



CONFERENCIA INTERNACIONAL  
SOBRE  
**VIALIDAD INVERNAL**

Del 27 al 30 de junio de 2017

Mendoza - Argentina

# Socio-Economic Costs Depending on Winter Maintenance Strategy

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ORGANIZAN

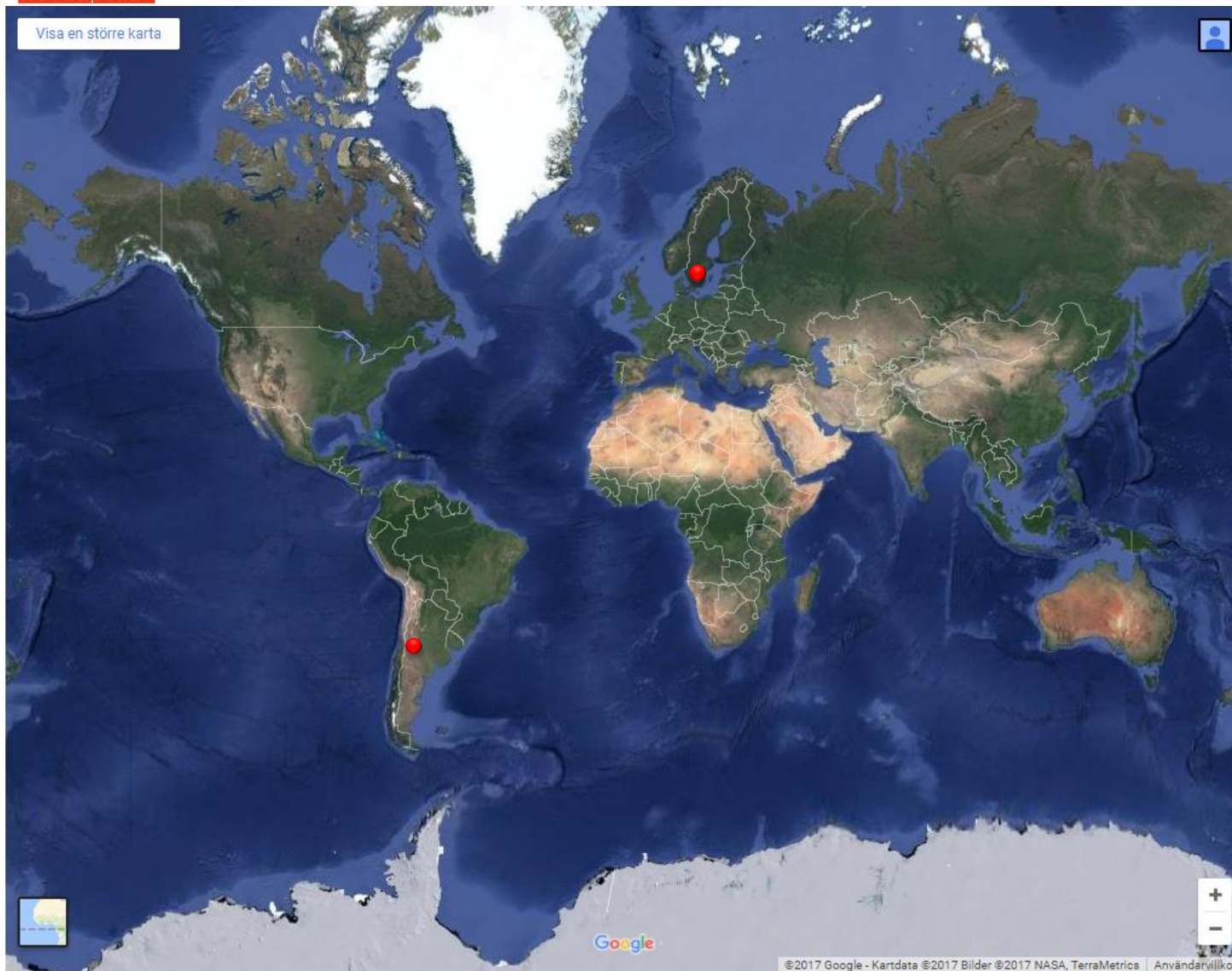




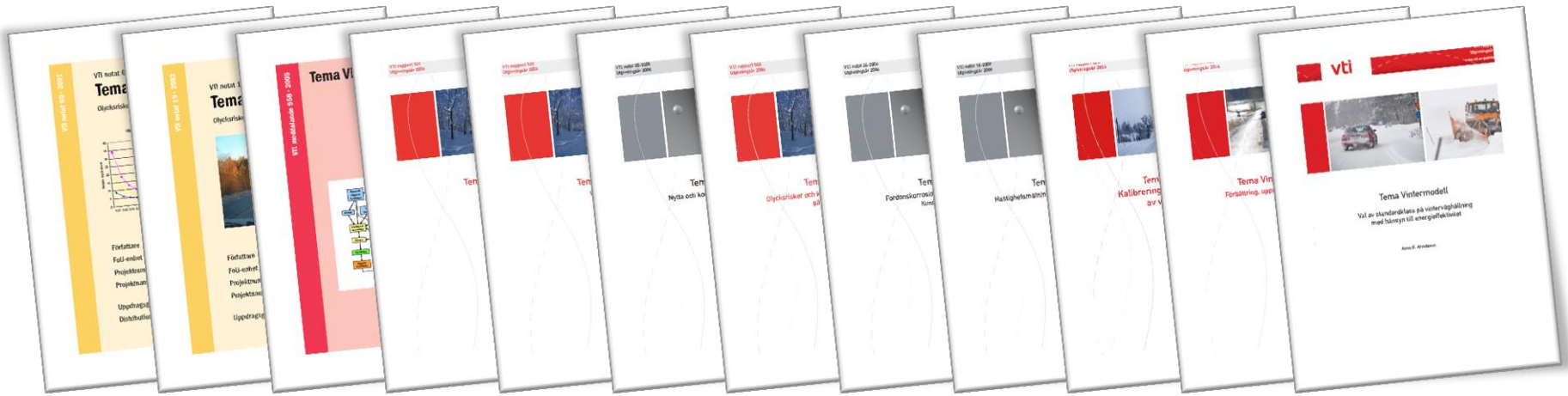
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Visa en större karta



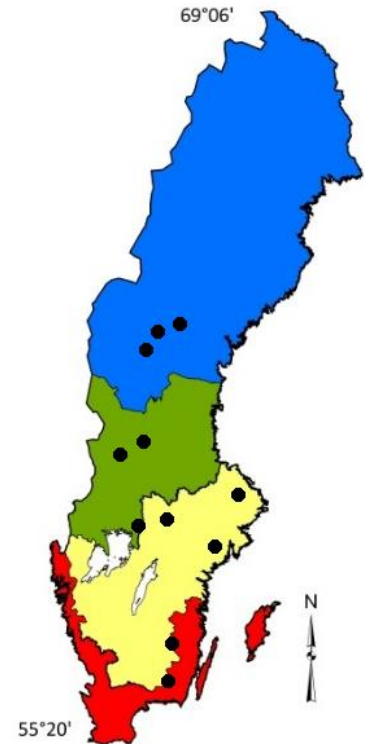
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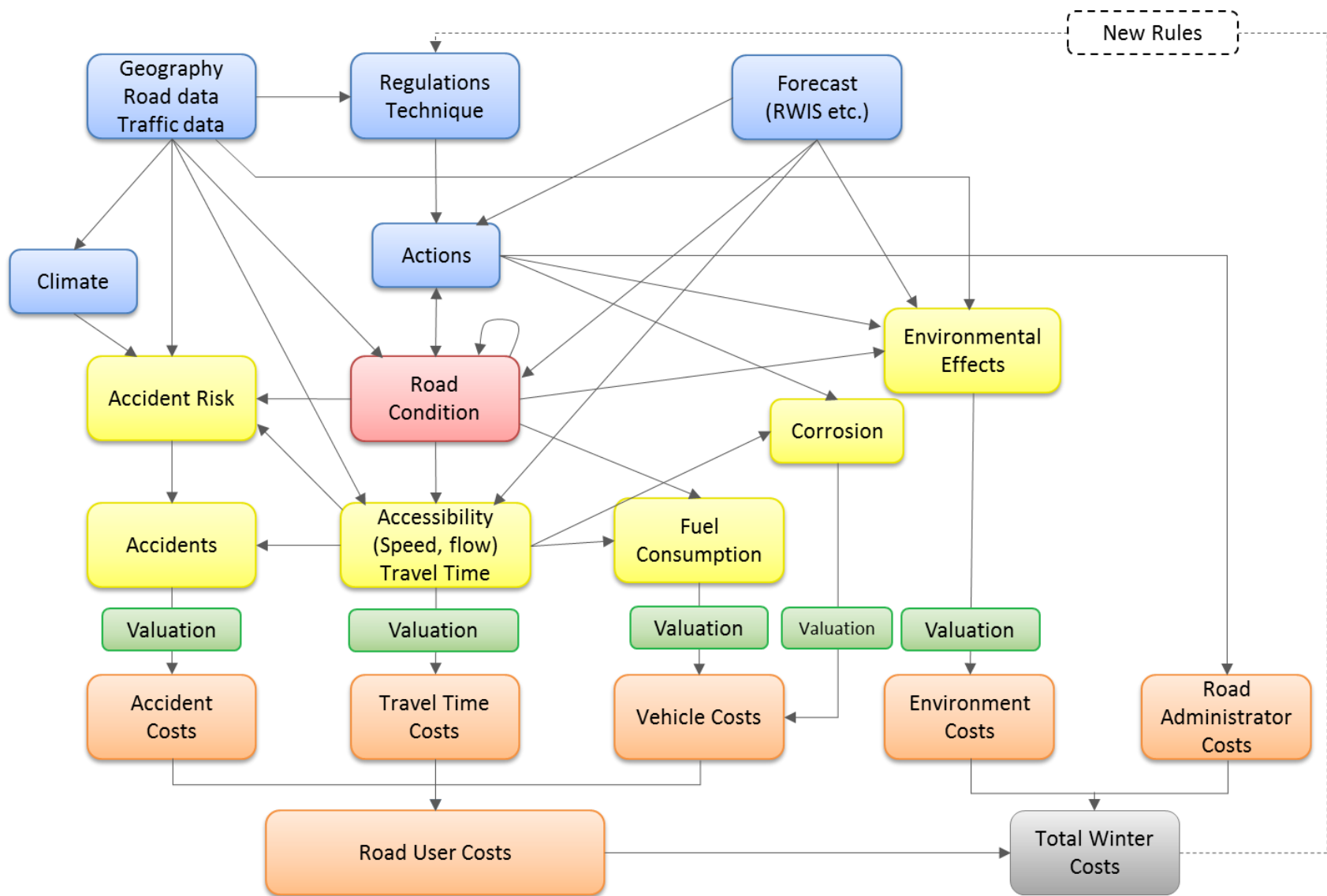


- The project “Winter model” started in the beginning of 2000s
- The idea was to try and predict the consequences of different winter maintenance strategies and to calculate the associated socio-economic costs

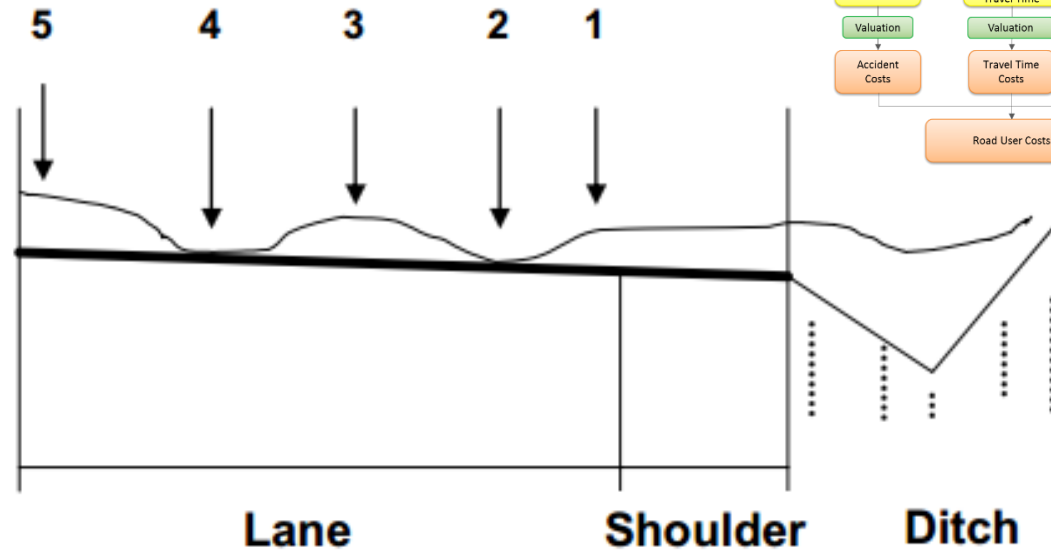
# Background of the Winter Model

- Detailed observations of road conditions
  - 5 winter seasons
  - 11 places around Sweden



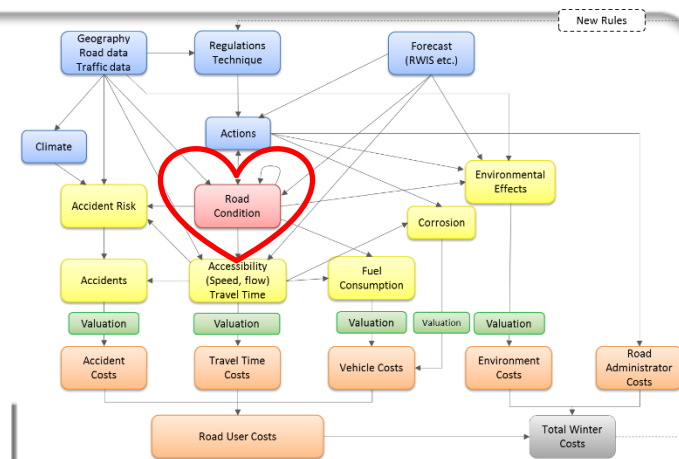


# Road Condition Model

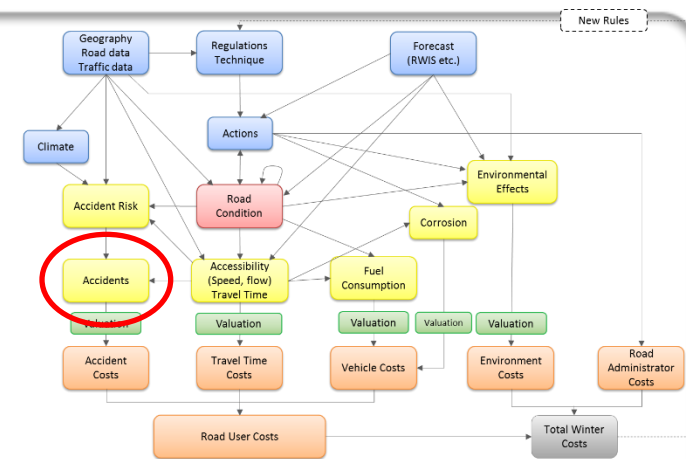


1. Edge of lane
2. Right wheel track
3. Between wheel tracks
4. Left wheel track
5. Middle of the carriageway

Calculates road conditions every half hour from weather, traffic and maintenance actions



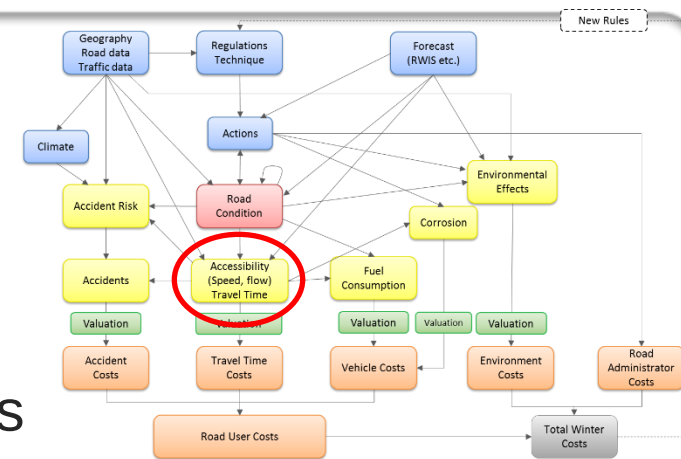
# Accident Model



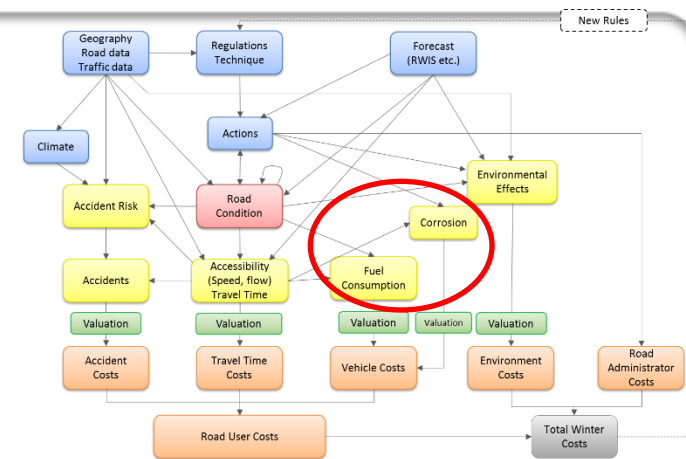
- Calculates accident risk and consequences connected to different road conditions and the duration of the weather
- Based on accident risks on bare ground (accidents/millions of vehicle km) are the amount of accidents divided into bare ground and snow/ice
- This model will be updated before 1 april 2018

# Accessibility Model

- Vehicle average velocity and travel times
- Three (four) vehicle types
  - Passenger car (fuel type: petrol or diesel)
  - Lorry without trailer, including buses (LNT)
  - Lorry with trailer (LWT)
- Travel times depends on the roads speed limit, design, and road conditions and have been developed for an average road
- operating road standard class 1-5
- 8 different road conditions



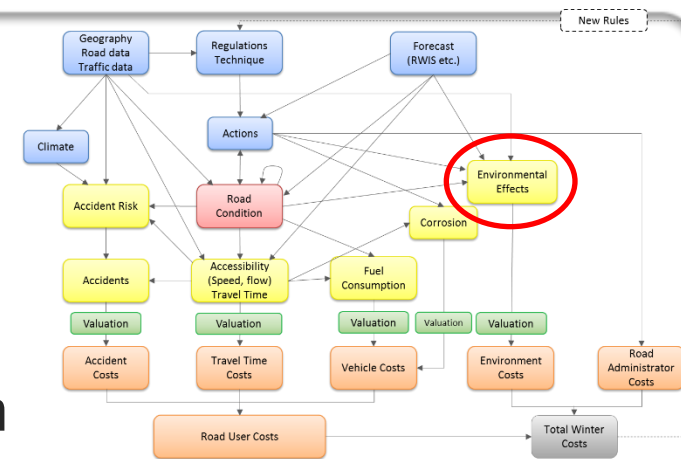
# Vehicle Cost Model



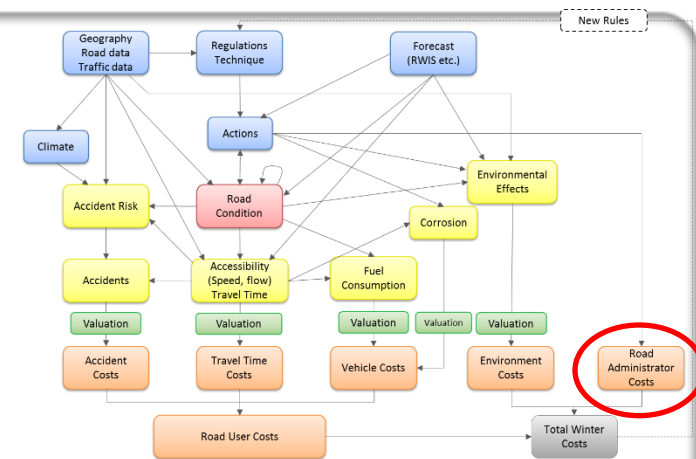
- Fuel consumption related to road condition, travel velocity and the operating standard class
  - 4 different vehicle types
  - 6 different road conditions
- Also includes the effect of salt corrosion based on vehicle mileage

# Environment Model

- Includes impact of salt on the vegetation close to the road and emissions
- Damage to vegetation
  - spread amount of salt
  - traffic flow
  - wind direction and velocity
  - distance from the road edge
  - roads condition
- Air pollutants and greenhouse gas emissions, CO<sub>2</sub>, SO<sub>2</sub>, HC and NO<sub>x</sub>, bases calculations on fuel consumption and mileage for 4 vehicles types



# Road Management Cost Model

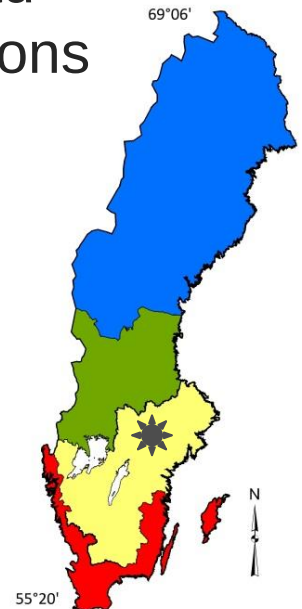
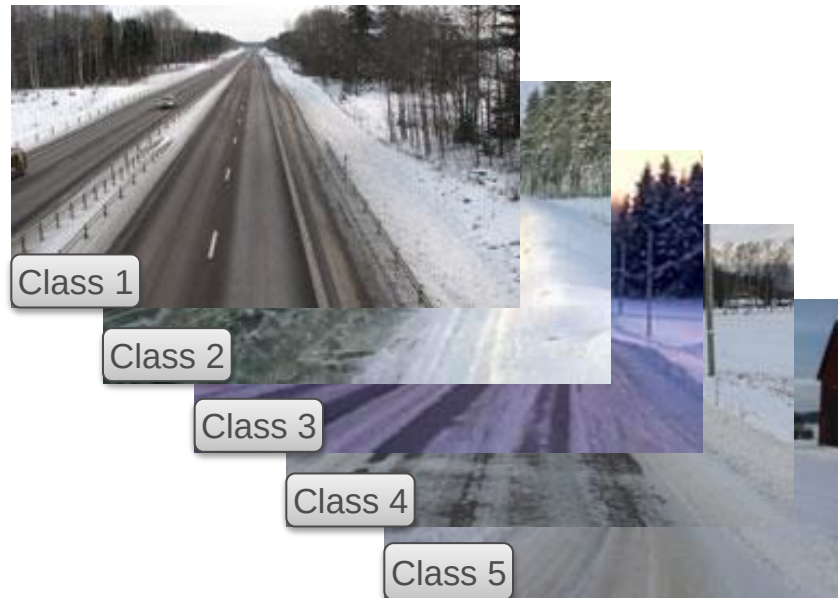


- Based on the amount and types of actions
- Salted roads (4 possible actions)
  - preventive salting with two different doses of brine
  - combination of ploughing and pre-wetted salting
  - pre-wetted salting
- Unsalted roads (2 possible actions)
  - ploughing
  - gritting with sand

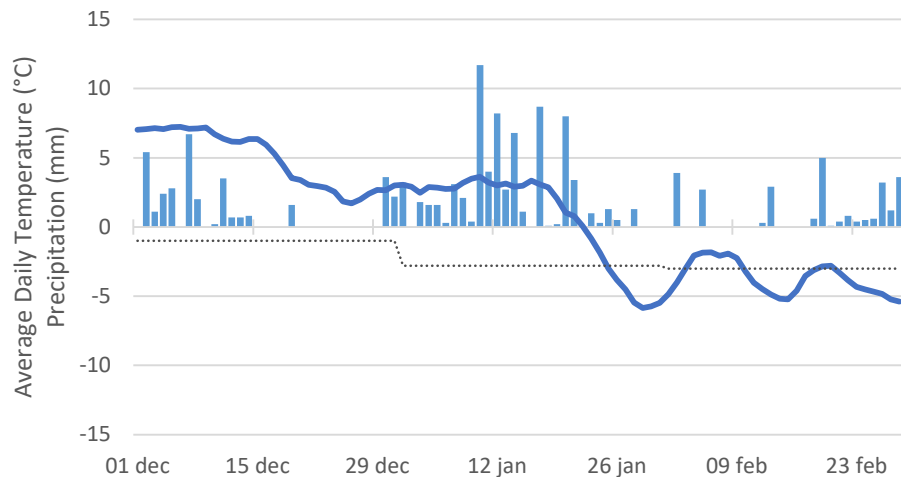
# Study Example

| Hour              | 0                  | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
|-------------------|--------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| <b>2007-01-19</b> | Weather situation  |      |      |      | S    | S    | S    | S    | S    |      |      |      |      |      |      |
|                   | Snow (mm)          | 0    | 0    | 0    | 0    | 0,2  | 7,3  | 6,6  | 6,4  | 1,1  | 0    | 0    | 0    | 0    | 0    |
| <b>Friday</b>     | Rain (mm)          | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
|                   | Air Temp (°C)      | 0,3  | -0,2 | 0,8  | 1,1  | 0,9  | 0,3  | -0,1 | -0,5 | -1,2 | -1,2 | -1,3 | -1,3 | -1,8 | -2,7 |
|                   | Surface Temp (°C)  | 0,8  | 0,1  | 0,9  | 1    | 0,9  | -0,1 | -0,1 | -0,1 | -0,2 | -0,4 | -0,4 | -0,9 | -1,2 | -1,4 |
|                   | Dewpoint Temp (°C) | -0,9 | -1,2 | -0,2 | -0,9 | -1,2 | -1   | -1,3 | -1,3 | -2   | -2,3 | -3,2 | -3,7 | -5,3 | -6,6 |
|                   | Windspeed (m/s)    | 1,7  | 1,4  | 1,7  | 1,4  | 0,3  | 0,9  | 1,6  | 2,1  | 1,9  | 1    | 2,1  | 2,1  | 2,9  | 3,2  |
|                   | Wind direction     | W    | W    | W    | E    | E    | E    | NE   | NE   | NE   | NE   | W    | W    | NW   | NW   |

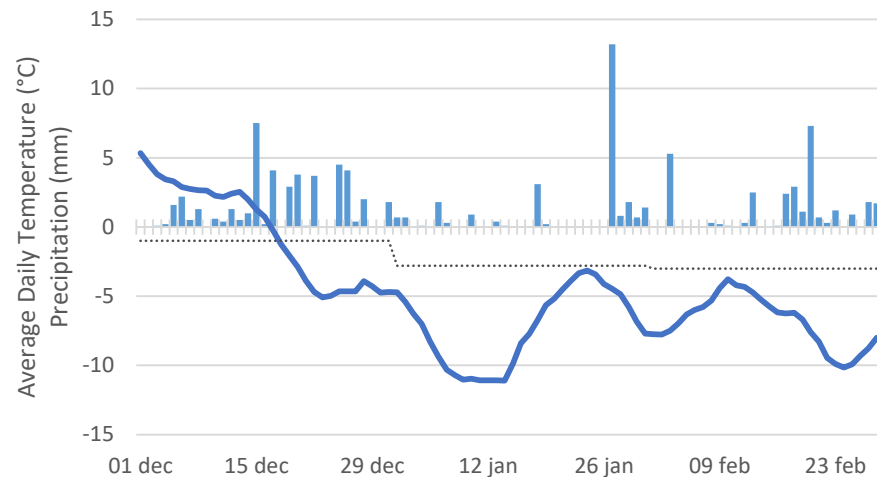
- Main goal was to compare the effects of changed road class in different winter seasons on maintenance actions
- Inputs
  - Climate zone
  - Weather data
  - AADT
  - Road class



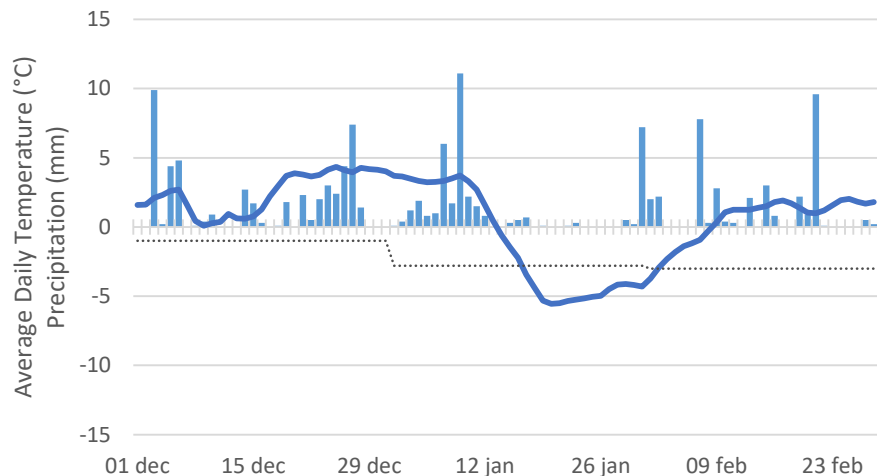
2006/2007



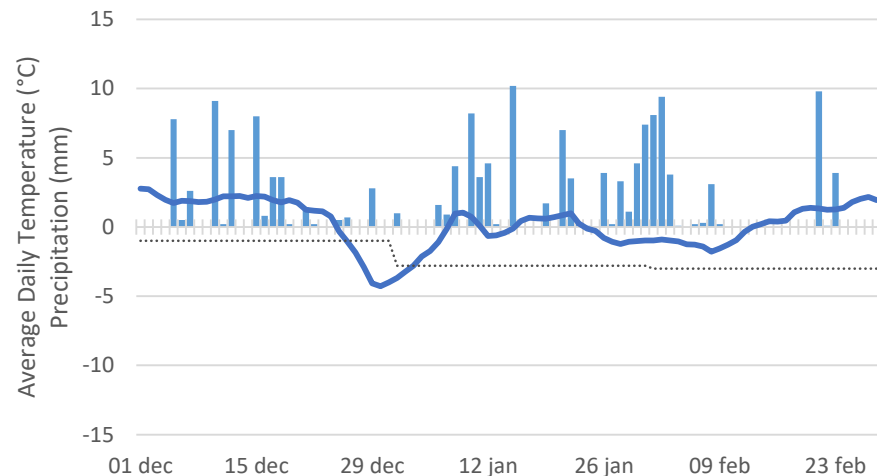
2009/2010



2013/2014



2014/2015



# Results

| Action                   | Standard Road Class | Entry criteria | Action time | AADT  | Speed limit | Climate zone |
|--------------------------|---------------------|----------------|-------------|-------|-------------|--------------|
| Combination, salted road | 2                   | 1 cm snow      | 3 hours     | 8 000 | 90 km/h     | Central      |
| Combination, salted road | 3                   | 2 cm snow      | 4 hours     | 8 000 | 90 km/h     | Central      |

Road length: 100km

## Road Condition

| Winter Season              | 2006/07 |      | 2009/10 |      | 2013/14 |      | 2014/15 |      |
|----------------------------|---------|------|---------|------|---------|------|---------|------|
| Road Standard Class        | 2       | 3    | 2       | 3    | 2       | 3    | 2       | 3    |
| Dry, bare ground           | 64,0    | 63,7 | 58,2    | 60,9 | 52,8    | 50,4 | 44,1    | 43,0 |
| Moist, bare ground         | 14,4    | 14,3 | 11,5    | 11,6 | 21,7    | 21,2 | 18,5    | 18,0 |
| Wet, bare ground           | 13,9    | 13,8 | 10,3    | 9,9  | 14,1    | 14,1 | 10,7    | 10,4 |
| Hoarfrost / black ice      | 0       | 0    | 0       | 0    | 0       | 0    | 0       | 0    |
| Hard-packed snow/thick ice | 0,2     | 0,2  | 0,2     | 0,2  | 0,02    | 0,02 | 0,03    | 0,03 |
| Loose snow / slush         | 0,3     | 0,3  | 0,8     | 0,8  | 0,4     | 0,4  | 0,4     | 0,4  |
| Ruts with bare ground      | 7,1     | 7,5  | 18,6    | 16,2 | 11,0    | 13,9 | 26,2    | 28,2 |
| Ruts with black ice        | 0,2     | 0,2  | 0,4     | 0,4  | 0,02    | 0,02 | 0,1     | 0,1  |

# Results

| Action                   | Standard Road Class | Entry criteria | Action time | AADT  | Speed limit | Climate zone |
|--------------------------|---------------------|----------------|-------------|-------|-------------|--------------|
| Combination, salted road | 2                   | 1 cm snow      | 3 hours     | 8 000 | 90 km/h     | Central      |
| Combination, salted road | 3                   | 2 cm snow      | 4 hours     | 8 000 | 90 km/h     | Central      |

Road length: 100km

## Maintenance Actions

| Winter Season                             | 2006/07 |    | 2009/10 |    | 2013/14 |    | 2014/15 |     |
|-------------------------------------------|---------|----|---------|----|---------|----|---------|-----|
| Road Standard Class                       | 2       | 3  | 2       | 3  | 2       | 3  | 2       | 3   |
| Preventative brine (40 g/m <sup>2</sup> ) | 14      | 14 | 4       | 4  | 12      | 12 | 24      | 25  |
| Preventative brine (20 g/m <sup>2</sup> ) | 63      | 63 | 26      | 26 | 63      | 63 | 105     | 103 |
| Comb plough/prewetted salt                | 37      | 35 | 100     | 84 | 42      | 38 | 50      | 47  |
| Combination prewetted salt                | 30      | 30 | 71      | 74 | 43      | 43 | 30      | 24  |

Road Class: 2  
Entry criteria: 1 cm  
Action time: 3 h

|                   | 2006/07        | 2009/10        | 2013/14        | 2014/15        |
|-------------------|----------------|----------------|----------------|----------------|
| Accidents         | 55 343         | 64 877         | 56 663         | 65 196         |
| Travel Time       | 289 434        | 292 728        | 290 746        | 294 405        |
| Fuel              | 42 703         | 42 523         | 42 718         | 42 285         |
| Corrosion         | 33 998         | 34 036         | 34 021         | 34 027         |
| Environment Salt  | 588            | 789            | 643            | 784            |
| Emissions         | 27 116         | 27 060         | 27 130         | 26 967         |
| Maintenance Cost  | 1 462          | 2 481          | 1 658          | 2 050          |
| <b>Total Cost</b> | <b>450 644</b> | <b>464 493</b> | <b>453 579</b> | <b>465 714</b> |

Road Class: 3  
Entry criteria: 2 cm  
Action time: 4 h

|                   | 2006/07        | 2009/10        | 2013/14        | 2014/15        |
|-------------------|----------------|----------------|----------------|----------------|
| Accidents         | 89 070         | 101 722        | 93 652         | 105 488        |
| Travel Time       | 299 147        | 301 783        | 301 162        | 304 934        |
| Fuel              | 43 164         | 43 071         | 43 128         | 42 718         |
| Corrosion         | 33 998         | 34 036         | 34 021         | 34 027         |
| Environment Salt  | 580            | 747            | 630            | 754            |
| Emissions         | 27 307         | 27 284         | 27 301         | 27 146         |
| Maintenance Cost  | 1 432          | 2 279          | 1 599          | 1 936          |
| <b>Total Cost</b> | <b>494 697</b> | <b>510 922</b> | <b>501 495</b> | <b>517 003</b> |

Road Class: 2 Entry criteria: 1 cm Action time: 3 h

|                   | 2006/07        | 2009/10        | 2013/14        | 2014/15        |
|-------------------|----------------|----------------|----------------|----------------|
| Accidents         | 55 343         | 64 877         | 56 663         | 65 196         |
| Travel Time       | 289 434        | 292 728        | 290 746        | 294 405        |
| Fuel              | 42 703         | 42 523         | 42 718         | 42 285         |
| Corrosion         | 33 998         | 34 036         | 34 021         | 34 027         |
| Environment Salt  | 588            | 789            | 643            | 784            |
| Emissions         | 27 116         | 27 060         | 27 130         | 26 967         |
| Maintenance Cost  | 1 462          | 2 481          | 1 658          | 2 050          |
| <b>Total Cost</b> | <b>450 644</b> | <b>464 493</b> | <b>453 579</b> | <b>465 714</b> |

Road Class: 3 Entry criteria: 2 cm Action time: 4 h

|                   | 2006/07        | 2009/10        | 2013/14        | 2014/15        |
|-------------------|----------------|----------------|----------------|----------------|
| Accidents         | 89 070         | 101 722        | 93 652         | 105 488        |
| Travel Time       | 299 147        | 301 783        | 301 162        | 304 934        |
| Fuel              | 43 164         | 43 071         | 43 128         | 42 718         |
| Corrosion         | 33 998         | 34 036         | 34 021         | 34 027         |
| Environment Salt  | 580            | 747            | 630            | 754            |
| Emissions         | 27 307         | 27 284         | 27 301         | 27 146         |
| Maintenance Cost  | 1 432          | 2 279          | 1 599          | 1 936          |
| <b>Total Cost</b> | <b>494 697</b> | <b>510 922</b> | <b>501 495</b> | <b>517 003</b> |

|                   | 2006/07    | 2009/10    | 2013/14    | 2014/15    |
|-------------------|------------|------------|------------|------------|
| Accidents         | 61%        | 57%        | 65%        | 62%        |
| Travel Time       | 3%         | 3%         | 4%         | 4%         |
| Fuel              | 1%         | 1%         | 1%         | 1%         |
| Corrosion         | 0%         | 0%         | 0%         | 0%         |
| Environment Salt  | -1%        | -5%        | -2%        | -4%        |
| Emissions         | 1%         | 1%         | 1%         | 1%         |
| Maintenance Cost  | -2%        | -8%        | -4%        | -6%        |
| <b>Total Cost</b> | <b>10%</b> | <b>10%</b> | <b>11%</b> | <b>11%</b> |

Thank you for listening!