotacke-per-ar-1.7937`).