Immobility Levels and Mobility Preferences among Elderly in the United States: Evidence from the 2009 National Household Travel Survey (NHTS)

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ABSTRACT

Transportation mobility is critically important to the well-being of the elderly population. Using data from the 2009 National Household Travel Survey, this paper proposes a metric to measure immobility among elderly over different time frames. Specifically, short-term immobility is defined as immobility over a single day, while long-term immobility refers to immobility over a week, and medium-term immobility lies in between. In addition, long-term immobile elderly are divided into two mobility-preference groups based on whether they prefer going out of home or not. Using this immobility metric, and respondent-stated mobility preferences, descriptive analysis and discrete choice models are used to analyze the correlates of immobility among American elderly. African American elderly are found to be more likely to be long-term immobile compared to those from other racial groups. Such racial differences are not readily apparent in immobility over shorter time frames. This result explains why most previous studies did not find any racial differences in elderly mobility - due to shorter time frames of analysis. Presence of another elderly companion in the household is found to have a significant positive influence on a persons' mobility. Medical conditions may impose physical constraints on the ability to travel but do not seem to curb the desire for mobility among elderly. However, inability to drive is associated with a strong preference against going out of home, suggesting that auto-centric land-use transportation system can potentially curb the desire of non-driving elderly to travel out of home.

1 INTRODUCTION

Over the next few decades, the elderly population in the United States (US) is expected to increase significantly. The US Census Bureau estimates that over 40 Million residents in the US (13% of the population) were over 65 years of age in 2010. This number is projected to increase rapidly over the next few decades, to a 72 Million in 2030 and a whopping 88.5 Million in 2050. As a result, at any time between 2030 and 2050, one in five Americans will be over 65.

The rapid aging of the US population is largely because of the aging of a large population cohort – the baby boomers. This group of elderly is expected to be different from today's elderly in several ways. Their mobility expectations are likely to be higher than that of the current elderly (*1, 2*). At the same time, however, elderly population is generally at a high risk of being mobility disadvantaged. Physical and cognitive limitations, combined with financial constrains and lack of familial support contribute to a decline in mobility among elderly. Literature (*3*) suggests that those who maintained higher mobility previously are likely to suffer the most due to reduced mobility during their old age. This is because of the difficulty in continuing their previous lifestyles (*4*). Therefore, the aging of the baby boomer population will pose new challenges for mobility policy and planning in the coming decades.

As individuals transition into old age, sustaining their transportation mobility is important to sustaining the quality of their lives. Mobility is important not only for satisfying the basic life-sustenance needs such as nourishment, livelihood and medical care, but also for higher-order needs such as social interaction and recreation that contribute to their well-being (*5*). On the other hand, immobility among elderly is a cause of decline in their physical and mental health. Further, immobility subjects them to social isolation, which can in turn affect their mental/physical health.

Mobility is a broadly encompassing concept. As one can note from the third column of Table 1, different studies *(1, 4, 7, 8 & 9)* use different definitions and metrics to measure mobility. Most of these metrics measure mobility based on the extent of activity participation and/or the extent of travel. While such mobility metrics offer useful insights into the different dimensions of mobility, they do not shed explicit light on the extent of **im**mobility among elderly. Although enhancing mobility is an important policy goal, decreasing **im**mobility (i.e., enabling mobility) is at least as important as, but not necessarily the same as, enhancing mobility. It is the immobile individuals who are perhaps at a high risk of social isolation and physical/mental health deterioration. Thus a metric to measure immobility can potentially offer complementary policy insights (to mobility metrics) by identifying the immobile segments in the population. In this direction, Giuliano (*10*) and Evans (*11*) measure immobility based on whether a person traveled out of home (or not) on a given day. However, as Evans (*11*) notes, a disadvantage of these two studies is that "*one–day travel period may limit the reliability of the measure of the mobility".* While a one day-based definition and metric provides some insight into the short-term immobility levels, it doesn't provide any insight on immobility levels over longer time periods (such as a week or longer). Long-term immobility is perhaps a more severe issue than short-term immobility. Further, it is possible that while short-term immobility levels appear to be similar among different socio-demographic segments, long-term immobility levels may differ. Thus, it is important to identify and distinguish the correlates of different levels of immobility among elderly.

The literature abounds with studies that investigate the correlates of mobility levels among elderly. The most common finding of all these studies is that mobility decreases with age. Other common findings include a positive association of mobility levels with better education

and higher income levels (*e.g. 11, 12, & 16*). In the context of gender, depending on the metric used to measure mobility, different studies report different results. For example, when the number of daily person trips is used as a metric, females are generally found to be more mobile compared to males (*12, 13, 14;* with exception *15*). On the other hand, using a travel distance measure suggests that males travel more than females (*11, 16).* In the context of race, it is interesting to note that most previous studies did not find any racial differences in mobility levels among elderly. Only one study (that considers mobility over a time frame of 4 weeks) suggests that African American elderly are likely to be less mobile than whites (*17*). Some studies report that the level of familial support and assistance for the travel needs of an elderly household member varies with race and ethnicity.

Notwithstanding the above discussed variables - age, education, income, gender, and race - not many studies appear to have investigated the influence of other factors such as household structure on mobility among elderly. It is also worth noting here that almost all findings in the literature are based on mobility metrics for short time periods such as one day.

Another relevant issue is the mobility-related preferences of the elderly. Literature suggests that mobility changes occur among the elderly as they age (*18*) due to physical, cognitive, financial and other limitations. In addition to all these factors, personal preferences and attitudes may also govern the mobility characteristics of individuals. For example, an individual who prefers an active and social lifestyle may often go out of home and engage in different activities, while another individual may simply prefer to stay at home. Efforts to improve mobility and the quality of life of elderly should be cognizant of such mobility preferences in the population. For instance, measures to enhance mobility among those who are intrinsically less inclined to travel may be less effective.

In view of the above discussion, we propose a metric to measure travel immobility among elderly based on the number of days a person does not travel out of home. More specifically, we define an immobility scale where short-term immobility is defined as the immobility over a single day while long-term immobility refers to the immobility over a week or longer. Between these two extremes, i.e. immobility between two to seven days is described as the medium-term immobility. The proposed immobility scale/metric overcomes the limitation of previous mobility (or immobility) metrics based on short time frames such as a day. Measuring immobility over longer time frames offers the ability to identify population segments subject to different levels of immobility among elderly.

The 2009 NHTS data is used to develop this immobility metric/scale. As part of the survey, the travel information from each respondent from each surveyed household was collected on a randomly assigned travel day. Besides, some new mobility-related questions have been included in the survey questionnaire, which provides a unique opportunity to distinguish different levels of immobility among elderly. One of the questions asked to elicit this information was "*Where did you go first on travel day*?" If the response to this question was "*Nowhere" or "Don't know"*, the respondent was asked the following to conform if he/she did not travel on the travel day: "*Does this mean you stayed at the same place/home all day?*" If the respondent answered "*Yes"* to this question, the next question was "*About how long ago before the travel day did you take a trip to another address*?" The answer to this question was elicited in terms of the number of days/weeks/months before the travel day the respondents did not travel to another address. If a respondent indicated more than a week of immobility (or no travel), (s)he was asked "*Would you like to get out more often?*" Thus, although the 2009 NHTS is a one-day travel survey, these questions elicit information on the (im)mobility levels of the respondents for

longer time periods. Further, the last question just discussed provides information on the mobility-related preferences (i.e. preferences of going out/staying at home) of those who did not travel for more than a week. We use all this information to define the (im)mobility scale discussed earlier. Specifically, we first divide the elderly population into mobile and immobile segments based on whether they traveled on the day (or not), and then divide the immobile segment into short-, medium-, and long-term immobile categories based on the number of days they did not travel. We further divide the long-term immobile elderly into two categories based on their mobility preference – those who prefer going out and those who do not. Using this immobility scale and the stated mobility preferences, we analyze the socio-demographic and land-use influences on immobility over different time frames and the mobility-related preferences among the American elderly.

Admittedly, the immobility scale we define takes into consideration only out of home travel. Thus it does not explicitly encompass other aspects related to mobility such as in-home mobility, physical activity, socialization and leisure activity engagement. Nonetheless, out-of-home travel is in itself an important dimension of mobility.

The next section provides an overview of the 2009 NHTS data set followed by a description of the sample and population characteristics with a special focus on the elderly. Section 3 presents a descriptive analysis to identify the socio-demographic segments that are subject to different levels of immobility. Section 4 utilizes discrete choice models to analyze the socio-demographic and land-use influences on the immobility levels and mobility preferences among elderly. Section 5 concludes the paper.

2 DATA

The data used in this study comes from the 2009 National Household Travel Survey (NHTS) conducted during 2008-2009 in the United States. The data includes a substantial sample of 86,112 elderly persons from 62,405 households representing an elderly population of 38.9 Million individuals from 33.8 Million households. Such a large sample size allows a unique opportunity to conduct meaningful and reliable statistical analysis of elderly mobility issues.

Note that the NHTS represents only the civilian, non-institutionalized population of the US. As such, the data doesn't include people living in institutional settings such as nursing homes, medical institutions, and living quarters. However, per the statistical records of the Administration on Aging (AOA) of the US Department of Health and Human Services, a relatively small portion (1.6 Million) of the 65+ population lived in such institutionalized settings in 2009. This suggests that NHTS represents a vast majority of the elderly population in the US.

2.1 Descriptive Analysis: Socio-Demographic Characteristics

All descriptive statistics are based on weighted analysis so that inferences pertain to the population rather than only the sample.

2.1.1 Household Characteristics

Table 2 presents key descriptive information pertaining to the socio-demographic characteristics of the households and individuals in the US. The first part of the table (i.e., the first set of rows) presents household-level information while the second part presents person-level information. The 2nd column in the table presents information for the entire US population based all the NHTS households, while the 3rd column presents data for households with at least one elderly member

(age 65+). The 4th column contains information from the 2009 American Community Survey (ACS), which is used to assess the representativeness of the NHTS elderly sample. Note, however, that the ACS represents households with an elderly householder, while the elderly households in the NHTS are those who have an elderly member, regardless of whether s/he is a householder or not. Besides, ACS includes people living in group quarters such as institutional settings. Thus this may not be an exact apples-to-apples comparison. Nonetheless, the comparison may give a rough idea on the representativeness of the NHTS elderly households' sample.

Within the first set of rows, it can be observed from the row labeled "Weighted households" and the 2009 NHTS columns that out of all the 113.1 Million households in the US, 29.9% have at least one elderly member in the household. That is 3 out of 10 households (or a little less than one-third of all households) in the US are elderly households. The ACS data, on the other hand, shows that 24.1 million households (21.3% of all households) have an elderly householder. Despite the differences between the NHTS and ACS (due to the differences in how an elderly household is defined), these statistics highlight the significant presence of the elderly households in the US and have far-reaching implications for mobility planning in the nation.

The first demographic characteristic in the table is household size. One can observe significantly higher proportions of single-person and two-person households among households with elderly than those in the general population. In fact, 84% the elderly households fall into this category – 41.5% single-person households and 42.5% two-person households. Clearly, as documented in several earlier studies, a significant portion of the elderly is living alone. If not living alone, a vast majority of them are living in two-person households – a factor that may have bearing to addressing the mobility needs of the elderly.

40.8% of elderly households fall in the lower income ($25K/annum) category, as opposed to only about a quarter of all households in the general population. Such low income levels may, in part, affect the ability of elderly to own mobility tools such as automobiles. This trend can be observed from the rows under "Vehicle ownership". A larger share of elderly households are either car-less or own only one vehicle compared to those in the general population. In the context of residential location, a slightly larger percentage of elderly households live in urban areas than those in the general population. Finally, the distributions of household size, income, car ownership, and residential area type between the NHTS elderly households and the ACS elderly households appear to be in reasonable agreement. This provides confidence in using the NHTS elderly household sample for further analysis.

2.1.2 Person Characteristics

Let us now turn to person characteristics data in the second part of Table 2. The NHTS data of 308,901 persons represents a national household population of about 283 Million, of which about 38.9 Million are elderly (aged 65 or above). The ACS shows a slightly higher number of 39.5 Million for the elderly population.

The gender-related statistics in the second and third columns echo the finding from many other data sources that the elderly population in the US comprises more females than males. The ACS also shows similar gender distribution of the elderly population. In terms of age, the elderly segment is divided into three typically defined categories: (1) young elderly (age 65-74), (2) middle elderly (age 75-84), and (3) older elderly (age 85 and above). It can be observed that the percentage distributions of age categories between the NHTS elderly and the ACS elderly are in

reasonable agreement. Further, a considerable, 11.5 percent of the elderly population belongs to "older elderly" category who are likely to face the highest risk of immobility.

In the context of race, both the NHTS and ACS data indicate that whites comprise a larger percentage of the elderly population than that in the general population. However, there are some differences in the racial composition between the NHTS and ACS data sources. Specifically, it appears that the African American elderly are slightly over represented in the NHTS, when compared to the ACS data. In terms of employment status, as expected, the percentage of non-workers among the elderly (in both the NHTS and ACS data) is significantly higher than that in the general population, although the NHTS data appears to over represent working elderly when compared to the ACS. In addition, elderly appear to be less educated in general than non-elderly, with about half of the elderly population at a high school or lower level of educational attainment (albeit the minor differences in between the NHTS and ACS numbers). In the context of driving status, consistent with the expectations, the percentage of non-drivers among the elderly is higher than that in the general population. This has important implications to elderly mobility because the elderly in the US are known to depend primarily on the private car for travel (*19*).

In summary, this discussion highlights the differences in the socio-demographic characteristics between the elderly population and the general population in the US. Also, other than the differences noted above in the context of race, education and working status, the NHTS elderly sample appears to be reasonably representative of the American elderly population.

3 IMMOBILITY LEVELS AND MOBILITY PREFERENCES AMONG ELDERLY: DESCRIPTIVE ANALYSIS

Table 3 presents the descriptive information on the different levels of immobility among elderly in the data. Note form the first and second rows that the entire sample of 86,112 elderly individuals from the NHTS is divided into different categories based on the number of days they did not travel out of home. Those who traveled on the travel day are categorized as mobile individuals (2nd column), while those who did not travel on the travel day are categorized as immobile individuals (3rd to 6th columns). Those who did not respond to the mobility related questions are in the last column labeled "mobility information missing". Within the immobile segment (columns 3-6), the sample is further divided into different levels of immobility depending on the number of days they were immobile. Specifically, those who did not travel for a day (i.e., on the travel day) are labeled short-term immobile, those who did not travel for 2-3 days and those who did not travel for 4-7 days (including the travel day) are labeled medium-term immobile, and those who did not travel for more than a week are called long-term immobile. Recall from earlier discussion that the long-term immobile individuals were further categorized into two mobility preference categories: (1) Prefer going out, and (2) Do not prefer going out. Thus, within the long-term immobile column, along with the percentage of the long-term immobile, the percentages of mobility preferences are provided in the parenthesis.

Note from the second row of the table that 73.4% of the elderly population in the US was mobile (i.e., traveled to another address out of home) on the travel day, while close to a quarter of the population (24.6%, to be precise) was immobile. Further, only 7.2% of the elderly population was short-term immobile in that they did not travel out of home for only one day, where as a significant 17% of the elderly population (i.e., 70.3% of the immobile elderly) was immobile for at least two days. Specifically, 5.7% of the elderly population was immobile for 2-3days, 4.9% was immobile for 4-7days, and 6.8% was immobile for more than a week. It is well

noted in the literature that immobile population is at a higher risk of social isolation and psychological and physiological disorders (*9*). Such risks are likely to increase with the length of the period (i.e., the level) of immobility. Therefore, it is important to identify and distinguish the correlates of different levels immobility levels among elderly. To this end, Table 3 presents the population distributions of the socio-demographic characteristics across the different immobility categories.

The gender related distributions in the table show higher percentages of females (than males) in all immobile categories (short-, medium-, and long-term), suggesting higher incidence of immobility in females than in males. In addition, the differences between the percentages of female and male immobile appear to increase with the level of immobility. Along the same lines, immobility appears to increase with age. In the context of race, African Americans and other racial groups appear to be more immobile than Whites. People with lower level of educational attainment, those who are not in the labor force, or those who are not licensed to drive appear to the more immobile than those with higher educational attainment, in the work force, or those who are licensed to drive. Individuals from lower income groups and car-less households also show higher levels of immobility. All these descriptive statistics indicate the possibility of various socio-demographic differences across different immobility levels among elderly. However, since many of the above discussed socio-demographic factors are likely correlated with each other, univariate descriptive statistics cannot provide conclusive evidence on which factors influence immobility and which do not. Besides, it is difficult to decipher if a certain factor has differential influence across different levels of immobility (e.g., it is possible that racial differences may exist in longer-term immobility while not readily apparent in shorter-term immobility). Thus, in the next section, we undertake a more thorough, multivariate analysis to isolate the influence of each of the above discussed (and several other) factors on the immobility levels among elderly.

4 DISCRETE CHOICE ANALYSIS OF IMMOBILITY LEVELS AND MOBILITY PREFERENCES AMONG ELDERLY

In this study, a binary logit (BL) and a mixed-multinomial logit (MMNL) model were estimated to analyze the immobility levels and mobility preferences among elderly population in the US.

The BL model is similar to previous efforts (*10*, *11*) in that those who traveled on the travel day (2nd column in table 3) were considered as mobile and those who did not travel on the travel day (3rd to 6th columns in table 3) were all pooled into an immobile category without distinguishing the different levels of immobility. The MMNL model, on the other hand, distinguishes the immobile population into different categories (short-, medium-, and long-term immobile), as well as divides the long-term immobile segment further into the two mobility preference categories – (1) prefer going out of home and (2) do not prefer going out. The MMNL is used primarily to make the inferences on the socio-demographic and land-use impacts on different immobility levels and mobility preferences, while the BL is compared with the MMNL to assess the importance of distinguishing the different levels of immobility.

Table 4 presents the model estimation results. Column 2 contains the BL results with the mobile category specified as the base category, while columns 3 to 9 contain the MMNL results. Column 9 reports the differences in the variable effects (coefficients) on the two mobility preferences (prefer going out/do not prefer going out) for the long-term immobile individuals. This is used to infer the variable effects on mobility preferences.

4.1 Model Estimation Results and Discussion

The MMNL coefficients pertaining to the female variable indicate that female elderly are likely to be more immobile compared to males. This is in contrast to the findings from previous studies that use number of trips as a measure of mobility. In other words, although female elderly may be making more trips per day than males if at all they travel, a significant portion of female elderly population appears to be more immobile (i.e., do not travel at all) than male elderly. Age-related coefficients suggest, as expected, that immobility increases with age and that the preference to stay at home (rather than going out) increases with age.

The MMNL coefficients on the race variables indicate that the African American elderly are more likely to be long-term immobile compared to those from other races. This may be because African Americans are typically captivated to walking and public transit modes for their travel (*20*), but their old age prevents them from using those physically active modes, ultimately forcing them to reduce travel. It is also possible that public transit and special transit services may not be well available in a minority residential area, or the surrounding land-use in minority neighborhoods may not be conducive to walking. This result may also be due to racial differences in the familial support for facilitating travel by elderly.

While racial differences are found to exist in the immobility levels over the long-term, they are not readily apparent in immobility over shorter time frames such as a day. This result explains why most previous studies did not find any racial differences in elderly mobility - due to shorter time frames of analysis such as a day. For instance, the BL model we estimated (which considers only a day as a time frame) also did not yield any significant racial differences in the mobility levels. This is due to pooling different levels of immobility into a single immobile category. The MMNL model, on the other hand, reveals the racial differences in the long-term immobility levels, which are not readily apparent in the short- and medium-term immobility levels. This result highlights the need for analyzing immobility over different time frames.

Coefficients on the driving status, worker and education variables indicate that the elderly without a driving license, those who are unemployed, and those with less education are likely to be more immobile compared to their counterparts. These results echo the findings of other studies in literature (e.g.*11, 12, 15, & 16*). An interesting result is that the inability to drive is associated with a strong preference against going out of home. This may be because non-driving elderly may have limited other options to travel by other modes.

The coefficients of the household size variables suggest very interesting influences of household structure on elderly mobility. Specifically, the MMNL model results indicate that the elderly living in households with other elderly are likely to be the least immobile, while those living with non-elderly members are likely to be the most immobile, and those from single-person elderly households lie between these two extremes. A plausible reason is that the companionship of another elderly person(s) may in general enhance the quality of life and the desire to travel. On the other hand, elderly living with non-elderly members may be highly immobile due to them depending on the non-elderly persons for their daily needs such as groceries (hence avoiding the need for travel; see *11*). Note that the severity of immobility increases as the number of non-elderly members in the household increases. The elderly living alone lie between these two extremes (those who live with other elderly, and those who live with non-elderly) perhaps because some travel is necessary for them as they do not have others to depend on.

The income effects show, as expected, that the severity of immobility is higher among low income elderly than those with higher incomes. In the context of vehicle ownership, the

MMNL model suggests that elderly from car-less households are most likely to be long-term immobile, followed by those from one car households. The BL model, on the other hand, does not show any differences in the mobility levels of those living in one-car and those with 2 or more cars. Intuition suggests that the MMNL model implications are more realistic, as one can expect one-car households to be less mobile than those from multiple car households. For instance, those in multi-person households but with a single car may not really have access to the car.

The residential land-use effects indicate that the individuals living in urban areas and those in high density neighborhoods are less likely to be immobile, perhaps because urban areas and high density neighborhoods offer better access to activity opportunities and travel options such as walking and public transit. Evans (11) also reported similar results, although using a one day-based (im)mobility metric.

The last two variables pertain to medical condition of the elderly. As expected, if the medical condition either makes their travel difficult or results in them giving up driving, the severity of the immobility is likely to be high. Interestingly, when the difference in the mobility preferences is considered (for the long-term immobile), it is found that the elderly with medical condition are more likely to prefer going out rather than staying at home. This suggests that the medical conditions may not necessarily curb their mental desire to travel out of home, but simply impose physical constraints to travel.

In summary, the model estimation results are reasonable and offer interesting insights into the socio-demographic and land-use influences on the immobility levels and mobility preferences among elderly. While the MMNL offers richer insights by distinguishing the variable impacts on different levels of immobility and mobility preferences, the BL model falls short of doing so. These results highlight the importance of differentiating different levels of immobility.

5 SUMMARY AND CONCLUSIONS

The coming decades will see a rapid increase in the American elderly population. As individuals transition into old age, sustaining their transportation mobility is paramount to sustaining the quality of their lives. Most previous studies on this issue focus on analyzing the extent of mobility using metrics such as travel frequency/distance/time and participation in leisure activities such as socialization and physical activity. While each of these mobility metrics offers useful insights into different dimensions of mobility, none sheds explicit light on the extent of immobility. Although enhancing mobility is an important policy goal, decreasing **im**mobility (i.e., enabling mobility) is at least as important as, but not necessarily the same as, enhancing mobility. It is the immobile individuals who are perhaps at a high risk of social isolation and physical/mental health deterioration than the mobile individuals. Thus a metric to measure immobility can potentially offer complementary policy insights (to mobility metrics) by identifying the immobile segments in the population. Further, most literature is based on mobility measurement over rather short time frames such as a single day.

This paper proposes a metric to measure immobility among elderly based on the number of days a person does not travel out of home. This metric overcomes the limitation of previous studies that measure mobility (or immobility) based on short time frames such as a day. Measuring immobility over longer time frames offers the ability to identify population segments subject to different levels of immobility among elderly.

The empirical analysis is based on the 2009 NHTS data that provides a large, reasonably representative sample of the elderly population in the nation. Responses to a set of new mobility related questions are exploited to create an immobility scale based on the number of days a person did not travel out of home. Specifically, short-term immobility is defined as the immobility over a single day while long-term immobility refers to immobility over multiple days (more than a week). Further, long-term immobile elderly are divided into two mobility-preference groups based on whether they prefer going out of home or not. Using the proposed immobility scale and respondent-stated mobility preferences, a detailed descriptive analysis and discrete choice models (a binary logit and a mixed multinomial logit model) were used to analyze the socio-demographic and land-use influences on the extent of immobility among American elderly. Results from this analysis highlight the need for distinguishing different levels of immobility rather than pooling all those who did not travel on a survey day into a single immobile category, as typically done in previous studies.

Several important findings have surfaced from this analysis. These findings are quickly summarized here along with a brief discussion of relevant policy implications. First, racial differences exist in the long-term immobility levels while not readily apparent in the short-term immobility levels. Thus, considering mobility over shorter time frames (as has been done in previous studies) can lead to masking of racial differences in immobility. Specifically, African American elderly are more likely to be long-term immobile compared to those from other racial groups. This finding suggests that African American elderly population ought to be a group of particular policy interest because of its expected significant growth over the next few decades. Strategies such as provision of alternate options to travel (e.g., transit, paratransit, walk) in minority residential neighborhoods may help reduce immobility in this group.

Second, elderly living with other elderly are likely to be the least immobile individuals, while those living with non-elderly are likely to be most immobile, and those living alone lie between these two groups in the extent of their immobility. Further investigation of the activity and travel patterns and preferences of those elderly who live with non-elderly may help better understand if (and what) policy measures are needed for enabling their mobility.

Third, inability to drive is associated with a preference against going out of home, suggesting that an auto-centric land-use transportation system can potentially curb the desire of non-driving elderly to travel out of home. Transportation and land-use planners and policy makers should work together toward providing land-uses conducive to non-auto modes of travel in the elderly residential neighborhoods.

Fourth, medical conditions might cause severe immobility by imposing physical constraints to travel, but not necessarily curb individuals' desire to travel out of home. This finding provides clues to questions such as: "*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?*"(*6*). A policy implication is that specialized mobility services can potentially improve the welfare of those who are not able to travel due to medical conditions, since a desire to travel is likely to exist in them.

Overall, these results can potentially be used to identify specific demographic segments subject to severe immobility and formulate targeted policy measures to enable mobility among them. It is hoped that the profession starts paying closer attention to the issues of immobility over different time frames in addition to looking at the extent of mobility among elderly. This study also offers insights into the issue of mobility preferences. Analyzing preferences can help identify those who are more likely to respond to alternate policy measures.

Some limitations of the current study are in order here. First, the analysis reveals racial differences in immobility over the longer time frames. However, the reasons behind such differences are unknown. It would be useful to investigate the underlying reasons behind these differences (e.g., differences in familial support, differences in the available transportation services in the residential neighborhoods, etc.) for devising appropriate policy measures. Second, the analysis on mobility preferences does not shed light on the specific types of mobility options needed by the elderly (e.g., availability of a car to drive independently vs. a pre-arranged paratransit option or availability of a family member to give a ride). Third, it is important to recognize that the mobility needs of elderly are not necessarily restricted to pursuing only mandatory activities such as medical appointments. While enabling mobility for mandatory activities is essential, providing mobility options for discretionary activities such as socializing and recreation is important for enhancing the quality of life among elderly. Fourth, some of the needs of elderly may be better met by policy options other than (or in conjunction with) mobility-enhancing strategies. For example, an appropriate medical prescription delivery service may serve the purpose as much as (or better than) providing a paratransit service to the pharmacy. Additional work is planned in the near future to address these questions.

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TABLE 1 A Summary of the Literature on Elderly Mobility

Paper	Data	Mobility Definition/Metrics	Time Frame	Research Findings
1. Rosenbloom (1988)	1977 &1983 Nationwide Personal Transportation Survey (NPTS), and Health Interview Survey	*Definition:* Ability to move about at will, to reach business & services, and to engage in social & recreational activities as desired *Metrics:* Mode shares, walking/bicycling rates, driving status.	1 day	The elderly living in sub-urban areas are highly dependent on automobile for their daily travel. Different personal (e.g. physical and financial) and environmental (e.g. land use and road system) barriers are likely to affect the use of automobile and other modes of travel.
2. Spinney et al. (2009)	1998 General Social Survey (GSS) Time-Use Data	*Definition:* The physical or mental ability to safely and independently move around, whether inside or outside the home. *Metrics:* Participation and duration of participation in leisure activities.	1 day	The elderly living alone are likely to participate in out- of- home social activities more (than the elderly living with others). Quality of life was found to be related to the benefits associated with transport mobility (e.g., being able to participate in leisure activities).
3. Siren & Blomqvist (2009)	Interview of 3 focus groups (total 13 retired persons) in Helsinki area.	*Definition:* Mobility is closely connected to physical health/ability for out-of-home travel. Mobility is closely tied to the ability to maintain previous lifestyles.	NA	Mobility is highly connected with physical health and ability, and also closely tied to the ability to maintain previous lifestyles. The relationship between mobility and well-being depends on many factors such as compensating strategies, resources, lifestyles and individual context in the life course.
4. Metz (2000)	Empirical evidence from the literature	*Definition:* Articulation of mobility should encompass: access to desired places, psychological benefits of going out and around, physiological benefits of physical activity, social interaction, and the potential to travel	NA	Explored a new concept/articulation of mobility (see column 3) that would help identify the benefits associated with mobility. The new concept of mobility discussed in this study would help assess the impacts of loss of mobility among the elderly in a more holistic fashion. It would also help to assess the impact of different measures undertaken to improve mobility among elderly.
5. Alsnih & Hensher, (2003)	Empirical evidence from literatures	*Definition:* Support the definition of mobility as in Metz (2000). *Metrics:* Person trips, trip distance, trip duration and travel mode	NA	Empirical evidence from a number of western nations pointed out substantial differences in travel patterns (car use, average number of trips, trip distance, trip duration, and trip purposes) between the younger old (age 65-75 years) and the older old (age >75 years). Elderly (age 65-75 years) of today are more mobile than the same group of elderly of a few years ago. Automobile is the dominant mode of transportation (as either driver or passenger) among the elderly.
6. Kim (2003)	1999 Household travel survey data of the Puget Sound Regional Council	*Metrics:* Out-of-home activity duration, person miles traveled and travel time	2 days	Older and female elderly are less likely to be mobile compared to their counterparts. Education level and driver's license are positively associated with the mobility of the elderly population but race, household size, income, vehicle ownership and urban form do not show significant impact on their mobility patterns.
7. Lefrancois et al. (1998)	A sample of 601 adults from Montreal and the eastern township, Canada	*Metrics:* Number of person trips, frequency of participation in exercise, sport, and outdoor recreation (gardening, theater or movies, restaurant and shopping etc.)	1 week (exercise/ sport), 1 Month (outdoor recreation)	Age alone cannot clearly explain the reduction in different types of activity participation among the elderly. Decline in health status plays the most vital role in the reduction of activities among the elderly. Females are likely to make more trips compared to males. Education is positively associated with travel, sport, and outdoor recreation activity participation.
8. Gagliardi et al. (2007)	Interview of 3950 older adults from five European countries: Germany, Finland, Hungary, The Netherlands and Italy	*Metrics:* Participation in outdoor and indoor leisure activities (home activities, hobbies, social & sports activities)	NA	Males (age $\geq$ 55years) are more likely to participate in hobbies and sports activities compared to other types of activities whereas females are more likely to participate in social activities. Besides, the female elderly with health problems are more likely to engage in home activities. These results indicate a variation in the mobility characteristics between the male and female elderly.
9. Giuliano (1999)	1995 Nationwide Personal Transportation Survey (NPTS) data	*Metrics:* Number of person trips, person miles traveled, trip making propensity on the travel day (traveled or not) and travel mode	1 day	Density (persons per square mile) affects trip generation but the effects are almost same across the three age groups (16-64, 65-74 and $\geq$75) considered in this study. Age is negatively associated with trip making propensity and travel distance. The elderly population is less likely to use transit (even when it is accessible) compared to car.
10. Evans (2001)	1995 Nationwide Personal Transportation Survey (NPTS)	*Metrics:* Mobility is measured based on whether a person traveled out of home (or not) on a given survey day.	1 day	Elderly with driver's license, those with higher income and education levels, and those living in high residential density areas are more likely to be mobile. Race did not show any significant impact on their mobility patterns.

TABLE 1 (Continued…) A Summary of the Literature on Elderly Mobility

Paper	Data	Mobility Definition/Metrics	Time Frame	Research Findings
11. Rosenbloom (1999)	1995 Nationwide Personal Transportation Survey and data from office of Highway Information Management	*Metrics:* Number of person trips, person miles traveled and travel mode	1 day	Auto-mobile is the dominantly used mode by elderly. A large gap is found in the total number of trips made by drivers and non- drivers. Women are likely to make fewer trips, travel fewer miles compared to men of all age cohorts and the difference is found to increase with age. White elderly (both males and females) are likely to make more person-trips than the elderly from other race groups (such as Hispanic and African American). Trip distance is found to be higher for white females compared to that of the female elderly from other race groups.
12. Collia et al. (2003)	2001 National Household Travel Survey (NHTS) data	*Metrics:* Number of person trips, person miles traveled, travel time and travel mode	1 day	Older drivers (age ≥ 65years) make fewer trips, travel in mid-day, travel shorter distances and for shorter times; these patterns are more pronounced among elderly women. A small percentage of the persons who had to give up driving due to medical condition were found to use alternative transportation modes and special transportation services such as dial-a-ride.
13. Paez et al. (2007)	1996 Transport Tomorrow Survey (TTS), Canada data	*Metrics:* Number of person trips	1 day	Trip making frequency of the elderly (age ≥ 65 years) decreases with age and female elderly are likely to undertake more trips compared to males. Elderly with driver's license, those who own vehicle, and those who live in affluent zones or live alone are likely to undertake more trips compared to their respective counterparts.
14. Pettersson and Schmocker (2010)	Person Trip Survey (PTS) from the Metro Manila Urban Travel Integration Study (MMUTIS)	*Metrics:* Number of person trips	1 day	Elderly (age ≥ 60 years) with higher income and those who own vehicle are likely to undertake more trips compared to their respective counterparts. Female elderly are likely to make more trips compare to males, and the trip making propensity decreases with age among the elderly (for both males and females). The decrease in total number of trips is considerably higher in a developing country (Manila, Philippines) compared to that in a developed country (London).
15. Benekohal et al. (1994)	Mail survey of 664 older drivers in Illinois (1991) and focus group interview	*Metrics:* Frequency of driving and vehicle miles traveled	NA	Driving frequency and average vehicle miles traveled (VMT) decrease with age among the drivers aged 65 and above. Males are likely to drive more compared to females.
16. Shoval et al. (2010)	Activity data of 49 elderly people from the Tel-Aviv Metropolitan area (Israel)	*Metrics:* Trip length (in km), trip duration and travel speed	4 weeks	Mobility (such as travel speed and length) decreases with the cognitive impairment of the elderly population (age 64-90 years). Access to car plays an important role in the out-of-home mobility of older adults.
17. Allman et al. (2004)	In –home interview of 905 participants in the University of Alabama at Birmingham (UAB) study of aging and a follow-up telephonic interview after 18 months	*Metrics:* Distance through which a person reports moving during 4 weeks	4 weeks	African American elderly are likely to be less mobile compared to Whites. Results from a follow up interview after 18 months indicate a decrease in the mobility among all race groups but the rate of decrease is higher among the whites compared to the African American.

TABLE 2 Household and Person Characteristics of the 2009 NHTS Data

Household Characteristics	All Households (2009 NHTS)	Households with Elderly	
		2009 NHTS*	2009 ACS**
Sample Size	150,147	62,405	Not Available
Weighted Households	113,101,330	33,865,629(29.9%)	24,144,494 (21.3%)
Household Size	2.47	1.86	Not Available
1 Person	28.1%	41.5%	38.8%
2 Person	33.4%	42.5%	61.2% (2+ HH size)
3+ Person	38.5%	16.0%	
Annual Income			
< $ 25 K	26.9%	40.8%	37.6%
$ 25 K - $50 K	27.3%	32.6%	29.5%
$ 51 K - $75 K	16.3%	12.1%	15.0%
> $ 75K	29.4%	14.5%	17.9%
Vehicle Ownership	1.86	1.54	Not Available
0 Vehicle	8.7%	13.3%	14.0%
1 Vehicle	32.3%	42.3%	86.0% (2+ vehicle)
2 + Vehicle	59.0%	44.4%	
Residential Area Type			
Urban	77.3%	78.7%	75.0%
Rural	22.7%	21.3%	25.0%
Person Characteristics	**All Persons (2009 NHTS)**	**Only Elderly**	
		2009 NHTS	**2009 ACS**
Sample Size	308,901	86,112	Not Available
Weighted Population (≥5years)	283,053,872	38,870,018(13.7%)	39,506,648 (13.8%)
Gender			
Male	49.2%	42.4%	42.5%
Female	50.8%	57.6%	57.5%
Age			
5-16 years	17.2%	NA	NA
17-24 years	11.9%	NA	NA
25-44 years	29.4%	NA	NA
45-54years	14.5%	NA	NA
55-64 years	13.2%	NA	NA
65-74 years	7.5%	54.4%	52.9%
75 – 84 years	4.7%	34.1%	33.4%
≥ 85 years	1.6%	11.5%	13.7%
Race			
White	73.8%	78.2%	85.2 %
African American	12.5%	13.9%	8.5%
Other	13.7%	7.9%	6.3%
Education Level			
High School or less	38.9%	52.1%	58.0%
Some College	28.7%	23.7%	21.8%
Bachelor/Higher	32.4%	24.2%	20.2%
Employment Status			
Worker	63.6%	21.3%	15.7%
Not a worker	36.4%	78.7%	84.3%
Driver Status			
Driver	87.5%	79.5%	Not Available
Not a Driver	12.5%	20.5%	Not Available

* Elderly Household: Household with at least one elderly age 65 or above

** Elderly Household: Household with the householder's age 65 or above

TABLE 3 Socio-demographic Characteristics of the Elderly Population across Different Immobility Levels

	Traveled on travel day (mobile)	Did not travel out of home (or Immobile) for the past				Mobility Information Missing
		1 day (short term immobile)	2-3 days (medium-term immobile)	4-7 days (medium- term immobile)	>7 days (week) (long term immobile)	
Sample (Weighted percentage)	64,885 (73.4%)	6,486 (7.2%)	4,720 (5.7%)	3,661 (4.9%)	4,380 (2,217 + 2,163) 6.8% (3.4% + 3.4%)*	1,980 (2.0%)
Gender						
Male	78.7%	6.3%	4.9%	3.0%	4.6% (2.5% + 2.1%)	2.5%
Female	69.5%	7.8%	6.2%	6.3%	8.4% (4.0% + 4.4%)	1.7%
Age						
65-74 yrs	79.0%	6.6%	4.6%	3.4%	4.0% (2.1% + 1.9%)	2.4%
75 -84 yrs	71.1%	7.6%	7.0%	5.2%	7.6% (3.8% + 3.8%)	1.5%
≥ 85 yrs	53.6%	8.6%	6.9%	11.6%	17.6% (8.2% + 9.4%)	1.7%
Race						
White	75.6%	7.1%	4.9%	4.7%	5.7% (2.9% + 2.8%)	1.9%
African American	64.1%	7.8%	8.9%	6.2%	10.6% (5.5% + 5.1%)	2.4%
Other	68.5%	6.5%	6.9%	5.1%	10.7% (4.7% + 6.0%)	2.3%
Education Level						
High School or less	68.4%	7.5%	6.6%	6.4%	9.5% (4.5% + 5.0%)	1.6%
Some College	77.7%	7.4%	4.9%	3.4%	4.7% (2.7% + 2.0%)	1.9%
Bachelor/Higher	81.1%	6.1%	4.0%	3.2%	2.6% (1.5% + 1.1%)	3.0%
Employment Status						
Worker	89.7%	5.0%	1.7%	1.4%	0.5% (0.2% + 0.3%)	1.8%
Not a worker	69.0%	7.8%	6.7%	5.9%	8.5% (4.3% + 4.2%)	2.1%
Driver Status						
Driver	80.3%	6.6%	4.6%	3.2%	3.4% (2.0% + 1.4%)	1.9%
Not a Driver	46.5%	9.3%	9.9%	11.8%	20.1% (9.0% + 11.1%)	2.4%
Annual Income						
< $ 25 K	66.9%	8.2%	6.8%	6.2%	10.2% (5.4% + 4.8%)	1.7%
$25 K - $50 K	77.5%	5.9%	5.3%	4.9%	4.7% (2.6% + 2.1%)	1.6%
$51 K - $75 K	77.5%	7.3%	5.4%	3.3%	4.5% (1.4% + 3.1%)	1.9%
>$75K	80.2%	7.0%	3.0%	2.9%	2.6% (1.3% + 1.3%)	4.3%
Vehicle ownership						
0 Vehicle	55.5%	8.0%	9.0%	9.8%	16.2% (7.2% + 9.0%)	1.5%
1 Vehicle	74.3%	7.0%	5.5%	4.9%	6.7% (3.7% + 3.0%)	1.6%
2+ Vehicle	76.8%	7.1%	5.0%	3.9%	4.7% (2.3% + 2.4%)	2.5%

* 1st percentage number in the parentheses is for those who "Prefer going out".
2nd percentage number in the parentheses is for those who "Do not prefer going out"
Both the percentages in the parentheses add up to the percentage of long-term immobile outside the parentheses.

TABLE 4 Discrete Choice Models of Immobility Levels and Mobility Preferences among Elderly in the US

	Binary Logit Model (BL)	Mixed Multinomial Logit Model (MMNL)						
Variables	**Did not Travel on Travel Day (Immobile)**	**Traveled On Travel Day**	**Traveled in Past Seven Days (Short- and Medium-Term Immobile)**			**Didn't Travel in Past Seven Days (Long-Term Immobile)**		**Difference in Coefficients of Columns (8) and (7)**
			Immobile for 1 day	**Immobile for 2-3 days**	**Immobile for 4-7 days**	**Prefer Going out of Home**	**Don't Prefer Going out of Home**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
	Coef. (t-stat.)	Coef.(t-stat.)	Coef.(t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)
Constant	-1.75 (- 41.29)	-	-3.09(-27.56)	-4.11 (-19.10)	-5.24 (-14.77)	-6.92 (-14.59)	-6.91 (-14.52)	-
Gender (Male is base) Female	0.28 (13.45)	-	0.33(11.62)	0.33(11.62)	0.33(11.62)	0.23(4.30)	0.23(4.30)	-
Age(< =75 years is base) Middle elderly (75-84 years) Older elderly (>= 85 years)	 0.12 (5.38) 0.38 (11.71)	 - -	 - 0.16(3.05)	 0.16(3.70) 0.37(5.82)	 0.36(6.37) 0.81(9.47)	 0.38 (4.91) 0.81 (7.47)	 0.69(8.57) 1.37(11.75)	 0.31(3.51) 0.56(5.34)
Race (White and others are base) Black only	-	-	-	-	-	0.52(5.62)	0.52(5.62)	-
Driver Status (Driver is base) Non- Driver (not licensed to drive)	0.82(23.37)	-	0.51(8.40)	0.86 (11.63)	1.42(14.45)	1.42(14.45)	1.90(14.23)	0.48(5.59)
Worker Status (Non-worker is base) Worker	-0.85(-22.31)	1.93 (11.14)	1.32(7.54)	0.77(4.24)	0.42(2.10)	-	-	-
Education (High school graduate through higher degree is base) High school graduate or lower	0.24 (11.22)	-	0.18(5.40)	0.38(8.73)	0.54(9.16)	0.74(9.11)	0.87(10.60)	0.13(1.64)
Household Size (Single person HH is base) 2 + elderly household 1 other member household 2+ other member household	 0.04(1.24) 0.28 (8.52) 0.43 (9.48)	 0.17(2.43) - -	 0.17(2.43) 0.20(6.53) 0.36(5.80)	 0.17(2.43) 0.20(6.53) 0.46(7.41)	 0.17(2.43) 0.20(6.53) 0.46(7.41)	 - 0.62(7.50) 0.71(6.79)	 - 0.62(7.50) 0.71(6.79)	 - - -
Household Income (>25k is base) <25k	0.20 (8.86)	-	0.11(3.21)	0.34(7.78)	0.50(10.72)	0.50(10.72)	0.50(10.72)	-

TABLE 4 (Continued…) Discrete Choice Models of Immobility Levels and Mobility Preferences among Elderly in the US

	Binary Logit Model (BL)	Mixed Multinomial Logit Model (MMNL)						
Variables	**Did not Travel on Travel Day (Immobile)**	**Traveled On Travel Day**	**Traveled in Past Seven Days (Short- and Medium-Term Immobile)**			**Didn't Travel in Past Seven Days (Long-Term Immobile)**		**Difference in Coefficients of Columns (8) and (7)**
			Immobile for 1 day	**Immobile for 2-3 days**	**Immobile for 4-7 days**	**Prefer Going out of Home**	**Don't Prefer Going out of Home**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
	Coef. (t-stat.)	Coef. (t-stat.)	Coef.(t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)
Number of HH Vehicles (2+ vehicle is base)								
0 vehicle	0.21(4.05)	-	-	-	-	0.62(6.12)	0.62(6.12)	-
1 vehicle	-	-	-	-	-	0.18(2.75)	0.18(2.75)	-
Residential Location Land- Use Variables								
Urban (Rural is base)	-0.20(-8.34)	0.19(4.34)	0.19(4.34)	0.19(4.34)	-	-	-	-
Population density (per square mile)	-0.006(-2.19)	0.01 (1.86)	0.01 (1.86)	-	-	-	-	-
Employment density (per square mile)	-0.003(-3.06)	0.004 (3.09)	0.004 (3.09)	-	-	-	-	-
Medical Condition								
Medical condition makes travel difficult	0.66(26.29)	-	0.44(9.79)	0.77(12.70)	1.14(13.22)	1.81(15.11)	0.76(7.51)	-1.05(-9.74)
Medical condition results giving up driving	0.34 (8.47)	-	0.11(1.54)	0.16(2.00)	0.25(2.92)	1.08(8.79)	0.87(7.08)	-0.21(-1.87)
Error Components								
Standard Deviation (SD1) (for correlations between all adjacent alternatives except those in columns 7 & 8)	-	0.99(6.60)						
Standard Deviation (SD2) (for correlation between alternatives in columns 7 & 8)	-	1.75(6.68)						
Log likelihood at convergence (Adjusted Rho-Square)	- 33,383.18 (0.481)	-56,920.82 (0.117)						
Number of Cases	71,048	71,048						