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The effect of snowfall and low temperature on road traffic accident rates in Southern Finland

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ABSTRACT

Adverse weather conditions have a negative impact on road traffic, especially when icing and snowfall are concerned. Ice and snow on the road reduce the friction effectively. Poor visibility caused by snowfall or drifting snow further worsens the driving conditions. Accident rates typically peak in Finland during days with plenty of snowfall, although people should be used to driving in snowy conditions due to Finland's northern location. Drivers are also warned in advance about the approaching snowfall and roads are generally well maintained. This study deals with the effect of snowfall and low temperature on traffic accident rates in Southern Finland, Kymenlaakso County being the compact study area. Daily weather observations (mean temperature and precipitation) and Finnish Motor Insurers Centre's accident data from winters 2002/03 – 2007/08 were used in the investigations. A relative accident rate was calculated for each individual day by dividing the accident amount by the mean value of the day of the week in question. The results indicate that there appears to be, on average, an increasing trend in the relative accident rate in function of the daily precipitation in temperatures equal or below 0 ^{o}C, although the variability is large. For example, a snowfall exceeding 10 cm results in a double amount of accidents, on average, compared to the daily mean value during wintertime. When studying the cases with highest relative accident rate ("top ten ranking"), it appeared that most of those cases were linked to daily snowfall amount of ca 5 cm or more.

Keywords: Accident rate, snowfall, reduced friction

1 INTRODUCTION

Poor weather conditions increase the road traffic accident risk. Rainfall and wet road surfaces decrease the grip, thus increasing the risk for car collisions. Snowfall or any precipitation on a frozen road surface has even more negative impact on road grip and accident rate. This has been shown by Andreescu and Frost [1] and Norrman et al. [2] for example. In Finland, Salli et al. [3] investigated the relationship between accident risk and wintertime road conditions. They found that the risk of accidents resulting in physical damage or injuries was about four times higher during snowy or icy road conditions compared to dry road conditions. In addition, drivers typically assessed the road conditions as less slippery than they actually were. Snow and ice on the road reduce the friction coefficient (C_f) effectively. Depending on the road state, C_f has a value between 0 and 1. Wallman and Åström [4] point out that in conditions with C_f below 0.15 (icy road, possibly covered with loose snow), the accident rate can be four times higher compared to conditions when C_f is of the order of 0.35-0.44. Rauhala and Juga [5] found that during a blizzard in Finland on 23-24 November 2008, the number of car accidents was up to fourfold compared to the daily average of the whole winter. This is in line with the above mentioned findings of Salli et al. [3] as well as Vallman and Åström [4] concerning the accident risk.

A very dangerous situation prevails when there is a sudden loss of visibility simultaneously with a decrease in road surface friction. This might happen due to heavy snowfall having a sharp leading edge. Then the drivers coming towards the snowfall area, possibly with high speed, are forced to encounter a rapid worsening in driving conditions, enabling the occurrence of severe pile-ups, as presented by Juga et al. [6]. Such an event occurred in the Helsinki metropolitan area in southern Finland on 17 March 2005. Then, almost 300 cars were crashed, 3 persons died and more than 60 persons got injured. Similar events have occurred for example in

March 2008 in Austria and in the Czech Republic. On 3 February 2012, severe pile-ups occurred again in the Helsinki metropolitan area due to very poor visibility caused by sea-induced local but dense snowfall.

The above mentioned facts give the motivation to investigate further the linkage between snowfall and traffic accident amounts and to find quantitative estimates based on data from several winters.

2 DATA AND METHODS

In this study, the connection between (low) temperature, snowfall and accident rate was investigated by using Finnish Meteorological Institute's weather observations and Finnish Motor Insurers' Centre's accident data, the daily amount of paid compensations being the "amount of accidents" (or accident rate). The data used here covered winter months (November – March) during the period from November 2002 to March 2008, in total 906 individual days. Kymenlaakso County was the study area (Figure 1). It is a compact area with several highways crossing it. Utti weather observation station is conveniently located in the middle of the area and there is also a road weather station nearby, operated by the Finnish Transport Agency. The daily accident amount in Kymenlaakso County and weather observations from Utti (daily mean temperature and total 24h-precipitation, 18-18 UTC) were used. The 18-18 UTC (20-20 LT) precipitation is probably a better predictor for the daily accident rate than the 06-06 UTC (08-08 LT) precipitation. The relative accident rate for each day was calculated so, that the daily accident amount in the county was divided by the mean accident rate of the day of the week in question (calculated from the whole data, see Table 1). This procedure removes the effect of different average traffic intensities occurring on different days of the week. Concerning the whole data, the day of the week (Monday-Sunday, i.e. by numbers 1-7) had a correlation R= -0.31 with the daily accident amount.

The main focus was to study the effect of snowfall on the accident rate. For that purpose, the days with mean temperature (T_mean) equal or less than 0 ^{o}C were investigated separately in detail (in total 627 days). This assures that we have the cases when the precipitation falls mainly in the form of snow (however, the "Top 10" ranking of accident cases was picked from the whole data. This is discussed at the end of Section 3).

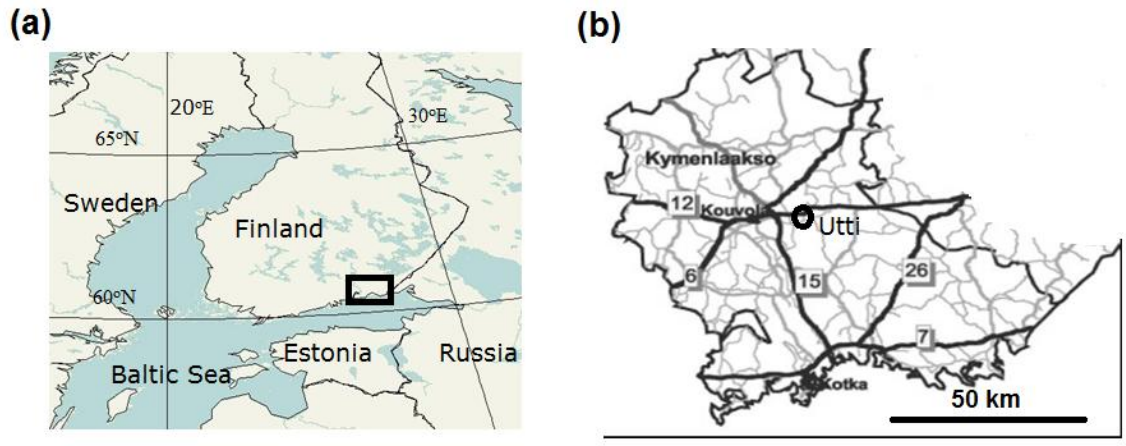

Figure 1. (a) The study area in south-eastern Finland (marked by a rectangle). (b) An enlarged map of Kymenlaakso County in south-eastern Finland with its main roads and cities (Kotka and Kouvola) and the location of Utti weather observation station (by a circle). Source for the Kymenlaakso map (b): The Finnish Transport Agency.

Table 1. Statistics of accident rate (=amount of paid compensations) in Kymenlaakso County on different days of the week during winters 2002/03 – 2007/08; the mean, maximum, minimum, number of cases (N_cases) and standard deviation (STD). The "status of Sunday" was given also to some religious holidays; that's why there are more cases in the Sunday-column than in the other columns.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Mean	10.21	8.78	9.78	10.38	11.28	7.10	4.86
Max	24	23	23	37	38	18	14
Min	3	2	2	2	4	1	1
N_cases	122	124	125	125	125	119	166
STD	4.18	3.51	4.34	5.62	5.01	3.08	2.54

3 RESULTS

Figure 2 shows the relationship between daily mean temperature (T_mean) and the relative accident rate. It appears that the distribution is wide with big variability. With temperatures above 0 °C the relative accident rate stays mostly below 1.5, but when T_mean decreases below 0 °C, there are also a couple of cases with high relative accident rates, from 2 up to ca 3.5.

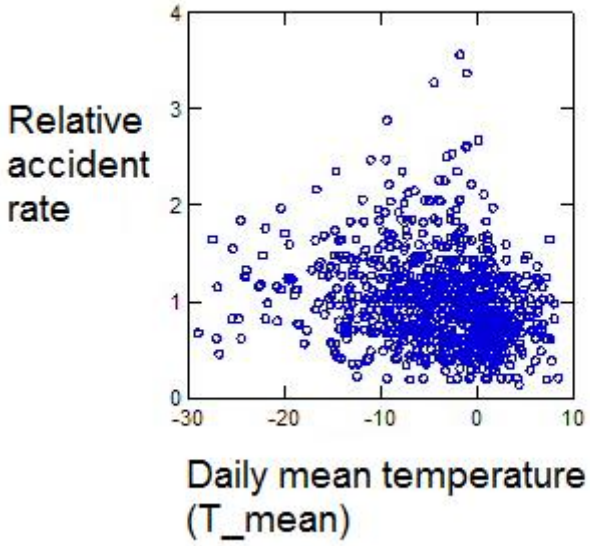

Figure 2. Scatter plot of relative traffic accident rate vs. daily mean temperature (°C). Correlation R= -0.20. Based on weather observations from Utti and daily accident amounts in Kymenlaakso County (data source: Finnish Motor Insurers' Centre). The data covers winter months (November – March) during the period from November 2002 to March 2008 (906 individual days).

To study the impacts of snowfall (with different precipitation amounts) on accident rate, the cases having daily T_mean ≤ 0 °C were investigated separately (in total 627 days). By using this temperature threshold we can assume that most of the precipitation falls in the form of snow. Table 2 shows the mean relative accident rate when using different precipitation thresholds. The first threshold (0 mm) covers all 627 cases (with or without precipitation). Then the mean relative accident rate is 1.06. The next threshold (0.1 mm) covers only those cases, where at least some precipitation was observed in Utti (so, the cases without precipitation are left out). The third row in Table 2 with the threshold 1 mm includes only those 177 cases when at least 1 mm of precipitation was observed in Utti. The number of cases exceeding the threshold decreases rapidly when the threshold value increases.

Table 2. Mean relative accident rate in function of precipitation exceeding different precipitation levels, during days when daily T_mean ≤ 0 °C. Based on weather observations from Utti and daily accident values in Kymenlaakso County (data source: Finnish Motor Insurers' Centre). The data covers winter months (November – March) during the period from November 2002 to March 2008.

24h-precipitation threshold	Number of cases	Mean relative accident rate	Max/min value	Standard deviation
0 mm	627	1.06	3.56/0.19	0.49
≥ 0.1 mm	354	1.15	3.56/0.21	0.51
≥ 1 mm	177	1.28	3.56/0.29	0.58
≥ 5 mm	49	1.52	3.56/0.39	0.64
≥ 10 mm	9	1.96	3.56/1.23	0.89
≥ 20 mm	2	1.40	1.57/1.23	0.24

From Table 2 it appears that the mean relative accident rate is about 2 when the 24h-precipitation amount is 10 mm or more (corresponding to about 10 cm of snow or more). In other words, a snowfall of the order of 10 cm results in a double accident rate compared to the daily mean. Concerning the highest precipitation threshold (≥ 20 mm, ca 20 cm of snowfall), only two cases exceeding the threshold were left, so the value 1.40 for mean relative accident rate is probably not representative. On the other hand, one could argue that during such a heavy snowfall there is less traffic, and probably more like traffic jams than accidents occur, but maybe there isn't any direct evidence of this. Figure 3 shows a scatter plot of all the 627 cases: the daily relative accident rate vs. the 24h-precipitation. It appears that the variation is big, but the general increasing trend of accident rate in function of precipitation (snow) can be seen from the image and all of the cases with 24 h precipitation ≥ 10 mm (ca 10 cm of snow) have the relative accident rate above 1.

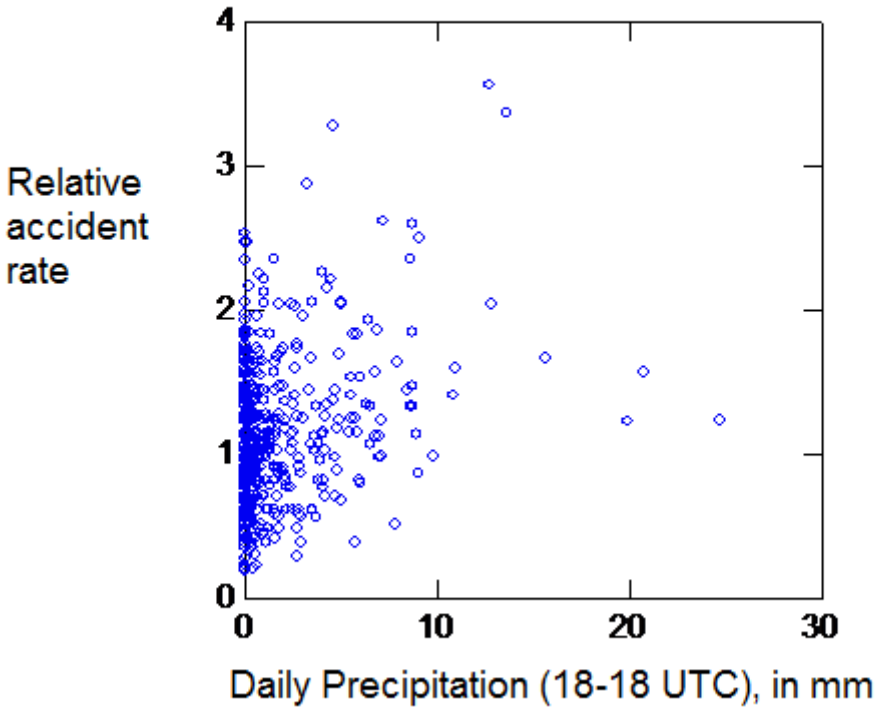

Figure 3. Scatter plot of relative traffic accident rate vs. daily precipitation (mm) during days when T_mean ≤ 0 °C. Correlation R= 0.33. Based on weather observations from Utti and daily accident values in Kymenlaakso County (data source: Finnish Motor Insurers' Centre). The data covers winter months (November – March) during the period from November 2002 to March 2008 (in total 627 individual days fulfilling the criterion T_mean ≤ 0 °C).

Finally, a "top 10 ranking" was picked from all the 906 individual days based on the daily relative accident rate, to see what sort of temperature and precipitation was observed during the worst accident days (see Table 3). The relative accident rate ranged from 3.6 (top) to 2.5, and in most of the cases (6 out of 10) the daily precipitation exceeded 5 mm (ca 5 cm of snow) in Utti. The great amount of snowfall during the day results in decreased road surface friction at least occasionally, in spite of efficient snow removal. This is shown by two cases (in Table 3) from the winter 2007/08, when friction coefficient (C_f) measurements by Vaisala's DSC111 instrument were available. Although the daily average values of C_f during the two cases were relatively high, i.e. around 0.6, the minimum observed values in those cases were below 0.2, indicating occasional dangerous driving conditions.

Table 3. "Top 10 ranking" of car accident cases in Kymenlaakso County during winters 2002/03 - 2007/08, based on the daily relative accident rate (data included 906 individual days). The prevailing daily mean temperature and precipitation (18-18 UTC) were observed at the Utti weather observation station; the friction coefficient (C_f) was measured with the DSC111 optical instrument at Utti road weather station (during winter 2007/08, data source: The Finnish Transport Agency).

Ranking	Date	Number of car crashes	Relative accident rate	Daily mean temperature in Utti (^oC)	Daily precip. (18-18 UTC) in Utti, mm	C_f Utti: daily mean/min
1	23.12.2004 (Thursday)	37	3.56	-1.8	12.7	
2	21.1.2005 (Friday)	38	3.37	-1.1	13.6	
3	2.11.2006 (Thursday)	34	3.27	-4.5	4.6	
4	24.12.2003 (Sunday)	14	2.88	-9.4	3.2	
5	19.12.2004 (Sunday)	13	2.67	0.1	5.6	
6	4.12.2007 (Tuesday)	23	2.62	-1.1	7.2	0.64/0.17
7	20.1.2005 (Thursday)	27	2.60	-1.2	8.7	
8	12.2. 2005 (Saturday)	18	2.54	-2.6	0	
9	27.3.2008 (Thursday)	26	2.50	-3.2	9.1	0.57/0.14
10	12.1.2003 (Sunday)	12	2.47	-9.5	0.1	

4 CONCLUDING REMARKS

The results show that the mean relative accident rate increases in function of precipitation (snow), but the variation from one case to another is large. It appears for example that in cases with 24h-precipitation exceeding 5 mm (ca 5 cm of snow), the accident rate increases by ca. 50 %, compared to the daily long-term mean value. Of course, accidents are dependent on many factors and in addition to the snowfall, ice formation due to road surface temperature falling below 0 ^oC and poor visibility due to dense fog have a negative impact on the accident risk. Road maintenance operations also play a major role there. To highlight the complexity in explaining the accident risk, we can apply the linear regression method. By having the relative accident rate as the dependent parameter and the 24h-precipitation and daily mean temperature as the independent parameters, we get the following equation (for conditions when T_mean $\leq$ 0 ^oC):

Relative accident rate = 0.068*Precipitation -0.015*T_mean + 0.871; N=627, R=0.37 and R^2=0.14.

It appears that the correlations are low due to the large variability.

Here the goal was to find a general dependence between precipitation (snow) and accident rate in some area. To study the impact of weather conditions on accidents more thoroughly, every individual accident should be investigated separately using the road weather observations from the nearest observation site and possibly also taking into account road maintenance operations. This kind of study was carried out by Norrman et al. [2]. Also, the distribution of different accident types (material damage / personal injuries) in different weather situations could be investigated.

The use of weather observations from just one station is a bit too coarse way of studying the effect of snowfall on the accident risk in a county. On the other hand, Kymenlaakso County was chosen for the study area due to its compact size and Utti observation station's ideal location in the middle of the area. Further studies can be carried out for wider areas by using for example radar based estimate of daily accumulated precipitation, averaged over the whole study area.

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ACKNOWLEGEMENTS

Esa Nysten of the Finnish Motor Insurers’ Centre is thanked for delivering the daily traffic accident data.