Rules of Practice

- Automation Overview
- Snow Depth / Chemical Concentration
- Automating FHWA Guidelines
- Supported Decisions / Treatments
- Summary
Road Condition-Treatment Algorithms

- Weather Variables
- Road Snow Depth
- Chemical Concentration
- Pavement Temperature
- Rules of Practice
- Treatment Plan
  - Chemical Application
  - Plowing

- Road
- Snow
- Depth
- Chemical
- Application
- Rules
- Practice
- Plowing
Estimating Snow Depth

Chemicals dilute
- Precipitation rate slowly become ineffective

Plowing
- Removes loose snow
- Anti-icing <0.5" remains
- De-icing leaves compacted snow

Compaction
- Water Content

Free-Falling
- Snow Depth

Chemicals
- NaCl
- MgCl
- CaCl

Melting
- Pavement Temperature

Traffic
- Blows snow/chemicals off road
- Compacts loose snow
- Reduces treatment effectiveness

Winds
- Blow snow on and off the road
Estimating Chemical Concentration Dilution

- Chemical Type: NaCl, MgCl, CaCl
- Spread Rate
- Road Splatter
- Traffic Splatter
- Liquid Runoff
- Liquid Water Dilution
- Chemicals Melt Frozen Precipitation
- Chemicals Fail (new treatment needed)

Reduces Chemical Concentration

Reduces Overall Available Chemicals
Automating Chemical Dilution

• Base decisions on chemical dilution curves
  
  ![Phase Diagram for Sodium Chloride](image)

  • C++ Algorithm (modular code with flexible interface)
    - Ingest snow depth, pavement temperature, precipitation forecast
    - Determines concentration based on CRREL dilution algorithm
    - Currently only NaCl, but new chemicals easily added
Automating Treatment Recommendations

- Base decisions on FHWA Anti-icing guideline tables

- C++ Algorithm (modular code with flexible interface)
  - Identify potential treatment trigger points
    - Level of snow on road
    - Ice on road
  - Determines consensus treatment from multiple time steps
  - Iteratively update road conditions based on treatment
  - Maintain LOS past end of storm
  - User-adjustable parameters
    - Acceptable road conditions (triggers)
    - Preferred treatment types
Rules of Practice – Automating FHWA Guidelines

Chemical Treatment (lbs/2-lane mile)

Road Surface Temperature (degC)

Precip Type

Precip Intensity

Nominal Treatment Rate

No Treatment
Rules of Practice – Integrating Forecasts to Optimize Treatment

- Maximum of all treatments
- Average of all treatments

Chemical Treatment (lbs/2-lane mile)

Road Surface Temperature (degC)

No Treatment

No Treatment
Rules of Practice - Example

TP (°C)

Snow Depth (in)

Chem Solution

Effective

Failure

Treatment 400 lbs/lane-mile NaCl
Rules of Practice – Supported Treatments

• **Chemicals**
  – Initially only NaCl
  – Algorithm allows new chemicals to be added easily
  – User controls preferred chem type, min/max application rates

• **Plowing**
  – User controls trigger point (default is 3” snow depth)

• **Sand**
  – Only as general guidance (no specific rates)

• **Pre-treatment**
  – All chemical treatments begin prior to the “trigger point”
  – Default offset is ½ of the expected route time
  – Treatment guidance for first treatment could indicate that the chemicals may be applied up to 12 hours prior to the event start.
## Rules of Practice – Supported Conditions

<table>
<thead>
<tr>
<th>Storm Conditions</th>
<th>Supported?</th>
<th>Recommended Treatments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precip Type</strong></td>
<td><strong>Temp Range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snow</td>
<td>-10 to 0* degC</td>
<td>Yes</td>
<td>Chemicals and Plowing</td>
</tr>
<tr>
<td>Snow</td>
<td>&lt; -10 degC</td>
<td>Yes</td>
<td>Plowing</td>
</tr>
<tr>
<td>Snow</td>
<td>Transition below -10 degC</td>
<td>Yes</td>
<td>Chemicals -&gt; Plow Only</td>
</tr>
<tr>
<td>Snow</td>
<td>Transition above 0* degC</td>
<td>Yes</td>
<td>Chemicals -&gt; No Action</td>
</tr>
<tr>
<td>Freezing Rain</td>
<td>Any</td>
<td>Partially</td>
<td>Chemicals</td>
</tr>
<tr>
<td>Black Ice</td>
<td>Any</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Blowing Snow</td>
<td>Any</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

*0 degC represents a threshold “freezing point” no treatment value*
Potential Short-term Enhancements

- Support additional chemicals (CaCl₂, MgCl₂)
## Chemical Dilution Timeline

<table>
<thead>
<tr>
<th>Weather</th>
<th>Road Surface</th>
<th>Chemical Dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td></td>
<td>Chemicals are applied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road splatter – <em>some chemicals are lost immediately</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traffic splatter – <em>the higher the level of traffic the more chemical levels are reduced</em></td>
</tr>
<tr>
<td>Rain</td>
<td></td>
<td>Liquid runoff – <em>dependent on the pitch of the road</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid water dilution – <em>reducing solution volume</em></td>
</tr>
<tr>
<td>Snow</td>
<td></td>
<td>Chemicals melt frozen precipitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid runoff</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid water dilution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concentration weakens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemicals fail (new treatment needed)</td>
</tr>
</tbody>
</table>