Winter Weather Demand Considerations

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Winter Weather Demand Considerations

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16. Abstract
Winter weather has varied effects on travel behavior. Using 418 survey responses from the Northern Virginia commuting area of Washington, DC and binary logit models, this study examines travel-related changes under different types of winter weather and the factors influencing the likelihood of making a given change. In particular, the types of weather and related conditions include snow, freezing rain, heavy rain, below-freezing temperatures, and icy roads. Two cases for these conditions are considered: beginning while the respondent is at work and while the respondent is at home. The travel-related changes investigated include cancelling trips, delaying trips, departing early, adding trips, changing destinations, changing routes, using more highways/freeways, and changing modes of transportation. The statistically significant factors are different for the different decisions and weather conditions, emphasizing the complexity of predicting demand for winter weather. For the types of changes respondents indicated they would make, the ranks were fairly consistent for winter weather beginning while the travelers are at work and when they are at home. The most common change is to cancel a trip/commute, followed by delaying a trip/commute, leaving early, and routing issues. The least common change is in mode of transportation. The report provides details for each of the variables that were found to be significant for each type of travel-related change.

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Winter weather; travel demand; behavior changes; travel changes; survey	

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1 INTRODUCTION

In 2011, the "perfect [snow] storm" hit the Washington, DC commuting area during the evening peak period, causing some drivers to spend up to 13 hours on the road. While this may seem like an anomaly, the winters of 2013-2014 and 2014-2015 both had many days of weather events that disrupted school and employer schedules and changed travel patterns and conditions.

Precipitation events affect road capacity (Federal Highway Administration 2009) through lane obstructions and driver visibility, which is manifested through speed reductions and increased vehicle headway (Goodwin 2002). A range of studies have examined specific weather impacts including travel time effects through regression (e.g., Stern, Shah et al. 2003) and signal timing effectiveness (Maki, Martin, Perrin et al. 2000; Perrin, Martin et al. 2001). Capacity and speed reductions are among the critical factors for signal timings and have also been explored for freeways (Agarwal, Maze et al. 2005). While these effects are widely accepted, their importance cannot be determined without knowing how many drivers will be affected. Predicting the winter weather demand involves understanding the complexities associated with the decision to travel at a particular time. In particular, school closures, workplace policies, storm characteristics, and road conditions influence drivers' trip decisions during winter events. This study explores these influences and complexities.

The overall goal of this work was to examine winter weather effects on demand so that the effectiveness of different winter weather road and traffic management strategies can be better evaluated and matched to demand. This goal involved developing a better understanding of the complexities associated with travel decisions during winter weather. To pursue this goal, a survey of residents in the Northern Virginia portion of the Washington, DC commuting area was conducted. These data served as the basis for statistical analyses of the factors related to a variety of travel behavior changes under two scenarios: winter weather conditions beginning while the respondent is at work, and such conditions beginning while the respondent is at home.

2 BACKGROUND

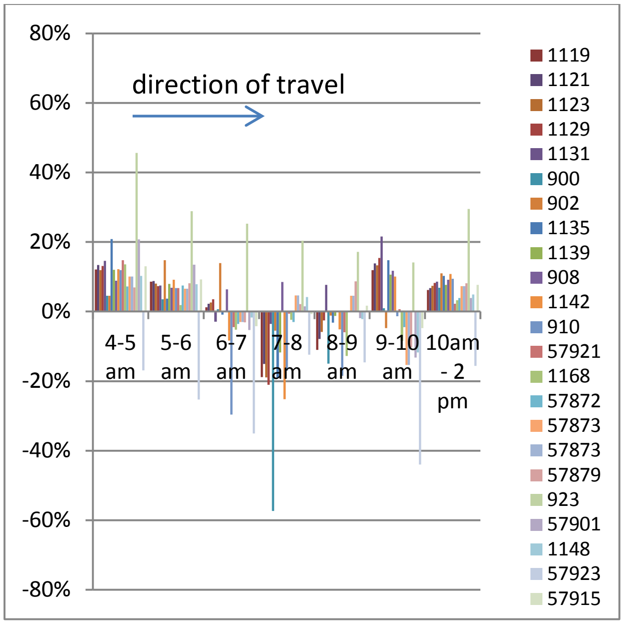
As context to the problem and survey, Table 1 shows Fairfax County Public Schools' decisions related to winter weather. Other school systems in the area were fairly similar, although not perfectly aligned. This table shows that, frequently, several days in the same week were affected. Note that this table does not include holidays or previously scheduled teacher work days.

Table 1 Fairfax County Public Schools Decisions Related to Winter Weather for Winters 2013-2014 and 2014-2015

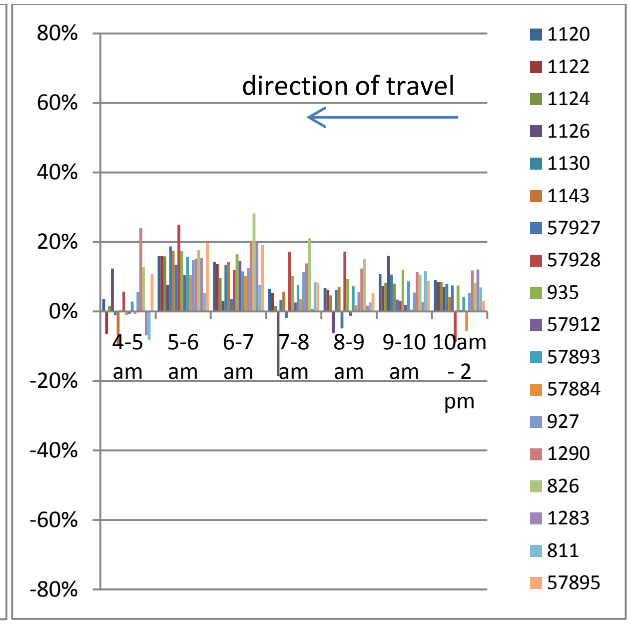
Date	Day of the Week	Closure	Delayed Opening
Dec. 9, 2013	Monday	X	
Dec. 10, 2013	Tuesday	X	
Dec. 11, 2013	Wednesday		X
Jan. 7, 2014	Tuesday	X	
Jan. 8, 2014	Wednesday		X
Jan. 10, 2014	Friday		X
Jan. 21, 2014	Tuesday	X	
Jan. 22, 2014	Wednesday	X	
Jan. 23, 2014	Thursday	X	
Jan. 24, 2014	Friday		X
Jan. 29, 2014	Wednesday		X
Feb. 5, 2014	Wednesday		X
Feb. 13, 2014	Thursday	X	
Feb. 14, 2014	Friday	X	
Feb. 18, 2014	Tuesday		X
Mar. 3, 2014	Monday	X	
Mar. 4, 2014	Tuesday	X	
Mar. 5, 2014	Wednesday		X
Mar. 17, 2014	Monday	X	
Mar. 18, 2014	Tuesday		X
Jan. 7, 2015	Wednesday		X
Jan. 8, 2015	Thursday	X	
Jan. 9, 2015	Friday		X
Jan. 12, 2015	Monday		X
Jan. 14, 2015	Wednesday	X	
Jan. 27, 2015	Tuesday	X	
Jan. 28, 2015	Wednesday		X
Feb. 17, 2015	Tuesday	X	
Feb. 18, 2015	Wednesday	X	
Feb. 20, 2015	Friday	X	
Feb. 23, 2015	Monday		X
Feb. 26, 2015	Thursday	X	
Mar. 2., 2015	Monday	X	
Mar. 5, 2015	Thursday	X	
Mar. 6, 2015	Friday	X	

Source: Fairfax Schools (2014, 2015) https://twitter.com/fcpsnews

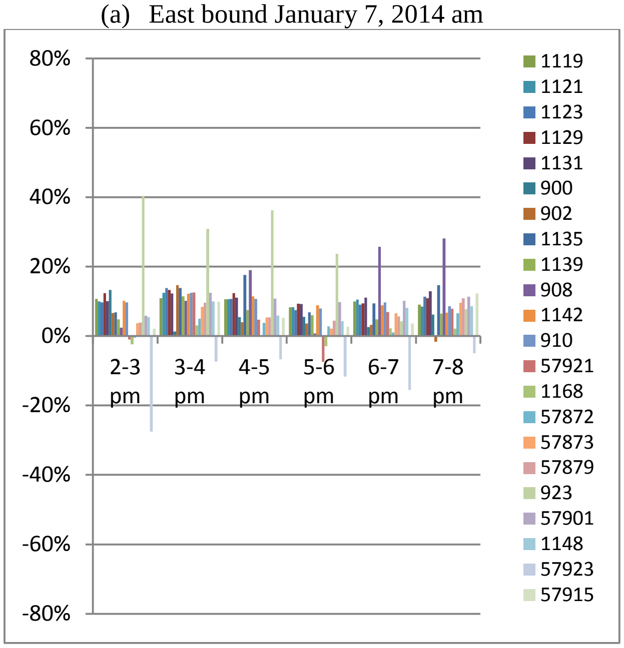
To emphasize the complexities associated with winter weather demand, detector data from I-66 was obtained to examine changes in volumes during winter weather compared to fair weather days. Figure 1 and Figure 2 show that the relative volume changes from a fair weather day can be dramatically different and that assuming a percentage of cancelled trips that is consistent across all school closure days can be faulty. In the figures, each data point represents a detector group, ordered from west to east. A positive value indicates that the winter weather day has less volume than the average for that day of the week for that month when there are no school closures or delayed openings. Figure 1 shows the data for January 7, 2014 and Figure 2 shows the data from two weeks later. January 7 had some positive and some negative volume changes, especially in the peak direction (east bound in the am, west bound in the pm). On the other hand January 22 has lower volumes for almost every detector. The magnitude of the change on January 22 is noticeably greater than that for January 7.



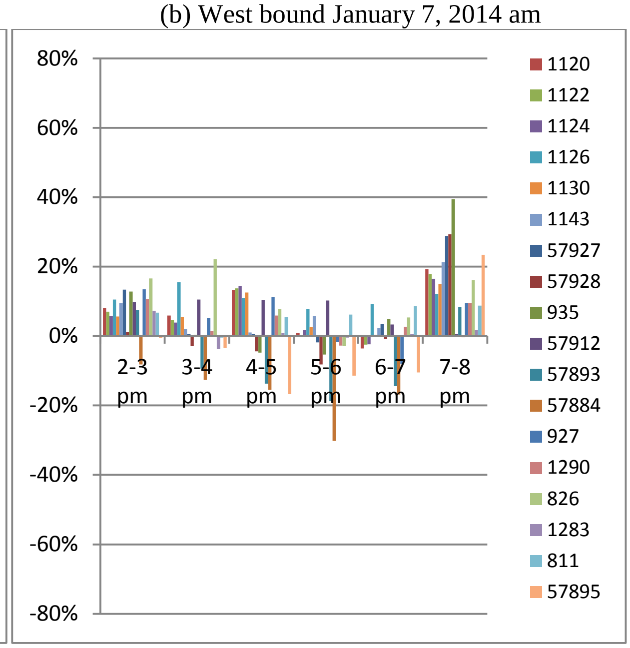
(a) East bound January 7, 2014 am



(b) West bound January 7, 2014 am



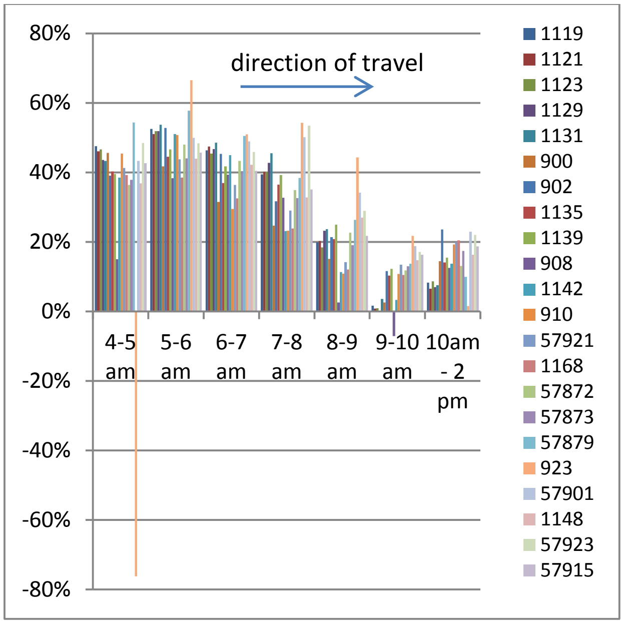
(c) East bound January 7, 2014 pm



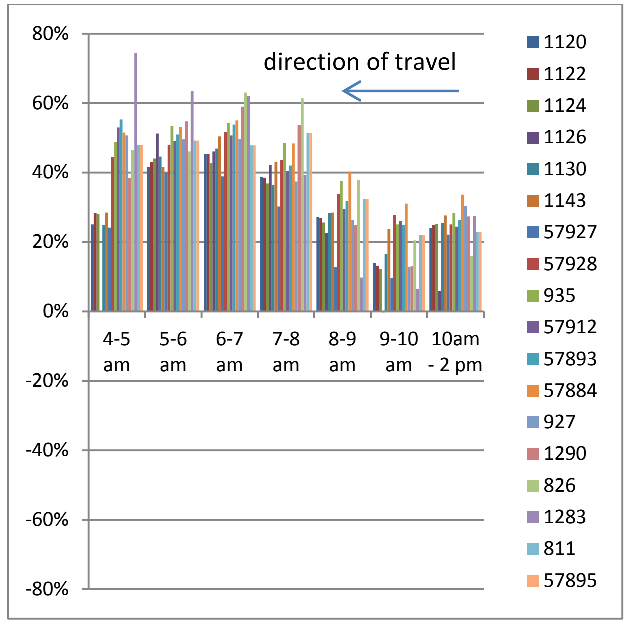
(d) West bound January 7, 2014 pm

[formula used: (average volume – closure volume)/(average volume)]

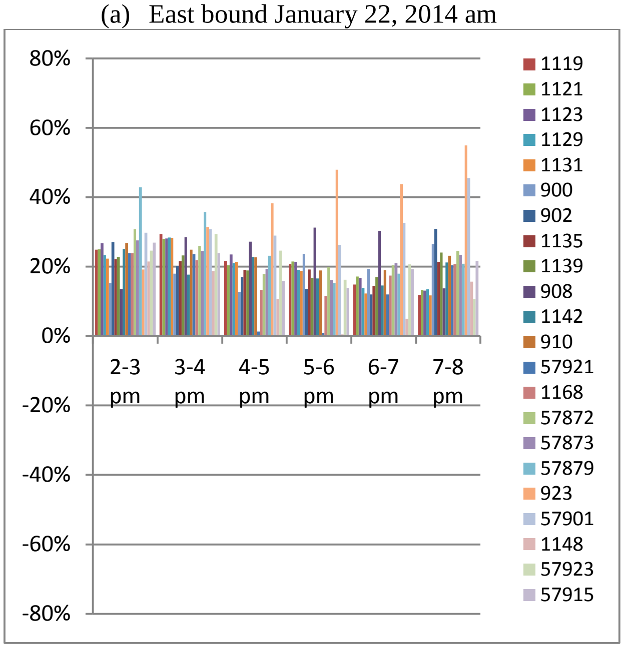
Figure 1 Relative Change in I-66 Detector Volumes for January 7, 2014 from an Average Fair Weather Day



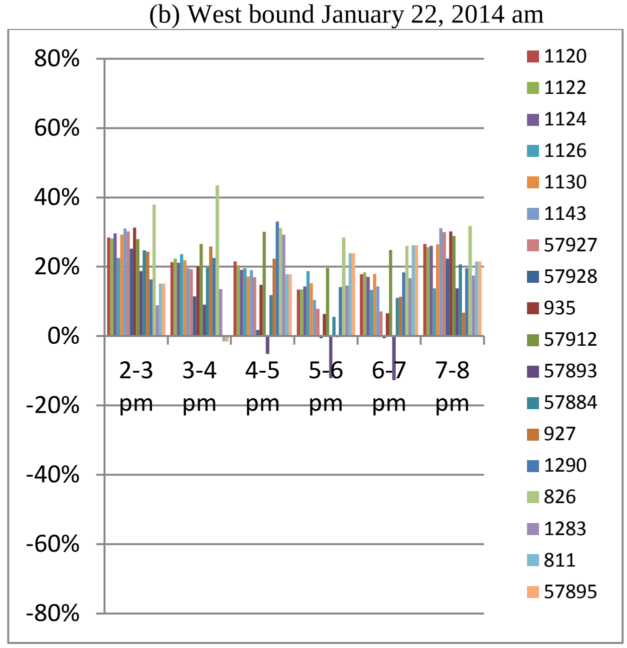
(a) East bound January 22, 2014 am



(b) West bound January 22, 2014 am



(c) East bound January 22, 2014 pm



(d) West bound January 22, 2014 pm

Figure 2 Relative Change in I-66 Detector Volumes for January 22, 2014 from an Average Fair Weather Day

3 SURVEY DATA

A telephone survey of Northern Virginia residents was conducted in late January and February 2014. As shown in Table 1, survey respondents had recent experience with winter weather on which to base their responses. The sample was randomly selected from Arlington, Fairfax, Loudoun, and Prince William counties in Northern Virginia as well as the independent cities of Falls Church, Fairfax, and Manassas (see Figure 3). A total of 418 responses were obtained, although not everyone answered all of the questions.

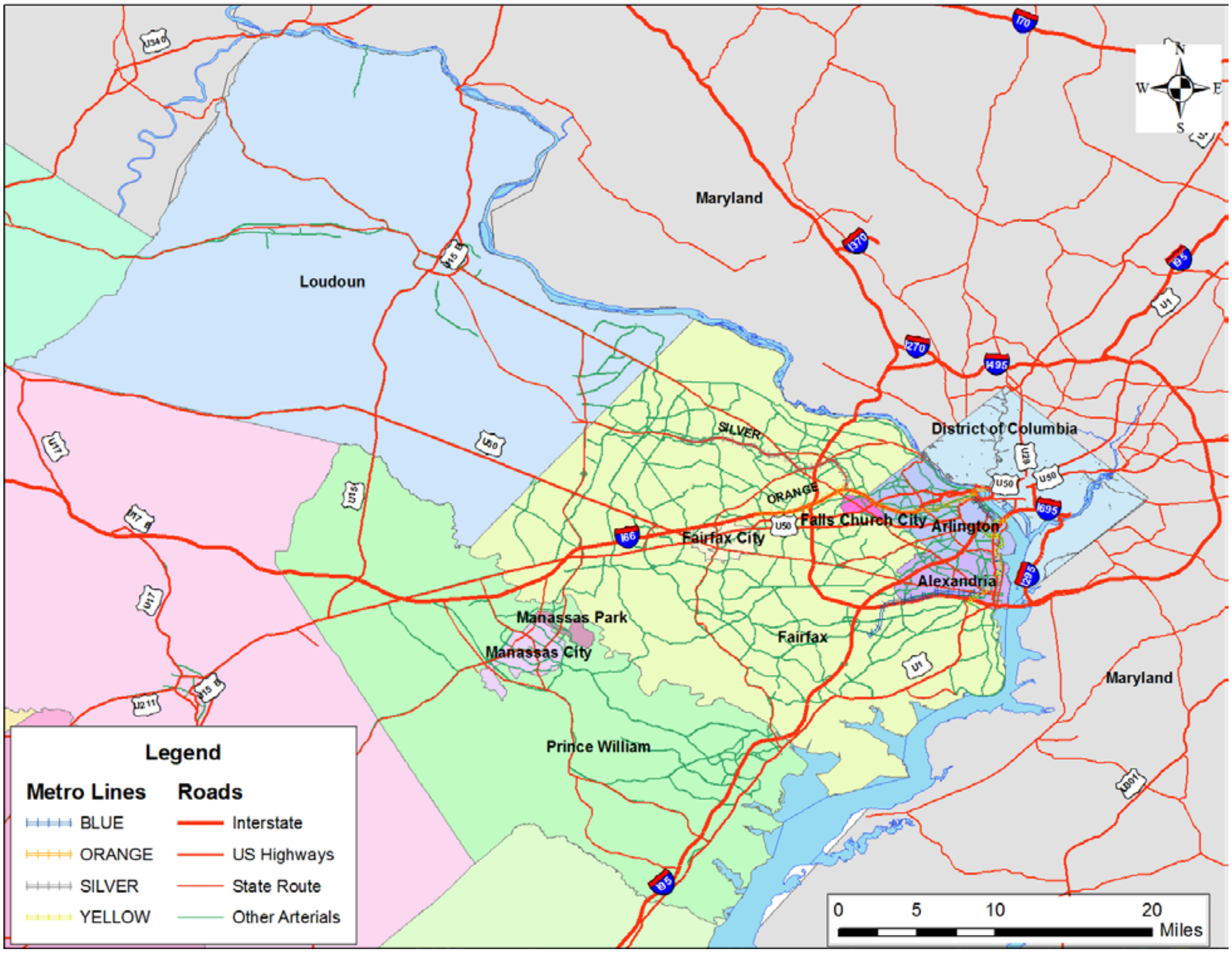


Figure 3 Northern Virginia Sample Area

The survey captured the following information:

- The day(s) of the week the respondent typically commutes, if any
- The typical departure time for the commute from home to work
- The typical departure time for the return commute (work to home)
- The day(s) of the week the respondent typically conducts errands, if any
- The day(s) of the week the respondent typically participates in child related travel, if any
    - The typical departure time from home for the child related travel
    - The typical departure time from work for child related travel
- The day(s) of the week the respondent typically participates in leisure or recreation travel, if any
- The mode of transportation used for the longest portion of the trip
- The types of roads used for the majority of the trip
- Whether the respondent normally makes stops during their primary trips
- Whether the respondent is currently employed
    - Whether the employer offers teleworking options during winter weather
    - Whether the employer offers a flexible schedule during winter weather
    - Whether the employer requires the respondent to use earned annual leave, compensatory time, credit hours, or sick leave during winter weather absences

    - Whether the employer treats winter weather absences as excused or administrative leave
    - Whether the respondent has to take leave without pay for winter weather absences
- For winter weather beginning or forecasted to begin while the respondent is at work:
    - Whether the respondent would cancel or reschedule a trip
    - Whether the respondent would delay a trip (if so, by how many minutes)
    - Whether the respondent would start a trip earlier (if so, by how many minutes)
    - Whether the respondent would add trips (if so, how many)
    - Whether the respondent would change destinations
    - Whether the respondent would change routes
    - Whether the respondent would use more highways or local roads
    - Whether the respondent would change modes of transportation (if so, with which mode)
    - Which types of winter weather would cause changes in transportation arrangements/routes (snow, freezing rain, heavy rain, temperatures below freezing, icy roads)
- For winter weather that begins or is forecasted while the respondent is home (and normally works)
    - Whether the respondent would cancel or reschedule a trip
    - Whether the respondent would delay a trip (if so, by how many minutes)
    - Whether the respondent would start a trip earlier (if so, by how many minutes)
    - Whether the respondent would add trips (if so, how many)
    - Whether the respondent would change destinations
    - Whether the respondent would change routes
    - Whether the respondent would use more highways or local roads
    - Whether the respondent would change modes of transportation (if so, with which mode)
    - Which types of winter weather would cause changes in transportation arrangements/routes (snow, freezing rain, heavy rain, temperatures below freezing, icy roads)
- For winter weather that starts or is forecasted while the respondent is home
    - Whether the respondent would change transportation plans for errands
    - Whether the respondent would change transportation plans for child related travel
    - Whether the respondent would change transportation plans for leisure/recreation
- The importance of visibility, road conditions, congestion, family/household responsibilities, school decisions about closures, etc., and employer decisions about closures, etc. for decisions related to transportation and travel during episodes of winter weather
- The timeframe over which the respondent starts to plan his/her travel for the weather conditions when they are concerned about visibility, road conditions, congestion, family/household responsibilities, school decisions about closures, etc., and employer decisions about closures, etc.
- The respondent’s household size
- The number of adults in the household
- The number of children in the household
- The age of the youngest child

- Whether the respondent is responsible for the children's travel
- The number of vehicles in the household
- The respondent's race
- The household's annual income category
- The respondent's gender

Responses to a few of these questions can be used to see how well the sample matches with the characteristics of the population as identified by the U.S. Census. This comparison can be seen in

Table 2. Household size is a good match between the weighted average household size for the area and the sample. The gender split shows a slight over-sampling of females. In terms of race and ethnicity, Whites were over-sampled, Blacks/African Americans slightly under-sampled, and Asians and Hispanics under-sampled. The median income for the sample was slightly higher than the Census median. The Census has aggregate mode splits for commute travel. The survey questions for this study related to travel mode were not restricted to commute trips, so the mode responses are not directly comparable. However, the sample did cover all of the transportation modes. It is likely that drive alone was over sampled.

As indicated by the lengthy list of items captured by the survey, the dataset contains many potentially useful decisions and thus dependent variables. Table 3 summarizes the characteristics of the decisions from the respondents.

In terms of the type of winter weather that leads to a change in transportation plans, icy roads were the most popular, regardless of where the respondents are when the weather begins. Snow and freezing rain follow icy roads in frequency. Heavy rain is the least common for changing transportation plans when the weather begins while the respondents are at work but next to least common when it begins while the respondents are at home. Below freezing temperatures are the next to least common when they begin while the respondent is at work and the least common when they begin while the respondent is at home.

For the types of changes respondents indicated they would make, the ranks of each type of change were fairly consistent for winter weather beginning while the travelers are at work and when they are at home. The most common change is to cancel a trip/commute, followed by delaying a trip/commute, and then leaving early. Routing issues are next in frequency, but the ranks change. For weather beginning while respondents are at work, 62% indicated changing routes and 58% indicating using more highways/freeways. For the weather beginning while respondents are at home, 55% indicated using more highways/freeways and 41% would use more routes (note the change in N). The least common change is in mode of transportation – only 11% when weather begins while the respondents are at work and 8% when the weather begins while the respondents are at home.

While the previous decisions are related to workers, three additional decisions are not limited to workers. If winter weather begins while the respondents are at home, 71% would change transportation plans for errands and 78% would change transportation plans for leisure trips. If the respondents have children, they were asked whether their plans for child related travel would change – 61% of respondents answering this question indicated they would.

Table 4 provides a summary of the variables that are considered as possible explanatory variables for the various decisions.

Table 2 Sample Characteristics Comparison with Census Statistics

County/ City	House-hold Size	Number of house-holds	Population	Female (%)	Race (%)				Median Income ($)	Commute (%)				Commuting to work (Workers 16 and older)
					White	Black	Asian	Hispanic		Drive alone	Car-pool	Public Transit	Walk	
Arlington County	2.24	94,454	207,682	50.2	71.7	8.5	9.6	15.1	103,208	52.8	7.4	27.2	5.6	128,181
Fairfax County	2.80	389,908	1,081,725	50.6	62.7	9.2	17.5	15.6	110,292	72.5	10.8	8.9	1.8	568,600
Loudon County	3.04	106,997	312,337	50.7	68.7	7.3	14.7	12.4	122,238	78.6	9.7	2.5	1.6	153,550
Prince William County	3.11	132,442	402,002	50.3	57.8	20.2	7.5	20.3	98,071	70.8	16.6	5.3	2.1	198,675
Alexandria	2.08	63,738	133,647	51.9	63.4	22	5.9	15.0	80,847	60.6	8.6	22.3	3.1	83,954
City of Falls Church	2.53	5,020	12,283	51	79.9	4.3	9.4	9.0	120,000	64	7.2	17.3	3.2	6,143
Fairfax	2.65	8,498	22,542	50.7	69.6	4.7	15.2	15.8	97,242	69.5	14	9	2	11,485
Manassas	3.24	12,072	37,821	49.9	61.7	13.7	5.0	31.4	71,036	76.6	13.5	3.7	3.1	18,700
Total		813,129	1,808,439											1,169,288
Weighted Average	**2.76**			**51**	**64**	**12**	**14**	**16**	**106,083**	**70.0**	**11.2**	**10.4**	**2.4**	
Sample	**2.82**			**54**	**74**	**9**	**5**	**5**	**125,000**	**84.2***	**5.3***	**7.9***	**1.0***	

Data Source: 2010 U.S. Census (www.Census.gov)
* The survey question was phrased as “For your normal travel, what one mode of transportation do you use for the longest portion of your trips?” and thus was not restricted to commuting. Thus the commuting percentages from the Census are not necessarily directly comparable to the survey.

Table 3 Characteristics of the Dependent Variables (Decisions)

Variable	**Variable Coding**	**Min**	**Max**	**Mean**	**N**
Snow Change Trans From Work	Binary variable: 1 if respondent would use change transportation plans if snow begins at work; 0 otherwise	0	1	0.53	293
Freezing Rain Change Trans from Work	Binary variable: 1 if respondent would use change transportation plans if freezing rain begins at work; 0 otherwise	0	1	0.52	293
Heavy Rain Change Trans From Work	Binary variable: 1 if respondent would use change transportation plans if heavy rain begins at work; 0 otherwise	0	1	0.15	293
Below Freeze Change Trans From Work	Binary variable: 1 if respondent would use change transportation plans if below freezing temperatures begin at work; 0 otherwise	0	1	0.17	293
Icy Roads Change Trans From Work	Binary variable: 1 if respondent would use change transportation plans if icy road conditions begin at work; 0 otherwise	0	1	0.71	293
Snow Change Trans Home2Work	Binary variable: 1 if respondent would use change commuting transportation plans if snow begins at home; 0 otherwise	0	1	0.52	293
Freezing Rain Change Trans Home2Work	Binary variable: 1 if respondent would use change commuting transportation plans if freezing rain begins at home; 0 otherwise	0	1	0.46	293
Heavy Rain Change Trans Home2Work	Binary variable: 1 if respondent would use change commuting transportation plans if heavy rain begins at home; 0 otherwise	0	1	0.14	293
Below Freeze Change Trans Home2Work	Binary variable: 1 if respondent would use change commuting transportation plans if below freezing temperatures begin at home; 0 otherwise	0	1	0.13	293
Icy Roads Change Trans Home2Work	Binary variable: 1 if respondent would use change commuting transportation plans if icy roads begin at home; 0 otherwise	0	1	0.65	293
Weather at Work Cancel a Trip	Binary variable: 1 if a trip would be canceled if winter weather begins at work; 0 otherwise	0	1	0.72	269
Weather at Work Delay a Trip	Binary variable: 1 if a trip would be delayed if winter weather begins at work; 0 otherwise	0	1	0.71	260
Weather at Work Leave Work Early	Binary variable: 1 if respondent would leave work early if winter weather begins at work; 0 otherwise	0	1	0.67	265
Weather at Work Add Trips	Binary variable: 1 if respondent would add trips to the return commute if winter weather begins at work; 0 otherwise	0	1	0.43	271
Weather at Work Change Destination	Binary variable: 1 if respondent would change the destination of a trip if winter weather begins at work; 0 otherwise	0	1	0.49	273
Weather at Work Change Route	Binary variable: 1 if respondent would change routes if winter weather begins at work; 0 otherwise	0	1	0.62	277

Weather at Work Use More Highways	Binary variable: 1 if respondent would use more highways if winter weather begins at work; 0 otherwise	0	1	0.58	255
Weather at Work Change Mode	Binary variable: 1 if respondent would use change transportation modes if winter weather begins at work; 0 otherwise	0	1	0.11	278
Weather at Home Cancel Commute	Binary variable: 1 if the commute would be canceled if winter weather begins at home 0 otherwise	0	1	0.64	262
Weather at Home Delay Commute	Binary variable: 1 if a commuting trip would be dalyed if winter weather begins at home; 0 otherwise	0	1	0.63	270
Weather at Home Commute Early	Binary variable: 1 if respondent would commute to work early if winter weather begins at home; 0 otherwise	0	1	0.55	268
Weather at Home Add to Commute	Binary variable: 1 if respondent would add trips to the commute if winter weather begins at home; 0 otherwise	0	1	0.19	263
Weather at Home Change Commute Route	Binary variable: 1 if respondent would change commuting routes if winter weather begins at home; 0 otherwise	0	1	0.41	271
Weather at Home Commute Use More HWY	Binary variable: 1 if respondent would use more highways to commute to work if winter weather begins at home; 0 otherwise	0	1	0.55	247
Weather at Home Commute Change Mode	Binary variable: 1 if respondent would use change transportation modes from home to work if winter weather begins at home; 0 otherwise	0	1	0.08	273
Weather at Home Change Trans Errands	Binary variable: 1 if respondent would use change transportation plans for errands if winter weather begins at home; 0 otherwise	0	1	0.71	341
Weather at Home Change Trans Child	Binary variable: 1 if respondent would use change transportation plans for child related travel if winter weather begins at home; 0 otherwise	0	1	0.61	139
Weather at Home Change Trans Leisure	Binary variable: 1 if respondent would use change transportation plans for leisure if winter weather begins at home; 0 otherwise	0	1	0.78	353

Table 4 Independent Variables and Their Characteristics

Term	Meaning	Min	Max	Mean	N
HHSIZE	Household size	1	5	2.82	410
hhsizeminusadults	Reported household size minus the reported number of adults in the household	0	3	0.73	410
AgeYoungestKid	Age of the youngest child (in years)	0	17	8.32	155
Female2	Binary variable: 1 if the respondent is female; 0 otherwise	0	1	0.53	418
ChildResp	Binary variable: 1 if the respondent is primarily responsible for child care; 0 otherwise	0	1	0.92	167
ChildTravelResp	Binary variable: 1 if the respondent is responsible for child related travel; 0 otherwise	0	1	0.61	163
Inc2_75-100	Binary variable: 1 if the annual household income is between $75,000 and $100,000	0	1	0.15	323
IncContin	Income represented as a continuous variable (midpoint of each income range)	5000	200,000	131,734	323
Hispanic2	Binary variable: 1 if respondent self-classified as Hispanic; 0 otherwise	0	1	0.05	401
White2	Binary variable: 1 if respondent self-classified as White/Caucasian; 0 otherwise	0	1	0.74	401
Black2	Binary variable: 1 if respondent self-classified as Black/African American; 0 otherwise	0	1	0.09	401
Asian2	Binary variable: 1 if respondent self-classified as Asian; 0 otherwise	0	1	0.05	401
StopsNormally01	Binary variable: 1 if the respondent normally makes stops during their primary trips; 0 otherwise	0	1	0.55	415
ModeDA2	Binary variable: 1 if the respondent normally drives alone; 0 otherwise	0	1	0.84	418
ModeBus	Binary variable: 1 if the respondent normally takes the bus alone; 0 otherwise	0	1	0.04	418
NumVeh2	Number of vehicles in the household	0	6	2.25	415
RoadNHwy2	Binary variable: 1 if the respondent normally uses more highways than other roads; 0 otherwise	0	1	0.46	406
ComNumDays	Number of days per week on which the respondent typically commutes	0	7	3.21	418
LeisNumDays	Number of days per week on which leisure trips are taken	0	7	2.58	418
LeisWkDay	Binary variable: 1 if leisure trips are undertaken on weekdays	0	1	0.49	418
LeisNone	Binary variable: 1 if no leisure trips are taken; 0 otherwise (cannot be used with LeisNumDays)	0	1	0.12	418
LeisSat	Binary variable: 1 if leisure trips are taken on Saturdays; 0 otherwise	0	1	0.70	418
ErrNumDays	Number of days per week on which errands are undertaken	0	7	2.70	418
ErWkEnd	Binary variable: 1 if leisure trips are undertaken on weekends	0	1	0.61	418
ErWkDay	Binary variable: 1 if leisure trips are undertaken on weekdays	0	1	0.54	418
FlexSchedOptWW	Binary variable: 1 if respondent has a flexible work schedule option during winter weather; 0 otherwise	0	1	0.68	282

TeleworkOptWW	Binary variable: 1 if the respondent has a teleworking option during winter weather; 0 otherwise	0	1	0.51	285
WWAbsences Excused	Binary variable: 1 if the respondent has winter weather absences from work excused; 0 otherwise	0	1	0.64	259
NoPay4WW Absences	Binary variable: 1 if the respondent is not paid for winter weather absences from work; 0 otherwise	0	1	0.25	271
EarnedLeave4 WWAbsence	Binary variable: 1 if the respondent can use earned leave for winter weather absences from work; 0 otherwise	0	1	0.39	271
RoadCondVeryImp	Binary variable: 1 if road conditions are very important in travel decisions; 0 otherwise	0	1	0.77	415
RoadCondVSImp	Binary variable: 1 if road conditions are very or somewhat important in travel decisions; 0 otherwise	0	1	0.95	415
SchoolVSImp	Binary variable: 1 if school decisions are very or somewhat important in travel decisions; 0 otherwise	0	1	0.62	332
SchoolDecisions SomewhatImp	Binary variable: 1 if school decisions are somewhat important in travel decisions; 0 otherwise	0	1	0.15	332
FamilyVSImp	Binary variable: 1 if family is very or somewhat important to travel decisions; 0 otherwise	0	1	0.78	396
EmployVSImp	Binary variable: 1 if employer decisions are very or somewhat important to travel decisions; 0 otherwise	0	1	0.73	342
Visibility SomewhatImp	Binary variable: 1 if visibility is somewhat important to travel decisions; 0 otherwise	0	1	0.24	415
Congestion SomewhatImp	Binary variable: 1 if congestion is somewhat important to travel decisions; 0 otherwise	0	1	0.40	411

4 METHODOLOGY

Statistical analyses were conducted in two steps. First, Chi-square (for binary variables) and single independent variable logistic regression analyses (for continuous variables) were conducted to identify individual variables' influences on the various decision variables. Second, independent variables individually significant at the p=0.25 level (Hosmer 2000) were considered for multi-variable binary logistic regression models. Models were also considered starting with all variables significant to any of the decisions, with the exception that the variables in a single model could not be well correlated.

Binary logistic models follow the general formulas shown in equations (1) and (2) based on Ben-Akiva and Lerman (1985).

$$P_n(i) = \frac{e^{V_{in}}}{e^{V_{jn}} + e^{V_{in}}} \quad (1)$$

where V_{in} is the deterministic utility function of alternative i , V_{jn} is the deterministic utility function of alternative j , and $P_n(i)$ is the probability of person *n* selecting alternative *i*. This probability is calculated based on the utility function where:

$$V_{in} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \quad (2)$$

where β_n are parameters of the model and $x_1, \ldots, x_n$ are the independent variables.

Initial models were developed using all of the individually significant variables at the p=0.25 as long as the independent variables were not significantly correlated. Then, insignificant variables were removed one at a time until either all of the variables were statistically significant or of theoretical significance. Log-likelihood tests were used to compare successive models.

5 RESULTS

The results of the binary logistic models are presented in three sections. The first provides models of making a change to transportation plans under different types of weather when winter weather begins or is projected to begin when the respondent is at work. The second is analogous to the first except the winter weather begins while the respondent is at home. The third section investigates the specific transportation changes that may be made.

5.1 Changing Transportation Plans When Winter Weather Begins While the Respondent is at Work

The final models for generally changing transportation arrangements or routes when winter weather starts or is forecasted to start while the respondent is at work are shown in Table 5. Only employed respondents were part of the dataset for these models. All of the models are statistically significant at the 0.05 (or better) level, which indicates that models using the independent variables are superior to models using constants only. None of the models have gender or race variables as significant factors. All of the intercept terms have negative parameters, indicating a reluctance to change travel behavior when winter weather begins at work. This is not unreasonable since many workers may be constrained by the mode of travel they chose in order to reach work. They may also wish to take the routes with which they are most familiar.

Table 5 Logit Models for Decisions to Change Transportation Plans with Work as the Origin

Weather Condition	Variable	Parameter Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Model ChiSq	Model Prob > ChiSq	N
Snow	Intercept	-0.95	0.41	5.30	0.021	17.14	0.001	289
	Number of Days Errands are conducted	-0.11 (0.90)	0.06	3.59	0.058			
	HHSIZE	+0.20 (1.22)	0.10	4.33	0.038			
	Road Conditions Very Important	+0.96 (2.61)	0.29	10.97	0.001			
Freezing Rain	Intercept	-0.06	0.14	0.18	0.675	4.92	0.027	239
	Income_$75-$100k	+0.84 (2.31)	0.39	4.62	0.032			
Heavy Rain	Intercept	-1.85	0.68	7.32	0.007	17.50	0.001	118
	Age of Youngest Child	-0.14 (0.87)	0.06	6.20	0.013			
	Errands Conducted on Weekdays	+1.04 (2.83)	0.55	3.63	0.057			
	Highways are normally used	+1.28 (3.60)	0.55	5.37	0.021			
Temperatures Below Freezing	Intercept	-1.93	0.65	8.79	0.003	17.39	0.006	112
	Age of Youngest Child	-0.14 (0.87)	0.06	5.44	0.020			
	Teleworking in an option for winter weather	+1.45 (4.26)	0.63	5.33	0.021			
	No pay for winter weather absences	+1.81 (6.10)	0.63	8.26	0.004			
Icy Roads	Intercept	-0.20	0.59	0.11	0.741	11.46	0.003	247
	Road Conditions Very or Somewhat Important	+1.32 (3.75)	0.61	4.68	0.031			
	School Decisions Somewhat Important	-0.93 (0.39)	0.35	7.11	0.008			

5.1.1 Snow starting at work

For snow, the variables significant at the p = 0.05 level or better are the household size and whether the respondent viewed road conditions as "very important" to their transportation and travel decisions. Larger households are more likely to make changes than smaller households. Potentially, respondents with larger households would provide transportation for other household members under snowy conditions or would make stops to pick up supplies or otherwise change their behavior to accommodate other household members' needs. Respondents who considered road conditions "very important" are 2.61 times as likely to make changes than respondents who considered road conditions "somewhat important," "not very important," or "not at all important." The AUC value for this model is 0.64, which indicates poor predictive power, despite the significance of the variables individually, and collectively.

5.1.2 Freezing rain starting at work

Under freezing rain conditions, respondents who have household incomes in the range of $75,000 to $99,999 are 2.31 times as likely to make changes than respondents from any other household income category. The AUC value for this model is 0.54, which indicates poor predictive power, despite the significance of the variable.

5.1.3 Heavy rain starting at work

For heavy rain conditions, the significant variables include the age of the youngest child, whether errands are conducted during weekdays, and whether the respondent typically uses highways. The negative parameter on the age of the youngest child indicates that the older the youngest child, the less likely the respondent is to make travel changes. This may reflect greater independence and ability to withstand heavy rain among older children. If errands are conducted during weekdays, the respondent is nearly three times more likely to change their travel plans, perhaps postponing some of these trips that may typically be conducted on the way home from work until a day with better weather. Finally, respondents who typically use highways for their commutes are 3.6 times as likely to make travel changes, perhaps preferring slower speeds of arterial roads under these weather conditions or anticipating that highways will experience congestion. The AUC value for this model is 0.77, indicating fair predictive capability.

5.1.4 Below freezing temperatures starting at work

For temperatures below freezing, the significant variables include the age of the youngest child and the work policies of having teleworking options or not paying the employee for missing work due to the weather. The negative parameter on the age of the youngest child indicates that the older the youngest child, the less likely the respondent is to make travel changes. This may reflect greater independence and ability to withstand below freezing temperatures among older children. Respondents with teleworking options are 4.26 times as likely to make travel changes as those without this option. These respondents may have been able to leave work early and work from home. Those who are not paid when they miss work because of the weather were over 6 times as likely to make travel changes. This may be due to a shift in transportation modes as these work policies are more common for wage based jobs rather than salaried employees and people with lower incomes are more likely to depend on transit, walking, or bicycle than higher income workers. The AUC value for this model is 0.79, indicating good/fair predictive capability.

5.1.5 Icy road conditions starting at work

When icy road conditions begin while the respondent is at work, the two statistically significant factors are whether the respondent considers the road conditions to be “very or somewhat important” and whether the school decisions are “somewhat important.” Those who consider the road conditions to be “very or somewhat important” are 3.75 times as likely to make changes compared to those who place little to no importance on road conditions, which is logical based on the condition examined. Respondents who considered school decisions to be “somewhat important” were less likely to make changes than those who considered school decisions to be “very important,” “not very important,” or “not at all important.” The AUC value for this model is 0.59, which indicates poor predictive power, despite the significance of the variables individually, and collectively.

5.2 Changing Transportation Plans When Winter Weather Begins While the Respondent is at Home

Table 6 presents the final models for generally changing transportation arrangements or routes when winter weather starts or is forecasted to start while the respondent is at home. All of the models are statistically significant at the 0.01 (or better) level, which indicates that models using the independent variables are superior to models using constants only.

Table 6 Logistic Regression Models of Changing Transportation Plans when Winter Weather Conditions Begin While the Respondent is at Home

Weather Condition	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Model ChiSq	Model Prob > ChiSq	N	Model AUC
Snow	Intercept	-1.02	0.40	6.37	0.012	21.52	0.0002	292	0.63 (poor)
	Errands –Num of Days	-0.14 (0.87)	0.06	5.91	0.015				
	Leisure - None	1.43 (4.17)	0.52	7.67	0.006				
	Leisure – on Sat	0.99 (2.68)	0.35	7.79	0.005				
	Road conditions very important	0.73 (2.08)	0.29	6.48	0.011				
Freezing Rain	Intercept	-1.22	0.41	8.76	0.003	19.31	0.0002	240	0.63 (poor)
	Family consideration very or somewhat important	1.00 (2.72)	0.38	7.1	0.008				
	School decisions very or somewhat important	-0.88 (0.41)	0.32	7.8	0.005				
	Employer decisions very or somewhat important	1.02 (2.78)	0.39	6.73	0.010				
Heavy Rain	Intercept	-0.42	0.41	1.04	0.308	12.15	0.0005	121	0.74 (fair)
	AgeYoungestKid	-0.20 (0.82)	0.06	9.43	0.002				
Below Freezing Temp.	Intercept	-0.76	0.47	2.63	0.105	12.82	0.0016	112	0.76 (fair)
	AgeYoungestKid	-0.20 (0.82)	0.07	7.66	0.006				
	No pay for weather absences	1.23 (3.43)	0.63	3.88	0.049				
Icy Roads	Intercept	0.07	0.27	0.06	0.806	19.69	<.0001	289	0.65 (poor)
	Road conditions very important	1.04 (2.83)	0.28	13.34	0.000				
	Household size minus adults	-0.26 (0.77)	0.13	4.31	0.038				

5.2.1 Snow starting at home

When snow begins while the traveler is at home, changing transportation plans depends on the number of days on which the person conducts errands, whether he/she conducts no leisure trips, whether he/she conducts leisure trips on Saturday, and whether he/she considers road conditions very important in his/her travel decisions. Although the predictive power indicated by the model AUC criterion falls into the “poor” range, the model is statistically significant at the 0.01 level, which indicates that the model using the independent variables is superior to a model using constants only. According to the parameter estimates and odds ratios, respondents who make trips for errands on a greater number of days are less likely to change their plans than those who travel for errands on fewer days. Perhaps those that conduct errands on more days have fewer necessary supplies stored at home and need to travel even during snowy conditions. Those who do not conduct any leisure travel are more likely to make changes than people who do make leisure trips. Those who conduct leisure travel on Saturdays are more likely to make changes than people who do not. Respondents who consider road conditions very important are twice as likely to change their plans compared to respondents who place lower importance on road conditions. These respondents are potentially more cautious and/or use more road based transportation.

5.2.2 Freezing rain starting at home

Although the predictive power indicated by the freezing rain model’s AUC criterion falls into the “poor” range, the model is statistically significant at the 0.01 level. The model for freezing rain depends on the importance the respondent places on different elements. Those who indicate family considerations are very or somewhat important are more than 2.5 times as likely to make changes as those who place lower importance on family considerations. This result makes sense since the needs of multiple people may need to be taken into account. Those that indicate school decisions are very or somewhat important are less likely to make changes. This may seem counterintuitive, except that when considering the effects of school decisions, one may also consider family. Adding the parameter estimates for the two variables results in a value of 0.12, which means that the person who indicates that both family and school decisions are very or somewhat important will be more likely to make changes. Finally, for those who consider employer decisions very or somewhat important, the odds of making a change are more than 2.5 times the odds for those who place less importance on employer decisions.

5.2.3 Heavy rain starting at home

For the heavy rain conditions, the model’s AUC criterion indicates fair predictive power and the model is significant at the 0.01 level. The only significant variable was the age of the youngest child. The older the child, the less likely the respondent is to change plans. This makes sense since rain is a fairly frequently experienced weather condition and older children are more likely to be able to handle the weather themselves than younger children.

5.2.4 Below freezing temperatures starting at home

The model for changing transportation plans when temperatures are below freezing has an AUC criterion indicating fair predictive power and is significant at the 0.01 level. The model includes the age of the youngest child and workplace policies as significant variables. Older children make the traveler less likely to make changes. Older children are probably more likely to be able to handle cold temperatures compared to younger children and thus require less travel accommodation on the part of parents. On the other hand, respondents who do not receive any pay for winter weather absences (e.g., wage employees) are more than three times as likely to make changes as those who are paid for such absences. Perhaps these respondents make changes to ensure that they can reach work.

5.2.5 Icy road conditions starting at home

Finally, despite an AUC value indicating poor predictive power, the model for icy roads is statistically significant at the 0.01 level. The statistically significant variables are considering road conditions very important and a variable representing the number of children in the household. Those who place the highest importance on road conditions are nearly 3 times as likely to make travel changes. More children in the household make the traveler less likely to make travel changes. This could be due to several factors not well captured by the survey, such as having someone else available to handle child related travel or already having the child related travel optimized.

5.3 Specific Changes in Transportation Plans

Binary logistic regression models were developed for specific changes when winter weather begins while the respondent is at work and when the weather begins while the respondent is at home. These results are shown in Table 7-Table 14. As shown in the tables, all of the models are significant at the p=0.01 level or better.

5.3.1 Cancelling a trip

As shown in Table 7, the explanatory variables for winter weather beginning at home or at work are different for the decision to cancel a trip or the commute.

The AUC value for the weather beginning at work model indicates "fair" predictive capabilities. The independent variables significant at the p=0.05 level are those that indicate a Hispanic ethnicity, teleworking options, and whether the respondent is responsible for child related travel. Respondents who identify themselves as Hispanic are less likely to cancel a trip than those who did not identify themselves as Hispanic. Possibly, the Hispanic respondents make fewer discretionary trips than other respondents. Although the number of trips is not captured in the survey, a larger proportion of Hispanic respondents (22.73%) reported 0 days on which leisure trips are made, than any other race/ethnicity. People with teleworking options are 3.5 times more likely to cancel a trip than those without this option. Finally, those with child related travel responsibilities are less likely to cancel a trip than those without this responsibility, which could reflect a need to make the trips as usual.

For weather beginning while the respondent is at home, the model has an AUC in the "poor" range although the model is significant at the 0.01 level. Two variables are significant at the 0.05 level. Respondents who have flexible work schedule options are more likely to cancel their commutes during winter weather than people without this option. Respondents who do not conduct errands on any day are less likely to cancel their commutes than people who do conduct errands. Respondents without errands may have more demanding and rigid work schedules.

Table 7 Cancelling a Trip

At Work: Cancel A Trip					At Home: Cancel Commute				
Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	1.38	0.46	8.92	0.003	Intercept	0.05	0.27	0.04	0.846
Hispanic 2	-1.85 (0.16)	0.70	6.92	0.009					
Telework OptWW	1.27 (3.55)	0.49	6.80	0.009					
ChildTravel Resp	-1.08 (0.34)	0.51	4.43	0.035					
					ErrNone	-0.91 (0.40)	0.43	4.55	0.033
					FlexSched OptWW	1.08 (2.94)	0.32	11.34	0.001
					EarnedLeave4 WWAbsence	0.60 (1.83)	0.33	3.35	0.067
					SchoolDecisions SomewhatImp	-0.69 (0.50)	0.39	3.11	0.078
Model ChiSq	18.41					20.85			
Model Prob > ChiSq	0.0004					0.0003			
N	113					209			
Model AUC	0.74	fair				0.68	poor		

5.3.2 *Delaying a trip/commute*

As shown in Table 8, the explanatory variables for weather beginning at home or at work are different for the decision to delay a trip or the commute.

According to the AUC classification of "poor," the model for weather beginning while travelers are at work has limited predictive capability, which is not surprising since only one independent variable is significant in the model. This variable is an indicator of whether the traveler normally makes stops. Those who normally make stops are 2.8 times as likely to delay a trip as those who do not normally stop.

For the model for the winter weather beginning while travelers are at home, the AUC indicates fair predictive power and the model is significant at the 0.01 level. The greater the number of days on which respondents commute, the less likely they are to delay the commute to work, which is likely due to work requirements. However, those who have winter weather absences from work excused are more than three times as likely to delay a commute as those who do not have this work policy. Those who consider employer decisions very or somewhat important are 3.74 times as likely to delay the commute as those who place lower importance on employer decisions. Respondents who consider school decisions somewhat important (but not very) are less likely to delay their commutes than people who place other importance levels on school decisions. This makes sense since people who consider school decisions very important would be more likely to tailor their travel to school decisions, such as delay openings. Those responsible for children (care - not necessarily travel) are less likely to delay their commutes. Perhaps this variable should be considered in conjunction with the school decisions.

Table 8 Delaying a Trip

At Work: Delay A Trip					At Home: Delay Commute				
Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	0.47	0.18	7.28	0.007	Intercept	3.59	1.50	5.70	0.017
Stops Normally01	1.04 (2.83)	0.29	12.61	0.0004					
					Com NumDays	-0.47 (0.62)	0.18	6.66	0.010
					WWAbsences Excused	1.21 (3.37)	0.52	5.40	0.020
					EmployVSImp	1.32 (3.74)	0.61	4.63	0.031
					SchoolDecisions SomewhatImp	-1.53 (0.22)	0.58	7.00	0.008
					ChildResp	-2.33 (0.10)	1.16	4.01	0.045
ChiSq	13.44					23.20			
Prob > ChiSq	0.0002					0.0003			
N	260					105			
Model AUC	0.62	poor				0.76	fair		

5.3.3 *Leaving early*

For the weather beginning while at home, no satisfactory model for commuting early was found in terms of predictive power. This is not entirely unexpected since weather may get worse and make it difficult for someone to get home if they do go to work. Those that absolutely have to be at work and would be likely to leave early (e.g., police officers) represent a minority of the population and may not have been captured in the survey.

Table 9 presents the results for departing early when weather begins while travelers are at work. The AUC for this model has "good" predictive power, although only 100 records are in the dataset for this model due to question non-response. Workers who commute more frequently are more likely to leave early when winter weather begins at work compared to those who commute less frequently. If winter weather absences are excused, the odds for these workers leaving early are 5.4 times the odds of workers without these policies available. This result is logical since workers with the policy available would not be penalized for leaving early. Having an older youngest child increases the likelihood of leaving work early. This result may seem counter-intuitive at first, however, very young children may be in day care rather than schools. There may be a little more flexibility in winter weather policies of day care centers compared to schools. It is also possible that the respondent's spouse would be able to care for the children instead of the respondent. Respondents who normally make stops during their commutes are 2.7 times as likely to leave work early as those who do not normally make stops. Perhaps the respondents who normally make stops still plan to make these stops and need more time to complete the additional travel before the weather conditions become too difficult.

Table 9 Departing Early from Work

Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	-3.30	1.06	9.65	0.002
ComNum Days	0.33 (1.39)	0.15	4.53	0.033
WWAbsences Excused	1.69 (5.42)	0.52	10.63	0.001
AgeYoungestKid	0.13 (1.13)	0.05	5.29	0.021
StopsNormally01	1.00 (2.72)	0.50	3.93	0.048
ChiSq		25.42727		
Prob > ChiSq		<.0001		
N		100		
Model AUC		0.81253	good	

5.3.4 Adding trips

Table 10 presents the models for adding trips. Again the variables are different, depending on when the winter weather begins.

According to the AUC value, for the case where the weather begins while the traveler is at work, the model has "fair" predictive capabilities. White (Caucasian) respondents are less likely than other races/ethnicities to add trips to their commutes. Respondents who participate in leisure activities on a greater number of days are more likely to add trips to their return commutes when winter weather conditions begin at work. Perhaps these respondents are more comfortable making additional stops since they are more accustomed to doing so. Households with more children increase the likelihood of adding trips to the commute. Respondents with more children may stop to pick up these children, even if they do not normally do so, or they may stop for items, such as groceries, particularly if the weather will make it difficult to shop in the coming days. Similarly, respondents who consider road conditions very or somewhat important in their decisions are more likely to add trips, potentially because they anticipate travel difficulties later. Finally, respondents for whom employer decisions are very or somewhat important have odds ratios 2.5 times those who place less weight on employer decisions for adding trips to the commute.

For the model corresponding to winter weather beginning while the traveler is at home, the AUC indicates fair predictive power. Those who normally make stops on a commute are more than 7 times as likely to add trips as those who do not normally make stops. This result indicates that the person responsible for making stops in good weather also takes this responsibility during poor weather. Those who have child travel responsibilities are less likely to add trips. Possible explanations include that they are more likely to stay home with the children during winter weather conditions or they simply conduct the child related travel without adding trips that would further subject the child to poor weather. Finally, those who normally use the bus are more likely to add trips.

Table 10 Adding Trips

At Work: Add Trips					At Home: Add Trips				
Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	-3.52	1.16	9.23	0.002	Intercept	-1.99	0.56	12.69	0.000
LeisNum Days	0.24 (1.27)	0.09	7.29	0.007	Stops Normally01	1.97 (7.20)	0.61	10.38	0.001
Employ VSImp	0.90 (2.46)	0.40	5.15	0.023	ChildTravel Resp	-1.10 (0.33)	0.50	4.77	0.029
Hhsizeminus adults	0.38 (1.46)	0.14	7.21	0.007	ModeBus	2.39 (10.86)	1.01	5.55	0.019
RoadCond VSImp	2.22 (9.19)	1.08	4.21	0.040					
White 2	-0.71 (0.49)	0.31	5.33	0.021					
ChiSq		37.87				21.53			
Prob > ChiSq		<.0001				<.0001			
N		246				107			
Model AUC		0.72	fair			0.77	fair		

5.3.5 Changing Destinations

Changing destinations was considered for the case where winter weather begins at work. The model is shown in Table 11. Despite the high significance of the model, the AUC for this model classified the predictive capability as poor. Increasing the number of days on which leisure trips are conducted increases the likelihood of changing the destination of a trip during winter weather. Perhaps the destinations of leisure trips are altered during winter weather or that portion of the trip is canceled altogether. Respondents for whom employer decisions are very or somewhat important to travel decisions are over 4 times more likely to change destinations as respondents placing less importance on employer decisions. The timing of employer decisions may influence how much time commuters feel they have to complete typical discretionary trips and may pick closer destinations to work or home (e.g., for groceries).

Table 11 Changing Destinations When Winter Weather Begins at Work

Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	-1.61	0.40	16.54	<0.0001
LeisNum Days	0.164 (1.179)	0.08	4.00	0.046
Employ VSImp	1.467 (4.334)	0.37	15.53	<0.0001
ChiSq		22.813		
Prob > ChiSq		<.0001		
N		262		
Model AUC		0.66	poor	

5.3.6 Changing routes

Table 12 presents the models for changing routes. The variables are different, depending on when the winter weather begins.

Despite the high significance of the model, the AUC for the weather beginning at work model classified the predictive capability as poor. While 62% of respondents indicated a change in route, only two variables are significant at the p=0.05 level. A greater number of days on which leisure trips are conducted increases the likelihood of changing routes; perhaps due to the addition or subtraction of such trips. Respondents for whom family considerations are very or somewhat important in travel decisions are more than three times as likely to change routes as those who place less importance on family considerations. Potentially, those with family priorities change routes to pick up children or spouses or to prepare for the weather.

For the model corresponding to winter weather beginning at work, the AUC indicates poor predictive power despite the model's significance at the 0.01 level. Those who have flexible work schedules are more likely to change routes than those who do not have this work policy. Perhaps employees with flexible schedules take a different route if they travel at a different time during winter weather compared to good weather due to expected traffic conditions. Not surprisingly, people who drive alone are more likely to change routes than other mode users, driving alone offers the most travel flexibility. Finally, those who conduct errands on a greater number of days are more likely to change routes. These travelers may be more familiar with travel route alternatives due to their experience traveling for errands.

Table 12 Changing Routes

At Work: Change Route					At Home: Change Route				
Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	-0.85	0.35	6.10	0.01	Intercept	-1.64	0.46	12.89	0.00
LeisNumDays	0.18 (1.19)	0.09	4.21	0.04	FlexSched OptWW	0.73 (2.07)	0.28	6.61	0.01
FamilyVSImp	1.18 (3.26)	0.31	14.49	0.00	ModeDA 2	0.68 (1.98)	0.39	3.06	0.08
					ErrNumDays	0.10 (1.11)	0.06	2.97	0.09
ChiSq		18.82					12.26		
Prob > ChiSq		<.0001					0.0065		
N		269					262		
Model AUC		0.64	poor				0.63	poor	

5.3.7 Using more highways

Table 13 presents the results for the models of using more highways. In both cases, the types of roads normally used influence the likelihood of using more highways during winter weather. Conducting leisure trips on weekdays and importance placed on school decisions are also significant to both models.

According to the AUC value, the model for weather beginning at work has "fair" predictive capabilities. Those conducting leisure trips on weekdays are less likely to use more highways when winter weather begins at work. If these leisure trips are still conducted, the destinations are not located on highways and the normal patterns are likely to be followed. Respondents who conduct errands on the weekends are less likely to use more highways than those who do not conduct errands at all or just not on the weekends. This may reflect familiarity and comfort with the use of local roads. Respondents for whom school decisions are very or somewhat important are less likely to use more highways than respondents for whom school decisions take on lower importance. This result is intuitive since schools are typically located on local roads and respondents may choose to pick up their children or simply follow normal travel patterns. Finally, respondents who normally use highways are over 6 times more likely to use more highways than normal compared to respondents who use other types of roads. This result again reflects a familiarity and comfort with the type of road typically used. Overall, this model reflects the importance of familiarity with different types of roads and their selection for winter weather conditions.

Table 13 Using More Highways

At Work: Use More Highways					At Home: Use More Highways				
Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	0.70	0.40	3.08	0.08	Intercept	-0.60	0.96	0.39	0.53
ErWkEnd	-0.70	0.34	4.29	0.04	TeleworkOptWW	1.08	0.35	9.27	0.00
	(0.50)					(2.93)			
LeisWkDay	-0.66	0.32	4.20	0.04	LeisWkDay	-0.88	0.35	6.20	0.01
	(0.52)					(0.41)			
RoadNHwy 2	1.81	0.32	31.36	<.0001	RoadNLocal	-2.02	0.35	33.79	<.0001
	(6.11)					(0.13)			
SchoolVSImp	-0.72	0.34	4.55	0.03	EmployerDecisions SomwhatImp	0.80	0.40	4.13	0.04
	(0.49)					(2.24)			
					RoadCondVSImp	2.16	0.92	5.54	0.02
						(8.68)			
					SchoolVSImp	-0.92	0.38	6.04	0.01
						(0.40)			
ChiSq		48.46				71.64			
Prob > ChiSq		<.0001				<.0001			
N		212				203			
Model AUC		0.76	fair			0.83	good		

The model for winter weather beginning while the traveler is at home has good predictive capabilities and is highly significant. Respondents with teleworking options are more likely to use more highways. Those conducting leisure trips on weekdays are less likely to use more highways when winter weather begins at home. If these leisure trips are still conducted, the destinations are not located on highways and the normal patterns are likely to be followed. Those who normally use more local roads are less likely to use more highways during winter weather; perhaps their destinations are not easily accessible by highway or they stay with the roads with which they are more familiar. Respondents who consider employer decisions somewhat important are more likely to use more highways. Those who consider road conditions very or somewhat important are more likely to use more highways, perhaps believing that these roads will be well treated for winter conditions. Respondents for whom school decisions are very or somewhat important are less likely to use more highways than respondents for whom school decisions take on lower importance. This result is intuitive since schools are typically located on local roads and respondents may choose to drop off their children or simply follow normal travel patterns.

5.3.8 Changing modes

Table 14 presents the models for changing transportation modes. Regardless of when the winter weather conditions begin, those who normally drive alone are less likely to change modes of transportation. This mode of transportation is likely the most comfortable during cold and wet weather.

Despite the high significance of the model, the AUC for the model with weather beginning while the traveler is at work classified the predictive capability as poor. This limited capability is not surprising since only one variable is significant besides the intercept. The negative intercept reflects an inherent inertia in changing modes of transportation (Murray-Tuite, Wernstedt et al. 2014), which is not particularly surprising when winter weather begins while commuters are at work since their options are limited by a combination of the transportation options available (e.g., transit) and the mode of transportation they selected in order to reach work (e.g., if they did not drive to work, they typically cannot drive home).

The model for changing modes when winter weather begins when the traveler is at home has good predictive power and is highly significant. Those who do not conduct leisure trips are more likely to change modes of transportation; perhaps they do not normally trip chain and have fewer logistics to work out if they change modes of transportation. Respondents who self-classified as Black/African American are more likely to change modes of transportation. Finally, greater levels of income decrease the likelihood of changing transportation modes but this variable is not significant at the p=0.05 level.

Table 14 Change Modes

At Work: Change Modes					At Home: Change Modes				
Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq	Variable	Estimate (odds ratio)	Std Err	Chi Sq	Prob> ChiSq
Intercept	-0.69	0.34	4.16	0.041	Intercept	0.15	0.75	0.04	0.841
ModeDA 2	-1.81 (0.16)	0.42	18.77	<.0001	ModeDA 2	-3.15 (0.04)	0.71	19.45	<.0001
					LeisNone	2.40 (10.97)	0.85	8.03	0.005
					Black 2	2.36 (10.55)	0.84	7.83	0.005
					IncContin	-9.32×10^{-6} 1.00	0.00	3.72	0.054
ChiSq		17.06				34.90			
Prob > ChiSq		<.0001				<.0001			
N		278				215			
Model AUC		0.66	poor			0.88	good		

6 CONCLUSIONS

Winter weather affects travel behavior in a variety of ways. Using survey data from the Northern Virginia commuting area of Washington, DC, this study examined a variety of travel-related changes under different types of winter weather and the factors influencing the likelihood of making a given change. In particular, the types of weather and related conditions included snow, freezing rain, heavy rain, below-freezing temperatures, and icy roads. Two timing cases for these conditions were considered: (1) beginning while the respondent is at work and (2) beginning while the respondent is at home. The travel-related changes investigated included: (1) cancelling trips, (2) delaying trips, (3) departing early, (4) adding trips, (5) changing destinations, (6) changing routes, (7) using more highways/freeways, and (8) changing modes of transportation. The statistically significant factors were different for the different decisions and weather conditions, emphasizing the complexity of predicting demand for winter weather.

The models of the likelihood of changing transportation plans when snow begins at work and at home have some similar and some different factors. Both models have a positive coefficient for road conditions being very important, meaning that travelers with these concerns are more likely to make changes in snowy conditions. This factor allows a tie among weather, road treatments, and travel decisions. While road conditions will inevitably be affected by the weather, the better the roads are treated and plowed, the more likely travel will be closer to normal. The number of days on which errands are conducted has a negative effect on the likelihood of changing transportation plans on both timing models. This suggests that some errands might be viewed as essential regardless of weather and/or a confidence and comfort with normally selected routes and travel plans in general. Aside from those two variables, the variables in the snow models differ depending on where the respondent is when the snow begins. When the respondent is at work, larger households have higher likelihoods of changing plans, perhaps to account for household member needs and interactions – factors that can be explored in the future through more in-depth interviews. When the respondent is at home when the snow begins, variables related to leisure trips are significant, indicating that multiple types of trips have interacting effects on travel plans.

For the models of the likelihoods of changing transportation plans in freezing rain, the significant variables are different. The only variable for the model when the weather begins at work is an income category. The variables for the weather beginning at home are all subjective evaluations of the importance of different considerations: family, school, and employer. These factors are more difficult to extract to the general population; however, surrogate measures can be investigated in the future, such as binary indicators of school age children in the household and types of employment.

For heavy rain, the age of the youngest child is significant in both models and with the same direction of effect. Having an older youngest child makes the respondent less likely to change transportation plans, suggesting that household concerns (e.g., concern for the comfort and health of young children) and household member interactions significantly impact travel decisions in adverse weather. This is the only variable significant when the weather begins at home. For the case when the weather begins at work, the influential variables suggest comfort with travel. Respondents conducting errands on weekdays and using highways/freeways normally are more likely to make changes.

Continuing with concern for the health and comfort of younger children, both models for below-freezing temperatures have the age of the youngest child as an influential variable. The other variables are related to workplace policies. Not being paid for winter weather absences increases the likelihood of making changes in both models. In the model of the weather beginning at work, teleworking options also increase the likelihood of making changes. While the specific workplace policies might be difficult to extend to the population, the type of work is something that is typically captured by Census surveys and may serve as a surrogate measure in future data collection and modeling efforts.

For the models relating to icy roads, concern for the road conditions is naturally a significant factor. Respondents indicating that road conditions are very (starting at home) or very or somewhat important (starting at work) to their travel decisions are more likely to make changes. The other variables are at least somewhat related to children—school decisions somewhat important (starting at work) and number of children (starting at home). These variables have a negative effect on the likelihood of making changes, emphasizing the role of household member interactions.

For the types of changes respondents indicated they would make, the ranks of each type of change were fairly consistent for winter weather beginning while the travelers are at work and when they are at home. The most common change is to cancel a trip/commute, followed by delaying a trip/commute, leaving early, and routing issues. The least common change is in mode of transportation. The preference to change departure time and/or routes instead of modes of transportation is consistent with the literature related to planned and unplanned disruptions (e.g., Hendrickson, Carrier et al. 1982, Meyer 1985, Mokhtarian, Ye et al. 2009, Kontou 2013).

Among the variables significant to the models of cancelling a trip are workplace policies and child-related variables. Workplace policies allowing flexibility increase the likelihood of canceling a trip, for weather beginning at both work and home. As mentioned above, extrapolating workplace policies to the general population may be accomplished with surrogate measures of the types of employment in the future. The child-related variables—child travel responsibility (beginning at work) and school decisions somewhat important (beginning at home)—decrease the likelihood of cancelling trips, again emphasizing the role of household member interactions.

Variables statistically significant to the decision to delay a trip differ depending on where the respondent is when the winter weather begins. For the case where the respondent is at work, the only variable is whether he/she normally makes stops on the way home from work. To extend this information to the population, similar techniques to examining trip chaining behavior (e.g., from travel diaries) can be used. For the case where the respondent is at home, workplace policies and expectations, school decisions, and child care responsibilities are significant, suggesting that many factors interact in this decision. These variables may need surrogates for modeling the larger population.

Leaving work early for winter weather depends on workplace policies, household considerations and interactions, and normal trip chaining. Departing early is a generally expected behavior and all of the identified factors increase the likelihood of leaving early.

Models of adding trips during winter weather have a wide variety of types of variables, including child considerations, race, normal travel decisions (e.g., leisure travel, trip chaining, mode of transportation), and importance associated with employer decisions and road conditions. Aside from the importance variables, data for the variables can come from regular travel surveys. The importance for employer decisions might be able to be inferred by type of employment. Road condition importance might be able to be inferred by types of commuting modes.

The model for changing destinations when winter weather starts at work includes leisure trip considerations and the importance of employer decisions. For the larger population, normal travel surveys can inform the first term while surrogates as mentioned above may be used for the second.

The statistically significant variables for the models of changing routes are completely different depending on where the respondent is when the winter weather begins. However, in both models, non-work trip frequency (leisure, starting at work; errands, starting at home) increases the likelihood of changing routes, suggesting that familiarity with the network can encourage route changes. Family importance encourages route changing when weather begins at work. For weather beginning at home, people who normally drive alone are more likely to change routes, which is logical since the drive-alone mode offers the most flexibility. The non-work trips and regular mode choice data for the larger population may come from normal travel surveys. The flexible work schedule option (significant to the model when weather begins at home) will likely need a surrogate measure.

Variables statistically significant in the models of the decision to use more highways/freeways during winter weather include non-work trip behavior (leisure trips and errands), school decisions, and normal road type choices. These variables imply consideration of the locations of the non-work activities and general comfort with the highways. Other variables for the case when winter weather begins at home, are related to work decisions and workplace policies.

Finally, the models of changing modes both include a variable indicating whether the respondent normally drives alone. In both cases, this variable has a negative effect on the likelihood of changing modes. For the case when the weather begins at home, the other variables are related to socio-demographic and economic characteristics and whether leisure trips are conducted. For the larger population, data for all of these variables are available from the Census and/or normal travel surveys.

Despite the models' statistical significance, the predictive power of several of the models is less than desirable. Thus, while this study increases the understanding of the factors influencing winter weather travel behavior, there is still more to investigate. Among the key issues are household member interactions. Better understanding of these interactions will require more of an interview approach than a survey, at least to start. Subsequent surveys, extending the findings from the interviews, and using the surrogate measures suggested above with large sample sizes should then be conducted.

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