SEVEN BEST PRACTICES IN SUSTAINABLE WINTER HIGHWAY MAINTENANCE OPERATIONS

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Associate Professor, Washington State University
BENEFITS OF W.M. OPERATIONS

• Fewer accidents, improved mobility, reduced travel costs, reduced fuel use

• Sustained economic productivity, continued emergency services, ...
W.M. IN THE U.S.

- > 70% roads, 70% population affected
- Hwys: 2.3 $bLn/yr + 5 $bLn/yr

**MnDOT Case Study:**

- (4,600 crashes) = 29% ↓
- $10.9M in travel time savings
- $48.4M in user fuel savings
- Total $227M saved, b/c of 6.2

**Intangible benefits**

Increased traffic volumes
Higher customer demands
Funding, staffing and technology constraints

Safety
$\text{Cost}$
Effectiveness

Mobility / Productivity

Level of Service
Customer Satisfaction

Minimized Corrosion
Environmental Stewardship

WHAT, WHY, HOW

Deliver the right type & amount of materials in the right location at the right time

↑ effectiveness & efficiency of winter operations

↓ material usage, $$\$, environmental footprint

Balancing LOS vs. sustainability: best practice in technology & management domains

BP1: **Passive Snow Control**

- Reduce blowing & drifting snow
- Low cost snow storage
- Increased safety
- Reduce need for ice control product
- 25 yr lifespan at $1.40 per ft²

Wildlife habitat, control erosion, improve water quality, reduce spring-time flooding, sequester carbon

≥8 ft
BP2: **Operational Strategies**

**Toolbox approach**

- Local needs
- Rd weather scenarios
- Local constraints

**Proactive vs. Reactive**

- Anti-icing
- Deicing (**pre-wet** salt, DLA, ...)
- Sanding (**pre-wet** sand)
- Mechanical (plowing/blowing)
“...prevent the formation or development of bonded snow & ice by timely applications of a chemical freezing-point depressant” (vs. DLA)

↑ LOS, ↓ product, abrasives & plowing
20 – 65 gal/lane-mi
Cost savings + mobility & safety ↑
reducing impacts to the environment, infrastructure, vehicles

Limitations:
- Cold temps, rain/sleet 雨夹雪, blowing snow 飞雪, air temp above freezing & rising, high humidity
PRE-WETTING SOLID MATERIAL

Adding liquid to products or abrasives at stockpile or at the spreader 撒布器

Benefits

- Eases product management & distribution
- Accelerates breakup of snow/ice & enhances melting
- Minimizes bounce & scatter, improves performance
- Increases longevity on road = less frequent applications
CASE STUDY: SLURRY TECHNOLOGY

High volume liquid anti-icer to dry salt (30%:70%)  
~ 60-90 gal/ton  
200 lb/lane-mi = ~ 9 gal  
Oatmeal consistency, salt grains fully saturated  
Slurry auger (螺旋输送器) & at spinner (旋转器)
SALT MATRIX & PRE-SET SPREADER APPLICATION RATES

Goal: Reduce application rates while maintaining same LOS

Considers: pavement temp., heating/cooling trends, road condition at time of service, available maintenance strategies

Provides: recommended application rates for liquid and solid for initial & subsequent treatments on reference sheets

- 4 storm scenarios (light, moderate, & heavy snow, freezing rain)
- Drivers use their judgment to make decisions

Kentucky Department of Highways
Chemical Usage Has Environmental Footprint

**Sustainability** = economic growth + social progress + ecological balance

SALT MANAGEMENT PLANS

- A statement of policies & objectives
  - Identifies: road use, salt vulnerable areas, storage sites, snow disposal sites, training, ...
- Documentation
- Proposed approaches
- Training & Management Review
Determine your **baseline** 基线

Use collected data to find trends and track:

- Total length of road, Winter severity rating, Number of events, Material used, *Equipment Calibration* dates, Treatment effectiveness ...
### Multi-Criteria Collaborative Decision Making

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost</th>
<th>Characteristic Temperature</th>
<th>Ice Melting Capacity</th>
<th>Corrosion to Metals</th>
<th>Effect on Concrete</th>
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<tr>
<td>1: Cost-first</td>
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</table>

**Anti-Icer Composite Index, User Scenario 1: Cost-First**

- 80-100
- 60-80
- 40-60
- 20-40

**CaCl₂·2H₂O Dosage (g/g NaCl)**

- 1.20
- 0.98
- 0.76
- 0.54
- 0.33
- 0.23
- 0.17
- 0.11
- 0.06
- 0.00

**Inhibitor Dosage (ml/g NaCl)**

## Multi-criteria Collaborative Decision Making

<table>
<thead>
<tr>
<th>Normalized Data</th>
<th>Cost per Lane Mile</th>
<th>Average Performance</th>
<th>Infrastructure /Vehicle Impacts</th>
<th>Environmental Impacts</th>
<th>Composite Index</th>
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</table>

A “Supermix” (85% salt brine, 10% De-ice, and 5% CaCl₂): anti-icing above 15°F @ 40 gln/ln-mi pre-wetting above 2°F @ 10 gln/ton

PERFORMANCE MEASURES

工作指标

- Mobility 流动性, accessibility 可达性, reliability, safety
- Example: time to bare lane
- Measured as: return to speed, friction, visual inspection, etc.
IOWA DOT SALT MODEL

Allocates salt to garages based on weather conditions & policy usage requirements.

Creates a salt budget for each garage

Garage Salt Use Summary

<table>
<thead>
<tr>
<th>CC</th>
<th>Garage</th>
<th>Allocation (Tons)</th>
<th>Salt Used (Tons)</th>
<th>Salt Target (Tons)</th>
<th>% Target Used</th>
<th>% Allocation Used</th>
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<td>551608</td>
<td>Iowa Falls</td>
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<td>512.4</td>
<td>820.6</td>
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<td>× 54.5%</td>
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<td>× 33.9%</td>
</tr>
</tbody>
</table>

Statewide Salt Use vs. Target

Annette Dunn
Iowa DOT
MANAGING DEICER CORROSION EFFECTS

• Costs associated with corrosion to cold-climate DOT equipment assets are substantial (reduced value & service life, increased maintenance & repair costs, downtime & safety risk, ...)

• Agencies are recommended to establish their corrosion management program as an integral part of Fleet Management

• Efforts should be focused on efficient investment in corrosion cost avoidance, which may entail an extensive risk-based maintenance program to preserve the value & performance of equipment assets
HWM-BP3: *Improved Weather Forecasts*

Estimates of Labor and Materials Cost based on Level of Usage of UDOT Weather Operations Program

<table>
<thead>
<tr>
<th></th>
<th>High Cost</th>
<th>Low Cost</th>
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<tbody>
<tr>
<td>Worst Weather Info</td>
<td>$20</td>
<td>$15</td>
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<tr>
<td>Without UDOT Program</td>
<td>$15</td>
<td>$10</td>
</tr>
<tr>
<td>Actual</td>
<td>$10</td>
<td>$5</td>
</tr>
<tr>
<td>Full Use of Weather Program</td>
<td>$5</td>
<td>$5</td>
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</tbody>
</table>
Improved Weather Forecasts


PAVEMENT SENSORS & THERMAL MAPPING

热分布测绘：
Monitoring, planning, treatment strategies, forecasting
Invasive & non-invasive

www.vaisala.com
HWM-BP4: *Fixed Anti-icing Spray Technology*  
固定防冰喷雾技术

FAST Summary

• Mixed picture
  o $$ savings: reduced mobile operations; reduced crash frequency/delay; less materials required
  o Challenges: activation frequency, system maintenance & training
• Installation challenges: site-specific
• Better system reliability via improvements in design, hardware, software, and installation techniques
• Appropriate only at a highly localized level, as a supplement to mobile operations
**Safety Analysis of FAST**

- FAST systems contributed to crash reductions of:
  - 2% on multilane rural highways
  - 16 – 70% on urban interstates
  - 31 – 57% on rural interstates
  - 19 – 40% on interchange ramps
  - Unclear for rural two-lane roads

- Changes to crash rates by severity provided safety benefits of $196,428 per winter
## HWM-BP5: Advanced Snowplows

<table>
<thead>
<tr>
<th>Technology</th>
<th>Detect Environmental/Road Surface Conditions</th>
<th>Detect Obstacles</th>
<th>Detect Position on Roadway</th>
<th>Conduct Road Treatment</th>
<th>Improve Vehicle-to-Center Coordination</th>
<th>Track Vehicle Location and Activity</th>
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<tbody>
<tr>
<td>AVL</td>
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<td>Ice-presence Detection System</td>
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</table>

*Used for this application only when coupled with other sensor technologies

- Technologies often linked with AVL
AUTOMATIC VEHICLE LOCATION (自动车辆定位)
CONFIGURATION 布局

- Location / timestamp
- Environmental conditions
- Vehicle activity
- Vehicle status
- Other data

- In-vehicle unit
- Antenna
- Activity / status sensors

- Air temperature
- Road surface temperature
- Salinity
- Freezing point / ice detection
- Friction

In-vehicle unit
Antenna
Activity / status sensors
Mobile RWIS Technologies

Integrated with AVL to provide improved real-time knowledge of road & environmental conditions throughout a network

- Surface temperature measurement devices
- On-board freezing point & ice presence detection sensors
- Salinity sensors

RESIDUAL CHEMICAL MEASUREMENT

Salinity sensors have been used to make educated decisions about reapplication (Ye et al., 2012).

Monitor road surface product concentration
On-vehicle, embedded, or non-contact
Accurate/recalibrated application rates
Link measurements with automatic spreader controls

Benefits:
- Prevents over-application, saves material & $$$
PRECISION APPLICATION TO MANAGE & REDUCE CHEMICAL APPLICATIONS

Benefits
- Improved material placement
- Return on investment
- Reduced chemical usage
- Improved environmental stewardship

• Costs
  - Equipment
  - Training
  - Calibration
HWM-BP6: *Pavement Technologies*

- Anti-freezing pavements that rely on physical action
- Asphalt pavements containing anti-icing additives
- Heated pavements
- High-friction *in situ* anti-icing polymer overlays
Monitoring, planning, treatment strategy, prevent over-application

**Colorado DOT**
- Non-contact friction measurements
- Provide good short/long-term assessment of product performance
HWM-BP7: **MDSS**
<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Road Temp</th>
<th>Road Cond</th>
<th>% Ice</th>
<th>Maint Action</th>
<th>Notes</th>
<th>Date/Time</th>
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</table>

**Notes:**
- Engaged: Road conditions are active and require immediate attention.
- None: No issues at this time.

**Date/Time:**
- Mon 05:30AM: 05:30 Monday morning.
NH: MDSS BENEFITS & COSTS

- Benefits (per winter season)

<table>
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<th>Scenarios</th>
<th>Delay Savings</th>
<th>Crash Savings</th>
<th>Resource Savings</th>
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<td>$72,461</td>
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- Costs per winter season: $332,879
- Benefit-Cost Ratios:
  - 2.1 (Same Conditions); 2.6 (Same Salt)

SUMMARY OF WM BEST PRACTICES

1. Passive Snow Control Measures
2. Operational Strategies
3. Improved Weather Forecasts
4. Fixed Automated Spray Technology
5. Advanced Snowplow Technologies
6. Pavement Technologies
7. Maintenance Decision Support System
TRAINING FOR SALT MANAGEMENT & WM OPERATIONS

Assess the needs of your staff

Consider who is being trained & how to best convey that information

Design training based on learning goals

Training methods:

- Classroom, field, post-storm debriefing, simulator, etc.
TRAINING CONTINUED...

Have experienced staff conduct the training
Evaluate your training program
Assess how much information was learned

Common training methods:
- Annual operator training, Snow University, Snow & Ice Rodeo, Computer Based Training (CBT)
A Look to the Future

- Technological & institutional barriers remain
- Micro-scale road weather forecasting & sensing
- ‘dynamic layer’ on the road surface: timing & freq.
- More integrated & automated onboard sensors + **Vehicle Infrastructure Integration**
- Performance measures + systematic approach to decision making in materials selection
- *Ultimate integration into the WM toolbox*: continued investment & efforts in R&D + user-needs driven product strategies
An Asset Management Framework

Policy Goals and Objectives

Integrated Evaluation of Alternatives and Tradeoffs
Program/project prioritization & optimization via scenario simulation ("what-if" analyses)

Decision on Allocating Agency Resources
Anti-icing vs. de-icing or sanding; chemical A vs. B; application rate

Program Delivery
Outsourcing, public/private partnership, procurement options, etc.

System Monitoring and Performance Results
Performance measures (including level of service & customer perceptions), economics, asset inventory (infrastructure & environment)

Quality Information and Analysis
E.g., resources, performance, costs, inventory, etc.

Feedback Mechanism
QUESTIONS?

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Overseas PhD Advisor, Harbin Institute of Technology
Associate Professor, Department of Civil and Environmental Engineering
Washington State University
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Pullman, WA 99164-2910
Phone: 1-509-335-7088; Email: xianming.shi@wsu.edu