MODELING RESIDENTIAL LOCATION OF THE ELDERLY POPULATION IN THE GREATER TORONTO AND HAMILTON AREA, CANADA

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Introduction

Canada's elderly population is increasing, yielding serious implications for transportation planning. The country's largest population cohort, the Baby Boomer generation, accounts for 9.6 million people, or nearly 3 out of 10 Canadians. In 2011, they began turning 65 and today are collectively becoming the largest elderly population.

In anticipation of this large shift in demographics, numerous studies have attempted to assess travel behavior of the elderly and its implications for physical planning. Some studies have attempted to predict the impacts that the elderly population will have on transportation, such as modal shifts (Arentze et al., 2008); however, most studies focus on understanding current elderly travel behavior, the factors that influence it, and how it has changed over time. Of these studies, many have found that elderly travel behavior differs from the general population with respect to trip purpose, trip frequency, trip distance, and mode choice. In addition, these studies have found that elderly travel behavior is changing. Travel behavior is intrinsically linked to residential location choice. However, despite the differences exhibited between elderly and non-elderly travel behavior, there have been no empirical studies on residential location choice for the elderly. Therefore, the objective of this paper is to examine the factors that affect residential location choice for the elderly population.

The next section of this paper presents a brief review of the relevant literature. This is followed by a detailed discussion of the data presented along with a description of the population sample. The modeling approach is then discussed. Finally, the results of the MNL and LCM models are discussed in detail. The paper concludes with a summary of contributions.

Literature Review

Existing research literature demonstrates that elderly behavior is different from that of the general population. Using the 2001 NHTS, Collia, Sharp and Gesbrecht (2003) found that trip purposes differ between elderly and non-elderly cohorts. Not surprisingly, the findings reveal that the elderly take more trips that are shopping, recreational, social, and medical-related; conversely, non-elderly groups take a higher percentage of work-related trips. Wasfi, Levinson and El-Geneidy (2007) corroborated these results by finding a tendency toward shopping, social and recreational trips by the elderly.

Studies also demonstrate differences in trip frequency between elderly and non-elderly groups. In their study of the General Social Survey, Newbold et al. (2005) found that the older population took fewer trips than their younger counterparts. Other studies support this finding (Schmöcker et al., 2005; Páez et al., 2007). Using NPTS data, Rosenbloom (1988) found that when work-related trips are disregarded, the elderly appear to make more trips than the non-elderly until the age of 80. This study also found that trip frequency declines faster for ageing drivers than non-drivers (Rosenbloom, 1988).

In addition, the elderly make trips of shorter distances as they age (Mercado & Páez, 2009; Rosenbloom, 2004*)* and generally have shorter trip distances than those of their younger cohorts (Newbold et al., 2005; Zhou & Lyles, 1997). For mode choice, the elderly overwhelmingly use a private vehicle as their primary mode of transportation (Stamatiadis et al., 1996). In addition to differences in travel behavior from their younger cohorts, numerous studies demonstrate that elderly travel behavior is changing over time. The number of private automobile trips made by people within the elderly cohort has been found to be increasing in Canada since 1986

(Newbold et al., 2005). Compared to previous generations of elderly, the current group is more likely to possess a license (Rosenbloom, 2001), own a car (Mercado & Miller, 2010), and use a vehicle (Hjorthol et al., 2010; Tacken, 1998). Conversely, the elderly and are less likely to take transit (Currie & Delbosc, 2010). Linking these trends to residential location, Rosenbloom and Winsten-Barlett (2002) found that the elderly who give up driving may be worse off than those who never drove because of the inaccessibility of their residence to other alternate modes.

The diverging travel trends of elderly cohorts - most notably, the greater dependency on personal vehicles - will have near-future impacts that extend from public transportation to environmental and social costs. Due to the inherent link between residential location choice and travel behavior, understanding one is critical to understanding the other. Studies on residential location choice modeling have, until now, focused largely on the general population, and in particular, the working age population (Chen et al., 2008). Since elderly often differ in their household composition from the general population (primarily in employment status and the absence of non-adult children), the factors affecting their residential location choice differ from the general population. However, only a handful of studies exist that examine residential location choice of the elderly (e.g. Duncombe et al., 2003; Duncombe et al. 2001). Particularly, there is a gap in the transportation research literature that comprehensively examines the factors affecting the residential location choices of the elderly.

This paper attempts to address this gap through a comprehensive empirical examination into the factors affecting elderly residential location choice using a sample of elderly over the age of 65 in the Greater Toronto and Hamilton Area (GTHA) by employing a latent class modelling (LCM) approach.

Data Used in the Empirical Application

Toronto Transportation Tomorrow Survey

The data source used for estimating the models is the 2006 Transportation Tomorrow Survey (TTS) of the Greater Toronto and Hamilton Area (GTHA) in Ontario, Canada. The survey is conducted using computer-assisted telephone interviewing techniques that collect each household member's basic socio-economic characteristics and travel behavior of the previous day. This survey includes information at both the individual and household level. The final dataset represents a 5 percent random sample of households.

Data Preparation for Modeling

Data preparation for model estimation involved several steps. First, the household, personal, and trip attributes from the TTS database were summarized and grouped for each individual over 65 years. Second, census tabulations from Statistics Canada were collected and joined to the dataset. Third, accessibility measures were derived using GIS techniques. For example, the Euclidian distance was calculated between each home location and a range of activity centers including Toronto's central business district (CBD), regional shopping centers, subway stations, parks, and outdoor recreation facilities. Fifth, parcel-level land use data for the GTA was obtained from Desktop Mapping Technologies Inc. DMTI ™. This was aggregated to the census tract level using geospatial methods. In addition to normalized proportions of individual land uses, a land use mix diversity index was calculated. Proposed by Bhat and Gossen (2002), the land use mix diversity index captures the degree of land use diversity of a given area based on four land use types—residential, commercial, industrial, and other. A value of 1 indicates perfect land use heterogeneity whereas a value of 0 signifies perfect homogeneity. Finally, the joined dataset was queried out for further analysis. Note that a random set of 9 alternative non-chosen home locations with associated attributes were generated for the elderly residential location choice modeling.

Sample Description

In total, the data sample includes 25 245 seniors in 19 432 households. The median age of the sample is 73, and males and females make up 49.35 and 50.63 percent of the sample, respectively. 85.85% of individuals were not employed on the day of the survey. 11.99% of individuals were without access to a vehicle. 79.43% of individuals in the sample possess a driver's licence, while 4.15% possess a transit pass.

Modeling Approach

A latent class logit modelling approach was used for modeling residential location choice of the elderly population cohort in the GTHA. Assuming that the random utility is independent and identically distributed (IID) with a Gumbel (type I extreme value) distribution, a multinomial logit model (MNL) can be defined by:

$$P_j(i \mid \beta) = e^{V_{ij}} \Big/ \sum_{k=1}^{K} e^{V_{ij}} = e^{\beta X_{ij}} \Big/ \sum_{k=1}^{K} e^{\beta X_{ij}} \quad (1)$$

where $P_j(i \mid \beta)$ is the probability of an individual j choosing alternative location i in a given choice scenario. X_{ij} represents the vector of the observed attributes of alternative i and individual j and β represents the parameters to be estimated. K represents the number of alternatives considered in the choice set, which is assumed to be 10 random samples of locations including the chosen alternative in this residential location choice modelling.

Although MNL has been extensively used for choice modeling in the past, recent literature suggests that latent class model formulations are better, particularly in terms of their ability to capture unobserved heterogeneity. The model implicitly sorts groups of individuals into discrete latent classes, which allows to capture variations in parametric values across classes. Let's assume $P_j(i \mid \beta_m)$ is the probability of individual j choosing alternative i conditional on individual j being sorted into m classes. The unconditional choice probability can be written as:

$$P_j(i \mid \beta_1, \ldots ..\beta_M) = \sum_{m=1}^{M} \phi_{jm} P_j(i \mid \beta_m) \quad (2)$$

where ϕ_{jm} represents the probability of individual j being assigned to class m. Note that although individuals are sorted into classes based on this probability, the class assignment of a specific individual remains unknown. Now, in order to estimate parameters of the LCM model, the log likelihood function can be written as:

$$\ln L = \sum_{j=1}^{N} \ln \left[\sum_{m=1}^{M} \phi_{jm} \left(\prod_{i} P_j(i \mid \beta_m) \right)^{\delta_{ij}} \right] \quad (3)$$

where ϕ_{jm} is the class membership probabilities and δ_{ij} represents a dummy variable which equals 1 when the alternative i is chosen by the individual j, and otherwise equals 0. N is the number of observations. This log-likelihood function is maximized using the expectation-maximum (EM) algorithm to estimate associated parameters, including the class membership probabilities. Note that the estimation of LCM does not require simulation (unlike other approaches of incorporating latent heterogeneity such as continuous mixture models), which reduces computation burdens during estimation. The model's goodness-of-fit can be evaluated in terms of AIC and BIC.

Discussions of Results

A large number of hypotheses were tested in the model estimation process using different types of variables, including accessibility measures, land use characteristics, and neighbourhood attributes. Additionally, interaction variables with personal and household characteristics were used. Table 1 shows the list of the variables retained in the final model specification. As explained earlier, this paper employs a latent class logit modeling technique to investigate the factors affecting elderly residential location choices. A traditional multinomial logit model was estimated for comparison purposes. Table 2 shows the results of the model estimation for both MNL and LCM models.

Results of the Multinomial Logit Model

The parameter estimates of the MNL model suggest that, generally, accessibility characteristics, land use, and neighborhood characteristics are factors in explaining residential location choices of the elderly population in the GTHA. Furthermore, individual and household characteristics in interaction with the aforementioned variables (particularly mobility tool ownership and employment status) explain the influence of these factors on elderly residential location choice.

Accessibility measures (including the distances from the neighbourhood to the central business district (CBD), nearest subway station, highway exit, regional shopping center, park and recreation center, and local shops) are found to be key factors in explaining elderly residential location choice. A positive relationship is found for distance to CBD of the non-working elderly, supporting the hypothesis that the appeal of living close to the CBD diminishes after retirement. In interaction with those without a household vehicle, the relationship is reversed. This is arguably the case since those without access to a vehicle are more inclined to locate in areas with better public transportation access, which generally comes with living closer to the CBD. The results also reveal that elderly with no private vehicle prefer to live closer to regional shopping centers, whereas for the elderly with access to a household vehicle, distance to a regional shopping center has the opposite effect. A dummy representing neighbourhoods within ten kilometers of a regional shopping center is found to have a negative relationship to residential location choice, demonstrating that there is low appeal of neighborhoods in immediate proximity of a shopping center for the elderly population in the GTHA. Proximity to a park or other outdoor recreational facility exhibits a similar relationship as the regional shopping center, where the elderly are less likely to locate within two kilometers, but those without a car tend to live closer. Distance to local shops responds similarly to mobility tool ownership: generally, the relationship is positive, but negative for those without a driver's license. Accessibility to public transportation infrastructure also predicts elderly residential location; in general, elderly prefer to live closer to a subway station. However, for those with a driver's license, this proximity is a deterrent. Finally, elderly people with at least one household vehicle prefer to live closer to a highway exit.

Diversity of land use (which is captured in the land use mix variable) is found to be one of the strongest predictors of elderly residential location choice. Generally, seniors prefer to live in neighborhoods of greater diversity of land use. However, in interaction with household car availability, the effect of land use diversity reverses, exhibiting a negative relationship. Thus car ownership detracts from the appeal of diverse neighborhoods. Looking at specific land uses, elderly are attracted to neighborhoods with higher proportions of open space and residential land use.

Neighborhood characteristics have also shown to be significant predictors of elderly residential location choice. The results of this study reveal that the elderly respond to population density differently depending on vehicle ownership. Those with no household car available prefer to live in higher density neighborhoods. In contrast, those with two cars available prefer to live in lower density neighborhoods. The negative relationship with population density becomes even stronger for those with three or more cars available. For built environment characteristics, neighborhoods with a greater proportion of apartment buildings five stories or higher are more attractive to the elderly. The elderly tend to live in neighborhoods with higher homeownership levels and dwelling values, in addition to lower incomes, fewer children, and a lower labor participation rate (i.e. retired or unemployed). This could be indicative of a tendency for the elderly to cluster in older neighborhoods with higher property values, but lower overall incomes due to higher proportions of retired people. The elderly also tend to live in neighborhoods with a greater proportion of people who have moved within the last five years, suggesting a tendency for this cohort to locate in more transient neighborhoods.

The models were evaluated in terms of AIC and BIC. The lower the value of AIC, the higher the model's goodness-of-fit. The AIC and BIC for the MNL model presented in this paper is 4.42 and 4.42 respectively. However, the latent class logit model exhibits lower AIC and BIC values. Since the LCM outperforms the MNL model, this paper considers LCM as the final model. The model also captures unobserved heterogeneity, allowing parameters to vary across classes. Discussion of the parameter estimates of the LCM model are presented below.

Latent Class Model

The LCM model used in this study assumes two latent classes. The parameter estimates of the LCM (see Table 2) suggest that significant heterogeneity exists within the sample. This is apparent across all variables, but a particularly notable divergence exists in the accessibility measures. The class membership probability is found to be 2:3 across Class 1 and Class 2, respectively.

For the accessibility measures, non-working elderly (i.e., retired or unemployed) prefer to live further away from the CBD, irrespective of class membership and consistent with the MNL model. Variation exists when distance to the CBD is interacted with no vehicle access, where in Class 1, elderly without a household vehicle prefer to live closer to the CBD. The opposite is true in Class 2. Considerable variation exists when considering the effect of the distance to the nearest regional shopping center. While living within ten kilometers of a shopping center is undesirable in both classes, the effect of no-car and one-car households differs across classes; Class 1 elderly prefer living closer to a regional shopping center regardless of household vehicle ownership levels, however the effect is reduced for those with one household car. The opposite is true for Class 2. Distance to local shopping for the general population as well as those without a driver's license is consistent with the MNL model, irrespective of class membership. Variability between classes also exists with proximity to outdoor recreation areas. Class 1 membership entails a preference for living within two kilometers of an outdoor recreation area. Class 2 demonstrates the opposite, and is consistent with the MNL model in this regard. Interestingly, no-car households tend to live further from parks in Class 1, where the opposite is true for Class 2.

Additionally, proximity to a subway station is almost five times stronger at predicting residential location in Class 1 compared to the MNL. Proximity to a subway is a weak predictor for Class 2. Interacting with those with a driver's license, the distance to a subway yields a positive parametric value (consistent with the MNL) across both classes, but has a stronger impact in Class 1. Finally, distance to a highway exit interacting with those with one or more household vehicles exhibits a negative relationship in Class 1. It shows the opposite effect for Class 2.

Generally, the effect of land use is consistent across both classes and with the MNL. The land use variables incorporated into the final model estimation are consistent with the MNL model. The effect of land use mix for elderly in general as well as elderly with one or more household cars is positive and negative, respectively. The preference for residential areas and open space is also consistent, however the influence of residential land use on residential location choice is stronger for Class 1 (1.079) compared to Class 2 (0.329). For open space, the opposite is true where Class 2 exhibits a noteworthy increase in effect compared to Class 1.

The model results for neighborhood characteristics reveal further variation. Class 1 elderly are adverse to higher population densities regardless of vehicle ownership. This runs contrary to Class 2 and the MNL model where no-car households tend to higher densities. For neighborhood built environment, it is found that in both classes there is a preference to live in neighborhoods with a greater proportion of dwellings in apartment buildings five stories or greater. The effect is notably greater in Class 1 than Class 2. A comparable pattern reveals itself in household ownership rates and average dwelling value variables. The reverse is true for neighborhood labor participation rate where the relationship is negative across both classes (consistent with MNL model), except the relationship is less influential in predicting residential location choice in Class 1 than Class 2. This suggests that the elderly in Class 1 place less importance on clustering with other retired or unemployed people in comparison to Class 2. The relationship between average number of household children and residential location choice is similar across classes and is consistent with MNL, suggesting that elderly prefer neighborhoods with fewer children regardless of class membership.

For neighborhood characteristics, recent movers (within 5 years) and average household income show variation. Class 1 elderly tend to prefer more stable neighborhoods. Class 2 is the opposite and consistent with the MNL model. For average household income, Class 2 shows variation in that they tend toward higher income neighborhoods, whereas income exerts the opposite effect for Class 1. Considering these two variables suggests that Class 1 elderly tend to choose residential locations of a more stable nature but with lower income. Class 2 choose less stable neighborhoods (i.e. a greater proportion of recent movers) but in areas of higher income.

TABLE 1 Summary Statistics of Explanatory Variables used in Elderly Residential Location Choice MNL and LCM

Variable	Description
Accessibility Characteristics	
CARSONEX	Distance to highway exit (m) X own 1+ cars
SUBWAY	Distance to subway station (m)
DLSUBWAY	Distance to subway station (m) X possess drivers' licence
LOCASHOP	Distance to local shop (m)
NDL_LSHP	Distance to local shop (m) X no drivers' licence
CAR0RCEN	Distance to regional shopping center (m) X own no car
CAR1RCEN	Distance to regional shopping center (m) X own 1 car
RCEND	Live within 10 km of regional shopping center (dummy)
ONPRPD	Live within 2 km of park or recreational facility (dummy)
CAR0_PRP	Distance to park or outdoor recreational facility (m) X own no car
CAR0PDEN	Population density (ppl/sq-km) X own no car
CAR2PDEN	Population density (ppl/sq-km) X own 2 cars
CAR3PDEN	Population density (ppl/sq-km) X own 3 cars
NWRK_CBD	Distance from home to CBD (m) X not employed
CAR0_CBD	Distance from home to CBD (m) X own no car
Land Use Characteristics	
LUINDEX4	Land use diversity mix
CARSINDX	Land use diversity mix X own 1+ cars
LURESP	Proportion of residential land use
LUPARKP	Proportion of park land use
Neighborhood Characteristics	
APT_GT5P	Proportion of dwellings in apartments 5 floors or greater
OWN_PRCT	Homeownership rate
PARTRATE	Labor participation rate
AVGCHILD	Average number of children per household
MOVE5YRP	Proportion of residents who moved within 5 years
AVDWLVAL	Average dwelling value (2001 CA$)
AVGHHINC	Average household income (2001 CA$)

TABLE 2 Parameter Estimation of Results from Elderly Residential Location Choice MNL and LCM

	MNL		Class 1 LCM		Class 2 LCM	
Variable	*Coeff.*	*t-stats*	*Coeff.*	*t-stats*	*Coeff.*	*t-stats*
Accessibility Characteristics						
NWRK_CBD	0.13	12.59	0.15	3.75	0.13	13.09
CAR0_CBD	-0.11	-7.22	-0.82	-9.41	0.02	1.51
CARSONEX	-0.13	-7.02	-1.31	-11.32	0.11	5.91
SUBWAY	-0.12	-7.78	-0.57	-7.33	0.01	0.54
DLSUBWAY	0.05	4.00	0.27	4.33	0.02	1.41
LOCASHOP	0.56	7.74	1.04	3.01	0.33	4.61
NDL_LSHP	-1.41	-7.65	-1.78	-1.47	-1.14	-7.46
CAR0RCEN	-0.12	-1.97	0.92	4.31	-0.40	-7.47
CAR1RCEN	0.07	2.84	0.40	3.30	-0.65	-3.00
RCEND	-0.41	-11.38	-0.44	-2.45	-0.31	-8.32
ONPRPD	-0.10	-6.94	0.07	1.68	-0.20	-11.51
CAR0_PRP	-1.15	-5.82	0.75	1.25	-1.23	-6.01
CAR0PDEN	0.43	13.24	-0.01	-0.10	0.81	20.20
CAR2PDEN	-1.10	-21.44	-0.23	-3.18	-1.68	-24.25
CAR3PDEN	-1.82	-15.09	-3.76	-4.60	-1.25	-9.95
Land Use Characteristics						
LUINDEX4	1.09	8.46	1.29	3.97	1.21	8.82
CARSINDX	-0.50	-3.79	-0.64	-1.96	-0.63	-4.36
LURESP	0.59	14.03	1.08	8.00	0.39	8.85
LUPARKP	0.60	9.48	0.42	2.42	0.72	9.76
Neighborhood Characteristics						
APT_GT5	0.63	15.05	1.15	10.35	0.33	6.54
OWN_PRCT	1.04	19.88	1.56	10.87	0.71	12.18
PARTRATE	-0.01	-13.36	0.00	-1.79	-0.01	-10.54
AVGCHILD	-0.79	-26.25	-0.87	-10.90	-0.82	-23.92
MOVE5YR	0.29	3.73	-1.03	-4.07	0.77	9.45
AVDWLVAL	0.02	15.59	0.04	10.30	0.01	7.73
AVGHHINC	-0.04	-9.67	-0.15	-10.12	0.01	2.89
Class Membership Allocation						
Constant			0.39	40.07	0.61	18.28
AIC	4.42		4.40			
BIC	4.43		4.42			

Note: Coefficients of ***Bolded Variables*** *are multiplied by 10,000*

Conclusion

This paper provides a comprehensive model of residential location choice of the elderly population, a gap that exists in the previous literature. Despite marked differences exhibited between successive and adjacent generations of elderly and non-elderly cohorts, few studies have addressed elderly residential location choice in isolation. One of the key contributions of this paper is the application of an LCM model to a residential location choice model. Advantages to using the LCM approach lie in an improved representation of latent heterogeneity in the sample. This type of model has largely been unexplored and is unique for elderly residential location choice.

The results of this research demonstrate that land-use and accessibility features are strong predictors for residential location choice of the elderly. Furthermore, interaction variables shows variation in residential location choice with respect to different mobility tools, specifically in interaction with population density and distance between home and amenities such as parks, outdoor recreational facilities, and local shops. Thus, this paper offers in-depth behavioural insights regarding factors affecting elderly residential location choices in the Greater Toronto and Hamilton Area (GTHA). Such insights will be useful for planners and policy makers, particularly in planning for equitable transportation services for the elderly population.

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