Road Condition & Rules of Practice Algorithm

Robert Hallowell
Road Condition-Treatment Automation

- Automation Overview

- Snow Depth / Chemical Concentration

- Rules of Practice
  - Automating FHWA Guidelines
  - Supported Decisions / Treatments

- Summary and future work
Road Condition-Treatment Algorithms

- RWFS Weather Forecast Variables
  - Road Snow Depth
  - Chemical Concentration
  - Pavement Temperature
  - Rules of Practice

- Treatment Plan
  - Chemical Application
  - Plowing
Estimating Snow Depth

**Chemical Application**
- Chemicals dilute
  - Precipitation rate slowly become ineffective

**Winds**
- Blow snow on and off the road

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

**Chemicals**
- NaCl
- MgCl
- CaCl

**Melting**
- Pavement Temperature

**Compaction**
- Water Content

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

**Free-Falling Snow Depth**

**Transportation**
- Blows snow/chemicals off road
- Compacts loose snow
- Reduces treatment effectiveness
Automating Chemical Dilution

- Base decisions on chemical dilution curves

- **C++ Algorithm** (modular code with flexible interface)
  - Ingest snow depth, pavement temperature, precipitation forecast (snow and liquid water)
  - Determines concentration based on CRREL dilution algorithm
  - NaCl, MgCl2, CaCl2
  - Infrastructure designed to make adding new chemicals easy
  - User adjustable parameters:
    - Preferred chemicals
    - Dilution factors
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
FHWA Anti-icing Guidelines

Tables for generic events:
light snow, mod/heavy snow, freezing rain, etc
Guide for NaCl applications

<table>
<thead>
<tr>
<th>PAVEMENT TEMPERATURE RANGE, AND TREND</th>
<th>INITIAL OPERATION</th>
<th>SUBSEQUENT OPERATIONS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pavement surface at time of initial operation</td>
<td>maintenance action</td>
<td>dry chemical spread rate, kg/lane-km (lb/lane-mi)</td>
</tr>
<tr>
<td>Above 0°C (32°F), steady or rising</td>
<td>Dry, wet, slush, or light snow cover</td>
<td>None, see comments</td>
<td>None, see comments</td>
</tr>
<tr>
<td>Above 0°C (32°F), 0°C (32°F) or below imminent:</td>
<td>Dry</td>
<td>Apply liquid or prewetted solid chemical</td>
<td>28 (100)</td>
</tr>
<tr>
<td>ALSO -7 to 0°C (20 to 32°F), remaining in range</td>
<td>Wet, slush, or light snow cover</td>
<td>Apply liquid or solid chemical</td>
<td>28 (100)</td>
</tr>
<tr>
<td>-10 to -7°C (15 to 20°F), remaining in range</td>
<td>Dry, wet, slush, or light snow cover</td>
<td>Apply prewetted solid chemical</td>
<td>55 (200)</td>
</tr>
<tr>
<td>Below -10°C (15°F), steady or falling</td>
<td>Dry or light snow cover</td>
<td>Plow as needed</td>
<td>Plow as needed</td>
</tr>
</tbody>
</table>

Notes
CHEMICAL APPLICATIONS. (1) Time initial and subsequent chemical applications to prevent deteriorating conditions or development of packed and bonded snow. (2) Apply chemical ahead of traffic rush periods occurring during storm.
PLOWING. If needed, plow before chemical applications so that excess snow, slush, or ice is removed and pavement is wet, slushy, or lightly snow covered when treated.
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
  - Multiple chemical support
  - User-adjustable parameters
    - Acceptable road conditions (triggers)
    - Preferred treatment types
Rules of Practice – Automating FHWA Guidelines

Chemical Treatment (lbs/2-lane mile)

Precip Type

Precip Intensity

Nominal Treatment Rate

No Treatment

Road Surface Temperature (degC)

No Treatment

Precip Type

Precip Intensity

Nominal Treatment Rate

No Treatment
Rules of Practice – Integrating Forecasts to Optimize Treatment

- **M**: Maximum of all treatments
- **A**: Average of all treatments

The graph shows the relationship between Road Surface Temperature (degC) and Chemical Treatment (lbs/2-lane mile) for No Treatment scenarios. The data points indicate that as the road surface temperature decreases, the chemical treatment required also decreases.

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MIT Lincoln Laboratory

MDSS FHWA/DOT Review
Robert Hallowell 06/13/2002
Rules of Practice – Supported Treatments

• **Chemicals**
  – Initially NaCl, CaCl$_2$, and MgCl$_2$
  – Algorithm allows new chemicals to be added easily
  – User controls preferred chemical 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
  – User specifies pre-storm treatment offset for first application
## Rules of Practice – Supported Conditions

<table>
<thead>
<tr>
<th>Precip Type</th>
<th>Temp Range</th>
<th>Supported?</th>
<th>Recommended Treatments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow or Mixed</td>
<td>-10** to 0* degC</td>
<td>Yes</td>
<td>Chemicals and Plowing</td>
<td></td>
</tr>
<tr>
<td>Snow or Mixed</td>
<td>&lt; -10 degC**</td>
<td>Yes</td>
<td>Plow Only</td>
<td>User sets threshold</td>
</tr>
<tr>
<td>Snow or Mixed</td>
<td>Transition below -10 degC**</td>
<td>Yes</td>
<td>Chemicals -&gt; Plow Only</td>
<td>Dependant on snow depth adjustments</td>
</tr>
<tr>
<td>Snow or Mixed</td>
<td>Transition above 0* degC</td>
<td>Yes</td>
<td>Chemicals -&gt; No Action</td>
<td>Triggers when Tpavement &lt; 0 and liquid precip</td>
</tr>
<tr>
<td>Freezing Rain</td>
<td>Any</td>
<td>Yes</td>
<td>Chemicals</td>
<td>General warning could be added</td>
</tr>
<tr>
<td>Black Ice</td>
<td>Any</td>
<td>No</td>
<td>-----------</td>
<td>General warning could be added</td>
</tr>
<tr>
<td>Blowing Snow</td>
<td>Any</td>
<td>No</td>
<td>-----------</td>
<td>General warning could be added</td>
</tr>
</tbody>
</table>

* 0 degC represents a threshold “freezing point” no treatment value

** -10 degC represents a threshold “chemical ineffectivity” temperature
Rules of Practice - Example

Tp (C) vs Snow Depth (in)

Treatment 400lbs/lane-mile NaCl

Effective Chem Solution Failure

Tp (C) vs Snow Depth

Effective Chem Solution Failure

Treatment 400lbs/lane-mile NaCl

Effective Chem Solution Failure
Potential Enhancement Efforts

• Direct calculation of chemicals needed for storm
  – Back calculate from chemical dilution algorithm

• Use estimates of storm duration to determine:
  – Optimal number of treatments
  – Level of chemical application

• Modularize Snow Depth and Pavement Temperature algorithms
  – Allows for vendor drop-in algorithms
Enhancing Rules of Practice

- Pavement Temperature
- Chemical Concentration
- Rules of Treatment:
  - How many?
  - How long
  - Min/max
- Road Snow Depth
- RWFS Weather Forecast Variables
- Treatment Plan
- Chemical Application
- Plowing