

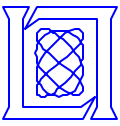
Road Condition & Rules of Practice Algorithm

Robert Hallowell

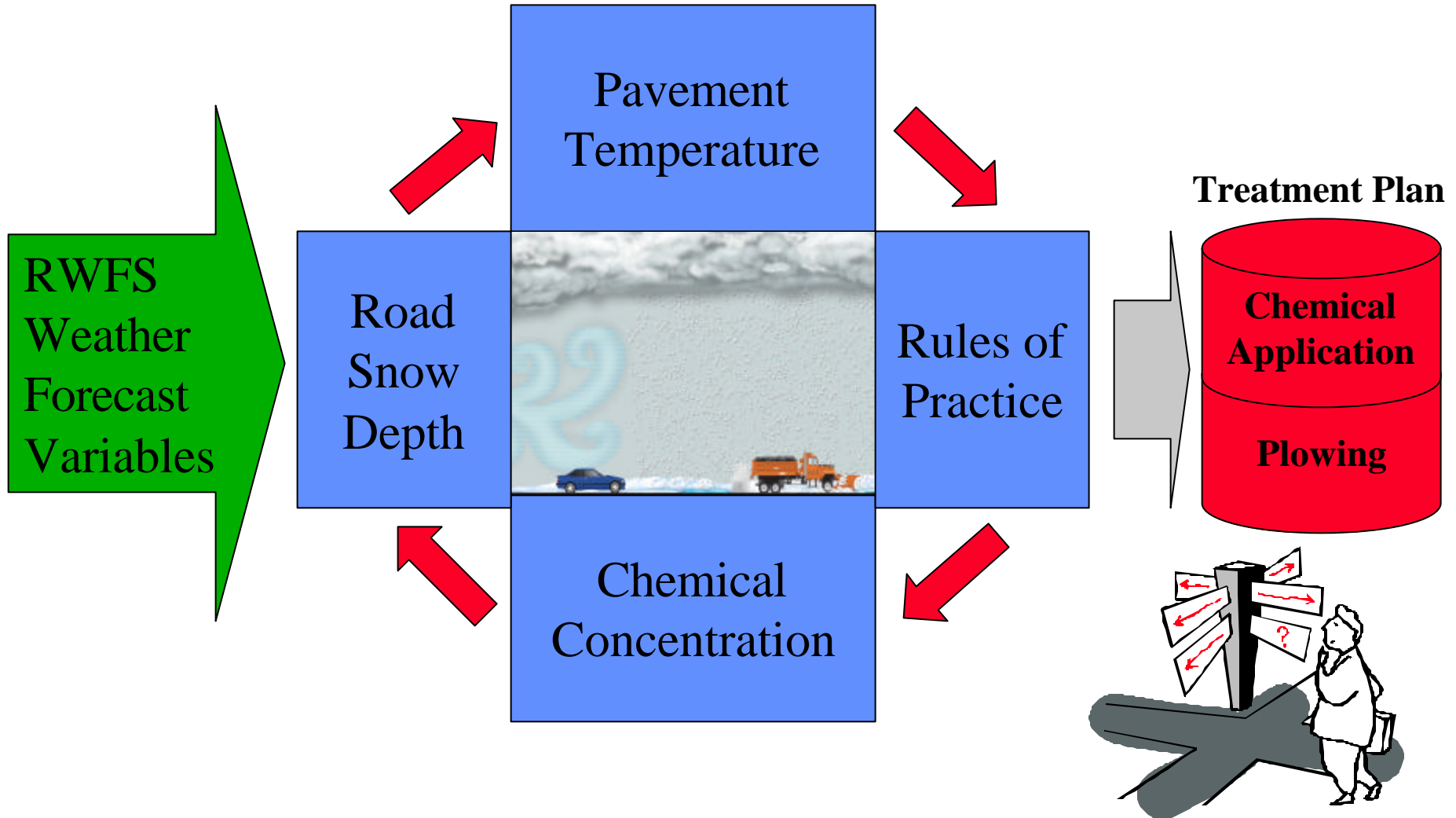


Road Condition-Treatment Automation

- **Automation Overview**
- **Snow Depth / Chemical Concentration**
- **Rules of Practice**
 - Automating FHWA Guidelines
 - Supported Decisions / Treatments
- **Summary and future work**

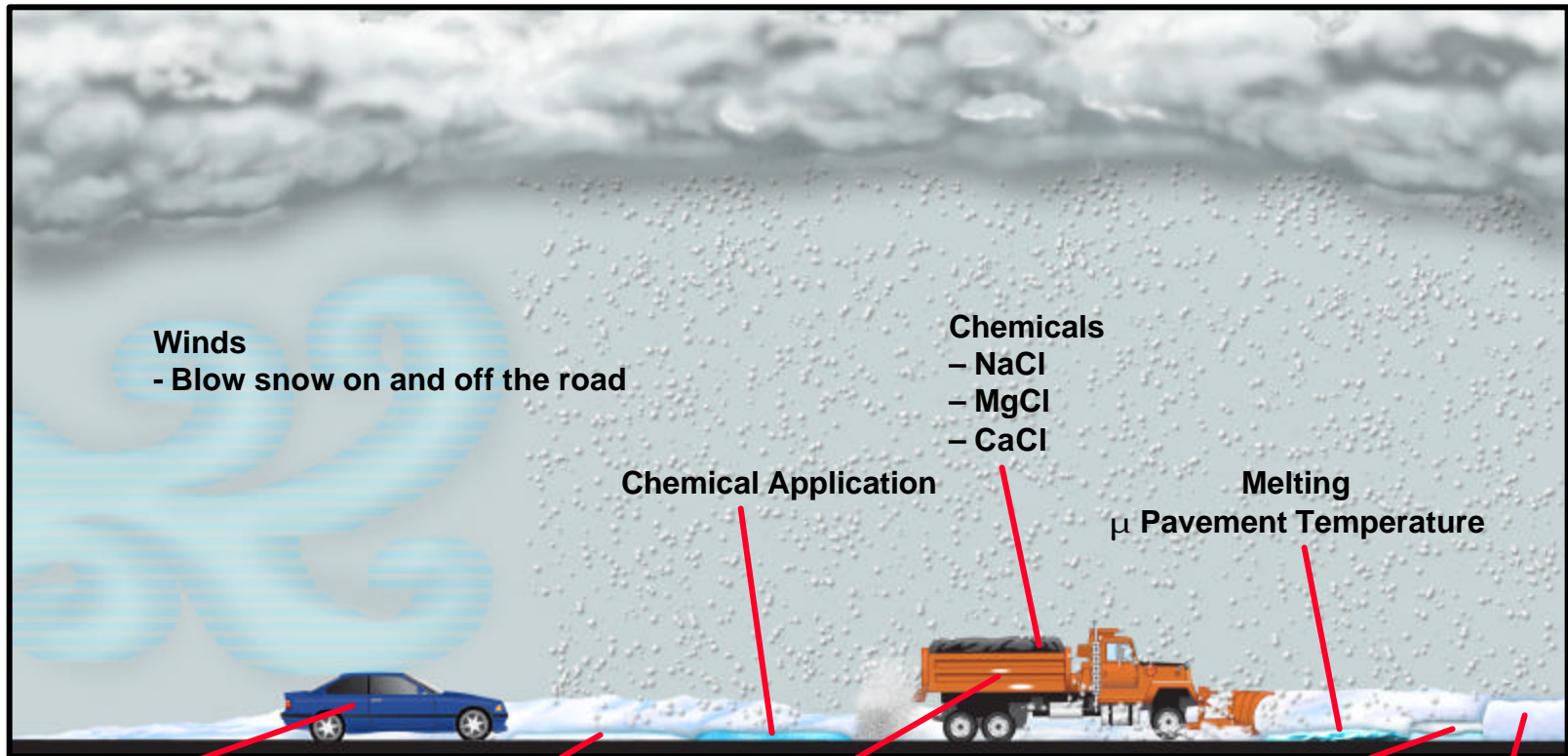


Road Condition-Treatment Algorithms





Estimating Snow Depth



Traffic

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

Chemicals dilute

- μ Precipitation rate slowly become ineffective

Plowing

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

Compaction

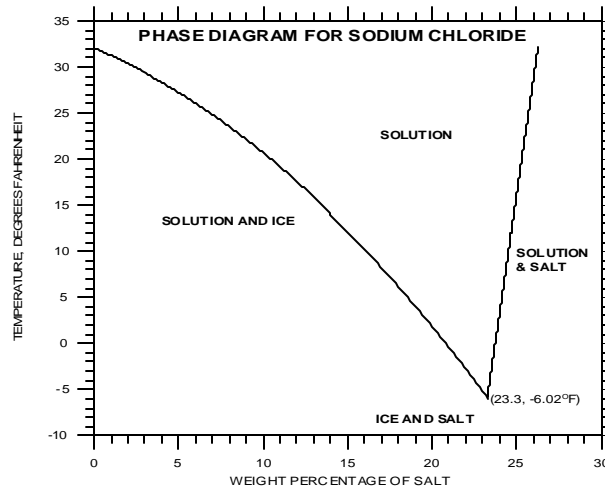
- μ Water Content

Free-Falling Snow Depth



Automating Chemical Dilution

- **Base decisions on chemical dilution curves**

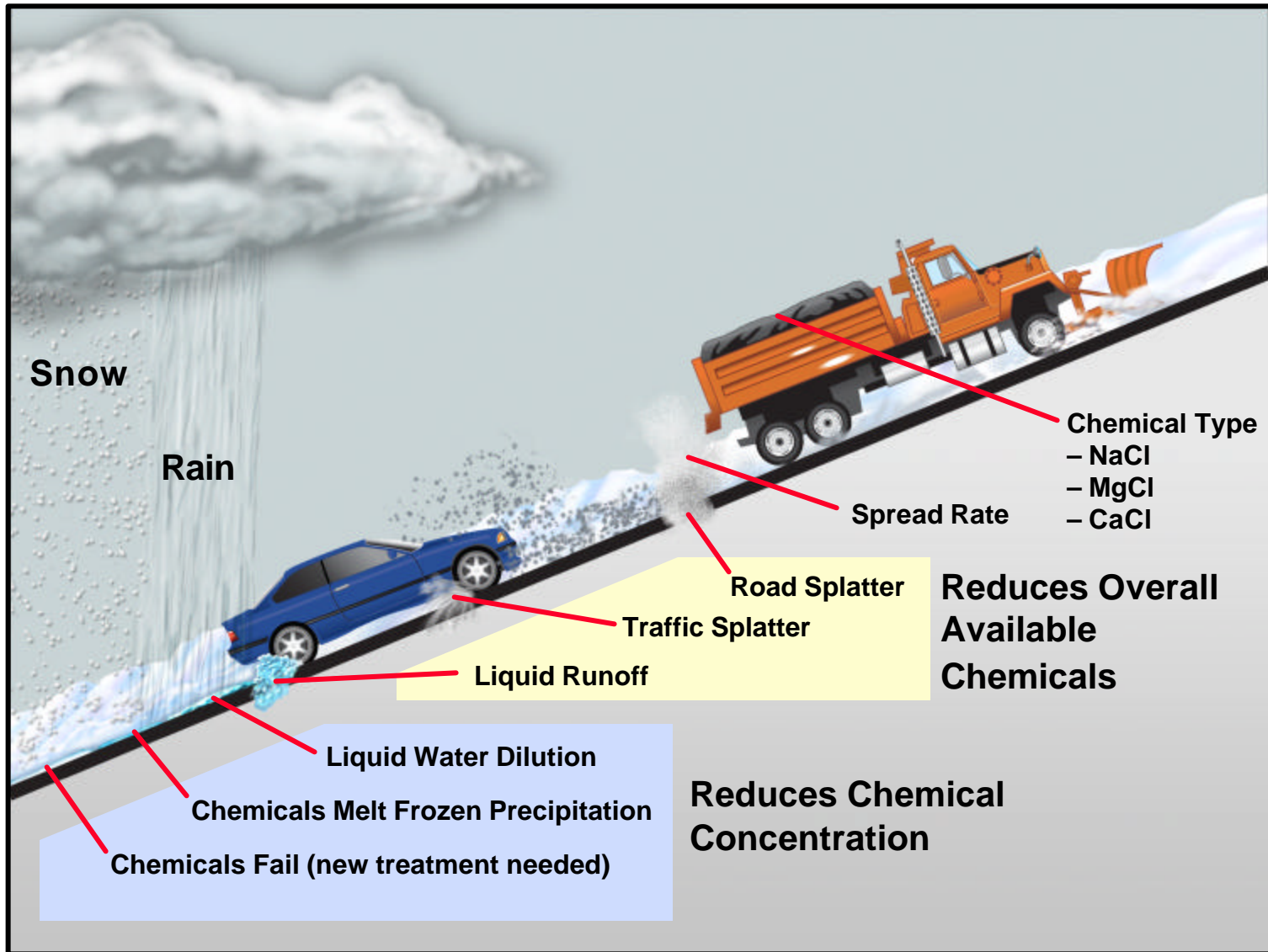


- **C++ Algorithm (modular code with flexible interface)**

- 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





FHWA Anti-icing Guidelines

Tables for generic events:

light snow, mod/heavy snow, freezing rain, etc
 Guide for NaCl applications



Table 8. Weather event: light snow storm.

PAVEMENT TEMPERATURE RANGE, AND TREND	INITIAL OPERATION				SUBSEQUENT OPERATIONS				COMMENTS
	pavement surface at time of initial operation	maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)		maintenance action	dry chemical spread rate, kg/lane-km (lb/lane-mi)			
			liquid	solid or prewetted solid		liquid	solid or prewetted solid		
Above 0°C (32°F), steady or rising	Dry, wet, slush, or light snow cover	None, see comments			None, see comments				1) Monitor pavement temperature closely for drops toward 0°C (32°F) and below 2) Treat icy patches if needed with chemical at 28 kg/lane-km (100 lb/lane-mi); plow if needed
Above 0°C (32°F), 0°C (32°F) or below is imminent; ALSO -7 to 0°C (20 to 32°F), remaining in range	Dry Wet, slush, or light snow cover	Apply liquid or prewetted solid chemical Apply liquid or solid chemical	28 (100) 28 (100)	28 (100) 28 (100)	Plow as needed; reapply liquid or solid chemical when needed	28 (100) 28 (100)	28 (100) 28 (100)		1) Applications will need to be more frequent at lower temperatures and higher snowfall rates 2) It is not advisable to apply a liquid chemical at the indicated spread rate when the pavement temperature drops below -5°C (23°F) 3) Do not apply liquid chemical onto heavy snow accumulation or packed snow
-10 to -7°C (15 to 20°F), remaining in range	Dry, wet, slush, or light snow cover	Apply prewetted solid chemical		55 (200)	Plow as needed; reapply prewetted solid chemical when needed		55 (200)		If sufficient moisture is present, solid chemical without prewetting can be applied
Below -10°C (15°F), steady or falling	Dry or light snow cover	Plow as needed			Plow as needed				1) It is not recommended that chemicals be applied in this temperature range 2) Abrasives can be applied to enhance traction

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



Table 6. Weather event: light snow storm.

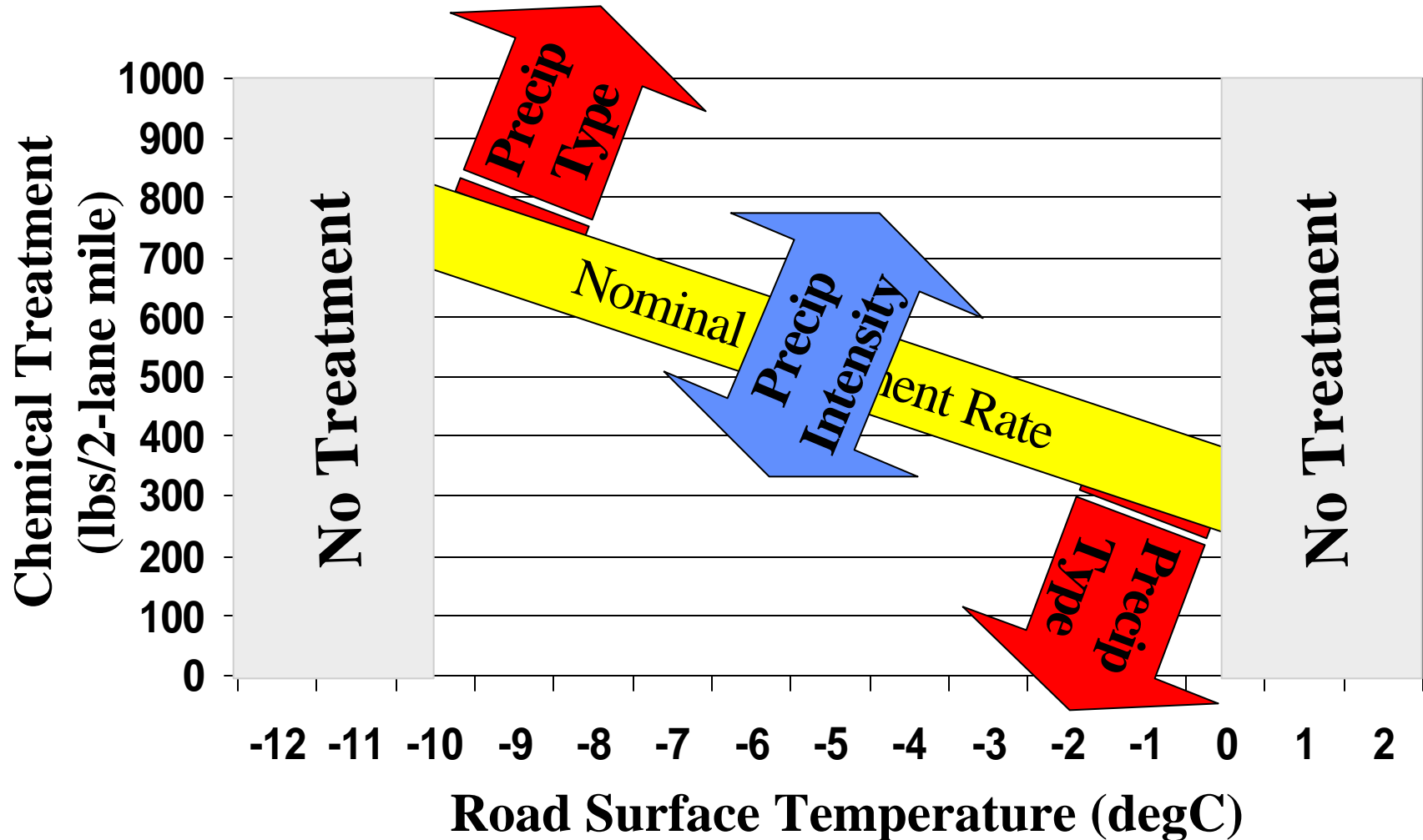
TEMPERATURE RANGE, Air (°F)	precipitation rate of 0.10 in/hr or greater	RECOMMENDED OPERATIONS		RECOMMENDED OPERATIONS		REMARKS
		action	chemical application	action	chemical application	
Above 40° (4°C) steady or rising	1/10 in. (2.5 mm) or lighter snow	None or salt	None	None or salt	None	1) Reduce pavement temperature slowly for longer snowfall, 10-15 min before. 2) Treat only pavements of roads with shoulders or 20 ft (6 m) or wider shoulders, urban arterials.
Above 30° (2°C) to 40° (4°C) steady or rising	1/10 in. (2.5 mm) or lighter snow	None or salt or prewetted salt	20 (100) or 20 (100)	None or salt or prewetted salt or salt or prewetted salt	20 (100) or 20 (100)	1) Apply chemical only in the hours between 40° and 30° and before snowfall. 2) If it is not advisable to apply a liquid chemical or salt, prewetted salt or salt or prewetted salt, use heavy salt or prewetted salt.
30° (2°C) to 40° (4°C) steady or rising	1/10 in. (2.5 mm) or lighter snow	None or salt or prewetted salt	20 (100) or 20 (100)	None or salt or prewetted salt or salt or prewetted salt	20 (100) or 20 (100)	1) Apply chemical only in the hours between 40° and 30° and before snowfall. 2) If it is not advisable to apply a liquid chemical or salt, prewetted salt or salt or prewetted salt, use heavy salt or prewetted salt.
Below 30° (2°C) steady or rising	1/10 in. (2.5 mm) or lighter snow	None or salt or prewetted salt	20 (100) or 20 (100)	None or salt or prewetted salt or salt or prewetted salt	20 (100) or 20 (100)	1) It is not recommended that chemicals be applied in the temperature range. 2) Chemicals can be applied to pavements.

REMARKS: (1) These tables and subsequent chemical applications to prevent deteriorating conditions or development of packed snow should be used. (2) Apply chemical ahead of traffic, with periodic reapplying being critical. (3) If it is not advisable to apply a liquid chemical or salt, prewetted salt or salt or prewetted salt, use heavy salt or prewetted salt.

- **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

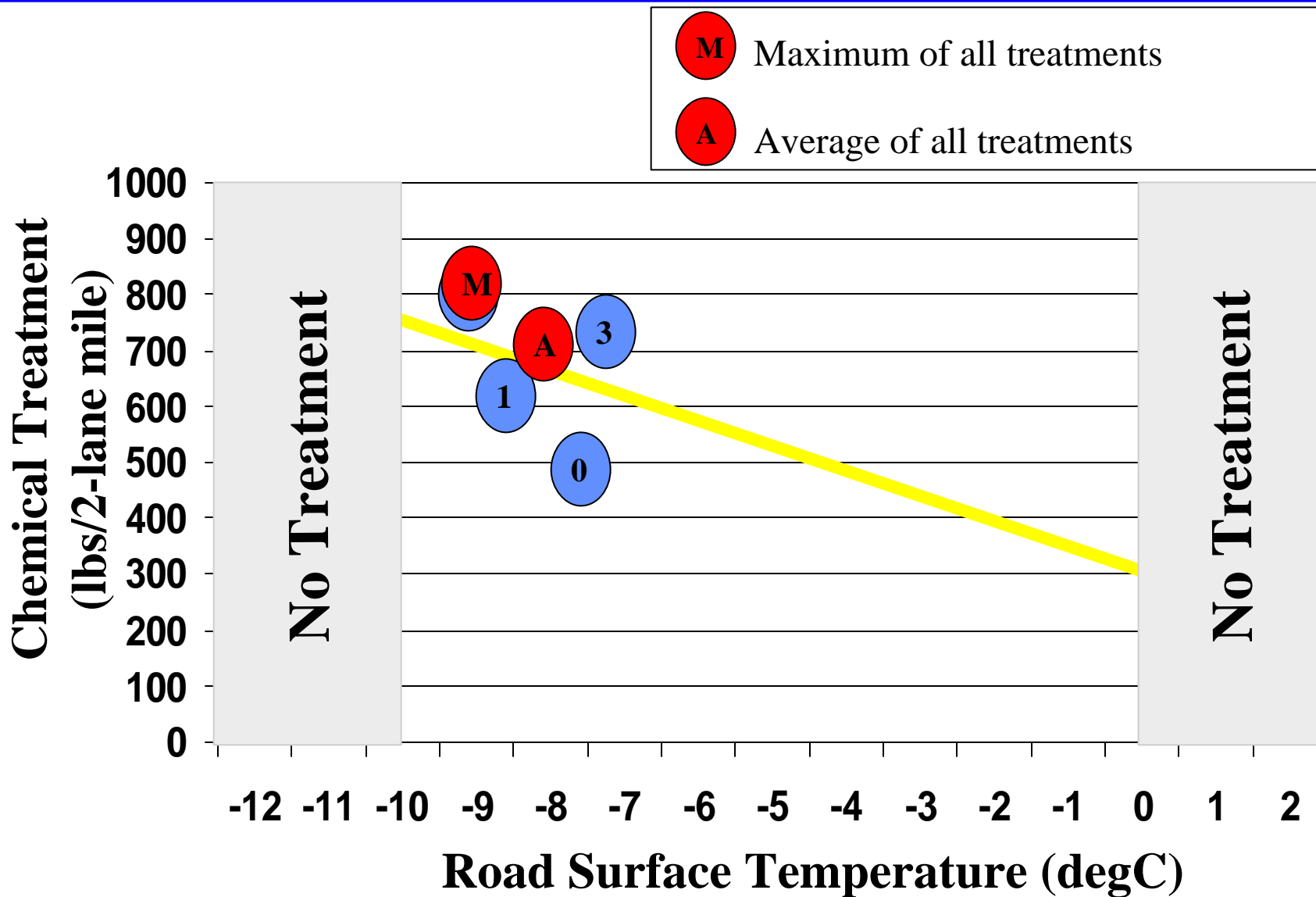


Rules of Practice – Automating FHWA Guidelines





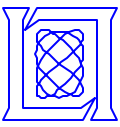
Rules of Practice – Integrating Forecasts to Optimize Treatment





Rules of Practice – Supported Treatments

- **Chemicals**
 - Initially NaCl, CaCl₂, and MgCl₂
 - 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 1/2 of the expected route time
 - User specifies pre-storm treatment offset for first application



Rules of Practice – Supported Conditions

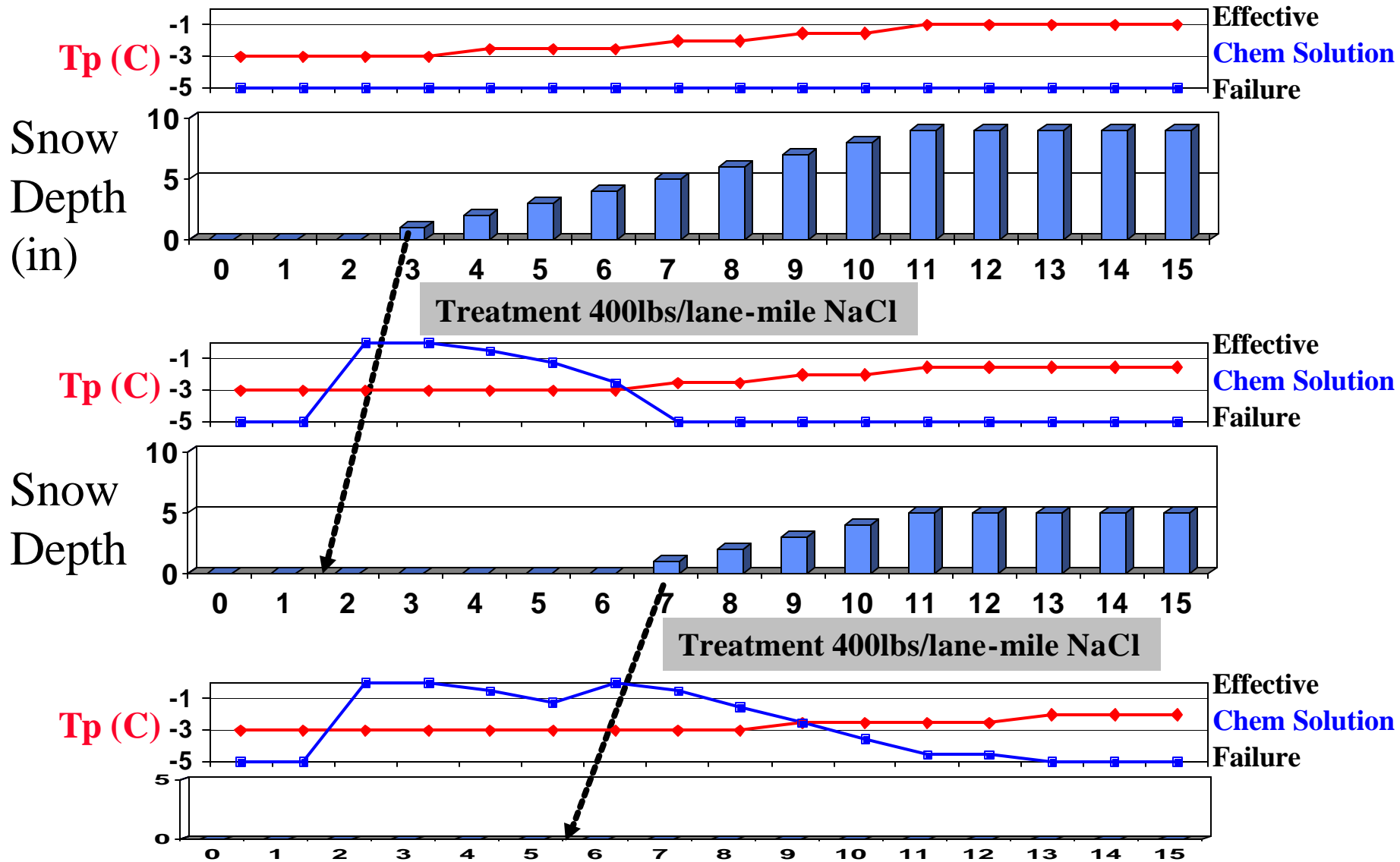
Precip Type	Temp Range	Supported?	Recommended Treatments	Comments
Snow or Mixed	-10** to 0* degC	Yes	Chemicals and Plowing	
Snow or Mixed	< -10 degC**	Yes	Plowing	User sets threshold
Snow or Mixed	Transition below -10 degC**	Yes	Chemicals -> Plow Only	
Snow or Mixed	Transition above 0* degC	Yes	Chemicals -> No Action	Dependent on snow depth adjustments
Freezing Rain	Any	Yes	Chemicals	Triggers when T _{pavement} < 0 and liquid precip
Black Ice	Any	No	-----	General warning could be added
Blowing Snow	Any	No	-----	General warning could be added

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

** -10 degC represents a threshold “chemical ineffectivity” temperature



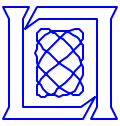
Rules of Practice - Example





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

