A Benefit-Cost Assessment of MDSS Implementation in the City and County of Denver

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11th Maintenance Decision Support System Stakeholder Meeting
September 16, 2009
Snow Response in City and County of Denver (C/C Denver)

- **Annual average snow fall: 60 inches**
  - Most storms: trace to 3 inches
  - 50 miles west of Denver: 250-300 inches

- **Denver Public Works Department provides snow response services**
  - 1,780 lane miles
  - 68 trucks (10 liquid, 18 dry, 40 combo units)
  - Materials: Ice-Slicer (dry naturally mined sand/salt mixture) and Apex (liquid commercial product)
  - Two 12-hour shifts (noon, midnight)
  - Six snow districts with dedicated supervisor and drivers

- **Planning event response starts with a snow meeting**
  - Crew deployment strategy
  - Pre-treatment decisions
C/C Denver Annual Snow Budgets/Costs

- CY Budgets $4.5M to $5M
  - Regular staff pay
  - Overtime pay ($250,000)
  - Supplies/materials/fuel
  - Capital equipment
  - Other

- Costs
  - Can include contracted services for major events
## Material Use in 07-08 and 08-09

<table>
<thead>
<tr>
<th>Year</th>
<th>Events and Events Treated</th>
<th>Ice-Slicer (000s)</th>
<th>Ice-Slicer Cost ($81/ton)</th>
<th>Apex (000s) gallons</th>
<th>Apex Cost (0.67/gal)</th>
<th>Total Cost</th>
<th>Lane Miles Treated</th>
<th>Cost/Lane Mile Treated</th>
<th>Cost/Event requiring treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-2009</td>
<td>37/16</td>
<td>13,109</td>
<td>$530,933</td>
<td>565</td>
<td>$378,550</td>
<td>$909,483</td>
<td>73,002</td>
<td>$12.46</td>
<td>$56,843</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>69/33</strong></td>
<td>27,895</td>
<td><strong>$1,129,754</strong></td>
<td>935</td>
<td><strong>$626,450</strong></td>
<td><strong>$1,756,204</strong></td>
<td>194,475</td>
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<td></td>
</tr>
</tbody>
</table>
MDSS Deployment

- Federal prototype MDSS developed and supported by NCAR

- Three basic modules
  - Weather forecasting (48 hours in advance)
  - Current and forecast pavement conditions
  - Treatment recommendations

- District-level recommendations
  - Updated every 3 hours
Evaluation Purposes

• **Primary**
  – Generate a credible Benefit-Cost Assessment (BCA) to support a business case for an agency considering implementing an MDSS
    - Measure agency cost
    - Quantify benefits and clarify pathway to benefits
    - Apply a defensible evaluation design

• **Secondary**
  – Add to the evidence base of benefits of the use of the MDSS
  – Identify both technical and institutional issues
  – Document how issues were addressed.
Evaluation Framework

Benefits

- Benefits from Event Forecasts
- Benefits from MDSS Treatment Recommendations
- Benefits from Geographic Forecasts
  - Travel Time Savings
  - Safety Cost Savings
  - Vehicle Operating Cost Savings
  - Improvement in Environment

Costs

- Fixed MDSS Deployment Costs
- Operating Costs

Net Benefits
(Total Benefits – Total Costs)
Evaluation Hypotheses

- **Tactical (or Management) Decisions**

  *Hypothesis:* By using the MDSS forecasts as a tactical decision support tool, C/C Denver will achieve reductions in shift hours or eliminate shift call-ins, thereby reducing labor hours and associated costs for winter maintenance.

- **Treatment Recommendations**

  *Hypothesis:* By using the MDSS updates and treatment recommendations, C/C Denver will experience a reduction in the amount and cost of material used and a decrease in the number of truck miles, and hence cost of fuel and maintenance, over the course of an entire winter.
Tactical (Management) Decision Support

- **Event information provided by the MDSS:**
  - Start time of precipitation
  - Duration of precipitation
  - Precipitation type
  - Pavement temperatures
  - Precipitation rate
  - Blowing snow
  - Road or bridge frost
  - Refreeze
  - Wind speed

- **Management decisions:**
  - The timing and size of crew call-ups (including overtime)
  - When to shift crews from daily assignments to snow shifts and vice versa
  - What deployment strategies to use
  - Whether anti-icing or pre-treatment may be warranted
  - Region-wide decisions
Tactical Decision Support Assessment

• Quantify the impact of the MDSS on tactical decisions
  – Compare MDSS with other forecast tools at the snow meeting
  – Document observed event data (start time, precipitation type/amount, end time)
  – Understand how tactical decision was affected by the use of the MDSS (What decision would have been made without the MDSS?)

• Challenges
  – Deciding how to weight the MDSS against the other forecast tools
  – Event timing has large effect tactical decisions
  – Tactical decision may be affected by political or other considerations
Example from last winter that resulted in a shift-savings (eliminated a noon shift based on lower MDSS forecasts)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MDSS</strong></td>
<td><strong>Sunday Midnight</strong></td>
<td><strong>Monday Late</strong></td>
<td>45°</td>
<td>31°</td>
<td>36°</td>
<td>29°</td>
<td>100%</td>
<td><em>Snow, trending down to 3”-4”</em></td>
</tr>
<tr>
<td>Private Weather Service #1</td>
<td>Sunday Evening</td>
<td>Monday Afternoon</td>
<td>45°</td>
<td>23°</td>
<td>37°</td>
<td>25°</td>
<td>75%</td>
<td>rain/snow 5”-10”</td>
</tr>
<tr>
<td>Private Weather Service #2</td>
<td>Sunday Evening</td>
<td>Monday Evening</td>
<td>47°</td>
<td>32°</td>
<td>26°</td>
<td>37°</td>
<td>100%</td>
<td>rain/snow 4”-8”</td>
</tr>
<tr>
<td>Local Television #1</td>
<td>Sunday Afternoon</td>
<td>Monday Evening</td>
<td>49°</td>
<td>28°</td>
<td>36°</td>
<td>28°</td>
<td></td>
<td>rain/snow &quot;enough to shovel&quot;</td>
</tr>
<tr>
<td>Local Television #2</td>
<td>Sunday Evening</td>
<td>Monday Evening</td>
<td>50°</td>
<td>26°</td>
<td>35°</td>
<td>23°</td>
<td>85%</td>
<td>rain/snow 5”-10”</td>
</tr>
<tr>
<td>Local Television #3</td>
<td>Sunday Afternoon</td>
<td>Monday Evening</td>
<td>50°</td>
<td>27°</td>
<td>35°</td>
<td>22°</td>
<td></td>
<td>rain/snow 4”-8”</td>
</tr>
<tr>
<td>Local Television #4</td>
<td>Sunday Evening</td>
<td>Monday Afternoon</td>
<td>49°</td>
<td>28°</td>
<td>38°</td>
<td>21°</td>
<td></td>
<td>rain/snow 5”-10”</td>
</tr>
</tbody>
</table>
# Results– Tactical Decision Support: Events and Savings

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Events</th>
<th>MDSS Used</th>
<th>MDSS Resulted in Savings</th>
<th>MDSS Resulted in Costs</th>
<th>Missed Events BY ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-2008</td>
<td>32</td>
<td>22</td>
<td>5</td>
<td>0</td>
<td>1 (Late storm prediction by MDSS others missed entirely)</td>
</tr>
<tr>
<td>2008-2009</td>
<td>37</td>
<td>34</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>56</td>
<td>10</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Cost – If decision based on MDSS was not warranted and a different decision with other services was possible.
## Results (2)– Tactical Decision Support: Events and Savings

<table>
<thead>
<tr>
<th>Year</th>
<th>Events with Savings</th>
<th>Type of Savings</th>
<th>Total Value of Savings ($)</th>
<th>As % of Overtime Budget</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-2008</td>
<td>5</td>
<td>2 Full Shift Savings 3 Partial Shift Savings (4 hours OT)</td>
<td>$136,000</td>
<td>55.5%</td>
<td>1 event where RPP* might have been mobilized without MDSS</td>
</tr>
<tr>
<td>2008-2009</td>
<td>5</td>
<td>Partial Shift Savings (4 hours OT, standby versus bringing one crew in)</td>
<td>$48,000</td>
<td>19.2%</td>
<td>1 event where RPP might be mobilized without MDSS</td>
</tr>
<tr>
<td>Average</td>
<td>5</td>
<td>1 Full Shift, 3.5 Partial Shift Savings</td>
<td>$92,000</td>
<td>36.8%</td>
<td></td>
</tr>
</tbody>
</table>

RPP- Residential Plowing Program
Results (3) – Tactical Decision Support

• **MDSS has become an indispensable tactical decision support tool.**
  
  – Average Annual shift savings over the past two years (avoided labor hours) = $ 92,000. This alone justified the investment in the MDSS.
  
  – More actionable
  
  – Accurate
  
  – No incurred costs due to MDSS use
  
  – Significant percent of C/C Denver’s overtime or discretionary budget (37%)
  
  – MDSS supports C/C Denver in deciding if the Residential Plow Program should be activated.
    
    - Twice in the past two winters, MDSS has been used to justify holding off on RPP.
    - If Residential Plow Program (RPP) savings were included, MDSS pays for itself many times over. Each RPP deployment costs the city $120,000 PER SHIFT.
Estimation of Benefits Due to MDSS Treatment Recommendations

*Hypothesis:* By using the MDSS updates and treatment recommendations, C/C Denver will experience a reduction in the amount and cost of material used and a decrease in the number of truck miles, and hence cost of fuel and maintenance, over the course of an entire winter.

- Set up a real world test-bed approach that C/C Denver can follow treatment recommendations, monitor performance, and collect data
  - Account for data collection challenges
  - Conduct assessment over one winter period
  - Monitor performance effectively of MDSS treatment recommendations
  - Compare and contrast with current practice
Treatment Module Assessment

• “With/without” research design

• Evolved from a district-level assessment to a route-level assessment

• Control Routes and Experimental Routes
  – Control Routes – normal procedures
  – Experimental Routes – follow MDSS treatment guidelines (as long as safety is not compromised)
  – Account for similar pavement types, traffic levels
Treatment Test Routes Map
Results – Treatment Module Tests

• Three tests were run during the winter
• All three storms petered out requiring only minor treatments
• C/C Denver observations during the test
  – MDSS sometimes was recommending over-application of materials
  – Recommendations are harder to follow for arterials than freeways.
    - Several passes through an intersection, problem areas, diversion to other side streets
    - Trucks are often not calibrated accurately so monitoring amounts of material used difficult
    - Compound treatments (liquid and solid materials applied at the same time) is not reflected yet in MDSS
    - Forward correction is a challenge, especially for night shifts as supervisors are on the field and drivers are out treating the roads
    - Supervisors unclear on the timing of treatment recommendations from MDSS
Results (2) – Treatment Module Tests – Experimental versus Control – Test 1

<table>
<thead>
<tr>
<th>Routes</th>
<th>Lane-Miles</th>
<th>@1600 hrs</th>
<th>@1700 hrs</th>
<th>@1800 hrs</th>
<th>Lane-miles</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colfax Ave.</td>
<td>18.8</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>6.25</td>
<td>No treatment</td>
</tr>
<tr>
<td>Federal Blvd.</td>
<td>18.7</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>23</td>
<td>No treatment</td>
</tr>
<tr>
<td>Colorado Blvd.</td>
<td>22.5</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>No treatment</td>
</tr>
<tr>
<td>Yale Ave.</td>
<td>6</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>10.63</td>
<td>No treatment</td>
</tr>
</tbody>
</table>

Notes - MDSS over-recommended material. No treatment was needed.

Following MDSS across the entire C/C Denver A-Route System (1,354 lane miles) for this storm would have resulted in 50 to 100 lbs/mi material usage when not needed.

Using 75lb/lane-mile and $81/ton as an average (excluding fuel/equipment costs), translates to 101,550 lbs of material use and cost of $4,112.
## Results (3) – Treatment Module Tests – Experimental versus Control – Test 2

<table>
<thead>
<tr>
<th>Test 2- March 26th</th>
<th>Experimental MDSS Recommended Treatment</th>
<th>Control Actual Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routes</td>
<td>Lane-Miles</td>
<td>@1100 hrs</td>
</tr>
<tr>
<td>Colfax Ave.</td>
<td>18.8</td>
<td>150</td>
</tr>
<tr>
<td>Federal Blvd.</td>
<td>18.75</td>
<td>150</td>
</tr>
<tr>
<td>Colorado Blvd.</td>
<td>22.5</td>
<td>150</td>
</tr>
<tr>
<td>Yale Ave.</td>
<td>6</td>
<td>150</td>
</tr>
</tbody>
</table>

Difficult to say which regime was better.

From an operations standpoint, Superintendents felt MDSS was over recommending. They did not follow the early treatment recommendation in experimental routes.
# Results (4) – Treatment Module Tests – Experimental versus Control – Test 3

MDSS and Control Districts were consistent. Storm petered out requiring only spot treatments.

One band of heavy snow passed over districts 1 and 2 at 1600. Over about a 45 minute period, roughly one inch fell but latent heat melted the snow on contact with very little accumulation on pavement. Later in the evening, after precipitation ended some minor icing occurred in district 1 and spot applications of material were deployed.

<table>
<thead>
<tr>
<th>Test 3- April 1st</th>
<th>Experimental MDSS Recommended Treatment</th>
<th>Control Actual Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routes</td>
<td>Lane-Miles @1800 hrs @2000 hrs @2200 hrs @2400 hrs Lane-Miles</td>
<td></td>
</tr>
<tr>
<td>Colfax Ave.</td>
<td>18.8</td>
<td>spot</td>
</tr>
<tr>
<td>Federal Blvd.</td>
<td>18.75</td>
<td>spot spot</td>
</tr>
<tr>
<td>Colorado Blvd.</td>
<td>22.5</td>
<td>spot</td>
</tr>
<tr>
<td>Yale Ave.</td>
<td>6</td>
<td>spot spot</td>
</tr>
</tbody>
</table>
Results (4) – Treatment Module Tests

- The benefits of the treatment recommendations are still unrealized
  - Mild winter. Most events did not require any more than spot treatments after the test protocol was set
  - Three tests resulted in three different scenarios
  - Superintendents finding it difficult to follow recommendations for arterials
    - Spot treatments, Diversions, Intersections ≠ std lb/ln-mile
    - Drivers responding to what they see
  - Feel that MDSS is over-recommending

Superintendent - “The MDSS is helping us save materials, *not by the treatment recommendations*, but by keeping us from treating blindly like we used to. In earlier winters, we’d wipe out half our magnesium chloride from pre-treating when we really didn’t need to as the forecasts were a wide-ranging.”
Lessons Learned: What do the Superintendents think about MDSS?

• Things they like
  – Weather information considered accurate (start times, accumulation amounts, precip type).
  – Localized information. Looking at their districts very helpful
  – Feel more comfortable making decisions with MDSS than with other tools (which have a larger forecast area)

• To be improved
  – More frequent updates than 3-hours. Live updates if possible
  – Longer forecast windows (especially for Sat-Sun events)
  – Understanding MDSS outputs (graphs etc).
  – More support especially during midnight shifts (feel like they are on an island)
  – Need *radar* information

• Not sure
  – Treatment module is not there yet for city streets
  – Maybe more useful with live updates, better information from vehicles (temp probes, AVL/MDCs)
  – Needing to provide information on current treatment during the storm
Summary and Conclusions

- Overall, MDSS is viewed as a success by C/C Denver
- MDSS benefits have exceeded cost
  - Real savings in labor costs. C/C Denver feels this alone justifies their investment.
  - Shift savings have ranged from $48,000 (08-09) to $136,000 (07-08)
  - Superintendents use, value the functionality the tool provides
  - Provides a sound basis for decision-making pre-event and during the event on shift call-ins
  - Treatment module has not yet realized benefits
  - Challenges in implementation and marginal over-recommendation of materials
  - Management, superintendents rely heavily on MDSS before and during the event
    - Pavement temperatures, 3-hour updates, district-level forecasts are “most-liked” features
Next Steps

• Final Report – September 2009

• For more information
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