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An Analysis of the Travel Patterns and Preferences of the Elderly

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An Analysis of the Travel Patterns and Preferences of the Elderly

by

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DEDICATION

This thesis is dedicated to my father, Samiran Sikder and my mother, Swapna Sikder for their love, affection and nurturing. I am greatly indebted to them for their support and encouragement thorough my life. I would also like to dedicate this thesis to my brother for his warm companionship.

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ABSTRACT

The number of elderly is increasing; to meet their transportation needs, it is important to clearly understand their travel patterns and preferences. Since travel patterns and preferences depend on socio-demographic and other factors, it is essential to identify these factors first to understand the travel behavior of the elderly. The main purpose of this thesis is to analyze the travel patterns and preferences of the elderly age 65 and above using 2009 National Household Travel Survey (NHTS) data. This thesis presents a detailed descriptive analysis of 2009 NHTS data to understand the travel patterns of the elderly. Along with a descriptive analysis, a multinomial logit model and a mixed-multinomial logit model are estimated to explore the factors associated with the overall travel preferences of the elderly and to identify individuals among the elderly who are the least mobile and at risk for social isolation.

The analysis results indicate the differences in the trip characteristics between the elderly and non-elderly. Variation is found even among the different groups of the elderly. The model estimation results show the presence of different travel preferences among the elderly and identify those individuals among the elderly who are immobile for longer periods (e.g., a week) and at risk for social isolation. Elderly individuals with

different travel preferences should be considered separately in research to determine the appropriate outcomes that can help transportation planners and policy makers improve planning and policy related to elderly individuals.

CHAPTER 1

INTRODUCTION

1.1 Background

Transportation mobility is critically important to our lives. Mobility is generally a derived demand for different needs in our daily life, and it is the transportation system that gets us to work and other places for shopping, social interaction, personal errands, etc., to fulfill those needs. An accessible, affordable, and reliable transportation system is desirable to us all. Although transportation mobility is critical in a person's life no matter what the age, this issue is more important for the elderly due to their physical and mental conditions. The total number of older people is increasing in almost all western European countries, North America, and Australia (Rosenbloom, 2001), and it is expected that the number of the elderly age 65 and over will be at least double by 2051 compared to 1999 (Alsnih and Hensher, 2003). Therefore, understanding the travel patterns and preferences of the elderly is becoming increasingly important.

Mobility is required not only for obtaining different commodities and goods in our daily lives, it is essentially important for participation in social relations and activities (Mollenkopf, 1997). Participation in such activities is important to our quality of life, especially in the lives of older people because social activities involving mobility reduce mortality in older people (Glass et al., 1999). Mobility provides some psychological

benefit as well (Metz, 2000). Older people are likely to develop physical, sensory, and cognitive limitations with the increase in age, resulting in a decline in their mobility. While they can satisfy their needs for medical appointments and grocery shopping through some services, they face difficulties in conducting the social or recreational activities that are an important part of their lives. These difficulties and other factors such as physical impairments, the desire to stay home, etc., decrease mobility among the elderly and, ultimately, force them into social isolation. The immobile elderly are at risk for social isolation, which affects their quality of life and accelerates the decline in their personal health (Trilling and Eberhard, 2002).

The elderly who travel generally make fewer trips, and the trip characteristics associated with those trips are different compared to their younger counterparts (Collia et al., 2003; Heaslip, 2007). The characteristics of these trips depend on the goods and services they need and also on their desire for social interaction (Skinner and Stearns, 1999). The desire or preference to socialize is one of the factors affecting the trip characteristics of the elderly. This preference is the individual's own decision and always is difficult to assess. The latest 2009 National Household Travel Survey (NHTS) provided an opportunity to identify the factors associated with the mobility patterns and preferences of the elderly by introducing some new questions on the 2009 questionnaire. One of these questions is, "About how long ago did you take a trip to another address?" If a person did not make any trips on the given reporting day (travel day) of the survey and mentioned that he/she had stayed at the same place (for example, at home) all day, he/she was asked to answer this question. If the answer was "more than a week ago," the next question was, "Would you like to get out more often?" This question was asked of only

those persons who traveled more than a week ago from the given reporting day (travel day) of the survey. Individuals who did not travel for long periods such as a week can be described as "long term immobile." These questions indirectly distinguish the short term (less than a week) and long term (more than a week) immobility of individuals.

Based on the questions mentioned above, a sample can be divided into four categories: individuals (1) who traveled on the travel day, (2) who did not travel on the travel day but traveled in the past seven days, (3) who did not travel in the past seven days but prefer going out more often, and (4) who did not travel in the past seven days and do not prefer going out more often. The first category can be identified as "frequent traveler," the second as "short term immobile" individuals, and the last two categories can be combined into a single group called "long term immobile" individuals. The "long term immobile" group consists of two separate groups of individuals, those who "prefer going out more often" but did not travel for longer periods due to some constraints and those who "do not prefer going out more often." These two groups of individuals revealed their inherent travel preferences on the survey and thus provided an opportunity to identify the factors associated with these preferences. Considering the importance of the mobility issues of the elderly, this study focuses only on persons age 65 and above. The next sections of this chapter describe the motivation, objectives, and organization of the thesis.

1.2 Motivation

The elderly are likely to become transportation disadvantaged with the increase of age (Giuliano, 1999), and the travel behavior of this group increasingly is seen as an important issue in transportation planning. In addition, the "baby boomers" are entering

into retirement age and the expectations of this group will be different from that of the current elderly because of their experience with affordable mobility and technology throughout their lives (Coughlin, 2009). The perceived differences in the mobility characteristics of the baby boomers and the current elderly warrant the need for in-depth research on elderly travel behavior.

The elderly are not homogeneous; differences exist in socio-economic characteristics such as household structure, gender, lifestyle, and race (Kim and Ulfarsson, 2004). These differences affect the mobility and travel patterns of the different groups of elderly (Hilderbrand, 2003).This diversity strikes the researchers and transportation planners to find out the avenues to fulfill the special transportation needs of different groups of the elderly. It also is important to minimize the level of depression among the elderly that may result from the loss of driving ability (Alsnih and Hensher, 2003). Tacken (1998) emphasizes taking necessary steps to keep the elderly mobile rather than to reactivate their desire for mobility. To keep the elderly mobile, it is important to identify the factors affecting their travel preferences through an in-depth analysis. Also, since some older persons do not travel but rather stay at home all day, it is necessary to understand the reasons for this behavior.

The elderly are generally less likely to make trips, and the trips they make are usually shorter in distance compared to their young counterparts (Collia et al., 2003; Heaslip, 2007). The travel patterns and different characteristics associated with the travels such as travel distance and travel time are dependent upon the travel preferences of the elderly. These travel preferences depend on several socio-demographic factors as well as the physical and mental conditions of the elderly. Most of the research in the

literature focuses only on the group that travels and the factors affecting their travel preferences. But it is important to understand the motivations behind the immobile population of the elderly. Since immobile persons are a share of the total elderly population and the success of any elderly mobility-related policy depends on the participation of both groups of elderly (travelers and non-travelers), it is important to understand the underlying factors affecting the travel preferences of the elderly. To state it succinctly, it is necessary to understand clearly those who are not traveling among the elderly and why they are not traveling. Essentially, it is important to identify and then distinguish the factors associated with the short- and long-term immobility of the elderly. These factors may help in taking appropriate measures to retain the mobility desires of the travelers and to reactivate the non-travelers. A multinomial and a mixed-multinomial logit model are estimated in this study for analyzing the different travel preferences of the elderly.

Most of the elderly travel behavior-related studies in the literature focus only on the travel patterns of the elderly, that is, how the trip characteristics of the elderly differ from their counterparts; the travel preferences of the elderly generally are not considered in those studies. Even if considered, it is limited to only one-day travel period data. However, the latest 2009 NHTS data provide an opportunity to analyze the travel preferences of the elderly for longer periods (such as a week) instead of focusing only on one-day travel period data. Many forms of special transportation services are provided for the elderly through support from the federal government and other sources (Trilling and Evarhard, 2002), and these services generate additional travel by the elderly. However, to develop policy in this area – for instance, to evaluate the efficient distribution of funds

and the success of the services – it would be valuable to identify the factors related to long-term immobility among the elderly.

1.3 Objectives

This study mainly aims to provide a detailed analysis of the travel patterns and preferences of the elderly in the context of socio-demographic and other factors using data from the 2009 NHTS. Persons age 65 and older are considered to be elderly in this study. The specific objectives of this study are as follows:

- To understand the trip characteristics of the elderly in order to examine how their travel patterns differ from those of their younger counterparts.
- To examine the presence of different travel patterns among the different groups of elderly.
- To identify the factors affecting the overall travel preferences of the elderly.
- To distinguish the socio-demographic and other factors affecting the different travel preferences of the elderly (a multinomial logit model and a mixed-multinomial logit model are developed to distinguish the factors).

1.4 Organization of the Thesis

The remainder of this thesis is organized as follows. Chapter 2 provides an extensive review of the literature available related to the thesis topic. Chapter 3 describes the 2009 NHTS data and gives a detailed description of household and personal characteristics of Americans. Trip characteristics of the elderly and how these characteristics differ among the elderly and non-elderly also are provided in this chapter. Chapter 4 explains the modeling efforts undertaken in this study. In addition, sample characteristics, sample preparation for the model estimation, and model estimation results

are provided. Finally, conclusions and the scope for further research are discussed in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Mobility issues related to elderly have been subject to extensive research by transportation planners and researchers. Understanding the travel patterns of the elderly is becoming increasingly important due to their special trip making characteristics. It is of strong policy interest as well because the share of the elderly in the total population is significant. Interestingly, most of the studies on elderly travel behavior are based on descriptive analysis. But, it is always difficult to conclude confidently without considering the effects of all variables together, because the results obtained from the descriptive analysis might change when the effects of all possible variables are considered together (Kim and Ulfarsson, 2004). However, some modeling efforts (Giuliano, 1999; Evans, 2001; Georggi and Pendyala, 2001; Rosenbloom and Waldorf, 2001; Kim and Ulfarsson, 2004) were also undertaken in this area. This chapter provides a review of those modeling efforts and other research efforts in the direction of analyzing the travel patterns and preferences of the elderly.

2.2 Effects of Socio-Demographics on Elderly Travel Behavior

Several studies in the literature explored the effects of socio-demographic characteristics on the travel patterns and preferences of the elderly. Among these,

Lefrancois et al. (1998) measured the effect of age and other socio-demographic factors such as gender, health status, education and region on the activity involvement among the older adults aged 65 and above by analyzing a sample of 601 adults from Montreal and the eastern township, Canada. They tested a hypothesis that different factors (health status, gender, educational level, marital status, rural and urban environment, social interaction) predict the reduction in activity among the older adults better than the age itself by using a canonical correlation approach. Travel activities (number of trips in the past year) were included as one of the four major categories of activities considered in this study. The other three were: exercise and sport, social activities and outdoor recreations. They found that health status played the most vital role in the reduction of activities among the elderly. Education was found to be positively related with the sport, travel and outdoor recreation activities participation.

Coughlin (2001) explored the perceptions and preference of the persons aged 75 and above about their transportation options by using data from three focus groups and 17 one-on-one in-person interviews conducted in Boston and Framingham, Massachusetts. The focus groups were formed in such a way that could reflect the characteristics of the 75 plus age group and difference in various socio-demographic factors such as age, gender and driver status among the persons of this group. In addition, "transportation disadvantaged" group was reflected in the focus groups through the variation in income of the participants. Coughlin observed that persons aged 75 and older were more inclined to the auto-mobile based transport and the factors that drove them towards this preference were reliability, convenience, personal security, and flexibility. In addition, the non-driver older people were more likely to ask for rides to friends and/or

family but the dependency and obligation resulted from requesting for rides were objectionable to them.

Kim and & Ulfarsson (2004) showed the effects of personal, household, neighborhood and trip characteristics on the mode choice of retired elderly aged 65 and above by using the 2000 Puget Sound Transportation Panel (PSTP) data of the Puget Sound Regional Council (PSRC) in Washington State and 2000 census data. They found a negative relationship between age and propensity to use privately owned vehicle. This result reveals the physical and cognitive deterioration of the elderly to drive and the dependency on transit. In addition, the negative relationship that they found between household vehicle availability and the transit use clearly warrants the need of special transit system for zero vehicle elderly households. Income and distance to the nearest bus stop were found to be negatively associated with the transit use of the elderly.

Gagliardi et al.(2007) explored the effects of personal and environmental characteristics on the outdoor mobility and leisure activities of older people by using data from the interview of 3950 older adults (age 55 and above) from five different European countries: Germany, Finland, Hungary, The Netherlands and Italy. One important observation they made from their study was that non-driver women of greater age with health problems were more likely to engage indoor activities so called 'home activities' as compared to other groups of older adults. Henderson et al. (1998) and Mollenkopf et al. (1997) also found the similar results in their studies.

By using the 1995 Nationwide Personal Transportation Survey (NPTS) data, Giuliano (1999) explored the relationship between land use and travel patterns among the elderly and other age groups. Though travel patterns were found to be affected by the

land use, the effects were almost same across the three age groups considered in this study. In addition, age of the travelers was found to be negatively associated with the trip making propensity and the travel distance. It was also found that the elderly were less likely to use transit even when it was accessible.

Rosenbloom (1999) identified the basic travel patterns and trends among the elderly (age 65 and above) with special focus on drivers, non-drivers and women's travel by using data from the 1995 nationwide personal transportation survey (NPTS) and from the office of Highway Information Management, FHWA. Auto-mobile was found to be the dominant mode for all elderly and a large gap was found in the total number of trips made by drivers and non- drivers. Rosenbloom also observed that women were likely to make fewer trips and travel fewer miles as compared to men of all age cohorts and this gap was found to increase with the age of the individuals. Besides this, elderly were found to be resided in the suburbs or in rural areas where automobile is necessity for mobility.

Collia et al. (2003) analyzed the travel patterns of the elderly (age 65 and above) and compared with that of the young adults (age 19 to 65years) by using the 2001 National Household Travel Survey (NHTS). They found that older adults generally made fewer trips, traveled in mid-day, traveled shorter distances and for shorter times. These patterns were more pronounced among the elderly women. In addition, older drivers were found to make more percentage of trips as passenger as compared to the younger adults (age 19 to 65). They also found a lower percentage of alternative transportation mode uses on the travel day when compared to the share of the persons who had to give up driving due to medical condition. It was also found that only a small percentage (12%) of

the people who identified the medical condition had affected their travel used special transportation service such as dial-a-ride on the travel day. The reasons behind this small percentage of alternative means and special transportation uses were not explored in this study. Since the percentage of the adults (24%) who reported medical condition had made their travel difficult was four times as compared to the younger adults (6%) (Collia et al. 2003), older adults were a good portion of the population for which special transportation systems were designed. So, the success of these services is dependent on the uses of those services by the elderly people. The potential reasons for lower percentage of special transportation service users could be the serious medical condition that prevented them from making travel on the travel day or they used another mode of transportation on the travel day due to special circumstances or the special transportation systems were not accessible to the individuals. In addition, it might also happen that the individuals wanted to travel on the day but some socio-demographic conditions prevented them from doing so. Finally and most importantly, another reason could be the individuals didn't want to go outside more often and liked to stay home. Due to lack of data, it is not possible to explore each and every reasons mentioned above for not using special transportation service or alternative transportation means on the travel day. But, the recently released 2009 NHTS provides an opportunity to explore at least the effects of different factors on the last two issues i.e. the preferences of going outside of home.

Evans (2001) explored the personal and community characteristics associated with the trip making propensity among the non-drivers aged 75 and above by using 1-day travel period data from the 1995 Nationwide Personal Transportation Survey (NPTS) combined with community data prepared by Claritas, Inc. Though some contradictory

findings such as low mobility in urban areas but high trip making propensity in areas with higher housing densities were found in this study, the overall results gave an idea of the personal and community characteristics associated with the trip making propensity of the non-driver individuals aged 75 and above. But the study was limited to 1-day travel periods and the author did not distinguish the short term and long term non-travelers. More clearly, the difference between the individuals who did not travel on the travel day and those who did not travel for a longer time period such as a week were not differentiated in this study. The personal and community characteristics associated with these two different groups may vary and thus, warrant investigation. It is likely that some people may want to go outside and some people may not want to go outside more often. But, the possibility of the existence of two groups (who prefer going outside more often and who do not prefer going outside more often) within the long-term non-travelers were ignored in this study and the different types of non-travelers were combined into a single group called " not having gone out". So, due to the possibility of the existence of two groups mentioned above, it is important to identify the factors affecting the travel preferences of the people who prefer going outside and who do not prefer going outside of home. This could be of great help to the transit industry and special transportation service providers to the elderly especially during taking decision on elderly prominent area. If the situation is such that most of the elderly in an area are not willing to go out more often, then the plan to provide special transportation service to that area will not be that much effective. So, from the policy perspective, the need of the individuals who want to go outside and who do not should be identified first and then special transportation service should be provided accordingly.

Heaslip (2007) analyzed the change of travel patterns among the older drivers (age 65 and above) by using the National Household Travel Survey data series from 1969 to 2001 and American Travel Survey from 1977 to 1995. Heaslip found a dramatic increase in the total number of trips made by this group for medical, religious and social/recreational purposes from 1995 to 2001. In addition, strong inclination of the elderly towards the personal vehicles was found in this study.

Besides this, older women were found to be less mobile in some studies (Collia et al., 2003; Rosenbloom, 1999) but they were more likely to use special transit services than the older men (Collia et al, 2003). The reasons behind these issues were not explored clearly in those studies. One Australia-based research (Alsnih and Hensher, 2003) urged on understanding the elderly population's travel behavior to come up with the needs of elderly for the better strategic plan of public transportation. They also focused on researching different groups (young and old) of elderly to understand the threshold of health change and the different needs of these two groups for the better implementation of the transportation related plan and policy.

On the other hand, driving characteristics of the older drivers are different from those of their younger counterparts and so, already addressed the attention of the researchers. Chu (1994) investigated the mobility issue of the elderly (65 or more) driver by exploring the effects of age on six different driving habits: daily driving exposure, driving by time of the day and type of the roadway, vehicle size, number of passengers carried and driving speed by using the 1990 Nationwide Personal Transportation Survey (NPTS) . He identified that the elderly made almost the same number of trips as their counterparts did but the total vehicle miles traveled (VMT) declined due to the shorter

distances of those trips. He also found that older drivers showed a good self protection effort in their driving habits.

Georggi and Pendyala (2001) explored the long distance travel (trips greater than 100 mi.) behavior of the elderly and the low income group by utilizing the 1995 American Travel Survey. They found that the elderly and the low income group made significantly fewer long-distance trips than their counterparts. Also, when they traveled, they were more likely to travel by bus and the trip purposes were most likely to be social and personal business activities. They also identified the different travel patterns of the older elderly (aged 75 years and above) as compared to the individuals aged below 75 years and so, urged on further study on the travel patterns of the elderly to explore the reasons behind their low mobility. Mallett (2001) also examined the long-distance travel behavior of the low-income households with special attention on elderly (65 or older) and children by using 1995 American Travel Survey. Mallett found a negative relationship between the age of the persons and the number of per capita trips for the elderly group aged 65 and above. The effect was more pronounced among the older elderly aged 85 and above.

Benekohal et al. (1994) examined the travel behavior of the elderly (65 or older) by using the data collected through a stateside survey of older drivers combined with the focus group meetings. They found that average vehicle trip length was negatively associated with the age of the elderly. Polzin et al. (2001) explored the mode choice of minority population for non-work travel by using data from the 1983, 1990, and 1995 National Personal Transportation Survey (NPTS) databases. They found that African American were more likely to use public transit for their non-work travel as compared to

other groups in the total population. While Polzin et al. (2001) focused on whole minority population for non-work travel mode choice, Rosenbloom and Waldorf (2001) considered only the elderly people in their mode choice model to explore the effects of race, ethnicity and residential location (Urban, Suburban, Second City and Town) on the mode choice of the elderly. It was found that minorities, non-Hispanic and the residents in urban core areas were more likely to use public transportation as compared to Privately Owned Vehicle.

2.3 Application of Modeling Techniques in Elderly Travel Behavior

Some of the studies mentioned in section 2.2 used modeling techniques while analyzing the elderly travel pattern. This section provides a brief overview of those modeling techniques. Evans (2001) estimated four models (stepwise discriminant analysis) to explore the effects of personal and community characteristics associated with trip making propensity of the elderly non-drivers aged 75and above. Of these four models, first one identified the characteristics associated with mobility of the elderly and the mobility was defined by a variable named "WENTOUT" which gave the measure of whether the person had gone out or not on the travel day. The estimates indicated that the individuals with higher levels of education who owned home and who lived in an apartment in higher housing density areas were more likely to make at least one trip on the travel day. On the other hand, age of the individuals, household size, higher concentration of retail employment were found to be negatively associated with the trip making propensity of the non-driving elderly aged 75 and above. In the second model, Evans explored the factors associated with the transit availability. He found a positive relationship between the public transportation availability and some socio-demographic

factors such as age, female and African American. Also a negative correlation was found between the transit availability and the rural areas. The relationship between different factors and the transit use was explored in the third model. Only the individuals who had available public transportation were considered in this model. The results showed the positive effects of housing density, urban areas, education, income and negative effects of age, household size, race (white) and detached house on the transit use. Finally, a mode choice model was estimated to identify the factors associated with the modal choice of the elderly aged 75 and above. It was found that this group of elderly was more likely to depend on transit for their daily trips though they were less likely to go out more often.

Kim and Ulfarsson (2004) estimated a mode choice model of the retired elderly aged 65 and above with an aim to fill-up the gap of application of modeling techniques in the literature related to elderly travel pattern. They used a multinomial logit model with four mode choice alternatives: private car or truck, carpool or vanpool, public transit and walk to identify the personal, household, neighborhood environment, trip characteristics and activity purpose associated with the mode choice of the elderly. Some of the important variables in the mode choice model such as in-vehicle and out-of-vehicle travel time, out-of-pocket cost were not considered in this model due to lack of data. In addition, physical and mental abilities of the individuals which are important in the elderly related research were not included in the model. They found that mode choices of the elderly varied with the trip purposes and the distance to the nearest bus stop. Rosenbloom and Waldorf (2001) also estimated two logit models to explore the effects of race, ethnicity and residential location on the mode choice of the elderly. In this study, mode choice was limited to Privately Owned Vehicle (POV) and Public Transit. In the

first logit model, they estimated the effects of race, ethnicity and residential location on the likelihood of choosing POV as a travel mode while in the second model, they estimated the effects of those socio-demographics characteristics on the likelihood of choosing public transportation as a mode during travel. They found that people of color, non-Hispanic and the residents in urban area were more likely to use public transportation as compared to privately Owned Vehicle.

Georggi and Pendyala (2001) estimated linear regression models of trip generation for the elderly and the low income group people to explore the differences in the likelihood of making long-distance trip among these two groups. They found that income, vehicle ownership, education level, employment and marital status positively affected trip generation and household size, single parent household types, African American were negatively associated with the trip generation. In addition, they also computed trip generation elasticity to explore the effects of vehicle ownership and income on the trip generation by different age groups. From this elasticity computation, it was found that vehicle ownership and income were positively associated with the trip making propensity of all the age groups except the older elderly (75 and above) and the possible reasons identified for this exception was the age-related limitations of this older age group individuals.

Giuliano (1999) estimated three models to explore the effects of land use on the travel patterns of the elderly and to examine whether these effects vary across the different age groups. Of these three, first one was a simple binary logit model to identify the effects of land use on trip making propensity on the travel day. It was found that age negatively affected the trip making propensity and this propensity was independent of the

type of land use. Then the effects of land use on the daily travel distance were estimated by regression models. It was found that elderly were more likely to make shorter trips than their counterparts and the neighborhood characteristics had a little effect on the travel distance of all age groups. After this, a binary logit model was estimated to explore the effects of land use on the transit use by the elderly. It was found that elderly were less likely to use transit even when it was accessible and land use pattern supported it.

In summary, the above reviews give an overall idea about the importance of the elderly mobility issues in the transportation sector. But, most of the studies in the literature were based on descriptive statistics and emphasized on different trip characteristics such as number of trips, trip distance and travel time associated with the trips of the elderly. Only a few studies (Evans, 2001; Giuliano, 1999) focused on the travel preferences of the elderly. But, these were limited to only 1-day travel period that means whether the individuals traveled on a given reporting day of the survey or not. It is likely that the travel preferences of the elderly may vary even within a week and there might be some individuals who want to be mobile and some who are completely inactive. Such variation on the elderly travel preferences, when not considered, may affect the final outcome of the research. This thesis aims to fill-up the gap in the literature by considering the travel preferences of the elderly for longer time periods such as a week.

CHAPTER 3

DATA DESCRIPTION

3.1 Introduction

Travel surveys are the main sources of information that transportation planners and travel behavior analysts need for their interests. Among these surveys, the NHTS is a national comprehensive survey of both daily and long-distance travel that provides an opportunity for researchers to analyze the travel patterns of Americans. Since 1969, the NHTS has been the only reliable source of the nation's inventory of household travel. In addition, the latest NHTS (2009), because of its larger sample size, enables researchers to further analyze the different issues related to daily travel. The next sections of this chapter provide an overview of the 2009 NHTS data and the key household, person, and trip characteristics of Americans, with special focus on the elderly to explore the factors affecting the travel patterns and preferences of older Americans.

3.2 National Household Travel Survey

The NHTS is a comprehensive travel survey that collects information in the daily and long distance travel of Americans and began in 2001. Before 2001, this travel information was collected through two different surveys: the National Personal Transportation Survey (NPTS) and the American Travel Survey (ATS). The dataset used in this study was obtained from the 2009 NHTS conducted from April 2008 to May 2009.

Overall, the 2009 NHTS sample consists of 150,147 households with 324,184 persons, 309,163 vehicles, and 1,167,321 daily trips made by those individuals. These larger sample sizes of households and the corresponding persons, vehicles, and trips provide a great opportunity for researchers to explore different issues that were not possible with the previous datasets of the NHTS series due to their smaller sample sizes.

There are several different stages of NHTS data collection. First, a stratified random telephone number was obtained and screened to identify residential households. People living in college dormitories, nursing homes, other medical institutions, prisons, and on military bases were excluded from the sample. Next, a member of each household was called and asked a series of questions about the number of persons and vehicles in the household. Following this interview, a travel diary was sent to the household to allow them to keep trip information of the travel day assigned for that household. Following the travel day, each eligible person in the household was interviewed for travel day trip information.

One of the main aspects of the 2009 NHTS survey that makes it different from the 2001 NHTS is that travel day trip information was collected only for persons age 5 or older; the 2001 NHTS contains travel information of the persons below 5 years of age.

The NHTS is the only data set available at the national level that provides information about the demographics of households, household members, vehicles owned by households, and detailed trip information for household members. Researchers in academics, consulting, and government use this data set extensively for different purposes, such as to explore the relationship between demographics and travel behavior, to quantify travel behavior, and to analyze the change in travel characteristics over time.

In the 2009 NHTS questionnaire, several new questions were included to aid researchers and other NHTS users in their respective interests. For example, if a person did not make any trips on the given reporting day of the survey and reported that he/she had stayed at the same place all day, then the question, "About how long ago did you take a trip to another address?" was asked. If the answer was "more than a week ago," the next question was, "Would you like to get out more often?" This study focuses on the questions mentioned above and persons age 65 or older to analyze the mobility patterns and preferences of the elderly.

3.3 Descriptive from the 2009 National Household Travel Survey

This section gives a brief overview of the 2009 NHTS sample used in the analysis of this study. As this study is intended to analyze the travel patterns and preferences of a specific socioeconomic group – the elderly – this overview provides descriptive statistics for the socio-demographic characteristics of the 2009 NHTS with special focus on that particular group. All descriptive statistics presented in this study were obtained from the weighted analysis. For this analysis, the final weight variables "WTHHFIN," "WTPERFIN," and "WTTRDFIN" were used from the household, person, and trip files, respectively. (Note: The Federal Highway Administration has decided to enhance the weights of the 2009 NHTS, so these results may change with the new weights). The next subsections provide a descriptive analysis of household, person, and trip characteristics from the 2009 NHTS.

3.3.1 Household Characteristics

Table 3.1 provides key descriptive information pertaining to the socio-demographic characteristics of the households. The 1st column of the table shows the

characteristics, and the 2nd column gives the share of the total household against those characteristics. The 3rd and 4th columns give the share of the households with elderly (above 65 years of age) and without elderly (below 65 years of age) corresponding to the characteristics mentioned in the 1st column. Among the total 112,520,151 households, 25,583,764 households (22.74%) have at least one elderly person age 65 and above, and the remaining 86,936,388 households (77.26%) do not have any elderly persons in their house. Almost one quarter of the households in the United States have at least one elderly person in the house. The characteristics of these households are considered separately from the non-elderly households in this section.

The average household size in the United States as a whole is 2.34, whereas for elderly and non-elderly households, it is 1.83 and 2.70, respectively. The reason for this lower average elderly household size is the higher percentages of one- and two-person households. Almost 42 percent of elderly households are one-person households, and 47 percent are two-person households. A higher percentage of the elderly are living alone, which should be considered seriously in mitigating the mobility needs of the elderly. Even when they live with other non-elderly, most of them live in two-person households. Therefore, the composition of two-person households also should be considered to determine how the age of the other household members affects the travel behavior of the elderly. The average number of children (<18 years) in households with elderly is 0.05, which is lower than that of the households without elderly (0.65). The life cycle composition of elderly households seems to be different than that of non-elderly households. When the number of elderly in the household is considered, it was found that 69.2 percent are one-elderly household and 30.7 percent are two or more elderly

Table 3.1 Household Characteristics of the 2009 NHTS Data

Characteristics	All Households	Households with Elderly	Households without Elderly
Sample Size	150,147	62,405	87,742
Weighted Households	112,520,151	25,583,764	86,936,388
Household Size	2.34	1.83	2.70
1 Person	24.5%	41.7%	19.4%
2 Person	36.3%	47.0%	33.1%
3 Person	15.8%	6.7%	18.6%
4 or more Persons	23.4%	4.7%	28.9%
No. of Children (Under 18)	0.40	0.05	0.65
0 Children	67.9%	95.6%	59.7%
1 Children	14.6%	2.6%	18.1%
2 Children	11.8%	1.2%	14.9%
3+ Children	5.8%	0.6%	7.3%
No. of Elderly			
0 Elderly	77.3%	NA	NA
1 Elderly	15.7%	69.2%	NA
2+ Elderly	7.0%	30.7%	NA
No. of Workers	0.93	0.39	1.31
0 Workers	28.9%	69.3%	17.0%
1 Workers	40.4%	23.3%	45.4%
2 Workers	26.3%	6.4%	32.1%
3 or more Workers	4.5%	1.0%	5.5%
No. of Drivers	1.80	1.56	1.96
0 Driver	4.9%	11.3%	3.0%
1 Driver	30.6%	42.8%	27.0%
2 Driver	51.6%	40.3%	54.9%
3 or more Driver	12.9%	5.6%	15.1%
Annual Income			
< $ 25 K	25.4%	40.5%	21.3%
$ 25 K - $50 K	25.8%	33.1%	23.8%
$ 51 K - $75 K	16.6%	12.2%	17.9%
> $ 75K	32.1%	14.3%	37.0%
Vehicle Ownership	2.05	1.72	2.28
0 Vehicle	8.8%	14.3%	7.2%
1 Vehicle	28.9%	41.7%	25.1%
2 Vehicle	37.7%	30.7%	39.8%
3 or more Vehicles	24.6%	13.3%	27.9%
Dwelling Unit Type			
Detached Single House	66.2%	63.6%	66.9%
Duplex	7.3%	6.3%	7.6%
Row /Town House	22.0%	25.0%	21.1%
Other	4.5%	5.2%	4.4%
Residential Area Type			
Urban	77.2%	79.0%	76.6%
Rural	22.8%	20.9%	23.4%

households. The elderly in the second category (two or more elderly) have the advantage of having the companionship of persons of the same age group; this may affect their travel behavior.

The average number of workers in households with elderly is significantly lower than that of households with non-elderly (0.39 vs.1.31). About one quarter of the household's income is equal to or less than $25 K at an aggregate level, which is lower than the households with elderly group. In this group, almost 40.5 percent of households fall into the lower income category (< $25K), whereas for the households without elderly it is 21.3 percent. Average vehicle ownership is lower for households with elderly (1.72) compared to households without elderly (2.28) and households in the U.S. as a whole (2.05). Average vehicle ownership and the income category variable indicate that most of the elderly are in the "transportation disadvantaged" group. Interestingly, the average number of drivers in the household is 1.80, which is less than the average number of vehicles per households (2.05) for U.S. as a whole. The same trend goes for both of the household groups: with elderly and without elderly. At an aggregate level, i.e., for the U.S. as a whole, about 66 percent of households live in a detached single home, which is very close to the percentage of households with elderly (63.6 percent) and households without elderly (66.9 percent) living in a detached single home. The same goes for households living in a row house/town house. So, there is no high variation among the households with elderly and without elderly by housing unit types. About 79 percent of households that have at least one elderly are in an urban residential location and the rest are in a rural location.

As mentioned earlier, almost 42 percent of elderly households are one-person households, and 47 percent are two-person households. The characteristics of these households are shown in Table 3.2.Of the two-person households, only 0.5 percent has children (below 18 years of age) and 58 percent has only elderly member (above 65

Table 3.2 Elderly Household (One-Person and Two-Person) Characteristics

Characteristics	One- Person HH	Two-Person HH
No. of Children (Under 18)		
0 Children	100%	99.5%
1 Children	NA	0.5%
2 Children	NA	NA
3+Children	NA	NA
No. of Elderly		
1 Elderly	100%	42.0%
2 Elderly	NA	58.0%
No. of Workers		
0 Workers	88.0%	64.1%
1 Workers	12.0%	28.5%
2 Workers	NA	7.4
3 or more Workers	NA	NA
No. of Drivers		
0 Driver	22.8%	3.5%
1 Driver	77.2%	20.0%
2 Driver	NA	76.5%
3 or more Driver	NA	NA
Annual Income		
< $ 25 K	60.1%	26.4%
$ 25 K - $50 K	28.1%	38.1%
$ 51 K - $75 K	6.9%	15.5%
> $ 75K	4.9%	19.9%
Vehicle Ownership		
0 Vehicle	26.8%	5.0%
1 Vehicle	63.4%	28.7%
2 Vehicle	8.2%	50.0%
3 or more Vehicles	1.6%	16.3%
Dwelling Unit Type		
Detached Single House	47.3%	75.4%
Duplex	6.1%	5.7%
Row /Town House	40.2%	14.6%
Other	6.4%	4.3%
Residential Area Type		
Urban	83.3%	75.4%
Rural	16.7%	24.6%

years of age). Moreover, it appears that the percentages of 0 drivers, low income (< $ 25 K) and 0 vehicle households are significantly higher in the one-person households. It indicates that the elderly in one-person households i.e. the elderly who live alone has several barriers in making trips. It is clear from this section that the household characteristics of the elderly are different from those of the non-elderly.

3.3.2 Person Characteristics

Table 3.3 gives an overview of the person socio-demographic characteristics of the 2009 NHTS data. The 1st column shows the characteristics, and the 3rd and 4th columns show the share of elderly (age 65 and above) and the non-elderly (age below 65 years) corresponding to the characteristics in the 1st column. Among the 299,801,601 persons in the United States as a whole, 37,850,918 (12.63 %) are elderly (age 65 years and above), and 261,950,683 (87.37 %) are non-elderly (age below 65 years).
Since the elderly are almost 13 percent of the total population and, in general, their personal characteristics are different from the non-elderly, they are considered separately in this section.

From Table 3.3, the percentage of females is higher than the percentage of males (57.8 % vs.42.2 %) among the elderly, whereas for the non-elderly these percentages are almost equal (49.7 % vs.50.3 %). This indicates the gender disparity among the elderly. From the age variable, it appears that about 53 percent of the elderly are in the 65 – 74 years of age. Although age is considered to be one of the barriers in the elderly mobility issue, it seems that the percentage of young (65 – 74years) and middle (75 – 84 years) elderly are higher than that of the older elderly (>= 85 years). This lower percentage of older elderly is a good news in mitigating the mobility issues of the elderly because

Table 3.3 Person Characteristics of the 2009 NHTS Data

Characteristics	All Persons	Elderly	Non-Elderly
Sample Size	324,184	86,113	238,071
Weighted Population	299,801,601	37,850,918	261,950,683
Gender			
Male	49.2%	42.2%	50.3%
Female	50.8%	57.8%	49.7%
Age			
0-5 years	7.1%	NA	8.1%
6-15 years	13.8%	NA	15.8%
16-25 years	13.7%	NA	15.6%
26-64years	52.8%	NA	60.5%
65-74 years	6.7%	52.7%	NA
75 – 84 years	4.5%	35.5%	NA
Greater than 85 years	1.5%	11.8%	NA
Race			
White	72.5%	80.4%	71.4%
African American	12.3%	11.8%	12.3%
Other	15.2%	7.8%	16.3%
Hispanic Status			
Hispanic	15.0%	7.5%	16.1%
Not Hispanic	85.0%	92.5%	83.9%
Worker			
Yes, a worker	59.9%	15.3%	68.3%
No, not a worker	40.1%	84.7%	31.7%
Highest Education Level			
High School/Less	40.1%	51.7%	37.8%
Some College	28.1%	24.0%	28.9%
College Graduate	18.7%	13.0%	19.8%
Post Graduate	13.1%	11.3%	13.4%
Driver Status			
Driver	87.0%	80.0%	88.2%
Not a Driver	13.0%	20.0%	11.8%
Daily Travel			
Average Person Trips /day	3.77	3.18	3.96
Average Vehicle Trips /day	2.21	2.08	2.29
Average Person Miles/day	37.18	26.87	41.10
Average Vehicle Miles/day	22.12	16.31	26.17

the lower the age of the elderly person, the easier to include him/her in different plans and policies. The percentage of Whites (80.4%) among the elderly is higher than that among the non-elderly (71.4%) and among the persons (72.5%) at an aggregate level. The percentage of non-workers among the elderly is 84.7, which is significantly higher than the percentages among the non- elderly (31.7%) and among the persons for the U.S. as a whole (40.1%). In addition, a little more than half of elderly people exhibit a lower level of education when compared with the other two groups. This should be seriously considered in mitigating the mobility needs of the elderly because lack of education may hamper the pursuit of many types of activities (Lefrancois et al., 1998). Older people are more likely to be dependent on the private car (Rosenbloom, 1999). The mobility of older persons is closely related to their driving status. From Table 3.3, it can be seen that the percentage of non-drivers is higher among the elderly as compared to the non-elderly (20.0 % vs. 11.8 %). This requires special attention in elderly-related research. On an average, each person makes 3.77 person trips and 2.21 vehicle trips per day at an aggregate level, whereas for the elderly these are 3.18 and 2.08 and for non-elderly, 3.96 and 2.29, respectively. The same trend goes for average person miles and vehicle miles traveled per day by these groups. This indicates that older people make fewer trips and travel shorter distances as compared to their younger counterparts (Collia et al., 2003; Heaslip, 2007).

Table 3.4 shows the characteristics of the individuals from one-person and two-person households that have at least one elderly. It seems that the percentage of females is significantly higher than the percentage of males among the elderly who live alone. Moreover, when the elderly live with other non- elderly member, they are more likely to

Table 3.4 Person Characteristics (One-Person and Two-Person Households)

Characteristics	One - Person Households	Two - Person Households	
	Elderly	Elderly	Non-Elderly
Gender			
Male	25.1%	51.8%	27.0%
Female	74.9%	48.2%	73.0%
Age			
0-5 years	NA	NA	0.1%
6-15 years	NA	NA	0.6%
16-25 years	NA	NA	2.2%
26-64years	NA	NA	97.1%
65-74 years	40.4%	59.4%	NA
75 – 84 years	43.2%	33.5%	NA
Greater than 85 years	16.4%	7.1%	NA
Worker			
Yes, a worker	12.2%	16.2%	49.1%
No, not a worker	87.8%	83.8%	50.9%
Highest Education Level			
High School/Less	46.9%	43.2%	38.4%
Some College	28.9%	25.5%	29.5%
College Graduate	13.3%	17.0%	17.8%
Post Graduate	10.9%	14.3%	14.3%
Driver Status			
Driver	85.1%	90.2%	94.1%
Not a Driver	14.9%	9.8%	5.9%

live with the persons age 26-65 years. This may be because the elderly are likely to depend on the middle-age person for their daily needs (shopping, social meeting etc.). There is no high variation among the elderly by worker status. Among the non-elderly in two-person households, the percentage of workers and non-workers are almost equal. From the education variable, it seems that the elderly in both types of households exhibit a lower education level. Also, the percentage of non-drivers is higher among the elderly especially who live alone. The next subsection provides a clear picture of the travel patterns and trip characteristics of Americans using 2009 NHTS data.

3.3.3 Trip Characteristics

Travel patterns vary among the elderly and the non-elderly populations. Variation is found even among different groups of elderly. The main intent of this section is to give an overview of the travel patterns and trip characteristics of Americans with special focus on older adults age 65 and above.

When a trip is made by a person, it can be either as a passenger or as a driver of a vehicle. If the trip is made by a person as a driver of a privately-operated vehicle, it is called a "vehicle trip." Otherwise, the term "person trip" is used to account for all the trips made by different modes of transportation. This section focuses mainly on person trips and the characteristics associated with those trips. Among the various characteristics of the trip, four characteristics – average daily person trips, average daily person miles, average person trip length, and average person trip travel time – are considered with special attention in this section. In addition, the total population is divided into three main categories: children (age 5 – 18 years), young adults (age 19 – 64 years) and older adults (age 65 years and above). To understand the travel behavior of the elderly more clearly, older adults are divided into three subcategories: young elderly (age 65 – 74 years), middle elderly (age 75 – 84 years) and older elderly (age ≥ 85 years). These terms will be used in the remainder of the thesis.

The total number of trips and the trip characteristics associated with those trips varies greatly with the age of the person making the trip. As shown in Table 3.5, persons age 19 – 64 make almost 70.30 percent of the total trips, and this trip percentage decreases significantly with the increase of age, especially after 64 years. When gender is considered along with age (Table 3.6), it is found that the percentage of trips by female is

higher than those by males in all age cohorts except children. It is important to note that the difference in the trip percentages between male and female is higher among the older elderly as compared to other age cohorts. This gender disparity in the trip characteristics of the elderly should be considered with special attention in elderly travel behavior

Table 3.5 Trip Distribution by Age

Characteristics	Number of Trips	Percent
5-18 Years	71,461,997,508	18.40
19-64 Years	273,500,704,534	70.30
65-74 Years	26,346,070,424	6.80
75-84 Years	14,351,731,207	3.70
≥ 85 Years	31,966,353,04	0.80
All Ages	388,857,138,977	100.00

Table 3.6 Trip Distribution by Age and Gender

Characteristics	Male	Female	Total
5-18 Years	51.0	49.00	100.00
19-64 Years	48.40	51.60	100.00
65-74 Years	46.90	53.10	100.00
75-84 Years	46.60	53.40	100.00
≥ 85 Years	42.60	57.40	100.00
All Ages	48.60	51.40	100.00

research. Table 3.7 shows the variation in different trip characteristics such as average daily person trips, average daily person miles, average person trip length (miles), and average person trip travel time (minutes) by different age groups and gender. It was found that the average daily person trips of female older adults are lower than of male older adults, but the pattern is the opposite for the children and young adult group. This comparison of male and female average daily person trips by age is shown in Figure 3.1.

Table 3.7 Trip Characteristics by Age and Gender

Characteristics	Male	Female
Average Person Trips per day		
5-18 Years	3.18	3.30
19-64 Years	3.96	4.19
65-74 Years	3.82	3.45
75-84 Years	3.35	2.63
≥ 85 Years	2.27	1.79
Average Person Miles Per day		
5-18 Years	27.25	24.89
19-64 Years	48.72	37.21
65-74 Years	37.54	29.01
75-84 Years	30.65	18.33
≥ 85 Years	13.50	9.58
Average Person Trip Length (miles)		
5-18 Years	8.83	7.80
19-64 Years	12.52	9.16
65-74 Years	9.97	8.62
75-84 Years	9.26	7.32
>= 85 Years	6.06	5.75
Average Person Trip Travel Time(minutes)		
5-18 Years	19.78	18.83
19-64 Years	22.33	19.30
65-74 Years	20.89	18.87
75-84 Years	20.07	18.64
≥85 Years	17.97	17.87

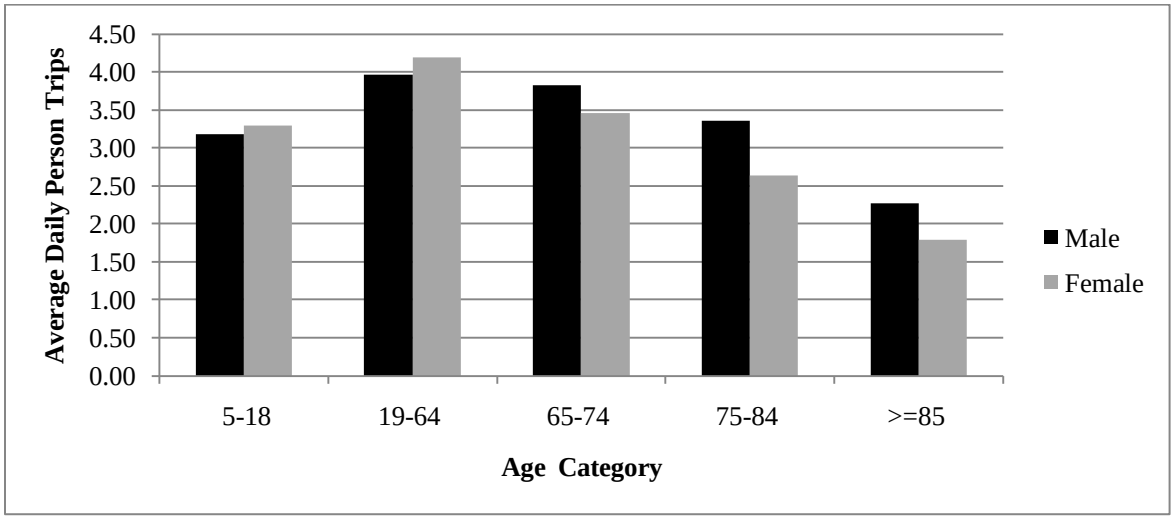

Figure 3.1 Average Daily Person Trips by Age and Gender

It appears that as age increases, average daily person trips of older adults decreases, and the difference between male and female person trips is found to increase with the increase in age of older adults. Interestingly, from Table 3.7, it was found that although females from two of the age groups (5 – 18 years and 19 – 64 years) have higher average person trips per day than males, the average trip characteristics such as person miles per day, person trip length, and person trip travel time of females are lower than those of males in all age cohorts. This reveals the shorter distance trip-making tendency for females as compared to males (Collia et al., 2003). In addition, all four trip characteristics mentioned in Table 3.7 were found to decrease with increase in age among older adults, irrespective of gender. Therefore, trip characteristics of older adults vary from their younger counterparts.

Trip-making propensity and the trip characteristics associated with those trips depend on different personal characteristics such as driver status and worker status; household characteristics such as race, household income, household vehicle ownership, etc.; and trip purposes and mode of transportation used for the trips. Table 3.8 presents the percentage of drivers and non-drivers by different age groups and gender, and Figure 3.2 provides a snapshot of the percentages of drivers and non-drivers among older adults. From the distribution of older adults, it was found that the percentage of non-drivers is higher among the older elderly compared to other age cohorts. This pattern is more pronounced for the female older elderly. About 58 percent of females in this group are non-drivers, which requires special attention. This driver status of older women may explain the reason for the lower average daily person trips of the older women mentioned in Table 3.7. Figure 3.3 depicts the mode use pattern by the older adults from zero

vehicle households. It seems that while the tendency to use a privately-owned vehicle (POV) increases with the age of older adults, the propensity to walk and use public transportation decreases with age. Interestingly, individuals in the 65 – 74 age cohort and living in zero vehicle households are more likely to walk than use a POV for their daily

Table 3.8 Distribution of Drivers and Non-Drivers by Age and Gender

Characteristics	Driver	Non-Driver	Total
Male			
19-64 Years	93.3	6.7	100.0
65-74 Years	92.7	7.3	100.0
75-84 Years	87.5	12.5	100.0
≥ 85 Years	69.7	30.3	100.0
All Ages	76.2	8.9	100.0
Female			
19-64 Years	90.0	9.9	100.0
65-74 Years	84.3	15.7	100.0
75-84 Years	70.3	29.6	100.0
≥ 85 Years	42.2	57.8	100.0
All Ages	72.8	13.3	100.0

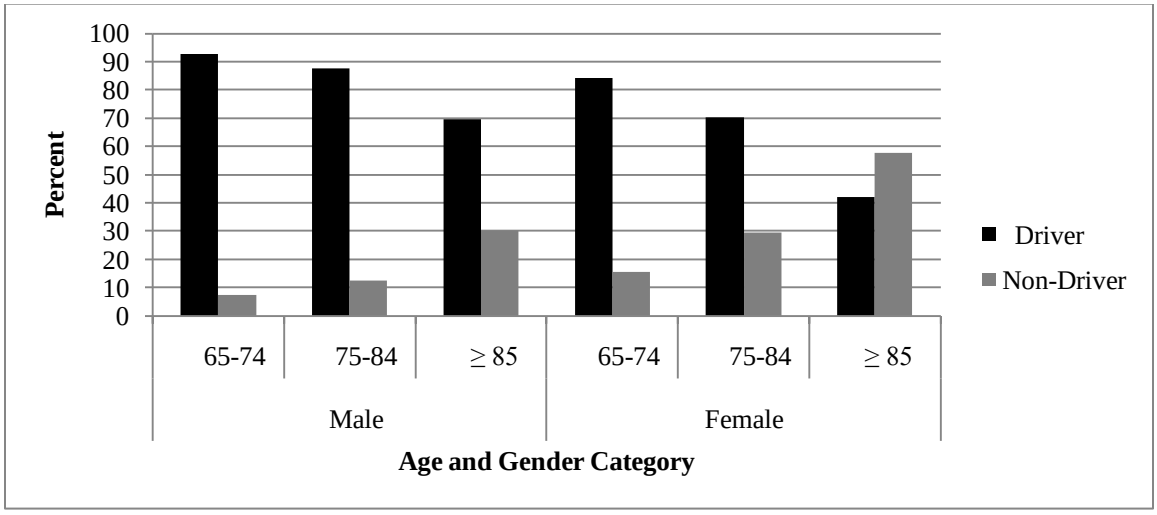

Figure 3.2 Distribution of Drivers and Non-Drivers by Age and Gender (Age ≥ 65 years)

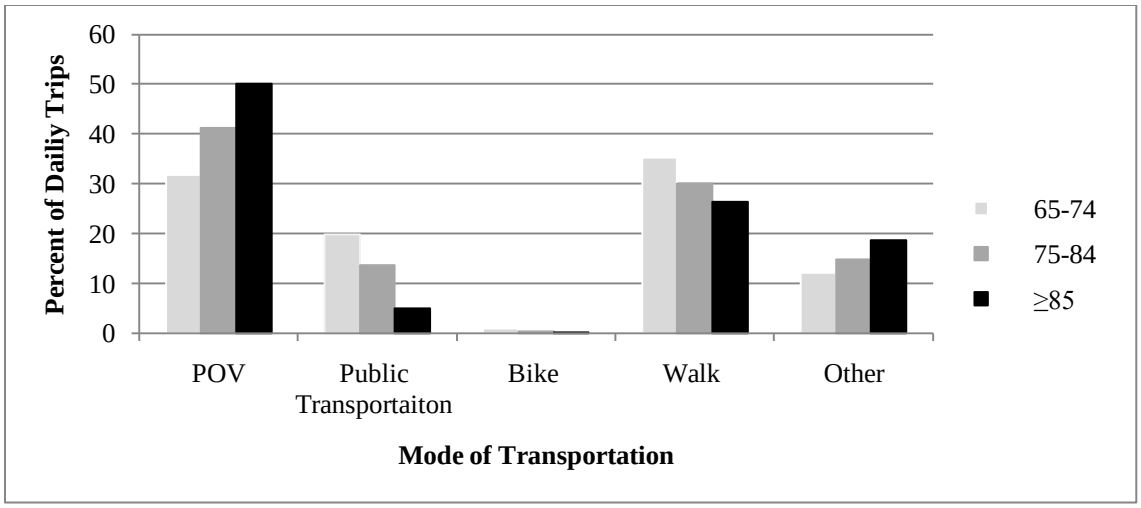

Figure 3.3 Distribution of Person Trips by Age and Mode of Transportation (For Zero Vehicle Household)

trips. If the mode of travel is considered along with age and driver status (Table 3.9), it seems that POV is the dominant mode of travel for both the driver and non-driver groups

Table 3.9 Distribution of Person Trips by Age, Driver Status and Mode

Characteristics	POV	Public Transportation	Bike	Walk	Other	Total
Driver						
19-64 Years	86.70	2.20	0.70	9.40	1.00	100.00
65-74 Years	89.00	1.40	0.50	8.20	0.80	100.00
75-84 Years	90.70	1.20	0.50	6.90	0.70	100.00
≥85 Years	89.10	1.10	0.10	7.70	2.00	100.00
All ages	86.80	2.20	0.70	9.20	1.20	100.00
Non-Driver						
19-64 Years	54.60	5.40	2.10	31.00	6.80	100.00
65-74 Years	59.40	5.00	0.80	23.90	11.00	100.00
75-84 Years	68.80	2.20	0.10	19.50	9.40	100.00
≥ 85 Years	73.50	0.60	0.10	15.50	10.30	100.00
All ages	59.80	4.00	1.80	25.20	9.20	100.00

for daily travel. As expected, the tendency of using a POV is higher among drivers compared to non-drivers. It also appears that walking and using public transportation are the 2nd and 3rd dominant modes, respectively, and the percentages of walk and public transportation trips made by non-drivers are higher than those of drivers. Also, while the

tendency to use a POV increases with the age, the tendency to use public transportation and to walk decreases with age. Although the same trend goes for both drivers and non-driver the rate of increase or decrease is higher among non-drivers. When elderly non-drivers are considered, they are more likely to use a POV compared to their younger counterparts. The highest percentage using a POV (73.5%) is found for the older elderly. In other words, dependency on a POV increases with age among the older elderly. On the other hand, a substantial subset of the elderly is non-drivers (Table 3.8). So it is important develop a special transportation system for the elderly that can reduce their dependency on POVs and keep them active. Table 3.10 shows the variation in trip characteristics by age, gender, and driver status. It was found that all average trip characteristics are lower

Table 3.10 Trip Characteristics by Age, Driver Status and Gender

Characteristics	Driver		Non-Driver	
	Male	Female	Male	Female
Average Person Trips per Day				
19-64 Years	4.06	4.37	2.47	2.57
65-74 Years	3.98	3.81	1.82	1.56
75-84 Years	3.61	3.07	1.60	1.60
≥ 85 Years	2.71	2.66	1.24	1.15
Average Person Miles per Day				
19-64 Years	51.02	39.19	16.64	19.50
65-74 Years	39.69	32.85	10.18	8.40
75-84 Years	33.21	22.17	12.84	9.22
≥ 85 Years	16.39	14.11	6.86	6.26
Average Person Trip Length				
19-64 Years	12.76	9.20	7.03	8.59
65-74 Years	10.12	8.81	5.83	5.93
75-84 Years	9.30	7.51	8.48	6.38
≥85 Years	6.15	5.55	5.63	6.13
Average Person Trip Travel Time				
19-64 Years	22.33	19.00	22.42	23.85
65-74 Years	20.11	18.73	42.61	20.83
75-84 Years	19.91	18.26	22.55	20.39
≥ 85 Years	17.23	16.73	21.73	19.83

for non-drivers compared to drivers, except for average trip travel time. Average trip travel time is higher for non-drivers. Also, the difference between the average person trip travel time of male elderly drivers and non-drivers is higher than that of their younger counterparts.

Table 3.11 presents the distribution of daily person trips by age, race, and mode of transportation, and Figure 3.4 depicts the variation in average daily person trips by age and race. From the distribution in Table3.11, it was found that although African are less likely to use a POV for their daily travel compared to Whites, the propensity to use walk and use public transportation is higher among this group compared to Whites.

Table 3.11 Distribution of Person Trips by Age, Race, and Mode of Transportation

Characteristics	POV	Public Transportation	Bike	Walk	Other	Total
White						
5-18 Years	75.40	0.60	2.60	11.10	10.20	100.00
19-64 Years	87.50	1.10	0.70	9.70	1.10	100.00
65-74 Years	88.80	0.80	0.60	8.70	1.10	100.00
75-84 Years	89.50	0.90	0.50	7.70	1.40	100.00
≥85 Years	85.80	0.60	0.10	9.80	3.70	100.00
All Ages	85.50	1.00	1.00	9.80	2.70	100.00
Black						
5-18 Years	58.40	4.90	3.70	21.00	12.00	100.00
19-64 Years	75.60	8.20	0.80	12.80	2.60	100.00
65-74 Years	82.00	4.60	0.30	9.70	3.40	100.00
75-84 Years	76.10	5.70	0.10	12.80	5.40	100.00
≥85 Years	76.40	3.10	0.00	6.60	14.00	100.00
All Ages	72.20	7.20	1.40	14.40	4.80	100.00
Other						
5-18 Years	64.00	4.70	1.60	20.30	9.40	100.00
19-64 Years	80.70	4.20	0.70	12.70	1.60	100.00
65-74 Years	78.50	7.40	0.50	11.80	1.90	100.00
75-84 Years	78.30	3.10	0.10	16.10	2.40	100.00
≥ 85 Years	79.40	4.20	0.30	12.70	3.40	100.00
All Ages	77.00	4.40	0.90	14.40	3.40	100.00

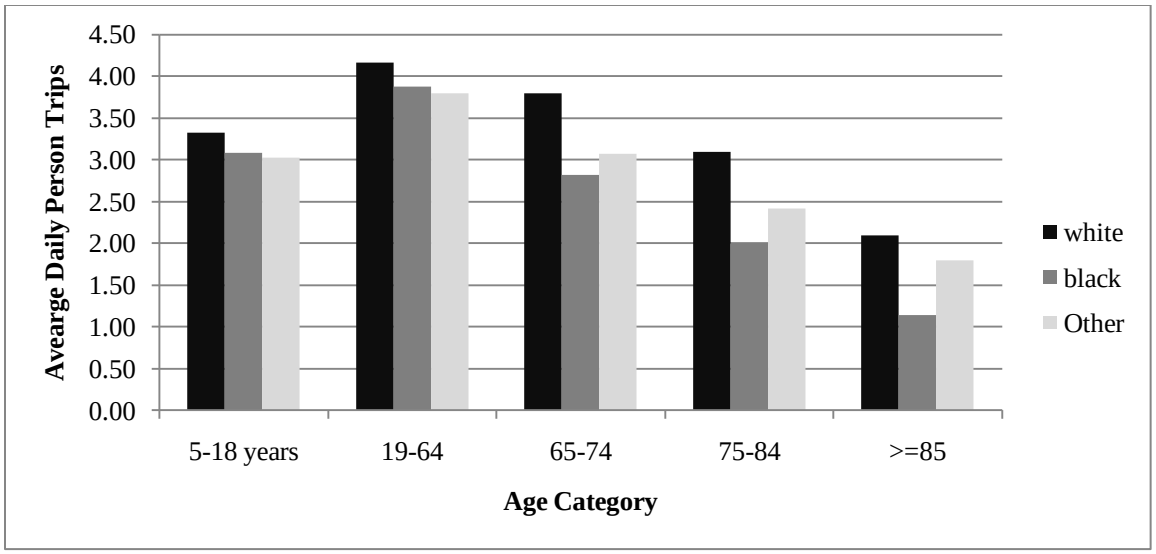

Figure 3.4 Average Daily Person Trips by Age and Race

This may be one of the main reasons for higher average travel times for African Americans in the Table 3.12. In other words, it is their dependency on transit and walking that forces them to travel for a longer time. In addition, Table 3.12 shows that the average daily person trips and person miles of Whites are higher than those of African Americans, and the pattern is the same for all age groups. If only older adults are considered, the difference in the average daily person trips of Whites and African Americans is higher than that of their younger counterparts.

Vehicle ownership plays an important role in the trip characteristics of household members. As shown in Table 3.13, walking and using public transportation are more likely to be used by persons from zero vehicle households compared to persons from one-vehicle or two-or more vehicles households. Figure 3.5 depicts this difference in trip distribution by vehicle ownership and mode of transportation. It appears that the mode use patterns of persons from zero vehicle households are different from persons of other types of households. In addition, within each type of households categorized by the

number of vehicles as shown in Table 3.13, it appears that the likelihood to use a POV increases and the propensity to walk decreases with the increase in age. Even within zero vehicle households, the propensity to use public transit and walk appears to decrease with age.

Table 3.12 Trip Characteristics by Age and Race

Characteristics	White	Black	Other
Average Person Trips per Day			
5-18 Years	3.33	3.09	3.02
19-64 Years	4.17	3.88	3.80
65-74 Years	3.80	2.82	3.07
75-84 Years	3.09	2.01	2.42
≥85 Years	2.09	1.14	1.79
Average Person Miles per Day			
5-18 Years	29.89	22.13	14.70
19-64 Years	46.25	35.19	33.35
65-74 Years	35.67	20.55	22.71
75-84 Years	24.02	21.48	18.37
≥ 85 Years	11.89	6.14	8.31
Average Person Trip Length (miles)			
5-18 Years	9.11	7.55	5.34
19-64 Years	11.24	9.49	9.47
65-74 Years	9.50	7.65	8.12
75-84 Years	7.95	11.66	8.62
≥ 85 Years	5.90	6.58	5.04
Average Person Trip Travel Time (min)			
5-18 Years	18.51	22.09	20.54
19-64 Years	19.89	24.56	22.24
65-74 Years	19.17	23.53	22.20
75-84 Years	18.36	27.81	23.09
≥ 85 Years	17.21	24.40	22.12

Table 3.13 Distribution of Person Trips by Age, Vehicle Ownership, and Mode

Characteristics	POV	Public Transportation	Bike	Walk	Other	Total
0-Vehicle						
5-18 Years	23.2	15.0	1.6	47.0	13.2	100.0
19-64 Years	23.7	25.4	2.5	42.9	5.6	100.0
65-74 Years	31.8	19.9	1.0	35.2	12.1	100.0
75-84 Years	41.3	13.6	0.3	30.0	14.8	100.0
≥85 Years	50.0	5.0	0.1	26.3	18.6	100.0
All Ages	25.7	21.9	2.0	42.1	8.3	100.0
1-Vehicle						
5-18 Years	63.8	3.2	4.9	15.8	12.3	100.0
19-64 Years	80.3	3.5	0.7	13.8	1.7	100.0
65-74 Years	87.1	1.4	0.7	9.7	1.1	100.0
75-84 Years	90.2	0.5	0.7	7.6	1.0	100.0
≥85 Years	89.0	0.3	0.2	7.9	2.7	100.0
All Ages	79.4	3.0	1.3	13.1	3.2	100.0
2-Vehicles						
5-18 Years	73.2	0.9	2.4	12.8	10.7	100.0
19-64 Years	88.7	0.8	0.7	8.8	1.0	100.0
65-74 Years	91.9	0.2	0.4	6.8	0.7	100.0
75-84 Years	92.9	0.3	0.2	6.0	0.6	100.0
≥85 Years	93.0	0.4	0.0	5.6	0.9	100.0
All Ages	86.2	0.8	1.0	9.3	2.8	100.0
3 or more Vehicles						
5-18 Years	79.9	0.5	0.5	9.4	8.4	100.0
19-64 Years	91.7	0.5	0.5	6.3	1.0	100.0
65-74 Years	92.9	0.0	0.0	6.1	0.4	100.0
75-84 Years	93.9	0.1	0.1	5.4	0.3	100.0
≥ 85 Years	91.1	0.3	0.3	7.5	1.1	100.0
All Ages	89.4	0.5	0.5	6.9	2.5	100.0

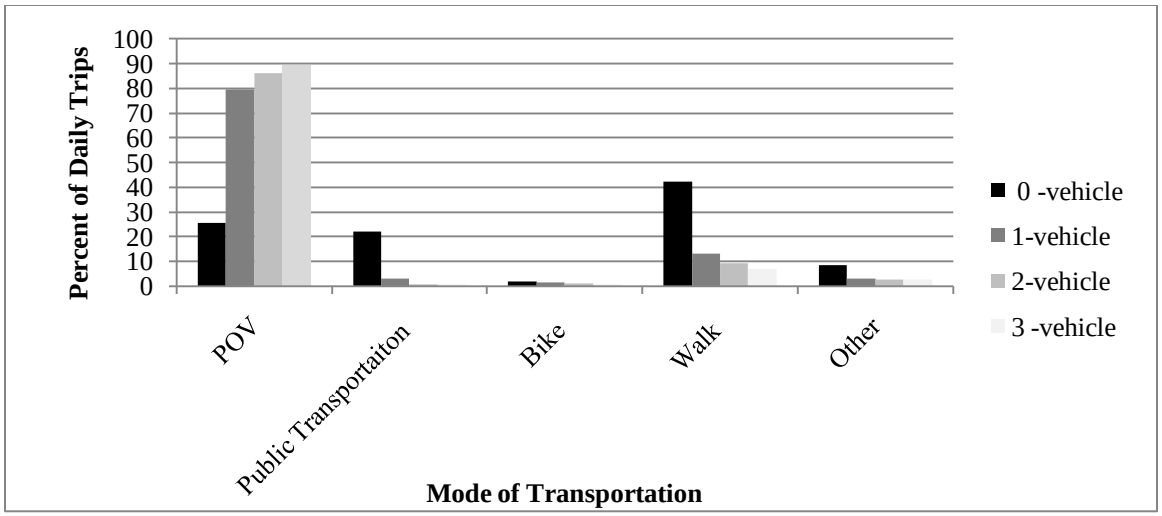

Figure 3.5 Distribution of Trips by Vehicle Ownership and Mode of Transportation

Table 3.14 and Figure 3.6 show that average daily person trips for all age cohorts increase with vehicle ownership of the household except those with three or more vehicles. Average daily person miles and average person trip length also increase with the number of vehicles in a household, but average person trip travel time does not follow the same trend. As expected, this is higher for persons from zero vehicle households, and the differences among zero vehicle and other types of household are significant. As shown in Table 3.15 and Figure 3.7, a similar pattern of relationship is found with household income. While average daily person trips, person miles, and person trip length increase with the increase in household income, average person trip travel time decreases with the income of households, with a few exceptions in households with income > $75 K and in the elderly groups. It seems that, up to a certain limit, income and age have a clear effect on average daily person trips. In addition, the effects of low income (< $25 K) on the trip characteristics of older adults are clear from their average daily person trips. These are significantly lower compared to other high-income groups. Also, within the same income group, average daily person trips of older adults are found to decrease with the increase in

Table 3.14 Trip Characteristics by Age and Vehicle Ownership

Characteristics	0 Vehicle	1 Vehicle	2 Vehicle	>= 3 vehicle
Average Person Trips per Day				
5-18 Years	2.73	3.04	3.33	3.33
19-64 Years	3.16	4.04	4.20	4.11
65-74 Years	2.24	3.53	3.93	3.72
75-84 Years	1.65	3.04	3.28	2.97
≥85 Years	1.13	2.26	2.19	2.14
Average Person Miles per Day				
5-18 Years	9.32	17.73	25.86	34.10
19-64 Years	12.99	35.66	44.01	51.38
65-74 Years	6.85	27.42	38.33	41.31
75-84 Years	7.90	22.95	28.77	28.10
≥ 85 Years	4.12	13.30	13.87	10.79
Average Person Trip Length (mile)				
5-18 Years	3.76	6.17	7.95	10.43
19-64 Years	4.57	9.19	10.66	12.67
65-74 Years	3.54	7.97	9.84	11.22
75-84 Years	5.58	7.79	8.90	9.60
≥ 85 Years	4.22	6.08	6.54	5.39
Average Person Trip Travel Time				
5-18 Years	30.96	19.25	18.17	18.96
19-64 Years	29.5	19.81	19.80	21.28
65-74 Years	25.51	19.01	19.28	20.69
75-84 Years	24.18	18.55	19.13	19.99
≥85 Years	22.27	17.07	18.14	16.20

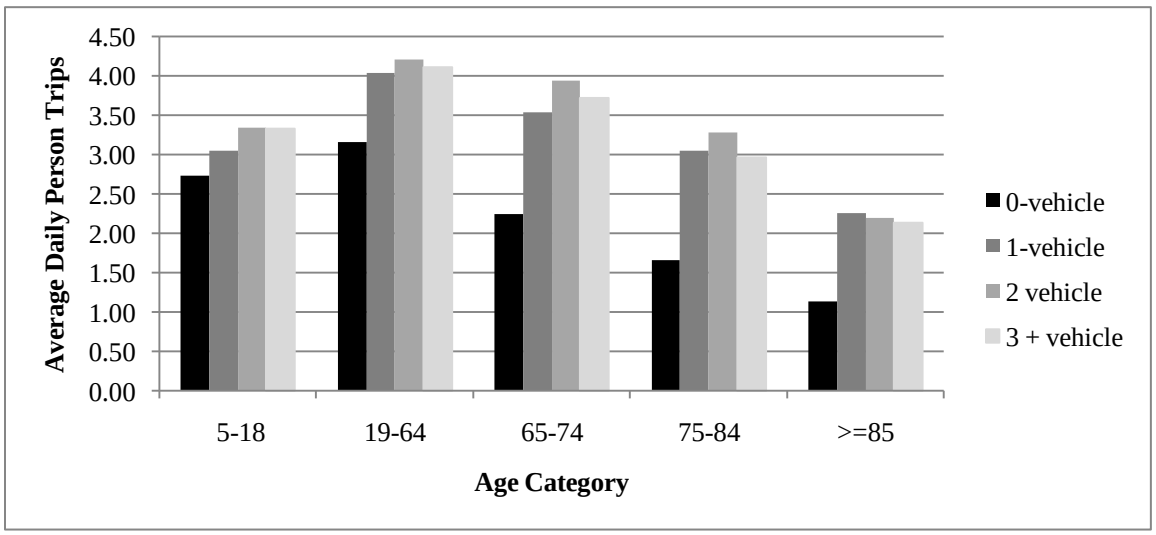

Figure 3.6 Average Daily Person Trips by Age and Vehicle Ownership

Table 3.15 Trip Characteristics by Age and Household Income

Characteristics	<$25K	$25-50k	$51-75k	>$75 k
Average Person Trips per Day				
5-18 Years	2.91	3.07	3.30	3.50
19-64 Years	3.56	3.96	4.15	4.47
65-74 Years	2.83	3.87	4.03	4.35
75-84 Years	2.45	3.29	3.67	3.48
≥ 85 Years	1.82	2.18	1.95	2.39
Average Person Miles per Day				
5-18 Years	17.23	20.95	24.28	34.85
19-64 Years	30.33	38.15	41.20	54.17
65-74 Years	21.01	33.03	36.38	47.79
75-84 Years	19.83	25.19	28.67	32.60
≥85 Years	10.05	13.40	12.07	11.56
Average Person Trip Length (mile)				
5-18 Years	6.44	7.03	7.50	10.04
19-64 Years	9.10	9.83	10.10	12.23
65-74 Years	7.78	8.67	9.08	11.07
75-84 Years	8.60	7.76	7.96	9.45
≥ 85 Years	5.77	6.35	6.27	4.95
Average Person Trip Travel Time				
5-18 Years	23.26	18.71	17.81	18.25
19-64 Years	22.47	20.15	19.79	20.65
65-74 Years	21.08	18.86	18.88	20.24
75-84 Years	20.21	18.83	18.00	19.32
≥85 Years	18.46	17.66	16.74	17.16

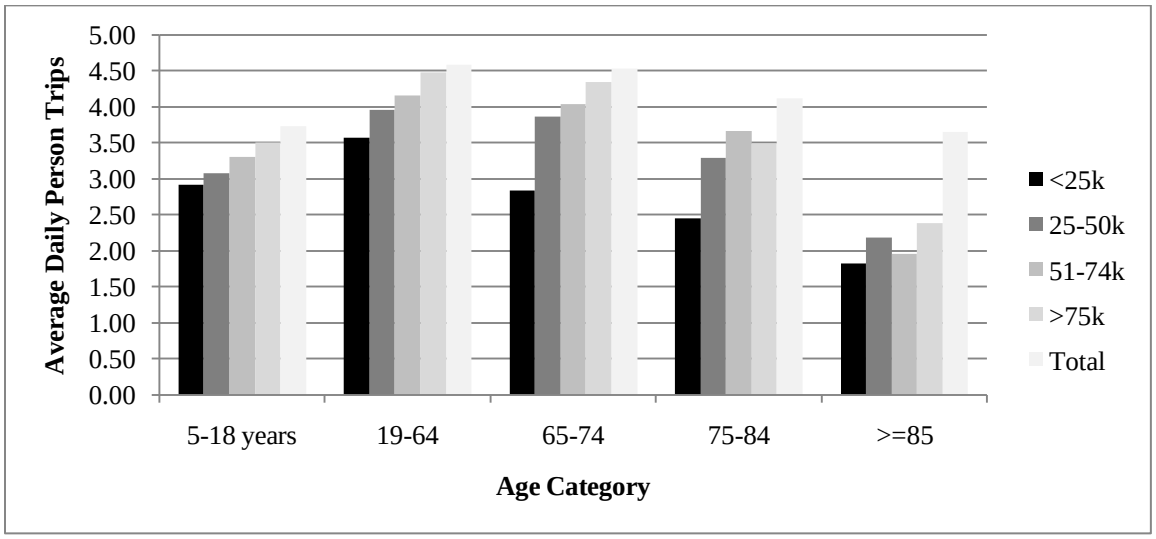

Figure 3.7 Average Daily Person Trips by Age and Household Income

age (Mallett [2001] reported such results for long distance travel). In short, Figures 3.6 and 3.7 indicate that older persons from zero vehicle and lower income (< $25K) households are more "transportation disadvantaged" compared to other groups in the population. So, while focusing on the mobility issues of the elderly, this group (with zero vehicle and income < $25 K) should be carefully considered.

Table 3.16 shows the distribution of trips by age, mode of transportation, and trip purposes. It appears that POV is the dominant mode for all age groups and for all trip purposes. Interestingly, the percentage of walking is highest for social/recreational purposes and is applicable to all age groups, even older adults. Tables 3.17 and 3.18 show the variations in trip characteristics for different trip purposes and for different modes of transportation. It seems that older adults are more likely to make trips for shopping purposes and their average daily person trips for this purpose decrease with the increase in age. But average trip length and average trip travel time for this purpose are lower compared to other trip purposes. Also, older elderly are found to have lower average daily person trips for social/recreational purposes (0.48) compared to other age cohorts. Since the benefit obtained from such trips can help the older elderly in many ways, proper care should be taken to increase the social/recreational trips among this group.

Table 3.16 Distribution of Person Trips by Age, Mode, and Trip Purpose

Characteristics	To/From work	Shopping	Family/ Personal	Social/ Recreational	Other
5-18 Years					
POV	87.10	86.50	83.90	73.40	61.90
Public Transportation	4.40	2.30	0.70	1.50	2.20
Bike	0.60	0.60	1.30	6.00	1.90
Walk	6.90	9.70	10.80	16.30	15.10
Other Transportation	1.00	0.90	3.30	2.80	19.00
Total	100.00	100.00	100.00	100.00	100.00
19-64 Years					
POV	91.20	89.00	84.70	75.60	83.30
Public Transportation	4.00	1.80	1.20	1.20	3.70
Bike	0.80	0.50	0.30	1.50	0.70
Walk	3.10	7.90	12.90	20.30	9.50
Other Transportation	1.00	0.80	0.90	1.40	2.70
Total	100.00	100.00	100.00	100.00	100.00
65-74 Years					
POV	91.80	91.50	88.90	78.40	89.10
Public Transportation	5.10	1.40	1.00	0.70	2.50
Bike	0.20	0.50	0.20	1.30	0.20
Walk	2.40	5.80	9.30	18.00	5.50
Other Transportation	0.60	0.90	0.60	1.60	2.70
Total	100.00	100.00	100.00	100.00	100.00
65-74 Years					
POV	93.80	92.80	90.20	79.30	89.50
Public Transportation	1.90	1.50	0.50	1.10	1.40
Bike	0.00	0.40	0.40	0.80	0.20
Walk	3.20	4.20	7.90	17.30	5.10
Other Transportation	1.20	1.10	1.10	1.50	3.70
Total	100.00	100.00	100.00	100.00	100.00
≥ 85 Years					
POV	92.10	90.70	86.20	72.80	88.00
Public Transportation	0.10	0.70	0.70	1.10	1.30
Bike	0.00	0.00	0.10	0.30	0.10
Walk	7.80	5.90	8.40	20.70	5.60
Other Transportation	0.00	2.60	4.60	5.00	5.10
Total	100.00	100.00	100.00	100.00	100.00

Table 3.17 Trip Characteristics by Age and Trip Purpose

Characteristics	To/From work	Shopping	Family/ Personal	Med /DDS	Social/ Recreation	Other	Total
Average Person Trips per day							
5-18 Years	0.08	0.44	0.37	0.05	0.77	1.50	3.20
19-64 Years	0.81	0.89	0.85	0.10	0.74	0.66	4.03
65-74 Years	0.22	1.07	0.72	0.19	0.83	0.58	3.60
75-84 Years	0.07	0.89	0.56	0.20	0.73	0.44	2.89
≥ 85 Years	0.01	0.62	0.33	0.18	0.48	0.32	1.94
Average Person Miles Per day							
5-18 Years	0.59	2.99	2.54	0.39	6.40	12.29	25.20
19-64 Years	9.77	5.99	5.55	0.94	6.38	12.70	41.33
65-74 Years	2.03	6.84	5.44	1.84	7.05	8.75	31.93
75-84 Years	0.57	5.03	4.15	1.89	4.93	6.03	22.59
≥85 Years	0.09	2.73	2.04	1.11	2.62	2.21	10.80
Average Person Trip Length (miles)							
5-18 Years	7.31	7.13	7.14	9.03	8.53	8.43	8.32
19-64 Years	12.38	6.88	6.69	10.1	8.84	19.89	10.8
65-74 Years	9.65	6.52	7.65	10.1	8.66	15.67	9.26
75-84 Years	8.69	5.78	7.53	9.81	6.98	14.14	8.24
≥85 Years	7.24	4.58	6.25	6.84	5.83	7.14	5.89
Average Person Trip Travel Time (minutes)							
5-18 Years	16.57	17.54	16.12	21.7	19.52	20.26	19.3
19-64 Years	24.86	15.88	15.46	23.4	19.60	28.67	20.8
65-74 Years	22.10	15.96	16.96	25.1	21.48	24.22	19.8
75-84 Years	20.70	16.08	17.24	24.1	19.82	23.73	19.3
≥ 85 Years	25.77	15.18	17.27	20.6	19.39	19.28	17.9

For all trip purposes, average person trip length is found to decrease with the increase in age among older adults. In addition, from Table 3.18, it was found that daily average

Table 3.18 Trip Characteristics by Age and Mode of Transportation

Characteristics	POV	Public Transportation	Bike	Walk	Other
Average Person Trips per day					
5-18 Years	2.30	0.06	0.08	0.45	0.33
19-64 Years	3.46	0.10	0.03	0.43	0.05
65-74 Years	3.16	0.06	0.02	0.33	0.05
75-84 Years	2.57	0.04	0.01	0.25	0.05
≥ 85 Years	1.66	0.02	0.00	0.19	0.09
Average Person Miles Per day					
5-18 Years	21.42	0.32	0.07	0.29	3.99
19-64 Years	37.97	0.84	0.09	0.32	3.67
65-74 Years	29.84	0.24	0.06	0.23	2.40
75-84 Years	21.66	0.14	0.03	0.14	1.35
≥85 Years	10.51	0.06	0.00	0.10	0.34
Average Person Trip Length (miles)					
5-18 Years	9.55	6.51	0.87	0.65	12.61
19-64 Years	11.19	10.6	3.23	0.76	72.83
65-74 Years	9.58	6.18	3.02	0.71	53.48
75-84 Years	8.66	4.65	2.28	0.58	30.73
≥85 Years	6.56	4.07	2.17	0.54	5.17
Average Person Trip Travel Time					
5-18 Years	18.14	44.43	14.42	15.61	29.17
19-64 Years	20.19	50.67	23.74	15.75	41.93
65-74 Years	19.29	43.50	22.85	18.44	34.35
75-84 Years	19.04	47.24	19.49	15.25	32.59
≥ 85 Years	17.47	41.03	27.12	16.03	25.05

person trips by public transportation are lowest among the older elderly (0.02). Also, public transportation is found to have the longest overall average travel time. Table 3.19 shows that the average daily person miles of male workers and non-workers are higher than workers and non-workers in the female cohort. It indicates that worker status does not change the shorter trip-making propensity of females. In addition, the difference

Table 3.19 Trip Characteristics by Age, Worker Status and Gender

Characteristics	Worker		Non-Worker	
	Male	Female	Male	Female
Average Person Trips per day				
19-64 Years	3.93	4.41	3.40	3.81
65-74 Years	4.10	4.23	3.60	3.26
75-84 Years	4.43	3.65	3.24	2.57
≥ 85 Years	4.34	3.39	2.33	1.76
Average Person Miles Per day				
19-64 Years	51.44	38.40	35.87	32.27
65-74 Years	47.15	34.12	33.39	26.83
75-84 Years	42.77	23.88	28.80	16.97
≥ 85 Years	9.96	16.32	13.46	8.43
Average Person Trip Length (mile)				
19-64 Years	12.87	9.13	10.92	9.23
65-74 Years	11.07	8.38	9.49	8.69
75-84 Years	10.13	6.76	9.11	7.36
≥85 Years	7.51	4.85	5.99	5.79
Average Person Trip Travel Time				
19-64 Years	22.43	19.16	21.88	19.59
65-74 Years	20.62	18.75	21.01	18.91
75-84 Years	21.10	19.05	19.89	18.61
≥ 85 Years	19.87	15.51	17.87	17.95

in daily person mile traveled between worker males and females is higher than that between non-worker males and females. The same trend is true for average person trip length as well. Another important observation is that the average daily person miles and average person trip travel time decreases with the increase in age. This is applicable to all age groups, irrespective of their gender and worker status. In addition, as expected, the average person miles per day for individuals age ≥ 85 years is significantly lower compared to other age groups.

Table 3.20 Trip Characteristics by Age and Population Size of MSA

Characteristics	Not in MSA	<1 million	1-3 million	>3 million
Average Person Trips per day				
5-18 Years	3.25	3.35	3.26	3.15
19-64 Years	3.95	4.11	4.15	4.06
65-74 Years	3.51	3.90	3.63	3.48
75-84 Years	2.93	3.05	2.94	2.82
≥ 85 Years	2.02	2.00	1.86	1.99
Average Person Miles Per day				
5-18 Years	30.77	27.91	24.96	23.66
19-64 Years	46.51	42.66	41.61	42.33
65-74 Years	41.19	33.00	31.77	27.96
75-84 Years	28.82	21.76	22.26	21.85
≥85 Years	13.72	11.76	10.62	9.49
Average Person Trip Length				
5-18 Years	9.62	8.61	7.82	7.84
19-64 Years	11.91	10.62	10.23	10.74
65-74 Years	11.87	8.65	8.87	8.29
75-84 Years	10.02	7.36	7.77	8.10
≥85 Years	6.89	6.13	5.92	5.18
Average Person Trip Travel Time (minutes)				
5-18 Years	19.08	20.47	17.57	19.71
19-64 Years	19.96	19.65	19.86	22.34
65-74 Years	20.25	19.68	18.28	20.60
75-84 Years	19.41	18.12	18.49	20.65
≥ 85 Years	16.32	17.91	17.48	18.99

As shown in Table 3.20, when the population size of a Metropolitan Statistical Area (MSA) is considered, the older elderly have the lowest daily average person trips in all categories. Travel distance varies more than travel time. Also, people living outside the MSA were found to travel the most miles compared to other groups (Giuliano, 1999) but the travel distance is significantly lower for the older elderly. Figure 3.8 shows the variations in trip start time among the different groups of travelers. It appears that daily

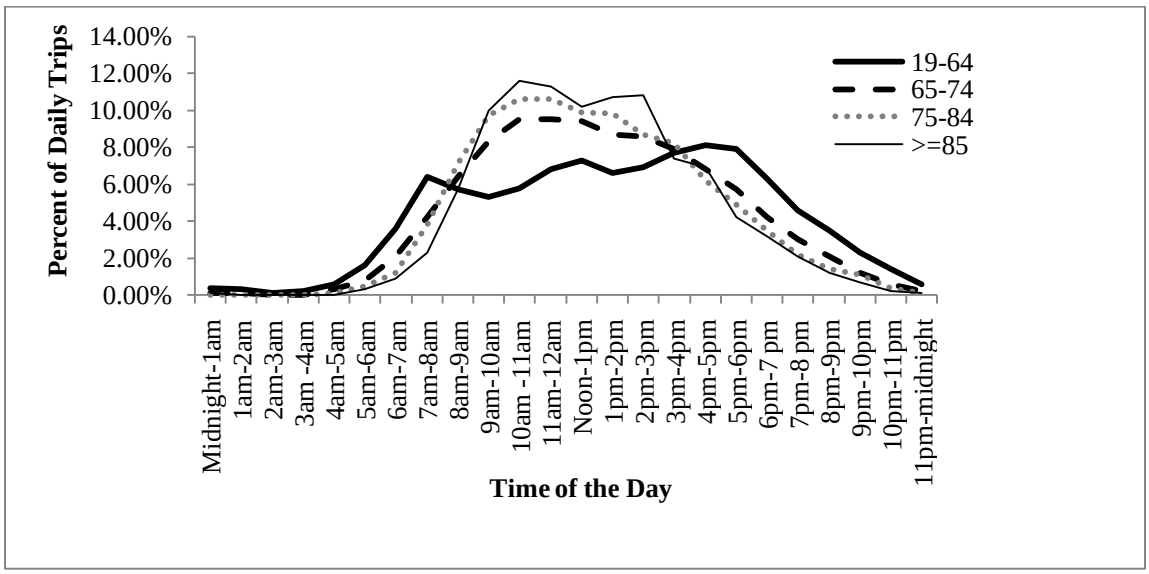

Figure 3.8 Distribution of Person Trips by Age and Time of the Day

trips of the different travelers are not distributed evenly throughout the day, and older adults show different travel patterns compared to other groups of travelers. They are more likely to start their trips in the late morning (10 a.m. – 12 a.m.) and mid-day periods (until 3 pm). It seems that older people tend to avoid the morning and after-work peak traffic times by choosing a different time for traveling (Collia et al., 2003). Interestingly, it appears that the older the traveler, the higher the tendency to start travel in the late morning and mid-day periods**.** The timing of travel is always important from the transportation planner's point of view because it is closely related to congestion. Congestion is a common occurrence in most large cities and metropolitan areas. When the elderly are considered, this is more important to consider because of their special transportation needs and trip characteristics. The timing of elderly travel, as shown in Figure 3.8, can help planners and special transportation service providers to mitigate the mobility problems of the elderly.

3.4 Conclusion

In summary, this chapter provides an overview of household and person characteristics of the 2009 NHTS. In addition, different trip characteristics of those persons are discussed in this chapter. From the discussion, it is clear that the trip characteristics of older persons are different from their younger counterparts. For example, older adults make fewer trips, and these trips are shorter in distance (Collia et al., 2003; Heaslip, 2007). An interesting observation is the variation in trip characteristics of the female elderly. In the child and young adults group, females were found to make more average daily trips compared to males, but in the older adults group, the situation is the opposite: average daily person trips are higher for males compared to females in this cohort. In addition, females are more likely to make short distance trips, and this pattern is the same among the working population. Also, the elderly are more likely to depend on the POV for their daily travel, but a substantial number of them is non-drivers.

Proper measures should be taken to keep the elderly active. For instance, special transportation services for the elderly should be provided in such way as to reduce their dependency on a POV. It also will reduce the frustration among older adults that develops from giving up driving. In addition, older adults make more trips for shopping purposes, and the older elderly have the lowest trip rate (0.48) for social and recreational purposes among all age cohorts. Appropriate measures should be taken to increase the social/recreational trips of the older elderly because social activities involving mobility can reduce mortality in older people (Glass et al., 1999).

Variation is observed even among the different groups of elderly. It was found that the difference between the average daily person trips of males and females increase

with the age of the older adults. In addition, female older adults are found to travel shorter distances compared to male. This gender variation should be carefully considered in elderly travel behavior. Young elderly living in zero vehicle households are more likely to walk than using a POV for their daily travel. The tendency to use public transit and walk appears to decrease with age. This pattern is observed even among the older adults from zero vehicle households. In addition, it is found that older elderly living in the zero vehicle and low income (< $25 K) households are the most "transportation disadvantaged" group in the total population.

The variation in the mode use patterns of the elderly due to the differences in vehicle ownership and household income provides a better picture of elderly travel behavior. In addition, the variation in trip start times of the different groups of older adults can help transportation planners and policy makers to develop appropriate strategies for the elderly. It would also help special transportation providers to meet the special transportation needs of the different groups of elderly at a particular time of day. However, several cautions should be exercised before directly using the results obtained from descriptive analysis.

All of the tables and figures in this chapter are based on a descriptive analysis. The travel patterns of the elderly obtained from this chapter may vary with the presence of other factors or when all the factors are considered together. To understand the travel patterns and preferences of the elderly more clearly, these variables should be taken into account through a modeling effort. Only then can the results be helpful for transportation planners and policy makers in developing a comprehensive plan and other strategies for older Americans.

CHAPTER 4

MODELING METHODOLOGY

4.1 Introduction

This chapter begins with a data (sample) description and is followed by the Multinomial Logit Model (MNL) methodology, results, and, finally, the Mixed-Multinomial Logit (M-MNL) model for analyzing the travel patterns and preferences of the elderly.

4.2 Data

This section describes the sample preparation that was required for modeling purposes and the sample characteristics of the elderly from the 2009 NHTS.

4.2.1 Sample Preparation

This subsection presents the structure of the 2009 NHTS data files and the main file used for the estimation of the MNL and M-MNL models to analyze the travel patterns and preferences of the elderly.

The 2009 NHTS has four different files: a household file, a person file, a travel day file, and a vehicle file. The household file contains different household-level information such as total number of workers, total number of household vehicles, and household income, all obtained from a household interview. The person file contains demographic information such as age, gender, and race of the interviewed persons from

each selected household for the 2009 NHTS. The travel day file contains travel-related information such as starting and ending time of trips, means of transportation, trip distance, and travel time for each trip made by household persons on a particular day of the week. The vehicle file contains information about each of the vehicles of the household. This study mainly focuses on the first three file – household, person, and travel day – to analyze the travel patterns and preferences of the elderly.

The original 2009 NHTS person file has a variable named 'MOREOFTEN' that reveals the information of those who traveled more than a week ago from the given reporting day of the survey (travel day) and whether the individuals prefer going out of home more often or not. More specifically, if the individuals did not make any trips on the travel day and reported that they had stayed at the same place (for example, at home) all that day, then the question, "About how long ago did you take a trip to another address?" was asked. If the answer to this question was "more than a week ago" the next question was, "Would you like to get out more often?" Based on these questions, mobility patterns and preferences were divided into four categories: (1) traveled on travel day, (2) did not travel on travel day but traveled in past seven days, (3) did not travel in past seven days but prefer going out of home more often, and (4) did not travel in the past seven days and do not prefer going out of home. In other words, individuals who made at least one trip in a week were included in the first two groups, and the last two groups include only the persons who did not make any trips in the past seven days. "Past seven days" is described as "travel week" in the rest of the thesis. Table 4.1 shows the variation in mobility patterns and preferences by age group. It appears that the older adults (age 65 and above) are more likely to be immobile than their younger counterparts. The pattern

Table 4.1 Comparison of Mobility Patterns and Preferences by Age Groups

Age	Traveled in Past Seven Days		Did Not Travel in Past Seven Days	
	On Travel Day	Not on Travel Day	Prefer Going Out of Home	Do Not Prefer Going Out of Home
19–64 Years	90.1%	8.6%	0.9%	0.4%
65 -74 Years	80.8%	15.3%	2.1%	1.9%
75 - 84 Years	72.4%	20.2%	3.7%	3.8%
≥85 Years	55.2%	27.8%	7.8%	9.2%
Total	87.4%	10.3%	1.3%	1.0%

is similar for both short and long term immobility. A new file of persons aged 65 and above was created from the original person file to analyze the travel patterns and preferences of older Americans. In addition, different household-level characteristics such as total number of trips of household members were imported into the new segmented person file from the household file. After this, several screening and consistency checks were performed, and records with missing and inconsistent data were eliminated. Finally, dummy variables were created in the segmented file based on the literature and an understanding of what factors potentially could affect the travel behavior of the elderly for the model estimation.

4.2.2 Sample Description

Table 4.2 presents a brief summary of the socio-demographic characteristics of the individuals in the sample. As shown in the table, there are a total of 71,261 elderly persons age 65 and above. Among them, 3,946 (1,962 + 1,984) individuals did not make a trip in the travel week and, of these 3,946 individuals, 1,962 individuals did not prefer to go out of home more often and 1,984 individuals did prefer to go out of home more often. A total of 54,783 individuals traveled on the travel day, and 12,532 individuals did

not travel on the travel day but traveled during the travel week. The percentage of elderly female in the groups who did not travel during the travel week is approximately 67 percent, which is higher than that of the United States as a whole (55.3%). Elderly females are less likely to go outside of home compared to elderly males. As expected, the percentage of individuals age 85 and above in the groups who did not travel in the travel week is higher than that in the groups who traveled at least once during the travel week. In addition, from the percentages of race, education, and employment status variables, it appears that African Americans, individuals with lower education, and non-workers are more likely to stay home compared to individuals from other races, with higher education, and workers. As expected, medical condition made travel difficult for 71 percent of the people who prefer going out of home more often, and when length of medical condition is considered, it is longer among the individuals who did not travel compared to those who traveled at least once during the travel week.

The percentages of non-drivers and individuals living in zero vehicle households are also higher in the groups who did not travel compared to those who traveled in the travel week. Percentage of Internet use (88.4) and household size (30.2) variables indicate that persons who never use the Internet and live alone are not likely to travel more frequently. Among the individuals who do not prefer going out of home more often, about 62 percent live in households with income less than $25K, and 18 percent live in a rented house, whereas for the whole United States, these percentages are 29.8 percent and 8.8 percent, respectively. Finally, the distributions of birth status, dwelling unit type, residential area type, life cycle classification, MSA size, and presence of multiple

Table 4.2 Sample Characteristics

Variables	Traveled in Past Seven Days		Did Not Travel in Past Seven Days		Total
	On Travel Day (1)	Not on Travel Day (2)	Prefer Going Out of Home (3)	Do Not Prefer Going Out of Home	
Number of Persons	54,783	12,532	1,984	1,962	71,261
Gender					
Male	47.5	36.5	33.0	32.7	44.7
Female	52.5	63.5	67.0	67.3	55.3
Age					
Young Elderly (65 - 74 years)	58.3	46.8	33.6	27.0	54.7
Middle Elderly (75 - 84 years)	34.2	38.4	41.7	43.0	35.4
Older Elderly (>= 85 years)	7.5	14.8	24.7	30.0	9.8
Hispanic Status					
Hispanic	4.1	4.5	6.4	9.5	4.4
Not Hispanic	95.9	95.5	93.6	90.5	95.6
Race					
White only	91.4	89.7	82.9	80.1	90.5
Black only	4.6	5.8	10.4	10.6	5.1
Other	4.1	4.5	6.7	9.3	4.4
Highest Level of Education					
High School Graduate or Lower	42.0	54.9	67.4	71.6	45.8
Some College through Bachelor's	43.4	37.0	27.3	24.4	41.3
Master's Degree or higher	14.5	8.0	5.3	4.0	12.9
Employment Status					
Full Time	8.3	2.8	0.7	0.8	6.9
Part Time	10.0	3.8	0.8	0.7	8.4
Not employed	81.7	93.4	98.6	98.6	84.7
Medical Condition					
Yes	16.3	35.7	70.5	52.0	22.2
No	83.7	64.3	29.5	48.0	77.8
Length of Medical Condition					
0 – 4 years	7.3	16.7	36.7	24.9	10.2
5 – 10 years	3.5	8.1	15.7	11.7	4.9
10 years or more	5.4	11.0	18.0	15.4	7.0
Driver Status					
Driver	93.0	76.3	46.5	45.5	87.5
Not a Driver	7.0	23.7	53.5	54.5	12.5
Birth Status					
Born in U.S.	93.3	93.3	91.1	89.1	93.1
Not born in U.S.	6.7	6.7	8.9	10.9	6.9

Table 4.2 (Continued)

Variables	Traveled in Past Seven Days		Did Not Travel in Past Seven Days		Total
	On Travel Day (1)	Not on Travel Day (2)	Prefer Going Out of Home (3)	Do Not Prefer Going Out of Home (4)	
Internet Use					
Almost Every Day	37.1	23.2	8.2	7.5	33.1
Sometimes	16.3	12.7	6.8	4.1	15.1
Never	46.6	64.2	85.1	88.4	51.9
Household Size					
1 person	23.9	25.6	28.0	30.2	24.5
2 persons	65.9	59.4	53.4	48.9	63.9
3 persons	7.0	9.6	11.7	13.7	7.8
>= 4 persons	3.1	5.5	6.9	7.2	3.8
Count of Household Vehicle					
0 vehicle	3.2	7.9	19.2	20.0	4.9
1 vehicle	33.9	37.0	38.9	40.0	34.7
2 vehicles	44.2	37.4	28.5	27.1	42.1
3 and above vehicles	18.8	17.8	13.4	12.9	18.3
Household Income					
< $25 K	25.8	37.5	59.1	62.0	29.8
$25K – $50K	37.0	35.4	26.4	22.6	36.1
$51K – $75K	17.2	12.7	7.6	8.1	15.9
> $75K	19.9	14.4	7.0	7.3	18.3
Housing Unit					
Own	92.3	89.1	82.9	82.4	91.2
Rent	7.7	10.9	17.1	17.6	8.8
Dwelling Unit Type					
Single Detached House	79.6	77.4	72.0	72.2	78.8
Other (Duplex, Condo, Mobile etc.)	20.4	22.6	28.0	27.8	21.2
Residential Area Type (Urban/Rural)					
Urban	71.9	67.7	72.0	72.2	71.2
Rural	28.1	32.3	28.0	27.8	28.8
Life Cycle Classification					
1 adult, no children/youngest child 0-21 years	5.1	4.0	4.3	4.9	4.9
1 adult, retired, no children	19.0	21.7	24.2	25.8	19.8
2+ adults, no children/ youngest child 0-21 years	11.5	10.1	9.7	10.5	11.3
2+ adults, retired, no children	64.3	64.2	61.7	58.9	64.1
MSA size					
MSA less than 1 million	31.8	31.8	29.8	29.1	31.7
MSA 1 to 3 million	21.6	20.5	19.5	21.0	21.3
MSA more than 3 million	24.6	23.9	25.7	24.7	24.5
Not in MSA	22.0	23.8	25.1	25.1	22.5

Table 4.2 (Continued)

Variables	Traveled in Past Seven Days		Did Not Travel in Past Seven Days		Total
	On Travel Day (1)	Not on Travel Day (2)	Prefer Going Out of Home (3)	Do Not Prefer Going Out of Home (4)	
Household Structure					
Only elderly	73.4	69.2	60.3	60.1	71.9
One other member	21.0	21.6	27.0	26.1	21.4
Two or more other members	5.6	9.2	12.7	13.8	6.6
Worker Status					
0 worker	68.2	74.0	78.1	77.2	69.7
1 worker	24.1	19.8	17.2	17.2	22.9
2+ workers	7.8	6.2	4.7	5.6	7.3
Presence of Multiple Job Holders					
Yes	1.5	1.9	2.0	2.2	1.6
No	98.5	98.1	98.0	97.8	98.4

job holder variables appear to be the same across the groups with different mobility patterns and preferences. From the household structure and number of vehicle variables, it appears that elderly persons living with two or more household members and in zero vehicle households are more likely to stay home.

4.3 Multinomial Logit Model

This section describes the methodology of the Multinomial Logit Model (MNL), which is one of the most widely used models in choice analysis. A random utility-based MNL model is specified in this study to analyze the travel patterns and preferences of the elderly. The following subsections describe this random utility approach, followed by the estimation and evaluation techniques of the MNL.

4.3.1 Random Utility Maximization Approach

Discrete choice models are based on a random utility maximization approach. This approach assumes that an individual will select the alternative from the choice set that provides him/her the maximum utility. A choice set generally contains all the alternatives available to the individual. In other words, if a decision maker has C choice set, he/she will select the alternative 'i' from the choice set C, if and only if the utility of alternative 'i' is greater than or equal to the utility of all other alternatives 'j' in the choice set. This can be expressed mathematically as:

$$U(X_{i,}S_n) \geq U(X_{j,}S_n) \forall j \in C$$

where, $U(.)$ is the utility function

X_i, X_j are the vectors of attributes describing alternatives i and j, respectively

S_n is a vector of the characteristics of individual n

If the situation is such that there is no uncertainty in the individual's decision process, i.e., if he/she always selects the alternative with highest utility from the choice set, a deterministic utility model can be used to predict the decision maker's choice behavior. However, the presence of different types of errors in the utility functions drives the analyst to use a random utility or probabilistic choice model instead of a deterministic utility model for predicting the decision maker's choice behavior. Three primary sources of these errors are: (1) lack of complete information to the decision maker about all the alternatives available to him/her, (2) incomplete information to the analyst about the alternatives available to the decision makers, and (3) the specific circumstances that the decision makers face in real life are completely unknown to the analyst (Koppelman and

Bhat, 2006). To capture all of this absent information in the choice prediction, a random utility approach is used. In this approach, the utility function is decomposed into two components and the uncertainty that results due to lack of information is included as one of those two components. This can be expressed as:

$$U_{ni} = V_{ni} + \varepsilon_{ni}$$

where, U_{ni} is the true utility of the alternatives i to the decision maker n

V_{ni} is the observable portion of the utility

ε_{ni} is the error portion of the utility unknown to the analyst

The observable or the deterministic portion of the utility can be expressed as

$$V_{ni} = V(X_i) + V(S_n) + V(X_i, S_n)$$

where,

V_{ni} is the observable portion of the utility of alternative i to decision maker n

$V(X_i)$ is the portion of the utility associated with the characteristics of alternative i

$V(S_n)$ is the portion of utility associated with the characteristics of decision maker n

$V(X_i, S_n)$ is the portion of the utility that results from interaction between the attributes of alternative i and characteristics of decision maker n

Again, these observable portions of the true utility function can be expressed as a linear function of the explanatory variables X_n:

$$V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n$$

where, $\beta_1, \beta_2, ..., \beta_n$ are the parameters associated with the attributes of alternatives and individual characteristics.

The error terms mentioned in the utility equation are assumed to be identically and independently distributed type 1 extreme values (the Gumbel distribution). Also, the error terms are assumed to be independent from the irrelevant alternative, which is well known as the independent from the irrelevant alternative (IIA) property of the MNL model. All of these assumptions lead to the MNL model for the following probability expression:

$$P_{ni} = \frac{e^{V_{ni}(\beta)}}{\sum_{j \in C} e^{V_{nj}(\beta)}}$$

OR

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_{j \in C} e^{\beta' x_{nj}}}$$

where, P_{ni} is the probability of choosing alternative i of individual n, and β' is a vector of coefficients of the observed characteristics of decision makers and the attributes of alternatives.

4.3.2 Estimation and Evaluation

Parameters associated with the decision maker's characteristics and the attributes of the alternatives are estimated using the Maximum Likelihood Method. The mathematical expression of this maximum likelihood method is given below:

Let N denote the sample size and define

y_{ni} = 1 if decision maker n choose alternative i

= 0 otherwise

The likelihood function for a general multinomial logit model becomes

$$L^* = \prod_{n=1}^{N} \prod_{i \in C} P_{ni}^{\,y_{ni}}$$

where, for the linear-in-parameters logit model:

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_{j \in C} e^{\beta' x_{nj}}}$$

Taking the logarithm provides the log-likelihood function as

$$L = \sum_{n=1}^{N} \sum_{i \in C} y_{ni} \left(\beta' x_{ni} - \ln \sum_{j \in C} e^{\beta' x_{nj}} \right)$$

Generally t-statistic is used to make the decision about the single variable in the model. However, when there is a need to make a decision about the whole model, the likelihood ratio test is used. In other words, the superiority of the model with respect to the base line model is determined by the likelihood ration test. It helps the researchers to make a decision during the hypothesis testing. The statistics are given by:

$-2[L(c) - L(\beta)]$ is χ^2 distributed with $K - J + 1$ degrees of freedom.

where, $L(c)$ is the Log-likelihood at market share

$L(\beta)$ is the Log-likelihood at convergence of the specified model

K is the number of parameters corresponding to K variables in the model

J is the number of alternatives

4.4 Multinomial Logit Model Results

This section provides the results of the Multinomial Logit model. Table 4.3 presents the parameter estimates and the corresponding t-statistics of the variables used to

analyze the mobility patterns and preferences of the elderly. These results offer reasonable hints that are consistent with the expectation.

As shown in Table 4.3, the choice set of the elderly mobility patterns and preferences is composed of four alternatives: individuals (1) who traveled on the travel day, (2) who did not travel on the travel day but traveled in the past seven days, (3) who did not travel in the past seven days but prefer going out of home more often, and (4) who did not travel in the past seven days and do not prefer going out of home more often. As mentioned in subsection 4.2.1, the past seven days are described as "travel week," and the first two travel choices will be described as the tendency to "travel frequently" and "travel less frequently," respectively. The term "travel less frequently" describes the individuals who traveled at least once in the travel week other than the travel day, i.e., they travel but not as frequent as the frequent travelers from the first category. On the other hand, the individuals who did not travel at least once in the travel week but prefer going out of home more often are described as "prefer going out of home," and the remaining group is referred to as "like to stay home." In addition, the first two choices are identified to have the tendency for "traveling," and the last two choices are described as "preferences" of the individuals in the rest of the thesis.

The last column in the model result table shows the difference in the effects of variables on the last two preferences. In this column, while some coefficients are positive, some are negative and some are blank. The positive sign of a coefficient in the last column against a variable indicates that the effect of that variable is higher on the preference of staying home compared to the preference of going out. The opposite is true for the negative coefficient. When it is blank, it indicates that the effects of that variable

Table 4.3 Multinomial Logit Model Results

Variables	Traveled in Past Seven Days				Did not Travel in Past Seven Days				Difference in the Effects of Variables on (3) and (4) Preferences	
	On Travel Day (1)		Not on Travel Day (2)		Prefer Going Out of Home (3)		Do Not Prefer Going Out of Home (4)			
	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.
Constant	-	-	-1.97	-65.19	-4.56	-48.18	-4.52	-48.90	-	-
Gender (Male is base)										
Female	-	-	0.28	12.80	0.16	4.03	0.16	4.03	-	-
Age (< =75 years is base)										
Middle Elderly (75–84 years)	-	-	0.06	2.41	0.11	1.96	0.42	7.12	0.32	4.07
Older Elderly (>= 85 years)	-	-	0.27	7.60	0.33	4.88	0.87	12.59	0.54	6.08
Race (White and Others are base)										
Black only	-	-	-	-	0.26	4.33	0.26	4.33	-	-
Driver Status (Driver is base)										
Non- Driver	-	-	0.68	19.35	0.95	15.16	1.34	21.13	0.39	5.08
Worker Status (Not worker is base)										
Worker	1.61	11.96	0.84	6.03	-	-	-	-	-	-
Education (High school graduate through higher degree)										
High School Graduate or Lower	-	-	0.22	9.82	0.37	7.09	0.50	9.43	0.13	1.86
Household Size (single elderly household is base)										
2 + elderly household (no other member)	-	-	-	-	-0.07	-1.30	-0.07	-1.30	-	-
1 other member household	-	-	0.19	7.19	0.50	8.79	0.50	8.79	-	-
2+ other member household	-	-	0.34	8.53	0.50	5.44	0.63	6.98	0.14	1.38
Household Income (>$25k is base)										
<$25k	-	-	0.19	8.03	0.31	6.02	0.24	4.73	-0.07	-1.02

Table 4.3 (Continued)

Variables	Traveled in Past Seven Days				Did Not Travel in Past Seven Days				Difference in the Effects of Variables on (3) and (4) Preferences	
	On Travel Day (1)		Not on Travel Day (2)		Prefer Going Out of Home (3)		Do Not Prefer Going Out of Home (4)			
	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.
Household Location (Urban/Rural)										
Urban	-	-	-	-	-0.09	-2.12	-0.09	-2.12	-	-
Number of HH Vehicle (2+ is base)										
0 vehicle	-	-	-	-	0.45	6.46	0.45	6.46	-	-
1 vehicle	-	-	-	-	0.09	1.65	0.17	3.02	0.08	1.14
Internet Use (Never is base)										
Almost Everyday	0.97	14.81	0.71	10.40	-	-	-	-	-	-
Sometimes	0.83	10.98	0.64	8.12	-	-	-	-	-	-
Medical Condition made travel difficult (No is base)										
Yes	-	-	0.59	21.67	1.43	22.32	0.50	7.32	-0.93	-10.35
Medical Condition results giving up driving (No is base)										
Yes	-	-	0.20	4.40	0.69	9.99	0.51	6.40	-0.18	-1.91
Log likelihood at convergence	44346.86									
Number of Cases	71261									

on the last two preferences are same. It is important to note here that there are two types of base variables in the model results. One is mentioned in parenthesis with the variable name in the first column of the table and another is indicated by the blank sign in the row against a variable. Variables in the model systems are different socio- demographic factors such as age, gender, race, education, driving and working status, number of household members, number of household vehicles, geographic location of the household (urban/rural), housing unit owned or rented, frequency of Internet use, household income, and different medical conditions related information of the elderly. These variables were selected based on the literature review and the judgment on what factors potentially could affect the elderly's mobility patterns and preferences.

The model estimates show that females are more likely to stay home compared to males, and this inclination increases with age. Age-related variable effects more specifically indicate that the elderly of age greater than 75 years are less likely to travel frequently compared to the young elderly of age 65 to 75 years. This pattern is more pronounced for the senior elderly of age greater than or equal to 85 years. Also, the positive coefficients in the last column against the age variables show the preferences of staying home of the individual's age greater than 75 and indicate that this preference increases with the age. This may be because the elderly women generally do not have sufficient funds to support their mobility due to lower earning and pensions in their late age when compared to males and, ultimately, some of them need to give up driving too early (Skinners and Stearns, 1999). The positive coefficient of the race-related variable indicates that the African Americans elderly are not likely to travel. Since people of color are more likely to use the walking mode and use public transit for their daily travel

(Rosenbloom, 1995; Rosenbloom and Waldorf, 2001), this result may be because their older age that is preventing them from walking and using public transit and ultimately forced them to reduce traveling. At the same time, it may also be due to lack of a special transit system in a minority-dominant area.

In addition, mobility of the elderly depends largely on the driving status of the individuals, especially in the areas where public transportation is not available. In this study, working and driving status of the elderly were found to significantly contribute to the elderly's mobility patterns and preferences. From the results, drivers and workers are more likely to travel frequently compared to non-drivers and non-workers. The positive parameter estimates in the last column against the driver variable show that non-drivers are more likely to stay home. In other words, they are not likely to go outside of home frequently. At the same time, the parameter estimates for the worker variable indicate that they are more likely to travel compared to non-workers. This may be because workers need to travel to their work place more frequently compared to their counterparts.

As expected, individuals with low education are less likely to travel frequently compared to their counterparts. It is hypothesized that education doesn't have different effects on the preferences of staying home and going out i.e. individuals with low and high education have the same preferences. But, the parameter estimate in the last column rejects the hypothesis and indicates that the higher the education level, the higher the desire for mobility. Besides this, number of members in households is likely to affect the travel preferences of the elderly. When only two or more elderly (no other member in the household) live in a household, they are more likely to travel compared to single elderly households because of having the companionship of a person of same mentality and

physical condition. On the other hand, when the elderly live with non-elderly in the same house, they are not likely to travel frequently because they tend to depend on the non-elderly person for their different needs such as shopping, social meeting etc. In other words, non-elderly persons are likely to do these things on behalf of the elderly persons in the household (Evans, 2001; Sommers and Rowell, 1992). From the results, it seems that the tendency to depend on non-elderly persons increases with the increase of the number of household members. This may be because the higher the number of non-elderly persons in the household, the more the options the elderly person has to rely on other members for their different needs instead of traveling outside. But the difference in the effects on the last two preferences is not statistically significant.

In addition, it was found that individuals living in low income households are less likely to travel frequently compared to their counterparts. The parameter in the last column for the income variable indicates that the preference of staying home increases with the increase in income. It appears that although income plays a role in the overall mobility patterns and preferences of the elderly, but when it comes to the preference of staying home, it does not dominate the individual's decision. But the difference as shown in the last column is not statistically significant.

The geographical location variable indicates that individuals living in urban areas are more likely to travel. This result may be due to the characteristics of the urban area because urban areas are characterized as residential areas with high density and of mixed land use where public transportation is available and enables older people to take their daily trips independently. The estimated results also show the difference in the effects of the number of household vehicles on the travel preferences of the elderly. Individuals

from zero and one vehicle households are less likely to travel compared to individuals from two or more vehicle households. Also, it appears that individuals living in households with one vehicle are less likely to stay home without making any trips compared to households with zero vehicles, but they do not travel as frequently as the elderly from households with two or more vehicles. Results related to income and the number of household vehicles indicates that individuals living in low income and zero vehicle households represent the "transportation disadvantaged".

The Internet use variable effects indicate that individuals who use the Internet almost every day or often in a week or month are more mobile than those who never use it. In other words, Internet use is positively associated with the mobility of older Americans. The elderly use the Internet generally for e-mail or for researching different topics such as health, investing, and entertainment. Ford et al. (2009) found that use of the Internet reduces depression among the elderly by 20 percent. The positive relationship of Internet use and being mobile in this model estimate indicates that the elderly who are using the Internet are more likely to be active and, hence, happy compared to their counterparts who never use Internet.

Medical condition-related information is important in travel-related research, especially when the elderly are considered. One might argue about the significant relationship between age and medical condition of the elderly, but the possibility of having different mental and physical conditions at the same age should not be ignored. In addition to the age of the elderly, medical information should be included in research to reflect the true effect of medical condition (Kim and Ulfarsson, 2004). In this study, as expected, it appears that medical condition affects the travel preferences of the elderly.

The significant positive co-efficient of the variable "giving up driving" indicates that the medical conditions results in giving up driving are positively associated with not traveling frequently. Interestingly, when the difference in the effects of medical condition-related variables on the last two preferences are considered, it is hypothesized that individuals with medical condition are more likely to stay home compared to go out. But, the significant negative co-efficient in the last column rejects the hypothesis and indicates that individuals with medical condition are more likely to go out. So, medical condition does not dominate the preferences of staying home when compared to the preferences of going out. In other words, it is the individual's preference or the effects of other factors that drive him/her towards the decision of staying home.

4.5 Mixed – Multinomial Logit Model

The mixed logit model is widely used for discrete choice modeling in transportation, economics, marketing, and many other fields because of its ability to capture the random taste variation, unrestricted substitution patterns, and the correlations in unobserved factors over time, which are the limitations of the standard logit model (Train, 2009). The mixed logit model offers high flexibility in terms of capturing correlations between the unobserved factors affecting choice alternatives. In this study, a mixed-multinomial logit (M-MNL) model is estimated to capture the correlations among the unobserved factors affecting the travel preferences of the elderly. The following subsections provide an overview of the mixed logit model methodology and briefly compare the estimated M-MNL results with the MNL results.

4.5.1 Error-Components Specification

As mentioned in subsection 4.3.1, the probability expression for standard MNL is:

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_{j \in C} e^{\beta' x_{nj}}}$$

where P_{ni} is the probability of choosing alternative i of the individual n.

The integral of this multinomial logit model probability expression over the density of parameters gives the probability expression for mixed logit model, as shown in the following equation:

$$L_{ni} = \int P_{ni}(\beta) f(\beta) d\beta \qquad (1)$$

where, $P_{ni}(\beta)$ is the logit probability evaluated at parameters β

$f(\beta)$ is a density function

Among the different ways of deriving the probability expression of the mixed logit model, random coefficients and error components based specifications are widely used. The error components specifications are used in this study to capture the correlations among the utilities for different alternatives. The utility equation is specified as:

$$U_{nj} = \alpha' x_{nj} + \mu' z_{nj} + \varepsilon_{nj}$$

where,

x_{nj} is the vector of observed variables relating to alternative j

α is a vector of fixed coefficients

μ is a vector of random terms with zero mean

z_{nj} and ε_{nj} are the error terms denoting the stochastic portion of utility

In short, the random part of the utility is $\eta_{nj} = \mu_n' z_{nj} + \varepsilon_{nj}$.

If $z_{nj} = 0$, the utility expression is converted into the standard logit model. If z_{nj} is not equal to zero i.e. if the utility is correlated over alternatives, then

$$Cov(\eta_{ni}, \eta_{nj}) = E(\mu_n' z_{ni} + \varepsilon_{ni})(\mu_n' z_{nj} + \varepsilon_{nj})$$

$$= z_{ni}' W z_{nj}$$

where,

W is the covariance of μ_n

In the mixed logit model with error components specifications, various correlations can be captured through the appropriate choice of variables as error components. For instance, a dummy variable was introduced in the model specification of this study that equals 1for the alternatives, among which there is a correlation and 0 for other alternatives.

4.5.2 Estimation and Evaluation

A simulation method is generally used for the mixed logit model estimation. As shown in equation (1), the probability expression for the mixed logit model is:

$$L_{ni} = \int P_{ni}(\beta) f(\beta) d\beta$$

where,

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_{j \in C} e^{\beta' x_{nj}}}$$

For the estimation, the researchers specify the functional form f(.) and estimate the mean and covariance of the error terms. In simulation, first, a value of β is drawn and then the

probability is calculated using that value in the logit formula. The same procedure is repeated many times, and the results are averaged. The average simulated probability is

$$L'_{ni} = \frac{1}{R}\sum_{r=1}^{R} P_{ni}(\beta^r)$$

where, R is the number of draws

L'_{ni} is the unbiased estimator of L_{ni}

β^r represents the serial draws

This simulated probability then is used in the log-likelihood function to obtain a simulated log-likelihood (SLL), as shown in the following equation:

$$SLL = \sum_{n=1}^{N}\sum_{j=1}^{J} d_{nj} \ln L'_{nj}$$

where,

d_{nj} = 1 if n chooses j and zero otherwise.

Then, the model with the best specifications is chosen based on the parameter estimate of the covariance.

4.6 Mixed – Multinomial Logit Model Results

This section presents the results of the Mixed-Multinomial Logit Model. Table 4.4 shows the parameter estimates and corresponding t-statistics for all four alternatives used in the Multinomial Logit model. The last column in the table presents the difference in the effects of variables on 3rd and 4th alternatives. More specifically, the parameter estimates and the corresponding t-statistics in the last column show the existence of two groups with different travel preferences within the elderly. The main objective of this

model estimation is to capture the correlation among the unobserved factors affecting the different travel preferences of the elderly. In this model, different types of correlations were explored, and only the specification that induced correlations in a parsimonious fashion is presented in this section. This specification captures the correlations between the unobserved factors affecting the last two travel preferences of the elderly.

The assumption that there is no correlation in utility over the alternatives gives the IIA property to the MNL model. Such assumption may result in distorted estimates of the influence of various factors on the travel preferences of the elderly. This can be observed by comparing the two model estimates as shown in Table 4.3 and Table 4.4. The significant coefficient of the standard deviation presented in Table 4.4 represents the level of correlation between the last two travel preferences, which is non-negligible. In addition, after capturing the correlations between the last two travel preferences, some significant changes are found in the t-statistics and parameter estimates of the variables in the M-MNL model results, although the overall effects remain same. Among these, the t-stats of the constants (represent the average effects of all unaccounted factors) for the last two travel preferences reduce greatly from the MNL (-48.18 & -48.90) to M-MNL model (-7.22 & -7.17). On the other hand, the parameter estimates of these constants increase from the MNL model to M-MNL model. The patterns are similar for the gender-, age-, and race-related variables, although the reductions of t-stats for these variables are not that high like constants of the M-MNL model. The new parameter estimates of these variables for the last two travel preferences in the M-MNL model indicates the higher preferences of staying home compared to the preferences found in the MNL model. But the relative differences in the effects of these variables on the last two alternatives,

Table 4.4 Mixed -Multinomial Logit Model Results

Variables	Traveled in Past Seven Days				Did not Travel in Past Seven Days				Difference in the Effects of Variables on (3) and (4) Preferences	
	On Travel Day (1)		Not on Travel Day (2)		Prefer Going Out of Home (3)		Do Not Prefer Going out of Home (4)			
	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.
Constant	-	-	-1.97	-64.93	-6.63	-7.22	-6.57	-7.17	-	-
Gender (Male is base)										
Female	-	-	0.28	12.70	0.21	3.55	0.21	3.55	-	-
Age(< =75 years is base)										
Middle Elderly (75–84 years)	-	-	0.06	2.36	0.22	2.48	0.51	5.96	0.30	3.79
Older Elderly (>= 85 years)	-	-	0.26	7.47	0.60	4.16	1.11	7.82	0.51	5.70
Race (White and Others are base)										
Black only	-	-	-	-	0.42	3.81	0.42	3.81	-	-
Driver Status (Driver is base)										
Non- Driver	-	-	0.68	19.36	1.41	6.45	1.73	7.89	0.32	4.05
Worker Status (Not worker is base)										
Worker	1.88	7.94	1.11	4.61	-	-	-	-	-	-
Education (High school graduate through higher degree)										
High School Graduate or Lower	-	-	0.22	9.72	0.53	5.27	0.66	6.61	0.13	1.76
Household Size (single elderly household is base)										
2 + elderly household (no other member)	-	-	-	-	-0.09	-1.21	-0.09	-1.21	-	-
1 other member household	-	-	0.18	7.04	0.70	5.65	0.70	5.65	-	-
2+ other member household	-	-	0.34	8.51	0.69	4.44	0.84	5.37	0.14	1.42
Household Income (>$25k is base)										
<$25k	-	-	0.18	7.90	0.42	5.18	0.35	4.36	-0.07	-1.03

Table 4.4 (Continued)

Variables	Traveled in Past Seven Days				Did not Travel in Past Seven Days				Difference in the Effects of Variables on (3) and (4) Preferences	
	On Travel Day (1)		Not on Travel Day (2)		Prefer Going Out of Home (3)		Do Not Prefer Going Out of Home (4)			
	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.	Par.	t-stat.
Household Location (Urban/Rural)										
Urban	-	-	-	-	-0.12	-2.01	-0.12	-2.01	-	-
Number of HH Vehicle (2+ is base)										
0 vehicle	-	-	-	-	0.70	4.59	0.70	4.59	-	-
1 vehicle	-	-	-	-	0.14	1.83	0.22	2.81	0.08	1.17
Internet Use (Never is base)										
Almost Every day	1.24	7.30	0.98	5.72	-	-	-	-	-	-
Sometimes	1.10	6.60	0.91	5.41	-	-	-	-	-	-
Medical Condition made travel difficult (No is base)										
Yes	-	-	0.59	21.68	1.74	10.08	0.81	4.65	-0.93	-10.27
Medical Condition results giving up driving (No is base)										
Yes	-	-	0.19	4.06	1.01	6.11	0.91	5.31	-0.10	-1.05
Standard Deviation	-	-	-	-	2.16	3.76	2.16	3.76	-	-
Log likelihood at convergence	44322.20									
Number of Cases	71261									

those who prefer going out of home and those who do not prefer going out of home, are almost same between the two models.

The effects (estimated in the M-MNL model) of the driver status variable indicates that the true preference of staying home among the non-drivers is higher than the preference estimated in the MNL model. The t-statistics also decrease in the M-MNL model after accounting for correlations between the unobserved factors of the last two alternatives. The parameter estimates of the worker, household location, and Internet use variables also indicate the higher tendency to travel than the tendency estimated in the MNL model. In the same way, for other variables in the model, it is found that the true effects (estimated in M-MNL model) are higher than the effects estimated in the MNL model without considering the correlations between the unobserved factors of the alternatives. Interestingly, the relative differences in the effects of variables on the last two preferences are almost same as estimated in the MNL model, except the last variable, which indicates whether the medical condition resulted in the person giving up driving or not. For this variable, the parameter estimates of the differences (-0.10) slightly decrease as compared to the MNL model (-0.18), although the patterns of overall effects on the alternatives remain the same.

In short, the M-MNL model explores the true effects of the variables on the travel preferences, and ignoring them may lead to poor model fit and biased estimates of variable coefficients. In the current empirical context, the log-likelihood value deteriorates from -44,322 (M-MNL) to -44,347 (MNL) when the correlations between the unobserved factors affecting the last two alternatives are not considered. This log-likelihood difference is equivalent to a log-likelihood ratio 50 , which is greater than the

95% critical chi-square value for 2 degrees of freedom (mean and standard deviation parameters), indicating the superiority of the M-MNL model.

4.7 Conclusion

This chapter employs a multinomial logit model and a mixed-multinomial logit model to explore the mobility patterns and preferences of the elderly. Although mobility patterns of the elderly were considered in some of the earlier studies, these were limited to only one-day travel period data – in other words, whether the elderly made at least one trip on the travel day or not were considered in those studies; long term (such as a week) mobility preferences were ignored in those studies. This study addresses two long term mobility preferences of the elderly – (1) prefer going out of home more often, and (2) do not prefer going out of home more often – using 2009 NHTS data.

The multinomial logit model results identify the factors affecting the overall mobility patterns and preferences of the elderly. Some of the important factors, such as medical condition, household income, and household vehicle ownership, were ignored or found insignificant in the models used in earlier studies (based on one-day travel period data) to analyze the mobility patterns of the elderly. When these factors are considered in this study along with long term mobility preferences, they are found to affect significantly the overall mobility patterns of the elderly. In addition, some contradictory results such as mobility appear reduced in urban areas, opposite to the conventional wisdom found in earlier studies based on one-day travel period data. In this study, urban areas are found to increase the mobility of the elderly, which is more intuitive.

These model estimation results also distinguish the effects of different factors on the mobility preferences of the elderly. Several important findings were obtained from

this analysis. For example, female elderly are more likely to stay home compared to male, and this propensity increases with the age of older adults. The composition of elderly households, especially the presence of another elderly person in the same household, was found to affect the travel behavior of the elderly. When two or more elderly (no other member) live in a household, they are more likely to travel compared to single elderly households because of having the company of a person of the same mentality and physical condition. In addition, household income and medical condition of the elderly does not dominate the individual's preference to stay home. In other words, low income and medical condition are not the driving factors on the preferences of staying home when compared to the preferences of going out. It is the individual's own preference or the effects of other factors that compel them to stay home.

These results provide some ideas related to the question, "Is the observed decrease in mobility among the elderly an autonomous choice – or is it the result of reduced physical abilities or of increasing psychological and social needs?"(Mollenkopf, 1997) that planners and policy makers might have about the elderly mobility issue. Moreover, the results identify the individuals who are inactive and at risk for social isolation. Necessary steps should be taken to make them active and mobile because isolation can affect the quality of life.

The mixed-multinomial logit model results capture the correlation between the unobserved factors affecting the travel preferences of the elderly. In short, it explores the true effects of the variables on travel preferences after capturing correlation; ignoring this may lead to poor model fit and biased estimates of variable coefficients. From the results, it seems that the true effects of the variables give the same pictures of elderly travel

behavior obtained from the multinomial-logit model results. In short, these model estimates provide a clear idea about the different travel preferences of the elderly and distinguish the factors that drive them towards these different travel preferences.

CHAPTER 5

CONCLUSIONS AND FUTURE RESEARCH

5.1 Conclusions

This thesis used the recently-released 2009 NHTS to analyze the travel patterns and preferences of the elderly, persons age 65 or older. The four types of travel choices considered in this thesis are traveling frequently (traveled on the travel day), traveling less frequently (traveled in the travel week but not on the travel day), prefer going out of home more often (did not travel in the travel week but want to go outside of home more often), and prefer to stay home (did not travel in the travel week and do not want to go outside of home more often). In other words, this study considers both the short term (less than a week) and long term (more than a week) immobility among older Americans. Also, the last two choices indicate the inherent travel preferences of the elderly, which were not considered in earlier studies. The earlier studies were limited to only one-day travel decisions of the elderly, and their mobility was defined based on whether they made at least one trip on the travel day or not. It was recognized that the limitation of one-day travel period data may restrict the reliability of the final outcome. The results obtained from this thesis after considering long term mobility provide greater insight into elderly travel behavior and contribute to the literature.

The detailed descriptive analysis provided in this thesis shows the difference in the trip characteristics of the elderly and non-elderly. An interesting observation is the variation in the trip characteristics of the female elderly. In the children and young adults groups, females were found to make more average daily trips compared to male, but in the older adult groups, the situation is the opposite: average daily person trips are higher for males compared to females. In addition, females are more likely to make short distance trips, and this pattern is the same among the working population. Also, the elderly are more likely to depend on the POV for their daily travel, but a substantial number of them are non-drivers.

Proper measures should be taken to keep the elderly active. For instance, special transportation service for the elderly should be designed and provided in such a way as to reduce their dependency on the POV. This would also reduce the frustration among older adults that develops from giving up driving. In addition, older adults are found to make more trips for shopping purposes, and the older elderly have the lowest trip rate (0.48) for social and recreational purposes among all age cohorts. Appropriate measures should be taken to increase the social/recreational trips of the older elderly because social activities involving mobility reduce mortality in older people (Glass et al., 1999).

One of the important questions in elderly-related policy is, "How can we meet the special transportation needs of the elderly?" Since the elderly are not homogeneous in mobility patterns, it is essential to understand the travel behavior of the different groups of elderly to get the answer to this question. In this thesis, the elderly are divided into three groups – young elderly (age 65 –74 years), middle elderly (age 75 – 84 years), and older elderly (age $\geq$ 85 years) – to identify the variations in the travel patterns of older

Americans. The descriptive analysis provided in this thesis shows that the difference between the average daily person trips of males and females increase with age. In addition, female older adults are found to travel shorter distance compared to male. This gender variation should be carefully considered in elderly travel behavior. Young elderly living in zero vehicle households are more likely to walk than use a POV for their daily travel. The tendency to use public transit and walk appears to decrease with age. This pattern is observed even among older adults from zero vehicle households. In addition, it was found that older elderly living in zero vehicles and low income (<$25 K) households are the most "transportation disadvantaged" group in the total population. The variation in trip start time of the different groups of older adults found in this study can help transportation planners and policy makers to develop appropriate strategies for the elderly. It would also help special transportation providers to meet the special transportation needs of the different groups of elderly at a particular time of the day. In short, understanding the different needs of these sub-groups among the elderly will help transportation planners and policy makers identify the services and facilities suitable for these heterogeneous groups.

The travel preferences of the elderly were examined through a multinomial logit model framework that provides insights into the effects of different factors on the inherent travel preferences of the elderly. Several important findings were obtained from this analysis. For example, female elderly are more likely to stay home compared to males, and this propensity increases with age. The composition of elderly households, especially the presence of another elderly in the same household, was found to affect the travel behavior of the elderly. When only two or more elderly persons (no other member)

live in a household, they are more likely to travel compared to single elderly households because of having the company of a person of the same mentality and physical condition. Household income and medical condition of the elderly do not dominate the individual's preference to stay home. In other words, low income and medical condition are not the driving factors of the preference to stay home when compared to the preference to go out. It is the individual's own preference or the effects of other factors that compel them to stay home.

Moreover, mixed-multinomial logit model results show the presence of the correlation between the unobserved factors affecting the travel preferences of the elderly and thus illustrated the necessity of considering such relationships through the appropriate modeling effort while analyzing the travel patterns and preferences of the elderly. In addition, this model result explores the true effects of the variables on the travel preferences of older adults after capturing the correlations between the unobserved factors.

Overall, this study summarizes the travel patterns and preferences of the elderly, which can help transportation planners and policy makers to develop or improve the planning and policy related to elderly mobility issues. The general idea for the decrease in mobility among the elderly is a limited or ineffective transportation system. This study showed the existence of different travel preferences among the long term immobile elderly. Some of them prefer going out of the home often, but certain constraints do not allow them to do so, while some of them prefer staying home, which may affect their overall travel decision. If this is case, necessary steps should be taken to increase the mobility of these individuals who are at risk for social isolation because isolation can

affect their quality of life. Transportation planners and policy makers must take into consideration the existence of different travel preferences among the elderly to accommodate their mobility needs, including planning for various special transportation services. However, several cautions should be exercised before directly using the results obtained from descriptive analysis and model estimates. The elderly might have several other characteristics that are not considered in this study. For example, past travel behavior of the elderly are not considered in this study. In addition, the Federal Highway Administration has decided to enhance the weights of the 2009 NHTS and so, these results may change with the new weights. In short, results obtained from this study should be used with caution. The next section provides some scopes for future research.

5.2 Future Research

This thesis analyzed the travel patterns and preferences of the elderly using 2009 NHTS cross sectional data. However, travel patterns and preferences change over time. The analysis could be carried out using a panel dataset to get better insights into elderly travel patterns and preferences. Besides this, the discrete choice components of travel choices used in this study could be modeled in a nested structure. Accessibility to preferable transportation is closely related to mobility, which is not considered in this study due to the limitations of the dataset. This could be addressed in future research for potential policy implications. Since the elderly are not homogeneous in nature, thorough research could be undertaken to address the diverse needs of the heterogeneous older population that can ensure older Americans the five A's of transportation: availability, accessibility, acceptability, affordability, and adaptability.

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