MODELING MODE SWITCHING BEHAVIOR ASSOCIATED WITH THE CHANGE OF RESIDENTIAL LOCATION USING LONGITUDINAL DATA

Mahmudur Rahman Fatmi*, MASc Candidate, Dalhousie Transportation Collaboratory, Department of Civil and Resource Engineering, Dalhousie University, Halifax, NS, B3H4R2, Canada, Email: mh982048@dal.ca*

Muhammad Ahsanul Habib*, PhD, Assistant Professor, School of Planning, and Department of Civil and Resource Engineering, Dalhousie University, Halifax, NS, B3H4R2, Canada, Phone: (902)494 3209, Email: ahsan.habib@dal.ca*

Abstract

This paper presents a random parameter logit model of mode switching behavior of individual using longitudinal data from two distinct points in their life stage. The key contribution of the model is analyzing the behavior whether an individual switch mode or not after relocating their household. The study uses a retrospective survey data set conducted in Halifax, Canada. The study uses several types of variables representing socio demographic characteristics, dwelling characteristics, accessibility variables, travel attributes and trip characteristics. The model uses dynamic variables to capture effects of life cycle events, such as increase in household size, increase in the number of driving licenses, decrease in the number of private vehicles and decrease in the number of bed rooms in the household. Since attitude is one of the most significant factors in choosing a mode, the study accounts the effect of attitude in two broad categories: a) attitude towards land use, environment and commute experiences and b) attitude towards travel modes. The study applies a random parameter logit model considering the attitudinal factors as random parameters. The model reveals that socio demographic and dwelling characteristics significantly affect mode switching behavior during household relocation. Previous travel behavior also exhibits considerable influence on later behavior. A binary logit model is compared with the random parameter logit model, where the random parameter logit model improves model fit and provides important behavioral insight.

Keywords: Mode Switch, Attitude, Life Cycle Event, Random Parameter Logit Model.

1. Introduction

This paper represents a random parameter logit (RPL) model that examines the mode switching behavior of individuals with the change in residential location. The interdependence of mode choice and residential location choice is evident in literature (Cao et al., 2009). Habib and Miller (2009) argued that residential stress triggered the decision to move. Several studies suggested that change in job and residence influence mode choice. However, limited research has explored whether or not a change in residential location accompany with a mode switch for commute. Most of the previous research concentrated on examining either residential location choice processes (Habib et al. 2008) or mode choices of individuals (Nurdeen et al. 2007). Some studies focused on jointly modeling these two choice processes (Nurlaela, 2012). However, majority of the research used cross-sectional observations, which limits their ability to explore mode switching behavior using data from two distinct temporal points. Therefore, this study attempts to investigate mode switching behavior using a retrospective survey data in the Halifax region.

The mode switching behavior is modeled using random-utility based discrete choice modeling techniques. The model includes a wide range of variables representing socio demographic characteristics, dwelling characteristics, accessibility variables, travel attributes, and trip characteristics. One of the key features of the model is the use of dynamic variables representing life cycle events, such as increase in household size, increase in the number of driving licenses, decrease in the number of private vehicles and decrease in the number of bed rooms in the household. The dynamic variables represent the occurrence of change in household state and their impacts on mode switching behavior. Additionally, attitude has significant impact on mode choice (Garling et al., 1998; Fuji and garling, 2003) and the model accommodates attitudinal effects in two broad categories: a) attitude towards land use, environment and commute experiences and b) attitude towards travel mode. The traditional binary logit (BL) model is extended to a random parameter model (RPL) formulation to capture heterogeneity in the effects of attitudes on the mode switching behavior.

The paper is organized as follows: the next section briefly reviews the relevant literature. It then discusses the modeling approach. After that discussion on the data used for empirical application and discussion on independent variables is presented. Later binary logit and random parameter logit models are explained in detail. Finally a summary on contribution and future research direction concludes the paper.

2. Literature Review

Residential location has always been considered significant aspect in travel behavior research (Weisbrod et al., 1980; Quigley et al., 1985). Most of the residential location choice studies have used cross-sectional data to replicate the choice behaviour (Habib et al., 2008). On the other hand, Habib and Miller (2009) modeled residential location choice using reference-dependent mixed logit modeling framework using longitudinal information. In general, residential location choice plays an important role in influencing individuals' travel decisions (Silva, 1977; Kitamura, 2001; Cao, 2006; Cao et al., 2009). Schwanen and Mokhtarian, (2007) observed that people living in a sub-urban area are more likely to use car for fast, flexible, and comfortable travel, whereas people living in urban core are more likely to use non motorized vehicle.

Similarly, most mode choice model used cross-sectional observations, and evaluated contributions of attributes in a given point in time (Hensher, 2005). Recently, researchers have been interested to capture traveler's mode switching behavior from different temporal points along with mode choice decision. Nurdeen et al., (2007) examined the mode switch behavior from car to public transportation. The study develops a binary logit model using both revealed and stated preference survey data. Athena et al., (2010) observed traveler's mode switch behavior on the basis of specific travel information acquisition, such as an incident or road closure. In fact mode switching can occur depending on the time of the day (Hess et al., 2007). Mode switching behavior is also investigated in relationship with travel happiness (Abou-Zeid et al., 2010). However, most of these studies used a particular reference temporal point in evaluating the mode switch behaviour. This study fills the gap by investigating modal switch in reference to two consecutive home locations.

Traveler's attitude is becoming an important aspect in travel behaviour research (Parkany, 2005). According to attitude theory, attitude refers to evaluation of a behavior, which disposes a person to behave in a certain way toward it (Dawes, 1985; Ajzen, 1987). Attitude is conceptualized as positive or negative evaluations or beliefs of something that affects one's behavior and can be broken down into cognitive, affective, and behavior components (Nairne, 2003). But the low degree of correspondence between attitude and behavior shed light on the fact that attitude does not predict behavior accurately (Wicker, 1969). This inconsistency between attitude and behavior was later explained by the Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) (Ajzen, 1987; Ajzen, 1991), which introduced the concept of behavior being dependent on intention (motivation), and behavioral control (ability). TRA states that intention mediates between attitude and behavior and explains behavior more accurately than attitude (Fishbein and Ajzen, 1975). So, the fact attitude explains behavior or not depends on two factors, which are (i) attitude-intention consistency, (ii) intention-behavior consistency.

Social psychologists described attitudes as an element in decision-making process (Fazio, 1986; Ajzen, 1989; Ronis et al., 1989) whereas transportation researchers described attitudes as part of the decision process (Golod et al. 1979; Gauthier and Shaw, 1986; Sunkanapalli, 2000). Additionally, attitude along with intentions have significant impact in understanding travel behavioral choices (Tardiff, 1977; Dobson et al., 1978; Golob and Hensher, 1998; Outwater et al., 2003). In case of choosing public transportation, attitude was found to be more significant indicators than demographics and travel needs (Garling et al., 1998; Fuji and Garling, 2003). Moreover, a choice model of travel mode choice on regular trips captured lifestyles concerning place of residence and neighborhood (Marketa, 2009). The random utility choice model (multinomial logit) allowed heterogeneity of taste and supports the hypothesis that lifestyle preferences exist and are determinants of travel mode choice. Attitudinal variables improve fitness and statistical significance of discrete mode choice models and comprehensively explains modal utility (Domarchi et al. 2008). Therefore, this research examines attitude of individuals on mode switching behavior. It has considered attitudes in two categories: a) attitude towards land use, environment and commute experiences and b) attitude towards travel mode.

Moreover, a number of studies suggest that built environment has strong influence on travel behavior (Wachs and Crawford, 1992; Mae, 1997; Kitamura et al., 1997; Coogan et al., 2007; Cao et al., 2009). People preferring single detached home, single occupancy vehicle are car owners (Wachs and Crawford, 1992) and live in sub-urban area (Mae, 1997). On the other hand, people who live in the urban area walk more (Coogan et al., 2007) and take more transit trips (Kitamura et al., 1997). Cao et al., (2009) applied seemingly unrelated regression approach and showed that proper land use planning will encourage residents to use transit and non motorized modes more than using motorized mode. The study found that mixed land uses promote transit and non motorized modes. Recently Wang and Cheng, (2012) examined attitude, built environment and mode choice using Puget Sound panel dataset. A micro analysis in San Francisco Bay area found that attitude influenced travel behavior more than land use characteristics (Kitamura et al., 1997). Handy et al., (2005) observed that the variation in attitude successfully explain the variation in travel behavior between urban and sub urban neighborhood. They found built environment to disappear when attitudes and socio-demographic factors are considered.

Life cycle events and life stages also affect travel behavior. For instance, Habib and Miller (2009) used reference dependent residential location choice modeling technique. On the other hand, Mohammadian and Miller (2003) have successfully used dynamic variable in a mixed logit modeling framework of automobile transaction. For this study, dynamic variables are an interesting proposition since the paper attempts to analyze mode switching behavior of people while changing residential location. Hence, the study captures the dynamics of life cycle and life stages on mode switching behavior using dynamic variables, such as increase in household size, increase in the number of driving licenses, decrease in the number of private vehicles and decrease in the number of bed rooms in the household. Finally, a random parameter logit model (RPL) is estimated for the analysis of mode switching behavior. The modeling framework for the random parameter logit (RPL) model is presented in the following section.

3. Modeling Approach

The mode switch analysis in this paper accounts for two possible choice scenarios: 1. Switch, 2. No Switch; after an individual relocates residence to a new location. The study considers the second scenario (no switch) as the base choice. A Random Utility based discrete choice modeling approach is used to analyze the mode switching behavior. According to random utility theory, while facing a choice situation, a particular alternative is chosen by an individual based on its utility that the alternative offers to the individual (Lee et al., 2003). The main focus of an individual is to maximize utility. So, the chosen alternative must yield the maximum utility possible among the alternatives. Now the random utility of alternative *i* assigned to individual *j* at occasion *t* is as follows (Lee et al., 2003):

$$U_{ijt} = \theta + \beta_j X_{ijt} + \varepsilon_{ijt} \quad \ldots\ldots (1)$$

Here, θ is intrinsic utility of alternative *i* for individual *j* at choice occasion *t*, β_j is a vector of parameters estimated for individual j, X_{ijt} is a vector of the observed attributes of alternative *i* for individual *j*, and ε_{ijt} is a random error. Assuming that the random error term is independently and identically distributed (IID), we can represent the logit model by:

$$P_{ijt} = \frac{e^{\beta j X i j}}{\sum_{i=1}^{k} e^{\beta j X_{ij}}} \quad \ldots\ldots (2)$$

Here, P_{ijt} represents the probability of individual *j* choosing alternative *i* in a certain choice occasion *t* and *k* is the number of alternatives considered in the choice set. Although MNL is widely used for mode choice analysis, the restrictive IID assumption and inability to account for unobserved heterogeneity has motivated researchers to examine some other modeling approach that could improve the model results by incorporating the effects of heterogeneous characteristics among the sample population. This limitation in modeling can be addressed by the introduction of random parameter logit (RPL) model, where the choice probabilities are obtained through the integrals of standard logit probabilities over a probability density of parameters (Train, 2003). So, in case of applying random parameter logit model in our study, the probability of choosing alternative *i* by individual *j*, conditional on β_j is expressed in the following equation.

$$g(y_j \mid \beta_j) = \frac{e^{\beta j X i j}}{\sum_{i=1}^{k} e^{\beta j X_{ij}}} \quad \ldots\ldots (3)$$

The unconditional probability is obtained by integrating $g(y_j \mid \beta j)$ over all values of βj weighted by the density of βj as shown below.

$$P_j (y_j \mid \mu, \nu) = \int g(y_j \mid \beta_j)\, f(\beta_j \mid \mu, \nu)\, d\nu \quad \ldots\ldots (4)$$

Here, $f(\beta_j \mid \mu, \nu)$ is the density function assumed to be normally ($\beta_j \sim (\mu, \nu)$) distributed (Revelt and Train, 1998). The log-likelihood function is constructed based on the above probability expression, and maximum likelihood estimation is employed to estimate the β_j in the following equation.

$$L(\mu, \nu) = \sum_{j=1}^{J} \ln \int g(y_j \mid \beta_j)\, f(\beta_j \mid \mu, \nu)\, d\nu \quad \ldots\ldots (5)$$

The above likelihood function cannot be evaluated in closed form as it is a multivariate integral, so the integral of the choice probabilities is approximated by Monte Carlo simulation. For each individual, through draws from f (βj | μ, ν), the conditional choice probability g (yj | βj) is calculated for each draw. This process is repeated R times. Finally, the integration over f (βj |μ, ν) is approximated by averaging the R draws. Hence, the resulting simulated log likelihood function (LL) can be expressed as:

$$LL_s = \sum_{j=1}^{J} ln \frac{1}{R} \sum_{r=1}^{R} \widehat{P_J} \ (y_j|\mu, \nu) \qquad (6)$$

where P_j is the simulated probability that person j will choose alternative i, and μ and ν are parameters to be estimated. The model is estimated by Quasi-Monte Carlo (QMC) approach with 500 halton draws.

4. Data used for Empirical Application

4.1. Household Mobility and Travel Survey in Halifax

The mode switch modeling utilizes data from Household Mobility and Travel Survey (HMTS). The wave 1 of this retrospective survey was conducted in Halifax, Nova Scotia in 2012. HMTS yielded 289 complete responses. The survey included a combination of questions that include socio-economic information, travel activity, vehicle ownership, residential and job location information, and statements reflecting the attitudes regarding transportation, land use, environment and travel satisfaction. Since it was a longitudinal survey, it also included information on current and previous home and job location as well as vehicle fleet ownership. The data from the survey was compared with the Canadian census data and was found to be a representative sample.

4.2. Data Preparation for Modeling

The data preparation for the modeling involved several steps. Based on the survey, the first step was to prepare a cleaned database with all relevant attributes. Respondents were asked about their three most recent home and work place location, which were later geocoded to derive the longitude and latitude of each location using an online tool, BatchGeo. The second step was to calculate the distances and time from home to employment and home to nearest transit stop using the network analyst tool of ArcGIS. After that, the neighborhood characteristics were collected based on dissemination area from the Statistics Canada Census tabulation. The data includes household income, average number of rooms and bedrooms, dwelling type, dwelling value, population and dwelling density, usual place of work and so on. Finally the neighborhood characteristics of each respondent were spatially joined on the basis of home location by the means of “spatial join” function of ArcGIS.

5. Independent Variables Considered

The binary logit (BL) and random parameter logit (RPL) models used a wide range of different types of independent variables which indicates household’s socio demographic characteristics, dwelling characteristics, accessibility variables, travel attributes, trip characteristics, dynamic variables and variables representing attitude towards land use, environment and commute experiences and attitude towards travel modes.

5.1. Attitudinal variables

The survey contained 33 attitudinal statements related to travel modes, land use, environment and commute experiences. The statements were on a three point likert scale ranging from “Agree” to “Disagree”. The statements are subdivided into two groups, which are: attitude towards land use, environment & commute experiences and attitude towards travel modes. Among the 33 attitudinal statements in the survey, 18 statements were directly connected to attitude towards land use, environment and commute experiences. On the other hand, 8 statements in the survey correspond directly to attitude towards travel modes.

5.1.1. Attitude towards Land Use, Environment and Commute Experiences

Factor analysis was conducted on 18 statements with a focus to explain attitude towards land use, environment and commute experiences. Factors were extracted with the help of principal component analysis with an oblique rotation (Redmond, 2000). The analysis yielded four dimensional solution (see Table.1) which are pro high density, pro environmental solution, travel satisfaction and travel stress. Standardized scores for each respondent on these factors have been used as potential explanatory variables.

The pro high density factor relates to those who prefer to live with vibrant lifestyle of the inner city and can access many facilities with relatively little effort in a high density environment. So people with high scores on this factor are likely to be less car dependent and more transit oriented. A high negative loading for suburban life and houses with backyard for this factor is also expected. A high secondary loading on global warming statement reveals their environmental consciousness and support their less car dependent attitude. The pro environmental solution factor represents those people who are extremely conscious about the environment. The high loading on statements regarding global warming and green house gas emission confirms that. The high positive loading to limit driving for the sake of air quality reveals their specific consciousness about air quality (Schwanen and Mokhtarian, 2007).

The factor travel satisfaction refers to those who gain utility from travelling. These people live in the inner city, extract maximum benefit from transit system and find commuting enjoyable. The negative loading on the statement mentioning travel as a wasted time is also an indication of gaining some kind of utility during traveling. The last factor travel stress reflects those people who find traveling as waste of time. These people are generally unsatisfied and stressed with their commute.

Respondents with high score on pro high density factor live in the inner city and can be hypothesized for both switching and not switching mode. The heterogeneity can be resulted from the fact that inner city offers well established transit services to reach daily destination easily. On the other hand, inner cities promote and facilitate modes such as bike and walk. So there might be multiple options for the pro high density people to either switch or not switch. In general, environmentally conscious individuals might try to contribute to reduce effects on environment, which might reflect in their mode choice after relocation. These people might be hypothesized to switch mode as they are always searching for a more environmentally friendly mode. People with high scores on travel satisfaction factor are less likely to switch mode. These people are more likely to use transit and utilize their travel time by reading book or listening to music. On the other hand, respondents with high scores on travel stress are more likely to switch mode.

5.1.2. Attitude towards Travel Modes

There are 8 statements in the survey which are directly related to attitude towards travel modes. Factor analysis was conducted again with principal component factor considering two dimensional oblique rotations (Table.2). The two dimensions are: pro active transportation and pro car (Cao et al., 2007). The pro active transportation factor reflects the attitude of those environmentally concerned people who enjoy walking or bicycling and consider it to be good for health. Pro car people find pride in owning a car. Car provides them travel freedom and helps to complete multiple activities in a trip for the family. It can be hypothesized that car dependent people are less likely to switch mode.

5.2. Socio Demographic, Dwelling Characteristics and Travel Attributes

Socio demographic characteristics are represented by a set of dummy variables that include: age of the respondents, household income and education of the primary worker. Dwelling characteristics is represented by dwelling type, rent of current household and reason for changing the household. Accessibility measures are examined using the distance between current home to transit stop and work location. Travel attributes considered in the study include number of driver license in the household and owning a monthly transit pass. On the other hand, trip characteristics are represented by primary mode of transportation in the past home.

5.3. Dynamic Variables

The retrospective database contains attributes of three recent households (including the current household) of each respondent. This provides the opportunity to capture the effect of life cycle events using dynamic variables on mode switching behavior. The study investigates the effects of changes in attributes of household on the mode switching behavior. The study only considers the changes that occur between the current and previous household for some specific attributes. Suppose if the number of private vehicles has increased in the present home with respect to the past home then we consider that as increase in number of vehicle and the vice versa is considered as decrease in number of vehicles. The variables considered in this category includes: change in household size, change in number of vehicle, change in number of driving license and change in number of bedroom in the household. All the above mentioned variables are tested in the final model. Table 3 shows summary statistics of all the explanatory variables retained in the final model.

6. Model Results

The exploratory analysis of the sample explains the distribution of respondents whether they decided to switch mode or not after changing household location. Among the total 289 respondents, 165 of them chose to switch mode with the change in household location and 124 respondents chose not to switch mode. A random parameter logit (RPL) model is used to investigate the predictors for switching mode. In addition to the RPL model, a conventional binary logit (BL) Model is also used to compare the results. Several types of variable are tested in the model estimation, which are discussed in the following section.

Table 4 shows the model analysis results of the mode switch behavior of the inhabitants of Halifax with the change of household location. RPL model outperformed BL model by showing better model fit in the results. A brief overview of both models is given below.

6.1. Binary Logit Model

The parameter estimates of the BL model suggest that, socio economic variables such as age, income, education and dwelling characteristics are generally highly significant in explaining mode switching behavior. Moreover accessibility factors such as home to transit stop and work place distance are also important. However, travel attributes have been extremely significant as expected in case of mode switch modeling. All the predictors have shown expected relationship in the BL model. The model performs reasonably well with likelihood ratio index Rho square of 0.286 (adjusted Rho square of 0.224).

Among the socio demographic characteristics, a dummy variable representing individual with age above 55 years are less likely to switch mode as expected. Individual with income below $25,000 represents low income group and are more likely to switch mode. Moreover, the variable representing highly educated individuals (minimum bachelor degree) have shown positive relationship with the mode switch.

All the variables representing dwelling characteristics have shown highly significant relationship with mode switching behavior. People living in a single detached house are expected to be car dependent and less likely to switch mode. People living in a house whose rent is below $1200 corresponds to low income group and are more likely to switch mode which is consistent with the socio demographic variable. Another dummy variable representing people who changed their household to come closer to work are less likely to switch. This may represent the group who prefer to walk.

Accessibility variables are well represented by home to transit stop distance being below 200m and home to work place distance being above 500m. The positive relation in case of people living within walking distance (200m) to transit stop is highly significant and reveals the mode switching tendency of people. The other accessibility variable represents people who are less likely to switch if the distance from home to work place is above 500m.

In case of travel attributes, dummy variables representing household with no driving license, household with monthly transit pass, individual whose primary mode was car in past home and individual whose primary mode was bike in past home have all shown negative relation. The results suggest people's inclination towards previous mode.

Among the dynamic variables, life cycle event is represented by the variable increase of household size has showed a positive relation, as expected. Moreover, people have to look for other modes with the decrease in the number of private vehicle in the household, which is appropriately reflected by the positive relation. Additionally, individuals are more likely to switch mode with the increase in driving license in the household. On the other hand, people are less likely to switch mode with the downsizing of houses represented in terms of decrease in number of bedroom.

The signs of the attitudinal variables are aligned with the hypothesis described earlier. None of the attitudinal variables have shown significant relationship in the BL model. The negative sign of the pro high density people, who mainly lives in the inner city show their intend of not switching mode. This may be an indicator of the sustainable transit system in their neighborhood. The well mixed land use in the inner city also promotes walking as a potential and enjoyable mode to commute to the shops and services as they are close by. Travel stress has shown a positive relation as expected. Pro car people are less likely to switch mode as car facilitates pride, travel freedom and ability to conduct multi activities. Pro active transportation people are more likely to switch mode as expected.

6.2. Random Parameter Logit (RPL) Model

Majority of the predictors in RPL model are highly significant and gives statistical significance of above 95% confidence interval (t-stat > 1.96). The RPL model improves the parameter estimates of all the variables in comparison to the conventional BL model. The model outperforms BL model with likelihood ratio index Rho square of 0.308 (adjusted Rho square of 0.248), where both the model fit values are higher than that in BL model.

Socio-demographic characteristics are explained very significantly by the three variables age, income and education. All these variables hold the same relation as it was in the binary logit model. A dummy variable representing people with income below $25000 have shown the strongest relationship of the three with a positive coefficient value of 1.5326. Older people with age above 55 years are less likely to switch mode and have shown a negative coefficient of -1.3093. It can be assumed that they are likely to live in the inner city, where the shops and services are close by (Mayers and Gearing, 2002).

All the variables in the dwelling characteristics group have been found statistically significant at least at 95% confidence interval, and the relations are 1.5 times significant than it was in BL model. People living in single detached house have shown negative relation with a coefficient value of -1.1823. This variable may represent high income group who are car dependent and are less likely to switch mode. On the other hand, people living in a house, whose rent is below $1200 have shown the most strongest relation among this group of variables with a positive coefficient value of 1.9325. This group can be considered as low income group who are more likely to switch mode as they are always looking for a cheaper option. People living close to work place generally prefer to walk to work, which is reflected in the result with a negative relationship.

For the accessibility characteristics, people living at walking distance (200m) to transit stop are more likely to switch mode to transit, which is represented by the strong positive coefficient value of 1.1698. This may be the case of residential self selection that prefers transit oriented living (Carvero, 2007). In general, individual show sustainable mode choice attitude to commute to work when work place is not within walking distance from home. This is explained by a dummy variable representing people who are less likely to switch mode if the distance from home to work place is above 500m.

Travel attributes have all returned the same relation as it was in the BL model. In general, household without a driving license have limited option to switch and in return have shown a strong negative coefficient value of -3.2621. People, who buy a monthly transit pass, are most likely to use transit. The negative relation in this case represents that this group of people are less likely to switch from transit. Both the variables representing people, whose primary mode in past home was car and bike have exhibited significant negative relation with coefficient value of -1.2996 and -3.1383 (1.5 times significant than BL model) respectively. So, travel attributes variables reveal the fact that people are more comfortable to persist with the mode, which might be an indicator of habit persistence (Bamberg et al., 2010).

All the dynamic variables have shown positive relation except the one representing downsizing of household with a strong negative coefficient value of -2.0964. This represents the fact that people are extremely sensitive about decrease in number of bedrooms, which is consistent with Habib and Miller (2009). Increase in the household size may be caused by the birth of a child or new members moving in, which may cause individual to switch mode to accommodate the travel need of all the family members. The positive relation with the increase of driving license extends the car dependent attitude of people. The positive relation with the decrease of private vehicle is also expected. The result reflects the general behavior of people in North America as they find it difficult in functioning their daily lives without one, two or sometimes three or more vehicles parked in their driveway (Roorda et al., 2000).

Although the parameter estimates of the attitudinal variables are improved in the RPL model but none have exhibited significant relationship. Other than pro high density all other variables have shown similar relationship as it was in the BL model. The positive sign of the pro high density factor explains the existence of significant heterogeneity among the sample population. The variable may represent that group of the sample population who are likely to switch mode because their neighborhood in the inner city is offering them a number of sustainable choice of mode as described earlier. Other significant variable among attitude towards land use, environment and travel experiences is travel stress, which showed the same positive relation with an improved coefficient value of 0.2626. Both the variables representing attitudes toward travel modes have shown expected relationship. Pro active transportation people have shown strong positive relation with coefficient value of 0.3565, which explains their preference towards bike and walk. On the other hand, the negative relation confirms that pro car people are less likely to switch mode, which is expected.

Although all the attitudinal variables in the RPL model are assumed to be random parameters, only two variables representing attitude towards land use, environment and travel satisfaction have exhibited significant standard deviation. The constant is also significant at 90% confidence level with a co-efficient value of -1.9652. The results suggest that population's preferences have significant variation across the two random parameters pro high density environment and travel stress. A few parameters are retained in the final model, which are below the threshold t-statistics value (95% confidence interval). These parameters are significant according to literature and also have important policy implication. They are retained with the assumption that if a larger data set were available, these parameters might show statistical significance.

7. Conclusion

This paper represents a modeling framework of the factors affecting an individual's choice to switch mode or not while changing household location. Specifically it offers an in-depth understanding of how an individual is going to accommodate his preference for mode choice with the changed location. The final mode switch analysis is conducted using RPL model assuming attitudinal variables as random parameters. Additionally, BL model was compared with RPL model and RPL model outperforms BL model. RPL model improves both model fit and parameter estimates significantly. Additionally RPL accounts for significant heterogeneity among the sample population in the effects of attitudes on the mode switching behavior.

The model has considered factors in seven broad categories: socio demographic characteristics, dwelling characteristics, accessibility characteristics, travel attributes, trip attributes, dynamic variables, attitudes towards land use, environment & travel experiences, and attitude towards travel modes. The study found socio-demographic and dwelling characteristics as the major determinants. Older individuals are found to be more persistent with their choice of mode, which is not subjected to change with the change of household location. Low income group have limited ability and may choose a location which will cost them minimum to commute. As a result, they cannot afford to continue with a particular mode. High-income individuals are in general car dependent and very unlikely to switch mode. Living closer to transit stop has positively influenced mode switch after relocation. Individuals living further from work place have exhibited sustainable attitude to commute to work. Moreover, the study deals with habit persistence and shows that previous travel behaviors have significant effect on later behavior.

The attitudinal variables have exhibited expected relationship but none of them were significant, which might be because of small sample size. The pro high density factor showed negative relation in BL model where as it showed a positive relation in RPL model. The random parameter, pro high density shows statistically significant standard deviation. It confirms the existence of considerable heterogeneity among the sample population according to pro high density. A number of variables (like gender, car attributes and dwelling density, neighborhood characteristics) were tested because they are important indicator of mode switch but did not exhibit expected relationship. As a result of that, these variables were not added to the final model.

The study is conducted on a comparatively small sample size of 289 respondents. A second wave of the data collection is planned for 2013. It will be interesting to investigate mode switching behaviour with the larger sample. Additionally, future work will include an examination of mode specific mode-switch (for instance, car to transit), which could not achieved with this small Halifax sample. This study, however, offers important behavioural insights regarding mode switch, and the effects of various types of determinants, including attitudinal variable. The study will assist in informing transport policy that aims at influencing shifts in travel behaviour.

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List of Tables

Table 1 Factor Analysis of Attitude towards Land Use, Environment and Commute Experiences (N = 289)[a]

Statements	***Pro high density***	***Pro environmental solution***	***Travel Satisfaction***	***Travel stress***
I love to live in the inner city	0.7852			
A suburban environment offers the best quality of life for families	-0.5142			
It is important for children to have a backyard to play in	-0.6756			
I am fully satisfied with my commute				-0.8147
My commute makes me feel stressed				0.7626
My commute offers a good transition between home and work				-0.7702
Travel time is generally wasted time			-0.2739	0.4236
I feel less stressed when taking transit than when driving			0.6926	
Taking good transit is an enjoyable experience			0.7327	
I consider global warming a major concern	0.3128	0.5334		
I limit my driving because its bad for air quality		0.7379		
Households should be fined if their greenhouse gas emissions exceed a set daily limit		0.7647		
Housholds that generate less greenhouse gas emissions should get a tax credit		0.6724		
Proximity to shops/services is important to me	0.5249			
Living in a multiple family unit does not provide enough privacy	-0.5851			
I consider transit an essential service	0.2915			
Increasing residential density is good city planning	0.4864		0.4971	
More highways are required to reduce traffic congestion	-0.2919		-0.5988	

Note: Loading less than 0.27 are suppressed for ease of interpretation.
[a] Pattern matrix for principal component analysis with oblique rotation.

Table 2. Factor Analysis of Attitude Towards Travel Modes (N = 289)[a]

Statements	***Pro car***	***Pro active transportation***
I enjoy riding a bicycle		0.2107
I prefer walking to driving whenever possible		0.7194
I take pride in owning a car	0.5485	
Driving provides me with freedom	0.4756	
Workplaces should provide free parking to all employees	0.4592	
Owning a vehicle is necessary when you have a family	0.6443	
I consider walking as part of my daily exercise	0.2015	0.3532
I limit my driving because it's bad for air quality		0.4641

Note: Loading less than 0.21 are suppressed for ease of interpretation.
[a] Pattern matrix for principal component analysis with oblique rotation.

Table 3 Summary Statistics of Explanatory Variables used in the Mode Switch Analysis for both BL and RPL models

Variables	Description	Mean/ Proportion	Std. Deviation
Socio-Demographic Characteristics			
AGE55up	Respondents age above 55 years (Dummy)	21.11%	-
INC25KBL	Respondents income less than $25000/year (Dummy)	15.92%	-
EDU_UGRAD	Highest education is of primary worker in the household is minimum under graduation (Dummy)	60.55%	-
Dwelling Characteristics			
S_DETACH	Respondents living in a single detached household (Dummy)	49.83%	-
RENT$1200BL	Respondents house rent less than $1200/month (Dummy)	87.20%	-
CLSTOWORK	Respondents reason of house hold change is to be closer to work (Dummy)	8.65%	-
Accessibility Characteristics			
H-TSD200mBL	Respondents home to transit stop distance less than 200 m (Dummy)	89.97%	-
H-WRK500mA	Respondents home to work place distance greater than 500 m (Dummy)	56.05%	-
Travel Attributes			
NODL	Respondents with no driving license in the household (Dummy)	1.73%	-
MNTHLYTPAS	Respondents purchase monthly transit pass (Dummy)	22.49%	-
Trip Characteristics			
P_CAR	Respondents primary mode of transportation was car in the past household (Dummy)	35.29%	-
P_BICYCLE	Respondents primary mode of transportation was bicycle in the past household (Dummy)	7.96%	-
Dynamic Variables			
HHSIZE_INC	Increase in household size	1.04	3.54
DL_INC	Increase in number of driving license	1.03	3.58
VEHCLE_DEC	Decrease in number of private vehicle	1.39	1.24
BED_DEC	Decrease in number of bed room	1.60	2.62
Attitudinal Variables			
PRO_HD	Pro transit and high density environment	1.51	2.07
TRVLSTRESS	Travel stress	-1.25	1.61

PRO_AT	Pro active transportation	2.07	1.68
PRO_CAR	Pro car dependent	3.23	2.66

Table 4 Parameter Estimation Results from mode switch BL and RPL

Variables	**BL**		**RPL**	
	coefficient	*t-stat*	*coefficient*	*t-stat*
Socio-Demographic Characteristics				
AGE55up	-0.7669	-1.917*	-1.3093	-2.154**
INC25KBL	1.2801	2.409**	1.5326	2.210**
EDU_UGRAD	0.8058	1.989**	1.0346	1.979**
Dwelling Characteristics				
S_DETACH	-0.7378	-2.236**	-1.1823	-2.325**
RENT$1200BL	1.2604	2.414**	1.9325	2.443**
CLSTOWORK	-0.8951	-1.573	-1.5439	-1.942**
Accessibility Characteristics				
HtoTSD<200m	1.0702	2.080**	1.1698	1.725*
HtoWork>500m	-0.8333	-2.452**	-0.9941	-2.223**
Travel Attributes				
NODL	-2.9315	-2.025**	-3.2621	-1.810*
MNTHLYTPAS	-0.5356	-1.290	-0.7330	-1.345
Trip Characteristics				
P_CAR	-0.8885	-2.472**	-1.2996	-2.576**
P_BICYCLE	-2.248	-3.701**	-3.1383	-3.028**
Dynamic Variables				
HHSIZE_INC	0.5179	2.005**	0.5062	1.494
DL_INC	0.3775	1.283	0.6577	1.588
VEHCLE_DEC	0.2029	1.234	0.2883	1.278
BED_DEC	-1.3751	-1.724*	-2.0964	-1.826*
Attitudinal Variables				
PRO_HD	-0.0233	-0.237	0.0527	0.331
TRVLSTRESS	0.1820	1.530	0.2626	1.552
PRO_AT	0.1982	0.952	0.3565	1.154
PRO_CAR	-0.0142	-0.130	-0.0730	-0.465
Standard Deviation of Random Parameters				
PRO_HD	-	-	0.7252	2.033**
TRVLSTRESS	-	-	0.1032	0.154
Rho square	0.2859		0.3077	
Adjusted Rho square	0.2242		0.2478	

****95% confidence interval; * 90% confidence interval.**