# Safety benefit of employing alternative standards for winter road maintenance

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# OUTLINE

- Introduction
- Methodology
- Comparative Analysis
- Models developed and Employed
- Conclusions

# Winter Road Safety

- Poor weather
- Different road driving conditions
- Increase in collision frequency
- Increase in collision related cost

An Accident occurred on Icy road

# Winter Road Maintenance

- Improve safety and mobility
- Cost
  - $ 1 billion/year in Canada
  - Environmental effect

# Highway Classification and Level of Service Standards

| Highway Class | WADT | Circuit time (hrs) | BPRT (hrs) |
|---|---|---|---|
| Urban Freeway | >100,000) | 1.3 | 4 |
| Class 1 | >10,000 | 1.3 | 8 |
| Class 2 | 2001-10,000 (1,501-10,000*) | 1.8 | 16 |
| Class 3 | 1001-2000 (801-15,00*) | 2.9 | 24 |
| Class 4 | 501-1000 (401-800*) | 4.9 | 24 |
| Class 5 | <500 (< 400*) | 8 | 24 |

First salt application rate up to 200 Kg/2Ln-Km from 130 Kg/2Ln-Km

Deployment time 20min from 30 min

Shoulder Plowing

Dedicated Spreaders

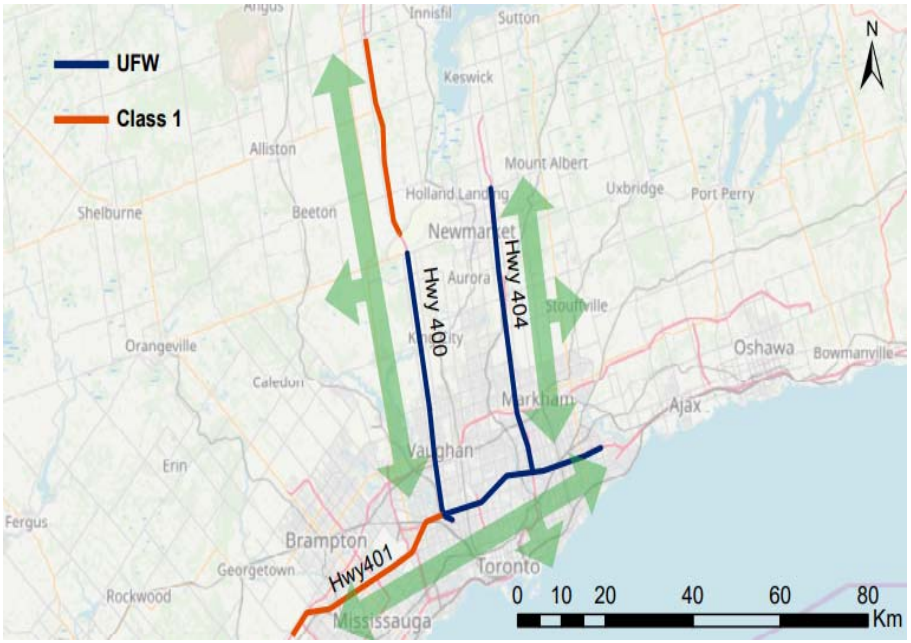
***Northern Ontario**

# Research Question and Objective

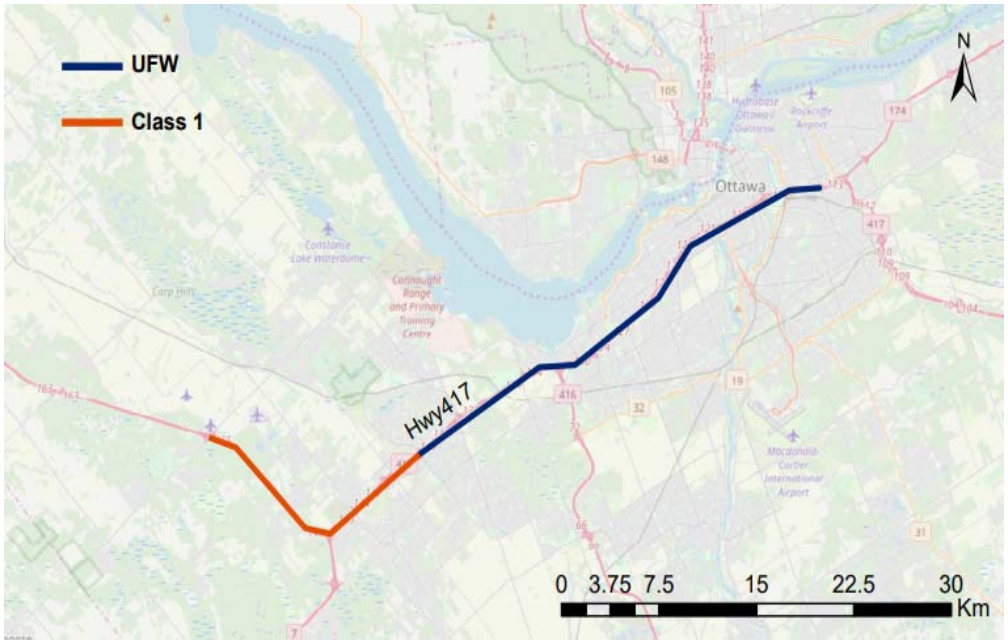
- Do the safety benefit resulting from the new changes justify their introduction?

- Assess the resource implication and performance outcome (safety benefit) of the proposed changes

# Study sites for UFW Field Trails

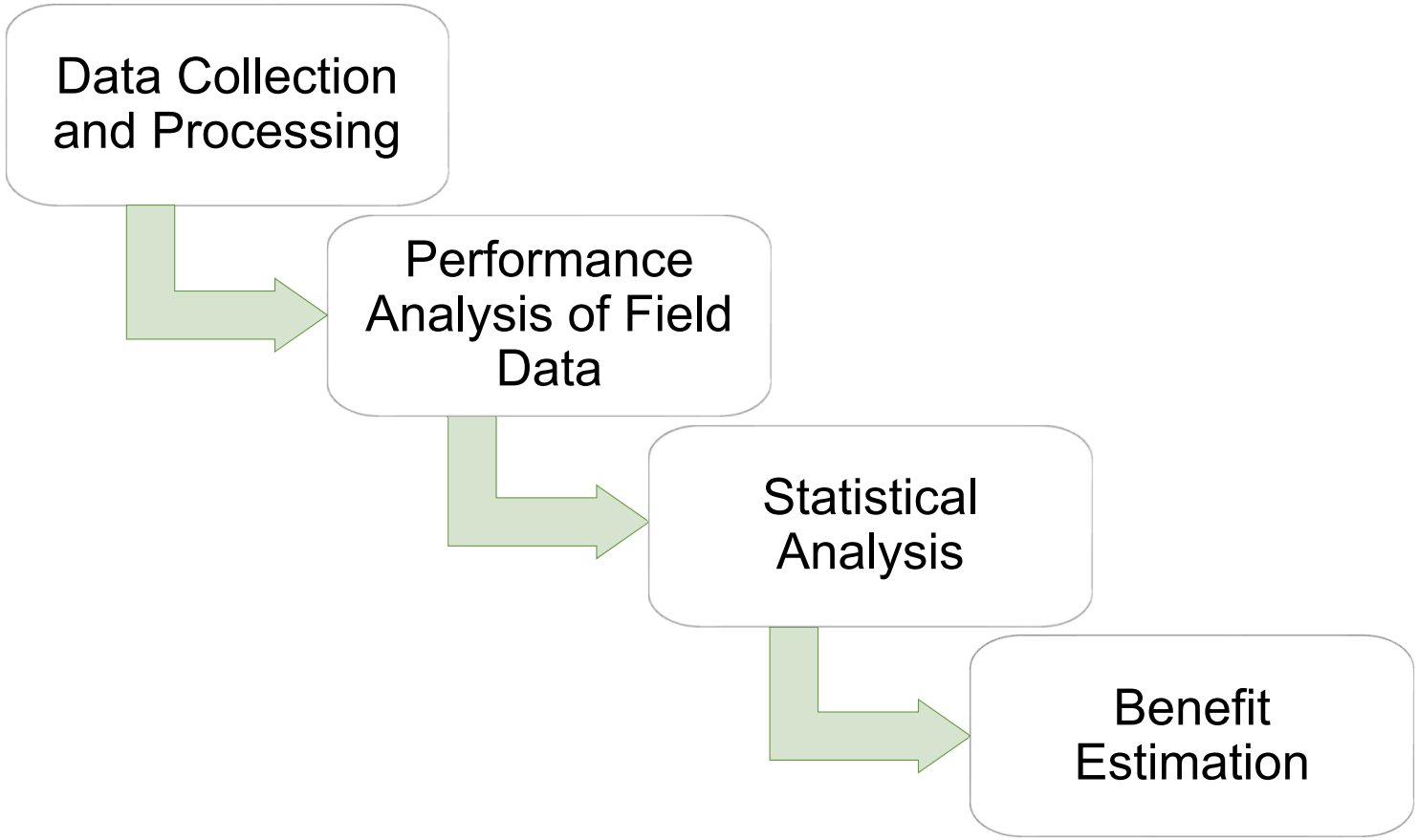



(a) Study sites in the Central region

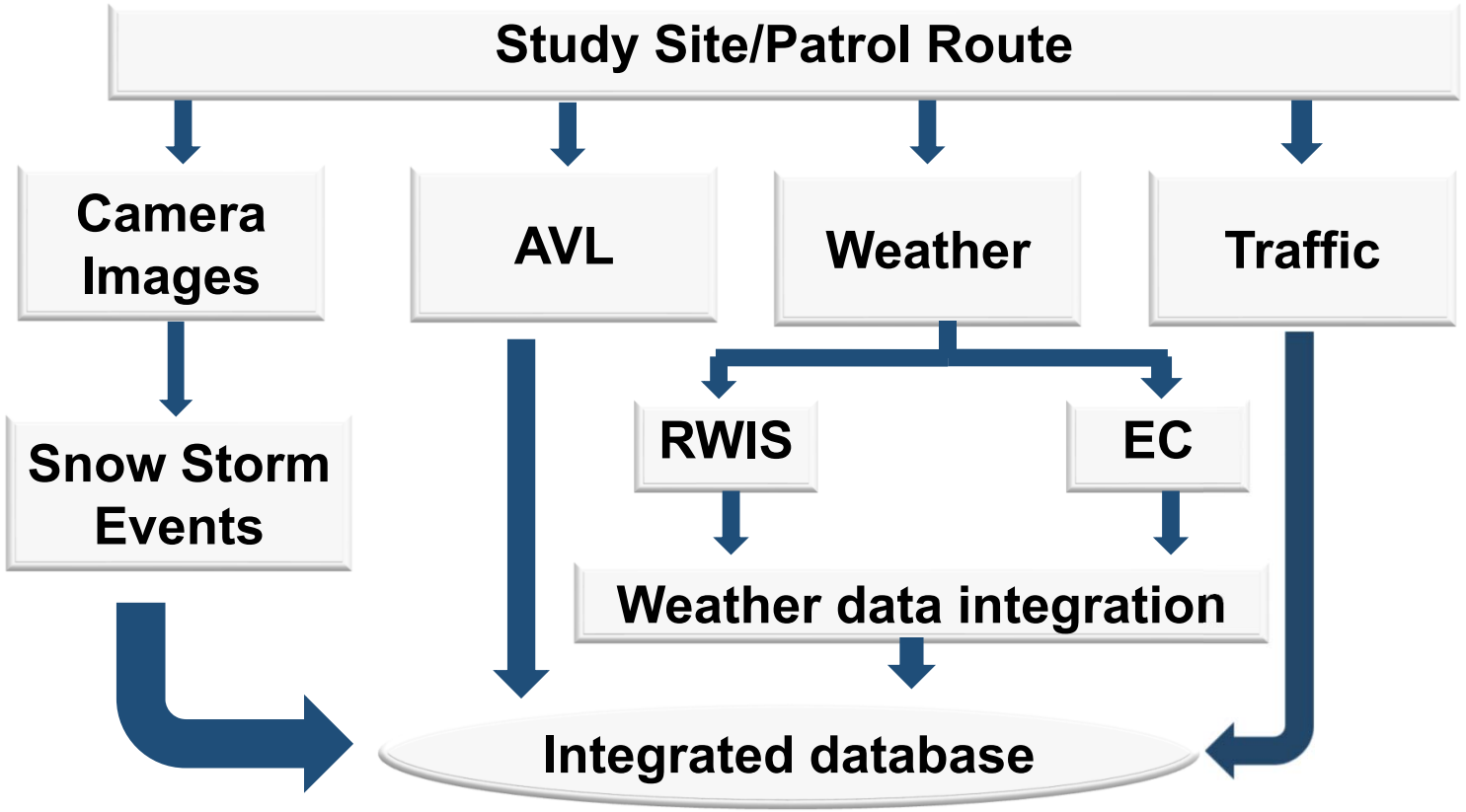



(b) Study sites in the Eastern region

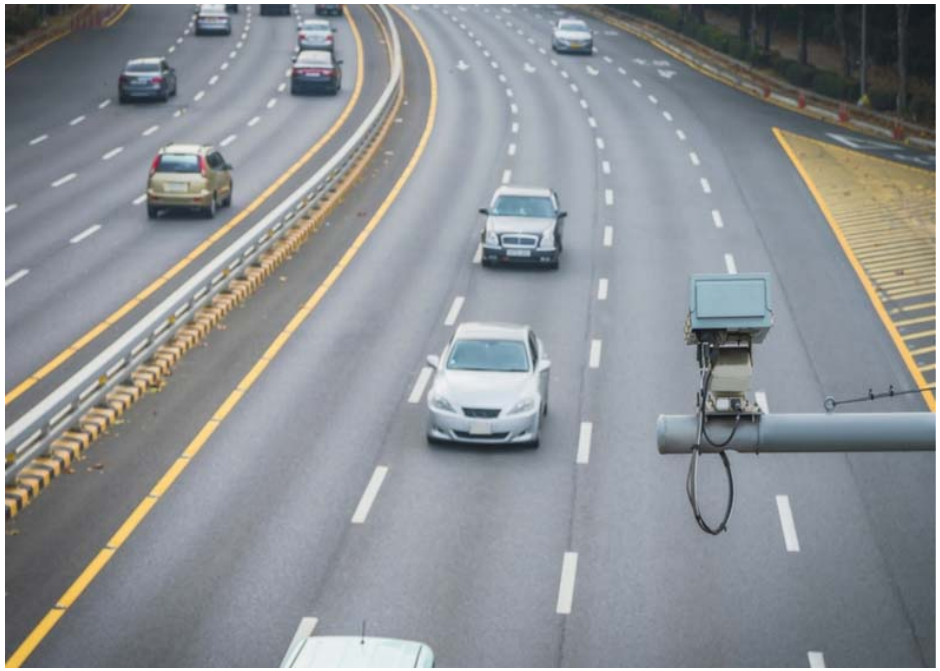
# Methodology



# Data Collection and Processing



# Image data



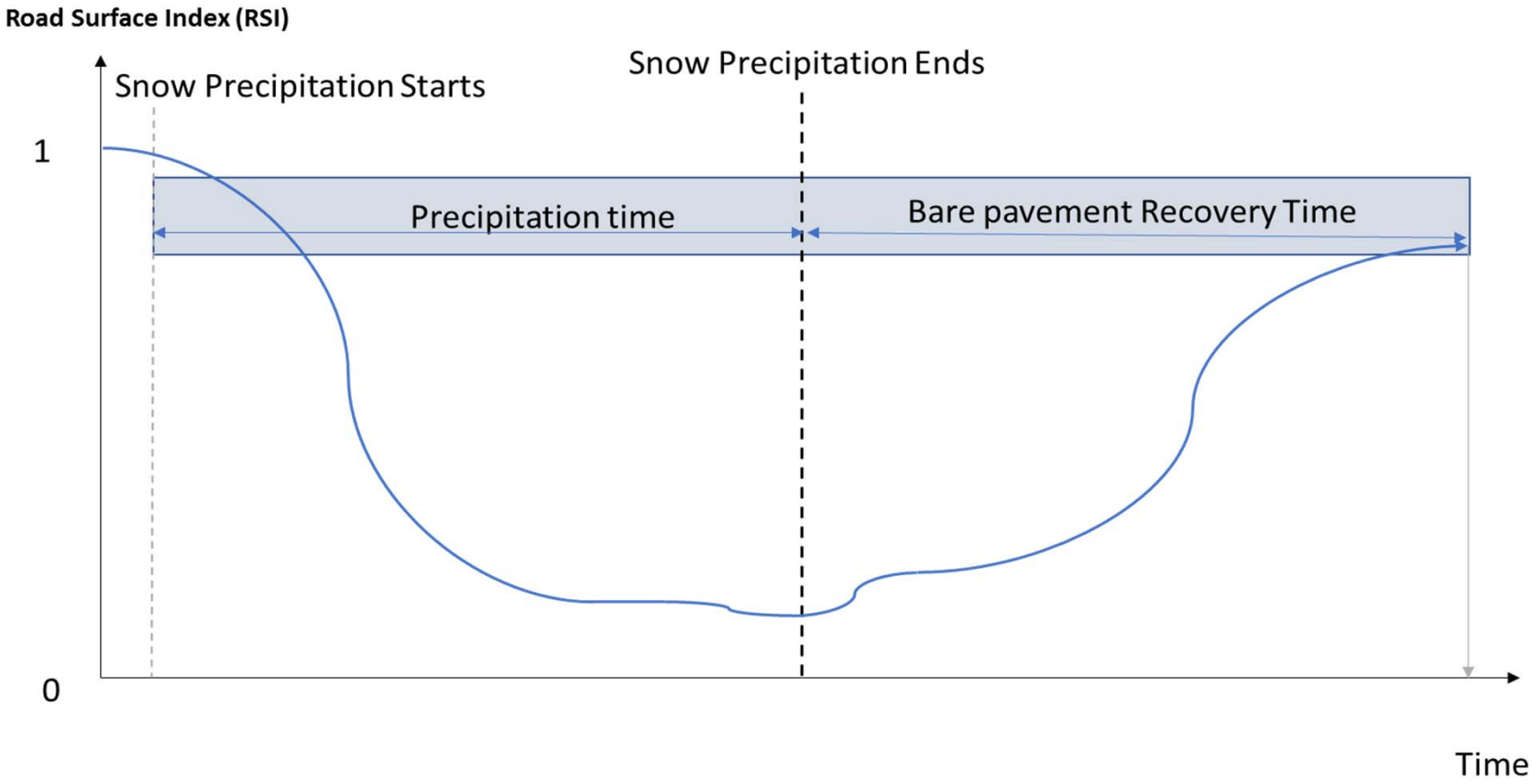
Traffic Camera


Camera Image

# Road Surface Condition

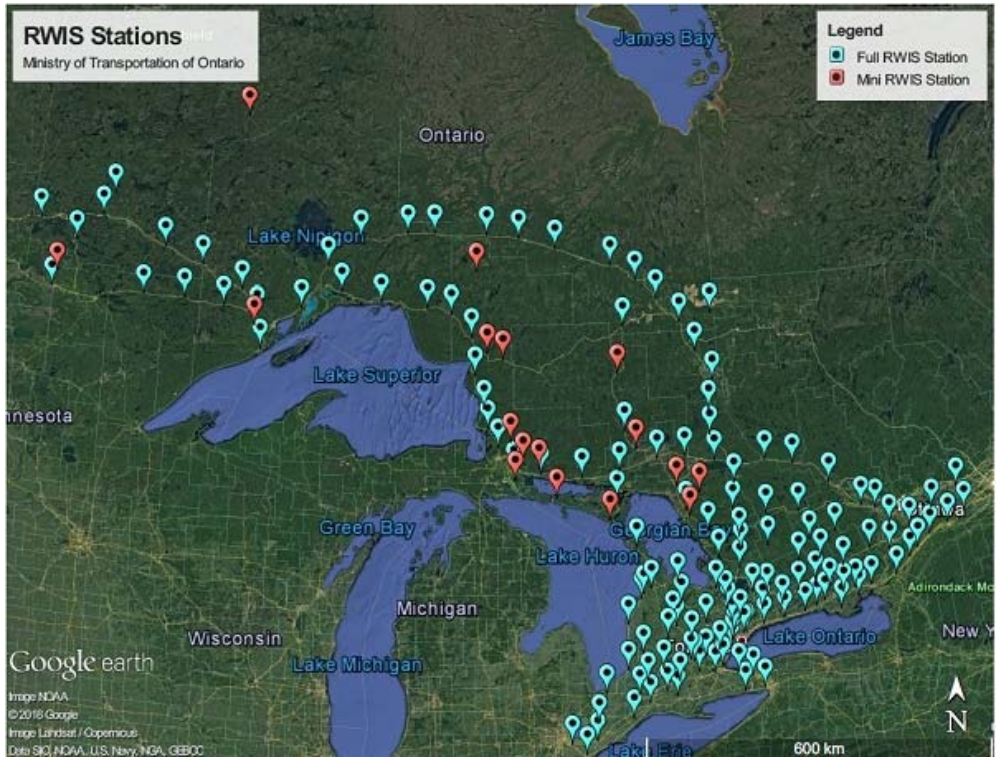
| Road Surface Condition | Road Surface Index (RSI) | % snow coverage |
|---|---|---|
| Bare and Dry | 0.95 | 0% - 5% |
| Bare and Wet | 0.85 | 5% - 10% |
| Slushy | 0.75 | 10% - 25% |
| Partly Snow Covered | 0.6 | 25% - 70% |
| Snow Covered | 0.4 | 70%-100% |
| Snow Packed | 0.25 | NA |
| Icy | 0.125 | NA |

# Snow Storm Event



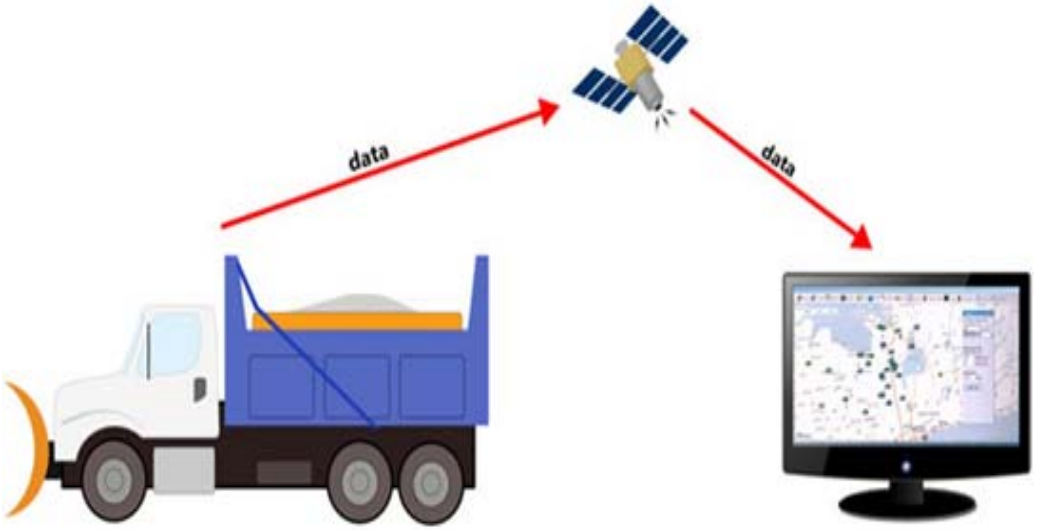
# Weather Data

- Air temperature (°C)
- Relative humidity (%)
- Wind speed (km/hr)
- Visibility (km)
- Wind chill (°C)
- Precipitation intensity (cm/hr)



# Automatic Vehicle Location (AVL) Data

- Vehicle GPS location
- Operation timing
- Material type
- Material application rate
- Material usage



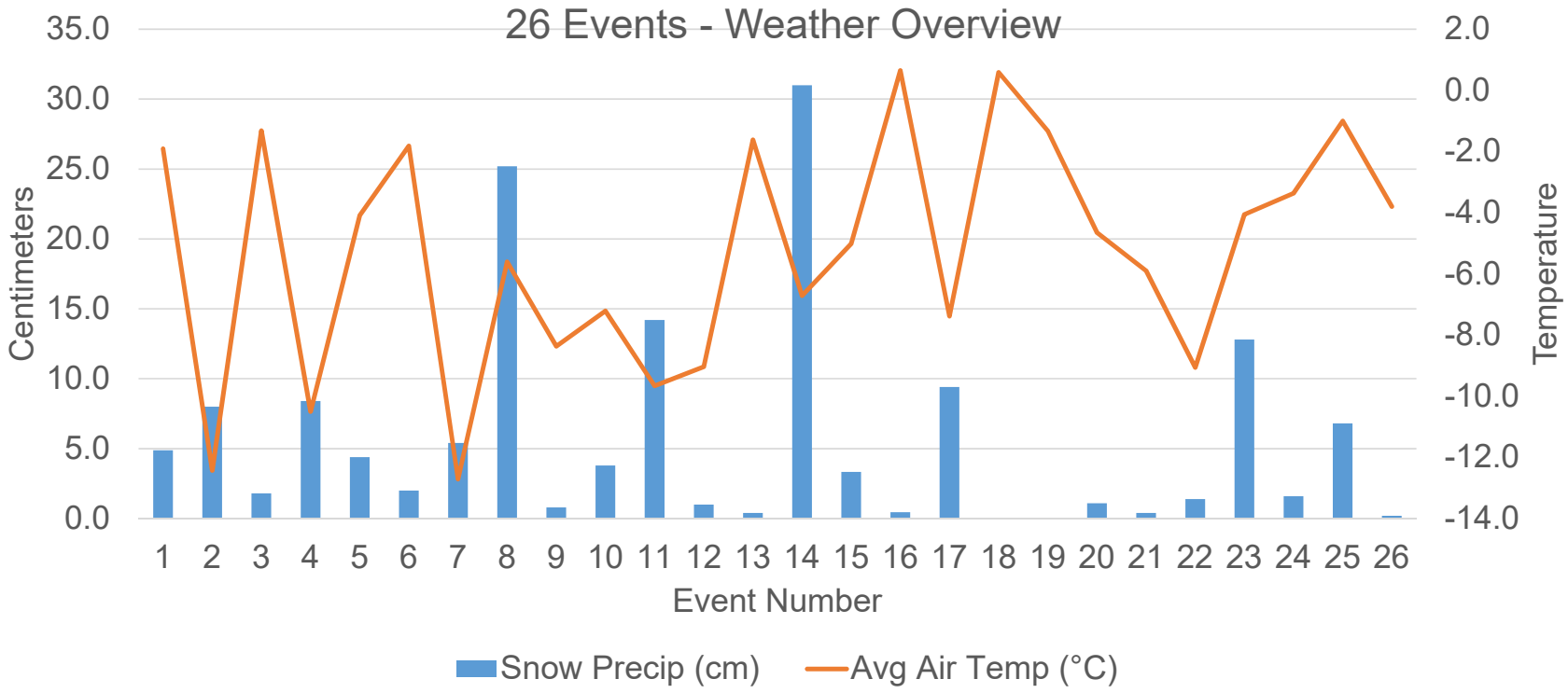
# Traffic volume Data

- Traffic volume data were collected through loop detectors and obtained from the MTO's permanent data count stations (PDCS)

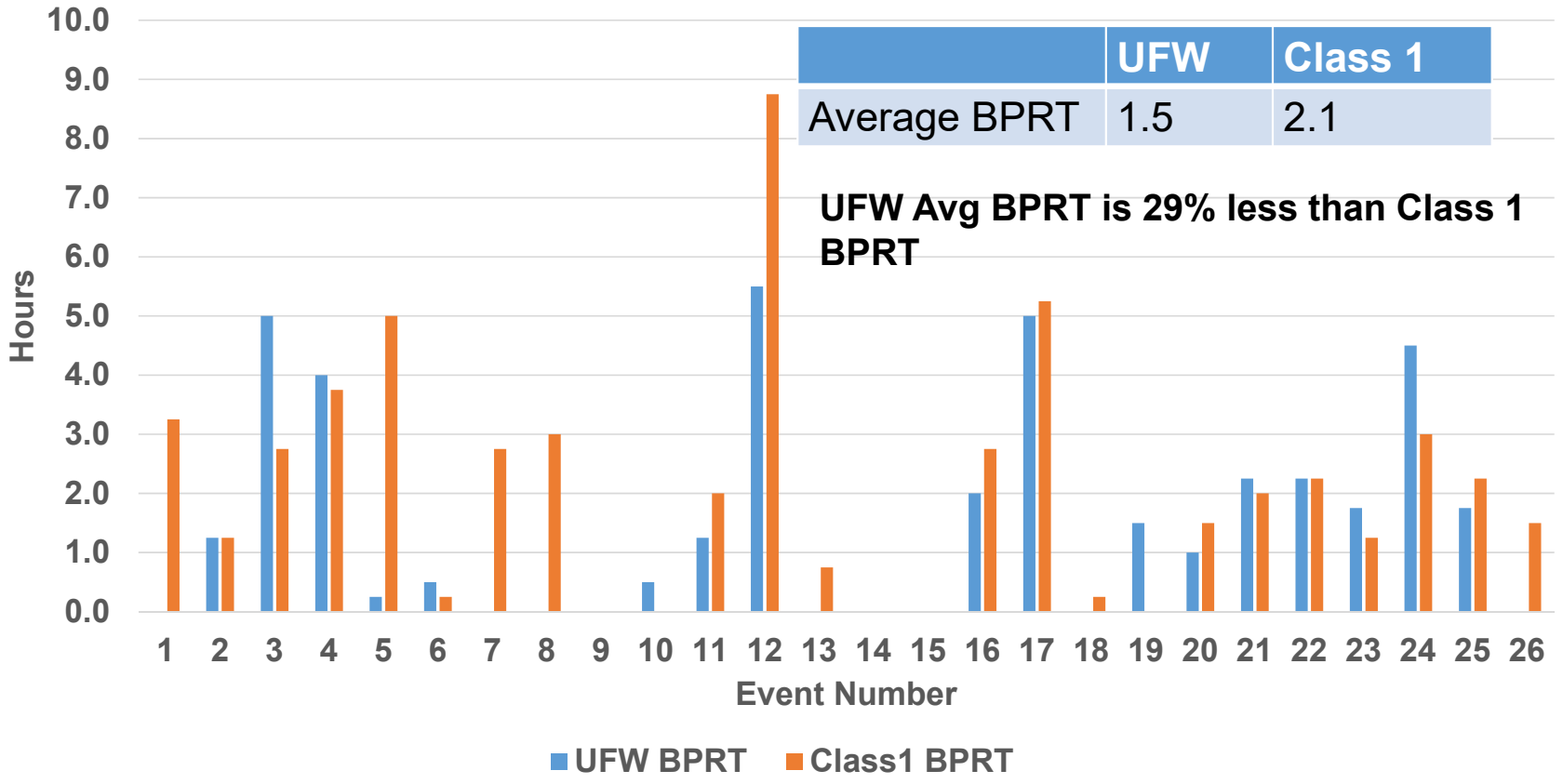
## Comparative analysis

- Performance measures
  - Bare pavement regains time (BPRT)
  - Within storm snow coverage
  - Material usage

# Study site: Hwy 417 2018-19 season (2018/12/31 to 2019/03/17)



# BPRT Comparison

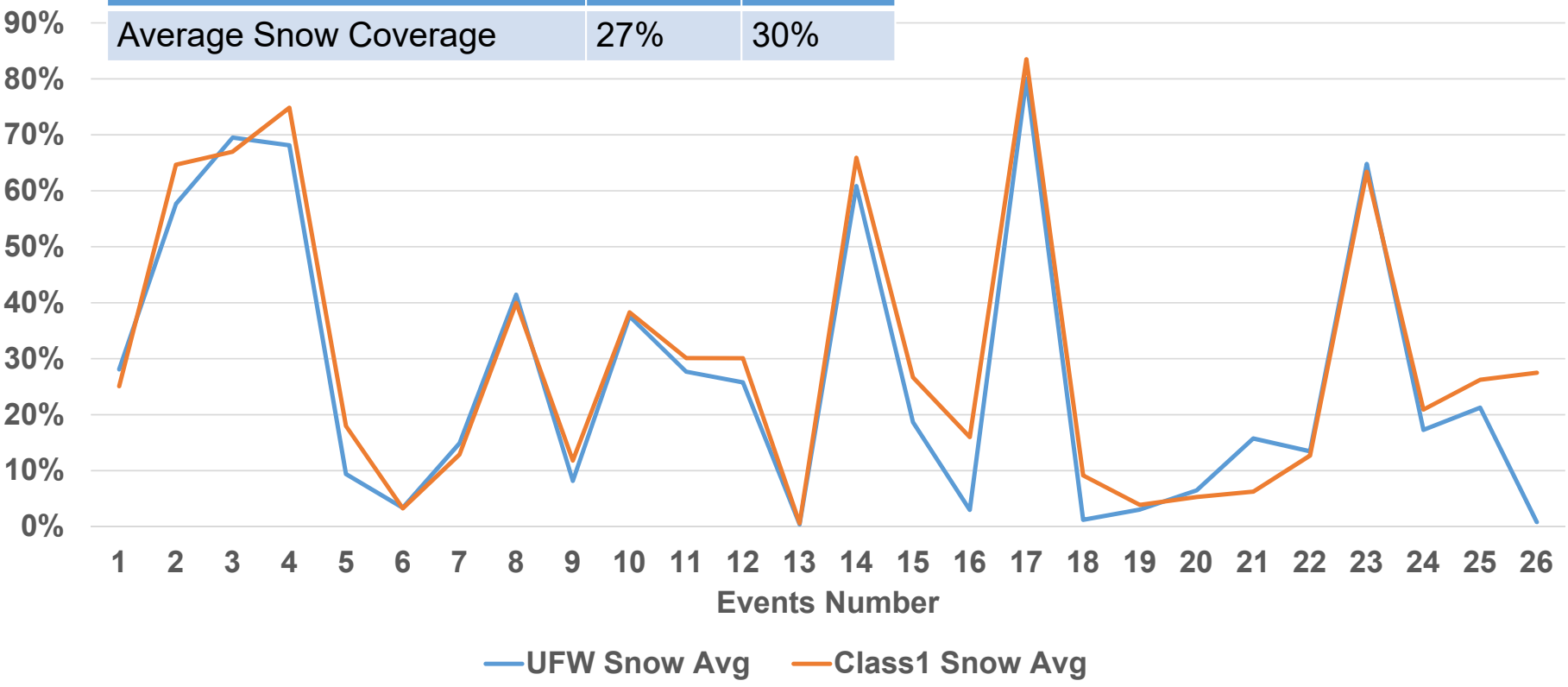



| | UFW | Class 1 |
|---|---|---|
| Average BPRT | 1.5 | 2.1 |

**UFW Avg BPRT is 29% less than Class 1 BPRT**

# Within storm snow coverage

| | UFW | Class 1 |
|---|---|---|
| Average Snow Coverage | 27% | 30% |



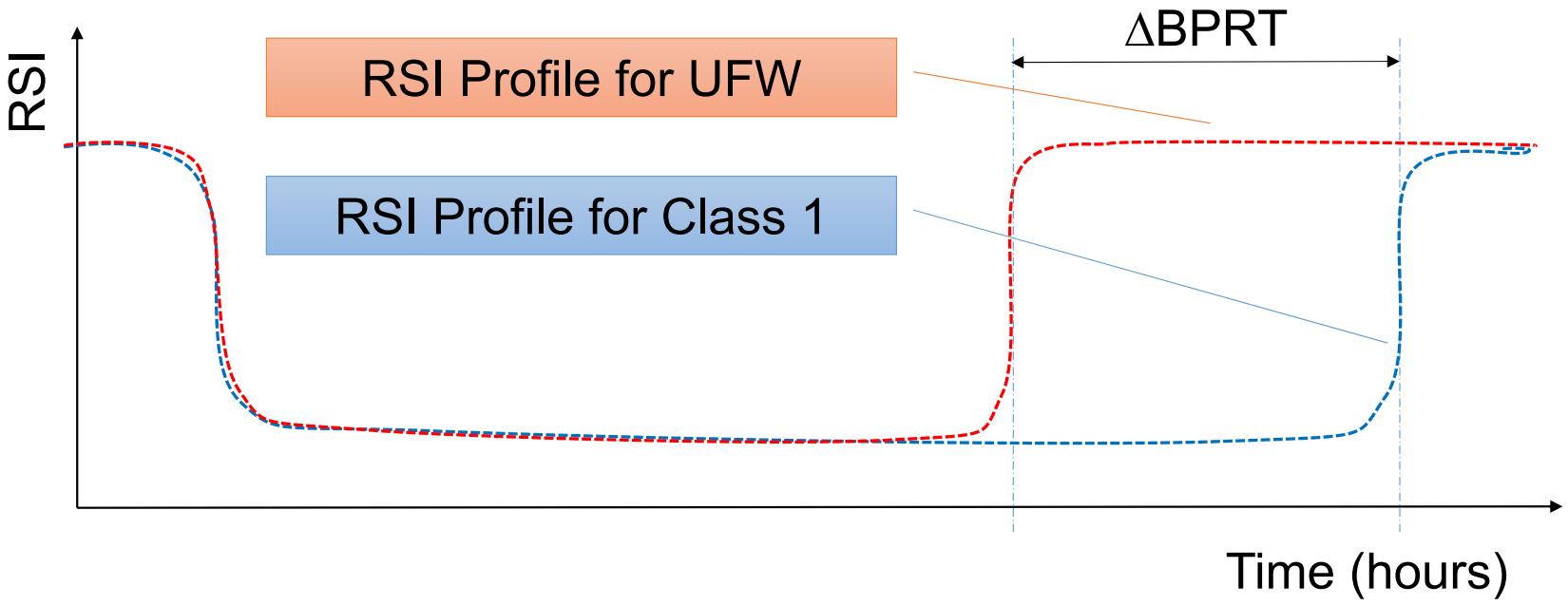
# Material usage

- UFW = 3647 kg/ln-km
- Class 1 = 2506 kg/ln-km
- UFW Material Usage is 45% more than Class 1

# Comparative Analysis Results

| Site | Material (Kg/ln-km) | | BPRT (h) | | Within storm Snow coverage | |
|---|---|---|---|---|---|---|
| | UFW | Class 1 | UFW | Class 1 | UFW | Class 1 |
| **Hwy417** | 3647 | 2506 | 1.5 | 2.1 | 27% | 30% |
| **Hwy401** | 3682 | 4736 | 1.4 | 2.8 | 16% | 18% |
| **Hwy400** | 4614 | 2258 | 0.5 | 1.3 | 15% | 14% |
| **Hwy404** | 5252 | 2258 | 0.7 | 1.3 | 16% | 15% |

# Safety Benefit Estimation



# Exploratory Analysis - Correlation Matrix

| | ∆BPRT | Snow Precip | Event Duration | Temperature | Wind Speed | Visibility |
|---|---|---|---|---|---|---|
| **∆BPRT** | 1 | | | | | |
| **Snow Precip** | 0.18 | 1 | | | | |
| **Event Duration** | 0.29 | 0.58 | 1 | | | |
| **Temperature** | -0.19 | -0.51 | -0.39 | 1 | | |
| **Wind Speed** | -0.05 | -0.18 | -0.12 | 0.35 | 1 | |
| **Visibility** | -0.12 | -0.50 | -0.24 | 0.38 | 0.39 | 1 |

# Cross-Categorical Model

| | | Temperature class | | | No. of Observations |
|---|---|---|---|---|---|
| **Event Duration Class** | | <-5 ℃ | -5℃ to -2.5℃ | >-2.5℃ | |
| **0-7 hours** | Avg ΔBPRT(h) | 0.00 | 0.81 | 0.20 | 21 |
| | Std. Deviation | 0.00 | 0.80 | 0.31 | |
| | Observation N | 2 | 9 | 10 | |
| **7-12 hours** | Avg ΔBPRT(h) | 0.06 | 1.18 | 0.81 | 20 |
| | Std. Deviation | 0.11 | 2.25 | 1.19 | |
| | Observation N | 4 | 7 | 9 | |
| **>12 hours** | Avg ΔBPRT(h) | 1.75 | 1.42 | 1.08 | 22 |
| | Std. Deviation | 1.14 | 1.89 | 1.53 | |
| | Observation N | 13 | 6 | 3 | |
| **No. of Observations** | | 19 | 22 | 22 | 63 |

# Safety Model Used

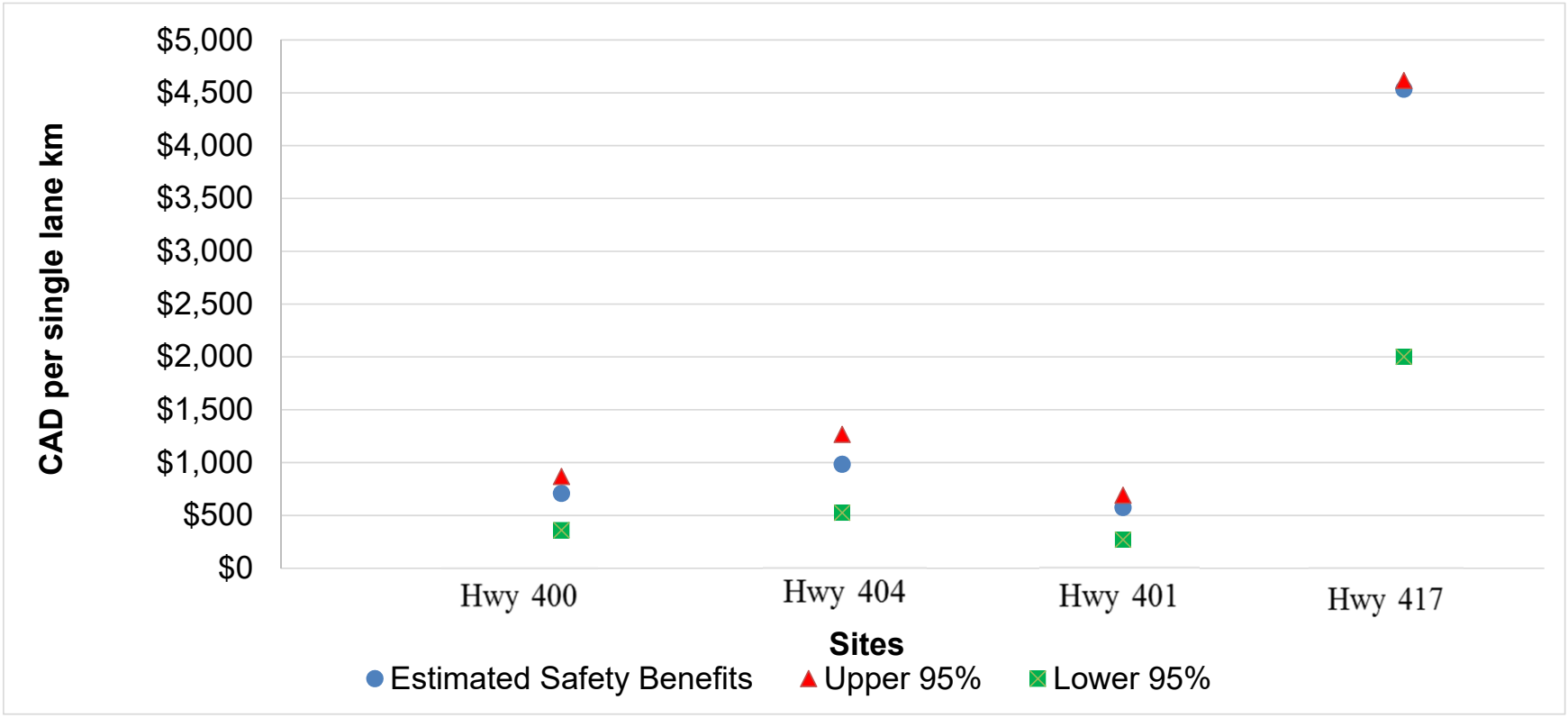
$$\mu = Exp^{0.235} * e^{-1.249-0.011T+0.005WS-0.039VIS+0.097\,HP-2.594RSI+M+S+FH}$$ Usman et al. (2010)

- where μ is the expected number of collisions of a highway
- Exp = exposure (equal to total traffic in given time multiplied by length of the road section)
- T = temperature (℃)
- WS = wind speed (Km/h)
- VIS = visibility (Km)
- HP = Hourly precipitation (cm)
- RSI = road surface index (unitless)
- M, S = indicator for month and site (unitless)
- FH = dummy variable for the effects of being the first hour (-0.302 if first hour; 0 otherwise).

# Assumptions

- The base scenario is considered with the UFW standard, while the alternative scenario is considered by applying the Class 1 standard.
- Base case RSI for UFW during ΔBPRT period = 0.85 (bare and wet condition)
- Alternative case RSI for Class 1during ΔBPRT period = 0.6 (partly snow-covered condition)
- Unit collision cost = $77,000.

# 2018/2019 Season
# -Safety benefits estimation



# Conclusions

- Bare pavement regain time: Implementation of UFW resulted in a significant reduction in BPRT ~ 41%.
- Material usage: Significantly more amount of salt was used on UFW sections compared Class sections for all the sites with an average 139% increase in material usage observed
- Within storm snow coverage: No significant difference was observed for this performance measure.
- Shortened BPRT at UFW sections was found to result in substantial safety benefits. Areas experiencing either more number of storms or more severe storms will observe more safety and mobility benefits associated with maintaining high LOS standards.

# Thanks And Questions!