RSI A TOOL FOR DIGITAL TRANSFORMATION WITHIN THE WINTER MAINTENANCE

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ABSTRACT

The winter maintenance industry is starting to evolve from a tradition of using RWIS and basic weather forecasts combined with treatment schemes when making decisions about actions. With new big data sources based on IOT - from sensors, floating car data, laser measurement and connected winter maintenance vehicles combined with state-of-the-art climate models it is already today possible to predict, plan and follow up on all winter maintenance activities in real time.

Maintenance decision tools such as RSI provides a comprehensive amount of information that enables smart and efficient actions. Results from practical use of RSI shows that efficiency and cost savings are achieved. A case study from first year use of RSI in Lithuania shows that the learning curve of the employees is steep and benefits such as a 6-9% decrease of salt amount for maintaining good road condition (in 2020) is achieved and is expected to go even further. The integration of RSI in everyday winter maintenance tasks was a challenge by itself, but this allowed for an educated and more accurate decision making, easier integration of new employees, and most importantly – safer roads in Lithuania.

RSI – Road Status Information was born 2013 in a strong collaboration with the largest winter maintenance contractors in Sweden. The aim was to develop a new type of Winter Maintenance Support System for optimizing salting routes and variable spreading.

Today RSI is established in seven countries in Europe and are the largest provider of Road Weather Condition data for the Winter Maintenance industry. The user base with over 600 online users every day gather user decisions, prediction and outcome that builds a completely new vision and strategy for transformation of the Winter maintenance industry.
The paper presents the outcome, experiences and user cases from several countries based on accuracy, relevant data sources for winter maintenance and the vision of smart society.

1. INTRODUCTION

Efficiency in winter maintenance operations is a more crucial factor than ever before. The best winter maintenance practice must be developed and used in accordance with the needs and ever-growing expectations of the road users. The expectations for safe road conditions during and after a critical weather event are high. The winter road maintenance actions must result in top quality road conditions no matter what the weather conditions are to ensure that the traffic can flow without disturbance.

Weather data is the most critical component when deciding on how to respond to a winter event but today the possibilities to include multiple amounts and sources of data into the models for a well-functioning Maintenance Decision Support System (MDSS). Traditionally Road Weather Information Systems (RWIS) which are fixed-point sensor arrays which can provide ambient temperature, dew point temperature, relative humidity, wind speed and direction, road surface temperature, subsurface temperature, road status, precipitation occurrence, and type of precipitation has been used.

The digital transformation within the winter maintenance industry is growing and provides a wide range of opportunities and challenges. Until today traditionally information is demanded by contractors, but now real-time information will be delivered also to road users and soon this information will also be used for autonomous driving. Today there is plenty of data about roads, road maintenance and weather, which can be gathered, analyzed, and provided as input to a MDSS. [1]

Since maintenance activities can be a in conflict with environmental factors a MDSS also can be a factor for reducing the environmental load. Knowing not only when but also where and what action to take a MDSS will make it easier for the entrepreneur to plan and manage the workflow according to the actual road conditions. This ensures that the entrepreneur can reach cost savings when the number of driving loops and amount of anti-skid material is optimized according to where the risk is expected to occur. Studies in the Nordics indicates that the entrepreneurs were able to reach a cost saving for the road maintenance by 20% and not only costs were saved. [2] . As a result of increased efficiency less salt was used, and less unnecessary callouts were made. With less salt usage the environmental impact was significantly reduced as well. The MDSS is also important on following up on quality aspects, attract talents and a new data driven generation and the most important aspect; increase the safety on the road with less recourses.

To ensure a high-quality level of the road maintenance it is important that the maintenance operators and decision maker have access to the best and up to date tools that are available to facilitate and ensure a correct decision about acting or not. However, when implementing a new system and a new concept of operating in an organization it is important to be aware of that it takes some efforts and to overcome the overwhelming organizational and cultural changes this causes. This is in line with the quote by W. Edwards Deming “Two basic rules of life are: 1- Change is inevitable. 2 – Everybody resists change”. [3]
In this paper we will address three cases on users’ impressions on how a modern MDSS can be used to increase the efficiency in winter maintenance operations by reducing salt and plan maintenance activities. We also see that there are some real challenges by the user’s skepticism that must be overcome to reach the goal of full benefit.

2. STUDIED CASES - RESULTS

2.1. First case

The first case is based on experiences from Lithuania. During the winter 2018/2019 the organization responsible for the national winter maintenance activities started an implementation process of the MDSS RSI (Road Status Information) by Klimator for operational use. This was a first-time experience of a MDSS for the operators. Previously RWIS was the main source of information. The study is based on a comparison of an objective performance analysis of RSI and a subjective part where the users were interviewed about their opinion on the RSI performance. [4].

In the first objective step the “hit rate” of the road surface temperature (RST) forecast was investigated together with the road condition forecast. The hit rate expressed as a mean absolute error MAE of the RST forecast for 1, 4 and 10 hours for the winter period was 0.54 °C respective 0.6 °C table 1. Notably the winter season 2019/2020 had an exceptional warm ending with very tricky weather from a forecaster’s perspective. The result was also compared for the same period to the result from the RSI implemented in Sweden.

Table 1 - Mean absolute error for the road surface temperature (RST) forecast winter season 2018/2019 and 2019/2020.

Time for forecast calculation hour	Forecast period hours	Sweden average MAE °C 2018/2019	Lithuania average MAE °C 2018/2019	Lithuania average MAE °C 2019/2020
23:00	+0	0.10	0.14	0.14
23:00	+1	0.35	0.28	0.27
23:00	+4	0.72	0.68	0.58
23:00	+10	1.01	1.18	1.22
00:00	+0	0.10	0.14	0.11
00:00	+1	0.30	0.28	0.28
00:00	+4	0.65	0.66	0.58
00:00	+10	0.98	1.11	1.39
01:00	+0	0.10	0.14	0.11
01:00	+1	0.28	0.27	0.28
01:00	+4	0.62	0.65	0.59
01:00	+10	0.91	1.05	1.50
02:00	+0	0.10	0.14	0.11
02:00	+1	0.40	0.27	0.27
02:00	+4	0.85	0.64	0.64
02:00	+10	1.07	1.02	1.48
03::00	+0	0.12	0.14	0.11
03:00	+1	0.54	0.28	0.27
03:00	+4	1.14	0.64	0.77
03:00	+10	1.38	1.00	1.39
	Average RST for the seasons	0.59	0.54	0.60

Testing the hit rate for the slipperiness forecast vs measured slipperiness the 03:00 RSI forecast for +1h to +18h with 1 h steps during December - April was used. The test compared if the forecast could predict friction less than 0.6 and if it was in accordance with measurement. This included 214 422 samples and resulted in a hit rate of 92% for the total forecasted values.

The second evaluation part that was done was based on questionnaires to the users. In this questionnaire the focus was on the users experience of the system and its performance.

For the question about “hit rate” - the resulting answer on the question “How often Does RSI show a good forecast?” was on an average 47.8%. The 40 different users should rate on a scale between 0 – 100% where 0% meant none of the time and 100% meant all the time.

On the willingness to use the system the question “How often do you use the RSI?” this was followed by the question “How do you rate RSI?” and finally “How much did RSI change your work and decision making?”. The result of the answers is shown in table 2.

Table 2 - Questions about usage of RSI for the 40 first season new users.

How often do you use RSI?		**How do you rate RSI?**		**How much did RSI change your work and decision making?**	
Very rarely (up to 2 times/month)	30%	Very good	2%	Did not change	31%
Rarely (up to 4 times/month)	30%	Good	26%	In significant change	18%
Often (up to 8 times/month)	10%	Average	59%	Some change	44%
Very often (10 times or more)	30%	Bad	10%	Significant change	5%
		Very bad	3%	It changed a lot	2%

The answer about the usage of the system shows that 60% re reluctant to use the system indicating that there is a threshold to overcome when new technology is introduced. On the other hand, 51% says that some or more change was happening on how to take decisions about actions.

2.1. Second case

The second case was performed in Denmark where 12 RSI users where asked about how much they used and trusted the MDSS RSI. [5]. The questions that were raised were 1 – How much/often do you use the RSI? 2 – How do you rank the quality of the frost forecast?

3 – How do you rank the quality of the snow forecast? and 4 – How good is RSI for decision about call out?

Each question was to be answered with a ranking number from 1 to 5 where 1 is little/bad and 5 often/very good. Table 3 shows the mean results for the poll.

Table 3 - The result from the poll for different user groups. Mean values for each question.

User group – How much do you use the system?	**Rank of forecast quality - frost**	**Rank of forecast quality - snow**	**Rank of How good RSI is for call out decisions**
Little 1.2	3.0	2.0	3.0
Often 5.0	3.6	3.4	3.8
Average all users 3.55	3.6	2.9	3.3

The result from this case study shows that there is an increasing gain of trust in the system the more the operator uses the RSI. The "Often" users have a marked higher rating of forecast quality as well as call out functionality than the average and the "Little" users.

2.2. Third case

The third case is a comparison of MDSS RSI treatment suggestions vs contractor maintenance actions. Asking the question whether using RSI would reduce the number of actions performed when compared to the number of treatment suggestions that RSI provided during a winter season of 2018-2019 in the southwest and southern parts of Sweden. [6].

To test this, a cohort approach was chosen as a method, where several maintenance contracts (N=12) where placed in three separate cohorts depending on their usage and experience of using RSI. Then the ratio between the number of performed actions and the number of recommended actions for the different groups where compared.

The contract areas included in the study were chosen for the availability of historical treatment data and that this data had been included in the forecasts that where analyzed.

The user groups (cohorts) were defined as follows:
Cohort 1: no usage of RSI
Cohort 2: Novice to intermediate users (first or second season)
Cohort 3: Advanced users

To simplify the study only actions and recommendations for roads with a functional road class between 0-3 where counted. These functional road classes represent the larger road network within the contract areas and are mainly treated with preemptive salting.
We also chose to focus the study on preemptive salting actions, and thus we chose to only include situations with frost and ice formation and excluding snowfall.

To count actions and recommendations in a meaningful way the time period was split into 6-hour increments: 21:00-03:00, 03:00-09:00, 09:00-15:00 and 15:00-21:00. These timeslots were chosen to match the natural time periods for maintenance actions in this region.

To minimize the risk of counting an action twice by just getting the beginning or the end of the action in an extra time slot we chose a cut of point: for an action to be counted it needs to cover more than 10% of the total length of the road network (in functional road-class 0-3)

We also chose the same cut off point for treatment recommendations, with the addition of the criteria that the recommendation can come up to three hours before the time slot starts. So, for the 09:00-15:00 time slot, the recommendation could be posted at 03:00 and be counted for that time.

All the contracts had a ratio of performed/recommended that was above 1, i.e., they perform more actions than RSI recommends. And the average amount of performed actions was 114 actions for 86 recommendations. That gives an average Ratio of 1.4, see table 4.

Table 4 - Performance for the different contract areas according to cohort classification and RSI recommendations.

Contract area nr	**Cohort classification**	**Ratio**	**RSI recommendations**	**Performed actions**
1	3	1,2	43	53
2	3	1,3	69	90
3	1	1,8	51	73
4	2	1,4	126	173
5	3	1,1	105	119
6	1	1,5	90	135
7	2	1,3	88	114
8	1	1,6	75	116
9	3	1,1	116	131
10	1	1,6	57	93
11	2	1,2	126	156
	Mean:	1,4	86	114

When we divide the contracts into cohorts based on their experience of using RSI we can see that cohort 1 has an average ratio of 1,6. Cohort 2 has an average ratio of 1,3 and cohort 3 has an average of 1,2, table 5.

Table 5 - Average ratios for the three different cohorts.

Cohort 1	Ratio	Cohort 2	Ratio	Cohort 3	Ratio
1	1,8	2	1,4	3	1,2
1	1,5	2	1,3	3	1,3
1	1,6	2	1,2	3	1,1
1	1,6			3	1,1
Average	1,6	**Average**	1,3	**Average**	1,2

The spread within each cohort can be viewed in figure 1 below.

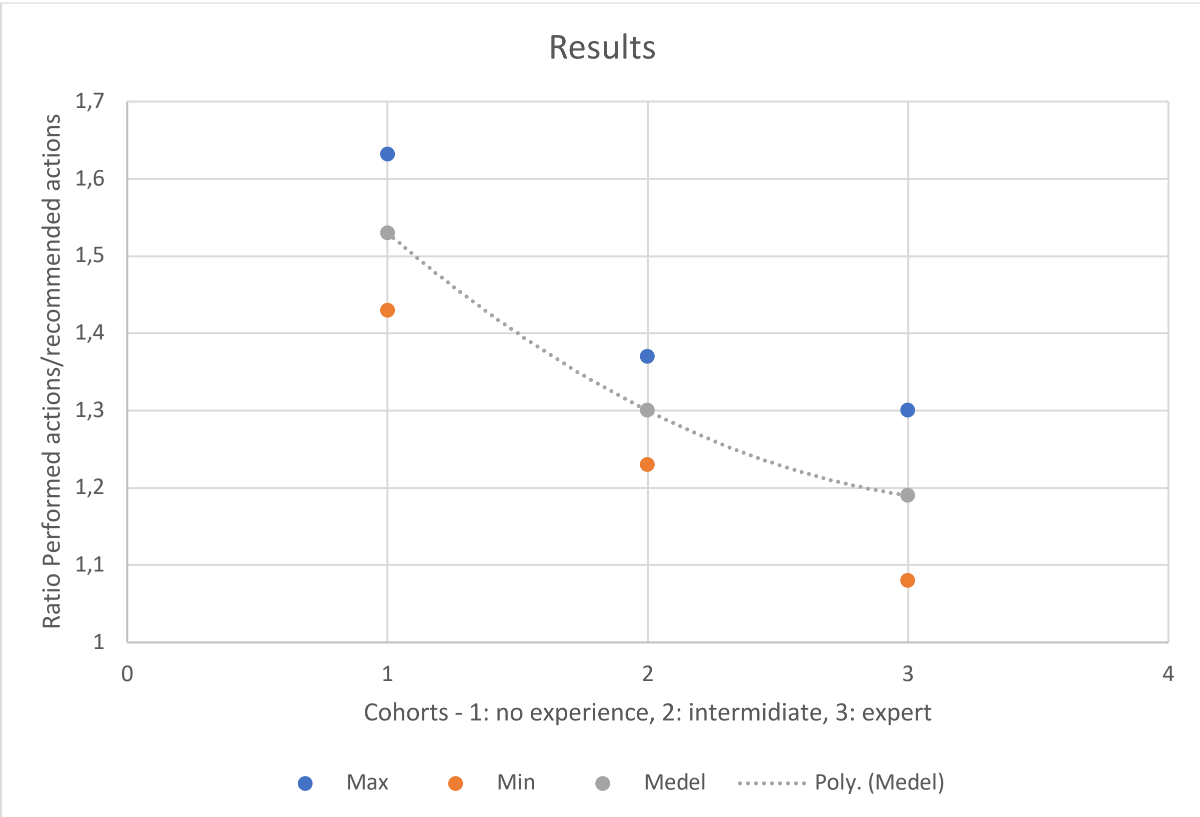

Figure 1. The spread within each cohort.

When we compare the results for the three cohorts, we can see that there is a marked difference between the cohorts. Here cohort 1 stands out as having a much higher average ratio but also the lowest ratio within the cohort is higher than the highest ratios found in both cohort 2 and 3. Between cohorts 2 and 3 there is some overlap with the average for cohort 2 and the maximum for cohort 3 being almost the same. The average for cohort 3 is lower than the lowest ratio for cohort 2.

This indicates that there is an optimization potential in using RSI as compared to the old RWIS system used by cohort 1. The lowering in ratio between cohort 1 and cohort 2 is the largest and would suggest that by just using RSI at a basic level gives the user better information and more confidence to not take unnecessary actions.

The result shows that the contracts in cohort 2 made 23% fewer actions than cohort. In cohort 3 (the experienced users) made 37% fewer actions than cohort 1.

3. DISCUSSION AND CONCLUSION

The digital transformation within the winter maintenance industry has started in the Nordic countries and has provided a wide range of opportunities and challenges. For the contractor big data and AI-based climate models together with a modern MDSS can be used to increase the efficiency by reducing salt, plan maintenance activities, follow up on quality aspects, attract talents and a new data driven generation and the most important aspect; increase the safety on the road with less recourses.

There are several goals with a big data based MDSS:

- Multiple data sources combined provide a significant more accurate forecast that can discover, warn, and visualize severe conditions. When, where and what.
- Big data colored on forecasted and segmented roads gives the contractor a precise overview over the contract area and witch parts that has a risk of wet, snowy, or icy road and witch actions that are relevant. Based on the information the contractor can create individual plans based on weather events combined with local focus. With a new strategy based on this treatment strategy – the contractor will potentially earn:
    - 10-30% yearly cost reduction of salt, fuel and personnel.
    - Contribution to create a sustainable world
- The contractor and the road authority can share and analyze activities in real time and work together with a continuously improvement av road safety.
- New relevant data sources such as floating car data or IOT sensors can easily be adopted and provide even more precise forecast based on local conditions and contractual aspects.
- The digitalization process within the field attracts new technologies that is more cost effective and more accessible than existing systems.
- The aggregation of data and combination with forecasting, maintenance activities and the result are also subject for new business models that attracts other market segments.

However, the transformation from a low-tech to a high-tech industry does not come easily by itself when new technology is implemented. Organizations and users need initial time and education to be prepared and convinced about the benefits of smart decision support systems. There is also a need for leadership and management to clarify the short and long objectives to drive the transformation when the business models are challenged.

The three case studies presented in this paper are showing that when implementing a new technology there is an initial resistance and skepticism against the all the new. But that when the initial user threshold is overridden the benefits show up which can help the contract area and contractor to reduce both costs, and the environmental footprint of the operations.

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