

Analysis of Maintenance Decision Support Systems Benefits and Costs

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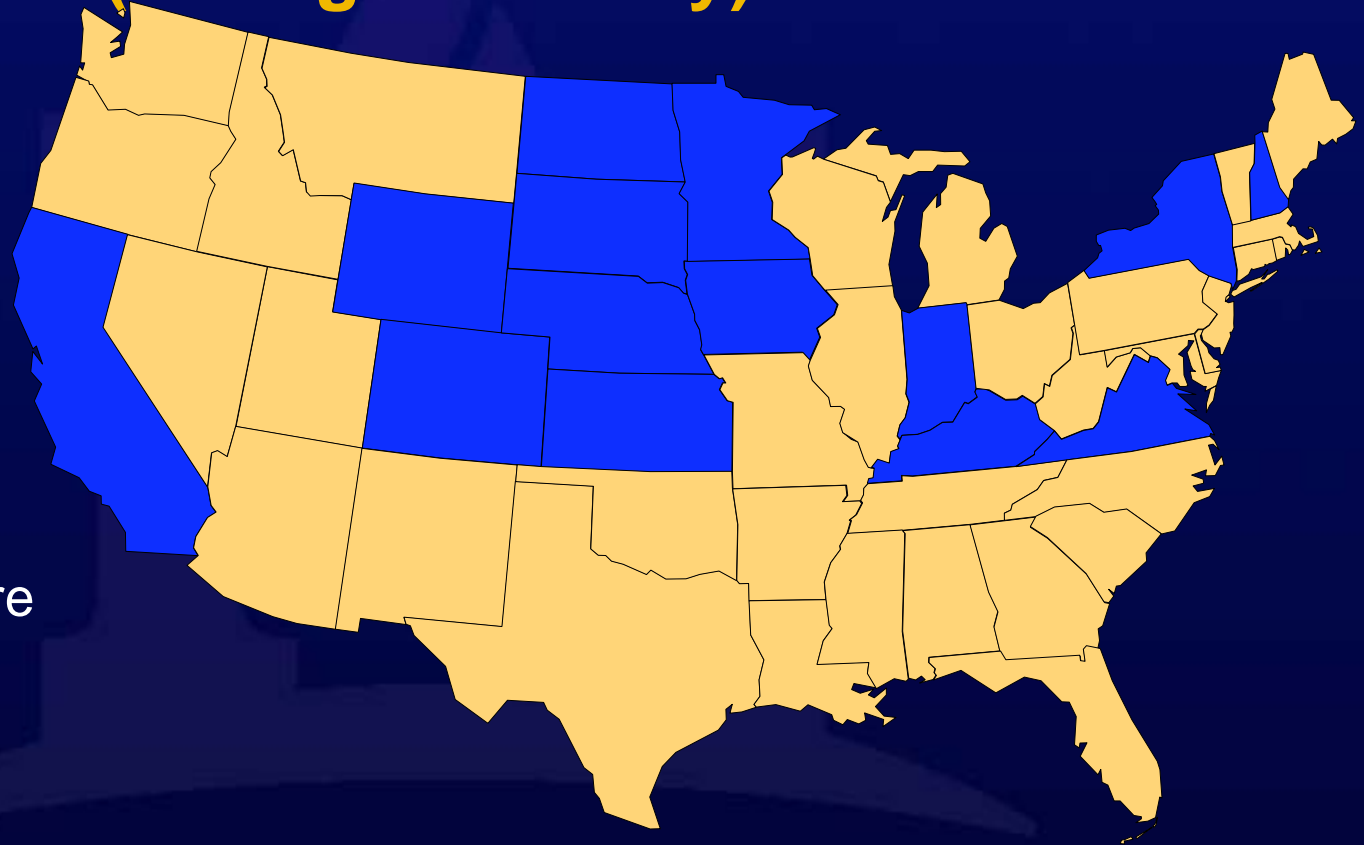
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SDDOT Office of Research

MDSS Stakeholders Meeting #11
Charlotte, NC September 16, 2009

Pooled Fund Study Partners (during B/C study)

- California
- Colorado
- Indiana
- Iowa
- Kansas
- Kentucky
- Minnesota
- Nebraska
- New Hampshire
- New York
- North Dakota
- South Dakota
- Virginia
- Wyoming



- Meridian Environmental Technology



MONTANA
STATE UNIVERSITY

College of
ENGINEERING

Western Transportation Institute

Project Background

- Field tests have not examined economic benefits and costs of MDSS
- Project Objectives
 - Describe the essential functions of a winter MDSS
 - Characterize and estimate the costs and benefits of deploying MDSS in state transportation departments



Essential Functions of MDSS

- Assess past & present weather conditions
- Assess present state of the roadway
- Report actual maintenance treatments
- Report actual road surface conditions
- Predict storm-event weather
- Predict road surface behavior
- Recognize resource constraints
- Identify feasible maintenance treatments
- Communicate recommendations to supervisors and workers



How PFS MDSS is Used



“A Tool”

Use MDSS real-time assessment of current and future road weather

Maybe use real-time maintenance recommendations

“A Revolution”

Rely on MDSS real-time assessment of current and future road weather

Rely on MDSS real-time maintenance recommendations

PFS states' experiences are generally between these levels

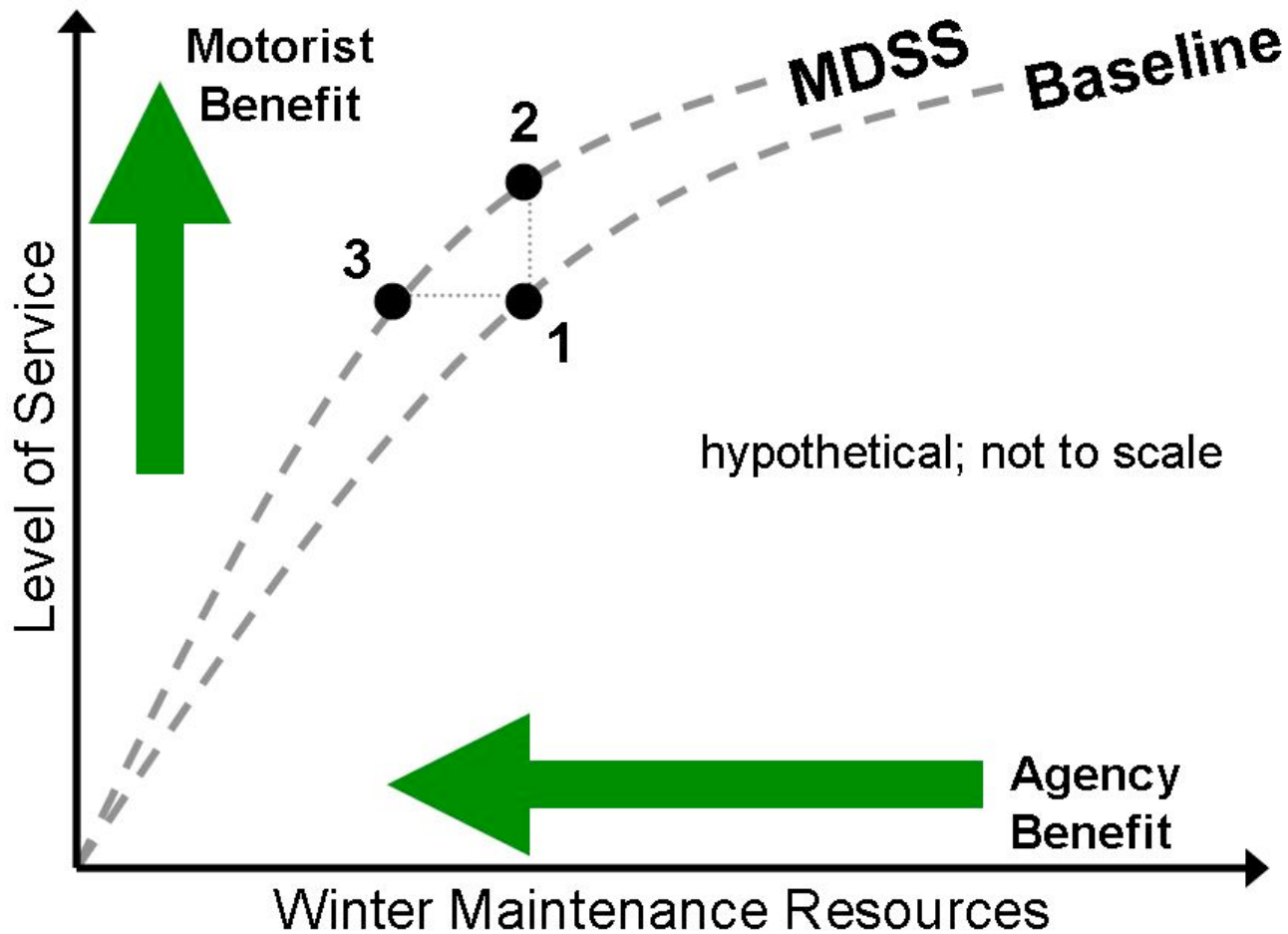


MDSS Benefits and Costs

	Agency	Motorist	Society
Benefits	<ul style="list-style-type: none"> • Reduced materials use • <i>Reduced labor costs</i> • <i>Reduced equipment & fuel use</i> • <i>Reduced fleet replacement costs</i> • <i>Reduced infrastructure damage</i> • ... 	<ul style="list-style-type: none"> • Reduced motorist delay (through improved LOS) • Improved safety (through improved LOS) • <i>Reduced response time</i> • <i>Reduced clearance time</i> • <i>Reduced vehicle corrosion</i> • ... 	<ul style="list-style-type: none"> • <i>Reduced environmental degradation</i>
Costs	<ul style="list-style-type: none"> • Software and support • Communications • In-vehicle computer hardware • Training • Administration costs • <i>Additional weather forecast provider costs</i> 		



Points of Comparison (Scenarios)



Point 1:
Calibration
Point (Base
Case)

Point 2: Keep
resources same
(Same
Resource)

Point 3: Keep
LOS same
(Same
Conditions)

Case Studies

- Three states (NH, MN, CO)
 - Representative of different climates
 - Good historical data on maintenance practices
 - Capture variety of traffic and terrain conditions
- Simulate using several years of historic weather and maintenance data
- Simulate three scenarios: base case (Point 1), same resource (Point 2), and same conditions (Point 3)
- Extrapolate to other routes in each state

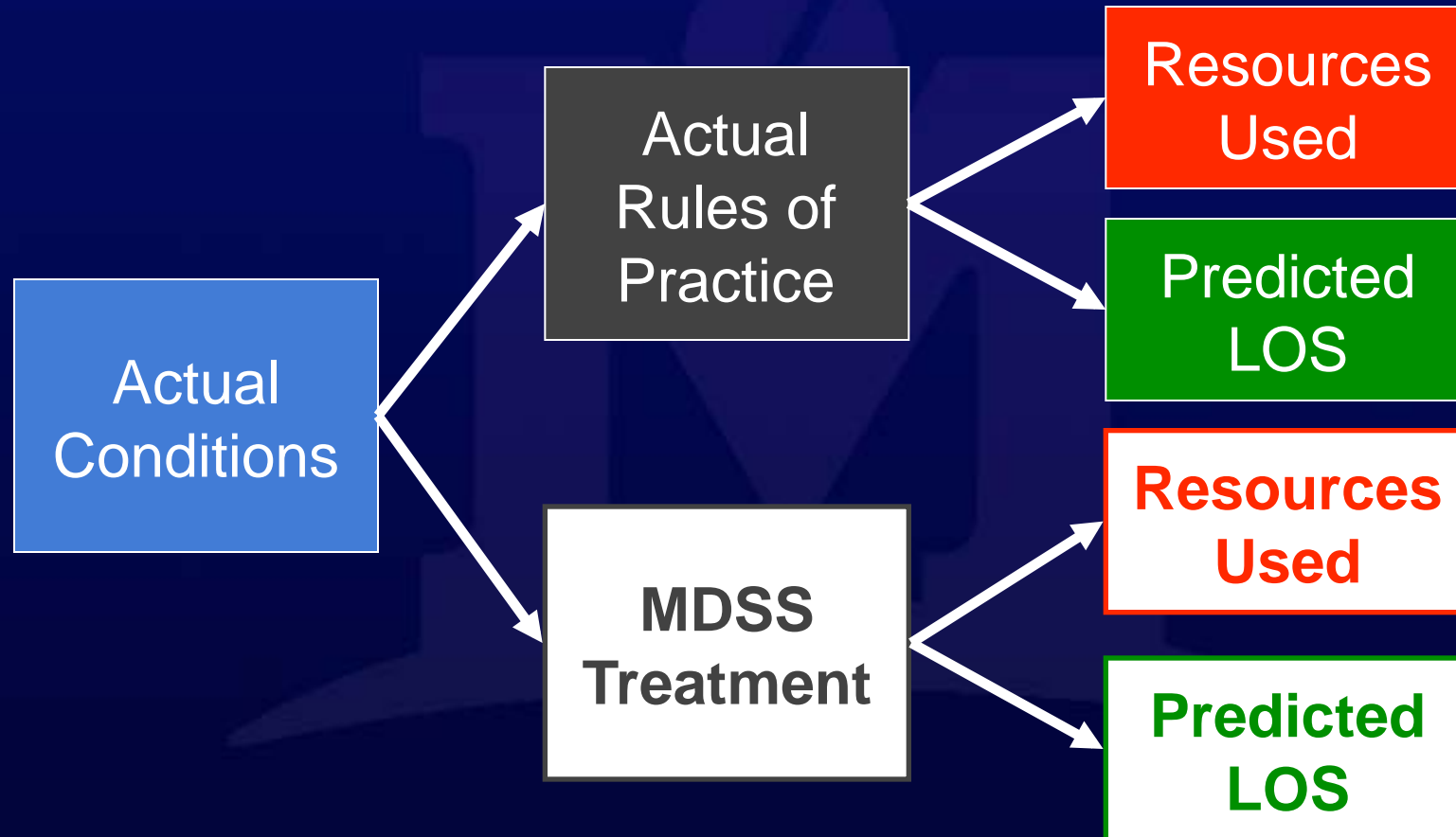


Why Simulate?

- Benefit-cost analysis must be quantifiable
- No PFS member state has adequate LOS data to measure tradeoff
- Simulator can generate objective and complete LOS data
- Simulation can allow for control of outside factors



How to Simulate?



Calibration

$$\text{Resources} = f(\text{Rules of Practice}, \text{Weather})$$



Result: Actual Rules of Practice



Storm Classification

- Large number of storms were identified
- Classification method: K-Means Cluster Analysis
 - A simple procedure to classify a given dataset through a certain number of clusters (assume k clusters)
 - Aims at minimizing an objective function

$$J = \sum_{j=1}^k \sum_{i=1}^n \|x_i^j - c_j\|^2$$

J = Squared Euclidean distance
 i : data point; j : cluster center



Motorist Benefits: Safety and Speed Adjustment Factors

- Crash rate and speed are affected by and vary with different pavement conditions
- Adjustment factors for crash rate and speed reduction were identified through literature review (> 30 past studies)
- Factors for around 15 types of pavement conditions
- Use storm types to connect the two modules



All three case studies confirm the benefits of MDSS

State	Scenario	Benefits (\$M)	User Savings (%)	Agency Savings (%)	Costs (\$M)	B-C Ratio
NH	Condition	\$2.37	50	50	\$0.33	7.11
	Resources	\$2.88	99	1		8.67
MN	Condition	\$3.20	51	49	\$0.50	6.40
	Resources	\$1.37	187	-87		2.75
CO	Condition	\$3.37	49	51	\$1.50	2.25
	Resources	\$1.99	90	10		1.33

Intangible Benefits

- Ability to portray information
- Improved documentation of actual maintenance activities for analysis
- Rich data to support performance monitoring and optimization
- A training tool
- Reduced response time
- Reduced clearance time
- A tactical operations tool to enable mid-course corrections to improve storm response
- Improve winter maintenance practices and encourage continuous improvement




Intangible Benefits


- Reduced labor costs
- Reduced equipment & fuel use
- Reduced fleet replacement costs
- Reduced infrastructure damage
- Reduced vehicle corrosion
- Reduced environmental degradation
- Allow consistency between areas
- Platform for future technology implementation
- Foster an agency climate of innovation and acceptance of new ideas




Project Deliverables



South Dakota
Department of Transportation
Office of Research

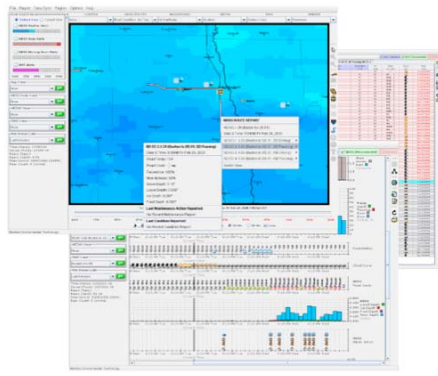


U.S. Department of
Transportation
**Federal Highway
Administration**



MDSS Pooled Fund Study TPF-5(054)

SD2006-10-F



Analysis of Maintenance Decision Support System (MDSS) Benefits & Costs

**Study SD2006-10
DRAFT Final Report**

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March 2009

Objectives

The goal of this research project was to conduct a benefit-cost analysis of the PF-MDSS that will provide applicable results. This study was tasked to:

- Describe the essential functions of a winter MDSS.
- Characterize and estimate the costs and benefits of deploying MDSS in state transportation departments.
- Offer a range of recommendations relating to future MDSS implementation or pre-MDSS activities that could improve the likelihood of successful MDSS implementation.

The driving force behind this study is that justification is an important issue in sound management practice when considering the incorporation of such a technological advancement and departure from existing methods of practice. A benefit/cost analysis is appropriate since field tests have not examined economic benefits and costs of MDSS.

Background

This project follows the earlier State-led Pooled Fund Study to develop and demonstrate a reliable decision support system capable of integrating multiple sources of data (weather observations, weather forecasts, road and mobile environmental sensor stations data, camera imagery, and maintenance resource information) and providing direct maintenance response recommendations.

The objective of the PF-MDSS is to provide support through software systems for proactive maintenance decision making before and during adverse weather events, with its use resulting in a higher level of service (LOS), reduced operational costs, and/or safer highway conditions.

The objective of winter maintenance operations is not snow delay or snow crashes. Rather, to improve the LOS, requiring the pavement to normal operations more quickly. MDSS meets this objective by providing information that can allow maintenance personnel to "stay on top of" a winter event and not be overwhelmed by it. It also allows maintenance personnel to see when a forecasted weather event will overwhelm available resources. This should have the positive benefits of reducing delay and improving safety.

Analysis of Maintenance Decision Support System (MDSS) Benefit & Costs



Prepared for the South Dakota Department of Transportation Office of Research Pierre, SD and The Member States of the Development of the Maintenance Decision Support System Pooled Fund Study



Summary of Benefit - Cost Analysis

The study produced report Tech Memo 2 describes the results and recommendations in detail. Function specifications and supporting functions outside of MDSS provided intangible benefit examples. These included:

- Use of the MDSS "force" a quantitative valuation of performance measures.
- MDSS provides insight and simulated experience through the training resources to allow A.
- Outcomes of changes in Rules of Practice can be evaluated through the use of MDSS.
- Successful application of MDSS requires quality weather prediction input.
- Quality recommendations from MDSS are reliant upon properly sized, appropriately maintained, and reliable ES.

Tangible and Intangible Analysis

The tangible results were arrived at through the application of the PF-MDSS in a simulation of seasons with known material use and weather parameters. In the absence of actual LOS data, the PF-MDSS itself was used as a tool to simulate the LOS that will result from various maintenance actions. Controlled scenarios were established to compare the results of applying MDSS recommendations with those achieved through following the rules of practice.

The tangible benefit-cost analysis was conducted in case studies of three pooled fund states, which belong to different climatologically groups: a transition (breeding) province (New Hampshire, a mountain/west state (Colorado), and a northern plains state (Montana).

Function Analysis System Technique (FAST) was utilized to identify the essential functions of the MDSS, assist in understanding the relationship of the functions of the PF-MDSS, and identify intangible benefits of the functions.

Findings/Results

Under a given operational philosophy, the LOS improves only with an increase in personnel, material and financial resources. The relationship between LOS and winter maintenance costs is represented in Figure 1. An agency operating under a baseline condition, following its standard rules of practice might operate at point 1. Additional or fewer resources would move the agency along the curve labeled "baseline." If an agency implements MDSS, it is anticipated that this would move the agency to a curve labeled "MDSS" on which it is assumed that the same level of resource investment would yield a better LOS. An agency could continue to decrease the case resources to winter maintenance operations, which would put the agency at point 2 on the MDSS curve. In this case, there are no savings in resources due to MDSS, but instead a LOS improvement results.

Another agency may elect to maintain the same LOS and choose to economize on winter maintenance costs. This would be represented as point 3. It is most likely that an agency implementing MDSS would fall somewhere between points 2 and 3, seeking to achieve both a LOS improvement and a reduction in winter maintenance costs.

The research team examined the PF-MDSS under two different scenarios:

Scenario 1: Assuming that LOS is kept constant, how much would winter maintenance costs be reduced by MDSS usage?

Scenario 2: Assuming that winter maintenance costs are kept constant, what would be the resulting LOS under MDSS usage?

Case Name	Scenario	Material	Personnel	Financial	LOS	ES	Cost	ES Rate
Baseline	1	100%	100%	100%	100%	100%	100%	100%
MDSS	1	100%	100%	100%	100%	100%	100%	100%
MDSS	2	100%	100%	100%	100%	100%	100%	100%
MDSS	3	100%	100%	100%	100%	100%	100%	100%

Methodology

This study relies heavily on two assumptions.

The feasibility of using the analysis methodology depends on MDSS having been validated in its ability to accurately simulate the future pavement condition that will result from weather and maintenance. Through some detailed case studies, the PF-MDSS provided established some confidence that it does reliably predict these pavement conditions.

Mobile data collection (MDC) is deployed to record the maintenance activities at a spatial and temporal resolution appropriate to integration with the MDSS recommendations and updates.

A classification of storm events was accomplished based on weather data collected from the three states. Use of these classifications makes the findings transferable to other states. The study produced report Tech Memo 1 describes the methodology in detail.

Conclusions

1. Report includes a synthesis of prior studies on quantitative effects of adverse weather
2. Stakeholder interviews revealed a generally positive view of the PF-MDSS, with potential for improved maintenance, cost savings, and training benefits
3. Study evaluated two of three identified types of benefits and costs associated with MDSS
 1. agency
 2. user (motorists)
 3. society



Conclusions

4. A simulation-based methodology was developed to analyze tangible benefits and costs, and validated through comparison with historical material use
5. The analysis method enabled comparison of different MDSS implementation scenarios
6. Three case studies collectively showed that the benefits of using MDSS outweigh associated costs. An agency implementing MDSS would likely seek to achieve both a level of service improvement and a reduction in winter maintenance costs.



Questions?



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<p>Objectives</p> <p>The goal of this research project was to conduct a benefit-cost analysis of the PF-MDSS that will provide applicable results. This study was tasked to:</p> <ul style="list-style-type: none">Describe the essential functions of a winter MDSS.Characterize and estimate the costs and benefits of deploying MDSS in state transportation departments.Offer a range of recommendations relating to future MDSS implementation or pre-MDSS activities that could improve the likelihood of successful MDSS implementation. <p>The driving force behind this study is that justification is an important issue in sound management practice when considering the incorporation of such a technological advancement and departure from existing methods of practice. A benefit / cost analysis is appropriate since field tests have not examined economic benefits and costs of MDSS.</p> <p>Background</p> <p>This project follows the earlier State-led Pooled Fund Study to develop and demonstrate a reliable decision support system capable of integrating multiple sources of data (weather observations, weather forecasts, fixed and mobile environmental sensor stations data, camera imagery, and maintenance resource information) and providing direct maintenance response recommendations.</p> <p>The objective of the PF-MDSS is to provide support (through software systems) for proactive maintenance decision making before and during adverse weather events, with its use resulting in a higher level of service (LOS), reduced operational costs, and/or safer highway conditions.</p> <p>The objective of winter maintenance operations is not zero delay or zero crashes. Rather, the is to improve the LOS, restoring the pavement to normal operations more quickly. MDSS meets this objective by providing information that can allow maintenance personnel to "stay on top of" a winter event and not be overwhelmed by it. It also allows maintenance personnel to see when a forecasted weather event will overwhelm available resources. This should have the positive benefits of reducing delay and improving safety.</p>	<ul style="list-style-type: none">BackgroundObjectivesMethodologyTangible and Intangible AnalysisFindings/ResultsSummary of Benefit & Cost Analysis 	<p>Analysis of Maintenance Decision Support System (MDSS)</p> <p>Benefit & Costs</p>  <p>Prepared for the South Dakota Department of Transportation Office of Research Pierre, SD and the Member States of the Development of the Maintenance Decision Support System Pooled Fund Study</p>  <p>State of South Dakota Department of Transportation</p>
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