A performance evaluation of winter maintenance using high frequency friction data

Johan Petersson, Björn Zachrisson
WRI, NIRA Dynamics AB, Wallenbergs gata 4, 583 30 Linköping, Sweden, johan.petersson@niradynamics.se, bjorn.zachrisson@niradynamics.se

Summary

This paper proposes a data-driven method to measure and improve the quality of winter maintenance activities on roads using high frequency friction data. The method computes the percentage of low, medium and high friction measurements for districts where winter maintenance is applied and visualizes them over time as well as compute key performance indicators (KPIs). The result shows how the road conditions develop over time together with the weather conditions. The method becomes a measurements tool for winter maintenance that enables continuous learning, improvements and understanding the effects of changes. Policy makers can make use of the method to set appropriate service levels by including the information in cost-benefit analyses.

Introduction

An ever-increasing number of industries are turning to data driven approaches to inform decision processes and to solve complex problems as well as optimizing cost and revenue[1]. The winter maintenance industry is at the verge of being a part of this movement[2].

Data driven problem solving often contains vast amounts of data, this sometimes causes difficulties in understanding how to interpret, use, and access the actual insights. The first step is to identify the purpose for which the data is extracted and organized towards, this to enable easy access to the benefits. One purpose is to create a performance evaluation for winter maintenance activities.

Within the winter maintenance community there are many discussions and projects focusing on improvements to different technologies[3], processes, and techniques. For example, improved routes, use of novel chemicals, and in different amounts, the frequency of spreading, the width of the spread, better forecasts, etc. In any search for improvement, it is fundamental to evaluate the output before and after a change. In other words, "*If you can't measure it, you can't improve it*" - William Thompson.

Any service, either state of the art or legacy, must continually evaluate its performance to ensure requirements are met, that continuous learning and improvements can be achieved, and that the service is providing value for money.

The performance evaluation of winter maintenance operations has some great challenges.

- Simultaneous measurements are required in multiple locations.
- Measurements must be made continuously before, during, and after a winter weather event.
- Measurements of road user experience are important.
- Measurable winter maintenance requirements must exist to evaluate against.

In this paper a performance evaluation method for winter maintenance activities is described. It will also give recommendations for entities such as DoT's or municipalities seeking to create measurable winter maintenance standards and requirements.

Method

Performance evaluations may be carried out on different road network hierarchies e.g. road segments, road networks, district networks, or salt networks. This report focusses on the performance evaluation of districts. A district is defined as a set of roads with a single entity responsible for winter maintenance. The analysis was carried out at the district level as this resulted in a holistic view of the performance of a single responsible entity.

The performance evaluation was carried out as follows:

- For a given district over a relevant period and for each 30 minutes:
    - Count the number of low friction measurements
    - Count the number of high friction measurements
    - (optional) Count the number of medium friction measurements
    - Compute the percentage of low, medium, and high friction measurements respectively.
- Visualize the percentages over a period.
- Compute KPI’s depending on the local winter maintenance requirements.

The thresholds for low, high, and medium friction may differ depending on the winter maintenance requirements in the specific area. In this proposal the following definitions were used

- Low friction: [0.0, 0.4[μ
- Medium friction: [0.4, 0.7[μ
- High friction: [0.7, 1.0[μ

For the KPI’s the proposal is to compute the number of minutes where the low friction percentage is above a certain threshold, such as 5 or 10%. In other words, minutes is the unit of the KPI. The computation of the KPI should only be done whenever the requirements for winter maintenance need to be met.

Result

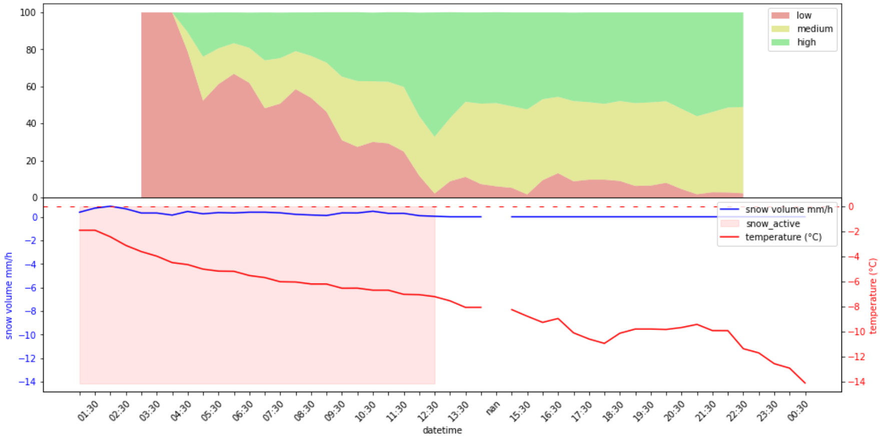

Fig. 1. Friction and weather data on primary roads visualized, Östergötland, Sweden, 2024-Jan-15.

The upper graph of Fig. 1 shows the result of the proposed method. White areas in the upper graph mean there were no measurements available at that time. The bottom graph shows the snow volume and the temperature (data sourced from openweathermap.org). It was snowing during the night and as soon as the first vehicles are active on the roads, in early morning, 100% of the measurements are low friction measurements. The graph then shows how winter maintenance crews were able to improve the road condition and when the snowfall ended, the roads could be stabilized at 5-10% low friction. This supports doing a cost-benefit analysis which makes it possible to assess the amount of money invested and the expected service level.

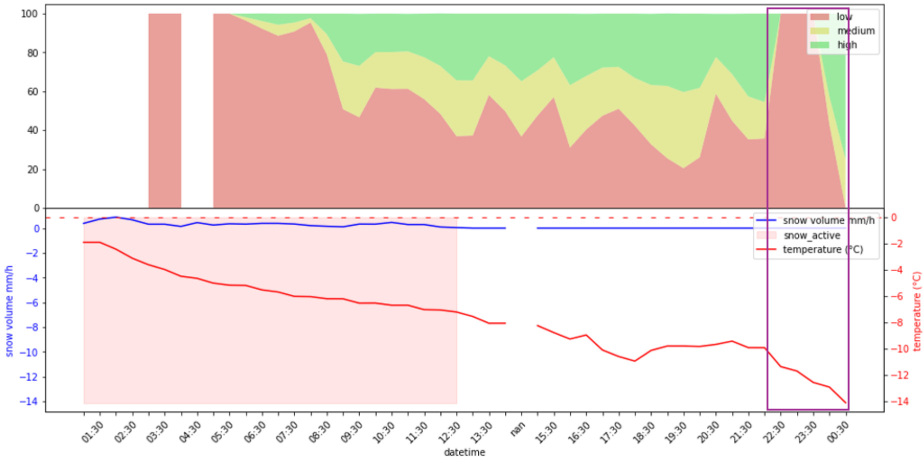

Fig. 2. Friction and weather data on secondary roads visualized, Östergötland, Sweden 2024-Jan-15. The purple square shows a peak in the percentage of low friction, happening at the same time as the temperature drops.

Fig. 2 tells a different story. Secondary roads have a lower traffic volume and a lower winter maintenance budget than primary roads. At the end of the snow fall the winter maintenance crew were able to keep the low friction at a level of 40-50%. Interestingly, a spike in low friction occurred in the late evening as the temperature dropped.

For reference Fig. 3 below shows the friction on a mild winter day. The temperature is above zero, the roads are slightly wet. No winter maintenance actions should be required if the temperature is above the freezing point.

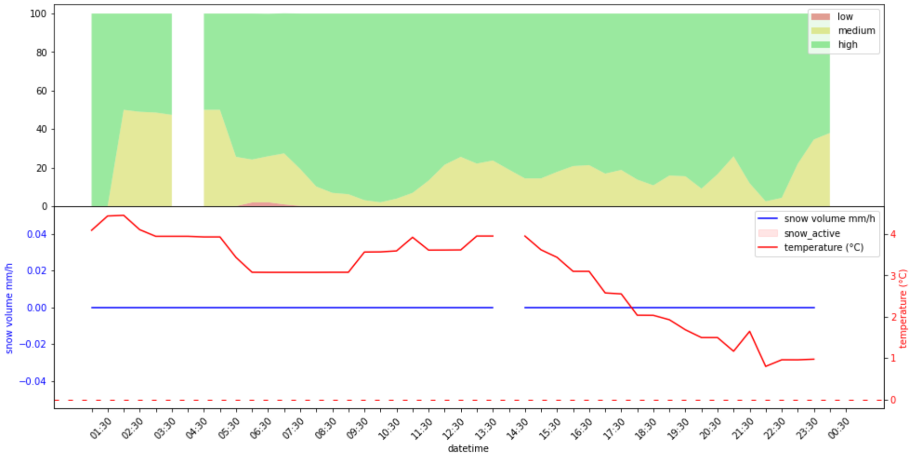

Fig. 3. Friction and weather data on primary roads visualized, Östergötland, Sweden 2024-Feb-01. Temperature above 0 and slightly wet roads.

Conclusion

Creating a universal KPI could be difficult as the requirements of winter maintenance differ between different countries, regions, or municipalities as well as within a region a suburban road and a highway have different needs in terms of safety and accessibility. However, they all depend on the same background data: friction, which is continuously collected over large parts of the road network creating an unrivaled performance measurement. All of them can even use the same metrics but parametrize the KPI: s differently.

- ***Tolerance:*** Sets the level of low friction percentage at which the winter maintenance approved.
- ***Definition of low friction:*** The threshold of when to count a measurement as low friction (for example, measurement below 0.4μ)
- ***Time after snowfall:*** The time after a snowfall when the winter maintenance requirements shall be fulfilled. (For example, 10% low friction measurements 2 hours after snow fall ended)

See Fig. 4 for an illustration of the KPI.

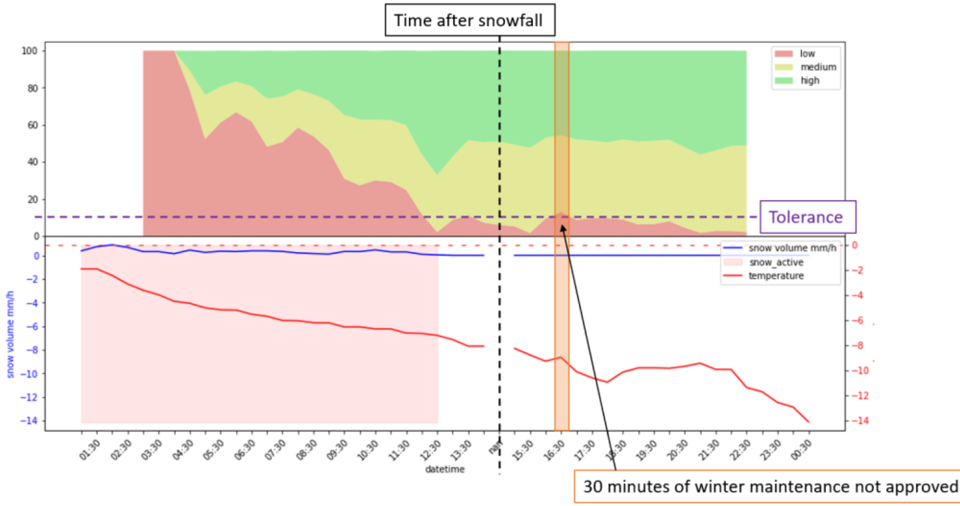

Fig. 4. KPI of winter maintenance illustrated. Purple line shows the tolerance parameter. Black dashed line shows the Time after snowfall parameter. Orange highlight shows when and for how long the winter maintenance was not approved.

Evaluating the performance of winter maintenance in this way does not only help with making improvements, but also gives insights of how the road conditions develop over time. It is now possible for policy makers to set appropriate service levels for their road network from a cost-benefit perspective. For example, having a service level at 0% low friction at all times is likely to be exponentially more expensive than ending up in the interval of 5-10%, after the end of a snowfall.

If the data is used together with other winter maintenance data, such as what actions were taken and when; it is possible to learn how to prevent events such as the spike of low friction seen in Fig. 2. Forecasters could learn how to detect such events and provide early warnings thus improving the winter maintenance further.

References

[1] McKinsey & Company, https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/how-six-companies-are-using-technology-and-data-to-transform-themselves (accessed 2024-02-21)

[2] Asp, A., Casselgren, J., Eriksson, D., Eriksson, C., Gustafsson, L., Johnson, A., … Wallin, M. **2021**. Slutrapport Införande av Digital Vinterväglagsinformation – ”Digital Vinter”. Retrieved from Trafikverket website: *https://urn.kb.se/resolve?urn=urn:nbn:se:trafikverket:diva-5070*

[3] Minnesota Department of Transportation *https://mdl.mndot.gov/index.php/_flysystem/fedora/2024-02/CR17-01Brief.pdf* (assessed 2024-02-21)