

**VERMONT AGENCY OF TRANSPORTATION**

**Materials & Research Section  
Research Report**



**IDENTIFYING PERFORMANCE BASED MEASURES  
FOR WINTER MAINTENANCE**

Report 2013 – 02

May 2, 2013

**Identifying Performance Based Measures for Winter Maintenance  
Practices**

**Report 2013 – 02**

**May, 2013**

Reporting on RAC SPR-725

STATE OF VERMONT  
AGENCY OF TRANSPORTATION

MATERIAL & RESEARCH SECTION

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16. Abstract <p>One of the Vermont Agency of Transportation's (VTrans) primary missions is to keep Vermont state highways open and safe for the transportation network users, while managing the system in a cost-effective and environmentally sensitive manner. Several states have initiated performance measures to ensure public safety, and improve efficiency. VTrans' Operations Division has developed levels of service for winter maintenance in its 2012 Snow and Ice Control Plan. Monitoring and evaluating the material usage during the winter months can lead to a substantial increase in cost-effectiveness. Unfortunately, VTrans does not currently have a standard method for rating its maintenance performance during winter maintenance activities.</p> <p>An in depth literature search was conducted to determine what winter maintenance performance measure guidelines have been established in state highway departments. In addition, state DOT's were contacted and surveyed regarding the use of Winter Maintenance Performance Measures. The survey was conducted to ensure that newly adopted measures and measures used informally would be discovered even if they had not appeared in any official plans or publications yet.</p> <p>According to NCHRP 6-17, three factors are commonly incorporated into determining maintenance performance. These factors are resources spent (Inputs), accomplishments of work performed (Outputs) and effectiveness of maintenance activities (Outcomes). A number of states have also created a Winter Severity Index of 0 to 100 to relate performance targets that are based on public safety and driver expectations better.</p> <p>A recommendation from this effort is that VTrans incorporate a performance metric that measures the "time to bare pavement conditions." This method includes recording the time it takes maintenance personnel to achieve bare pavement conditions in the wheel paths of the roadway from the time the storm event ends. The use of Global Positioning Systems, and other computerized data collection and analysis technology is a means that could promote in effectiveness both in costs and in effort over time. The use of these technologies will become more feasible as the automatic vehicle location (AVL) systems are implemented fleet-wide in Vermont's snow and ice control vehicles.</p> <p>Further research should focus on the relationships between performance metrics and safety. Establishing performance measures is the first step in helping to improve and target roadway safety during winter months.</p>					
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## **ABSTRACT**

One of the Vermont Agency of Transportation's (VTrans) primary missions is to keep Vermont state highways open and safe for the transportation network users, while managing the system in a cost-effective and environmentally sensitive manner. Several states have initiated performance measures to ensure public safety, and improve efficiency. VTrans' Operations Division has developed levels of service for winter maintenance in its 2012 Snow and Ice Control Plan. Monitoring and evaluating the material usage during the winter months can lead to a substantial increase in cost-effectiveness. Unfortunately, VTrans does not currently have a standard method for rating its maintenance performance during winter maintenance activities.

An in depth literature search was conducted to determine what winter maintenance performance measure guidelines have been established in state highway departments. In addition, state DOT's were contacted and surveyed regarding the use of Winter Maintenance Performance Measures. The survey was conducted to ensure that newly adopted measures and measures used informally would be discovered even if they had not appeared in any official plans or publications yet.

According to NCHRP 6-17, three factors are commonly incorporated into determining maintenance performance. These factors are resources spent (Inputs), accomplishments of work performed (Outputs) and effectiveness of maintenance activities (Outcomes). A number of states have also created a Winter Severity Index of 0 to 100 to relate performance targets that are based on public safety and driver expectations better.

A recommendation from this effort is that VTrans incorporate a performance metric that measures the "time to bare pavement conditions." This method includes recording the time it takes maintenance personnel to achieve bare pavement conditions in the wheel paths of the roadway from the time the storm event ends. The use of Global Positioning Systems, and other computerized data collection and analysis technology is a means that could promote in effectiveness both in costs and in effort over time. The use of these technologies will become more feasible as the automatic vehicle location (AVL) systems are implemented fleet-wide in Vermont's snow and ice control vehicles.

Further research should focus on the relationships between performance metrics and safety. Establishing performance measures is the first step in helping to improve and target roadway safety during winter months.

## **INTRODUCTION**

One of the Vermont Agency of Transportation's (VTrans) primary missions is to keep Vermont state highways open and safe for the transportation network users, while managing the system in a cost-effective and environmentally sensitive manner. Vermont is divided into six physiographical regions based on the age and type of rock in the area, landscape (lowlands, hills, mountains), and climate (1). Climate across these regions is extremely variable. Areas within milder climate regions may receive an average annual snowfall of 80 inches, whereas more harsh mountainous regions may receive an average of 380 inches (2, 3). This climatic variation, paired with widely varying Annual Average Daily Traffic (AADT) levels on its roadways and a relatively high level of annual Vehicle Miles Travelled (VMT) per capita of 14,798, makes the task of achieving safe roads for all users statewide during winter storm events daunting (4). To maintain acceptable levels of service (LOS) statewide, the Operations Division deploys several winter maintenance methods including plowing, and application of various substrates including standard road salt, sand, and salt brine blends. Due to the characteristics of each region and weather conditions, some methods or combination of methods work better than others do.

Safety is listed as one of VTrans four primary goals and with limited budgets, it is ever more important to find an efficient and cost-effective method to maintain all routes effectively year round. According to the National Cooperative Highway Research Program (NCHRP) project, 6-17, "Monitoring the performance in snow and ice control operations has become an increasingly important task for highway agencies and contractors because of the limited resources available to highway agencies and the increased outsourcing of these activities (5)." Unfortunately, VTrans does not currently have a standard method for rating maintenance performance during winter maintenance activities.

## **PROJECT SUMMARY**

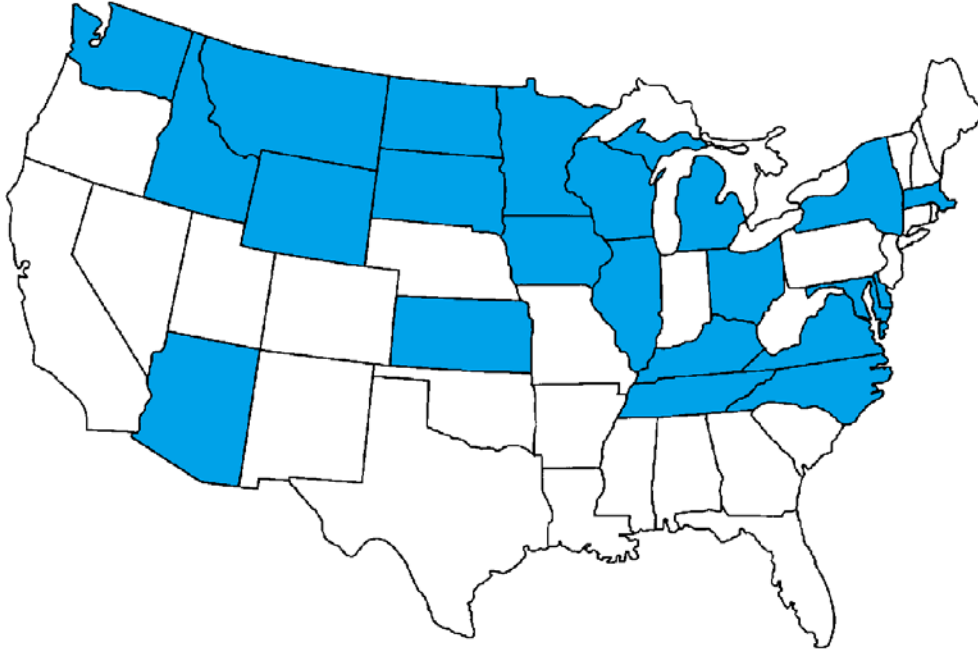
### **Literature Search**

An in depth literature search was conducted to determine what performance measures have been established in other states. Specifically the literature search focused on what the individual performance measures are, how the states determined those measures to be of importance, what factors lead to the achieve increased roadway conditions, and how each state implemented the measures.

### **Survey of State Highway Departments**

The literature search was supplemented with a survey of state highway departments. State Highway Departments were contacted and surveyed regarding the use of Winter Maintenance Performance Measures. States were asked to share their experiences with

performance measures and to provide any guidelines that may be helpful in our efforts to establish a rating scale/performance measures in Vermont. Figure 1 shows the states that have responded to the survey.



**Figure 1 Respondents to Survey**

### **Data Acquisition**

The original intent was to complete a full research project on winter performance measures; however, due to the findings from the survey and literature search it was decided that a more in-depth look at the data available for the development of performance measures was required to solidify a proper approach to choosing guidelines. The literature search and survey determined that vehicle speeds and surface conditions provide direct performance metrics. UVM has been awarded a research project, “Long-Term and Short-Term Measures of Roadway Snow and Ice Control (RSIC) Performance” that will expand upon identifying more effective and objective metrics such as the ones identified in this study.

## **FINDINGS**

### **Literature Search**

Through an extensive document review, it was found that the use of Automated Vehicle Location (AVL), Global Positioning Systems (GPS), friction meters, Road Weather Information Systems (RWIS), and other technologies in snow and ice control operations facilitate obtaining



the data needed to enhance performance measurement practices. Agencies can establish targets toward which activities can be directed and, where necessary, identify and implement improvement strategies to achieve more effective winter maintenance programs. Technologies such as Automated Vehicle Location (AVL), Roadway Weather Information System (RWIS), GPS and Personal Digital Assistants (PDAs) could be used to record input, output and outcome data more efficiently. Maintenance personnel could be responsible for recording the amount of time spent on each route, roadway conditions, weather conditions, time of day, traffic volumes, etc.

According to VTrans Snow and Ice Control Plan, the following information will be reviewed by the Director of Operations, the Maintenance Transportation Administrator (MTA) and the District Transportation Administrators (“DTAs”) annually to gage program effectiveness:

1. Material application rates
2. Vehicle speeds during and after storm events
3. Condition of travel lanes and shoulders during and after storm events
4. Storm data (precipitation, air temperature, road surface temperature, wind speed, etc)
5. Plowing frequency

Field tests are recommended for developing a performance measurement program; and examine snow and ice control practices. Such tests should account for the resources used in snow and ice control operations (Inputs) and the accomplishments of work performed (Outputs) because of these resources spent. The tests should also assess the Outcomes such as operational efficiency; the extent of meeting expected goals in terms of safety, mobility, public satisfaction, and controlling adverse impacts on the environment.

### **Survey of States**

Twenty-one states replied to the performance measures survey. Of the twenty-one states, nine do not have a system in place to evaluate winter maintenance treatments and the associated level of service including Illinois, Tennessee, Michigan, Delaware, Montana, Kentucky, North Dakota, Wyoming, and Virginia. Wyoming Department of Transportation (WYDOT) is currently involved in an investigation regarding winter performance measures; however, they have not yet established any clear criteria for evaluation of maintenance procedures. WYDOT is interested in the results of the study being performed by VTrans Materials and Research Section with hopes that it will help the progression of their own study.

The results of the survey indicate that the main performance measures of states that responded can be summarized into five types of performance measures:

1. Time to return to normal driving speeds after winter storm events.
2. Time to achieve bare pavement after storm events subside.
3. Material usage.

4. Storm severity classification and.
5. Crash rates.

Some states use a combination of performance measures. These states include Maryland, New York, and Wisconsin. These three states all measure performance in both operating speed recovery time, and time to achieve bare pavement.

<b>Survey Results on Performance Measures</b>		
<b>Measure</b>	<b>Number of States</b>	<b>States Using the Measure</b>
Operating speed recovery from the end of storm events	2	Ohio, Minnesota
Time to achieve bare pavement after storm events subside	5	Maryland, New York, North Carolina, Massachusetts, Wisconsin
Material Usage	3	Maryland, New York, Wisconsin
Storm Severity classification	1	Idaho
Accident Rates	1	Arizona

Ohio DOT performance measures were recently established and implemented in February and March of 2012, and consequently this will be the first year on record used for comparison. Ohio uses Road Weather Information System (RWIS) and Intrix speed data to determine operating speed of priority routes to recover from the end of snow and ice events. Maryland State Highway Administration (MD SHA) uses primary and secondary measures. The primary measure is the achievement of bare pavement on all interstate and primary highways, the threshold goal being within four hours of the ending of frozen precipitation. The secondary measure is the pounds of salt used per lane miles per inch of snow. MD SHA uses a self-reporting system, in which each maintenance shop submits a report to MD SHA's Emergency Operations Reporting System (EORS) when frozen precipitation ends in their area, and another report when wet or dry pavement is achieved. In addition, the shops also report their total usage and inches of snow. Wisconsin DOT uses winter performance measures that were developed in the 2005-2006 winter. The two strategies they measure are time to wet/bare pavement and crew reaction times. New York State DOT (NYS DOT) uses a similar system to report time required to return highway conditions to bare or wet pavement, the desirable threshold being within two hours.

### **COST ANALYSIS**

As previously described, one of the suggested Performance Measures involves monitoring the material usage by maintenance personnel during winter storm events. Aside from employee compensation for the task of evaluating material usage, there is no added cost with this

measure, since the data is currently collected for other reasons. In addition, monitoring the material usage could help make the process more efficient, thus increasing the cost-effectiveness of each dollar spent on materials used to clear hazardous roads.

Implementing the “time to bare pavement” Performance Measure has been suggested. If the VTrans chooses to use Personal Digital Assistants (PDA), GPS or any other technologies to help obtain the data from maintenance personnel the initial overhead cost would be notable. However, the use of such technologies would increase efficiency, and create a more cost-effective process of obtaining data quickly.

### **SUMMARY AND RECOMMENDATIONS**

After extensive research concerning winter performance measures as a means of determining Level of Service (LOS) rating in the state of Vermont, the Materials and Research section has determined many different possible methods exist. It is recommended that the state implement a combination of different methods to determine LOS.

Some states such as Minnesota have created a Winter Severity Index of 0 to 100, which could be beneficial to simplify performance targets that are based on public safety and driver expectations. As a primary measure, it is recommended that the state use a statistic to observe “time to bare pavement conditions.” This would include recording the time it takes maintenance personnel to achieve bare pavement conditions in the wheel paths of the roadway from the time the storm event ends. This method may present some difficulty as these collection methods are based on a visual determination by maintenance personnel. The precipitation in each storm event (i.e. Snow, ice, rain, etc.) must also be taken into consideration. Acceptable parameters for time to bare pavement must also be determined based on the severity of the storm, and reasonable goals for maintenance crews to attain. It is also recommended that a point system be established to evaluate how effectively the crews are reaching their goals.

Research personnel has determined that another acceptable way of determining LOS rating is to monitor the material usage by maintenance crews, as the attempt to combat hazardous roadway conditions during winter storm events. According to NCHRP 6-17 the three factors that assist in determining winter maintenance performance are resources spent (Inputs), accomplishments of work performed (Outputs) and effectiveness of maintenance activities (Outcomes). Inputs represent the resources spent or utilized to perform maintenance activities including fuel, materials, equipment, and labor. Outputs quantify the results of the work performed such as the time it takes to return to normal driving conditions. Outcomes assess how effective the maintenance activity was, these might include improvements in safety, mobility, and user satisfaction. This material usage classification may include the pounds of salt or sand

used during a winter storm event, as well as the costs associated with addressing this event. These costs include fuel, labor, equipment and equipment maintenance, etc.

Further research should be conducted to determine or estimate the data needed for conducting a more thorough evaluation, particularly the costs associated with weather severity and the application of treatment alternatives. Additional research should also investigate innovative new metrics to help connect storm severity with performance, as well as technologies that may yield new data for the development of these metrics. This research should include determining a way to establish relationships between performance metrics and safety. It is clear that establishing performance measures is the first step in helping to improve and target roadway safety during winter months.

## REFERENCES

1. Saint Michael's College. "The Physiographic Regions of Vermont."  
[http://academics.smcvt.edu/vtgeographic/textbook/physiographic/physiographic\\_regions\\_of\\_vermont.htm#sparsely%20populated](http://academics.smcvt.edu/vtgeographic/textbook/physiographic/physiographic_regions_of_vermont.htm#sparsely%20populated).
2. National Weather Service Forecast Office. Average Snowfall.  
[http://www.erh.noaa.gov/btv/climo/BTV/monthly\\_totals/snowfall.shtml](http://www.erh.noaa.gov/btv/climo/BTV/monthly_totals/snowfall.shtml)
3. Jay Peak Mountain Facts.  
[http://www.jaypeakresort.com/#/about\\_jay\\_peak/press/facts\\_and\\_figures/jay\\_peak\\_mountain\\_facts/](http://www.jaypeakresort.com/#/about_jay_peak/press/facts_and_figures/jay_peak_mountain_facts/)
4. The Vermont Transportation Energy Report: Clean Cities Coalition.  
[http://www.uvm.edu/~transctr/trc\\_reports/UVM-TRC-10-017.pdf](http://www.uvm.edu/~transctr/trc_reports/UVM-TRC-10-017.pdf)
5. Hanna, Amir N. "Performance Measures for Snow and Ice Control Operations." Research Results Digest 335. NCHRP Project 6-17. March 2009.  
[http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rrd\\_335.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_335.pdf)
6. Minnesota Department of Transportation. 2009-2010 Annual Winter Maintenance Report At a Glance. <http://www.dot.state.mn.us/maintenance/docs/MnDOTWinterAt-a-Glance.pdf>.
7. Kipp, Wendy. "Office Memorandum, 5-29-12 Meeting Minutes." Vermont Agency Of Transportation. February 2, 2012.

## **SCOPE OF WORK**

### **Identifying Performance Based Measures for Winter Maintenance Practices**

#### **PROBLEM STATEMENT**

One of the Vermont Agency of Transportation's (VTrans) primary mission is to keep Vermont state highways open and safe for the transportation network users, while managing the system in a cost-effective and environmentally sensitive manner. Vermont is divided into six physiographical regions based on the age and type of rock in the area, landscape (lowlands, hills, mountains), and climate (1). Climate across these regions is extremely variable. Areas within milder climate regions may receive an average annual snowfall of 80 inches where more harsh, mountainous regions may receive an average of 380 inches (2, 3). This, paired with varying Annual Average Daily Traffic (AADT) and an average Vehicle Miles Travelled (VMT) per year of 14,798, creates the daunting task of achieving safe roads for all users statewide during winter storm events (4). To maintain acceptable levels of service (LOS) statewide, the Operations Division deploys several winter maintenance methods including plowing, and application of various substrates including standard road salt, sand, and salt brine blends. Due to the characteristics of each region and weather conditions some methods or combination of methods work better than others.

Safety is listed as one of VTrans four primary goals and with limited budgets, it is ever more important to find an efficient and cost-effective method to maintain all routes at effectively year round. According to the National Cooperative Highway Research Program (NCHRP) project, 6-17, "Monitoring the performance in snow and ice control operations has become an increasingly important task for highway agencies and contractors because of the limited resources available to highway agencies and the increased outsourcing of these activities (5)." Unfortunately, VTrans does not currently have a standard method for rating maintenance performance during winter maintenance activities.

#### **BACKGROUND**

According to NCHRP's Research Results Digest 335, it has been difficult for agencies to identify proper performance measures in relation to winter maintenance practices because in the past agencies have relied on static standards for determining the level of service (LOS) of roads during and after storm events. With recent advancements in information technology and data, collection capability developing performance measures has become attainable. The summary notes, "Winter maintenance of roadways is a core and critical business element of many state transportation agencies; measuring performance is essential for managing this critical business element. Performance measurement will help winter maintenance managers control and direct activities to achieve best use of available resources and reduce user costs (5)."

Several states have initiated performance measures to ensure public safety. According to NCHRP 6-17, inputs, outputs, and outcomes are three factors that are incorporated into determining maintenance performance. Inputs represent the resources spent or utilized to perform maintenance activities including fuel, equipment, and labor. Outputs quantify the results of the work performed. Outcomes assess how effective the maintenance activity was, these may include improvements in safety, mobility, and user satisfaction (5). Some states such as Minnesota have created a Winter Severity Index of 0 to 100 to simplify performance targets that are based on public safety and driver expectations (6).

## **OBJECTIVES**

The objectives of this research initiative include summarizing performance measures in other states that maintain an acceptable LOS for roadways in winter seasons, identifying current winter maintenance practices in Vermont and gathering data needed to establish a scale of performance measures.

## **SCOPE OF WORK**

### *Literature Search*

An in depth literature search will be conducted to determine what performance measure guidelines have been established in other states. Specifically the literature search will focus on what the individual performance measures are, how the states determined those measures to be of importance, what factors lead to the achieve increased roadway conditions, and how each state implemented the measures.

### *Survey of States*

Other states will be contacted and surveyed regarding the use of winter maintenance performance measures. States will be asked to share their experiences with performance measures to provide any guidelines that may be helpful in our efforts to establish a rating scale/performance measures in Vermont.

### *Data Acquisition*

Gather and summarize current data such as 1) RWIS that collects information during storm events, 2) The Regional Integrated Transportation Information System (RITIS), and 3) Salt, salt brine, sand usage, and plowing activities to begin to formulate performance measure recommendations specific to Vermont.

## **PROJECT DURATION:**

This project will be completed over a 12-month duration.

## **PROJECT COST:**

The projected cost to complete the above referenced tasks is approximately \$10,000.

## **PROJECT DELIVERABLES:**

The project deliverables will include a publication summarizing all research efforts and subsequent findings. The publication will also provide recommendations for performance measures that will provide guidance and structure in VTrans efforts to keep Vermont roadways safe for all users at all times.

## **REFERENCES:**

1. Saint Michael's College. "The Physiographic Regions of Vermont."  
[http://academics.smcvt.edu/vtgeographic/textbook/physiographic/physiographic\\_regions\\_of\\_vermont.htm#sparsely%20populated](http://academics.smcvt.edu/vtgeographic/textbook/physiographic/physiographic_regions_of_vermont.htm#sparsely%20populated).
2. National Weather Service Forecast Office. Average Snowfall.  
[http://www.erh.noaa.gov/btv/climo/BTV/monthly\\_totals/snowfall.shtml](http://www.erh.noaa.gov/btv/climo/BTV/monthly_totals/snowfall.shtml)
3. Jay Peak Mountain Facts.  
[http://www.jaypeakresort.com/#/about\\_jay\\_peak/press/facts\\_and\\_figures/jay\\_peak\\_mountain\\_facts/](http://www.jaypeakresort.com/#/about_jay_peak/press/facts_and_figures/jay_peak_mountain_facts/)
4. The Vermont Transportation Energy Report: Clean Cities Coalition.  
[http://www.uvm.edu/~transctr/trc\\_reports/UVM-TRC-10-017.pdf](http://www.uvm.edu/~transctr/trc_reports/UVM-TRC-10-017.pdf)
5. Hanna, Amir N. "Performance Measures for Snow and Ice Control Operations." Research Results Digest 335. NCHRP Project 6-17. March 2009.  
[http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rrd\\_335.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_335.pdf)
6. Minnesota Department of Transportation. 2009-2010 Annual Winter Maintenance Report At a Glance. <http://www.dot.state.mn.us/maintenance/docs/MnDOTWinterAt-a-Glance.pdf>.

**Approved by Material and Research on Date (III)**

**Approved by Federal Highway Administration on Date (CPJ)**