BUILT ENVIRONMENT AND TRIP GENERATION FOR NON-MOTORIZED TRAVEL

Felipe Targa, MRP
Doctoral student
Department of Civil and Environmental Engineering
University of Maryland - College Park
1173 Glenn L. Martin Hall
College Park, MD 20742
Telephone: (202) 213-2892
www.wam.umd.edu/~ftarga
Email: ftarga@umd.edu

Kelly J. Clifton, Ph.D.
Assistant Professor
Department of Civil and Environmental Engineering
University of Maryland - College Park
1173 Glenn L. Martin Hall
College Park, MD 20742
Telephone: (301) 405-1945
Fax: (301) 405-2585
Email: kclifton@umd.edu

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INTRODUCTION

Theoretically, trip generation rates are expected to vary with different levels of accessibility. Some authors have argued that in urban environments where destinations are close by or more accessible, the cost per trips will be lower, and consequently, higher trip generation rates are expected (*1*). If there are cases where differences in trip generation rates can be attributed to differences of the built environment, they will also depend on the elasticity of the demand for travel with respect to changes in accessibility. The degree and existence of this effect is also moderated by particular travel-activity attributes, such as trip purpose or mode of travel, as well as individual and household socio-demographic characteristics.

Over the last decade, researchers have focused on empirically testing the effect of several measures of urban form and neighborhood-level characteristics on travel demand (see *2* and *3* for a review of built environment and urban form impacts on different travel outcomes). Overall, results from the most disaggregated and carefully controlled studies suggest that effects on trip generation rates depend mainly on household socio-economic characteristics and that travel demand is inelastic with respect to accessibility (*3*). Nonetheless, some studies have also shown that urban environments with higher densities, a mix of land uses, and grid-style street configurations are associated with higher frequencies for walking/biking and other non work-based trips (*4, 5, 6, 7, 8, 9*, and *10*).

Within the existing empirical studies, questions remain about the degree of trip substitution effects among different modes of travel and issues of self-selectivity (*e.g.*, people who prefer walking/biking choose to live in built environments that facilitate that behavior as opposed to the urban form influencing their behaviors). The empirical analysis conducted in this paper contributes to the general understanding of the relationship between land use and travel behavior by testing the effects of several urban form/design characteristics and traveler attitudes on the frequency of walking.

METHODOLOGY AND DATA DESCRIPTION

This paper analyzes the effect of the built environment associated with measures of land use, urban form, and neighborhood-level design characteristics on trip generation rates for non-motorized travel such as walking. The primary data source of the study is the 2001 National Household Travel Survey (NHTS), in particular the additional 3,446 households surveyed from June 2001 through July 2002 in the Baltimore metropolitan region. Households were randomly selected for participation in the Baltimore add-on sample. The survey was gathered through computer assisted telephone interviews (CATI). In order to be consistent with the national data, the 2001 NHTS add-on survey was conducted following basically the same definitions and procedures of the 2001 NHTS national sample.

Land use and urban form/design attributes used in the empirical examination were obtained from several sources such as Census and County TIGER-enhanced files for year 2000. Household locations were geocoded based on the respondent-provided closer location of place of residence. Using Geographic Information Systems (GIS), land use, urban form, and neighborhood-level design characteristics were assigned to each household record based on its geographic location. Most of these measures were operationalized following the procedures of previous studies that aimed to characterize various attributes of the built environment (*12, 13*). This effort has been aided by the advent of geographic information systems and increasing availability of land-use and transportation data in electronic format. Census 2000 sociodemographic information was also obtained for the research study area. The geographic area of analysis considered in this paper is restricted to the City of Baltimore. In this restricted area, there were 1,539 surveyed households (Figure 1), which correspond to 2,934 persons with reported travel-day data.

[Insert Table 1]

Conceptually, we expect that neighborhoods with higher densities, fine land use mixes, better street connectivity, and generally better access to transit, parks and commercial-shopping areas would be associated with higher frequency of walking trips. Since shopping trips and other non work-based trips tend to be more elastic with respect to accessibility and more likely to be done by non-motorized modes, differences in urban form and design attributes are expected to be more influential for these trips.

Walking trip generation rates were calculated at the person-level for all members with reported travel-day data (24-hour period) in the sampled households for the area of study. In particular, number of walking trips per person in a given day is positive integer or count-type data. Given the nature of the data, a Poisson regression model was considered the most appropriate methodological approach to employ in this particular study. In a Poisson model specification, a random variable indicates the number of events (*e.g.*, walking trips) a person makes during an interval of time (*e.g.*, during the day of travel). In the regression model, the number of events y has a Poisson distribution with a conditional mean that depends on household or travelers' characteristics, trip characteristics, and land use/urban form attributes according to the following structural model:

$$\mu_i = E(y_i | x_i) = \exp(x_i \beta)$$

where $\boldsymbol{x}_i$ is a row vector with the observations of the explanatory variables for each person, and $\boldsymbol{\beta}$ is a column vector of estimated coefficients associated to each explanatory variable. This structural model is estimated by means of Maximum Likelihood (ML) to test the statistical significance of built environment measures on trip generation rates for non-motorized travel.

Based upon the availability of new variables in the 2001 NHTS, the conceptual structure and model specification take into account additional factors intended to make the modeling of the travel decision-making process more behavioral and descriptive. Recent studies of the relationship between land use and travel behavior (*11*) have recognized that travel-related choices are expected to not exclusively depend on objective measures of the transportation system or the land use characteristics, but also on the perceived subjective attributes of the system. In addition to control for traditional socioeconomic and demographic characteristics, and trip-related attributes, the analytical methods employed in this paper use attitudinal and perceptual data as proxies for socio-psychological factors influencing travel- and activity-related outcomes. Perceptual data used in this study include attitudes toward traffic accidents, highway congestion, the presence of drunk drivers on the road, lack of sidewalks and walkways, and price of gas. The existence of a medical condition is also expected to influence travel behavior by limiting driving or use of transit or simply by traveling less.

The last group of explanatory variables consists of urban form, neighborhood design, and land use attributes associated to the geographic location of each person's household. Although several variables were constructed using GIS-based data, household units density at the Census block-level, street connectivity (measured as the perimeter of the Census block), proportion of vacant household units at the Census block-level, distance to the nearest bus stop, proportion of area designated to parks in the Census block, and proportion of household units within ¼ of mile of commercial land uses were the group of variables selected based on statistical and study-specific considerations. Neighborhood sociodemographic characteristics were also obtained at the Census block-level for year 2000. Table 1 presents summary statistics for the set of dependent and explanatory variables for the area of analysis (Baltimore City).

[Insert Table 1]

MODEL ESTIMATION

This section presents the estimation results for the model discussed in the preceding section. The coefficients of the explanatory variables included in the model specification are estimated by means of ML, and represent the relative effect of the associated variable on the frequency of walking. Expansion factors or analysis weights commonly used to avoid bias in the statistical analyses were not necessary because of the properties of ML estimation. Particular attention is devoted to the estimates of the built environment measures, which constitute the primary interest of this study.

The structural model was estimated under three different specifications. The first model includes only traditional household and person socio-economic characteristics (Model 1, Table 2). The second model includes all variables used in Model 1 along with attitudinal and perceptual data of the urban and transportation system (Model 2, Table 2). The last model includes all variables used in Model 2, as well as all the built environment attributes and the neighborhood sociodemographic characteristics (Model 3, Table 2).

[Insert Table 2]

Table 2 summarizes the corresponding coefficient estimates, *t* statistics, and the statistical significance test for each coefficient. All models were statistically significant at the 99% confidence level ($p<0.001$ for the $\chi 2$ test). The model specification with traditional explanatory variables for trip generation models (Model 1) explains ten percent of the variability of frequency of walking for the region of analysis (adjusted-R^2= 0.10). Among household characteristics, lower number of vehicles and higher number of bicycles per household member, college dorms, and lower household income are associated with higher frequency of walking, as expected. Characteristics of persons associated with higher frequency of walking include young, male, non licensed driver, temporarily absent from a job or looking for work, professional category if working, healthy, graduate, and people that frequently walk for exercising and have their work location closer from home.

By adding the attitudinal variables to the model specification, the explanatory power of the model increases by 11 percent with respect to Model 1. In particular, Model 2 explains 11 percent of the variability of frequency of walking (adjusted-R^2= 0.11). Among the attitudinal variables, the estimated coefficients suggest that people more concerned with traffic accidents, highway congestion, and drunk drivers in the road are likely to walk more frequently than people less concerned with these system perceptions. Interestingly, people that expressed more concerned for the prices of gas are less likely to walk, probably reflecting the fact that frequent drivers are the ones that complain more about the price of gas. Perceptions stating that the conditions of sidewalks presented “a little” and “somewhat” of a problem are associated with higher frequency of walking trips.

A particularly notable finding of this analysis is the statistical significant association between built environment attributes and frequency of walking. Comparing the overall performance of Model 3 (adjusted-R^2=0.14), the explanatory power of the model increases by 26 percent with respect to Model 2, and 36 percent with respect to Model 3. Although any of the estimated models explains a significant proportion of the variance in the frequency of trips, the primary interest of the study lays on the significant effect that built environment variables have on the non-motorized trip generation variable. In particular, and congruent with the conceptual structure, people living in denser urban forms, measured as the number of household units per square mile in the corresponding household Census block, tend to walk more frequently in a given day of travel, all else being equal. Likewise, people living in neighborhoods with higher street connectivity or with more gridlike street networks, measured as the perimeter of the corresponding household Census block, are likely to walk more frequently in a day of travel. The presence of higher proportions of vacant household units in the neighborhood is associated with lower frequency of walking. This variable is probably capturing confounded effects such as safety perceptions. Access to transit is also statistically associated with higher frequency of walking, as expected. In particular, people living closer from a bus stop tend to walk more frequently in a day of travel. Although the test for the variables capturing the mixed of land uses, including access to commercial land uses and parks, did not reach the 90% confidence level, their positive sign suggests that more mixed land use and access to open space are also associated with higher frequencies of walking.

Surprisingly, even after controlling for household units density, population density is statistically significant and carries a negative sign. The high degree of multicolliniarity between the two density variables theoretically affects the power of the test, and if they are indeed measuring the same effect, the tests of the estimated coefficients would tend to be rejected. Nonetheless, both coefficients are statistically significant and with opposite signs. The last set of estimated coefficients suggests that people living in neighborhoods with lower median age and higher white population proportion are likely to walk more frequently in a day of travel.

CONCLUDING DISCUSSION

Although the proposed methodology and conceptual structure in this paper advances on the understanding of the relationship between land use and travel behavior, more detailed data of the travel decision-making process on consecutive days of travel is perhaps required in order to formalize the analytical approach. There are also major limitations regarding the analytical models given the self-selectivity problem discussed previously. The use of cross-sectional data precluded us to specify a conceptual model that could capture the endogenous processes found in travel decision-making. These processes include the interactions among short-term activity and travel choices and long-term decisions such as auto ownership, residential and job location, and lifestyle. Endogeneity in the model estimation would yield inconsistent (biased) estimates of the relationships described in the study. Future research will be benefited by better data availability that will come from the new release of the 2001 NHTS, when travel data tabulation for the long-period of travel will be ready.

Another potential limitation of the study is the degree of generalization of the results that can be drawn from the empirical study. Although the additional surveys on the Baltimore region were randomly selected, and previous analysis of this dataset have shown that the sample is representative of the population (*14*), there is some caution with respect the potential transferability of the study results to different locations. In addition to these issues, a full-length version of this paper will suggest additional research and data needs, including an evaluation of the 2001 NHTS in terms of its suitability for studies of non-motorized transport, and offering suggestions for future NHTS efforts.

Even with the potential limitations of the study, the results of this paper are highly relevant for transportation planning practitioners and researchers contributing to improve our understanding on the relation between land-use and travel behavior. In particular, effects of the built environment on trip generation rates for walking are significant and add a considerable proportion of the variance of the trip frequency variable. These results are expected given the theoretical high elasticity of demand for non-motorized trips with respect to accessibility. Ultimately, the empirical evidence provided in this paper will contribute to the growing body of literature aiming to reduce the uncertainty for those that either support or question the rationale of “new urbanism” planning policy directions as a tool for leveraging the demand for travel and promoting non-motorized travel.

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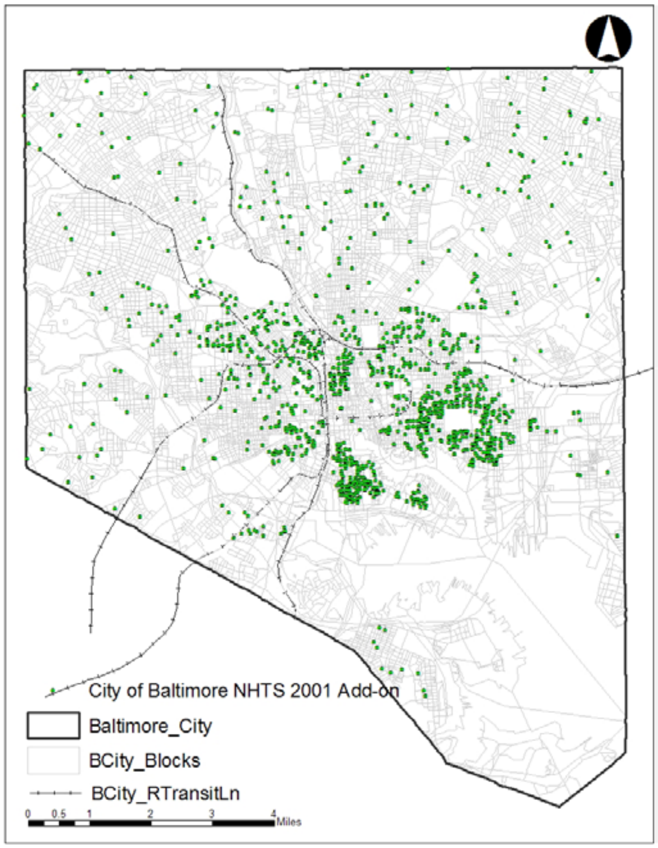

FIGURE 1 2001 NHTS Baltimore add-on (City of Baltimore – surveyed households)

TABLE 1 Data Description and Summary Statistics

Variable Name	Variable Label / Response Category Description	Valid N	Mean	Std. Dev.	Min.	Max.
Dependent Variable						
WALK_TRIPS	Number of Walking Trips in the Surveyed Day	2,934	0.80	1.48	0	12
Household Characteristics						
VEH_HH	Number of Vehicles in Household per Household Member	2,934	0.53	0.47	0	4.5
BIKES_HH	Number of Full Size Bicycles per Household Member	2,932	0.25	0.41	0	4
HOMETYPE	Type of Housing Unit					
HOMETYPE_1	Detached single house	2,931	0.13	0.34	0	1
HOMETYPE_2	Duplex, triplex	2,931	0.02	0.15	0	1
HOMETYPE_3	Row house, townhouse	2,931	0.62	0.49	0	1
HOMETYPE_4	Apartment, condominium	2,931	0.22	0.41	0	1
HOMETYPE_5	Dorm room, fraternity or sorority house	2,931	0.00	0.03	0	1
HOMETYPE_6	Semi-attached/Semi-detached house	2,931	0.00	0.04	0	1
HOMETYPE_7	Boat	2,931	0.00	0.05	0	1
HOMEOWN	Housing Unit (=1 Owned, =0 Rented)	2,925	0.62	0.49	0	1
HHFAMINC	Household Income (=1 $30K or less, =0 $30K and more)	2,934	0.27	0.45	0	1
Individual Characteristics						
R_AGE	Age (Years)	2,891	41.26	22.61	0	96
R_SEX	Gender (=1 Female, =0 Male)	2,934	0.57	0.50	0	1
DRIVER	Driver Status (=1 Driver, =0 Non Driver)	2,933	0.58	0.49	0	1
PRMACT	Working/School Status Last Week					
PRMACT_1	Working	2,933	0.44	0.50	0	1
PRMACT_2	Temporarily absent from a job or business	2,933	0.03	0.16	0	1
PRMACT_3	Looking for work	2,933	0.02	0.14	0	1
PRMACT_4	A homemaker	2,933	0.04	0.21	0	1
PRMACT_5	Going to school	2,933	0.05	0.22	0	1
PRMACT_6	Retired	2,933	0.21	0.40	0	1
PRMACT_7	Doing something else	2,933	0.06	0.24	0	1
WKFTPT	Work Status (=1 Full-Time, =0 Part-Time)	2,934	0.41	0.49	0	1
OCCCAT	Occupation Category					
OCCCAT_1	Sales or service	2,934	0.13	0.34	0	1

OCCCAT_2	Clerical or administrative support	2,934	0.07	0.25	0	1
OCCCAT_3	Manufacturing, construction, maintenance	2,934	0.05	0.22	0	1
OCCCAT_4	Professional, managerial, or technical	2,934	0.24	0.42	0	1
OCCCAT_5	Transportation/Machine operator	2,934	0.00	0.05	0	1
OCCCAT_6	Military	2,934	0.00	0.03	0	1
OCCCAT_7	Police/Firefighter/Corrections officer	2,934	0.00	0.03	0	1
COMMDRVR	Drive Licensed Vehicle as Part of Work (=1 Yes, =0 No)	2,934	0.07	0.25	0	1
DISTTOWK	One-Way Distance to Work - Miles	2,905	4.45	10.59	0	200
NWALKTR	Number of Outside (Exercising) Walk Trips in Past Week	2,919	0.24	0.66	0	7
NBIKETR	Number of Outside (Exercising) Bike Trips in Past Wk	2,928	0.00	0.08	0	3
MEDCOND	Med Condition Makes Travel Out of Home Difficult (=1 Yes, =0 No)	2,930	0.12	0.33	0	1
EDUCATION	Highest Grade of School Completed (=1 Graduate, =0 Other)	2,923	0.15	0.36	0	1
Attitudes / Perceptions						
DTACDT	Worry About Traffic Accident					
DTACDT_1	1 - Not a problem	2,922	0.05	0.21	0	1
DTACDT_2	2 - A little problem	2,922	0.03	0.17	0	1
DTACDT_3	3 - Somewhat of a problem	2,922	0.03	0.17	0	1
DTACDT_4	4 - Very much of a problem	2,922	0.01	0.10	0	1
DTACDT_5	5 - A severe problem	2,922	0.02	0.14	0	1
DTCONJ	Worry About Highway Congestion					
DTCONJ_1	1 - Not a problem	2,860	0.16	0.36	0	1
DTCONJ_2	2 - A little problem	2,860	0.09	0.29	0	1
DTCONJ_3	3 - Somewhat of a problem	2,860	0.13	0.33	0	1
DTCONJ_4	4 - Very much of a problem	2,860	0.08	0.28	0	1
DTCONJ_5	5 - A severe problem	2,860	0.10	0.30	0	1
DTDRUNK	Worry About Drunk Drivers					
DTDRUNK_1	1 - Not a problem	2,913	0.05	0.21	0	1
DTDRUNK_2	2 - A little problem	2,913	0.02	0.14	0	1
DTDRUNK_3	3 - Somewhat of a problem	2,913	0.01	0.12	0	1
DTDRUNK_4	4 - Very much of a problem	2,913	0.01	0.12	0	1
DTDRUNK_5	5 - A severe problem	2,913	0.04	0.21	0	1
DTGAS	Worry About Price of Gasoline					
DTGAS_1	1 - Not a problem	2,817	0.17	0.38	0	1

DTGAS_2	2 - A little problem	2,817	0.09	0.29	0	1
DTGAS_3	3 - Somewhat of a problem	2,817	0.11	0.31	0	1
DTGAS_4	4 - Very much of a problem	2,817	0.06	0.23	0	1
DTGAS_5	5 - A severe problem	2,817	0.12	0.32	0	1
DTWALK	Worry About Poor Walkways or Sidewalks					
DTWALK_1	1 - Not a problem	2,922	0.09	0.28	0	1
DTWALK_2	2 - A little problem	2,922	0.02	0.14	0	1
DTWALK_3	3 - Somewhat of a problem	2,922	0.01	0.11	0	1
DTWALK_4	4 - Very much of a problem	2,922	0.01	0.07	0	1
DTWALK_5	5 - A severe problem	2,922	0.01	0.09	0	1
Urban Form, Neighborhood Design and Land Use Attributes						
HHDENSITY	Household Density at the Census Block-Level (household units / mile^2)	2,857	9.34	0.92	1.95	11.71
STCONNECT	Street Connectivity (Census Block's perimeter in miles)	2,934	0.34	0.26	0.07	3.01
VACANT	Proportion of Vacant Household Units at the Census Block-Level	2,857	0.15	0.13	0.00	0.91
TRANSITACC	Transit Accessibility (distance in miles to the nearest bus stop)	2,934	0.08	0.06	0.05	0.35
PARKS	Proportion of Census Block's Area Designated to Parks	2,934	0.06	0.12	0.00	0.89
MIXUSE	Proportion of Household Units within 1/4 Mile of Commercial Uses	2,934	0.94	0.14	0.09	1.00
Neighborhood Socio-Demographics						
POPDENSITY	Population Density at the Census Block-Level (people / mile^2)	2,863	10.00	0.91	1.52	12.58
MEDAGE	Median Age at the Census Block-Level	2,934	35.37	11.29	0.00	77.80
RACE	Proportion of Whites at the Census Block-Level	2,863	0.45	0.39	0.00	1.00

TABLE 2 Estimated Poisson Models for Number of Walking Trips in a Day

	Model 1		Model 2		Model 3	
Variable Name	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Household Characteristics						
VEH_HH	-0.310***	-4.98	-0.213***	-3.41	-0.307***	-4.53
BIKES_HH	0.338***	7.79	0.302***	6.78	0.288***	6.24
HOMETYPE						
HOMETYPE_4	0.014	0.27	0.031	0.60	0.068	1.11
HOMETYPE_5	1.121***	3.42	0.891***	2.60	1.343***	3.68
HHFAMINC	0.102**	2.11	0.099**	1.98	0.133***	2.60
Individual Characteristics						
R_AGE	-0.003***	-2.88	-0.005***	-4.17	-0.004***	-3.20
R_SEX	-0.049	-1.15	-0.057	-1.30	-0.073*	-1.63
DRIVER	-0.155**	-2.55	-0.174***	-2.79	-0.293***	-4.57
PRMACT						
PRMACT_2	0.230*	1.85	0.218*	1.74	0.322**	2.51
PRMACT_3	0.336***	2.70	0.269**	2.16	0.269**	2.14
WKFTPT	-0.264***	-3.96	-0.321***	-4.72	-0.312***	-4.45
OCCCAT						
OCCCAT_1	-0.009	-0.10	-0.073	-0.86	-0.119	-1.36
OCCCAT_3	-0.075	-0.59	-0.115	-0.89	-0.248*	-1.88
OCCCAT_4	0.494***	6.46	0.489***	6.31	0.322***	4.04
COMMDRVR	-0.583***	-4.87	-0.536***	-4.45	-0.453***	-3.74
DISTTOWK	-0.016***	-5.30	-0.016***	-5.47	-0.016***	-5.01
NWALKTR	0.413***	21.50	0.401***	20.17	0.357***	17.26
MEDCOND	-0.595***	-6.41	-0.597***	-6.04	-0.687***	-6.86
EDUCATION	0.316***	5.03	0.253***	3.94	0.176***	2.68
Attitudes / Perceptions						
DTACDT						
DTACDT_1			-0.260**	-2.15	-0.364***	-2.80
DTCONJ						
DTCONJ_4			0.164**	1.99	0.160*	1.94
DTCONJ_5			0.414***	5.60	0.372***	4.95
DTDRUNK						
DTDRUNK_5			0.269***	2.93	0.271***	2.93
DTGAS						
DTGAS_1			0.352***	6.19	0.394***	6.80
DTGAS_5			-0.324***	-3.70	-0.210**	-2.38
DTWALK						
DTWALK_2			0.274**	2.06	0.261*	1.94
DTWALK_3			0.433***	2.56	0.557***	3.27
Urban Form, Neighborhood Design and Land Use Attributes						

HHDENSITY					0.316***	3.20
STCONNECT					-0.971***	-5.76
VACANT					-0.594**	-2.47
TRANSITACC					-0.846**	-2.15
PARKS					0.203	1.05
MIXUSE					0.280	1.28
Neighborhood Socio-demographics						
POPDENSITY					-0.328***	-3.16
MEDAGE					-0.008***	-2.96
RACE					0.661***	9.19
Constant	-0.071	-1.21	-0.089	-1.49	0.155	0.34
Valid N=	2,837		2,704		2,632	
Log-Likelihood Intercept Only:	-4,248.99		-4,073.30		-3,976.62	
Log-Likelihood Full Model:	-3,805.95		-3,592.14		-3,383.73	
McFadden's R^2:	0.104		0.118		0.149	
McFadden's Adjusted R^2:	0.100		0.111		0.140	
Change (improve) of R^2:			11%		26%	

***, **, and * denote coefficient significantly different from zero at the 1%, 5%, and 10% level of significance (two-tail test), respectively.