WEATHER DESCRIPTIONS AND COMPENSATION MODEL FOR WINTER ROAD MAINTENANCE

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Abstract

A good compensation model for regulating costs for winter road maintenance between client and contractor requires two well-functioning sub models.

- A sub model that describes the weather during the winter season.
- A sub model that links the weather descriptions to the need to take measures/set in resources.

The basis for the weather descriptions are data collected from the individual stations in the Swedish National Road Administration system for road weather information, RWiS. Through using special definitions, the data are translated into eight weather situations at an hourly level. Examples of weather situations are snowfall, drifting snow and risk of slipperiness caused by rain or sleet on a cold roadway.

The hour-by-hour weather descriptions are then summarised into clearly defined weather occurrences, for instance drifting snow during 6 hours or a snowfall lasting 20 hours with a snow depth of 10 cm. The final result of weather descriptions for a winter is a number of clearly defined weather occurrences.

The compensation model is based on the number of weather occurrences for each RWiS station chosen as representative for a certain maintenance area. Starting from each weather occurrence the number of so-called resultant weathers is calculated being the basis of compensation. In this step the connection is made between weather and the need to take measures.

Background

A good compensation model (payment model) for regulating costs for winter road maintenance between client and contractor, based on winter conditions, requires two well-functioning sub models.

- A sub model that describes the weather during the winter season.
- A sub model that links weather descriptions to the need to take measures/set in resources.

Weather Situations

Weather descriptions are based on raw data from individual stations in the Swedish National Road Administration system for road weather information, RWiS. The following raw data are used.

- Air temperature.
- Road surface temperature.
- Relative humidity.
- Dew point temperature.
- Precipitation type.
- Precipitation quantity.
- Wind speed.

With the aid of specific definitions, these raw data are translated from the RWiS to the eight weather situations below on an hourly basis.

- Snowfall (S).
- Drifting snow (D).
- Slippery surface due to rain or sleet on a cold road (SSP).
- Slippery surface due to damp/wet roads freezing (SSF).
- Slippery surface due to light hoar frost (SSH1).
- Slippery surface due to heavy hoar frost (SSH2).
- Specific weather, type 1, i.e. drifting snow with high wind speed (SW1).
- Specific weather, type 2, i.e. snowfall with high snow intensity (SW2).

The following are two examples of definitions for translating raw data into weather situations:

Drifting snow (D).
- Snow likely to drift should be present (as in a specific definition).
- The average wind speed should be 5 m/s or above.

Slippery surface due to light hoar frost (SSH1).
- Road surface temperature must be at least 0.5 °C lower than the dew point temperature.
- Road surface temperature must be below + 1.0 °C.

Weather Situations On An Hourly Basis

An example of hourly weather situations is given in table 1 below. The situations are for an operating area where three RWiS stations, 307, 312 and 320, have been selected as representative.

Station	Weather	Hour																							Snow depth (mm)
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Date: 28 Nov.																										
307	Weather situation													S	S		S	S	S	S	S	S	S	S	S	
307	Snow depth (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.2	0	3.5	4.8	5.8	8.5	5.8	8.8	9.9	8.2	5.8	62
312	Weather situation													S			S	S	S	S	S	S	D	D	D	
312	Snow depth (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	1,0	1.6	4.8	4.8	9.0	7.1	5.9	6.6	41
320	Weather situation														S		S	S	S	S	S	S	S	S	S	
320	Snow depth (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	0	1.3	4.0	5.6	7.1	5.1	2.4	3.5	9.8	9.7	51
Date: 29 Nov.																										
307	Weather situation	S	S	S	S	S	S	S							S	S	S	S	S	S				S	S	
307	Snow depth (mm)	5.0	4.6	5.5	5.9	6.0	3.8	0.6	0	0	0	0	0	0	0.3	0.8	1.6	0.2	0.2	1.5	0	0	0	1.4	2.4	40
312	Weather situation	D	D	S	S	S	S	S							S	S	S	S	S	S	S	S		S	S	
312	Snow depth (mm)	5.0	3.1	3.4	4.2	2.3	6.1	2.3	0	0	0	0	0	0	0.2	0.6	1.1	0.8	0.5	0.3	0.8	0.2	0	0.4	1.0	32
320	Weather situation	S	S	S	S	S	S	S						S	S	S	S	S	S	S	S			S	S	
320	Snow depth (mm)	6.6	9.5	5.8	7.8	9.8	5.6	1.5	0	0	0	0	0	0.5	0.5	1.2	0.5	1.7	0.5	1.4	2.8	0	0	0.3	2.4	58
Date: 30 Nov.																										
307	Weather situation	S						S	S	S				S	S	S										
307	Snow depth (mm)	1.1	0	0	0	0	0	0.4	1.5	2.1	0	0	0	0.7	0.3	0.2	0	0	0	0	0	0	0	0	0	6
312	Weather situation	S	S					S	S	S	S					S										
312	Snow depth (mm)	1.0	0.3	0	0	0	0	1.0	0.8	1.6	0.3	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	5
320	Weather situation	S			S		S	S	S	S	S					S	S									
320	Snow depth (mm)	1.0	0	0	0.5	0	0.2	0.8	1.1	2.1	0.2	0	0	0	0	1.0	0.8	0	0	0	0	0	0	0	0	8

Table 1 72-hour Weather Situations At Hourly Intervals For An Operation Area.

The weather description table reveals that a relatively heavy snowfall (S) started at approximately 12.00 on 28 November and continued for around 20 hours, i.e. until 07.00 the next morning. At station 312 drifting snow (D) occurred for 5 hours around midnight at the same time as it snowed.

After a break of around 6 hours, it started snowing again. This time in the form of light snowfall that continued for around 24 hours, although this stopped several times. When this snowfall had ended, between 8 and 12 cm of snow had fallen, depending on the individual RWiS stations.

Payment Model

The payment model is based on weather occurrences, not on specific hours with certain weather situations. Examples of weather occurrences are a snowfall between 06.00 and 12.00 or slippery surface due to hoar frost between 01.00 and 05.00. The payment model is based on weather occurrences because for example, an occurrence of hoar frost for four hours is not equivalent to four separate hours of hoar frost on four different days. The first four-hour hoar frost may perhaps call for just one salting run while the four separate hours would probably need four runs.

The starting point for payment calculations is the weather situations on an hourly basis set out above. These weather situations at hourly intervals are first merged together into weather occurrences. Each weather occurrence then generates one or several so-called resultant weathers that form the basis for payment. The calculations are done for one RWiS station at a time and then summarised for the whole maintenance area. It is at this stage that a relation is set up between weather and need for action. It must be stressed that **one** resultant weather does not equal **one** action to be taken, e.g. a salting run or a ploughing run.

The following rules apply when resultant weather calculations are performed.

Calculation Order For Different Weather Situations

1. Specific weather, type 1 (SW1).
2. Specific weather, type 2 (SW2).
3. Drifting snow (D).
4. Snowfall (S).
5. Slippery surfaces of all types (SSP, SSF, SSH1, SSH2).

Demarcation Of Weather Occurrences

The following method for the demarcation of weather occurrences applies for all weather situations except SW2.

The first hour during winter with the current weather situation, generally called W, is identified. The last hour during this first occurrence of W is identified. This is found when there is a break of at least 6 hours until the next hour of W. The following weather occurrences with W during the winter season are demarcated in the same way. See illustration 1 below.

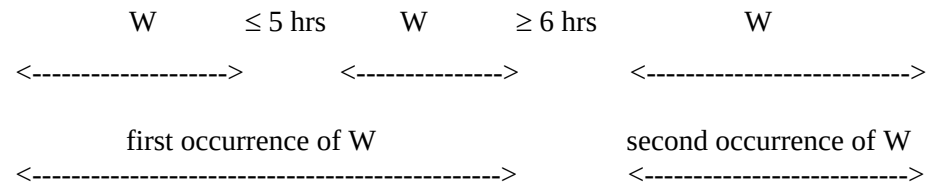

Illustration 1 Demarcation Of Weather Occurrences Of Weather Type W.

Specific Weather Type 1 (SW1)

1. All hours with SW1 during the current calculation period are demarcated as weather occurrences according to the method given in illustration 1.
2. How long the SW1 occurrences found last is determined in the following way. If SW1 occurs ≥ H_{SW1} hours consecutively then specific weather type 1 arises. Otherwise there are just intermittent hours of SW1.
3. The SW1 occurrences that meet the time period requirements are shown under the heading "Resultant weather, SW1". This states the start and finish times for each occurrence.
4. During the time period when an SW1 occurs and $H_{SW1\ after}$ hours thereafter no calculations are done for weather of types drifting snow, snowfall and slippery surface, (payment for the SW1 weather plus the subsequent $H_{SW1\ after}$ hours takes precedence). If however several SW1 or SW2 occurrences arise within $H_{SW1\ after}$ hours after an SW1 occurrence ends, the end time point is extended.

Specific Weather Type 2 (SW2)

1. Weather occurrences of type SW2 are calculated and how long they lasted is determined for each RWiS station with the aid of a specific procedure. The calculations are done such that the snow intensity shall amount to not less than I_{SW2} cm/hr for not less than H_{SW2} hrs. The SW2 occurrences are given under the heading "Resultant weather, SW2" where the start and end time point is given for each occurrence.
2. During the course of an SW2 occurrence and $H_{SW2\ after}$ hours afterwards no calculations are done for weather of types drifting snow, snowfall and slippery surface (payment for SW2 weather and the following $H_{SW2\ after}$ hours takes precedence). However if there are several SW2 or SW1 occurrences within $H_{SW2\ after}$ hours after an SW2 occurrence ends, the end time point is extended.

Drifting Snow (D)

1. All hours with D during the current calculation period are demarcated as weather occurrences in accordance with the method in illustration 1.
2. If D arises ≥ H_{DRIFT} hours in succession during the course of the D-occurrence the time period requirement for drifting snow is met, i.e. drifting snow occurs. For instance, as SW1 is a heavier type of D, a 4-hour combination of situations D, D, SW1, D can be counted as drifting snow.
3. Each D-occurrence that meets the duration requirement is divided into 4-hour intervals (the last 4-hour interval can be between 1 and 4 D hours) and the number of intervals is calculated. The amount of snow in each 4-hour interval is calculated. The intervals that have both ≤ 0,3 cm of snow and do not have D or SV1 hours are discounted. The remaining intervals are shown in four classes under the heading "Resultant weather, drifting snow".

   The classes are defined according to the following amounts of snow d (cm).

   $0{,}0 \leq d \leq 0{,}3$
   $0{,}3 < d \leq 1{,}0$
   $1{,}0 < d \leq 2{,}5$
   $2{,}5 < d$.

Snowfall (S)

1. All hours with S during the current calculation period are demarcated as weather occurrences according to the method in illustration 1.
2. Each occurrence of S is divided into 4-hour intervals (the last 4-hour interval can be between 1 and 4 S hours) and the number of intervals is calculated. The amount of snow in each 4-hour interval is calculated. The intervals that have ≤ 0,3 cm of snow are discounted. The remaining intervals are shown in three snow quantity classes under the heading "Resultant weather, snowfall".

   The snow quantity classes are defined by the following amounts of snow d (cm).
   $0{,}3 < d \leq 1{,}0$
   $1{,}0 < d \leq 2{,}5$
   $2{,}5 < d$.

Slippery Surface Occurrences Of Type SSP, SSF, SSH1 And SSH2

1. When snowfall or drifting snow occurs and up to 6 hours after such weather, no demarcation is done for slippery surfaces. Nor during the occurrence of SW1 or SW2 and up to $H_{SW1\ after}$ resp. $H_{SW2\ after}$ hours thereafter is any demarcation made for the occurrence of slippery surfaces. The following tests are done for the remaining periods.
2. When demarcating occurrences of slippery surfaces, all types of slippery surface, i.e. SSP, SSF, SSH1 and SSH2 are classed the same.
3. All hours of slippery surface weather during the current calculation period are demarcated as occurrences of slippery surfaces according to the method in illustration 1.
4. The duration of the resultant weather is linked to the type of slippery surface weather, H_{SSP}, H_{SSF}, H_{SSH1} and H_{SSH2} hours.
5. The slippery surface type during the first hour in the first occurrence of slippery surface (generally called type SS1) is identified. The duration of this type is H_{SS1} hours. An interval of H_{SS1} hours is set out from the first hour of such inclusive. A test is done to see if some type of slippery surface weather shorter than H_{SS1} hours occurred within the interval. If no such type is found then a resultant weather of type SS1 has occurred. This is shown under the heading "Resultant weather, slippery surface type SS1".
6. Otherwise the interval is shortened by one hour at a time and new tests are done until no slippery surface type shorter than the length of the interval is found within the interval. Then a resultant weather of the slippery surface type with the shortest duration within the interval (generally called type SS2) has been found. This is shown under the heading "Resultant weather, slippery surface type SS2".
7. The slippery surface type in the first hour after the resultant weather found and shown according to the above is identified and steps 5 and 6 are repeated until the first slippery surface occurrence is resolved. The next occurrence of slippery surface is dealt with in the same way.

Implementation

Regulating the costs between client and contractor for winter road maintenance has previously been done in accordance with three principles.

1. Payment has been based on the resources used such as ploughing hours, amount of salt spread etc.
2. The contractor has been paid for the stretch cleared, e.g. number of kilometres ploughed and number of kilometres salted/sanded etc.
3. Payment has been based on different types of so called weather days, e.g. days with snowfall and days with icy roads.

With the aid of the payment model described above, payment will be based on the same basic data that the contractor uses to decide what action to take.

Before the start of the tendering procedure of winter road maintenance in an operating area, a number of RWiS stations are selected that are representative for the operating area in question and that will form the basis for payment. Three or four stations are normally selected. These can be within or outside the boundaries of the operating area.

Data from different RWiS stations can be combined. For instance, one can choose to get temperature and precipitation from one RWiS station and wind speed from another.

A number of parameters are then set that are included in the eight different weather situations (see page 1) and also govern the resultant weather. Examples of such parameters are:

- Lowest snow intensity for SW2 to arise, I_{SW2} [cm/hr].
- Shortest duration for triggering SW2 payment, H_{SW2} [hrs].
- Lowest wind speed for drifting snow to be declared. V_{DRIFT} [m/s].
- Shortest duration to trigger drifting snow payment, H_{DRIFT} [hrs].
- Length of resultant weather SSP, H_{SSP} [hrs].

The resultant weather is determined for a “normal” winter in the operating area with the help of historic data from a number of winter seasons. The number of SW1, S, SSP, SSH1 etc. is then listed. As a part of the tendering procedure the contractor sets prices for each of them.

It should be added that in first hand the payment model described above covers snowploughing and salting actions. The need for sanding measures is normally regulated according to some other payment model.