Changes in Travel Behavior in Response to Weather Conditions

Do Type of Weather and Trip Purpose Matter?

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Weather can influence travel demand, traffic flow, and traffic safety. A hypothesis—the type of weather determined the likelihood of a change in travel behavior, and changes in travel behavior because of weather conditions depended on trip purpose—was assayed. A stated adaptation study was conducted in Flanders (the Dutch-speaking region of Belgium). A survey, completed by 586 respondents, was administered both on the Internet and as a traditional paper-and-pencil questionnaire. To ensure optimal correspondence between the survey sample composition and the Flemish population, observations in the sample were weighted. To test the main hypotheses, Pearson chi-square independence tests were performed. Results from both the descriptive analysis and the independence tests confirm that the type of weather matters and that changes in travel behavior in response to these weather conditions are highly dependent on trip purpose. This dependence of behavioral adjustments on trip purpose provides policy makers with a deeper understanding of how weather conditions affect traffic. Further generalizations of the findings are possible by shifting the scope toward revealed travel behavior. Triangulation of both stated and revealed travel behavior on the one hand and traffic intensities on the other hand is a key challenge for further research.

A deeper understanding of how various weather conditions affect traffic is essential for policy makers. This is stressed by policy issues that often are related to adverse weather events, such as increased fuel consumption, economic losses due to traffic delays, and higher traffic counts. At the network level, adverse weather events increase uncertainty in system performance, resulting, for instance, in a network capacity reduction ranging from 10% to 20% in heavy rain (*1*). Maze et al. reported that weather events affect three predominant traffic variables: travel demand, traffic safety, and the traffic flow relationship (*2*). This paper focuses on the effect of weather on travel demand.

Weather can influence travel demand in various ways, including diversions of trips to other modes or other paths and cancellation of trips (*2*). Day-to-day weather conditions such as fog and precipitation can decrease travel demand, for instance, when drivers postpone or cancel discretionary activities (e.g., leisure activities), but can also have an increasing effect when travel modes are shifted from slow modes (walking, cycling) to motorized vehicles (*3*). Mode changes, changes in departure time, and diversions to an alternate route were reported by Khattak and De Palma as the most prevalent behavioral adaptations (*4*). Bos indicated that in the Netherlands, heavy rain reduces the number of cyclists (*5*), whereas mild winters and warm summers increase bicycle use. Van Berkum et al. noted that the reduction in bicycle use during heavy rain is accompanied by a modal shift from bicycle to car (for either driver or passenger) (*6*). A similar result was found by Nankervis (*7*), who examined the effect of both (short-term) weather conditions and (long-term) seasonal variation patterns on bicycle commuting patterns among students in the temperate climate of Melbourne, Australia: cycle commuting was affected by long-term, climatic conditions as well as daily weather conditions. According to Guo et al., temperature, rain, snow, and wind all influence transit ridership of the Chicago Transit Authority: good weather increases ridership, whereas bad weather has a diminishing effect (*8*). Guo et al. stressed that vehicle running and dwell times, as well as cost of operation, also are affected by weather (*8*). In Brussels, Belgium, however, the transit agency reported higher levels of transit ridership during adverse weather (*4*).

The main objectives for this paper are to test the hypothesis that the type of weather influences the likelihood of a change in travel behavior (e.g., assessing whether more people change their transport mode during snow than during periods of fog) and to assay whether changes in travel behavior due to weather conditions are dependent on trip purpose (e.g., examining whether because of snowy weather, more people cancel leisure and shopping trips than school- or work-related trips). To this end, a stated adaptation study was conducted in Flanders, the Dutch-speaking region of Belgium.

METHODOLOGY

Stated Adaptation Approach

The data needed to address the main research questions were collected by means of a stated adaptation experiment. Various descriptions of stated adaptation experiments can be found in the literature (*9, 10*). In this paper, stated adaptation experiments are regarded as an alternative to the more widely used stated preference and choice experiments. The main difference between stated adaptation and stated preference and choice experiments is the task posed to respondents. In stated preference experiments, respondents are asked to indicate their preference to sequentially presented attribute profiles. In stated choice experiments, respondents are shown choice sets of two or more attribute profiles and are asked to choose the profile they like best (or, alternatively, to allocate some fixed budget among the profile).

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In stated adaptation experiments, respondents are asked to indicate if and how they would change their behavior considering experimentally varied attribute profiles, typically representing scenarios.

A stated adaptation survey, administered both on the Internet (86.7%) and via a traditional paper-and-pencil questionnaire (13.3%), was completed by 586 respondents. This dual-mode administration remedied the sample bias that is introduced when only an Internet-based data collection is conducted; studies have demonstrated that some socioeconomic classes, such as older-age and lower-education groups, may be more reluctant to use computer-assisted instruments for data collection (*11, 12*). In total, 90 behavioral adaptations in response to different weather conditions were queried; the frequencies of five changes in travel behavior in response to six weather conditions were surveyed, and this observation was repeated for three types of trips.

Weather Conditions

The following weather conditions were considered: cold temperature, defined as temperatures below freezing; warm temperature, defined as temperatures above 28°C (82.4°F); snow or freezing rain; heavy rain or thunderstorm (abbreviated as rain); fog; and storm or heavy wind. Cools et al. reported that these weather conditions had a significant effect on daily traffic intensities measured on Belgian highways (*13*). Therefore, the decision was made to analyze the effect of these weather conditions on underlying travel behavior. How frequently these weather events occur is demonstrated by the various weather-related measures in Table 1 (*14*). Flanders has a moderate maritime climate.

Changes in Travel Behavior

The stated adaptation questionnaire was split into three parts, corresponding to the three types of trips that were considered for the analysis. These three trip types correspond to the categories of most commonly performed trips according to the Flemish travel behavior survey (*15*): commuting (work, school), shopping, and leisure trips. Equivalent questions were asked in each part: for a certain behavioral change, the respondents were to indicate how often (never, in 1% to 25% of the cases, in 26% to 50% of the cases, or in more than 50% of the cases) they make a certain change in travel behavior for each of the six weather conditions. The following changes in travel behavior were queried: (*a*) change in transport mode, (*b*) change in timing of the trip [postponement (advancing) of the trip to a later (earlier) time on the same day], (*c*) change in the location where the activity (work or school, shopping, or leisure) will be performed, (*d*) elimination of the trip by skipping the activity (trip cancellation), and (*e*) change in the route of the trip. As an illustration of the questionnaire style, Figure 1 shows a question concerning the postponement or advancing

TABLE 1 Weather Parameters, Uccle, Belgium (*14*)

Parameter	2007	2008	Normal[a]
Average wind speed (m/s)	3.3	3.4	3.7
Sunshine duration (h)	1,472.0	1,449.0	1,554.0
Average temperature (°C)	11.5	10.9	9.7
Average maximum temperature (°C)	15.3	14.6	13.8
Average minimum temperature (°C)	7.8	7.2	6.7
Absolute maximum temperature (°C)	30.9	31.0	31.7
Absolute minimum temperature (°C)	–6.8	–6.1	–8.9
Number of freezing days (min. < 0°C)	27.0	37.0	47.0
Number of wintry days (max. < 0°C)	1.0	0.0	8.0
Number of summery days (max. ≥ 25°C)	23.0	25.0	25.0
Number of heat wave days (max. ≥ 30°C)	2.0	1.0	3.0
Average relative atmospheric humidity (%)	80.0	77.0	81.0
Total precipitation (mm)	879.5	861.5	804.8
Number of days with measurable precipitation (≥ 0,1 mm)	204.0	209.0	207.0
Number of days with thunderstorm	94.0	95.0	94.0

[a]Normal: long-term meteorological average (1971–2000).

Do you <u>postpone</u> or <u>advance</u> your work/school-related trip to a later/earlier moment the same day due to any of the following weather conditions?

*Mark the answer that corresponds mostly to your situation. Only **one** answer is possible for **each weather condition**.*

	No, never	Yes, occasionally (<25% of the cases)	Yes, sometimes (<50% of the cases)	Yes, usually (>50% of the cases)
Cold temperature	○	○	○	○
Snow/freezing rain	○	○	○	○
Heavy rain/thunderstorm	○	○	○	○
Fog	○	○	○	○
Warm temperature	○	○	○	○
Storm/heavy wind	○	○	○	○

FIGURE 1 Stated adaptation question about postponement or advancing of work- or school-related trips.

of work- or school-related trips to a later or earlier moment in the same day.

Statistical Analyses

So that there is an optimal correspondence between the survey sample composition and the Flemish population, the observations in the sample are weighted. The weights were calculated by matching the marginal distributions of the sample with the marginal distributions of the population. Age, gender, and civil state were the basis for this matching process. Recall that the main objectives for this paper are to test the hypothesis that the type of weather determines the likelihood of a change in travel behavior and to assay whether changes in travel behavior because of weather conditions are associated with the type of trip. To test these hypotheses, independence tests are performed.

To test independence (this is the null hypothesis) between two multinomial (categorical) variables, one could use the Pearson statistic Q_p, which is defined by the following equation:

$$Q_p = \sum_{i=1}^{k}\sum_{j=1}^{l}\frac{\left(n_{ij}-\hat{\mu}_{ij}\right)^2}{\hat{\mu}_{ij}}$$

where n_{ij} is the observed frequency in cell (i, j), calculated by multiplying the observed chance by the sample size, and $\hat{\mu}_{ij}$ is the expected frequency for table cell (i, j). When the row and column variables are independent, Q_p has an asymptotic chi-square distribution with $(k-1)(l-1)$ degrees of freedom (*16*).

A criticism of the Pearson statistic is that is does not give a meaningful description of the degree of dependence (or strength of association). Cramer's contingency coefficient, often referred to as Cramer's *V,* is a method for interpreting the strength of association and is calculated with the following formula:

$$V = \sqrt{\frac{Q_p}{N(m-1)}}$$

where

Q_p = Pearson chi-square statistic defined earlier,
N = total sample size, and
m = minimum of number of rows and number of columns in the contingency table.

Basically, Cramer's *V* scales the chi-square statistic Q_p to a value between 0 (no association) and 1 (maximum association). Note that Cramer's *V* has the desirable property of scale invariance, that is, if the sample size increases, the value of Cramer's *V* does not change so long as values in the contingency table change the same relative to each other (*17*).

DESCRIPTIVE ANALYSIS OF CHANGES IN TRAVEL BEHAVIOR

Changes in Commuting Trips

For the commuting (work, school) trips, the percentages of respondents making a certain travel behavior change are given in Table 2. When different weather conditions are compared, it is clear that snow has the largest effect on commuting trips. Time-of-day decisions (postponing the trip to a later moment) especially are common practice: more than one person in two appears to postpone his or her trip in the presence of snow. Route taken is changed by almost half the respondents. This major impact of snow on travel behavior is revealed on the network. For example, Hanbali and Kuemmel found traffic volume reductions on highways away from the major urban centers in the United States ranging from 7% to 56%, depending on the intensity of the snowfall (*18*).

Extreme temperatures (both cold and warm) appear to have the least impact on commuting behavior, whereas storms, fog, and heavy rain appear to have an effect mainly on the timing of the trip: people appear to postpone their trips until more favorable weather conditions apply.

When the focus turns to behavioral changes, it is immediately clear that the work or school location is the least frequently changed.

TABLE 2 Changes in Work and School Trips

Change	Frequency (%)	Cold (%)	Snow (%)	Rain (%)	Fog (%)	Warm (%)	Storm (%)
Mode change	Never	93.8	75.8	84.8	94.6	81.6	86.8
	1–25	4.4	14.6	7.9	3.7	10.5	8.1
	26–50	0.9	2.6	1.4	0.1	4.4	0.9
	>50	0.9	7.0	5.9	1.6	3.5	4.2
Time-of-day change	Never	89.5	47.8	70.3	74.0	94.4	74.9
	1–25	6.0	23.7	17.0	13.7	2.8	14.9
	26–50	2.5	9.2	6.9	6.9	1.5	4.7
	>50	2.0	19.3	5.8	5.4	1.3	5.5
Location change	Never	96.6	86.6	94.4	97.5	97.0	93.3
	1–25	2.2	8.4	3.3	1.3	2.0	4.1
	26–50	0.6	3.0	1.0	0.5	0.8	1.1
	>50	0.6	2.0	1.3	0.7	0.2	1.5
Trip cancellation	Never	96.2	75.4	93.8	95.3	89.0	92.6
	1–25	3.4	19.4	5.0	4.3	10.1	6.1
	26–50	0.4	4.1	0.2	0.4	0.9	0.7
	>50	0.0	1.1	1.0	0.0	0.0	0.6
Route change	Never	90.5	56.4	85.0	85.4	96.4	87.1
	1–25	6.3	26.7	9.9	10.0	2.4	8.4
	26–50	1.8	9.8	2.5	1.5	0.9	2.7
	>50	1.4	7.1	2.6	3.1	0.3	1.8

Obviously, the locations of work and school sites are relatively fixed. Nonetheless, telecommuting alternatives, satellite offices, and e-learning are opportunities that make location change feasible. The most prevalent changes in commuting behavior are changes in the timing of the trip and changes in the route chosen. A possible reason for this is that people try to avoid traffic jams by diverging their paths and changing the departure times of their trips.

Changes in Shopping Trips

The percentages of respondents making a certain travel behavior change for shopping trips are displayed in Table 3. Similar to commuting trips, the most marked finding from the comparison of weather conditions is that snow has the largest effect on shopping trips. Time-of-day changes (trip postponements) and trip cancellations especially are standard: about 70% of the respondents postpone their shopping trips, and the same percentage cancels their shopping trips.

The effects of heavy rain and heavy winds or storms are striking: about 60% of the respondents postpone and around 50% cancel their shopping trips during periods of heavy rain, and about 50% of the respondents postpone their shopping trips during stormy periods, whereas 45% cancel their shopping trips.

A comparison of extreme temperatures provides the insight that more people change their transport mode for shopping trips during warm temperatures (above 28°C) than during cold temperatures (below freezing). A possible explanation is that people are more interested in using slow modes (walking, cycling) during highly favorable weather conditions. This is in line with the results of Bos (*5*), who found an increase in bicycle use during warm summers.

The most prevalent changes in shopping-related travel behavior are trip postponements and trip cancellations. Extreme weather conditions appear to cause serious changes in the activities people want to perform. When the overall results of shopping trips are compared with commuting trips, a considerably larger percentage of people change their shopping-related travel behavior than change their commuting behavior. This change occurs because it is much easier to postpone or cancel shopping activities than work- or school-related activities, which is also observed on the Flemish highway network (*13*).

Changes in Leisure Trips

For the final category of trips that were considered, namely, leisure trips, the percentages of respondents making certain travel behavior changes are shown in Table 4. Yet again, snowy weather has the largest impact. Similar to shopping trips, trip postponements and trip cancellations are the most frequent changes in travel behavior: about 65% of the respondents postpone their leisure trips, and the same number of respondents cancel their leisure trips.

Heavy rain and heavy wind or storms also clearly influence leisure-related travel behavior: about 45% of the respondents postpone and a similar percentage cancel their leisure trips during periods of heavy rain or heavy wind. The effect of extreme temperature on leisure trips is similar to the effect on shopping trips: more people alter their transport modes for leisure trips during warm temperatures than during cold temperatures. The resemblances between shopping and leisure trips are further underlined when the most prevalent changes in leisure trips are discussed: trip postponements and trip cancellations are the most frequently performed changes in leisure-related travel behavior. There is homogeneity between behavioral changes concerning leisure trips and shopping trips, because both leisure and shopping activities are nonobligatory activities, which are more flexible (more easy to postpone, advance, or cancel) than are obligatory activities such as school and work.

STATISTICAL ANALYSIS OF CHANGES IN TRAVEL BEHAVIOR

The descriptive results in the previous section clearly indicate that changes in travel behavior in response to weather conditions are dependent on the type of weather condition. Moreover, the results suggested that behavioral changes are strongly dependent on the

TABLE 3 Changes in Shopping Trips

Change	Frequency (%)	Cold (%)	Snow (%)	Rain (%)	Fog (%)	Warm (%)	Storm (%)
Mode change	Never	91.5	78.2	85.6	91.9	79.7	86.8
	1–25	5.2	11.2	6.0	4.4	10.2	6.5
	26–50	1.4	3.4	2.2	0.8	4.9	1.6
	>50	1.9	7.2	6.2	2.9	5.2	5.1
Time-of-day change	Never	80.2	29.4	41.8	59.9	80.0	47.7
	1–25	13.1	28.2	24.1	19.2	13.0	22.8
	26–50	3.9	16.9	13.6	11.4	4.2	13.7
	>50	2.8	25.5	20.5	9.5	2.8	15.8
Location change	Never	86.8	54.0	68.4	72.2	83.7	69.3
	1–25	7.4	20.6	12.6	11.9	10.5	13.7
	26–50	2.8	9.4	10.7	8.8	2.6	10.0
	>50	3.0	16.0	8.3	7.1	3.2	7.0
Trip cancellation	Never	86.7	31.9	48.4	64.4	82.6	55.0
	1–25	7.1	33.7	29.3	20.4	13.3	23.3
	26–50	3.0	14.5	11.6	8.8	2.7	11.6
	>50	3.2	19.9	10.7	6.4	1.4	10.1
Route change	Never	93.1	58.8	81.7	80.6	93.3	81.7
	1–25	4.5	23.2	11.0	11.3	4.7	10.7
	26–50	1.4	10.3	3.7	4.8	0.5	4.6
	>50	1.0	7.7	3.6	3.3	1.5	3.0

TABLE 4 Changes in Leisure Trips

Change	Frequency (%)	Cold (%)	Snow (%)	Rain (%)	Fog (%)	Warm (%)	Storm (%)
Mode change	Never	89.9	74.4	83.9	87.3	77.3	85.6
	1–25	7.7	13.5	8.9	8.1	11.7	8.7
	26–50	1.2	3.8	3.1	3.5	6.4	3.0
	>50	1.2	8.3	4.1	1.1	4.6	2.7
Time-of-day change	Never	85.3	35.1	54.3	61.8	85.3	58.6
	1–25	10.5	30.9	26.1	21.3	11.5	20.1
	26–50	2.0	15.0	12.7	9.2	2.0	13.0
	>50	2.2	19.0	6.9	7.7	1.2	8.3
Location change	Never	83.3	70.9	75.1	81.5	83.9	74.1
	1–25	9.9	14.1	11.3	9.3	10.0	13.1
	26–50	2.8	6.5	6.3	5.3	3.3	6.5
	>50	4.0	8.5	7.3	3.9	2.8	6.3
Trip cancellation	Never	79.3	35.6	56.1	66.1	82.2	55.3
	1–25	14.4	34.0	24.2	20.2	13.9	23.5
	26–50	4.1	13.8	9.6	8.0	3.0	12.1
	>50	2.2	16.6	10.1	5.7	0.9	9.1
Route change	Never	92.8	55.1	76.4	78.6	94.3	76.9
	1–25	4.4	24.4	13.9	13.5	3.6	12.4
	26–50	2.1	11.9	5.9	4.5	1.2	6.9
	>50	0.7	8.6	3.8	3.4	0.9	3.8

underlying activity. In this section, these two hypotheses are formally tested by using Pearson chi-square independence tests. A statistical analysis is provided of the hypothesis that the type of weather determines the likelihood of a change in travel behavior. An elaboration on the test of the hypothesis that changes in travel behavior due to weather conditions are dependent on trip purpose is made. Multiple testing is accounted for by lowering the significance level in a Bonferroni-like approach.

Dependence of Changes in Travel Behavior on Type of Weather

For each activity (trip purpose), the dependency between change in travel behavior and type of weather was formally tested. Table 5 gives the chi-square values, degrees of freedom, and corresponding significance levels of the different tests. First, for each activity, the dependency between all travel behavior changes and weather conditions was tested. Then the dependencies of specific travel behavior changes and weather conditions were assessed.

It can be concluded from Table 5 that all behavioral changes highly depend on the type of weather. (The null hypothesis of independence is rejected for all behavioral changes with a p-value smaller than .001.) Similar to the preliminary conclusions drawn from the descriptive results, for work- and school-related trips trip postponement (time-of-day change) and route changes are the strongest depending on the weather type; for shopping and leisure trips, the relationship is the most significant (higher chi-squared value, same degrees of freedom) for trip postponements and trip cancellations. Although highly significant (p-value smaller than .001), the interdependence

TABLE 5 Dependence of Changes on Weather

Trip Purpose	Behavioral Change	χ^2	df	Signif.	Cramer's V
Work or School	All changes	1,185.75	95	***	0.125
	Mode change	138.71	15	***	0.123
	Time-of-day change	409.05	15	***	0.212
	Location change	81.12	15	***	0.094
	Trip cancellation[a]	174.79	5	***	0.240
	Route change	362.56	15	***	0.199
Shopping	All	1,728.89	95	***	0.142
	Mode change	92.24	15	***	0.095
	Time-of-day change	542.97	15	***	0.230
	Location change	235.69	15	***	0.152
	Trip cancellation	555.65	15	***	0.233
	Route change	302.34	15	***	0.172
Leisure	All	1,456.24	95	***	0.130
	Mode change	107.92	15	***	0.102
	Time-of-day change	522.45	15	***	0.224
	Location change	62.85	15	***	0.078
	Trip cancellation	405.26	15	***	0.197
	Route change	357.76	15	***	0.185

[a]Estimated using reduced answer possibilities (yes/no).
***p-value < .001.

between changes in travel behavior and type of weather was smallest for location and mode changes.

Recall that the number of degrees of freedom is calculated by multiplying the number of rows minus one by the number of columns minus one. For the dependence of specific travel behavior changes on weather conditions, the independence test followed a chi-square distribution with 15 degrees of freedom: four frequencies (the number of people who would never change their behavior and, respectively, the ones who change their behavior in 1% to 25%, 26% to 50%, and more than 50% of the cases) minus one multiplied by six weather conditions minus one. Since the underlying assumption of the independence test (minimum 80% of the cells expected counts should be at least equal to 5) was not fulfilled for the hypothesis test that assessed the relationship between trip cancellations of commuting trips and weather conditions, an alternative independence test was tabulated by combining the three categories of people that change their behavior. As a result, the number of degrees of freedom for this test was smaller than that for the other test, as shown in Table 5.

Dependence of Changes in Travel Behavior on Trip Purpose

To test the dependence of changes in travel behavior on activity type (trip purpose), independence tests are performed on an aggregate level (aggregation over all travel behavior changes). Table 6 displays the chi-square values, degrees of freedom, and corresponding significance levels of these tests.

In line with tests that assess the dependence of changes in travel behavior on type of weather, the dependence of changes in travel behavior on trip purpose also confirm the preliminary conclusions drawn from the descriptive results: the extent to which people adapt their travel behavior is strongly dependent (all p-values smaller than .001) on trip purpose. This dependence appears to be the largest for periods of heavy rain, snow, and heavy wind. For extreme temperatures, this dependency appears to be smaller (lower chi-square value and same number of degrees of freedom) yet still highly significant.

To further investigate the dependence of changes in travel behavior on trip purpose, a more-detailed analysis is performed: for all six weather conditions, the dependence of the specific behavioral changes on trip purpose was investigated. Various conclusions could be drawn from this disaggregate analysis. First, for all weather conditions, time-of-day changes (trip postponements), location changes, and trip cancellations significantly depended on trip purpose (p-values all smaller than .01 and for location changes all smaller than 0.001).

TABLE 6 Dependence of Changes on Trip Purpose, Aggregate Level

Weather	Behavioral Change	χ^2	df	Signif.	Cramer's V
All types	All changes	2,180.35	238	***	0.148
Cold	All changes	165.69	38	***	0.100
Snow	All changes	473.46	38	***	0.169
Rain	All changes	550.80	38	***	0.183
Fog	All changes	382.66	38	***	0.152
Warm	All changes	144.80	38	***	0.094
Storm	All changes	462.94	38	***	0.167

***p-value < .001.

TABLE 7 Dependence of Changes on Trip Purpose, Disaggregate Level

Weather	Behavioral Change	χ^2	df	Signif.	Cramer's V
Cold	Mode change	9.03	6	NS	0.052
	Time-of-day change	21.24	6	**	0.080
	Location change	50.88	6	***	0.124
	Trip cancellation	79.41	6	***	0.155
	Route change	5.12	6	NS	0.039
Snow	Mode change	5.07	6	NS	0.039
	Time-of-day change	49.55	6	***	0.122
	Location change	143.46	6	***	0.208
	Trip cancellation	271.33	6	***	0.287
	Route change	4.06	6	NS	0.035
Rain	Mode change	9.93	6	NS	0.055
	Time-of-day change	129.11	6	***	0.198
	Location change	120.21	6	***	0.191
	Trip cancellation	275.88	6	***	0.289
	Route change	15.68	6	*	0.069
Fog	Mode change	42.05	6	***	0.113
	Time-of-day change	30.06	6	***	0.095
	Location change	126.67	6	***	0.196
	Trip cancellation	170.08	6	***	0.227
	Route change	13.80	6	*	0.065
Warm	Mode change	5.41	6	NS	0.040
	Time-of-day change	54.24	6	***	0.128
	Location change	58.03	6	***	0.133
	Trip cancellation[a]	11.59	2	**	0.059
	Route change[a]	5.15	2	NS	0.039
Storm	Mode change	13.15	6	*	0.063
	Time-of-day change	97.85	6	***	0.172
	Location change	104.97	6	***	0.178
	Trip cancellation	225.54	6	***	0.261
	Route change	21.42	6	**	0.081

[a]Estimated using reduced answer possibilities (yes/no).
*p-value < .05, **p-value < .01, ***p-value < .001, NS = not significant.

In addition, all behavioral changes in response to fog and heavy wind or storm were statistically significantly depending on the trip purpose (p-values all smaller than .05).

A thorough look at the effects of cold and warm weather, as well as snow, shows that the extent to which people change their mode or route in response to these weather conditions does not depend on trip purpose. Furthermore, Table 7 shows that for all weather conditions (except warm weather), the highest dependency of behavioral changes on trip purpose was found for trip cancellations. A possible explanation for this contrast with warm-weather conditions is that all other weather conditions are considered to be unfavorable, whereas high temperatures may be considered as favorable, at least for some part of the population.

CONCLUSIONS

In this study, the hypothesis of dependence of changes in travel behavior on type of weather and the hypothesis of dependence of changes in travel behavior on trip purpose (activity type) were formally tested. Results from both the descriptive analysis and the Pearson chi-square independence tests confirm that the type of weather matters and that the changes in travel behavior in response to weather conditions are highly dependent on trip purpose.

Whereas most papers in the international literature focus on traffic safety and traffic flows, this paper contributes to the literature by looking at the underlying travel behavior by means of a multifaceted stated adaptation approach. The clear dependence of behavioral adjustments on activities (trip purposes) provides policy makers with a deeper understanding of how weather conditions affect traffic. The value of this contribution is stressed by weather-related policy issues, such as increased fuel consumption, economic losses due to traffic delays, and higher traffic counts.

The findings in this paper are consonant with international literature and provide a solid basis for further analysis of weather-related policy measures, such as an examination of whether extreme weather conditions cause last-minute changes in travel mode, or an assessment of whether high-quality bus shelters make a difference in last-minute mode changes. Further generalizations of the findings are possible by shifting the scope toward revealed travel behavior and by breaking down modal changes to different transport modes. Triangulation of both stated and revealed travel behavior on the one hand and traffic intensities on the other hand is a key challenge for further research.

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