Analysis of Maintenance Decision Support Systems Benefits and Costs

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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
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

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Agency</th>
<th>Motorist</th>
<th>Society</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reduced materials use</td>
<td>• Reduced motorist delay (through improved LOS)</td>
<td>• Reduced environmental degradation</td>
<td></td>
</tr>
<tr>
<td>• Reduced labor costs</td>
<td>• Improved safety (through improved LOS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reduced equipment &amp; fuel use</td>
<td>• Reduced response time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reduced fleet replacement costs</td>
<td>• Reduced clearance time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reduced infrastructure damage</td>
<td>• Reduced vehicle corrosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• ...</td>
<td>• ...</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Software and support</td>
<td></td>
</tr>
<tr>
<td>• Communications</td>
<td></td>
</tr>
<tr>
<td>• In-vehicle computer hardware</td>
<td></td>
</tr>
<tr>
<td>• Training</td>
<td></td>
</tr>
<tr>
<td>• Administration costs</td>
<td></td>
</tr>
<tr>
<td>• Additional weather forecast provider costs</td>
<td></td>
</tr>
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</table>
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?

Actual Conditions

Actual Rules of Practice

MDSS Treatment

Resources Used

Predicted LOS

Resources Used

Predicted LOS
Calibration

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

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

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

$J =$ 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

<table>
<thead>
<tr>
<th>State</th>
<th>Scenario Same:</th>
<th>Benefits ($M)</th>
<th>User Savings (%)</th>
<th>Agency Savings (%)</th>
<th>Costs ($M)</th>
<th>B-C Ratio</th>
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<tbody>
<tr>
<td>NH</td>
<td>Condition</td>
<td>$2.37</td>
<td>50</td>
<td>50</td>
<td>$0.33</td>
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<td>$0.50</td>
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<td>-87</td>
<td>$0.50</td>
<td>2.75</td>
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<tr>
<td>CO</td>
<td>Condition</td>
<td>$3.37</td>
<td>49</td>
<td>51</td>
<td>$1.50</td>
<td>2.25</td>
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<tr>
<td></td>
<td>Resources</td>
<td>$1.99</td>
<td>90</td>
<td>10</td>
<td>$1.50</td>
<td>1.33</td>
</tr>
</tbody>
</table>
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
Analysis of Maintenance Decision Support System (MDSS) Benefits & Costs

Study SD2006-10
DRAFT Final Report

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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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