Performance Measures for Snow- and Ice-Control Activities

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In 1996, the Washington State Department of Transportation implemented a system of performance measures and service levels for highway maintenance activities known as the Maintenance Accountability Process (MAP). Initially, the MAP did not include service levels for snow- and ice-control activities based on field measurement, as it does for the majority of other maintenance activities. To gain similar benefits for snow- and ice-control activities, a pilot project that included performance measures, service levels, and field measurement protocols was developed and implemented. Two performance measures were used: the amount of roadway traction provided at the time of a field measurement, and the time taken to regain bare pavement after the end of a snowfall event. More than 100 3-km (2-mi) segments of highway were randomly selected for field condition measurement throughout the winter season (November 1 to March 31). At the end of the season, point values were added together for service level determinations. The initial pilot project was assessed in spring 2000 to make revisions and to determine the long-term direction of the activity. The intended outcome of the pilot project is to identify a performance-based service level being delivered for snow and ice control. This information could then be used for more accurate budget planning and resource allocation in the future.

In developing performance measures for snow- and ice-control activities, the Washington State Department of Transportation (WSDOT) faced some significant challenges. One of the greatest challenges is the diverse geography and climate in Washington State. This kind of diversity may not have a significant bearing for measuring something such as guardrail maintenance, but it is integral in measuring performance for snow- and ice-control activities.

Washington is a fairly mountainous state. The Olympic Mountains lie in the western portion; the Cascade Mountains run from Canada to Oregon down the middle; and several lesser mountains are found in the eastern half of the state. Being located on the receiving end of moisture-laden weather systems coming directly off the Pacific Ocean, many areas in Washington receive copious amounts of precipitation. The combination of precipitation and mountainous terrain results in significant amounts of snowfall. Washington State holds the world record for snowfall during a single winter season, set during winter 1998–1999 at Mount Baker, where total snowfall was 2896 cm (1,140 in.). The world record before this was also in Washington: 2851 cm (1,122.5 in.) at Mount Rainier. Throughout the winter, WSDOT maintains and operates 10 mountain-pass highways, where it must deal with large volumes of snow. A performance measure for maintenance activities on mountain-pass highways logically should address snow removal.

A large part of western Washington (coastal lowlands) includes the vast majority of the state's population centers (e.g., Seattle) and highway traffic. These areas experience a fairly mild maritime climate with large amounts of rainfall but not too much snowfall—maybe one or two minor snow events per winter. In some years, the coastal lowlands have no snow at all. However, during occasional

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cold spells, frost events are common, so most of the snow and ice control in these areas consists of pretreating with anti-icing chemicals and spreading sand on icy highways for traction. Obviously, this focus is considerably different from that in the mountain passes, and the same performance measure will not work for both areas.

The other large geographic area is the inland plateau on the east side of the Cascade Mountains. This area does not get the large amounts of moisture from the Pacific Ocean or a moderating effect on its air temperatures. The climate is dry and cold; winter is characterized by numerous frost events and moderate snowfall. Most efforts from maintenance forces during the winter are managing icy roads, by pretreating with anti-icing chemicals or applying sand for traction. It is not unusual to have subfreezing temperatures on 80 percent of the days during the winter season (November 1 to March 31). A performance measure that works well for mountain-pass highways or coastal lowland areas may not be in the best interests of eastern Washington.

In addition to the challenges in measuring snow- and ice-control performance related to Washington's geographic diversity, the dynamic road conditions found during winter weather events further complicate performance measurement. One hour, the roadway can be icy and dangerous; the next hour, it can be bare and wet without any intervention from maintenance personnel. When and how performance is measured in such an instance can make a world of difference.

Sometimes when a problem is being addressed, a single solution is obviously the one and only answer to the question. No such solution was found for snow and ice control. Performance can be measured in several ways, none of which is absolutely superior to all others under all circumstances. WSDOT sought a solution from its counterparts around the United States but was unable to find another state department of transportation (DOT) that had a time-tested model to follow that would suit its needs. Some DOTs were measuring snow- and ice-control performance (such as the California and Minnesota DOTs), but they, too, were in fairly early stages of developing their measures and learning from experience.

Performance Measures

A team of maintenance personnel was assembled to develop snow- and ice-control performance measures and the associated data collection protocols. The team was primarily made up of regional maintenance personnel who had considerable experience with snow and ice control activities.

Two performance measures that were to be combined into a single level of service (LOS) rating for snow and ice control were developed. The first measure was a rated condition of a representative segment of highway at a given time during each week of the winter season. Specifically, the roadway segment would be rated based on the extent to which it was maintained in a bare (bare and dry, or bare and wet) or sanded condition. The highest score (1 point) would be assigned to a surveyed segment of highway that was either completely bare or completely sanded. As the extent to which the survey segment was maintained in a bare or sanded condition varied, other point values (2, 3, 4, and 5 points) were assigned. The conditions were distinguished primarily by identifying "emphasis areas" (e.g., curves, hills, and intersections) that were maintained in a bare or sanded condition. Although this performance measure gave an indication of the condition to which the roadway was maintained throughout the winter, it did not really indicate how well WSDOT responded to individual storm events—an important part of its task, especially in the eyes of its customers.

Thus, a second measure was added that focused on the time to regain bare pavement after a winter precipitation event ends—that is, the hours elapsed between these two points. Point values (1 through 5, where 1 is the highest and 5 the lowest) were assigned to different hour thresholds; faster times resulted in higher scores and slower times in lower scores. Different hour thresholds were assigned to different categories of highways. For example, a category 1 highway [average daily traffic (ADT) > 80,000 vehicles] would be assigned a high rating of 1 point if bare pavement conditions were maintained during the winter precipitation event. However, a category 5 highway (ADT < 5,000 vehicles) would be assigned the same high rating if bare pavement could be regained within 6 h of the end of the winter precipitation event.

The second performance measure was used only when a winter precipitation event was occurring at the time of the field survey. The point values of the two performance measures were translated into a letter grade (A, B, C, D, or F) LOS rating similar to those of other Maintenance Accountability Process (MAP) activities.

Who, When, Where, and How

Quite a few more details pull together the two performance measures into a full-fledged pilot project. Field surveys were assigned to regional maintenance personnel throughout the state. Training sessions were conducted in the 24 maintenance areas at the beginning of the winter season to ensure adequate communication about and understanding of the performance measure procedures. Personnel from WSDOT's central maintenance office also conducted field surveys on a small percentage of the highway segments that were surveyed by regional maintenance personnel for quality assurance and quality control (QA/QC) purposes.

For the purposes of performance measurement, the winter season was defined as the period between November 1 and March 31. All the field surveys were conducted during this time.

For the first performance measure (rating the condition of the roadway), one field survey was conducted at each survey point every week of the winter season. The weekly field checks were conducted on designated days; different maintenance areas were assigned different days, Monday through Thursday. All field checks were conducted between 6 a.m. and 9 a.m. statewide for consistency.

A total of 133 3-km (2-mi) highway segments around the state were randomly selected to be assessed for snow- and ice-control performance. The sites represented various categories of highways based on ADT. At survey locations, the focus was on the condition of the mainline highway between the foglines. All lanes of travel within the survey segment were included—lanes in both directions on divided as well as undivided highways. If conditions varied across multiple lanes, the surveyor "averaged" the conditions and recorded the data. Roadway shoulders, pull-outs, chain-up areas, and other areas outside the main travel lane were not included for the purposes of the pilot project, nor were on-ramps, off-ramps, and overpasses.

The performance assessments were conducted via a "windshield survey." Whereas other MAP field survey protocols (such as those for pavement patching and repair) require maintenance personnel to leave their vehicles, walk the roadway, and take some fairly precise measurements, the performance measures for snow and ice could be obtained from the safety of their vehicles.

The information from each field survey was documented on a one-page form (Figure 1). Some people preferred to use electronic forms, whereas others used paper forms; both options were available. In some areas, radio dispatchers completed forms at the office from information transmitted via radio from personnel in the field.

The LOS ratings from the pilot project were to be accompanied by an index value that reflected the severity of winter in Washington State. This value would help provide the appropriate context (a severe winter or a mild winter?) within which the LOS rating could be used. The index was based on the winter index (WI) developed by the Strategic Highway Research Program (SHRP H-350).

The WI (Figure 2) includes snowfall data in its calculation. WSDOT wanted to have a "real-time" WI for use during the winter season, but real-time snowfall data are not available statewide in Washington. So, the WI was modified by removing the snowfall data and renaming it the "frost index." Frost indices were calculated back to 1991 and compared with the winter indices for the same years. The correlation between the two indices was good, and WSDOT opted to use the frost index.

Results

Analysis of the data and observations of the pilot project's participants yielded mixed results. The data from the field data collection forms were compiled and tabulated for review and analysis. Debriefing sessions were conducted in each of the 24 maintenance areas to gather observations and input from the regional maintenance personnel who were involved with the pilot project.

The tabulated data (Figure 3) show an overall level of service to be slightly higher than average. No data were used in the tabulation unless it was the result of specific maintenance activities. In other words, all of the "bare pavement" ratings that received this rating simply due to warm weather conditions were thrown out. Only ratings for bare pavement that were the result of anti-icing chemical application and ratings for sanded pavement were used.

Without the benefit of field measurements, the LOS provided has been traditionally estimated to be in the C-to-C+ range (average), whereby motorists are likely to experience some delay and slow travel on roads with black ice, packed snow, or only portions of the roadway sanded or treated with anti-icing chemicals. The data from the pilot project produced a statewide overall LOS of B+. Many maintenance managers at WSDOT felt that a B+ was a higher LOS than was actually provided.

Integration of two factors can help clarify the significance of the B+ LOS. Throughout all of western Washington and most of eastern Washington, the winter of 1999–2000 was considerably warmer than average. Approximately three-quarters of the weekly field surveys statewide resulted in a "bare pavement" rating simply because the weather was above freezing. Additionally, mountain-pass highways (category 6) were not included in the body of highways from which the survey locations were randomly selected. Because winter conditions vary so much more in mountain-pass areas than at lower elevations, these highways were excluded in the initial pilot project. If the winter had been more severe and mountain-pass highways had been included for field surveys, one could reasonably expect that the overall LOS would have been lower than the B+ attained—probably much closer to the C or C+.

The LOS calculated for individual regions was higher in western Washington than for those in eastern Washington. Because of the few subfreezing weather events in western Washington, the higher LOS for the western Washington regions appears to be more related to the mild weather than the LOS actually provided by the maintenance program.

In general terms, the performance measures and data collection protocols seemed to work out fairly well for field personnel. The personnel who conducted the field surveys indicated that the measures and protocols were

Site No: SR No: Beg MP: End MP:

Category No: Sample Date: Sample Time:

Name:

Part 1 - Traction Control **Sample Time Range: 6:00 am to 9:00 am weekly**

Sanding:
Condition Indicator: Presence of sand on 60% or more of the traveled lane. Emphasis areas are defined in the Maintenance Manual to include bridges, hills, curves and intersections.

Outcome Measurement: Percent (%) of traveled way sanded.

- Bare
- Entire Sample Area Sanded
- Emphasis Areas & 50% or More of Remaining Area
- Emphasis Areas Only
- 50% or More of Emphasis Areas
- < 50% of Emphasis Areas

Part 2 - Precipitation Event **Precipitation At 35 Degress or Below**

Begin Date: Begin Time: Precipitation End Time:

End Date: Time When Bare Pavement Achieved:

Elapsed Time (Hours):

Event Type:
- Snow
- Freezing Rain
- Freezing Fog
- Other

Traveled Way Condition (Fog Line to Fog Line):
Condition Indicator: Presence of bare pavement.
End of Event Indicator: A cessation of precipitation for a 6 hour period.
Outcome Measurement: Elapsed time from the end of precipitation to attainment of bare pavement.

Part 2 Invalid

Elapsed Time To Bare Pavement:

Category 1	Category 2	Category 3	Category 4	Category 5
Bare Pavt Maint	Bare Pavt Maint	< 2 Hours	< 4 Hours	< 6 Hours
< 2 Hours	< 2 Hours	< 4 Hours	< 6 Hours	< 8 Hours
< 4 Hours	< 4 Hours	< 8 Hours	< 12 Hours	< 16 Hours
< 6 Hours	< 8 Hours	< 12 Hours	< 16 Hours	< 24 Hours
> 6 Hours	> 8 Hours	> 12 Hours	> 16 Hours	> 24 Hours

Comments:(weather conditions, presence of deicer or anti-icing materials, other)

FIGURE 1 Field data collection form.

clear and understandable and that they could be applied and interpreted consistently around the state. Preliminary feedback indicates that the system was not much of a burden. Regional personnel did not report that they were spending so much time conducting field checks that they could not do their regular jobs. After having completed the winter pilot project, maintenance personnel felt that WSDOT was measuring the right things to represent the LOS it provided.

Regional maintenance personnel indicated that some of the surveys that resulted in a "bare pavement" rating were not included in the overall LOS calculation because sometimes people did not indicate the bare pavement condition due to pretreatment with anti-icing chemicals.

$$WI = -25.58\sqrt{TI} + (-35.68)\ln((S/10)+1) + (-99.5)\sqrt{N/(R+10)} + 50\ *$$

Temperature Index (TI) = 0 if the minimum air temperature is above 32°F; 1 if the maximum air temperature is above 32°F while the minimum air temperature is at or below 32°F; 2 if the maximum air temperature is at or below 32°F. The averaged daily value is used. (Weighted 35%)

Snowfall (S) = the daily amount of snowfall in millimeters. (Weighted 35%)

Number of Air Frosts (N) = mean daily values of days with minimum air temperature at or below 32°F. (Weighted 30%)

Temperature Range (R) = the difference between the mean monthly maximum air temperature and the mean monthly minimum air temperature. (Weighted 30%)

* The four coefficients in this equation tailor the Winter Index to United States climate.

FIGURE 2 Winter index calculation.

Leaving this information as something to be added in a general comments box on the form rather than including it as a formal check box was the main reason these records were lost.

The North Central Region opted to include additional survey sites so they could have ratings more representative of the LOS provided by their individual maintenance areas. At the end of the winter season, one maintenance area that had aggressively used anti-icing chemicals had a lower LOS rating than an adjacent maintenance area that had relied more on conventional plowing and sanding practices, with limited use of anti-icing chemicals. Observations and experience (as well as input from the traveling public) indicated that these LOS ratings did not accurately reflect the snow- and ice-control services that were actually provided by one area relative to the other.

To understand the cause of this problem, WSDOT examined the individual field condition surveys from the two subject maintenance areas and found discrepancies in the way Part 2 of the form was being completed. The system was designed so that Part 2 would only be completed if a winter precipitation event was occurring while the weekly field survey and Part 1 completion were taking place. However, on the majority of the forms for which Part 2 had been completed, the documented time when bare pavement was regained occurred before the field check even began. Apparently, many people had understood that if any remnant of a winter precipitation event remained on the roadway at the time of the weekly field check, then Part 2 of the form should be completed—the time to regain bare pavement from the previous event calculated and recorded. After the records were deleted that had been incorrectly completed, the LOS rating for the area that was believed to have provided a higher LOS rose above that of the adjacent area perceived to have provided a lower LOS.

After identifying this problem in 2 of the 24 maintenance areas, individual field survey records in other maintenance areas were examined. The problem was found to be fairly pervasive throughout the state. All records of incorrectly completed forms were deleted from the tabulations. Although many of the area and regional LOS ratings changed to varying degrees, the overall statewide LOS remained nearly identical.

The main revision that regional maintenance personnel wanted in the system was to have more flexibility in selecting locations and times for the field surveys so response to more subfreezing weather events could be measured. They felt some frustration in being limited to a single 3-h period during the week in which the field survey could take place. WSDOT responses to many subfreezing weather events were not measured for inclusion in the LOS rating because the events took place outside of the designated survey time or day. Also, some of the randomly selected survey sites were at locations least likely to experience severe snow or ice conditions in a general area. If those locations had been moved to where the likelihood of snow or ice conditions were more prevalent, opportunities for measuring our response to subfreezing weather events would have increased.

The weather information that supplies the data for the frost index is obtained from the National Weather Service (NWS), which gathers daily high- and low-temperature readings from a multitude of weather stations throughout the state and makes them available on their website. The data are tabulated in a format that is amenable for use in calculating the frost index.

In late summer 1999, the NWS website crashed and had to be reconstructed. As of May 2000, the component of the NWS website that contained the temperature data had not been reestablished. The NWS webmaster has stated that NWS intends to provide this information on their website in the future. WSDOT is currently exploring other options in case acquisition of the needed data continues to be problematic in the future.

Conclusions

Nothwithstanding some of the problems mentioned earlier, the WSDOT pilot project appeared to meet its objectives. Performance measures, service level ratings, and field measurement protocols for snow and ice control were developed and implemented. Although assessment of the pilot project revealed the need for improvement and revision, the basic principles in this system are sound and suitable for future incorporation into the MAP.

The team that initially developed the performance measure system for snow and ice will reconvene in the summer of 2000. They will evaluate the results of the

FY2000 STATEWIDE MAP SNOW & ICE SURVEY RESULTS

Sampling Statistics

Description	Number	Percent
Total Surveys	1,718	100.0%
Total Bare Pav't Surveys	1,441	83.9%
Total Bare Pav't Surveys w/ Deicer Use	136	7.9%
Total Non Service Level Surveys (2-3)	1,305	76.0%
Total Possible Part 1 Surveys (1-4)	413	24.0%

SL	Threshold
A	1.0 - 1.9
B	2.0 - 2.9
C	3.0 - 3.9
D	4.0 - 4.9
F	5.0

Part 1 - Traction Control

Description	Number	Percent	Multiplier	Score	Service Level
Total Bare Pav't With Deicer Use	136	33.8%	1	136	
Entire Sample Area Sanded	96	23.9%	1	96	
Emphasis Areas & 50% of Remaining	59	14.7%	2	118	
Emphasis Areas Only	41	10.2%	3	123	
50% of Emphasis Areas	25	6.2%	4	100	
< 50% of Emphasis Areas	45	11.2%	5	225	
Total Sanding Records	402	100.0%		798	**2.0**

Part 2 - Precipitation Events

Description	Number	Percent	Multiplier	Score	Service Level
Category 1 Records	0	0.0%			
Category 2 Records	8	8.3%			
Category 3 Records	17	17.7%			
Category 4 Records	19	19.8%			
Category 5 Records	52	54.2%			
Total Records All Categories	96	100.0%			
Combined Categories - box 1	61	63.5%	1	61	
Combined Categories - box 2	8	8.3%	2	16	
Combined Categories - box 3	8	8.3%	3	24	
Combined Categories - box 4	2	2.1%	4	8	
Combined Categories - box 5	17	17.7%	5	85	
Total Records All Categories	96	100.0%		194	**2.0**
Combined Part 1 & 2 Service Level					**2.0**

FIGURE 3 Tabulated pilot project data.

pilot project and make revisions as needed before continuing implementation during the winter of 2000–2001. WSDOT anticipates that increased flexibility in survey site location and time will be incorporated in an effort to increase the data available for LOS calculations. It is also anticipated that mountain-pass highways will be included, additional detail (e.g., application of anti-icing chemicals) will be added to the form, and increased QA/QC measures will be implemented to identify problems early and make adjustments as needed.

One indirect result of this pilot project is that more field maintenance personnel have been included in performance measurement than ever before. For a long time, performance measures and performance-based budgeting were something the people at headquarters dealt with. That scenario has been changing. With their participation in the snow and ice pilot project, regional maintenance personnel have learned about the tools and benefits that MAP provides to assist them in the day-to-day delivery of the highway maintenance program services.