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Aging, Gender and Neighbourhood Determinants of Distance Traveled: A Multilevel Analysis in the Hamilton CMA

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SEDAP Research Paper No. 209

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June 2007

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Aging, Gender and Neighbourhood Determinants of Distance Traveled: A Multilevel Analysis in the Hamilton CMA

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Abstract. The objective of this study is to investigate the determinants of mean trip distance traveled by different mode types. The study uses data from the Hamilton CMA in Canada, and multilevel models to investigate demographic aging factors, gender differentials, and neighbourhood attributes on distance traveled. The results of the study validate previous findings regarding the decline in distance traveled as age advances. In addition, it is found that: 1) While this effect of age is present for all modes analyzed (car-driving, car-passenger, and bus) it is considerably more marked for car-driving; 2) There are significant gender effects compounded by the interrelated factors of employment constraints, household dynamics, and greater reliance on travel modes other than car driving; and 3) Neighbourhoods with high commercial and residential mix showed a negative relation with distance traveled only in the case of car-driver.

Keywords: distance traveled, aging, elderly, gender, neighbourhood influence, multilevel analysis

JEL Classifications: R22, R23, R41, R52, R58

Résumé
L'objectif de cette étude est d'analyser les facteurs déterminants la distance moyenne parcourue par différents moyens de transport. L'étude s'appuie sur des données de la région métropolitaine de recensement d'Hamilton au Canada, et des modèles multi-niveaux afin d'examiner l'influence sur la distance parcourue des facteurs démographiques liés à l'âge, les différences de genre, et de la spécificité des zones d'habitation. Les résultats de cette étude confirment les résultats d'études antérieures démontrant une association négative entre l'âge et la distance parcourue. De plus, il apparaît que: 1. Bien que l'effet lié à l'âge soit présent indépendamment du mode de transports considéré (automobiliste, passager d'automobile, autobus), il est beaucoup plus prononcé parmi les automobilistes 2. Il existe des effets significatifs de genre renforcés par des facteurs en corrélation avec les contraintes liées à l'emploi, la dynamique au sein du ménage, et une plus grande confiance envers des moyens de transport autres que l'automobile 3. Une corrélation négative avec la distance parcourue est seulement observée dans les zones à forte mixité urbaine (commerciale et résidentielle) parmi les automobilistes.

1. Introduction

Trip distance is one of the key geographical variables in travel analysis and given its implications to road efficiency and environmental impacts, it has been considered an important indicator of sustainable transportation in many countries including Canada (Transport Canada, 2007). The distance a person travels is also a useful indicator of quality of life -- an important development goal and component of sustainability- given that it provides an indirect measure of mobility and freedom to move around one's environment. In the subject of population aging, distance traveled is an important indicator of "active aging" as it allows a good measurement of a person's "everyday competence" or the ability to accomplish maintenance activities and to participate in social and economic activities important for successful aging (WHO, 2002; Schaie et al., 2005; Rowe and Kahn, 1997).

A considerable amount of studies have been done focusing on the concept of commuting distance/time (e.g. Chen and McKnight, 2007; Helminen and Ristimaki, 2007; McGuckin et al., 2005; Cao and Mokhtarian, 2005; Shuttleworth and Lloyd, 2005; Johansson-Stenman, 2002; Coombes and Raybould, 2000; Scott et al, 1997; Rouwendal and Rietveld, 1994) and excess commuting (e.g. Horner and O'Kelly, 2005; Rodriguez, 2004; Buliung and Kanaroglou, 2002) including the examination of gender differentials (e.g. Vance and Iovanna, 2007; Cristaldi, 2005, Lee and McDonald, 2003; Kwan, 2000; Camstra, 1996; Blumen, 1994; Johnston-Anumonwo, 1992; Brookergross and Maraffa, 1985; Hanson and Johnston, 1985), and ethnicity (e.g. Clark and Wang, 2004; Wyly, 1996). There has also been a growing resurgence of interest in the urban structure determinants of distance traveled, again from the perspective of journey to work (e.g. Ettema et al., 2007; Shearmur, 2006; Titheridge and Hall, 2006; Schwanen and Mokhtarian, 2005; Schwanen et al., 2004; van Eck et al., 2004; Timmermans et al., 2003; Weber and Kwan, 2003; Bagley and Mokhtarian, 2002; Weber, 2003; Giuliano and Small, 1993). In general, these studies have provided important contributions to understanding the connections between commuting distance and individual and geographic factors. A consistent finding is that women travel shorter distance than men which have been linked to their traditional domestic roles and constraints with respect to employment opportunities and child rearing. Ethnicity (i.e. being black or white) has been found to affect commuting distance via residential choice relative to job location. Findings on the significant effect of urban structure to commute distance or on travel behavior in general remains inconclusive (van Wee, 2002; Boarnet and Crane, 2001; Boarnet and Sarmiento, 1998; Reilly and Landis, 2002) and thus, studies in this area continue to thrive (e.g. Schwanen and Mokhtarian, 2005; Timmermans et al., 2003; Krizek, 2003). More recently, the debate continues as additional evidence of the relative impacts of urban form on travel behavior is produced that provides conflicting and mixed results. This includes, for instance, studies that suggest a strong importance of geographic context in influencing travel distance/time and mode choice (Chen and McKnight, 2007; Titheride and Hall, 2006; van Eck et al., 2004), a weak influence of urban patterns and land uses on individual accessibility (Weber and Kwan, 2003; Weber, 2003; Bagley and Mokhtarian, 2002; Timmermans, 2003) and various studies that point to other factors that play greater role than urban structure to influence travel behavior such as gender differential reactions (Shearmur, 2006; Ettema et al., 2007), mismatch between person's neighbourhood structure and preference (Schwanen and Mokhtarian, 2005), social and labor market distribution across areas (Shuttleworth and Lloyd, 2005; Schwanen et al., 2004), and intra- and interpersonal linkages in activity choice and time allocation (Ettema et al., 2007). A call for more studies on the individual-spatial relationship is, therefore, still in order.

In contrast to the mounting studies on trip distance related to gender and urban structure, there has been limited research that focuses on the elderly, despite a growing body of evidence that the travel behavior of the 65+ cohort is significantly different from other segments of the population. Age, in the above cited studies where it has been considered a variable in the model, showed negative effect on distance traveled. For instance, Rouwendal and Rietvield (1994) found that older people tend to undertake shorter commuting distance than young people (*ceteris paribus*), a finding that Schwanen et al., (2003) also evinced. Commuting distance (by car or public transport) has been found to reach its peak at about the age of 50 (Johansson-Stenman, 2002). It should be emphasized that studies that have so far been done on commute distance/time are less useful to help understand the behavior of the elderly inasmuch as journey-to-work is less prevalent or dominant among this group. In fact, as shown by Schmocker et al., (2005) (which to our best knowledge has been the only published study to date that modeled distance traveled by the elderly) showed that trip distance declines with age in general, but recreational trip distance increases among the elderly until about the age of 80. In terms of variables that have been found to positively affect distance traveled, they reported household income, work status, driving license ownership, and household car ownership. Among the factors that are associated with shorter trips include walking disability as well as living in the city core (Inner London). Collia et al., (2003), reporting on the results of the 2001 U.S. National Household Travel Survey (NHTS) also reported that older people travel shorter distance compared to the rest of the population and this is more pronounced among those with medical conditions. In view of the changing physical, economic status and social status of the elderly, the factors that affect their travel behavior are relatively different from the rest of the population. As the number and proportion of older persons in the populations of most countries of the world continue to grow at an unprecedented rate (UN, 2002), the manner and extent to which this demographic change will impact transportation systems have attracted considerable attention. The focal interest in aging and transportation has been framed within the context of meeting social, health and environmental goals. This is apparent in calls for policy reforms (e.g. ECMT, 2001; OECD, 2001; Katz and Puentes, 2005; Rosenbloom, 2005) as well as in the motivation of empirical investigations on travel behavior and needs of the elderly population (e.g. Hensher, 2007; Paez et al., 2007; Golob and Hensher, 2007; Newbold et al., 2005; Blomqvist and Siren, 2003; Hildebrand, 2003; Burkhardt and McGavock, 1999; Rosenbloom, 2001; Rosenbloom and Morris, 1998).

The present study complements these efforts of benchmarking elderly travel behavior in support of transportation planning in an aging population. There is a need to examine elderly distance traveled to solidify knowledge not only of the socio-demographic but also the geographic factors at play. The relevance of the individual and built environment relationships is particularly acute in the case of the elderly segment of the population, given the type of sprawling development observed in a large number of North American cities (Rodriguez et al, 2006), as well as current aging-in-place trends

(Blanchard et al, 2004; Lloyd, 2000; Harlow and Garcia, 2002) that may place the current and future elderly in a built environment situation not particularly sustainable in terms of contemporary mobility needs. In particular, the objective of this study is to investigate distance traveled and the variability of this factor in regards to the major mode types in the study area. Using as a case study the Hamilton CMA in Canada, this study aims to tease out the relative impacts of individual factors and geographical context in influencing travel outcomes. The use of multilevel models allows us to measure the relative effects of these individual and spatial variations. This study complements previous work on trip generation in the Hamilton CMA (Paez et al., 2007), and hopes to inform the development of a Geographic Information System (GIS)-based decision support system for evaluating the impact of demographic change and socio-economic policies in relation to sustainable transportation in the metropolitan area (Maoh et al., 2005; Mercado et al., 2006). Finally, the findings of the study contribute to the general discussion regarding the need to promote communities that facilitate healthy aging (Masotti et al., 2006).

2. Theoretical Perspectives

This study draws its conceptual background from the classic time-geographic framework (Hagerstrand, 1970; Lenntorp, 1976). Space-time geography revolutionized analysis of transportation systems in terms of its focus on individuals (versus zones) and how their constraints over time and space influence travel outcomes. Time-geography frames an individual's existence in a space-time path (or a space-time prism) -- a trajectory or movement, or what Pred (1977) graphically described as a "weaving dance through time and space" or the "choreography of human existence". A space-time "prism" is the set of all locations that can be potentially reached by an individual given a maximum speed limit from a starting location to a destination point in space-time. The space-time paths that an individual take are controlled by the constraints in each of these space-time prisms or "potential path spaces," (PPS) (Lenntorp, 1976). Distance traveled measures a key aspect of this potential path as it is realized, and provides a tangible connection with the context of individual decisions resulting from constraints on activity participation in time and space, all aspects that are paramount in the investigation of travel behavior.

Pred (1997), reflecting upon the application of Hagerstrand's time-geography perspective in human geography, reviews the three major classes of constraints that affect an individual's PPSs. These constraints provide a valuable framework for identifying individual and geographic factors affecting travel behavior. The first is "*capability constraints*" which refer to physical or biological factors that limit human movement (e.g. distance traveled in a given time-span) as well as the transportation technology adapted to these physical restrictions available to the individual. A person's time is constrained by his/her physiological necessities (essential maintenance activities) and physical limitations (indivisibility). Thus, an individual would allocate a large chunk of time to personal maintenance activities such as sleeping, eating and personal care and has to budget the remaining time for other activities. The indivisibility of a person means that no one can be in two locations at the same time and thus a trade-off in space and time is required. Overcoming capability constraints would make it possible for an individual to take advantage of transport means or technology available to efficiently carry out the activity agenda. Thus, a person that travels by car could have more advantage over someone walking or taking the bus in terms of time saved traveling, going to more places or spending more time in a particular destination given a time budget.

The second set of constraints is "*coupling constraints*" which relates to the limitation of the person to perform activities (and therefore travel) in isolation as these activities must be temporarily linked up or "bundled" with other people's space-time paths. An example of this coincidence of space-time paths is shopping where an individual can join other shoppers at a certain length of time the store or the mall is open. Being employed is also a coupling constraint as a person needs to adhere to a fixed time schedule depending on the type of work and shift demands. Kwan (2000) strongly underlined the case for the possibility of a "feminist time-geography" to flourish in understanding spatio-temporal experiences in daily life by showing evidence of the significant differences in women's time-budget and fixity constraints (i.e. fixed activities imposing "hard constraints" on activity-travel pattern and job location) compared to men. She found that regardless of employment status (whether part-time or full-time) women encounter more fixed activities in their daily lives than men. These fixed activities are mostly associated with household needs that put constraints on job location and non-employment activities. These findings are consistent with previous studies on gender differences in traditional domestic roles and employment opportunities wherein the constraints take on different forms and context as evinced by empirical findings in this regard (Palm and Pead, 1974; Tivers, 1985; Hanson and Hanson, 1981; Hanson and Pratt, 1990; Kwan, 1999; Miller, 1983; Dyck, 1990; England, 1993; Vance and Iovanna, 2007).

The last set of constraints is called "*authority constraints*" which refer to limits of accessibility to certain places or "domain" placed by authorities (i.e. certain people or institutions) to individuals. These limits come in the form of general rules, laws, economic barriers, and power relationships. In large respect, the possession of "mobility tools" (Scott and Axhausen, 2005) such as personal vehicles, driver license or transit pass could be considered authority constraints in terms of creating rules and/or economic barriers to who can or cannot have access to road systems and highways.

The time-geographic perspective has been instrumental in innovations in modern transportation planning as in case of development in GIS science (e.g. Miller, 1991). More importantly with its focus on people and the concern for "quality of life" (Pred, 1977), the analysis of individual accessibility has proved useful in facilitating the understanding of social issues and thus has given rise to a movement towards a "spatially integrated social science" (Goodchild et al., 2000; Goodchild and Janelle, 2003; Kwan et al., 2003). For instance, the application of the space-time model has allowed the demonstration of the impact of gender disparities in space-time constraints and their impact on men's and women's activity-travel patterns which has not been the case for traditional spatial gravity models (e.g. Palm and Pred, 1974; Hanson and Pratt, 1995; Kwan, 2000).

While the older population has not been, to our knowledge, the specific focus of time-space geographic research, it can be hypothesized that the elderly possess the same constraints as the rest of the population but the nature, degree or quality of these constraints will be remarkably different. To illustrate, the elderly would face greater capability constraints as the physiological and psychological limitations take hold. Such increasing constraint will lead to reduced distance travel. However, given that most of them will opt to retire from work, their coupling constraints will be more relaxed as they perform fewer fixed activities (e.g. 9-5 jobs), thus increasing their time budget and expanding their time-space prisms. Such potential expansion of their PPAs will lead to longer distance traveled. The net outcome of these varying constraints presents a challenge for research. As Hagerstrand (1970) notes, the three constraints interact in many ways, both obvious and latent. Thus, even with gained time from being free from coupling constraints of a regular job schedule, the elderly can face a new coupling constraint if they are dependent on family members for mobility. That is, they may have to schedule their activities to coincide with the work schedule of family members in getting out of the home and/or returning home. This could happen as a result of the elderly's capability constraint which could lead, say, to loss of driver license when driving skills decline (authority constraint). Therefore, with no other options for independent mobility (e.g. bus, taxi, etc) coupled with prohibitive time-space locations of residence, social activities and recreation or economic means (authority constraints), they may not have a choice but become car passengers or in the face of inadequate social support, mobility could be significantly threatened. Consequently, their quality of life becomes an important issue. In this study, the time-space geographic perspective as applied to the elderly provides the basic reflection guide for the analysis of empirical results on distance traveled by this population group. The study employs multilevel analysis in testing for the effects of these various constraint factors on distance traveled as will be fully discussed in the next section.

3. Methods and Data Sources

3.1 Multilevel Models

Multilevel models are statistical models that specify and estimate the relationship between variables observed at different levels of hierarchical structures (Rashbash, 2004). In other words, multilevel modeling allows one to determine the relative impacts of each level of the hierarchy (individual, groups, sub-groups, etc.) on the response (dependent) variable and to identify the factors at each of the levels associated with the dependent variable. This type of modeling has been considered an important alternative modeling approach that addresses the recognized limitations of multiple regression analysis as it captures variations in differences between individuals and between places that regression analysis fails to consider (Duncan and Jones, 2000; see also similar discussions in Paez et al., 2007). At the same time, it addresses recommendations from previous research (e.g. Reilly and Landis, 2002) to explore other complex models that will provide additional light regarding individual and contextual effects on travel behavior as it relates to the debate on land-use-travel linkages.

3.2 Model Specification

The basic two-level multilevel model with no parameters but only the intercept, or what is variously termed in the applied literature as an empty model (e.g. Merlo et al., 2005), or intercepts-only model (Schwanen et al., 2004), can be written as applied to the case of the present analysis as:

$$y_{ij} = B_{0j} + e_{ij} \quad (1)$$

$$B_{0j} = B_0 + u_0j \quad (2)$$

where individual i within zone j is denoted i=1,2,…n_j and zone is denoted j=1,2…J; y_{ij} is the average distance traveled (distance score) of the individual i nested within zone j; B_{0j} is the mean of y within zone j; B_0 is the grand mean of y across all i and j.
Substituting (2) into (1)

$$y_{ij} = B_{0j} + u_{0j} + e_{ij}$$
$$u_{0j} \sim N(0,\delta^2_{u0})$$
$$e_{ij} \sim N(0,\delta^2_{e})$$

where e_{ij} is the deviation of the individual's distance score from the mean distance score of the zone with variance, δ^2_e ; and u_{0j} is the deviation of the mean distance score of zone j from the grand mean across all J, with variance δ^2_{u0};

Additional explanatory variables B_{1j}, B_{2j}....Bij are added to (3) based on the variable selections.

In multilevel modeling, the total variance of y_{ij} is broken down into two components: the variance between individuals within a given zone or σ_e^2 and the variance between zones or $\delta^2_{u0.}$. Thus,

$$\text{Var}(y_{ij}) = \sigma_e^2 + \delta^2_{u0.}$$

3.3 Evaluation and Test of Goodness of Fit of Multilevel Models

3.3.1 Intra-class Correlation (ICC)

In order to determine the proportion of the total variability that is accounted for by differences among zones, a coefficient is determined expressed as:

$$ICC = \frac{\sigma^2_{u0}}{\sigma^2_{u0} + \sigma^2_{e}}$$

The ICC is also called the Variance Partition Coefficient (VPC) since it represents the proportion of the total residual variation that is due to differences between zones. Normally the ICC is expressed in percentage form. Model comparison of ICC is also evaluated as to whether the addition of variables in the model accounts for the group effects.

3.3.2 Likelihood Ratio Test

In order to test the significance of the random effects model with the naïve (restricted or constrained) model or to determine the goodness of fit of two models (e.g. regression model versus random effects model), the likelihood test is employed. This test requires obtaining the difference between the log-likelihoods of the two models being compared, i.e $-2 \log L_1 - (-2 \log L_2)$. The statistic derived is then compared to a chi-squared distribution on q degrees of freedom, where q is the difference in the number of parameters between two comparative models.

As is well known, the conventional regression model is in fact a reduced form of the multilevel framework (when the random components are removed). Thus, multilevel analysis is a flexible tool that allows single level analysis (i.e. ordinary multiple regression) while enabling more complex questions of where and how effects are occurring (i.e whether between individuals or between groups of individuals). In this study of distance traveled, we are interested in determining to what extent individual attributes and differences among individuals in the various zones or neighborhoods affect the outcome variable. To select the best models that would better explain these determinants, multilevel models were estimated for a pooled dataset (motorized modes), as well as specific travel modes (i.e. car-driving, car-passenger, bus), and then tested for significance relative to the respective multiple regression models estimated.

Interested readers can seek extended explanations of the multilevel model specifications and evaluation in Bryk and Raudenbush (1992), Longford (1993), and Goldstein (1995), and their use in geographical research in Duncan and Jones (2000). This study utilized Microsoft Excel® for data processing and MLwiN® Software version 2.02 (Rasbash et al., 2004) for the descriptive analysis as well as estimation of the multiple regression and multilevel models.

3.4 Study Area

The geographic focus of this study is the Hamilton Census Metropolitan Area (CMA), the 9th largest metropolis in Canada and an important component of the Greater Toronto Area (GTA). The Hamilton CMA is a planning area consisting of three different administrative units, namely the City of Hamilton (composed of the municipalities of Hamilton, Dundas, Ancaster, Stoney Creek, Glanbrook and Flamborough), the City of Burlington, and Grimsby. The area plays an important role as a growth centre in the province of Ontario, being its 4th largest urban center after Toronto, Ottawa, and Mississauga. Much of its 650,000 population (Statistics Canada, 2007) reside in the City of Hamilton (500,000) but the distribution of the elderly population is geographically dispersed in these eight municipalities (Paez et al., 2007).

3.5 Data Sources

Data used for this study come from the Transportation Tomorrow Survey (TTS), a comprehensive travel survey conducted since 1986 (once every five years) in the GTA, coinciding with the Canada Census. The present study uses the 1996 (3rd of series) survey data for Hamilton CMA extracted from the larger sample that include information on individuals and households and the trips they made using public and private transportation during one weekday. The sample used in this study is a sub-set of the Hamilton CMA and contains 16,190 individuals distributed in the 205 TAZs with a corresponding total of 50,860 trips. The TAZ created for the 1996 TTS conforms to municipal boundaries and street patterns and approximates the census tracts or boundaries in the case of Hamilton CMA. This is noteworthy since census tracts developed by Statistics Canada based on physical boundaries and social homogeneity had been found to be ecologically meaningful scales for use in neighborhood studies (Ross et al., 2004). In addition, this study uses the land use data processed from the DMTI® Spatial Inc. CanMap 2001 for the Ontario Province using ArcView 3.2 (GIS) software. The DMTI® Spatial Inc is Canada's premier spatial data provider and an authorized user and distributor of selected Statistics Canada computer files.

4. Model Variables and Selection

Table 1 outlines the variables used in the model analysis. The following describes these more fully including the selection of the variables.

4.1 Dependent Variable – Mean Trip Distance

Mean trip distance is a variable created from the TTS database, which is the ratio of the total distance traveled (in kilometers) and the number of trips taken by an individual in a particular weekday. There are two aspects of analysis undertaken in this study: 1) mean trip distance for each of the major transport modes (i.e car-driver, car passenger, bus, walking, rail, and bicycle) and 2) mean trip distance for all motorized modes of travel chosen (i.e. car-driver, car passenger and bus). Most of the trips carried out by an individual in the study area were done using a single mode. In few cases wherein more than one mode is used, the more dominant mode (i.e more trips using a particular mode) is considered and the trip length using such mode has been recorded for the individual.

4.2 Explanatory Variables

The selection of the variables employed in the present analysis has been informed by previous research on trip frequency in the study area (Paez et al., 2007) as well as by past and most recent studies carried out on distance traveled. The theoretical perspectives outlined earlier aided in putting into context the variables considered in the model with consideration on the data available in the TTS. As shown in Table 1, the independent variables were classified into individual and zonal (spatial opportunity) variables. Individual variables were further categorized into three major factors following Hagerstrand's classes of mobility constraints.

The first set of variables is the *capability constraint factors* which include age cohort and gender. In this study, age classifications have been constructed so as to reflect the differentiation in experiences between age groups and in the case of elderly age groupings, to bring out the unique factors affecting the travel behavior between the young old and the old-old. The age-group categories represent major episodes in the life course, a concept that taps the changing social and economic roles that individuals hold as they age (Elder, 1985; George, 1996). The classification used in this paper captures the three conventional classes of childhood/adolescence, adulthood and old-age. However, a more detailed categorization has been used to allow more information on travel behaviour that occurs within specific life transitions, as follows: the very young (age less than 20), young adult (20-35), middle age (36-50), pre-retirement (51-64) and the elderly group (65+). The latter group is further broken down into the young old (65-79) and old-old (80 and over) as has been suggested in recent literature concerning the differentiation in physical state and societal issues between these groups of older population (Poon et al., 2005). Moreover, the old-old has been considered one of the fastest growing population segments especially in developed countries and thus an important subject of research inquiry in aging (George, 1996; Poon et al., 2005) as well as policy intervention (e.g. Tasca, 2005). Previous studies on distance traveled have shown that age is negatively related to number of trip distance (Rosenbloom, 1995; Benekohal et al., 1994; Chu, 1994; Boarnet and Sarmiento, 1998) and with particular evidence with respect to car and bus modes (Stradling, 2005). In elderly travel studies, the same finding was evidenced in terms of this inverse relationship of age and trip propensity (Paez et al., 2007) as well as trip length (e.g. Schmocker et al., 2005). With regards to gender, more recent studies such as that of Vance and Iovanna (2007) in studying car owning households in Germany showed that gender significantly affect the probability of car use and distance driven. Meanwhile Limtanakool et al. (2006) based on UK and Netherlands travel survey revealed that males are more likely to engage in medium- and long-distance travel. This complements the study of Stradling et al. (2005), which found significant negative effect of being female on distance traveled.

Table 1
Variable Definitions

DEPENDENT VARIABLE	
Mean distance (total distance traveled over total number of trips)	
INDEPENDENT VARIABLES	
Individual Variables	
Capability Constraint Factors	
Age <20	Age<20: 1 if true, otherwise 0
Age 20-35	20<=Age<35: 1 if true, otherwise 0
Age 36-50	35<=Age<50: 1 if true, othertwise 0
Age 51-64	50<=Age<65: 1 if true, otherwise 0
Age 65-79	65<=Age<80: 1 if true, otherwise 0
Age 80+	Age>=80: 1 if true, otherwise 0
Gender	Female=1; Male = 0
Coupling Constraint Factors	
Employment Status	1=Fulltime;,2=Part-time, 3=Not Employed
Household Size	Continuous variable
Authority Constraint Factors	
Travel Mode	
CarD	Car as driver: 1 if true, otherwise 0
CarP	Car as passenger: 1 if true, otherwise 0
Bus	Bus: 1 if true, otherwise 0
License	License holder: 1 if true, otherwise 0
Vehicle Ownership	Cars>0: 1 if true, otherwise 0
Transit Pass Possession	Transit pass holder: 1 if true, otherwise 0
Vehicle and Transit Pass	Vehicle>0 AND Transit pass=1: 1 if true, otherwise 0
Spatial Opportunity Variables	
Median Income	Continuous variable
Population Density	Continuous variable
LandUse	
Low Commercial and Low Residential (LC-LR)	1 If true, otherwise 0
Low Commercial and HIgh Residential (LC-HR)	1 If true, otherwise 0
High Commercial and Low Residential (HC-LR)	1 If true, otherwise 0
High Commercial and High Residential (HC-HR)	1 If true, otherwise 0

The second set of individual factors referred to as *coupling constraint factors* include employment status and household size. As explained in Section 2.2, the impact of the type of employment (whether full-time or part-time) has significant effect on travel length incurred. In addition, Vance and Iovanna (2007) found a negative impact of employment status on the probability of car use and distance driven. In particular, employed persons drive less than 1.56 kilometres than their non-employed counterparts. No significant gender differences have been found, although the magnitude of difference was found to be lower for females compared to males. The effect of household size is hypothesized to have a negative effect on distance traveled via the effects of increasing need for social interactions at home in relation to increased number of children at home (Stradling, 2005), complementarities in trip-making (Paez et al., 2007) or the complexity in intra-household decision-making (Scott and Kanaroglou, 2002).

The third set of individual attributes are the *authority constraint factors* which include the mobility tools such as travel mode, license ownership, vehicle ownership, transit pass ownership or a combination of these as well as median income. Vance and Iovanna (2007) argued on the close interrelationships between mode choice and distance traveled while Stradling et al (2005) gave empirical evidences to show differences in factors affecting distance traveled by specific travel modes. In particular, they found differing (sometimes conflicting) findings on the factors affecting distance traveled between car and bus modes. For example they found that distance traveled by car decreases as frequency of local bus service rises but this has not been found true in the case of bus as the mode of travel. However, they did find consistent positive effects of license ownership, number of cars in the household as an indicator of car availability. Car availability has also been found significant in the study of Vance and Iovanna (2007) including the gender effect particularly on increasing the probability of women to use car and travel longer distances. They explained this as revealing the "patriarchal constraints" or traditional gender roles that limit women's access to the car in cases in which a choice between drivers must be made and that "the general pattern is for husbands to have first choice of car-use" (Pickup, 1985). License ownership and transit pass ownership were found significant in the study of Paez et al., (2007) in the study area and it would be interesting to validate the significance of these mobility tools in the case of distance traveled.

There are two major zonal (spatial opportunity) variables that have been selected for use in the model. The first is population density which is the number of persons in the zone relative to its land size, a variable that has been traditionally used in travel behavior analysis (e.g. Reilly and Landis, 2002; Cervero and Kockelman (1997). In regards to distance traveled, Limtanakool et al., (2006) showed that the overall structure of the urban system in combination with the size of the country and the local population density affect the participation in medium- and long-distance travel. The second variable relates to residential and commercial land use mix in the zones. The various zones, which depict the neighborhoods where the sample population reside, were characterized with respect to the degree of their residential and commercial coverage. Four land use types were identified in this regard using the median value of the 205 zones as cut-off, such that less than or equal to the median is considered low, and above the median is high, to wit: 1) low commercial-low residential (LC-LR); 2) low commercial-high residential (LC-HR); 3) high commercial-low residential (HC-LR); and 4) high commercial-high residential (HC-HR). It is hypothesized that the higher the residential and commercial density is in the zone, the shorter will be the travel distance that will be incurred. A related study concerning distance traveled and the urban accessibility have shown that relative to large urban areas, small accessible towns, accessible rural locations and remote rural locations result in more travel by car while very remote locations (typically Island locations) generated less car travel (Stradling et al., 2005). For this study, in view of information constraint on household income, the median income of the zone which captures the income of households of the sample population has been used. The findings on trip frequency with regards to income effects has been mixed (Schmocker et al., 2005; Boarnet and Sarmiento, 1998; Smith and Sylvestre, 2001) while an examination of median income of traffic analysis zones in the study area showed no significant effect (Paez et al., 2007). While household income has been found to have a significant positive effect on distance traveled (e.g. Georgii and Pendyala, 2001; Stradling et al., 2005; Limtanakool et al., 2006), the survey used in this analysis does not have information on income to validate such findings. However, the income of the zones or neighborhood studied provides some sense as to household income effects on distance traveled in the study area considering the income-based geographic distribution of residents in the study area. Paez et al.'s (2007) study showed weak and insignificant effect of this variable in terms of trip frequency and it would be noteworthy to re-consider this variable with respect to distance traveled.

5. Descriptive Analysis

5.1 Trip-making and Distance Traveled

Trip indicators show a general decline in average travel frequency and distance as age advances (Table 2). Compared to the average number of trips taken, a more pronounced decline from one age group to another can be seen in average distance traveled. On the average, people in the study area travel about three to four trips in a day with an average trip distance of about 8.1 km. Average distance traveled peaks in early adulthood (20-35), at around 10 km. and then gradually declines, dropping to 4.3 km. in the elderly group. The pre-retirement group (51-64) behaves more similarly with the younger group but already exhibits a gradual decline in both trip indicators.

Compared to the average number of trips taken, there is a marked gender difference in distance traveled (Figure 1). Women tend to travel shorter distances relative to men. This gender divide tends to vanish among the elderly group. In this group, while elderly males tend to still travel farther than females, the difference is only by half a kilometer for the young-old and almost a kilometer for the old-old group. Among younger adults, such difference between gender is about 3 km in favor of males.

Table 2
Comparative Trip Indicators, By Population Group and Gender, Hamilton CMA, 1996

Age/Gender	Sample *N*	Mean No. Trips *trip/person*	Mean Distance *km/trip*
Less 20	2502	2.72	3.52
Male	1305	2.70	3.63
Female	1197	2.74	3.40
20-35	4788	3.14	9.95
Male	2384	3.09	11.30
Female	2404	3.20	8.60
36-50	4661	3.41	9.62
Male	2345	3.27	11.40
Female	2316	3.55	7.86
51-64	2348	3.15	8.42
Male	1175	3.17	9.81
Female	1173	3.12	7.03
65-79	1681	3.06	5.31
Male	814	3.13	5.59
Female	867	2.99	5.06
80+	210	2.78	4.27
Male	89	2.76	4.72
Female	121	2.79	3.94
ALL	16190	3.14	8.08
Male	8112	3.09	9.23
Female	8078	3.19	6.94

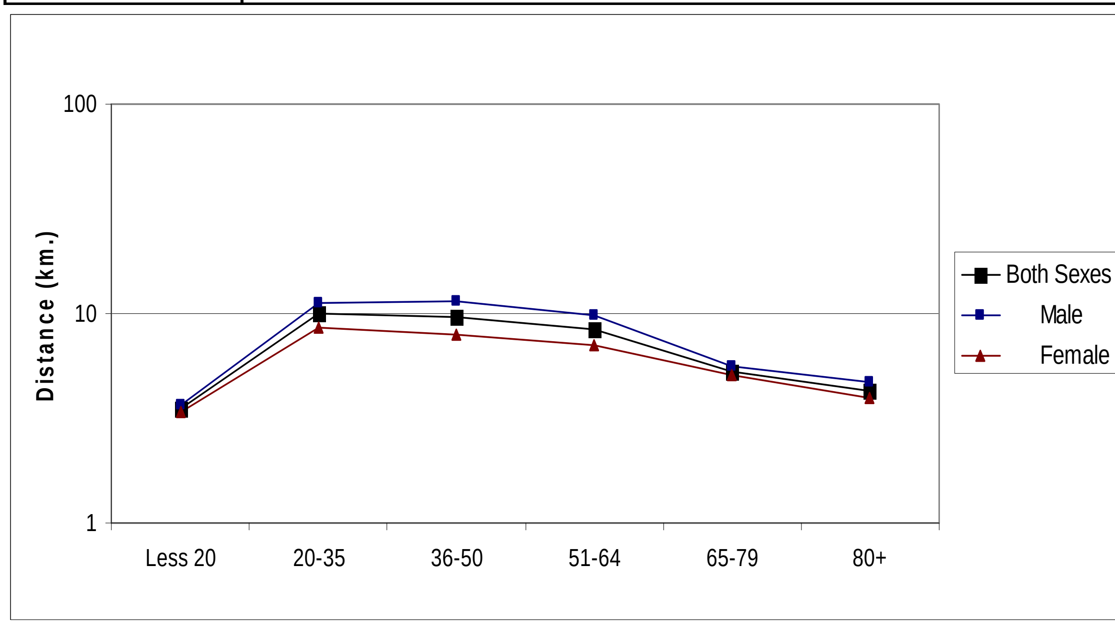

Figure 1. Mean Distance Traveled, By Age Group and Gender

5.2 Average Distance Traveled By Travel Mode

The TTS database records seven (7) major transport modes, in particular, car driving, car-passenger, walking, bus, taxi, cycling, and rail. In as much as rail constitutes a very insignificant mode in the study area, it has been excluded in the present analysis. A majority of the population (60.8%) in the study area drive a vehicle as their primary transport mode followed by car-passenger (17.0%), bus (11.2%) and walking (9.2%).

Table 3 shows the distance traveled for each major travel mode by age and gender. The general trend in average trip distance is mirrored by car driving in as much as most are car-drivers. Distance traveled by driving a car swells in the age group 20-35 then gradually declines as one ages. Male drivers travel significantly farther than women drivers. It is interesting to note also that while men continue to drive more in their later life than women, the difference in trip distance in the elderly age group is no longer significant. In fact, women who drive in their 80s even drive half a kilometer farther than men in this age group.

Table 3
Distance Traveled by Age, Gender and Transport Mode

Mode/Gender	Less 20	20-35	36-50	51-64	65-79	80+	ALL
Car-driver	7.54	11.30	10.40	9.15	5.63	5.07	9.92
Male	7.69	12.60	12.00	10.20	5.78	4.85	11.00
Female	7.39	9.83	8.53	7.67	5.37	5.34	8.53
Car-passenger	4.80	8.50	7.28	7.10	5.31	4.38	6.78
Male	5.33	9.61	7.37	7.92	4.95	5.47	7.34
Female	4.30	7.76	7.22	6.75	5.45	3.81	6.45
Walk	1.50	1.63	1.88	1.41	2.50	2.93	1.57
Male	1.60	1.48	2.04	2.13	2.17	2.15	1.64
Female	1.39	1.74	1.78	1.08	2.58	4.50	1.51
Bus	4.73	8.12	10.40	8.28	3.93	2.25	6.40
Male	4.84	8.39	16.60	12.10	5.16	2.54	7.33
Female	4.61	7.95	6.76	6.57	3.49	2.12	5.69
Taxi	3.05	3.98	3.78	3.22	2.64	1.87	3.34
Male	2.31	5.56	3.33	4.25	2.35	0.00	3.92
Female	3.92	3.11	4.49	2.40	2.67	1.87	3.02
Bicycle	2.01	2.81	4.02	4.14	1.70	0.50	2.79
Male	1.94	3.26	4.18	4.25	1.70	0.00	2.99
Female	2.12	2.14	3.69	4.00	0.00	1.00	2.46
All Modes	3.52	9.95	9.62	8.42	5.31	4.27	8.08
Male	3.63	11.30	11.40	9.81	5.59	4.72	9.23
Female	3.40	8.63	7.86	7.03	5.06	3.94	6.94

While distance traveled as car passenger takes the same general trend as car driving in terms of reduction as age advances, gender difference is not as marked. The difference in distance traveled among elderly group is also not as marked but old-old men travel more than a kilometer than old-old women. While bus represents a relative modest share in comparison with private car use, it showed the farthest distance traveled among adults who use it especially among male bus riders (16.6 km.). This suggests that the bus is a very important mode for longer distance commuting. Percent bus usage remains relatively stable among adult groups but as one gets older, distance traveled using this mode dramatically drops.

6. Multilevel Analysis

Results of multilevel analysis performed for distance traveled by mode of transport are reported in this section. The final models selected for presentation include car-driving, car passenger, bus, and a combined general model which we call "motorized modes". Walking and cycling models were estimated but suffered convergence problems. Two levels of modeling were performed on these four models: individual (using multiple regression analysis) and zonal (using a two-level random intercept model analysis).

Table 4 shows the summary of the model results based on multiple regression analysis and Table 5 provides the model results for the multilevel analysis. Significance testing of the multilevel model based on likelihood ratio tests shows that three models have significant spatial heterogeneity. These are: motorized, car-driver and bus. Thus, the multilevel model is to be preferred over the regression model in regards to these modes. However, ICC scores were low (ranging from 3-5%) indicating that individual/compositional effects account largely for the variation in distance traveled, as opposed to contextual factors (i.e. the differences between zones or neighborhoods). The multilevel model on car-passenger showed no significant spatial variation (the likelihood ratio statistic is not significant) and therefore suggests that the regression model for this particular mode is to be preferred over the multilevel model on the basis of efficiency and parsimony. The low R-squared derived from the four models in the multiple regression analysis indicate that while the variables that are significant in the models contribute to explain distance traveled, a large amount of variability remains unexplained, and therefore other factors should be considered to make the models useful in making predictions in the study area. In any case, the results of the models provide evidence on the effects (direction and magnitude) on travel distance, even if the models are unsuitable for predictive purposes.

It is noteworthy that the variables are consistent with respect to the two levels of analysis in terms of strength (only small decimal changes) and direction of the coefficients, with only one exception -- the effect of the land use variable "HCHR" was masked in level 1 (regression model) but found to be significant in level 2 (random intercept model) for car-driver. The next sections discuss the results of the selected models and the variables found significant for each of these models.

6.1 Individual Variables

6.1.1 Capability Constraint Factors

Age is a significant determinant of distance traveled by motorized mode. This result is, however, reflective of car driving as significant results have not been found for car-passenger and bus. The negative and increasing magnitude of the coefficients as a person moves from one age cohort to another starting from adulthood confirm the observed general declining trend in distance traveled as age advances. This finding complements results by Paez et al. (2007) on trip frequency in the study area and further validates current knowledge regarding the negative effect of age on travel demand. Young people and the elderly are more likely to travel four to five kilometers less than the younger adults (reference group is 20-35).

In addition, between older persons, the results show that the young-old travel more than the old-old by a kilometer difference. For car drivers, the magnitude of reduction in travel distance is much more pronounced especially among the older population. A reduction of about 5 km. could be expected upon reaching the retirement age of 65. Interestingly, there is not a marked difference in the magnitude of travel distance reduction between young-old and old-old groups. This suggests that amongst elderly peers, they travel about the same distance as long as they keep their ability to drive. As mentioned, the expected decline in distance traveled as one ages does not hold in the case of car passengers and those who take the bus. For these modes of transportation, based on the significance of the coefficients, the respective difference in distance traveled do not vary much with reference to the reference group 20-35. In other words, no matter how old a person is, distance traveled stays relatively the same if a person travels using these modes. For bus riders, the positive coefficient returned by the 36-50 age-group is interesting as this is also the group that has the highest proportion of car drivers (78%). This finding depicts the importance of the bus for those who use it as the main mode of transport or who use the same as an alternative to their private vehicle. The effect of gender on distance traveled only appeared to matter for car passenger mode. Being female returned a negative and large coefficient (-7.7) suggesting the gender-sensitivity of distance traveled by this travel mode. It reflects the high disparity of distance traveled between men and women even as a car passenger. Gender effects come into play for other modes when interacted with other constraint factor variables, as will be discussed in later sections.

Table 4
Results of Multiple Regression Models - Average Distance Traveled

Variables	MOTORIZED (Car and Bus)		CAR-DRIVER		CAR PASSENGER		BUS	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	11.7840	0.0000	12.5660	0.0000	13.1500	0.0000	5.7780	0.0265
INDIVIDUAL ATTRIBUTES								
Capability Constraint Factors								
Age Cohort								
Less 20	-4.0840	0.0000	-2.9770	0.0012	-3.5290	0.0000	-3.2560	0.0000
20-35	REFERENCE							
36-50	-1.0450	0.0000	-1.2740	0.0000	-1.2160	0.0048	1.6620	0.0167
51-64	-1.7760	0.0000	-2.0730	0.0000	-1.1780	0.0124	0.1550	0.4371
65-79	-4.1760	0.0245	-7.4570	0.0093	-1.0310	0.3579	-0.1030	0.4962
80+	-4.7250	0.0171	-7.4470	0.0139	-1.9630	0.2514	-1.8620	0.4327
Gender								
Male	REFERENCE							
Female	-2.6350	0.0227	0.3350	0.4290	-7.6680	0.0010	-4.5400	0.1026
Coupling Constraint Factors								
Employment Status								
Full-time	REFERENCE							
Part-time	-3.4890	0.0000	-4.1270	0.0000	0.8020	0.1949	-5.4100	0.0000
Female	1.7330	0.0016	1.8690	0.0068	-0.5980	0.2960	3.5440	0.0066
Age 65+	2.4510	0.0264	3.4160	0.0174	-1.4700	0.2355	0.0560	0.4955
Not-Employed	-3.1850	0.0000	-3.1520	0.0000	-1.6610	0.0037	-3.8750	0.0000
Female	1.8230	0.0000	1.2420	0.0102	1.3920	0.0322	3.2680	0.0000
Age 65+	1.0530	0.1034	1.2930	0.1244	-0.3250	0.4013	-0.9400	0.4026
Household Size	-1.5040	0.0000	-0.2630	0.0007	0.0700	0.2660	0.1420	0.1687
Authority Constraint Factors								
Trip Mode								
Car Driver	REFERENCE							
Car passenger	-1.5040	0.0000						
Bus	-1.3220	0.0001						
License Ownership	0.6800	0.0671	-0.3930	0.3227	-0.0830	0.4522	2.6090	0.0000
Female	1.1130	0.0198	-2.9560	0.0034	0.9630	0.1135	-0.7470	0.2199
Age 65+	-0.8440	0.1133	0.8970	0.3013	-0.2100	0.4036	-2.8310	0.0411
Vehicle Ownership (VO)	-1.1920	0.0880	-0.7240	0.2461	-4.5720	0.0145	-0.6550	0.4003
Female	0.6220	0.3055	-0.7910	0.3070	5.4800	0.0110	1.7240	0.3113
Age 65+	0.0470	0.4903	0.6650	0.4044	-1.0850	0.3318	0.5700	0.4773
Transit pass ownership (TP)	-2.1170	0.1821	-4.4790	0.0819	-2.9440	0.2663	4.9390	0.1447
Female	2.0910	0.2648	1.1530	0.4168	8.6520	0.0799	-4.2710	0.2419
Age 65+	0.7600	0.4382	1.2740	0.4359	3.6290	0.0799	0.5420	0.4817
VO + TP	3.1370	0.0920	5.2390	0.0540	2.5480	0.2967	-2.5940	0.2910
Female	-1.4830	0.3297	0.5730	0.4588	-7.4330	0.1164	2.6490	0.3339
Age 65+	-2.6020	0.2994	-2.7400	0.3625	-3.9970	0.3398	-3.8190	0.3741
SPATIAL OPPORTUNITY VARIABLES								
Median Income	1.5790	0.0000	1.7910	0.0000	0.6490	0.0300	2.1110	0.0000
Population Density	-0.0318	0.2943	-0.0018	0.4909	-0.1538	0.0742	0.0333	0.4000
Land use								
LC-LR	REFERENCE							
LC-HR	-0.2300	0.2040	-0.5040	0.0808	0.4710	0.1693	0.4030	0.2841
HC-LR	-0.0640	0.4093	-0.2770	0.2240	0.6180	0.1060	0.9120	0.0919
HC-HR	-0.4270	0.0477	-0.4040	0.1132	0.2350	0.3043	-0.0860	0.4472
Variance (individual)	117.9	0.0000	134.7	0.0000	71.4	0.0000	90.7	0.0000
-2* log-likelihood at convergence	109678.03		76214.97		19549.38		13361.97	
N	14416		9846		2751		1819	
R2	0.0759		0.0653		0.0462		0.1167	
R2_adj	0.0758		0.0651		0.0457		0.1147	

Table 5
Results of Multilevel Models of Average Distance Traveled

Variables	MOTORIZED (Car and Bus)		CAR-DRIVER		CAR PASSENGER		BUS	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	12.1250	0.0000	12.2920	0.0000	13.2810	0.0000	6.7210	0.0143
INDIVIDUAL ATTRIBUTES								
Capability Constraint Factors								
Age Cohort								
Less 20	-4.5370	0.0000	-3.2500	0.0004	-3.6010	0.0000	-3.6120	0.0000
20-35	REFERENCE							
36-50	-1.1400	0.0000	-1.3490	0.0000	-1.2400	0.0041	1.5660	0.0219
51-64	-1.7600	0.0000	-1.9920	0.0000	-1.2100	0.0106	-0.1790	0.4270
65-79	-4.2550	0.0000	-7.1450	0.0114	-1.1290	0.3449	-0.3490	0.4870
80+	-4.9490	0.0000	-7.4250	0.0134	-2.0710	0.2396	-1.6640	0.4393
Gender								
Male	REFERENCE							
Female	-2.3450	0.0574	0.4880	0.3962	-7.7290	0.0009	-4.2980	0.1135
Coupling Constraint Factors								
Employment Status								
Full-time	REFERENCE							
Part-time	-3.6510	0.0000	-4.2530	0.0000	0.7050	0.2249	-5.1330	0.0000
Female	1.9070	0.0005	2.0080	0.0038	-0.4730	0.3360	3.1370	0.0134
Age 65+	2.7660	0.0139	3.7490	0.0098	-1.3840	0.2484	0.2250	0.4819
Not-Employed	-3.3260	0.0000	-3.3980	0.0000	-1.6520	0.0038	-3.5310	0.0000
Female	1.8650	0.0000	1.3090	0.0068	1.4450	0.0273	2.9680	0.0028
Age 65+	1.7870	0.0164	1.9690	0.0398	-0.2060	0.4374	-1.2490	0.3712
Household Size	-0.1060	0.0613	-0.2230	0.0056	0.0880	0.2201	0.1160	0.2300
Authority Constraint Factors								
Trip Mode								
Car Driver	REFERENCE							
Car passenger	-1.2610	0.0000						
Bus	-0.7870	0.0149						
License Ownership	0.8350	0.0318	0.3680	0.3342	-0.0780	0.4553	2.7610	0.0001
Female	-1.2630	0.0092	-3.0250	0.0027	0.9320	0.1208	-0.8610	0.1844
Age 65+	-0.7460	0.1405	1.1380	0.2523	-0.2630	0.3800	-2.7110	0.0475
Vehicle Ownership (VO)	-1.1440	0.0953	-0.6630	0.2631	-4.6630	0.0129	-0.6890	0.3949
Female	0.3620	0.3825	-1.0100	0.2576	5.5450	0.0102	1.8450	0.2980
Age 65+	-0.4500	0.4068	-0.1880	0.4725	-1.0810	0.3323	0.6910	0.4722
Transit pass ownership (TP)	-2.7940	0.1138	-5.0320	0.0577	-3.5620	0.2248	4.2590	0.1789
Female	2.7710	0.1999	1.9130	0.3623	9.1790	0.0677	-3.2990	0.2932
Age 65+	-2.7940	0.1138	1.2140	0.4369	3.0700	0.3745	1.8980	0.4356
VO + TP	3.6470	0.0595	5.2940	0.0507	3.0740	0.2593	-1.6840	0.3596
Female	-2.0570	0.2683	-0.0910	0.1934	-7.9920	0.0997	1.6610	0.3932
Age 65+	-2.7040	0.2907	-2.5140	0.3727	-3.4740	0.3597	-4.9650	0.3369
SPATIAL OPPORTUNITY VARIABLES								
Median Income	1.2830	0.0000	1.5460	0.0000	0.6230	0.0479	1.7870	0.0010
Population Density	-0.0933	0.3629	-0.0508	0.6759	-0.1565	0.1726	-0.0508	0.7615
Land use								
LC-LR								
LC-HR	-0.4470	0.1837	-0.7030	0.1135	0.3770	0.2438	0.3650	0.3371
HC-LR	-0.2640	0.2962	-0.4550	0.2180	0.5340	0.1640	1.0340	0.1108
HC-HR	-0.9020	0.0240	-0.9420	0.0408	-0.2960	0.2789	-0.3360	0.3355
Variance Component								
Individual	115.1	0.0000	130.8	0.0000	70.5	0.0000	86.8	0.0000
Neighbourhood	3.4	0.0000	4.1	0.0000	0.9	0.0538	4.1	0.0024
ICC (%)	2.841		3.009		1.250		4.50	
-2* log-likelihood at convergence	109526.8		76094.79		19546.26		13346.4	
N (Level 1)	14416		9846		2751		1819	
N (Level 2)	205		204		198		183	
Level 1								
-2* log-likelihood at convergence	109678.03		76214.97		19549.38		13361.97	
Chi-Square stat	151.23		120.18		3.12		15.57	
p	0.0000		0.0000		0.1175		0.0000	

Figure 2 depicts the age effects on distance traveled for each of the mobility mode studied, all things being equal with respect to the other mobility constraints. The figure demonstrates the impact of age on distance traveled which is extremely more pronounced in the case of car-driver than for car-passenger and bus.

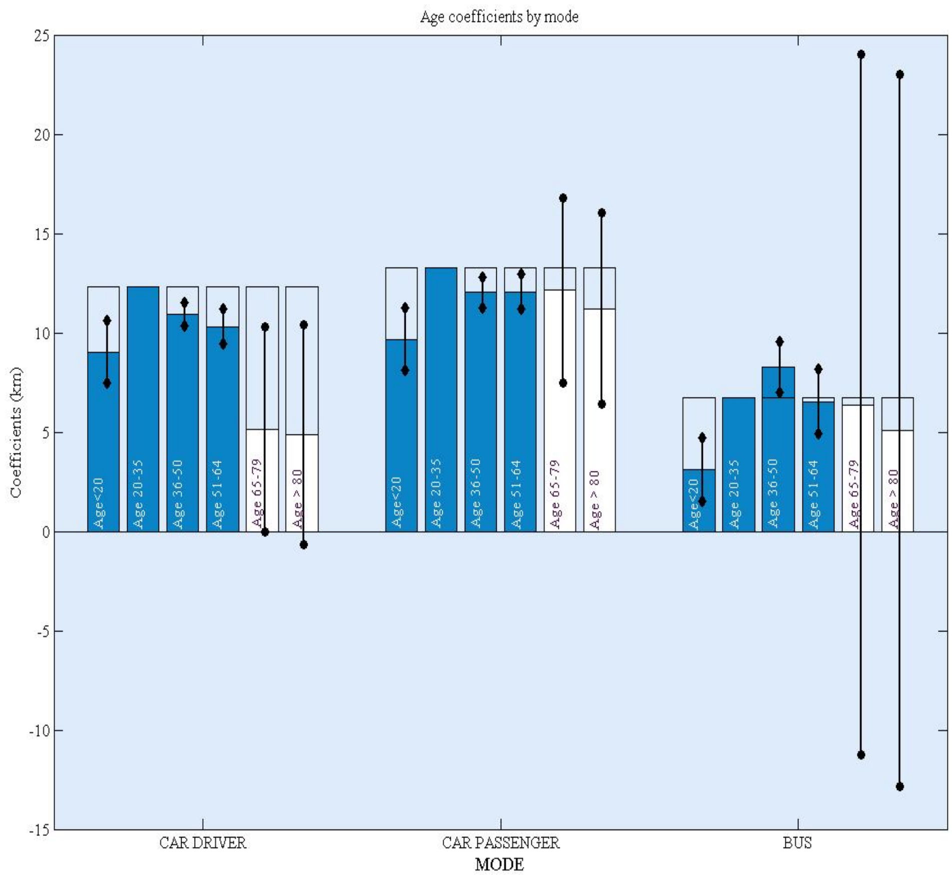

Figure 2. Age Coefficients for Distance Traveled By Travel Mode, with 90% confidence intervals (based on Table 5)

6.1.2 Coupling Constraint Factors.

Results showed that relative to full-time workers, people working part-time as well as those not employed travel shorter distance, which tends to confirm the notion that full employment drives people to travel farther. This is particularly true in cases where there is a substantial area of separation between home and job locations, such as in the metropolitan area of Hamilton where economic linkages are strong with other parts of the GTA. The reduction in distance is quite substantial (more than 3 km.) when a person is part-time or not employed. The results also confirm that females who are not employed or who work part-time tend to travel shorter distance relative to those working full-time. The fairly close coefficients between females working part-time and not employed reveal the fixity of constraints they experience in terms of job limitations and household services. Results also reveal that part-time elderly workers travel farther than their counterpart females. It is fair to say that the former do not experience as much fixity constraints as much as part-time women. Part-time elderly workers tend to travel only about less than a kilometer than full-time workers. However, non-employed elderly showed almost similar magnitude of coefficient with their counterpart females which, reveals that they may not have home-related constraints but other constraints such as capability constraints (i.e. health limitations) that put them at a similar level of constraint or even at a greater disadvantage.

The above results are very much reflective of the car driver mode as shown by the significantly large magnitude of the coefficients with respect to employment indicators. The same results were neither found on car passengers nor bus riders. Distance traveled by car passenger does not vary significantly whether a person works part-time although this is the case if a person is not employed. Being not employed returned a significant negative coefficient, suggesting the reducing effect of non-participation in economic activities on distance traveled. Relative to full-time employment distance traveled by bus is lesser when a person works part-time or is not employed. Part-time workers travel lesser than those not employed which supports expectation considering the greater free time those not employed has compared to those working. Being female reduces the negative effect exemplifying women's home-service related travels on top of work requirements if they work full-time.

Household size returned a negative but small coefficient suggesting that the factors associated with multiple-person household (e.g. number of children) come into play in curtailing the distance traveled by an individual.

6.1.3 Authority Constraint Factors

Being a car passenger and taking the bus relates negatively to distance traveled. Relative to car driving, traveling by these modes reduces travel by about 1.3 km. and 0.8 km., respectively. The shorter distance reflects the constraint experienced by the individual to travel greater distances when car driving is not an option.

Among the mobility tools, only license ownership and vehicle ownership figured significantly among the mobility tools. Transit pass ownership, joint auto and transit pass possession did not show significant results. License ownership positively affects travel distance. Gender differences were evident for car-driver with respect to this variable. The relationship returned a negative and large coefficient, a finding which provides evidence of the comparative distance traveled between licensed men and women. Again the constraints posed on women to drive farther than men in spite of having a driving license could be hindered by a number of reasons that pertain to their household role or to the relinquishment of driving to men. For bus mode, only license ownership figured significantly among the other variables with a positive and large coefficient. This echoes the importance of bus not only as an important alternative to car driving but also as have been discussed in the descriptive analysis, the bus seems to be a mode choice for long-distance commuting. Vehicle ownership has also been found to negatively affect distance traveled as car passenger. But being female increases distance traveled which provides the evidence of the greater tendency for women auto owners to travel farther than men as car passengers. Again, the traditional gender role seems to be in effect that increases the chance of women to be in the backseat. There were no significant difference between elderly and non-elderly with respect to these constraint factors.

2.6.2 Spatial Opportunity Variables

Median income provided positive significant result. This has been found true across all modes. The positive coefficient of this variable suggests that living in more affluent zones relates to increased distance traveled. Specifically, it suggests an addition of 2 km. traveled by a person living in a zone as average income in that zone rises by $10,000. With regards to car passenger, median income related positively to distance traveled although the magnitude of the coefficient was not as large as compared to other modes. For bus mode, median income showed a positive relation with distance traveled confirming the usefulness and patronage of public transit as incomes rise perhaps as an important alternative to car driving.

Population density did not figure as a significant variable. However, land use mix provided some interesting results. It showed that a high commercial and residential mix is negatively related to distance traveled but only for motorized and car driver mode. This finding provides evidence of the effect of land use on curtailing travel distance by these modes. The absence of significant results found on other residential-commercial mixes suggests that a certain level of residential and commercial density has to be achieved in order to influence the reduction in travel distance. The finding suggests the stronger influence of land use variables on distance traveled due to car driving compared to car passenger or bus modes.

7. Summary and Implications

The main objective of this study has been to investigate the determinants of mean trip distance traveled by different mode types with focus on the elderly. The study aimed to provide greater understanding of the dynamics of interactions among individual and geographic factors in the context of sustainable transportation objectives and aging societies. Using Hagerstand's time-space framework, the study analyzed the various constraints affecting a person's time-space path, namely capability, coupling and authority constraints. Spatial opportunity factors including density, income and land use mix of the neighborhoods in the study area, which is the Hamilton CMA, were also analyzed. Multilevel analysis was employed to obtain models to explain the strength of these factors and to account for the geographical variability of different determinants. Four models representing four mode types were selected and discussed in this paper: motorized (car and bus), car-driving, car passenger and bus. It is important to summarize the most important findings of the study and reflect on its implications to policy and research.

The results of the study validated existing literature on the general decline in distance traveled as age advances. However, we find that the expected decline in distance is more marked for car-driving compared to car passenger and bus. We also found that the reduction in distance traveled is much more pronounced in car driving among the older population but not as clearly marked between elderly groups. Amongst themselves, elderly people drive the same distance so long as they keep their driving ability intact. The ability to move around freely and make choices is an important element of quality of life, a concern that Hagerstrand's time-geography ultimately wishes to address. This has an important implication to population aging inasmuch as, as one gets older, there is a greater risk for that freedom to be curtailed because of physical limitations and/or if the capability to drive is withheld by economic barriers (e.g. income), authorities (e.g. licensing agency) or by the lack of other options available to meet mobility demands.

In general, men travel farther than women or conversely, women travel shorter distances than men. This gender divide in distance traveled, however, tends to vanish among the elderly irrespective of the travel modes they use. The new gender divide is in the travel mode. As pointed out, 68% in the study area drive a car as the primary mode of transport. Men tend to be more of a car driver than women but they to strive to be car drivers as long as possible in their golden years while, in contrast, women tend to shift from driving to become car and bus passengers when they get older. Being female tends to have a negative effect on distance traveled as car passenger. In other words, women travel shorter distances as car passenger relative to their counterpart men. However, owning a car blurs this difference. This finding points to the need for greater accessibility of mobility tools and the need for gender sensitivity of transport services. This is relevant in as much as women live longer than men and they have a greater tendency to give up driving (Rabbit et al., 1996; Blomqvist and Siren, 2003) and would therefore rely greatly on alternatives to driving for their mobility needs in old age. Gender effects on distance traveled with respect to other modes showed no significance in the rest of the modes. However, when interacted with employment variables, we found that gender effects become significant. Non-employed elderly (which comprises the majority of the elderly in the study area) showed similarities in distance traveled with unemployed women. It would be interesting to find out whether the elderly have similar domestic constraints (e.g. taking care of grandchildren, etc.) as women or other factors such as capability or authority constraints (e.g. health limitations) or authority constraints (e.g. loss of license, etc) that put them at a similar degree of constraint to travel farther.

License ownership as well as vehicle possession are two of the most important mobility tools found significant in the study that characterize the mobility options for both elderly and non-elderly that should be a concern for policy. The concerns are, however, more critical for the elderly as the non-possession of these mobility tools exacerbates their greater capability constraints compared to other age groups given their higher health risks. Being a car-passenger is an inevitable choice for both men and women relative to car driving but as literature suggests, most elderly have some problems dealing with reliance on family members to drive them. In fact studies have demonstrated that older adults prefer the independence afforded by fixed routes and demand-responsive public transportation to the dependence on family or friends for a ride (Burkhart and McGavock, 1996; 1999; Sterns et al., 2003; USDOT, 2003). This presents an enormous challenge to long-term planning for transportation in an aging society. Granting that current trends of elderly travel behavior continues, the results point to the need for greater choices for mobility beyond car driving, i.e. making bus and taxi or related innovative services important alternative transport choices for the elderly upon driving cessation given the number of trips they make and the relatively shorter distance they travel.

Finally, this study provided some evidence on how the built environment and travel behavior are linked particularly in relation to distance traveled. We found that for car driving, neighborhoods with high commercial and residential mix showed a negative relation with distance traveled. The absence of significant results found on other land-use mixes seems to imply that a certain level of residential and commercial density has to be achieved in order to influence the reduction in travel distance. The findings on the strong positive effect of income of neighborhoods on distance traveled for motorized modes and car driving, on one hand, and the curtailing effect of high density land-use mixes, on the other, characterize the growing policy challenge to curb travel demand through the built environment in the face of the much stronger influence of the capacity of individuals to travel longer distances given the limits of their resources. This calls for policy to develop land use strategies in tandem with policies affecting individual travel behavior (e.g. regulation policy, transit alternatives, pricing). As the present study suggests, while land use changes may potentially contribute to influence the mobility of people, it is important to keep in mind that policies could also be effectively directed to finding effective ways to deal with changing travel behavior that maximizes both quality of life and sustainable transportation objectives.

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No. 124:	Exploring the Use of a Nonparametrically Generated Instrumental Variable in the Estimation of a Linear Parametric Equation	F.T. Denton
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No. 126:	Entry Costs and Stock Market Participation Over the Life Cycle	S. Alan
No. 127:	Income Inequality and Self-Rated Health Status: Evidence from the European Community Household Panel	V. Hildebrand P. Van Kerm
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