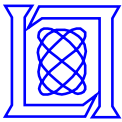




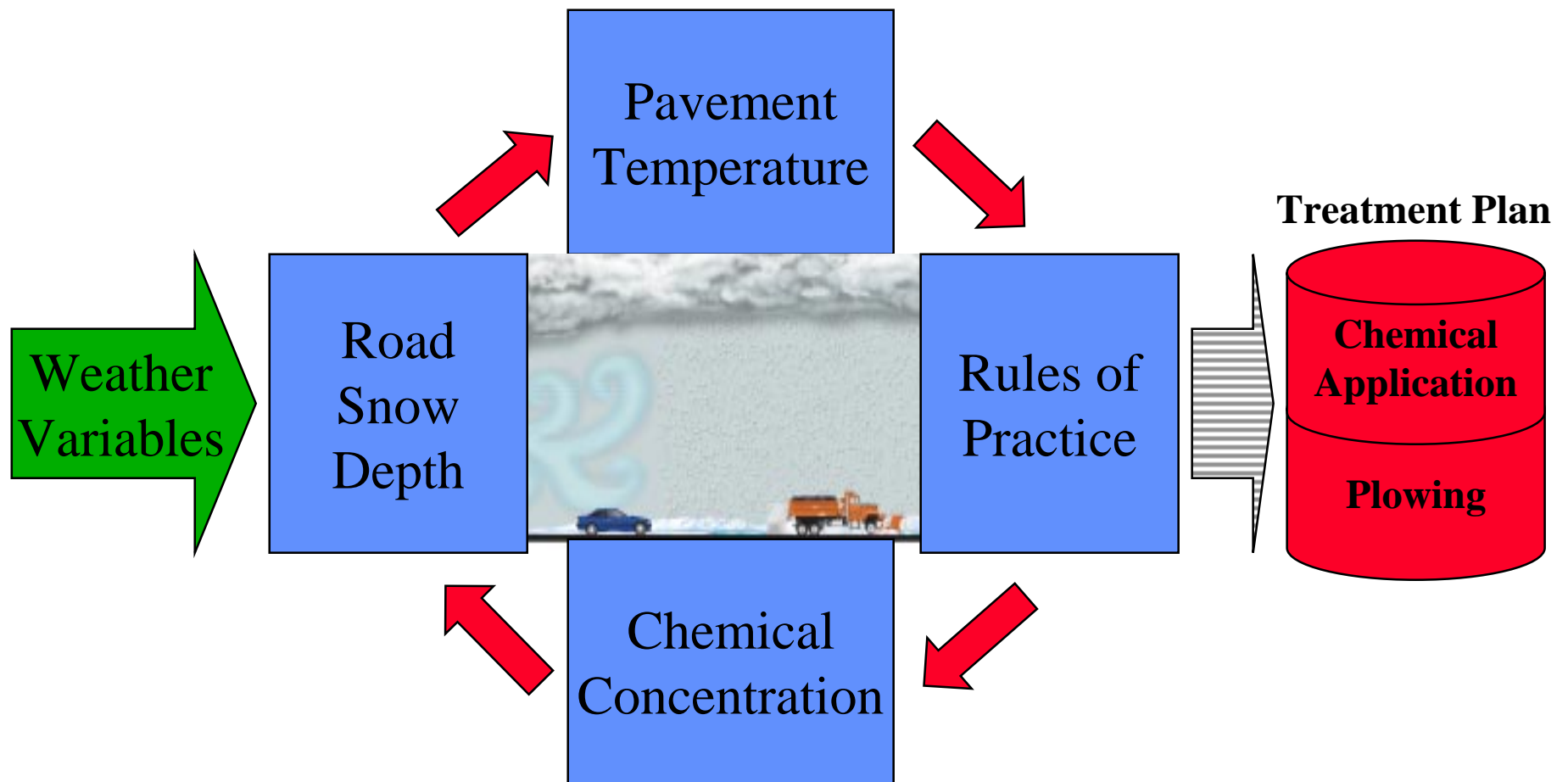
# Rules of Practice

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- **Automation Overview**
- **Snow Depth / Chemical Concentration**
- **Automating FHWA Guidelines**
- **Supported Decisions / Treatments**
- **Summary**

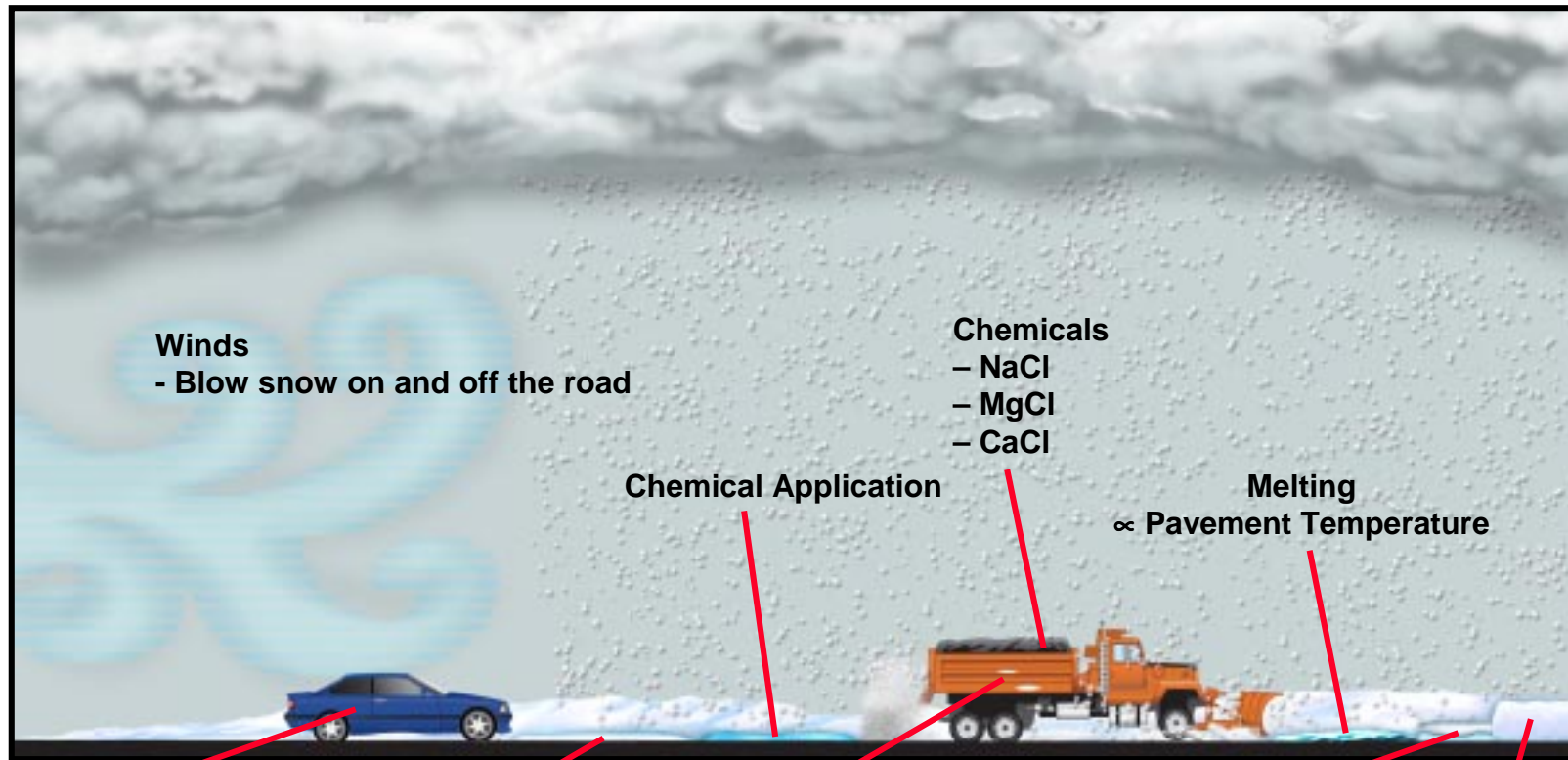


# Road Condition-Treatment Algorithms





# Estimating Snow Depth



## Traffic

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

## Chemicals dilute

- $\propto$  Precipitation rate slowly become ineffective

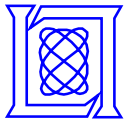
## Plowing

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

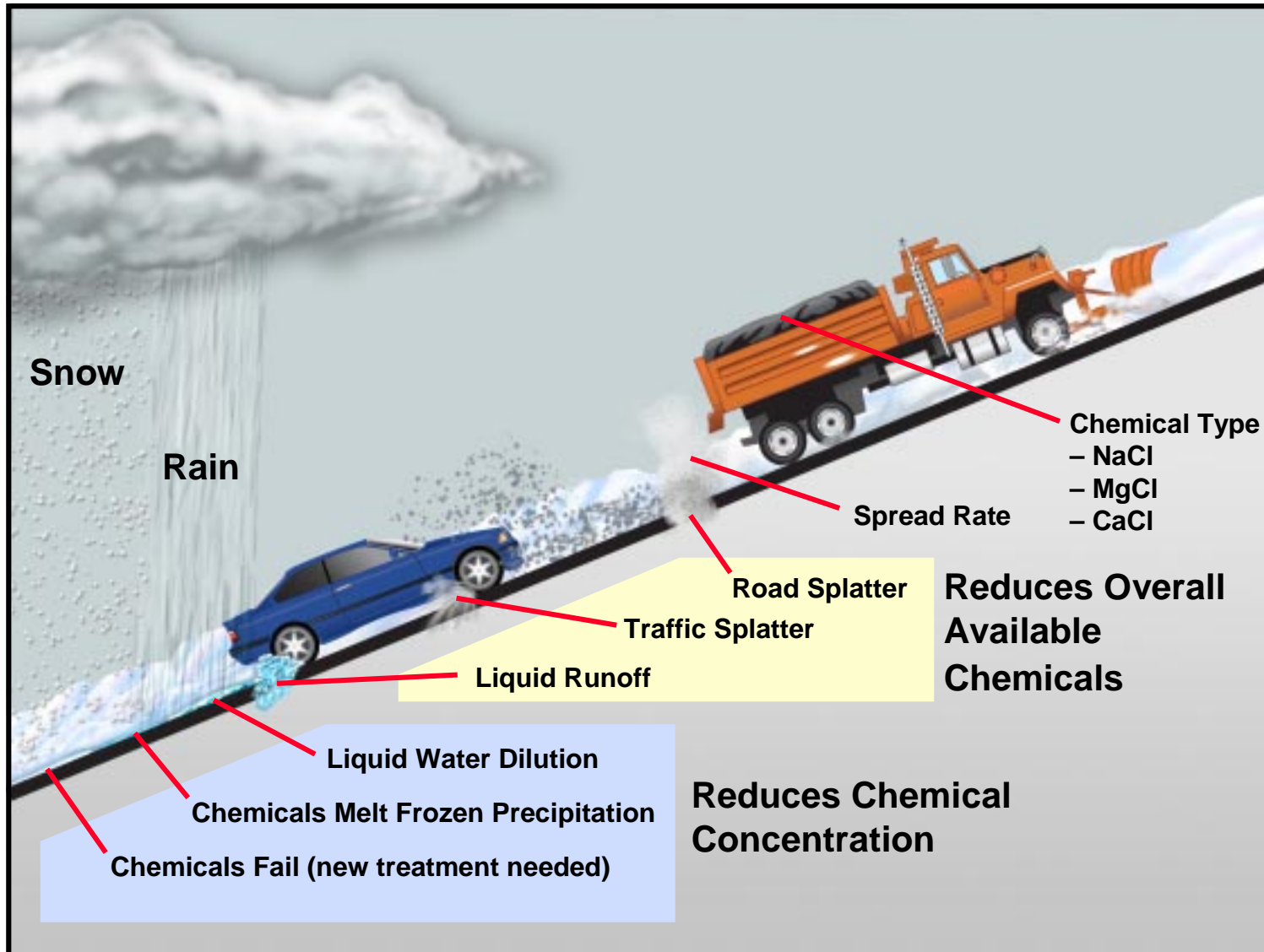
## Compaction

- $\propto$  Water Content

## Free-Falling Snow Depth



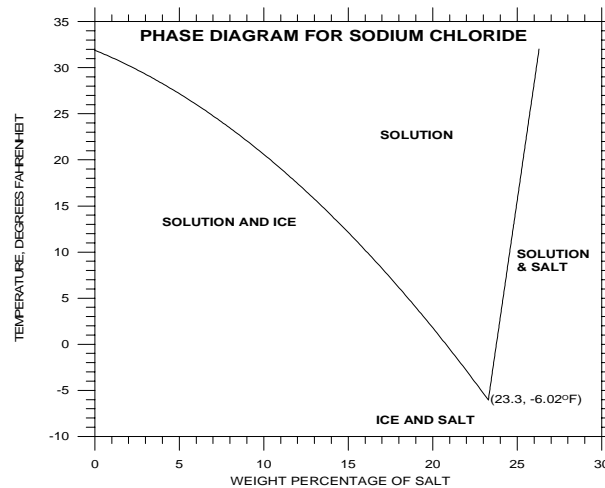
# Estimating Chemical Concentration Dilution





# Automating Chemical Dilution

- **Base decisions on chemical dilution curves**



- **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

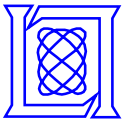
- Base decisions on FHWA Anti-icing guideline tables



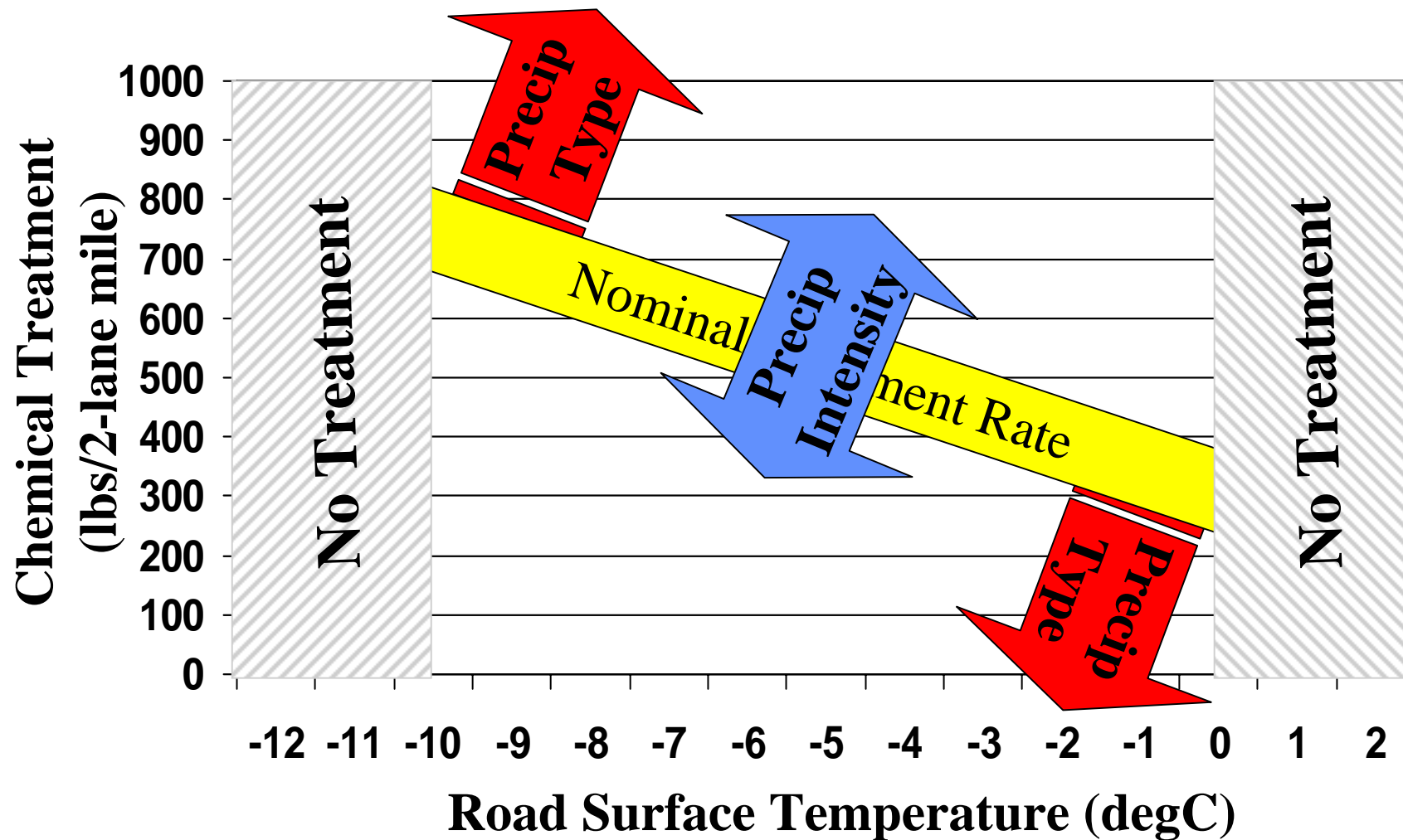
Table 6. Weather event trigger table

Weather Event	Normal Conditions		Winter Conditions		Comments
	Trigger	Response	Trigger	Response	
Light Snow	0.5 in. or more	Apply salt	0.5 in. or more	Apply salt	Apply salt when snow accumulates to a depth of 0.5 in. or more.
Heavy Snow	1.0 in. or more	Apply salt	1.0 in. or more	Apply salt	Apply salt when snow accumulates to a depth of 1.0 in. or more.
Ice	0.1 in. or more	Apply salt	0.1 in. or more	Apply salt	Apply salt when ice accumulates to a depth of 0.1 in. or more.
Freezing Rain	0.1 in. or more	Apply salt	0.1 in. or more	Apply salt	Apply salt when freezing rain accumulates to a depth of 0.1 in. or more.

- **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

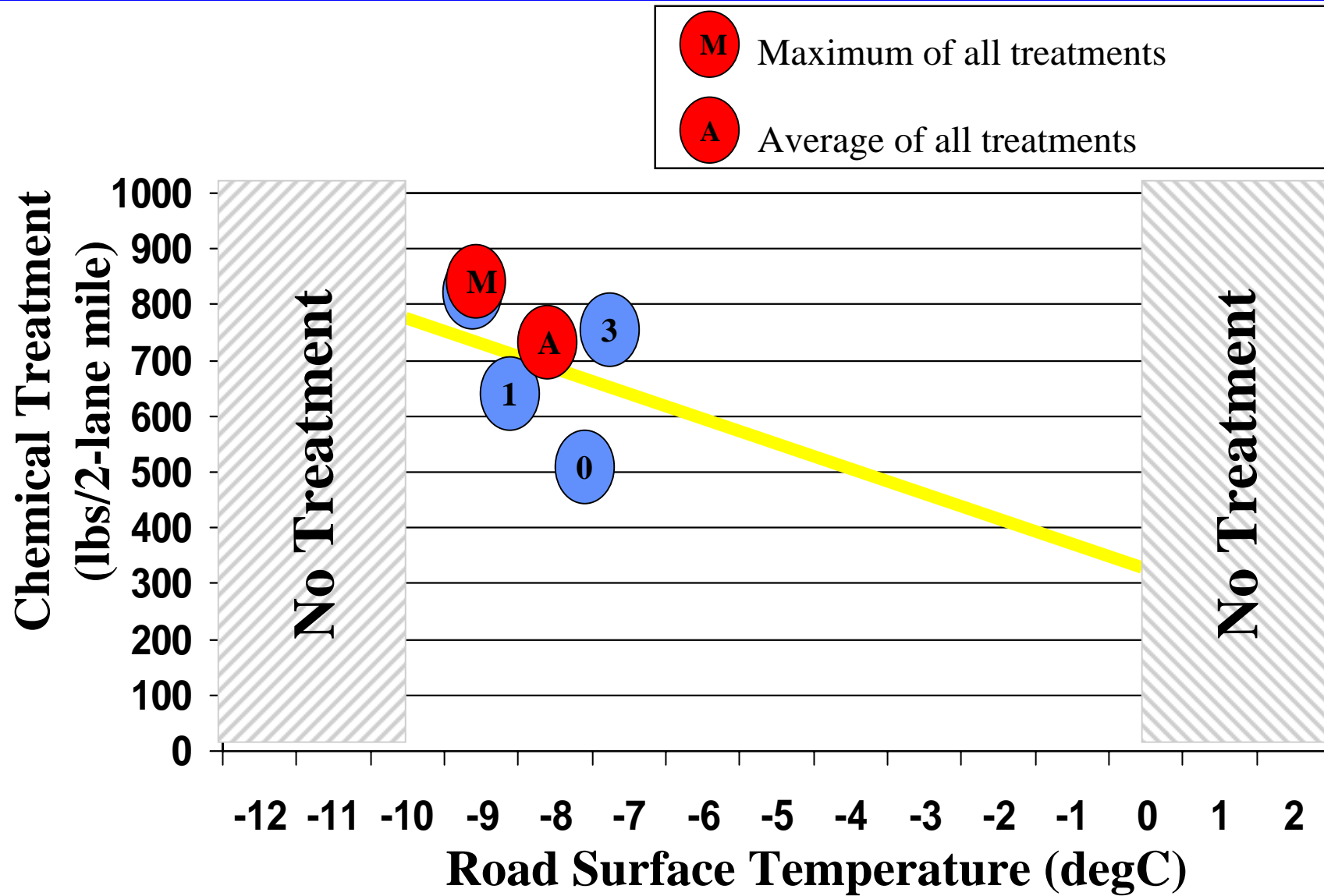


# Rules of Practice – Automating FHWA Guidelines



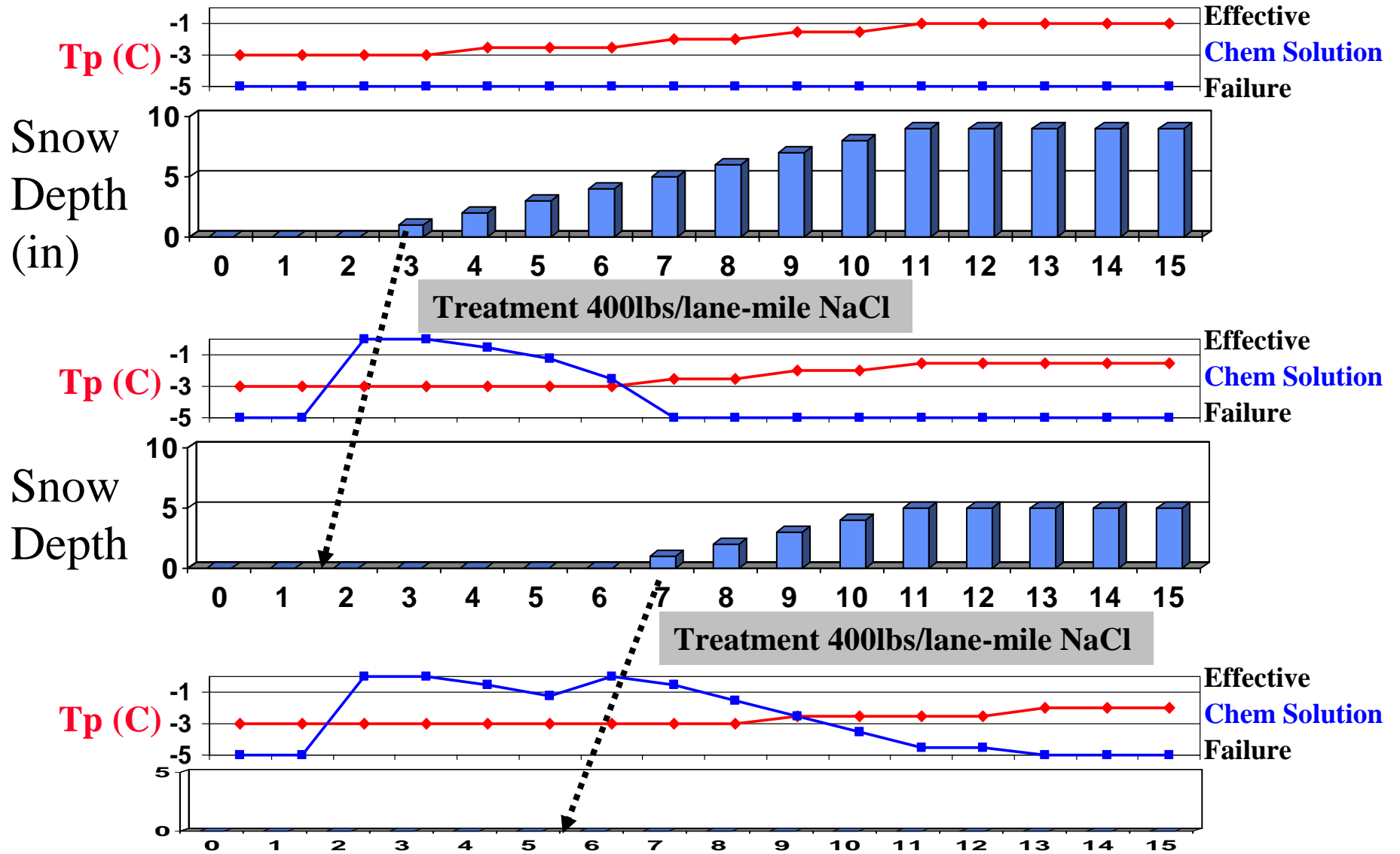


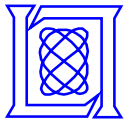
# Rules of Practice – Integrating Forecasts to Optimize Treatment





# Rules of Practice - Example

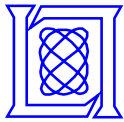




# Rules of Practice – Supported Treatments

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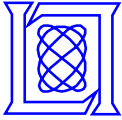
- **Chemicals**
  - Initially only NaCl
  - Algorithm allows new chemicals to be added easily
  - User controls preferred chem type, min/max application rates
- **Plowing**
  - User controls trigger point (default is 3” snow depth)
- **Sand**
  - Only as general guidance (no specific rates)
- **Pre-treatment**
  - All chemical treatments begin prior to the “trigger point”
  - Default offset is  $\frac{1}{2}$  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

Storm Conditions		Supported?	Recommended Treatments	Comments
Precip Type	Temp Range			
Snow	-10 to 0* degC	Yes	Chemicals and Plowing	
Snow	< -10 degC	Yes	Plowing	
Snow	Transition below -10 degC	Yes	Chemicals -> Plow Only	Guidance needed on transition criteria
Snow	Transition above 0* degC	Yes	Chemicals -> No Action	Dependent on snow depth adjustments
Freezing Rain	Any	Partially	Chemicals	Only triggers when snow depth > 0
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



# Potential Short-term Enhancements

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- Support additional chemicals (CaCl, MgCl)



# Chemical Dilution Timeline

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