ENSURING AND QUANTIFYING RETURN ON INVESTMENT THROUGH THE DEVELOPMENT OF WINTER MAINTENANCE PERFORMANCE MEASURES

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ABSTRACT

The Idaho Transportation Department (ITD) budget is approximately $7.5 million annually for winter maintenance materials, $12 million for snow plow operations and $6 million in operator salaries. However until recently, it was difficult to assess how well the money was being spent and what efficiencies in terms of mobility and safety were being realized on our road network. ITD places a high priority on providing excellent customer service and this extends to our winter road operations for the traveling public.

This paper describes how two key performance measures for winter maintenance were developed and implemented. It also outlines some of the immediate and potential benefits of the performance measures.

Key Words: ITS, winter maintenance, performance measures, RWIS, mobility, safety.

BACKGROUND

Idaho has a very diverse geography, ranging from high desert to mountainous terrain as illustrated in Figure 1 below. The Idaho Transportation Department has, over the years, developed a progressive winter maintenance program which involves investment in a number of areas such as labor, training, equipment and materials. Typical treatment materials include salt, salt brine, magnesium chloride and anti-skid. These materials are applied by a winter maintenance operations fleet of 500 plus vehicles to maintain highways in order to promote safe travel and winter mobility.

Figure 1 – Idaho Terrain

ITD has currently deployed a network of 99 Road Weather Information Systems (RWIS) statewide to monitor atmospheric and pavement conditions. The roadside RWIS stations are polled on 15-minute intervals and data is plotted to track trends that reflect ice/snow build up or removal, air and pavement temperature changes and surface friction. Maintenance staffs are able to review the data plots and make decisions about road treatment options, application rates and treatment timing.

When the RWIS system was first introduced, there was a mixed reaction from staff, both positive and negative, as to how the data should be used and applied. However there has been a gradual acceptance and increased use of the data within the winter decision making process. In particular, two early ITD adopters of the system began to realize that there were patterns in the RWIS data that could be directly linked with winter maintenance operations.

The RWIS sites include atmospheric sensors and remote pavement sensors. The data received from the pavement sensors includes: road surface temperature, surface condition (e.g. dry, wet, snow and ice), layer thickness and friction coefficient ("grip").

It was the latter parameter, grip, which allowed the users to make an easy connection between a storms severity and the impact it had on vehicle mobility. The grip level is provided as a number, as per international convention, between 0 and 1. Higher numbers indicate good grip, so a figure of 0.82 would indicate bare pavement, whereas lower numbers, such as 0.1 would indicate the presence of snow or ice and very slippery conditions. Users in Idaho made the following observations (figure 2):

- > 0.6 usually dry (or wet) surface
- 0.5 to 0.6 slush or ice forming
- 0.4 to 0.5 snow pack or icy
- 0.3 to 0.4 icy - vehicles may start sliding off
- <0.3 icy - multiple vehicle slide offs possible; mobility greatly affected

Figure 2 – Grip Descriptions

The grip reading is derived from the Vaisala DSC111 sensor, which is based on active transmission of infrared light beam on the road surface and detection of the backscattered signal at selected wavelengths. By proper selection of wavelength it is possible to observe absorption of water and ice practically independently of each other. Since white ice, i.e. snow or hoar frost, reflect light much better than black ice, these two main types of ice can be distinguished as well. The observed absorption signal is readily transformable to water layer, to ice layer or to snow/frost amount in millimeters of water equivalent. With this information it is straight forward to determine the surface state as dry, moist, wet, icy, snowy/frosty or slushy. By correlating the surface state with a decelerometer it was possible to derive friction values.

From 2010 to 2012, ITD developed and refined the relationships to produce two winter maintenance performance measures:

1. Winter performance index
2. **Storm Severity Index**

The Winter Performance Index is derived using a two step process starting with the Storm Severity Index that uses sensor data inserted into a formula (wind speed, surface precipitation layers and surface temperatures) to calculate an index value. The Storm Severity Index value is then inserted into a formula along with the ice-up duration to establish the Winter Performance Index. This value is then compared with a performance scale (typically 0.00 to 0.7 with a goal of 0.5 or less) to identify how successful the road treatment and timing were by the field maintenance personnel.

Storm Severity Index = **WS** (Max) + **WEL** (Max) + **300/ST** (Min)

Where the following units are used:

WS = Wind Speed (mph)
WEL = Water Equivalent Layer (millimeters)
ST = Surface Temperature (degrees F)

[Index range is 10 to 80 for typical storm events with severe cold and high winds running as high as 500]

Winter Performance Index = **Ice-Up Time** (hours) / **Storm Severity Index**

Where:

Ice-Up Time is when the grip is below 0.6 for at least a 30 minute period
The goal is to have a Winter Performance Index of 0.5 or less.

Figure 3 – Storm Severity Index Formula

WINTER MOBILITY INDEX

The Winter Mobility Index (0-1.00) is derived using the percentage of time the road conditions did not significantly impede mobility during a storm event (safe “grip” value of 0.6 or higher) when precipitation was on the surface with below freezing surface temperatures being observed.

The calculations of the two indices was initially a manual process, with detailed analysis of each winter storm performed for each set of RWIS surface and atmospheric data. This proved to be a laborious task, so ITD partnered with Vaisala in order to automate the process allowing the results to be produced much quicker. By integrating the model and algorithms directly into the RWIS program visualization application (Navigator II), maintenance managers can now view the results of their maintenance performance almost immediately after each winter storm has passed. Both the Winter Performance Measure and the Winter Mobility Index tabulations are shown in Figure 4.

Storm Performance Index Legend	
0	Successfully treated
0.00 - 0.30	Significantly accelerated grip recovery
0.31 - 0.49	Some success at grip recovery
0.50 - 0.69	Very little success at deicing
0.70 -	Limited maintenance or no deicer success
	Observation data / parameter missing or temp is below threshold

Station	Date	Time Range	Event	Duration (hours)	Max Wind Speed (mph)	Max Ice Layer (mm)	Max Snow Layer (mm)	Max Water Layer (mm)	Min Surface Temp (°F)	Severity Index	Performance Index	Mobility Index	Comments
D1 - 4th of July Pass													
	22.02.201	12:45 - 22:00	TREATED	9.25	6.26	0.12	0.11	1.12	29.30	17.62	0		
	22.02.201	22:00 - 22:30	GRIP<.6	0.50	5.82	0.00	0.00	1.17	31.10	16.63	0.03		
	22.02.201	22:30 - 07:15	TREATED	8.75	10.96	0.03	0.01	1.02	27.50	22.89	0		
	23.02.201	07:15 - 08:00	FROST trea	0.75	5.37	0.00	0.00	0.03	27.14	16.45	0	96%	
	23.02.201	08:00 - 08:45	TREATED	0.75	3.13	0.05	0.14	0.05	27.32	14.25	0		
	23.02.201	08:45 - 09:15	GRIP<.6	0.50	4.03	0.05	0.20	0.00	26.78	15.43	0.03		
	23.02.201	09:15 - 11:30	TREATED	2.25	6.71	0.03	0.10	0.32	26.06	18.54	0		
	23.02.201	18:00 - 21:00	FROST trea	3.00	4.03	0.00	0.00	0.01	26.96	15.16	0	100%	
	25.02.201	07:00 - 10:15	TREATED	3.25	4.92	0.16	0.21	0.28	26.24	16.63	0		
	25.02.201	10:15 - 11:30	GRIP<.6	1.25	1.79	0.08	0.27	0.03	28.22	12.69	0.10	80%	
	25.02.201	11:30 - 13:15	TREATED	1.75	9.84	0.04	0.06	0.59	28.22	21.06	0		

Figure 4 – Layout of Winter Performance Measure and the Winter Mobility Index

The goals of the Winter Maintenance Performance Measures are tied directly to ITD's Strategic Plan:

- Track progress to maintaining safe roads
- Track progress to maintaining mobility
- Promote economic opportunity by minimizing weather impacts on commerce
- Achieve greater uniformity in winter operations statewide
- Promote a cost-effective winter road maintenance program within available resources

RESULTS

Each of the six ITD Districts deals with its own specific winter maintenance challenges that are defined by topography, weather patterns, highway usage, maintenance resources available and maintenance priorities. Therefore, the results should be viewed in relative terms rather than comparing one area of the state to another area. The focus is to build tools for managing winter performance improvements for each district, starting with baseline data that was gathered in the most recent winter season.

Through the winter of 2011-2012 the results by ITD district are shown below in Table 1.

District	Number of Storm Events	Average storm duration (hours)	Percentage of Storm Events that ice/snow durations significantly reduced	Average time to recovery (hours)	Winter Mobility Percentage

1	439	15.2	66%	5.7	63%
2	164	8.9	67%	5.5	39%
3	290	10.8	64%	5.9	46%
4	340	7.2	91%	3.7	49%
5	294	9.7	89%	3.8	60%
6	382	15.4	66%	11.8	23%

Table 1 - 2011-2012 the results by ITD district

Data collected over the past three winters (2010-2013) indicates a positive trend on the Mobility Performance Index as shown in Figure 5.

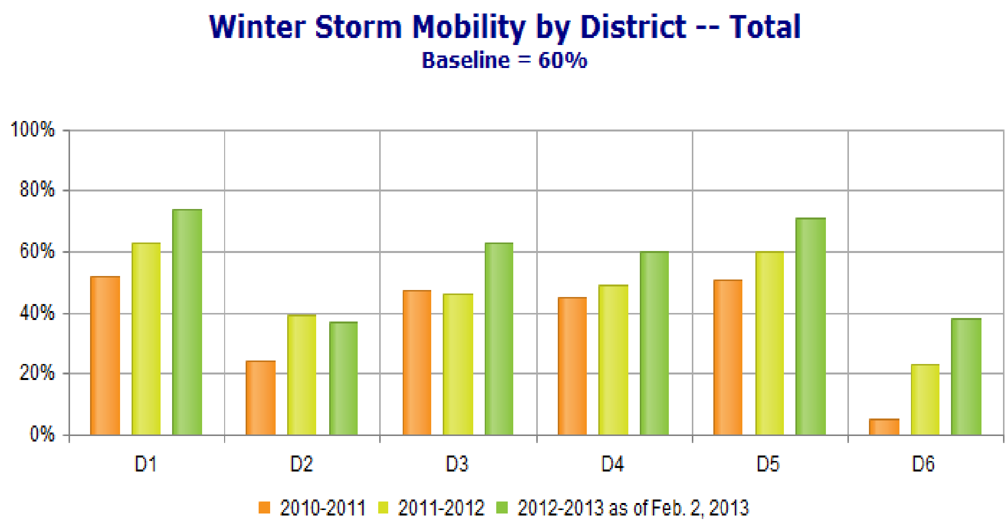

Figure 5 - Data collected over the past three winters (2010-2013) indicates a positive trend on the Mobility Performance Index

NEXT STEPS

ITD plans to continue monitoring the Winter Performance Measures and make any adjustments to the formulas as necessary to more closely model and correlate the Winter Performance Measures to winter road conditions experienced by our customers. ITD also plans to add RWIS sites at strategic locations to increase the sampling density. Training and coaching are also important components of the winter maintenance program and need to be provided to the maintenance staff on a continuing basis.

CONCLUSIONS

The adoption of winter maintenance performance measures has created the ability for ITD to quantify storm event severity, index the response into a measureable efficiency and then allow the ITD districts to make adjustments to improve winter operations that were not previously recognizable or quantifiable. This has been highly beneficial to ITD and the traveling public.
ITD intends to continue the use of Winter Performance Measures and analysis to improve services to our customers, increase our own efficiencies and reduce costs to the taxpayers. While going through the development process ITD realized that the benefits they we were seeing with respect to the return on investment in the RWIS program could

be utilized by other highway operators and these benefits are potentially enormous when considered as a global application.

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