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Weather Types and Traffic Accidents

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A B S T R A C T

Traffic accident data for the Zagreb area for the 1981–1982 period were analyzed to investigate possible relationships between the daily number of accidents and the weather conditions that occurred for the 5 consecutive days, starting two days before the particular day. In the statistical analysis of low accident days weather type classification developed by Poje was used. For the high accident days a detailed analyses of surface and radiosonde data were performed in order to identify possible front passages. A test for independence by contingency table confirmed that conditional probability of the day with small number of accidents is the highest, provided that one day after it »N« or »NW« weather types occur, while it is the smallest for »N_1« and »B_c« types. For the remaining 4 days of the examined periods dependence was not statistically confirmed. However, northern (»N«, »NE« and »NW«) and anticyclonic (»V_c«, »V_4«, »V_3«, »V_2« and »mv«) weather types predominated during 5-days intervals related to the days with small number of accidents. On the contrary, the weather types with cyclonic characteristics (»N_1«, »N_2«, »N_3«, »B_c«, »Dol1« and »Dol«), that are generally accompanied by fronts, were the rarest. For 85% days with large number of accidents, which had not been caused by objective circumstances (such as poor visibility, damaged or slippery road etc.), at least one front passage was recorded during the 3-days period, starting one day before the day with large number of accidents.

Introduction

By scientific standards, biometeorology is a young science. However, a human interest in the influence of weather and climate on living organisms dates from the earliest historic times. As early as 400 BC Hippocrates described a connection between certain weather situations and certain diseases. In his book *Airs, Waters, Places*, he wrote: »One should be especially on one's guard against the most violent changes of the seasons, and unless compelled, one should neither purge nor apply cautery or knife to bowels, until at least ten days have passed«[1].

In a last few decades scientists became aware that weather sensitivity, known as meteorotropism, is not only psychological, but also, and most importantly, a true

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physiological phenomenon which can be explained by the laws of physicochemistry and electrophysiology. Recent studies related to the influence of the weather on human health and behavior include a wide spectrum of problems, such as the influence of naturally occurring very short electromagnetic impulses (known as atmospherics or spherics) on epileptic fits[2], effects of the chinook on physical and mental well-being[3,4], relationship between weather conditions and domestic violence[5], etc.

Some of the first studies of the possible influence of weather on accidents were done in the1950's by Reiter, who analyzed both industrial and traffic accidents[1]. In both cases he found a significant increase in the number of accidents on days with considerable disturbance of the atmospheric electromagnetic field. Moreover, he believed that the relationship is an indirect one due to the influence of weather on the driver's or operative's speed of reaction. More recently Hoffman et al. investigated the correlation between the main spherics occurring at different frequencies and car incidents[2]. They found the astonishing result that the correlation spectra are week-day in specific. Authors could offer no reasonable explanation for this phenomenon.

Investigation of the relationship between traffic accidents and weather types takes into account a whole set of meteorological influences, which simultaneously affect traffic participants. A few such studies show that increased number of accidents occurs during the cyclonic-type weather conditions and frontal passages[6,7]. However, those results are not very surprising, since such weather conditions are usually accompanied by precipitation, which deteriorates road and driving conditions.

This study also investigates the relationship between weather types and traffic accidents. However, as opposed to previous studies, all cases where meteorological factors obviously make driving more difficult are discarded. Further, previous studies were focused only on situations with increased numbers of accidents, while here the days with small number of accidents are analyzed as well.

Other factors favoring the occurrence of traffic accidents are investigated elsewhere. Such studies are the most frequently related to the alcohol and drug abuse[8–10]. Recently, the effects of age[11], gender[12] and personality type[13] had also been examined.

Materials and Methods

Traffic accidents data

Traffic accident data for the Zagreb area were obtained from the Police Station for Traffic Security. They cover a period from 1 January 1981 to 31 December 1982. Every incident recorded by the Police was considered as an accident provided that at least one vehicle was involved (e.g. two or more vehicles; one vehicle and a pedestrian, cyclist, or stationary object etc.). The distinction between the different outcomes that varied from harmless to fatal was not made. During the selected period a 14898 accidents were registered: 7733 for 1981 and 7165 for 1982, respectively. A total of 327 persons died: 148 in 1981 and 179 in 1982. The decrease in total number of traffic accidents in 1982 as compared to 1981 was most probably caused by considerable shortages of fuel that occurred 1982.

Figure 1 shows frequency distributions of daily numbers of traffic accidents. Due to the above mentioned fuel supply problems, each year is analyzed separately. One may see that during the 1981 days with 22 traffic accidents occurred most often, while during 1982, and during the whole two-year period, days with 17 accidents were most frequent.

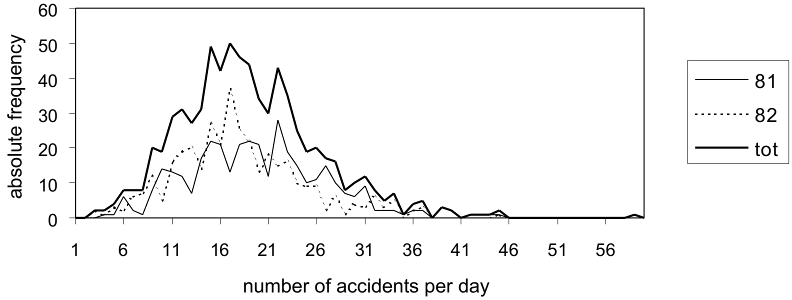

Fig. 1. Frequency distributions of number of accidents per day for Zagreb area for 1981, 1982 and the whole two-year period.

In order to define days with small and days with a large number of accidents, factors affecting the number of accidents per day should be taken into account. It is well known that daily numbers of traffic accidents exhibit a weekly variation[7,14,15]. Maximum numbers occur on Friday and are attributed to fatigue at the end of the working week, resulting in loss of attention. The secondary maximum on Monday reflects the fact that traffic participants are not yet sufficiently concentrated after the weekend relaxation. On the other hand, Sunday minima are strongly influenced by the reduced traffic density. Weekly variation for the Zagreb area for the study period is illustrated in Figure 2.

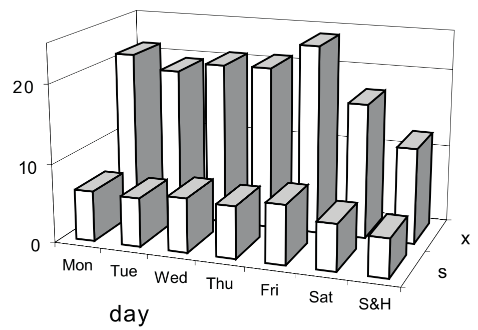

Fig. 2. Weekly variation of the average daily number of traffic accidents (x) and corresponding standard deviations (s) for Zagreb area during the 1981–1982 period. Saturdays and holidays (S & H) are analyzed together.

The frequency of traffic accidents also exhibits an annual variation[14,15]. As illustrated in Figure 3, accidents in the Zagreb area were most frequent in spring and fall, e.g. in seasons that for northern Croatia are characterized by increased cyclonal and frontal activities. (Note that due to the fuel supply problems, 1982 is less representative of this annual cycle.)

Further, the number of accidents is affected by traffic density. Since such data were not available, the influence of traffic density was roughly incorporated by discarding Sunday and holiday data.

A day was considered as a day with a large number of accidents if following conditions were satisfied:

$$\begin{aligned} x \quad & x_{day} + s_{day} \\ x \quad & x_{month} + s_{month} \end{aligned} \qquad (1)$$

where x is a number of accidents for a particular date; x_{day} and s_{day} are the average number of accidents and the standard deviation for the corresponding day of the week (Figure 2); x_{month} and s_{month} are the average number of accidents and the standard deviation for the month and the year that correspond to the date concerned (Figure 3).

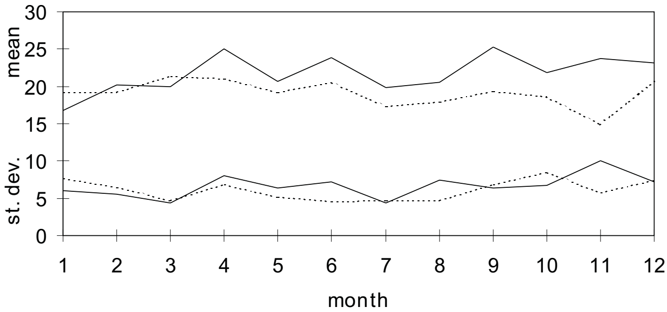

Fig. 3. Annual variation of the average daily number of traffic accidents and corresponding standard deviations for Zagreb. Data for 1981 and 1982 are represented with solid and dashed lines, respectively.

Days with large number of accidents were thereafter filtered in order to minimize contribution of specific conditions that could trigger an accident. Such conditions are poor visibility (due to precipitation or fog), poor road surface (damaged road or rain, snow or ice on it), problematic driver (drunk or without a license) and vehicles unfit for use. If more than 35% of accidents on a day were attributed to the above mentioned circumstances, the day, although it satisfied condition (1), was considered as predominately caused by specific conditions, and it was discarded from further analysis. For 1981 –1982 period 64 days satisfied condition (1). After discarding those that were influenced by specific conditions, 20 of them remained.

Similarly, a day was considered as a day with a small number of accidents if:

$$x \quad x_{day}-s_{day}$$
$$x \quad x_{month}-s_{month} \qquad (2)$$

(It may be noted that contribution of specific conditions to the total number of accidents does not change the fact that a day is characterized by small number of accidents.) For the selected period there were 51 days that satisfied condition (2).

Meteorological data

The weather type data for the Zagreb area for 1981–1982 period were used in statistical analysis of the days with small number of accidents. Weather types for each day were determined by Meteorological and Hydrological Service following the classification[16] developed by Poje (Table 1).

For analysis of the days with large numbers of accidents, diurnal variations and daily means of surface pressure, temperature, relative humidity, cloudiness, wind vector and visibility were used. Additionally, from a 1200 GMT and a 0000 GMT radiosonde data vertical cross-sections of the temperature, wind vector, mixing ratio and pseudopotential temperature were determined. Both, surface and radiosonde data were measured at Maksimir (45°49' N, 16°02' E, 123 m), which is the most representative for the wider area of Zagreb.

Results and Discussion

1. Days with small number of traffic accidents

In the analysis of the days with small number of accidents the independence of the variables was tested by a contingency table[17]. When creating the contingency table, each day was classified according

TABLE 1
CLASSIFICATION[16] OF WEATHER TYPES, THEIR MAIN WEATHER CHARACTERISTICS AND THE NUMBER OF DAYS WITH PARTICULAR WEATHER TYPE FOR ZAGREB DURING THE 1981–1982 PERIOD (N_{ALL} CORRESPONDS TO THE WHOLE TWO-YEAR PERIOD, WHILE IN DETERMINATION OF N SATURDAYS AND HOLIDAYS ARE ELIMINATED)

Notation	Type	Main weather characteristics	No. of days n_{all}	n
B_a	non-gradient anticyclonal field	calm and mostly clear anticyclonic-type weather	127	109
g	a ridge of high pressure	generally associated with fine, anticyclonic-type weather	120	104
V_1	front (eastern, cold) side of anticyclone		44	36
V_2	southern side of anticyclone	fine, sunny and stable in	50	47
V_3	back (western, warm) side of anticyclone	summer months; evening and morning fogs in winter	51	39
V_4	northern side of anticyclone		6	3
V_c	center of anticyclone		5	3
mv	high pressure area situated between the two wide areas of low pressure	generally anticyclonic	20	17
Dol1	front (eastern) side of trough of low pressure		47	40
Dol2	axis of trough of low pressure	front side of trough is	21	17
Dol3	back (western) side of trough of low pressure	characterized with a bad weather conditions; while	16	12
Zodol1	front side of trough whose axis is zonally oriented	back side is clearing up, precipitation stops and air	0	0
Zodol2	zonally oriented axis of trough	pressure increases	1	1
Zodol3	back side of trough whose axis is zonally oriented		1	0
Dol	shallow trough with pressure gradient oriented toward the south		18	12
N_1	front (eastern,. warm) side of cyclone	bad weather, cloudy, often with the precipitation,	44	35
N_2	southern side of cyclone (warm sector)	intensive changes, pressure is decreasing	15	13
N_3	back (western, cold) side of cyclone	often cloudy with weak	12	12
N_4	northern side of anticyclone	precipitation, pressure low, but increases	11	9
B_c	non-gradient cyclonal field	cyclonic-type, calm, possible cloudiness and weak precipitation	57	50
N	northern type		2	2
NE	northeastern type	the most often clear and fine	6	5
E	eastern type		11	6
SE	southeastern type		21	18
S	southern type	variable with weak	5	5
SW	southwestern type	precipitation	11	10
W	western type	variable	4	3
NW	northwestern type		4	2
		Total:	730	610

to two characteristics: occurrence of the day with small number of accidents and the weather types. The first characteristic has only two groups (e.g. the day with small number of accidents happened or it did not happen), while for the second characteristic, the number of groups corresponds to the number of weather types.

For each particular date with low number of accidents weather types for 5 consecutive days, starting two days before the particular date, were examined. Therefore, five contingency tables were created. The first corresponds to the weather types that occurred 2 days before each particular date and it is marked with the value D=–2. Second is related to the weather types that occurred one day before the particular date (D=–1), etc. The corresponding hypotheses that were tested are as follows:

a) The occurrence of the day with a small number of traffic accidents does not depend on the weather type that existed two days before.
b) The occurrence of the day with a small number of traffic accidents does not depend on the weather type that existed one day before.
c) The occurrence of the day with a small number of traffic accidents does not depend on the weather type on that day.
d) The occurrence of the day with small number of traffic accidents does not depend on the weather type that existed one day afterwards.
e) The occurrence of the day with small number of traffic accidents does not depend on the weather type that existed two days afterwards.

Results of the ^{2} test at the significance level =0.05 show that all hypothesis except (d) are acceptable. In other words, occurrence of the day with small number of traffic accidents is associated with the weather type that occurs one day after the day with a small number of accidents. As listed in the Table 2, the conditional probability P for such an event is the largest for the northern weather types »N« and »NW« (50.0% and 25.0%, respectively) and it is smallest for non-gradient cyclonal field »B_c« (3.5%). Conditional probability is used in order to take into account the fact that various weather types occur with very different frequencies. For example, »B_a« and »g« are very common for the Zagreb area, while »Zodol1« is extremely rare (Table 1). Conditional probability is defined as the probability of occurrence of a day with a small number of accidents, provided that a particular weather type occurred. It is calculated as follows:

$$P = (n_{st}/n_{type}) \quad 100\ (\%) \qquad (3)$$

where n_{st} is number of days with both conditions satisfied (small number of accidents and the particular weather type), while n_{type} is total number of days with that particular weather type.

Although the association between a small number of accidents and certain weather types was statistically confirmed only for the types that occurred the day after (D=+1), one may see that the conditional probability for the whole 5-days period is generally highest for the northern (»N«, »NE« and »NW«) and anticyclonic (»V_c«, »V_4«, »V_3«, »V_2« and »mv«) weather types (Table 2). A few exceptions of relatively large probability are related to weather types with cyclonic characteristics: »Dol« and »N_3« (at D=0, P=16.7%), and »Dol3« (at D=–2 and at D=+2, P=12.5%). However, one should note that in »N_3«, »Dol3« and »Dol« cyclonic characteristics are slightly pronounced and moreover, in »N_3« and »Dol3« they are weakening. On the other hand, the smallest probability is generally related to the cyclonic weather types that are associated with fronts (»N_1«, »N_2«, »N_3«, »B_c«, »Dol1« and »Dol«).

TABLE 2
CONDITIONAL PROBABILITY OF OCCURRENCE OF THE DAY WITH SMALL NUMBER OF TRAFFIC ACCIDENTS P (%), PROVIDED THAT PARTICULAR WEATHER TYPE OCCURRED TWO DAYS BEFORE (D=–2), DAY BEFORE (D=–1), ON THE DAY CONCERNED (D=0), THE DAY AFTER (D=+1) AND TWO DAYS (D=+2) AFTER THE DAY WITH SMALL NUMBER OF ACCIDENTS, RESPECTIVELY

D=–2		D=–1		D=0		D=+1		D=+2	
Weather type	P(%)	Weather type	P(%)	Weather type	P(%)	Weather type	P(%)	Weather type	P(%)
N	50.0	N	50.0	NE	40.0	N	50.0	V_c	40.0
NE	33.3	S	20.0	S	20.0	NW	25.0	SW	18.2
NW	25.0	V_4	16.7	Dol	16.7	S	20.0	NE	16.7
V_c	20.0	V_3	15.7	N_3	16.7	mv	20.0	V_2	14.0
Dol3	12.5	mv	15.0	V_3	15.4	V_2	20.0	Dol3	12.5
V_3	12.0	V_2	14.0	Dol2	11.8	NE	16.7	V_3	11.8
Dol	11.1	N_2	13.3	SE	11.1	SE	14.3	mv	10.0
SE	9.5	Dol3	12.5	V_1	11.1	V_3	9.8	SE	9.5
g	9.2	V_1	11.4	V_2	10.6	SW	9.1	N_4	9.1
N_1	9.1	B_c	8.8	B_a	10.1	N_3	8.3	Dol1	8.5
N_3	8.3	N_3	8.3	SW	10.0	B_a	7.1	N_3	8.3
V_2	8.0	Dol	5.6	g	8.7	Dol1	6.4	B_a	7.9
N_2	6.7	g	5.0	mv	5.9	Dol3	6.3	N_1	6.8
B_a	5.5	B_a	4.7	B_c	4.0	g	5.0	N_2	6.7
B_c	5.3	N_1	4.6	Dol1	2.5	N_1	4.6	Dol	5.6
Dol1	4.3					B_c	3.5	B_c	5.3
V_1	2.3							g	2.5

2. Days with large number of traffic accidents

The sample of 20 days with a large number of traffic accidents was too small for the statistical analysis performed above. Therefore, a detailed analysis of meteorological data for the time period starting two days before (D=–2) and ending two days after the day with large number of accidents (D=+2) was performed. Diurnal variations and daily means of surface data (pressure, temperature, relative humidity, cloudiness, wind vector and visibility) and vertical cross-sections (temperature, wind vector, mixing ratio and pseudopotential temperature) were investigated in order to identify possible front passages over the Zagreb area as described by Klaić[18].

For 17 among 20 days at least one front passage was identified: 16 cold and 10 warm fronts (Table 3). The largest number of fronts passed one day after the day with large number of accidents (7 cold and 3 warm). Most of the fronts passed during the time periods from D=–1 to D=+1. (As an information, weather types for these days are listed in Table 4). For the total of 20 high accident days (this produces to consider 60 days), 20 front passages were identified (7+3+10). That means that on the average a front passage occurred in one third of the days. However, for the D=–2 and D=+2 only approximately one sixth of the days were accompanied by the front passage. Since disturbance of the electromagnetic field of the atmosphere is a frontal feature, the results obtained here are in accordance with some studies of human reaction time, where a statistically significant decrease of reaction speed (up to 20%) was

TABLE 3
NUMBER OF COLD (CF) AND WARM (WF) FRONTS THAT PASSED OVER THE ZAGREB AREA TWO DAYS BEFORE (D=–2), DAY BEFORE (D=–1), ON THE DAY CONCERNED (D=0), THE DAY AFTER (D=+1) AND TWO DAYS (D=+2) AFTER THE DAY WITH LARGE NUMBER OF ACCIDENTS, RESPECTIVELY

	D=–2	D=–1	D=0	D=+1	D=+2	Total
CF	4	4	1	7	0	16
WF	1	3	2	3	1	10
Total	5	7	3	10	1	26

TABLE 4
RELATIVE FREQUENCIES OF HIGH ACCIDENT DAYS F (%), PROVIDED THAT PARTICULAR WEATHER TYPE OCCURRED DURING THE PERIOD FROM D= –1 TO D= +1

Weather type	SE	Dol2	S	Dol1	V_4	V_2	V_3	N_1	V_1	E	N_3	g	B_a	B_c	N_2	Dol	mv
F (%)	36.5	21.3	20.0	17.1	16.7	14.4	14.3	12.5	11.9	9.1	8.3	8.3	7.6	7.5	6.7	5.6	5.0

found for the days of considerable disturbance of the electromagnetic field[1,19].

Apart from electromagnetic disturbances, frontal passages also cause sudden changes of other meteorological fields such as pressure, temperature, humidity, wind speed etc. This sudden change of a group of factors can also negatively affect human beings and probably reduces driving capability. Unfortunately, measurements of the atmospheric electromagnetic field are still not performed in Croatia, so it was not possible to distinguish between the electromagnetic and other influences.

Considering the remaining 3 days with a large number of accidents, which were not related to the front passages, a two of them occurred on Friday, when the number of accidents is generally the highest. The third was one day before New Year's Eve when the traffic is much denser than usual.

Conclusion

The relation between days with small numbers of traffic accidents and weather types was statistically confirmed for the weather types that occurred one day after the day with the small number of accidents. The relative frequency of such events is highest provided that »N« or »NW« weather types occur, while it is smallest for »N_1« and »B_c« types.

Although for the remaining days of the examined 5-day period, starting two days before the day with small number of accidents, relation was not statistically confirmed, they most often had northern (»N«, »NE« and »NW«) and anticyclonic (»V_c«, »V_4«, »V_3«, »V_2« and »mv«) weather types. Conversely, the rarest weather types had cyclonic characteristics (»N_1«, »N_2«, »N_3«, »B_c«, »Dol1« and »Dol«).

Analysis of the 20 days with large number of accidents showed that for 17 of them at least one front passage was recorded during the 3-day period starting one day before. Twice as many frontal passages occurred during this period as compared to the frequency for the days: 2 days prior and 2 days after the day with the large number of accidents. These results show that increased numbers of accidents are not only a consequence of meteorological factors which evidently deteriorate driving conditions (precipitation, fog, etc.), but that they are also associated with other events caused by a frontal passage. Driving capability is probably reduced due to a sudden change of several meteorological fields, particularly electromagnetic field of the atmosphere. This is in accordance with other research results showing the significant increase of reaction time during the days with considerable disturbance of electromagnetic field.

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VREMENSKE PRILIKE I PROMETNE NEZGODE

SAŽETAK

Analizirani su podaci o prometnim nezgodama na Zagrebačkom području tijekom razdoblja 1981.–1982. s ciljem da se ispita moguća veza između dnevnog broja nezgoda i vremenskih uvjeta koji su vladali tijekom 5 uzastopnih dana, počevši 2 dana ranije od promatranog dana. U statističkoj analizi dana s malo nezgoda korištena je Pojina klasifikacija tipova vremena. Za dane s mnogo nezgoda detaljno su analizirani prizemni i radiosondažni podaci s ciljem da se identificira eventualni prolazak fronte. Test za nezavisnost u tablici kontingencije potvrdio je da je uvjetna vjerojatnost dana s malo nezgoda najveća, ako se dan nakon njega pojavi »N« ili »NW« tip, a najmanja ako se pojavi

»N_1« ili »B_c«. Za preostala 4 dana ispitivanih intervala zavisnost nije statistički potvrđena, ali su u danima s malo nezgoda i oko njih prevladavala sjeverna (»N«, »NE« i »NW«) i anticiklonalna (»V_c«, »V_4«, »V_3«, »V_2« i »mv«) stanja, dok su najrjeđi bili tipovi vremena ciklonalnih karakteristika (»N_1«, »N_2«, »N_3«, »B_c«, »Dol1« i »Dol«), koji su općenito vezani uz fronte. Za 85% dana s velikim brojem nezgoda, koje nisu bile uzrokovane objektivnim uvjetima (poput slabe vidljivosti, oštećenog ili skliskog kolnika itd.), zabilježen je bar jedan prolazak fronte tijekom trodnevnog razdoblja počev od dana prije dana s mnogo nezgoda.