ACCIDENTS, SPEEDS AND SALT CONSUMPTION ON ROADS IN WINTER

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1. Abstract

Winter days with temperatures around zero degrees Celsius and enough snow to warrant ploughing entail several problems: lower average speeds, a higher accident risk and increased expenses for the road manager. In addition to ploughing, a considerable amount of salt is used to maintain a dry carriageway on major roads after a snowfall.

This report defines a basic matrix with nine different weather situations classified according to temperature, air humidity and melted precipitation. This matrix was used to present the number of days of each weather situation, the traffic volume, average speed for cars and lorries with trailers respectively, and the salt used on the E20 European Highway outside Mariestad in mid-western Sweden. This matrix was also used to present accident statistics from seven counties in central Sweden.

Between 1 October 1995 and 31 March 1996, there were 13 days with temperatures around or below zero and more than 2 mm of melted precipitation. The following observations were made:

- 5-10 percent less traffic than during winter days with better weather
- 400 kg salt/km was used on roads of second highest maintenance priority
- the average speed for cars on the E20 was 86-92 km/h, which is 2-8 km/h lower than under favourable conditions.
- the number of accidents resulting in death or serious injury was about 2.7 per day, twice as many as during a good winter day.
- less serious accidents increased somewhat more.

The first three snowfalls in November were studied extra carefully through looking at the number of accidents 4 days ahead of and 4 days after the snowfall. The same pattern was found repeatedly, with the maximum number of accidents occurring on the day of the snowfall. Many of the additional accidents on that particular day occur on loose snow or slush, which is common when roads are salted while it is snowing.

An average speed of about 89 km/h in the summer had been measured at the same point. This speed is partially due to the highway being relatively narrow and intermittently congested.

The results indicate a high transport standard on the E20 in winter. However, when there is snow on the road, the speed is sufficiently high so as to pose a serious threat to road safety.

2. **Introduction**

In 1993, a major Nordic study was conducted by Fridström et al, entitled ”Explaining the Variation in Road Accident Counts”. After analysing monthly road injury statistics, it was ascertained that there was a lower risk of accidents involving human injury during winter when there was snow on the ground and temperatures below zero (Celsius). Previous studies conducted at the Swedish Road and Transport Research Institute (VTI) by Schandersson et al had, however, clearly indicated the greater risks during days of snowfall.

Although these results could initially seem contradictory, it became clear after some reflection that both could be true. The one study includes injury statistics on a monthly basis while the other refers to conditions during part of a twenty-four hour period.

Results of this kind stimulate the interest in risk calculations during different winter road conditions. The official adoption of ”Vision Zero” has also resulted in a greater general interest in road safety correlations, although with a focus on accidents of serious outcome.

Access to data often governs what can be evaluated in practice. In this case, data was available on the daily salt consumption for winter maintenance operations within a particular area in the SNRA Western Region. Comparing salt consumption with a day-by-day description of the weather during the winter is of interest in itself. Being able to relate this to accidents and speeds on the road network provides input for a great many analyses.

The Norwegian winter maintenance model that was presented at the PIARC Winter Congress in Tromsö in 1990 was used to classify weather according to temperature, air humidity and amount of melted precipitation. This classification is also suitable for Sweden, since many major roads are salted only if the temperature is above minus 6 degrees Celsius. See the following figure:

Figure 1. Weather classification

Temperature	Relative humidity < 80 %	Relative humidity > 80 % or precipitation 0 -1.9 mm	Precipitation 2.0 mm or more (melted form)
> +2	N1	N2	N3
+2 -- -6	N4	N5	N6
< -6	N7	N8	N9

Quite a large geographic area is required for material on accidents of serious outcome. Further, the winter weather conditions within this area should preferably be as homogeneous as possible to be able to assign each 24-hour period (calendar day) to one of the 9 classes. The geographical area chosen comprised seven counties in central Sweden, covering an area of about 300 by 300 kilometres. The vehicle mileage was estimated to be about one third of all vehicle mileage on the state road network in Sweden.

With the assistance of the Swedish Meteorological and Hydrological Institute (SMHI), data from 9 weather stations in this area was extracted and each day was classified as per the model above. According to professional opinion at SMHI, winter weather conditions within the chosen geographical area are pretty similar over a 24-hour period. A morning snowfall in the southern part of the area would have moved on to the northern part later the same day.

Naturally enough, there will be cases where rain in one part falls as snow in another. This somewhat evens out the risk differentiation between good and poorer conditions.

Period chosen: 1 October 1995 to 31 March 1996
Geographical area: 7 of Sweden's 24 counties.
State road network.
Weather data from 9 SMHI stations.
Speed data from a fixed survey point at Hova on the E20 European Highway north of Mariestad.
Salt consumption refers to roads in maintenance class A2 (second highest class) in the Mariestad district.

3. Weather description

From 1 October 1995 to 31 March 1996, 183 days all told, weather situation N5 was found to be most common. This means a risk of slippery roads, but is something that generally can be handled through preventive skid control measures.

Table 1. Number of calendar days in each class between 1 Oct 1995 and 31 March 1996

Temperature	Relative humidity < 80 %	Relative humidity > 80 % or precipitation 0 -1.9 mm	Precipitation 2.0 mm or more (melted form)
> +2	8	18	12
+2 -- -6	24	70	11
< -6	5	33	2

Weather situation N6 occurred 11 times, which is quite typical for the winter in this part of the country. This necessitates snow ploughing at least once, and means that there will be loose snow or slush on the roads at times. Weather situation N6 was studied more closely than the others with a view to the injury risk found in the in-depth analysis described below.

Weather situation N9 means it is cold and snowing. This occurred on 23 December and coincided with a day (Saturday) when there was heavy Christmas traffic.

Weather situation N1 is common in the autumn while situation N4 is more common in late winter, and means fine winter weather, often with completely dry carriageways on major roads.

4. Traffic volume, speeds and salt consumption

The following data on the traffic volume during different weather conditions was collected from the single traffic survey point used in the study.

Table 2. Traffic volume per calendar day at Hova on the E20 European Highway

Temperature	Relative humidity < 80 proc	Relative humidity > 80 % or precipitation 0 -1.9 mm	Precipitation 2.0 mm or more (melted form)
> +2	5590	5360	5710
+2 -- -6	4350	4200	3930
< -6	4010	4420	5960

Since most days of snow occur in December and January, while weather situations N1 and N4 occur at the beginning and end of winter, the pattern shown in the table is quite natural. The fact that situation N9 coincided with Christmas travel in this case breaks the pattern somewhat.

Data concerning the average speed on a day-by-day basis during the winter was also collected at the same traffic survey point at Hova.

Table 3. Average speed, km/h, of private cars at Hova on the E20, maintenance class A2.

Temperature	Relative humidity < 80 proc	Relative humidity > 80 % or precipitation 0 -1.9 mm	Precipitation 2.0 mm or more (melted form)
> +2	94	93	93
+2 -- -6	94	93	92
< -6	93	92	86

The speed of private passenger cars at Hova was relatively high during the 5 days or so when precipitation exceeded 2 mm and the measurement equipment was in proper working order. No measurement data at all is available for the approximate 5 days of heavy snowfall.

The speed data collected at Hova is an indication of the high transport standard on the E20. It can also be mentioned that, in the summer, the average speed at this point, which is 9m wide, with a 90 km/h speed limit and an AADT of 5860, is about 89 km/h. Queues do, however, build up at times.

During weather situation N5, salt is used as a preventive skid control measure. For weather situation N6, salt is used both while it is snowing and afterwards to maintain a bare roadway.

Table 4. Salt consumption in kg per calendar day and km on roads in maintenance class A2

Temperature	Relative humidity < 80 proc	Relative humidity > 80 % or precipitation 0 -1.9 mm	Precipitation 2.0 mm or more (melted form)
> +2	3	0	27
+2 -- -6	29	120	401
< -6	67	105	562

The large quantity of salt used during weather situation N9 is somewhat surprising since there could hardly be any risk of snow compaction on the road at such cold temperatures. Further, when it is really cold, a bare roadway is not a requirement.

5. Injury statistics results

Accidents involving death or serious injury are presented in one table below, and accidents involving minor injury or property damage only are shown in another. This division is based on the reasoning that speed reductions during adverse weather conditions could result in fewer serious accidents.

Table 5. Accidents involving death or serious injury per day. Based on statistics from 7 counties and a total of 260 serious accidents.

Temperature	Relative humidity < 80 %	Relative humidity > 80 % or precipitation 0 -1.9 mm	Precipitation 2.0 mm or more (melted form)
> +2	1.3	1.2	1.5
+2 -- -6	1.3	1.3	2.7
< -6	1.2	1.5	1.5

Table 6. Accidents involving minor injury or property damage. Based on statistics from 7 counties and 2 343 less serious accidents.

Temperature	Relative humidity < 80 %	Relative humidity > 80 % or precipitation 0-1.9mm	Precipitation 2.0mm or more (melted form)
> +2	9	11	14
+2 -- -6	9	11	27
< -6	16	15	25

It can be seen that the pattern is similar for both serious and less serious accidents. The tables show that there were twice as many accidents on the 11 days or so when the precipitation exceeded 2 mm as on days when the humidity is relatively low and temperatures drop below minus 6 degrees Celsius. It should be kept in mind that there is less traffic during heavy snowfall, as shown in Table 2, and that the method that was chosen to classify calendar days underestimates the risks during snowfall.

The results obtained from this simple study do not imply that results from previous accident studies must be questioned.

6. In-depth accident analysis

The in-depth analysis examines the levels of risk before, during and after the 3 heaviest days of snow in November. Weather situation N6 (more than 2 cm snow) occurred on Friday, November 3, Thursday November 16 and Monday November 27. In other words, the first snow fell on a Friday when there is somewhat more traffic than on other weekdays. Table 7 shows the number of accidents during the 4 days prior to the snowfall as well as during the 4 days afterwards; i.e., day 5 is the day of snowfall in each example.

Table 7 Accidents 4 days before and 4 days after a day of major snowfall at the beginning of winter

	Days before				Day of snowfall	Days after			
	4	**3**	**2**	**1**	**0**	**1**	**2**	**3**	**4**
3 Nov	8	16	19	25	54	15	3	6	12
16 Nov	10	12	11	13	25	19	7	11	14
27 Nov	13	12	7	11	27	13	12	20	15
Total	31	40	37	49	106	47	22	37	41

It can be seen that the same pattern is repeated for every day of snowfall, and that in the majority of cases, there are more than twice as many accidents on that day as on the day before and after.

In conclusion, a description of the road surface conditions at the time of the accident is shown in the following table. This clearly shows that there is a major difference between a Friday with poor driving conditions and a Sunday when the roads are basically bare. The large additional number of accidents on 3 November occurred on a surface of ”loose snow/slush”, which is quite common on major roads that are salted in conjunction with ploughing during snowfall.

Table 8. Road surface conditions at the time of the accidents that occurred 4 days before and 4 days after the first major snowfall.
The first major snowfall occurred on 3 November that winter.

Date	Dry	Wet	Thick ice/ compacted snow	Thin ice	Loose snow Slush	Unknown	Total
30 Oct	3	4		1			8
31 Oct	7	9					16
1 Nov	9	5	1	3	1		19
2 Nov	5	5	1	9	3	2	25
3 Nov	1	2	14	5	31	1	54
4 Nov	3	2	3	4	3		15
5 Nov		3					3
6 Nov	1	2	1		2		6
7 Nov	7	5					12

7. References

Fridström, Ifver, Ingebrigtsen, Kulmala, Thomsen, 1994
Measuring the contribution of randomness, exposure, weather and daylight to the variation in road accidents counts.

Schandersson
Olycksrisker vid olika mängd snönederbörd. VTI- Meddelande 514. 1988

SMHI stations used in the study

no.	name	no. before/after Feb 1996	geographic location	climate	county designation
1	Arvika	02404/02411	'västra Bergslagen'	upland	S
2	Ställdaen	02424	östra Bergslagen	upland	T
3	Nässjö	02555/02549	Sydsv höglandet	upland	F
4	Zinkgruvan	02560/02554	Tylöskog	forest	T
5	Malexander	02564/02552	Ydre	forest	E
6	Västerås	02446	Mälardalen	flatland	U
7	Malmslätt	02562	östgötaslätten	flatland	E
8	Karlstad	02418	Väneområdet	maritime	S
9	Såtenäs	02520	Väneområdet	maritime	P