The Impact on Non-Driver Mobility of Destinations and Bus Routes within Walking Distance of Residences

Robert B. Case, PE
rcase@hrpdcva.gov
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ABSTRACT

The definition of “non-driver” used in this analysis is a person who does not consider themselves to be a driver, i.e. one who can not drive themselves even when a vehicle is available, as opposed to one who periodically chooses not to drive. The literature contains many studies of the impact which urban design and transit service have on the travel habits of the general public. The focus of this study, however, is non-drivers.

The NHTS reveals that non-drivers largely rely on being driven by others, resulting in mobility which is significantly lower than that of persons who can drive themselves. Interest arises, therefore, in the self-directed modes of walking and public transit, but the structure of the NHTS prevents that data from being used to measure the impact which living within walking distance of destinations and living near transit has on non-driver mobility. In this paper, data from a survey conducted in the Hampton Roads region of Virginia—augmented with a new GIS technique for directly measuring proximity to destinations—are analyzed using logistic models to measure the mobility impact of living within walking distance of destinations and bus transit. Findings include the significant impact of these proximities, the quantifications of which can be used to promote the land use and bus infrastructure recommendations developed from the findings to improve the mobility of non-drivers.

INTRODUCTION

Purpose of this Analysis

The definition of "non-driver" used in this analysis is a person who does not consider themselves to be a driver, i.e. one who can not drive even when a vehicle is available, as opposed to one who periodically chooses not to drive. People are non-drivers for a variety of reasons: legal (e.g. DUI), mental/physical (e.g. poor eyesight), situational (e.g. grew up in household without vehicles), etc. As shown below, non-drivers suffer a mobility deficit and are often dependent on being driven by others. It is self-evident, therefore, that living where alternative, self-directed travel modes are available increases the mobility of non-drivers. Living near bus stops increases bus usage; living within walking distance of destinations increases walking trips. The *degree* to which these proximities increase non-driver mobility, is, however, neither self-evident nor available in existing research. The purpose of this analysis, therefore, is to measure the mobility impact, for non-drivers, of living within walking distance of destinations and bus transit. The findings of the analysis—high positive measurements of the impact of these proximities on non-driver mobility—can be used to help implement the recommendations for better urban design and more bus transit which emanate from the findings.

Non-Drivers Desire for More Mobility

Non-drivers apparently have a significant desire to improve their mobility. Case found that non-drivers, both elderly and those age 18-64, make half as many trips per day as their driving counterparts (*1*) (*2*). For elderly persons, the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area reported:

> "The point at which older people voluntarily give up or are forced to relinquish their driving privileges is viewed by elders and those around them as a watershed event with significant implications regarding independence, self-sufficiency, and social responsibilities." *(6)*

For persons of all ages, Gorti found that the percentage of people immobile on the survey day (2001 NHTS) was twice as high (24%) for those in zero-vehicle households as for the whole data set (12%) *(7)*. Although some non-drivers may be satisfied with their mobility, it is self-evident that persons who cannot perform the activity providing the most mobility in human history—driving—due to a circumstance which does not reduce their desire to travel (e.g. DUI, poor eyesight, having parents who did not drive, etc.) suffer a mobility deficit.

Studying the Hampton Roads region of Virginia, Case found that the number of non-drivers in that area is expected to increase significantly in the future. Although the population of non-drivers age 18-64 is expected to remain constant over the next few decades (*2*), with the aging of the Baby Boom generation, the number of elderly non-drivers is expected to double by 2030 (*1*). This Baby Boom effect should produce similar demographic results across the nation.

Profile of Local Non-Drivers

Echoing the above found mobility needs, the survey of non-drivers in Hampton Roads, Virginia conducted for this study (metadata of which survey is discussed in "Local Phone Survey" section below) reveals a transportation-challenged population relying primarily on being driven by others for their travel. These non-drivers tend to also be disadvantaged in other ways. Approximately 20% of surveyed non-drivers did not graduated from high school, and three-fourths of surveyed non-drivers had incomes below $25,000 per year. Older non-drivers are rarely employed (3%), and only one-third of younger non-drivers are employed. Approximately one-quarter of younger non-drivers and half of elderly non-drivers considered their health "fair" or "poor".

THE IMPACT ON NON-DRIVER MOBILITY OF DESTINATIONS AND BUS ROUTES WITHIN WALKING DISTANCE

Findings To-Date from Multi-year Project

This analysis is part of a multi-year non-driver project begun in 2003. The project's first non-driver analysis (*1*) sought improvements to the mobility of elderly non-drivers by analyzing National Household Travel Survey (NHTS) data. It found that residential density (when controlling for other factors) is related to higher mobility for elderly non-drivers, and that the higher mobility comes via an increase in walking and bus usage. The second analysis (*2*) examined younger non-drivers (age 18-64) using the NHTS, and found that living in central areas (when controlling for other factors) is related to higher mobility, and that walking and use of public transit give younger non-drivers in central areas the observed mobility benefit.

The results from the first two analyses indicated that living near destinations and having access to public transit likely cause higher non-driver mobility. Due to the structure of the NHTS survey, however, neither analysis was able to prove or measure the impacts which living near transit and living within walking distance of destinations have on non-driver mobility.

Findings from Existing Research by Others

Existing research examines the transportation impact of destinations and public transit within walking distance of residences.

The Transportation Impact of Destinations within Walking Distance of Residences

Examining older non-drivers, Bailey found that "one in three older non-drivers walks on a given day in denser areas, as compared to 1 in 14 in more spread-out areas." (*9*) Examining the general public (as opposed to non-drivers), several researchers have found a relationship between distance and walk trips. According to Burkhardt (referencing Carp and Handy), "a strong correlation exists between the frequency of trips taken by walking and the nearness of the destination to the person's home." (*4*) Cao, Mokhtarian, and Handy found a similar relationship when they studied persons in Northern California, concluding that "land-use policies designed to put residents closer to destinations and provide them with alternative transportation options will actually lead to less driving and more walking." (*5*) Lee surveyed able-bodied adults living in city limits of Seattle and found "the likelihood of walking to banks increased by over 36% with each additional bank located within 1 km from home." (*27*)

Many of the pedestrian studies summarized in FHWA's *Guidebook on Methods to Estimate Non-Motorized Travel: Supporting Documentation* estimate pedestrian activity based on variables related to destinations being within walking distance of residences (*26*), as follows. Behnam and Patel (1977) estimated pedestrian volumes based on, among other variables, commercial and residential land use space. The model developed by Kocur, Hyman, and Aunet (1982) to estimate walk mode choice for work trips used distance to work as an independent variable. Portland's regional travel model (1993) calculated non-motorized mode choice as a function of travel distance and total employment within one mile. For this purpose, San Francisco's model (1995-1997) uses travel distance and employment density, and Los Angeles uses distance and population density. Kagan, Scott, and Avin (1978) developed a pedestrian demand model (with a structure similar to that of regional transportation models) which used land use type to estimate trip generation. Ness, Morrall, and Hutchinson (1969) developed a pedestrian model for Toronto using gravity-type distribution based on waiting time at intersections, street attractiveness, and turn penalties, as well as distance.

The Transportation Impact of Public Transit within Walking Distance of Residences

Examining the general public, as opposed to non-drivers, several researchers have found a relationship between distance to public transit and transit trips. According to Giuliano, "the likelihood of being a regular transit user is higher for…living near a transit stop." (*10*) Burkhardt reported that "Loutzenheiser found that walking distance is the most significant factor in deciding to walk" to transit. (*4*) Polzin found "the significant influence that development density [which is related to distance to transit] has on public transit mode share." (*8*) Examining specifically rail and ferry transit in the San Francisco Bay Area, Gossen found that the number of transit trips per person increases with the proximity of the household to the transit station. (*11*)

Examining carless households, Grengs developed an accessibility indicator based on whether or not the subject households were located within a quarter mile of a bus route which directly served a supermarket. (*24*) Examining older persons (age 65+) in carless households by differences in MSA category, urban area size, and density, Crepeau and Lave concluded that that the presence or absence of transit [assumed to be related to the three preceding variables] makes little difference in the mobility patterns of older people [in zero-vehicle households]." (*25*) The finding of Lave, as quoted (without a corresponding reference entry) in a thesis by Gorti, that "the concentration of zero vehicle households in a particular area is independent of the effectiveness and reach of transit in that particular neighborhood" (*7*) calls into question the positive impact of transit on persons in these transportation handicapped households.

Employment being related to mobility, existing research examining the impact of public transit on employment is of interest. The findings of this body of work are, however, mixed. According to Meyer and Gomez-Ibanez, federally-funding demonstration projects in the 1960's which improved bus service to outlying employment centers had disappointing results and were discontinued (*28*). Examining autoless adults on welfare in Los Angeles, Kawabata found that "transit-based job accessibility has a significant and positive effect on the employment probability." (*21*) Examining a similar population in Los Angeles (single female welfare recipients without access to a household auto), Ong and Houston found that "transit access…makes a moderate, yet statistically significant, contribution to increasing the probability of employment for autoless welfare recipients." (*23*) The results of an analysis by Sanchez, Shen, and Peng, however, "indicate that TANF recipients in Atlanta, Baltimore, Dallas, Denver, Milwaukee and Portland with relatively higher levels of transit and regional employment access were not more likely to find employment and leave public assistance compared with other TANF recipients." (*22*)

The Transportation Impact of Living in Urban Areas

The likelihood of destinations and pubic transit being within walking distance of residences is higher in urban areas, making urban transportation studies relevant to this paper. That portion of existing urban research which goes beyond transportation mode to examine mobility, i.e. total travel by any mode, is particularly relevant to this study. According to Boarnet and Crane (as quoted by Shay and Khattak), for the general population "higher density…may increase trip generation." (*15*) Focusing on older persons, Gorti found that "the trip rates of older people living in urban areas [3.98 trips/day for age 65-74] are higher than those living in non-urban areas [3.60 trips/day for age 65-74]" (*7*) and Lynott found that "16 percent of seniors in [urban/town] communities did not go out the previous day, compared to 22 percent in [suburban and rural/exurban] communities." (*14*) Reflecting Case's findings for older non-drivers noted above, Evans found that housing density had a "positive relationship with having made at least one trip on the NPTS trip day" for non-driving older persons (*12*) and Bailey found that "61% of older non-drivers stay home on a given day in more spread-out areas, as compared to 43% in denser areas." (*9*) Finally, Gorti found that the trip rates of persons residing in zero-vehicle households in urban areas (2.86 trips/day) is significantly higher than that in non-urban areas (2.12 trips/day). (*7*)

Original Research

Need for Original Research

Although related to the purpose of this paper—to quantitatively determine the impact on non-driver mobility of destinations and bus routes within walking distance of residences—the existing research by others (discussed above) studies the general public, the elderly, or the autoless, as opposed to the target population of this paper: non-drivers. Although similar to and overlapping with other disadvantaged populations, non-drivers differ significantly from them. According to the 2001 NHTS: 1) most elderly persons are drivers and half of adult non-drivers are not elderly, and 2) one third of adults in zero-vehicle households are drivers and most adult non-drivers live in households with vehicles.

Therefore, finding no adequate measurement of the effects on non-driver mobility of destinations within walking distance of residences and bus transit within walking distance of residences in the literature, original research was conducted to directly measure these effects.

Inputs to Model Development Process

Regression Modeling In order to accurately measure the extent to which destinations within walking distance of residences and bus transit within walking distance of residences increase non-driver mobility, one must account for the other factors which promote mobility. For example, according to Genevieve Giuliano, "the appropriate way to examine the extent to which land use affects travel is to control all the other factors known to be important."(*3*) In this research effort multiple regression modeling was used to account for and measure all significant factors.

Local Phone Survey Data concerning non-driver travel were needed as input for the regression models. The NHTS, the largest such data set available, does not include direct measures of proximity to destinations and proximity to public transit. Therefore, questions for a phone survey were designed and the survey was conducted. 790 surveys were collected from non-drivers in Hampton Roads, Virginia, half of them from elderly non-drivers (age 65+), the other half from younger non-drivers (age 18-64). This 1:1 ratio of older to younger non-drivers is similar to that found in the national sample of the 2001 NHTS (0.9:1). The following types of data were collected:

- demographic (e.g. age, income, family structure)
- health
- travel on previous day (e.g. trips made, mode used)
- home address

Dependent Variable The measure of interest, or dependent variable, used in this research for representing mobility is the chance of non-drivers leaving home via any mode on a given day. In the survey data set, all persons who left home at least once on the survey day where assigned a value of “1” for this variable, all others a value of “0”. Modal trips were not measured because they are an unsatisfactory measure of mobility. Case found that non-drivers’ use of alternative modes decreases their requests for rides in private vehicles (while increasing their total trip-making) (*1*), indicating that many alternative mode non-driver trips are simply substitutes for other trips and therefore are not an adequate measure of mobility. “Leaving home” was favored over using “number of trips” because, unlike drivers, non-drivers often make zero trips in a day. Therefore, it was considered more important to increase (and thus to first model) the number of days that a non-driver leaves the home than to increase the average number of trips that a non-driver makes in a day. Evans used this measure of mobility (leaving home) in his research on non-driving older Americans (*12*) and Lynott did likewise for her analysis of senior travel and land use. (*14*)

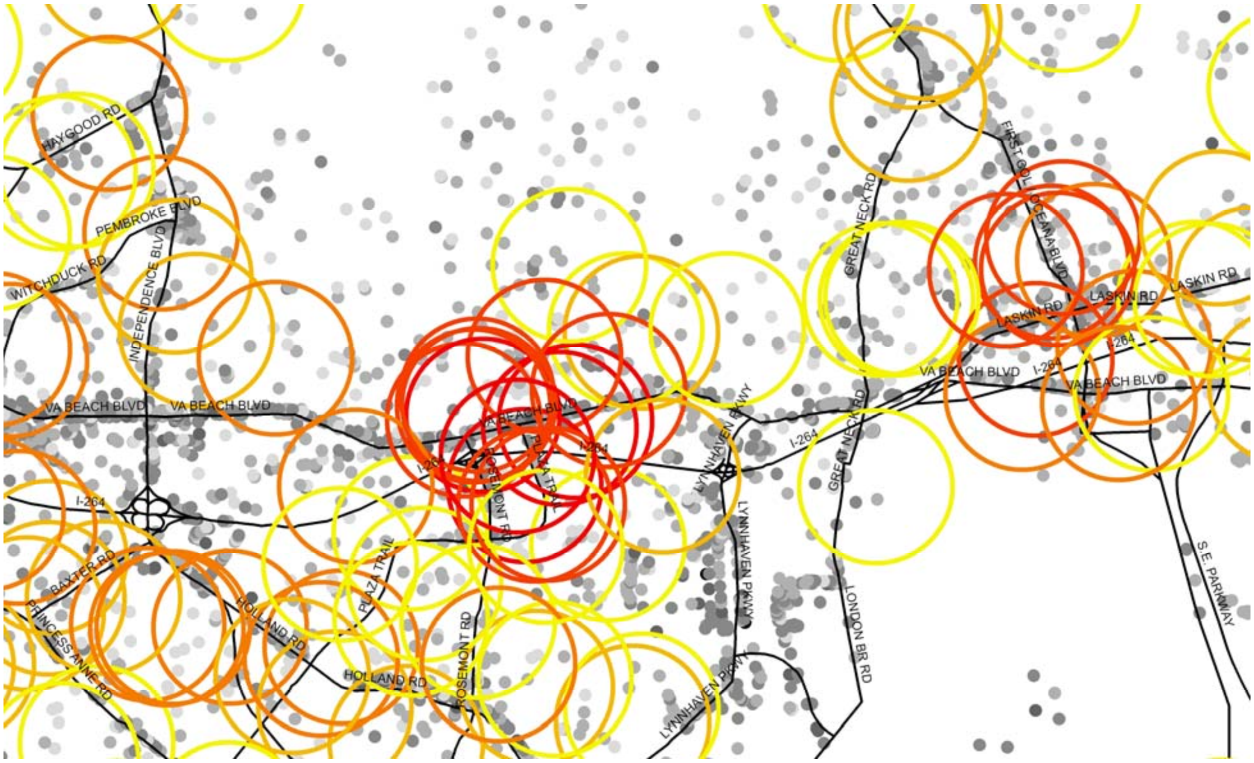
Direct Measure of Destinations within Walking Distance of Residences In order to measure the impact on mobility of destinations within walking distance of residences of non-drivers, a measure of this proximity was needed. According to Asha Weinstein, “the two most commonly considered land-use factors [in pedestrian research] are residential density and land-use mix, both of these serving in essence as a proxy for the likely number of destinations near a home.” (*17*) But using proxy variables instead of direct measurement of the nearness of destinations is problematic. Crepeau (as quoted by Greenwald and Boarnet) explains: “Though these [density] variables are readily available and relatively easy to incorporate and interpret in existing models, they do not get to the heart of incorporating land use characteristics into travel behavior.” (*18*) Likewise, according to Giuliano et al., concerning improving access for the poor, “it is not necessarily density that counts, but rather access to jobs, goods, and services.” (*16*) According to Maat and Timmermans, “to explain the role of land use, most studies analyzed the residential environment, but neglected the destinations.” (*13*) Lee, however, using data for Seattle, directly measured the “distances from home to the closest single and agglomerations of destinations” and tallied the "total number of destinations within 1 km from home". (*27*) Consequently, for this research, the attractiveness of establishments within walking distance was measured directly using a GIS technique developed for this research. This technique was developed in steps.

First, the type of destinations to which non-drivers travel was examined. An analysis of NHTS data indicated non-drivers frequent the same type of destinations as do all persons. Whether a person is employed and making a work trip, or a person is making another type of trip (such as shopping, medical, dining, etc.), the destination of a person leaving his/her home is typically a place of *employment* (a business, a church, a library, etc.). Retail locations attract approximately three times the number of trips per employee than do non-retail locations. For example, in Hampton Road's 4-step transportation model, each retail employee attracts 3.4 trips per day and each non-retail employee attracts 1.4 trips per day. Therefore, attractiveness values—called "Activity Location Units" (ALU's)— reflecting this retail/non-retail difference were calculated for each place of employment in Hampton Roads. The ALU's of retail establishments were set equal to the number of employees multiplied by 3; the ALU's for non-retail establishments were set equal to the number of employees multiplied by 1. Finally, the Euclidian distances between these destinations and each survey respondents' home were measured. Choosing not to presuppose the maximum distance at which the attractiveness of destinations is effective, several candidate independent model variables were developed:

- Activity Location Units within one-quarter mile of residence of surveyed non-driver
- Activity Location Units within one-half mile of residence of surveyed non-driver
- Activity Location Units within one mile of residence of surveyed non-driver
- Activity Location Units within five miles or residence of surveyed non-driver

A map showing an example calculation of Activity Location Units is shown on the following page (Figure 1).

FIGURE 1 Activity Location Units (ALU's) within Half-Mile in Central Va. Beach



Key
Gray dots are employment locations; light gray dots represent 1 ALU; dark gray dots represent more than 1,000 ALU's.
Circles have half mile radii and are centered on residential locations of surveyed non-drivers.
Yellow circles contain less than 800 ALU's (averaging approx. 500 ALU's); red circles contain more than 8,200 ALU's (averaging approx. 10,000 ALU's).

Direct Measure of Bus Transit within Walking Distance of Residences Proximity of non-driver residences to transit was measured using GIS in various ways. First, GIS was used to measure the distance (along the street network) to the closest bus stop. Additional candidate independent variables based on the maximum distance which non-drivers will typically walk to transit were created using this measurement of distance to closest bus stop. Choosing not to presuppose that typical maximum distance, a dichotomous variable (i.e. having two possible values, 0 or 1) was created for each of several distances: one-quarter mile, one-half mile, and one mile.

Basic Model Structure

Ability to Walk Living within walking distance of destinations and bus transit are factors expected to affect the mobility of non-drivers who walk well to a greater degree than they affect non-drivers who do not walk well. Therefore, mixing these two types of non-drivers in one model would mask the actual impact of these proximities. Therefore, the set of 790 survey-based records was split into two sets based on the ability of the respondent to walk, and a model was developed for each group. To measure the ability to walk, an index was created based on the following four survey questions:

- Does physical health limit trip making?
- Do you receive disability income?
- Is your general health fair or poor? (as opposed to good, very good, or excellent)
- Do you use a cane, walker, or wheelchair?

Those answering "yes" to any of these questions were considered "Lesser Walkers" (492 respondents); those answering "no" to all of these questions were considered "Better Walkers" (298 respondents).

Regression

The dichotomous nature of the dependent mobility variable ("Leaving the Home") dictated a binary logistic regression structure. Using the database of 790 non-driver records of survey and GIS data in the form of one dependent variable (mobility) and approximately 200 candidate independent variables, a model of 10 independent variables for lesser walkers (Table 1) and a model of 8 independent variables for better walkers (Table 2) were built using forward stepwise regression, adding variables statistically-significant at the 0.05 level. These models indicate which factors are related to non-driver mobility, and they measure the extent to which these factors affect non-driver mobility. Tables showing the structure of the two models—and definitions, descriptive statistics, significance, and influence of the variables found to be related to non-driver mobility—are included below.

TABLE 1 Lesser Walkers Model

Dependent Variable: Leaving the Home on Survey Day (I)

Independent Variable- Definition & Descriptive Statistics	Range	Mean	Std. Dev.
"Years Over 35": age less 35 (0 if under age 35)	0-64	32.7	17.0
"Masters Degree or Higher": highest education attained	0,1	0.04	0.20
"Income Not Reported": "1" if no answer given to income question	0,1	0.42	0.49
"Disab. Income or Phys. Health Limits" (II)	0,1	0.76	0.43
"Group Living": "1" if live in group facility	0,1	0.02	0.14
"Religious Affiliation": "1" if affiliated with a religious org.	0,1	0.54	0.50
"Paralysis": "1" if paralyzed	0,1	0.08	0.27
"Use Walker": "1" if reported using a walker	0,1	0.32	0.47
"# of Bus Stops within 5 miles": measures density of bus network	0-901	238	265
"More than 50 Blocks within Half-Mile": density of road network	0,1	0.24	0.43

Independent Variable- Regression Results	B	S.E.	Sig.	Exp(B)
Years Over 35	-0.029	0.006	0.00	0.972
Masters Degree or Higher	1.152	0.525	0.03	3.166
Income Not Reported	-0.559	0.211	0.01	0.572
Disab. Income or Phys. Health Limits (II)	-0.538	0.233	0.02	0.584
Group Living	-2.339	1.114	0.04	0.096
Religious Affiliation	0.535	0.205	0.01	1.707
Paralysis	-0.888	0.413	0.03	0.412
Use Walker	-0.548	0.230	0.02	0.578
# of Bus Stops within 5 miles	0.0015	0.0005	0.01	1.0015
More than 50 Blocks within Half-Mile	-1.346	0.343	0.00	0.260
Constant	1.156	0.318	0.00	3.178

Notes

"B": Binary logistic model coefficient "S.E.": Standard error

"Sig.": Significance (chance of incorrectly assuming relationship with dependent variable)

"Exp(B)": e^B (measures variable's impact on the odds of leaving the home)

I: Dichotomous variable (range of values: 0,1)

II: "1" if either receiving disability income or reported that physical health limits trip-making

TABLE 2 Better Walkers Model

Dependent Variable: Leaving the Home on Survey Day (I)

Independent Variable- Definition & Descriptive Statistics	Range	Mean	Std. Dev.
"Sunday Travel Day": "1" if survey day was a Sunday	0,1	0.10	0.31
"Age^2, thousands": age squared, then divided by 1,000 (IV)	0.3-9.8	3.22	2.57
"Ages 30 thru 61": "1" if age is greater than 29 and less than 62	0,1	0.32	0.47
"Parent(s) in Home": "1" if parents of respondent live in home	0,1	0.20	0.40
"Vehicles in Household or Family Vehicles in Area" (V)	0,1	0.76	0.43
"Activity Location Units within Half-Mile, thousands" (II)	0.0-10.4	1.24	1.79
"Closest Bus Stop is within One Mile": "1" if true for home (VI)	0,1	0.73	0.44
High Property Crime Rate Locality (III)	0,1	0.87	0.34

Independent Variable- Regression Results	B	S.E.	Sig.	Exp(B)
Sunday Travel Day	1.925	0.677	0.00	6.852
Age^2, thousands (IV)	-0.186	0.063	0.00	0.831
Ages 30 thru 61	0.981	0.346	0.00	2.666
Parent(s) in Home	1.364	0.473	0.00	3.912
Vehicles in Household or Family Vehicles in Area (V)	0.849	0.325	0.01	2.338
Activity Location Units within Half-Mile, thousands (II)	0.175	0.093	0.06	1.192
Closest Bus Stop is within One Mile (VI)	0.767	0.356	0.03	2.153
High Property Crime Rate Locality (III)	-1.441	0.507	0.00	0.237
Constant	0.530	0.634	0.40	1.699

Notes

"B": Binary logistic model coefficient "S.E.": Standard error

"Sig.": Significance (chance of incorrectly assuming relationship with the dependent variable)

"Exp(B)": e^B (measures variable's impact on the odds of leaving the home)

I: Dichotomous variable (range of values: 0,1)

II: "Activity Location Units" = (non-retail employees)*1 + (retail employees)*3; Euclidian distance

III: More than 20 property crimes per 1,000 persons in 2005

IV: Age^2 was included as candidate variable to enable model to reflect non-linear effects of age

V: "1" if there are any vehicles in the home or if any relatives with vehicles live in the area

VI: Distance measured via road network

Checking Model Validity

Checking Threats to Model Validity Threats to the validity of the Lesser Walkers and Better Walkers models resulting from the above regression process were checked by addressing the following topics:

- Logical independent variables and coefficient signs
- Influence points
- Normality
- Homoscedasticity
- Linearity
- Independence of error terms
- Multicollinearity
- Self selection

First, the models appear to have logical independent variables with logical coefficient signs. In addition to variables reflecting the hypothesized impact of living within walking distance of destinations and bus transit, the stepwise process chose other variables for which both logic and prior research indicate a relationship to mobility: age, education/income, health, social network, vehicle availability, and crime. It is logical that health issues define mobility in the Lesser Walkers model, and geographic issues define mobility in the Better Walkers model. The inclusion of religious affiliation and income variables in the first model (income being related to the education variable) reflects the logical reliance of lesser walkers on others (both volunteer and paid) to supply their transportation, whereas the inclusion of the "Ages 30 thru 61" variable in the second model perhaps reflects the travel needs of persons fulfilling the family responsibilities associated with middle age.

A detailed investigation of the next six issues above revealed no fatal flaws in the analysis:

- Analyses of outliers eliminated concern over influence points.
- In accordance with Hair et al. (*19*), the sample sizes of the Lesser Walkers and Better Walkers models both exceeding 200 records, the issue of normality was considered not to be problematic.
- The dependent variable being dichotomous, homoscedasticity is not a concern.
- Residual plots for metric independent variables and the inclusion of "age squared" candidate variable satisfied the concern over linearity.
- In accordance with Hair et al. (*19*), the independence of error terms was ensured by addressing sequencing, in this case by including as a candidate variable "Post-Revision Survey", which indicated whether or not the subject survey was taken after the survey script was slightly revised for privacy concerns.
- The impact of high correlation of pairs of independent variables on the volatility of their coefficients was checked by dropping one variable at a time from the model. The one problematic pair is discussed in "Findings" below.

Self Selection "Self selection" occurs when individuals select a group to join. For example, people may choose to live in a pedestrian-friendly neighborhood. When research attempts to compare pedestrian habits of a pedestrian-friendly neighborhood to that of a less-friendly neighborhood, it must attempt to differentiate between the impact of the neighborhood and the impact of the characteristics of the people who chose to live in each neighborhood. For many characteristics, such as income and health, this differentiation can be achieved by inclusion of these variables in a multiple regression. Personality traits, e.g. the tendency to place extraordinary value on walking (i.e. a value much higher than otherwise similar people would place), however, are difficult to measure and therefore threaten the validity of research on matters strongly affected by these traits. According to Pinjari, land use and transportation studies "often ignore the residential self-selection process that may be taking place in the housing market." (*20*) He concludes that "in the presence of such residential sorting effects, one may erroneously overestimate the impacts of built environment attributes on travel choices." Therefore, the question of whether self selection causes this research to overestimate the impact of bus transit and destinations within walking distance of residences on the mobility of better-walking non-drivers must be addressed.

An examination of the factors involved in non-driver mobility indicate that self selection may not pose a significant threat to the validity of the measurements resulting from this research. First, many of the characteristics that differentiate between people of various neighborhoods (age, income, health) have been included in the models and are thereby accounted for. Secondly, because of the their reliance on others and the associated unmet desire for more mobility, one would expect little variance in the attitudes of otherwise similar non-drivers (e.g. same age, income, and health) toward means of increasing independent mobility, regardless of their personality traits. Since the existence of unmeasured characteristics which affect observed outcomes is necessary for self selection to distort research findings, it appears reasonable that the vast majority of the effect of living within walking distance of destinations and bus transit observed in this paper is a function of the opportunity provided by those proximities and not a function of non-drivers with a *personality-based* desire for more travel choosing neighborhoods with good proximities.

Checking Model Fit In addition to the fact that each of the variables in the models are significantly related to the mobility of non-drivers, it is important to examine the degree to which model output reflects the original data by measuring percentage correct, goodness-of-fit, and reduction in errors. The Lesser Walkers model replicated the actual mobility result for 70% of the survey records, and the Better Walkers model did so for 76% of the survey records. The goodness-of-fit between the actual mobility values and those "predicted" by the models was measured by R-Square, specifically the "Nagelkerke R Square" associated with binary logistic models. The Lesser Walkers model has an R^2 of 0.23 and the Better Walkers model has an R^2 of 0.33. The reduction in errors was measured by "Tau", the percentage of fewer errors achieved via the subject model than by chance. Both models have a Tau value of 30%.

At first glance, the above R-Square and Tau values appear low. But it is inherently difficult to predict the behavior of persons when examining only one day's activity—even when using a model comprised of variables which are valid explainers of mobility. For example, a generally mobile person may have been sick on the survey day, or a bed-ridden person may have been taken to the doctor on the survey day. Considering the difficulties associated with one day's data, the R-Square and Tau values appear to be fairly good.

Interpretation of Model Results

Meaning of Exp(B) Values Because the mobility variable in question is dichotomous (one either leaves the home on a given day, or one does not), the exponent of each model variable's coefficient, "Exp(B)", indicates the variable's impact on the odds of getting out of the home on a given day. For example, the Exp(B) value of the "Use Walker" variable is 0.578 in the first model. Therefore, if a non-driver with certain characteristics (e.g. age, education, etc.) who does not use a walker has 2-to-1 odds (i.e. 67% chance) of getting out of the home on a given day, a non-driver with the same characteristics who uses a walker would have odds lower by a factor of 0.578, or 1.2-to-1 odds, i.e. a 55% chance of leaving the home (2 x 0.578 = 1.2; 1.2 / (1.2+1) = 55%).

Findings

Lesser Walkers The key finding from the Lesser Walkers model is that bus infrastructure appears to increase mobility, even for lesser walkers. According to the Exp(B) value from the above table, the odds of lesser-walking non-drivers getting out of the home on a given day appear to increase by 0.15% for each additional bus stop within a 5 mile radius of their home. Because people do not walk 5 miles to reach a bus route, the strength of this variable may reflect the utility of living where relatively short bus trips can reach many destinations. The high correlation, however, between the bus variable and another variable in the model (the block variable) makes the true value of the bus variable coefficient uncertain. Therefore, further study would be required prior to basing bus infrastructure investments on the magnitude of that coefficient. One can assume, however, that some lesser walkers use the bus system, and, therefore, that improvements to bus infrastructure and the existence of destinations easily reached by bus (i.e. within five miles) improves the mobility of lesser walkers.

Better Walkers The first key finding from the Better Walkers model is that living within a half-mile of a moderately high level of destinations increases the odds of better-walking non-drivers leaving the home five fold. According to the Exp(B) value from the above table (1.192), for each increase in 1,000 Activity Location Units (ALU's) within a half-mile of the residence of a better-walking non-driver, the odds of leaving home on a given day increase by 19%. High Activity Locations in this study have approximately 10,000 Activity Location Units within a half-mile radius. Surveyed non-drivers living in High Activity Locations are represented by red circles on map in "Direct Measure of Destinations" section above. It should be noted that these "High Activity Locations" are found in the suburbs as well as in the downtown areas of the moderately-sized metropolitan area studied (population between 1 and 2 million). Low Activity Locations have approximately 500 Activity Location Units within a half-mile radius. Surveyed non-drivers living in Low Activity Locations are represented by yellow circles on map in "Direct Measure of Destinations" section above. Consequently, better-walking non-drivers living in High Activity Locations in Hampton Roads are expected to have odds of leaving home five times higher than those living in Low Activity Locations (1.192^(10-0.5) = 5.3). For example, if a better-walking non-driver with certain characteristics (e.g. age, vehicles in household, etc.) who lives in a Low Activity Location has a 50% chance of getting out of the home on a given day, a non-driver with the same characteristics who lives in a High Activity Location would have five times higher odds, or an 84% chance (1.192^(10-0.5) = 5.3; 5.3 / (5.3 + 1) = 0.84) of leaving home on any given day.

The second key finding from the Better Walkers model is that living within one mile of a bus stop increases mobility, giving non-drivers who are better walkers twice the odds (Exp(B) = 2.153, from table above) of getting out of the home than the odds of those who do not live near bus transit. For example, if a better-walking non-driver with certain characteristics (e.g. age, vehicles in household, etc.) who lives away from any bus route has a 50% chance of getting out of the home on a given day, a non-driver with the same characteristics who lives within one mile of a bus route would have a 68% chance of leaving home (1 * 2.153 = 2.153; 2.153 / (2.153 + 1) = 0.68).

CONCLUSIONS AND RECOMMENDATIONS

Given the lower mobility generally experienced by non-drivers, and given the increase in the number of non-drivers expected with the aging of the Baby Boom generation, methods of increasing non-driver mobility are valuable. The findings of this study—specifically 1) that bus infrastructure increases the mobility of lesser-walking non-drivers, 2) that living within a half-mile of a moderately high number of destinations increases the odds of better-walking non-drivers leaving the home five fold, and 3) that living within one-mile of a bus route doubles the odds of better-walking non-drivers leaving the home—lead to the following recommendations of local government actions designed to improve the mobility of non-drivers.

Bus Infrastructure

Given the measured impact on non-driver mobility of living near bus routes (the odds of leaving home doubling for better-walking non-drivers living within one mile of a bus stop), new bus routes located on roads with a large number of existing or planned residences within a one mile walk of that road will improve the mobility of many non-drivers. This recommendation parallels that of Giuliano et al. who state that “fixed route transit should be concentrated in high-density areas where it can be effective, especially in high-poverty/high-density areas.” (*16*)

Government Facilities

Given the demonstrated improvement in the mobility of non-drivers living within a half-mile of destinations, local governments can measurably increase the mobility of non-drivers by locating government facilities within one half-mile of existing and planned locations of large numbers of residences. For example, locating recreation centers, schools, and libraries within a half-mile of higher-density residential areas can improve the mobility of the many non-drivers who live in those areas.

Zoning Authority

Given the demonstrated improvement in the mobility of non-drivers living within one half-mile of destinations, local government can measurably increase the mobility of non-drivers by using its zoning authority to ensure that:

1) adequate numbers of residences are allowed to be built within a half-mile of concentrations of destinations,
2) adequate numbers of destinations (businesses, institutions, etc.) are allowed to be built within a half-mile of existing high-density residential locations, and
3) new developments containing a mixture of both destinations and residences are allowed to be built

The first recommendation parallels that of Giuliano who proposes "more low-income housing in areas of high job accessibility." (*10*) Finally, given the demonstrated improvement in the mobility of non-drivers living within one mile of bus stops, local government can measurably increase the mobility of non-drivers by using its zoning authority to ensure that adequate numbers of residences are allowed to be built within one mile of existing and planned bus routes.

In summation, this study's measurement of the impact on mobility of living within a half-mile of a moderate number of destinations and living within one mile of a bus route—giving better walking non-drivers odds of leaving home which are 5 times and 2 times higher, respectively—can be used to promote the land use and bus infrastructure changes proposed herein. Given that the non-drivers surveyed for this study are located in a variety of built environments (urban, suburban, and rural areas), the applicability of this study to the rest of the nation should be high.

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