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# **IMPROVING THE MOBILITY OF NON-DRIVERS USING LOCAL SURVEY AND GIS DATA**

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for Fiscal Year 2006-2007, which was approved by the  
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**ABSTRACT**

HRPDC staff is conducting a multi-year study to determine ways to increase the mobility of non-drivers in Hampton Roads. The first two published reports investigated improving the mobility of non-drivers using the National Household Travel Survey (NHTS). The third report presented statistics on non-drivers in Hampton Roads from a local survey. In this fourth report, data from a local survey—augmented with geographic data—are used to determine ways to improve the mobility of non-drivers.

**ACKNOWLEDGEMENTS**

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## INTRODUCTION

### OVERVIEW OF MULTI-YEAR STUDY

This document is the fourth in a series of documents emanating from the non-driver studies begun by HRPDC staff in 2003. The first non-driver document (published in June 2005) examined improvements to the mobility of elderly non-drivers using the National Household Travel Survey (NHTS). It revealed that:

- elderly non-drivers travel half as much as elderly drivers, but
- elderly non-drivers living in denser areas have higher mobility due to walking and bus usage.

The second document (published in November 2006) examined non-drivers age 18-64 again using the NHTS. It revealed that:

- 18-64 non-drivers also make half as many trips as their driving counterparts,
- the mobility of 18-64 non-drivers living in central areas is significantly higher than those living in other areas, and
- walking and use of public transit give non-drivers in central areas this higher mobility.

Combining the following three items:

- the above finding that non-driver mobility is higher in dense areas and central areas,
- the understanding that destinations tend to be closer and public transit tends to be available in dense areas and central areas, and
- the understanding that proximity to destinations and access to public transit increase non-driver mobility<sup>1</sup>,

it was concluded in these first two documents that living near destinations and having access to public transit causes the higher non-driver mobility. But due to the structure of the NHTS survey, neither study was able to directly measure the mobility impact of living near transit and living within walking distance of destinations. Therefore, a local survey was designed, implemented, and analyzed to measure these factors. A third document (published in 2007) presents a statistical snapshot of local non-drivers based on data from the survey.

### Purpose of this Document

This fourth document presents a model based on the local survey (and associated GIS data) which measures the mobility impact of proximity to transit and destinations, and

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<sup>1</sup> "The general hypothesis is that people will walk more often if they can access desired destinations quickly." ("How Much do Americans Walk?", Asha Weinstein, TRB 2005 Annual Meeting CD, pg. 5).

presents recommendations, developed from the model, for improving the mobility of local non-drivers.

## EXISTING NON-DRIVER RESEARCH

Existing research also indicates that non-driver mobility can be improved by changes in urban form and public transportation. Three types of research are examined below: 1) stated preference (i.e. what surveyed people say they would do under certain circumstances; 2) revealed preference (i.e. what surveyed people say that they actually did do under certain circumstances); and 3) expert opinion.

No research was found which determines and measures those factors which explain the overall mobility of non-drivers. Instead, the discovered research was typically oriented toward that which increases usage of particular *modes of travel* (walking and riding public transportation) as opposed to that which increases mobility. Even though modal research must be used with care when examining mobility (for example, access to vehicles lowers non-driver walking<sup>2</sup> but raises non-driver mobility<sup>3</sup>), modal research is valuable because of the apparent increase in mobility associated with having the *option* of walking and using public transportation. The mobility effect of having options was shown by the first document emanating from HRPDC non-driver research which revealed that older non-drivers who live in higher density census tracts are more likely to walk and use bus transportation, are less likely to use personal vehicle transportation, and (most importantly) have higher overall mobility than their cohorts who live at lower densities.<sup>4</sup>

### Stated Preference

A recent AARP survey of elderly (75+) persons<sup>5</sup> indicates the importance which surveyed persons place on proximity (in this case, proximity to bus stops and grocery stores) as a determinant of the likelihood of making bus and walk trips. In the survey, elderly non-drivers who had reported that they cannot walk to a bus stop chose the following four responses with approximately equal frequency when asked “What would make it possible to walk to a bus stop?”:

1. Better sidewalks
2. Routes not on busy streets
3. Bus stop within 5 blocks of home<sup>6</sup>
4. Resting place along the way

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<sup>2</sup> “There is general agreement across research studies that access to a car...correlates with lower walking rates.” (“How Much do Americans Walk?”, Asha Weinstein, TRB 2005 Annual Meeting CD, pg. 4).

<sup>3</sup> As shown in following sections of this document.

<sup>4</sup> “Improving Elderly Transportation Using the NHTS”, Robert B. Case, HRPDC, June 2005, pg’s 22, 23.

<sup>5</sup> “Community Transportation Survey”, Audrey Straight, AARP, 1997, pg’s 16, 17.

<sup>6</sup> The distance of 5 blocks was apparently included in a pre-scripted optional response.

When asked “What would make it possible to walk to a grocery store?”, the two most frequent responses were:

1. Resting place along the way
2. Store within 5 blocks<sup>2</sup>

## Revealed Preference

Researchers have found an empirical (i.e. revealed) relationship between density and both walking and public transportation. According to the Surface Transportation Policy Project (STPP):

“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.”<sup>7</sup>

“More than half of older non-drivers use public transportation occasionally in denser areas, as compared to 1 in 20 in more spread-out areas.”<sup>8</sup>

Although the STPP studied older non-drivers, the same density effect would logically apply to younger non-drivers as well.

In studying the impact of urban form on walking, Asha Weinstein looked beyond density, noting that density is a “proxy for the likely number of destinations near a home”.<sup>9</sup> She supported this hypothesis by referring to a study of revealed behavior by Greenwald and Boarnet which “concluded that density of the residential neighborhood had a significant effect on non-work walk trips in the Portland area....”<sup>10</sup> She also reported that a study by Handy “concluded that the variable most closely predicting walk trips to local stores was the distance from home to the destination.”<sup>11</sup>

## Expert Opinion

Sandra Rosenbloom, Ph. D., Director of the Drachman Institute at the University of Arizona, believes that urban form and public transportation are important factors in improving the mobility of older persons. According to her, four strategies should be considered for elderly mobility:

1. “promoting the centralization of a metropolitan area”
2. “target public transit services...directly for the elderly”

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<sup>7</sup> “Aging Americans” Stranded Without Options”, Linda Bailey, Surface Transportation Policy Project, Apr. 2004, pg. 2.

<sup>8</sup> “Aging Americans” Stranded Without Options”, Linda Bailey, Surface Transportation Policy Project, Apr. 2004, pg. 2.

<sup>9</sup> “How Much do Americans Walk?”, Asha Weinstein, TRB 2005 Annual Meeting CD, pg. 5.

<sup>10</sup> “How Much do Americans Walk?”, Asha Weinstein, TRB 2005 Annual Meeting CD, pg. 5.

<sup>11</sup> “How Much do Americans Walk?”, Asha Weinstein, TRB 2005 Annual Meeting CD, pg. 5.

3. “support alternative transportation options, for example by encouraging ride-sharing, introducing voucher programs, and strengthening the role of for-profit transportation providers”
4. promote safety by “improving the highway and street infrastructure” especially for pedestrians<sup>12</sup>

Although Dr. Rosenbloom was addressing the mobility of all older persons (drivers and non-drivers), an examination of her recommendations and an understanding that the likelihood of being a non-driver increases with age<sup>13</sup> indicates that her strategies are applicable to all non-driving persons.

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<sup>12</sup> “Regional Report”, Sandra Rosenbloom, Sacramento Area Council of Governments, Nov. 2003, pg. 5.

<sup>13</sup> “Improving Elderly Transportation Using the NHTS”, Robert B. Case, HRPDC, June 2005.

## ORIGINAL RESEARCH

Having learned, through research by HRPDC and others, that proximity to destinations and public transit increases non-driver mobility, HRPDC staff conducted original research to measure the extent to which proximity increases mobility.

### INPUTS TO THE MODEL DEVELOPMENT PROCESS

In order to accurately measure the extent to which proximity to destinations and public transit increases 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.”<sup>14</sup> In this research effort regression modeling was used to account for all significant factors.

#### Local Phone Survey

Data concerning non-driver travel were needed as input for the regression models. As noted above, the NHTS, the largest such data set available, did not include data on proximity to destinations and proximity to public transit. Therefore, HRPDC staff designed questions for a phone survey and conducted that survey in Hampton Roads. HRPDC hired the survey firm HQR which collected 800 surveys from local non-drivers. The following data was collected:

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

#### GIS Data Added to Survey Data

HRPDC staff entered the home address (described above) into its geographic information system (GIS) to directly measure:

- The survey respondents' proximity to destinations (explored in detail below)
- The survey respondents' proximity to bus routes (e.g. distance, in miles, to closest bus stop)
- The walkability of each respondent's neighborhood (e.g. number of blocks within half-mile, distance to closest sidewalk, local crime rate)

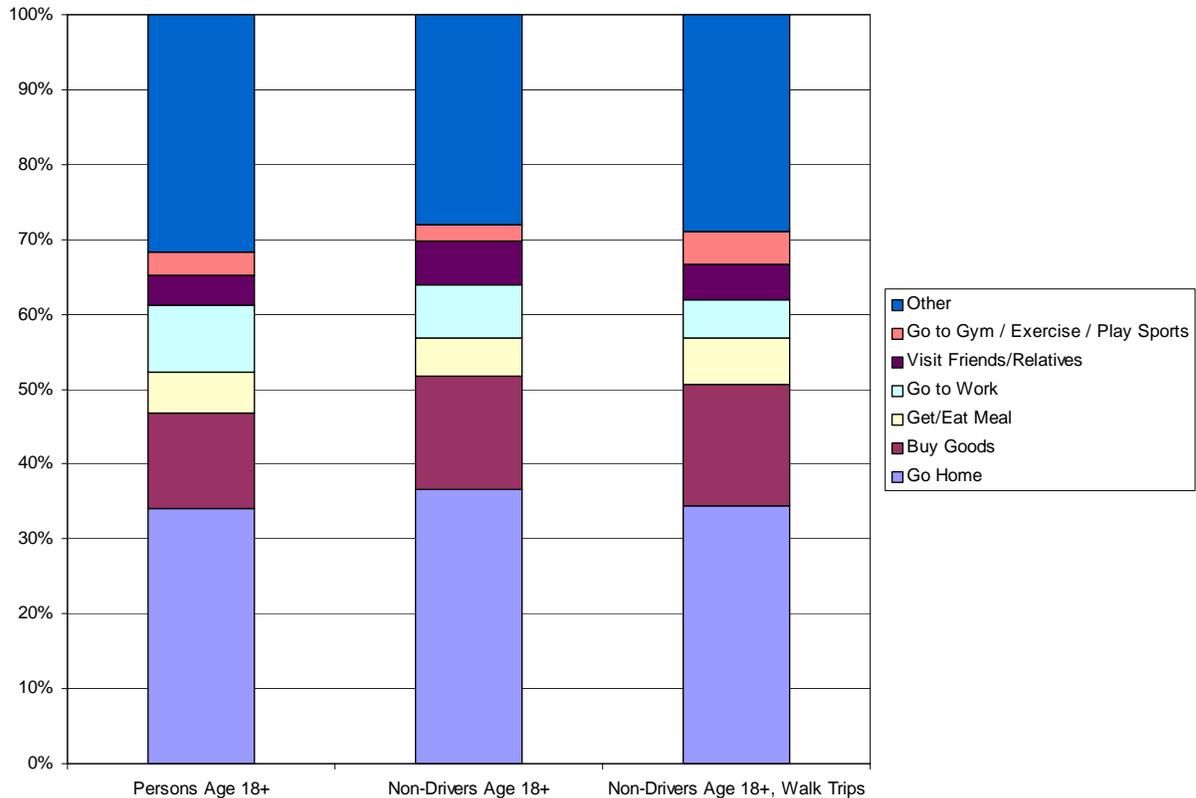
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<sup>14</sup> “Land Use and Travel Patterns Among the Elderly”, Genevieve Giuliano, in *Transportation in an Aging Society*, TRB, 2004, p. 202.

## Proximity to Destinations

In order to measure the impact on mobility of living near destinations, a measure of these destinations was needed. First, the type of destinations to which non-drivers travel was examined. An analysis of NHTS data (below) indicated non-drivers travel to the same type of destinations as do all persons.

**Trip Destinations, Mid-Atlantic States, 2001 NHTS, National Sample**



nat samp- Mid-Atlantic trips.xls

Secondly, 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 generally a place of *employment* (a business, a church, a library, etc.). Thirdly, travel surveys have shown that retail locations attract approximately 3 times the number of trips per employee than do non-retail locations.<sup>15</sup> Therefore, fourthly, in order to measure the attractiveness of destinations, attractiveness values—called “Activity Location Units”—were calculated for employment locations in Hampton Roads by multiplying 3 times the number of employees for retail

<sup>15</sup> 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.

establishments and multiplying 1 times the number of employees for non-retail establishments. The resulting Activity Location Units are shown below.

### Activity Location Units in Central Va. Beach



VB Blvd- network & attr units.jpg

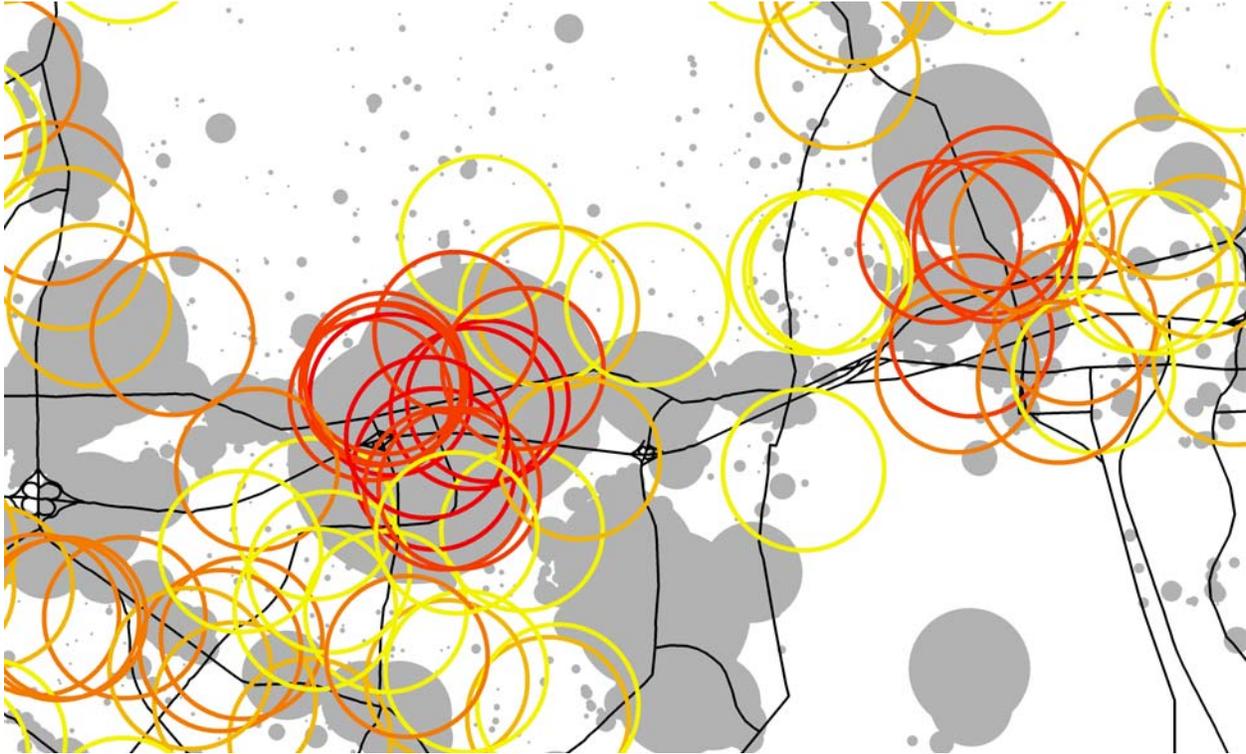
Key: dot size based on number of Activity Location Units at each employment location

Finally, the number of Activity Location Units near each survey respondents' home was measured. Not knowing with certainty the maximum distance at which the attractiveness of destinations is effective, several measures were calculated:

- Activity Location Units within one-quarter mile
- Activity Location Units within one-half mile
- Activity Location Units within one mile
- Activity Location Units within five miles

An example (Activity Location Units within one-half mile) is shown below.

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



VB Blvd- units & colored circles.jpg

Key: red circles contain approx. 10,000 ALU's; yellow circles contain approx. 1,000 ALU's.

These measures of ALU's at various distances from the survey respondents became candidate variables for the regression models developed to identify and measure the factors which impact non-driver mobility.

### Preparation of Data

#### Dependent Variable: Mobility

For the purpose of this analysis, "mobility" was defined as "leaving the home on the survey day". This measure was favored over using "number of trips made on survey day" because it was assumed to be more important to increase the number of days per week that a non-driver is able to leave the home (from, say, 2 days to 3 days per week) than to increase the number of trips that a non-driver makes in a day (from say 2 trips to 3 trips). "Leaving the Home on Survey Day" was used as the dependent variable (i.e. the variable whose values one is attempting to explain) in the model-building/regression process.

## Independent Variables

Most of the candidate independent variables (i.e. the variables which may explain mobility) from the survey and GIS are dichotomous (i.e. having two possible values, 0 or 1). For example, the presence (or absence) of a vehicle in the household is a dichotomous variable. Prior to regression, scalar variables (i.e. having a range of values) were analyzed to determine whether transformation of the data was required. For example, the GIS provided distance to the nearest bus stop, but—it being unlikely that living 5 miles from a bus stop vs. living 10 miles from a bus stop has any mobility impact—a transformation was required to create a variable which indicates whether the subject person lives within walking distance of a bus stop. Based on an analysis of the results of the survey, use of bus is fairly consistent up to 1 mile distance.<sup>16</sup> Therefore, a new (dichotomous) bus stop variable was created with the following values: “1” if  $\leq 1$  mile, “0” if  $> 1$  mile.

In order to account for possible interaction between variables,<sup>17</sup> “interaction” variables were created which are simply the product of two variables thought to interact. Interaction variables were added to the database for all combinations of 7 key variables related to geography and use of alternative modes.<sup>18</sup>

After all data preparation was complete, a database of 790 non-driver records, with mobility data and data for approximately 200 candidate variables, was used in the final regression analysis.

## **Basic Model Structure**

Two aspects of the basic model structure require explanation prior to discussing the regression process.

### Ability to Walk

In order to identify and measure those geographic factors which impact non-driver mobility, the set of 790 survey-based records was split into two sets based on the ability of the respondent to walk (or not walk). 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?

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<sup>16</sup> For more detail, see chart in “Findings” section below.

<sup>17</sup> For example, crime and gender may interact in that fear of crime may impact the mobility of women more than men.

<sup>18</sup> During the regression process, these interaction variables masked the impact of geographic factors and were, therefore, eliminated from the final input data set.

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).

Note that the ability to walk is expected to impact the non-driver’s frequency of making trips in vehicles, in addition to impacting the frequency of walking trips.

### Type of Model

The dichotomous nature of the dependent mobility variable (“Leaving the Home”) dictated that a binary logistic regression be used. As opposed to linear regression models which provide estimates along an infinite range of potential values, models resulting from binary logistic regressions provide estimated values of the dependent variable which range from 0 to 1.

### **Regression Process**

In order to include in the models only those variables which explain mobility after accounting for other variables, forward “step-wise” regression was used, adding variables statistically-significant at the 0.05 level<sup>19</sup> to the model one-at-a-time. For more details concerning the regression process, see Appendix A.

## **RESULTS OF THE MODEL DEVELOPMENT PROCESS**

### **Models Emerging from Stepwise Process**

From a database of 790 non-driver records containing survey and GIS data in approximately 200 candidate variables, a model of 10 independent variables for Lesser Walkers and a model of 8 independent variables for Better Walkers emerged from the stepwise regression process described above. Because the stepwise process chooses only those variables with high statistical significance, these models indicate, with a high degree of certainty, which factors are related to non-driver mobility, and they also measure the extent to which these factors impact non-driver mobility. For details concerning the validity of the models, see Appendix B.

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<sup>19</sup> “0.05” significance indicates a 5% chance of assuming a relationship between the independent and dependent variables when, in fact, there is no relationship.

## Lesser Walkers Model

Dependent Variable: Leaving the Home on Survey Day

<u>Independent Variable</u>	<u>Range of Values</u>	<u>B</u>	<u>S.E.</u>	<u>Sig.</u>	<u>Exp(B)</u>
Years Over 35	0-64 (ages 18 thru 99)	-0.029	0.006	0.00	0.972
Masters Degree or Higher	0,1	1.152	0.525	0.03	3.166
Income Not Reported	0,1	-0.559	0.211	0.01	0.572
Disab. Income or Phys. Health Limits	0,1	-0.538	0.233	0.02	0.584
Group Living	0,1	-2.339	1.114	0.04	0.096
Religious Affiliation	0,1	0.535	0.205	0.01	1.707
Paralysis	0,1	-0.888	0.413	0.03	0.412
Use Walker	0,1	-0.548	0.230	0.02	0.578
# of Bus Stops within 5 miles	0-901	0.0015	0.0005	0.01	1.0015
More than 50 Blocks within Half-Mile	0,1	-1.346	0.343	0.00	0.260
Constant	n.a.	1.156	0.318	0.00	3.178

### Definitions

"B": Binary logistic model coefficient

"S.E.": Standard error

"Sig.": Significance (chance of incorrectly assuming relationship between this variable and the dependent variable)

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

## Better Walkers Model

Dependent Variable: Leaving the Home on Survey Day

<u>Independent Variable</u>	<u>Range of Values</u>	<u>B</u>	<u>S.E.</u>	<u>Sig.</u>	<u>Exp(B)</u>
Sunday Travel Day	0,1	1.925	0.677	0.00	6.852
Age^2, thousands (3)	0.3-9.8 (age 18 thru age 99)	-0.186	0.063	0.00	0.831
Ages 30 thru 61	0,1	0.981	0.346	0.00	2.666
Parent(s) in Home	0,1	1.364	0.473	0.00	3.912
Vehicles in Household or Family Vehicles in Area	0,1	0.849	0.325	0.01	2.338
Activity Location Units within Half-Mile, thousands (1)	0.0-10.4	0.175	0.093	0.06	1.192
Closest Bus Stop is within One Mile	0,1	0.767	0.356	0.03	2.153
High Property Crime Rate Locality (2)	0,1	-1.441	0.507	0.00	0.237
Constant	n.a.	0.530	0.634	0.40	1.699

### Definitions and Footnotes

"B": Binary logistic model coefficient

"S.E.": Standard error

"Sig.": Significance (chance of incorrectly assuming relationship between this variable and the dependent variable)

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

(1) "Activity Location Units" = (non-retail employees)\*1 + (retail employees)\*3

(2) More than 20 property crimes per 1,000 persons in 2005

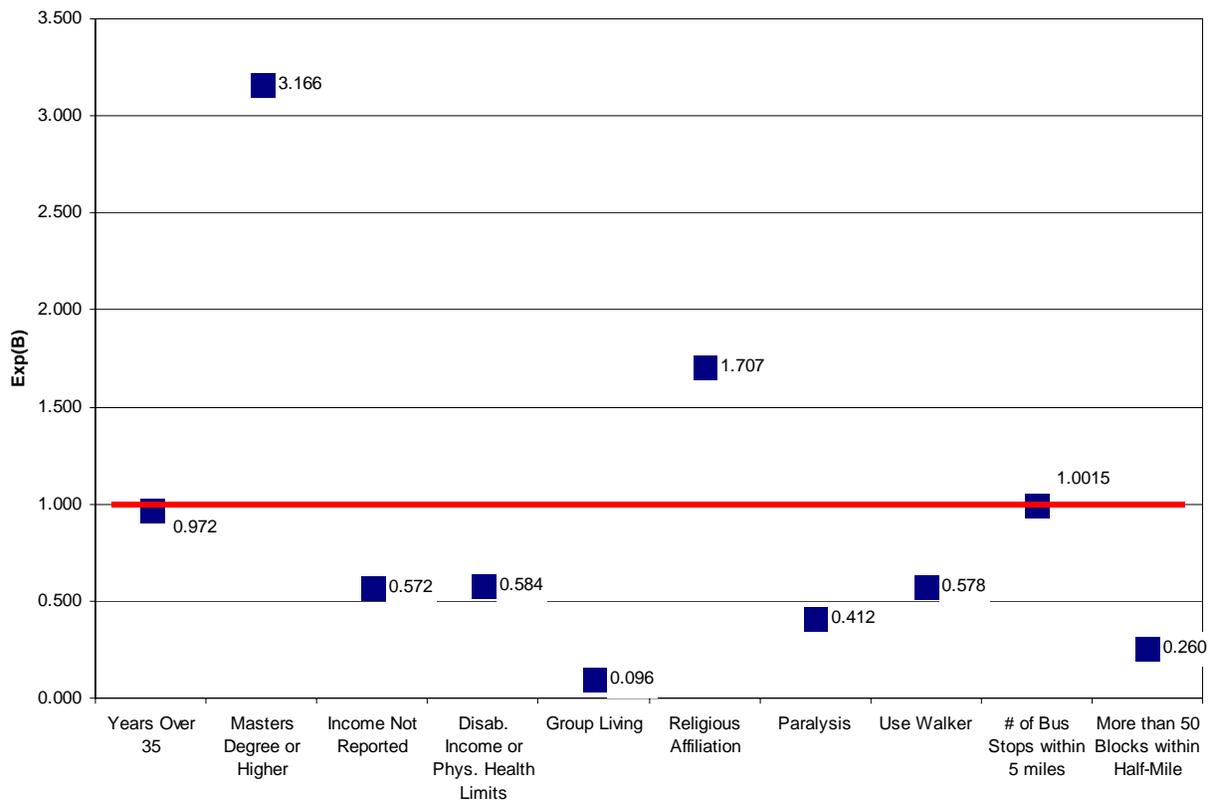
(3) The square of age was included as a candidate variable to enable the model to reflect non-linear effects of age.

## 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. 55% chance)<sup>20</sup>.

### Impact on Odds of Non-Drivers Leaving the Home, Lesser Walkers

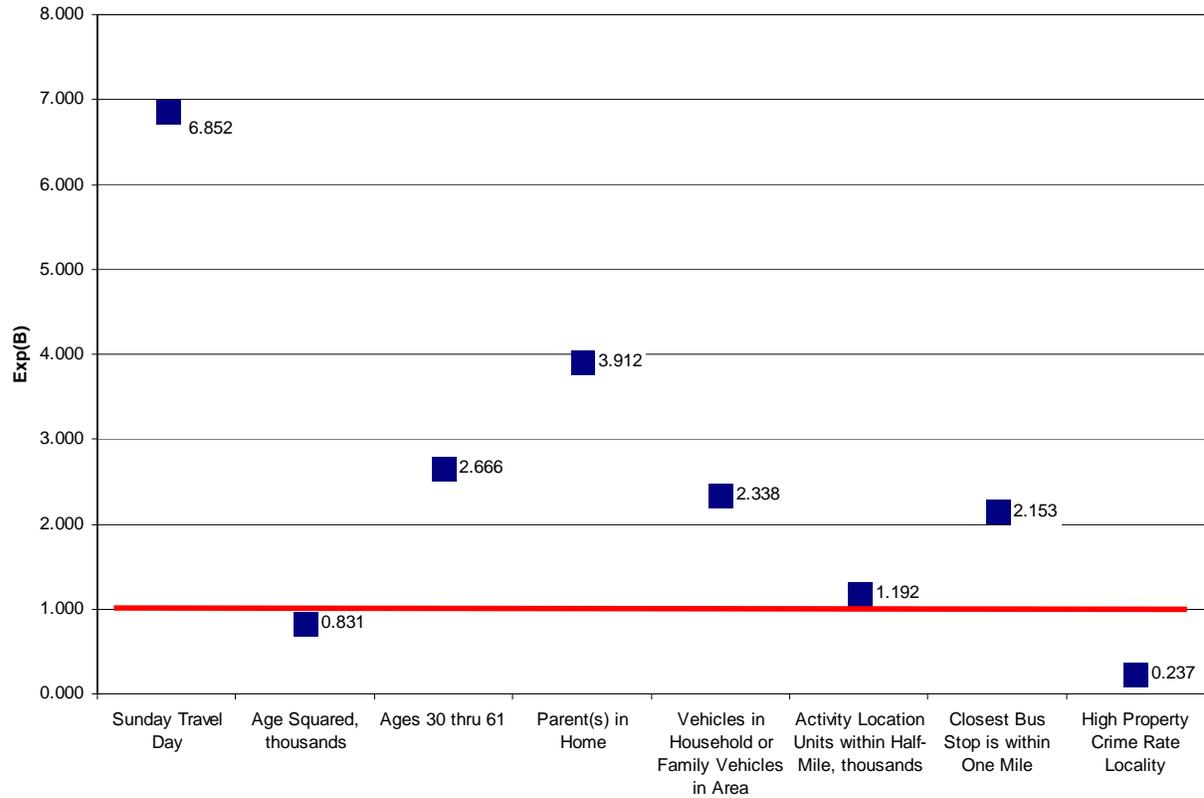


Results77.xls

Key: Factors above red line increase mobility; those below red line decrease mobility.

<sup>20</sup>  $2 \times 0.578 = 1.2$ ;  $1.2 / (1.2+1) = 55\%$

## Impact on Odds of Non-Drivers Leaving the Home, Better Walkers



Results77.xls

Key: Factors above red line increase mobility; those below red line decrease mobility.

## Findings

Findings from each of the models are presented below.

### Lesser Walkers

Examining the Exp(B) values of the Lesser Walkers model variables, one notices this surprising finding:

Smaller block size is associated with lower mobility.

This finding is surprising because a denser street network shortens walking distances. Because this model examined only lesser walkers, the negative coefficient of the “More than 50 Blocks within Half-Mile” variable indicates that this variable probably reflects some factor other than walking, such as high crime or low income.

The model results also indicate the following:

Both higher education and religious affiliation increases mobility.

Having a masters degree or higher increases the odds of getting out of the home by a factor of three<sup>21</sup>; being affiliated with a religious organization increases the odds of getting out of the home by 71%<sup>22</sup>. Perhaps the effect of educational attainment is related to higher income or a greater likelihood of working (and therefore of traveling [to work] approximately five days a week). Religious affiliation may provide the non-driver with a network of persons who can provide rides and/or a more active lifestyle.

### Key Finding: Bus Infrastructure

Considering the basic purpose of this study effort—to directly measure the mobility impact of living near transit and living within walking distance of destinations—the key finding from the Lesser Walkers model is:

Bus infrastructure appears to increase mobility, even for lesser walkers.

The odds of lesser-walking non-drivers getting out of the home on a given day appear to increase by 0.15%<sup>23</sup> for each additional bus stop within a 5 mile radius of their home. Therefore, for each increase in 100 bus stops, the odds of leaving home appear to increase by 16% ( $1.0015^{100} = 1.16$ ). 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 investments on the magnitude of that coefficient. One can assume, however,

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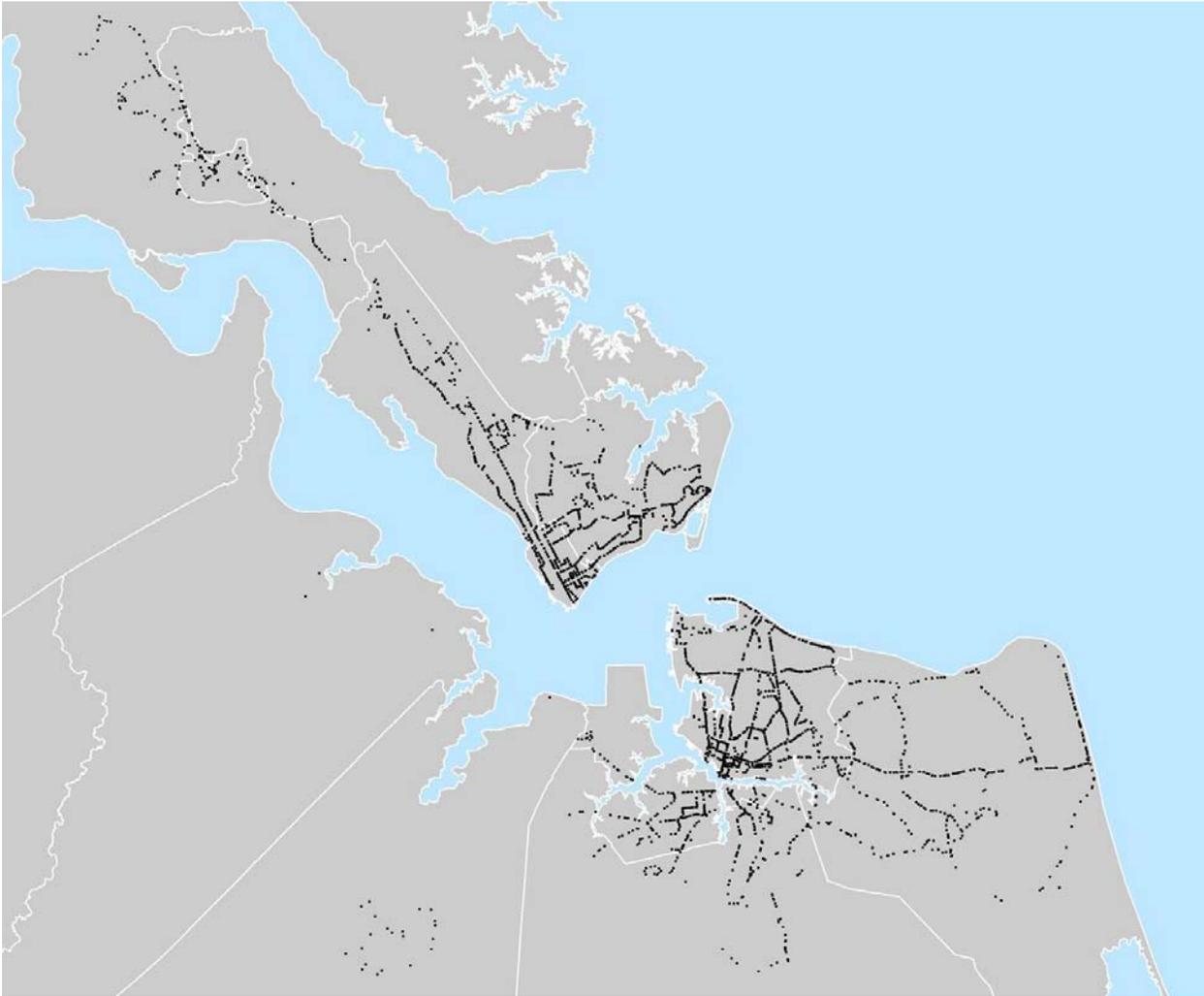
<sup>21</sup> Exp(B)=3.166, from table above.

<sup>22</sup> Exp(B)=1.707, from table above.

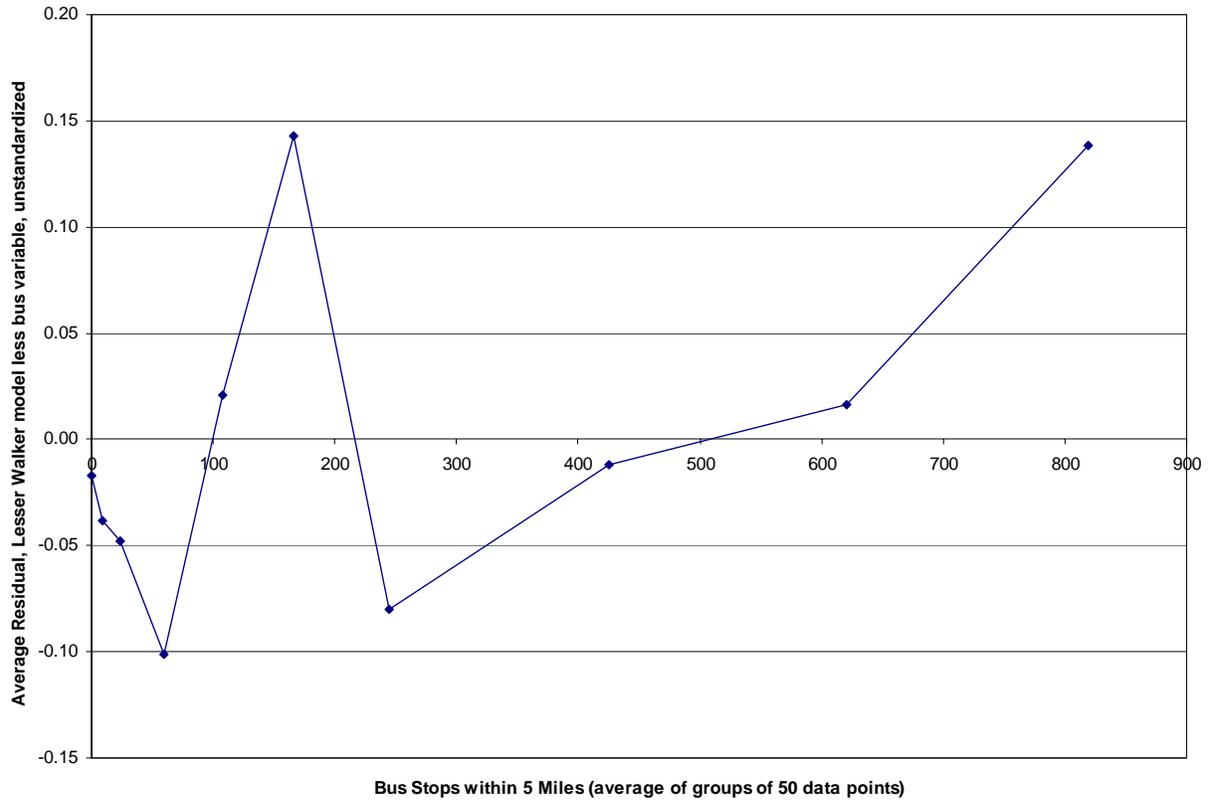
<sup>23</sup> Exp(B)=1.0015, from table above.

that some lesser walkers use the bus system, and, therefore, that improvements to bus infrastructure improves the mobility of lesser walkers.

### Bus Stops in Hampton Roads



## Mobility vs. Bus Infrastructure, Lesser Walkers



residual tests 77.xls

Although results are mixed for less than 250 bus stops, the mobility increase can be clearly seen in the group of non-drivers with the highest number of bus stops within 5 miles.

### Better Walkers

Examining the  $\text{Exp}(B)$  values of the Better Walkers model variables, one notices several useful findings. The first useful finding is:

Living with parents increases mobility.

Living with one or more parent provides odds of getting out of the home on a given day which are 4 times<sup>25</sup> higher than the odds associated with living in other situations. For young adult non-drivers, perhaps the parents provide rides; for middle-aged non-drivers, perhaps living with their parents creates a greater need for making trips.

<sup>25</sup>  $\text{Exp}(B)=3.912$ , from table above.

The second useful finding from the Better Walkers model is:

Access to vehicles increases non-driver mobility.

Non-drivers who either 1) live in a household with vehicles, or 2) have a family member in the area with a vehicle have twice<sup>26</sup> the mobility odds of non-drivers living in other situations. This is reasonable in light of the fact that most non-driver trips are made in private vehicles.

The third useful finding is:

Crime may lower non-driver mobility.

The odds of non-drivers getting out of the home on a given day decreases by 76% for those living in higher crime rate localities.<sup>27</sup> This effect is perhaps due to the fear of walking and bus-riding in localities with higher crime rates, or perhaps due to other problems associated with higher crime areas, such as fractured families and lower income.

#### Key Finding: Proximity to Destinations

Considering the basic purpose of this study effort—to directly measure the mobility impact of living near transit and living within walking distance of destinations—the first key finding from the Better Walkers model is:

Living within a half-mile of destinations increases mobility. For each increase in 1,000 Activity Location Units<sup>28</sup> within a half-mile of the better-walking non-driver, the odds of leaving home on a given day increase by 19%<sup>29</sup>. Consequently, Better-walking non-drivers living in High Activity Locations<sup>30</sup> in Hampton Roads have odds of leaving home five (5) times higher<sup>31</sup> than those living in Low Activity Locations.<sup>32</sup>

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

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<sup>26</sup>  $\text{Exp}(B)=2.338$ , from table above.

<sup>27</sup>  $\text{Exp}(B)=0.237$ , from table above.

<sup>28</sup> Activity Location Units= non-retail employees\*1 + retail employees\*3; see “Proximity to Destinations” section above.

<sup>29</sup>  $\text{Exp}(B)=1.192$ , from table above.

<sup>30</sup> “High Activity Locations” 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 “Proximity to Destinations” section above.

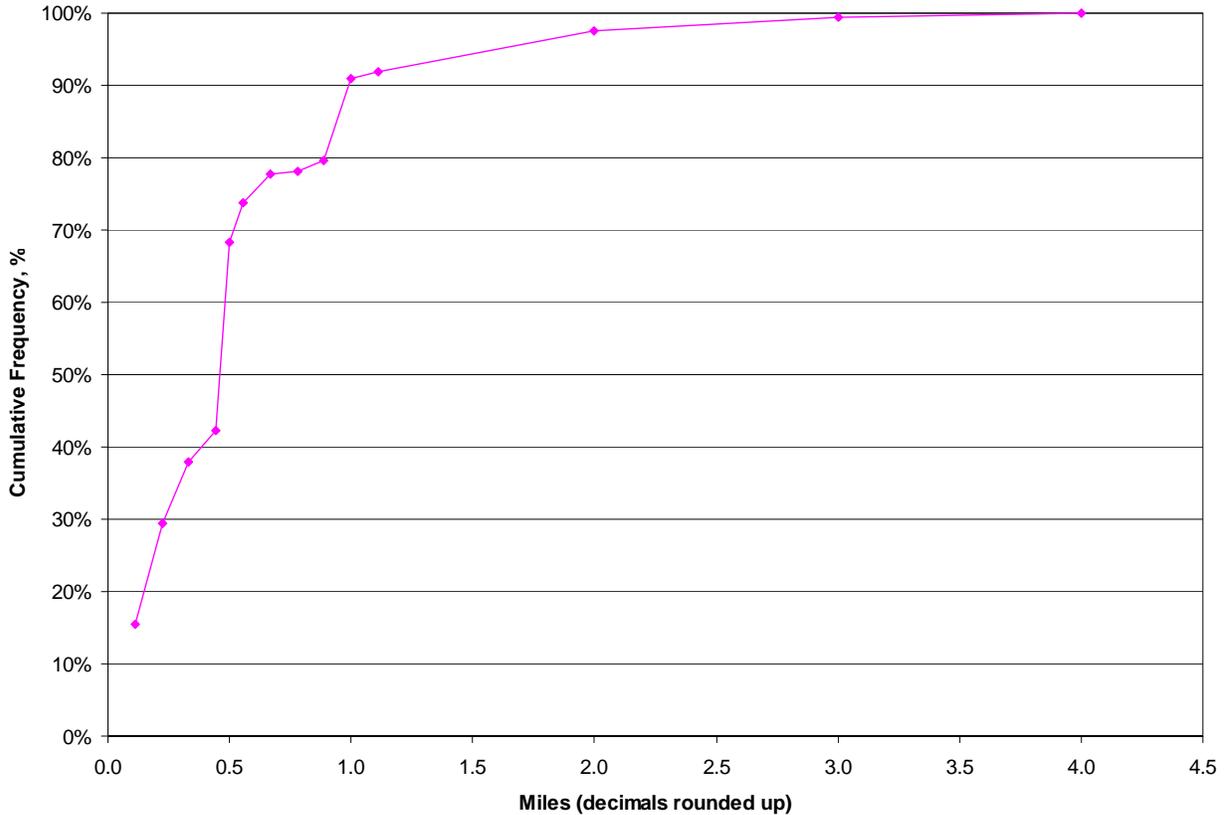
<sup>31</sup>  $1.192^{(10-0.5)}=5.3$

<sup>32</sup> “Low Activity Locations” have fewer than 1,000 Activity Location Units within a half-mile radius. Surveyed non-drivers living in “Low Activity Locations” are represented by yellow circles on map in “Proximity to Destinations” section above.

lives in a High Activity Location would have five (5) times higher odds, or an 84% chance of leaving home<sup>33</sup> on any given day. Consequently, the subject non-driver in the Low Activity Location would leave the home 15 days per month, whereas the hypothetical non-driver in the High Activity Location would leave the home 25 days per month.

The regression indicates that the half-mile radius (as opposed to the quarter-mile, one-mile, and five-mile variables also included as candidates for the model) is the most important indicator of mobility with regard to proximity to destinations. This coincides well with the NHTS which shows (as reported in chart below) that approximately 50% of all non-driver walk trips are half-mile or less. Only approximately 25% of non-driver walk trips exceed three-quarters of a mile.

**Non-Driver Walking Trip Distance, 2001 NHTS, National Sample, MSAs w/ Pop. 1 to 3 Million**

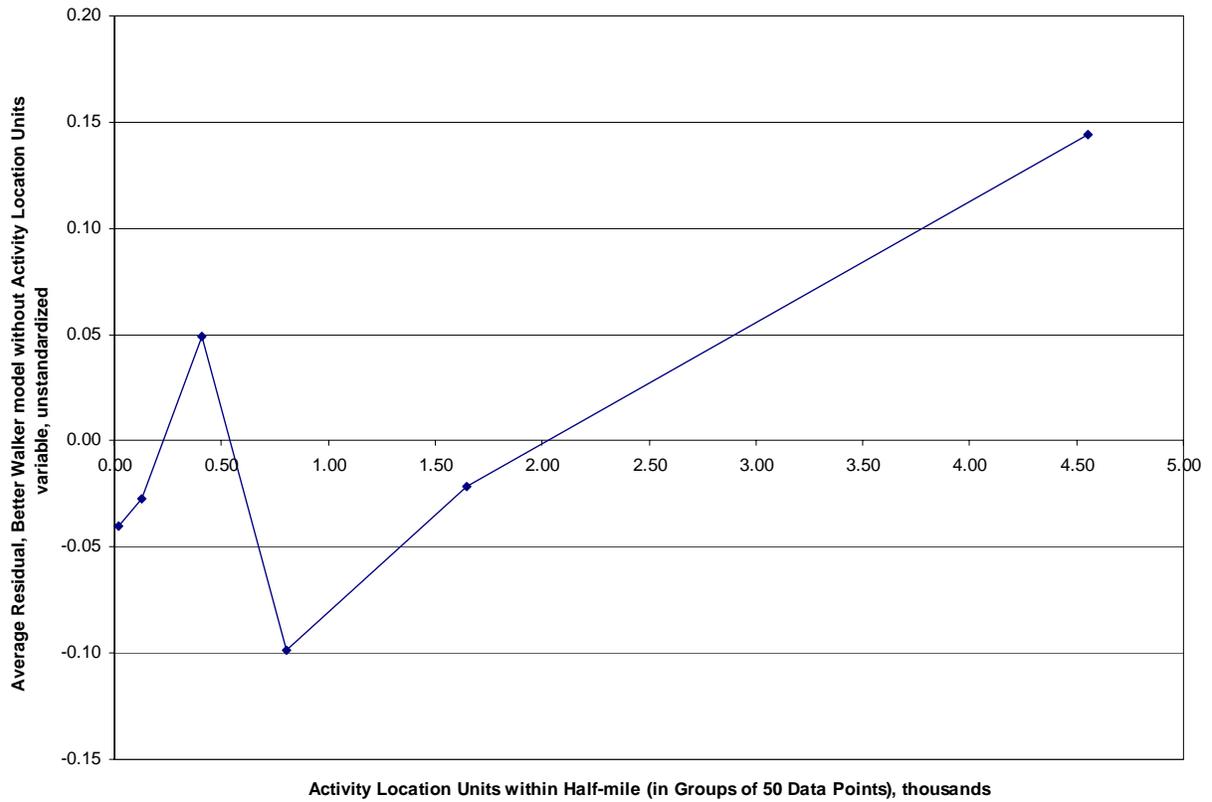


NatSam\_MSA1to3m\_Trips.xls

<sup>33</sup>  $1.192^{(10-0.5)} = 5.3$ ;  $5.3 / (5.3 + 1) = 0.84$

Although results are mixed at lower levels, the mobility increase can be clearly seen for Hampton Roads non-drivers (Better Walkers) living near higher numbers of Activity Location Units, as shown below.

**Mobility vs. Nearby Destinations, Hampton Roads, 2006**



residual tests 77.xls

## Key Finding: Proximity to Bus Stops

Considering the basic purpose of this study effort—to directly measure the mobility impact of living near transit and living within walking distance of destinations—the second key finding from the Better Walkers model is:

Living within one mile of a bus stop increases mobility, giving non-drivers who are better walkers twice<sup>34</sup> the odds of getting out of the home than the odds of those who do not live near 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 68% chance of leaving home.<sup>35</sup> Consequently, the subject non-driver living away from a bus route would leave the home 15 days per month, whereas the hypothetical non-driver living within one mile of a bus route would leave the home 20 days per month.

The fact that the stepwise regression process selected the bus stop variable with a one-mile maximum distance between home and bus stop for considering a non-driver to have access to the bus system (as opposed to the quarter-mile and half-mile variables also included as candidates for the model) indicates the importance of the one-mile distance when planning the location of bus routes or housing. The length of this distance is surprising. According to Asha Weinstein et al:

“Conventional wisdom among planners has often been that pedestrians in the U.S. will only walk a quarter to a third of a mile for any reason, including to access transit.”<sup>36</sup>

An analysis by HRPDC staff of the distances between home and nearest bus stop of those who reported using the bus (in the HRPDC non-driver survey) revealed that use of bus is fairly consistent up to a one mile distance (as shown below), confirming the regression result.

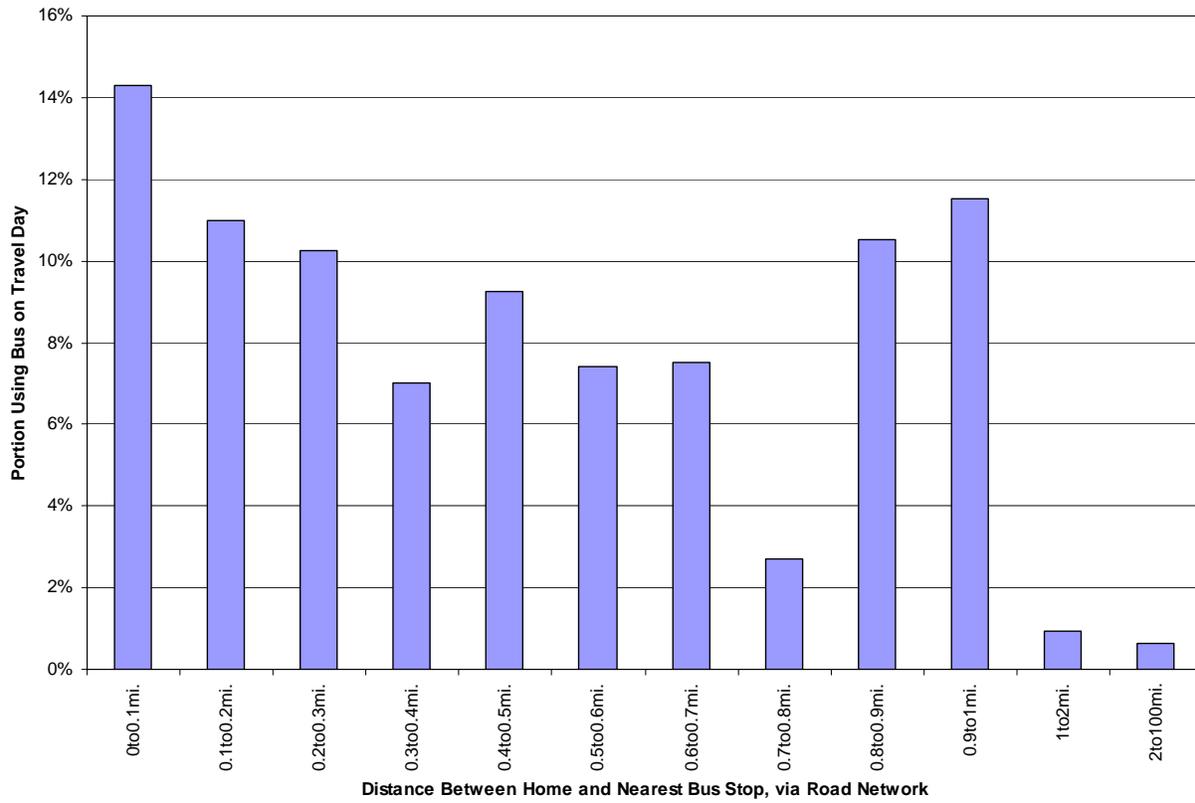
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<sup>34</sup>  $\text{Exp}(B)=2.153$ , from table above.

<sup>35</sup>  $1 * 2.153 = 2.153$ ;  $2.153 / (2.153 + 1) = 0.68$

<sup>36</sup> “How Far, by Which Route, and Why? A Spatial Analysis of Pedestrian Preference”, Asha Weinstein (corresponding author), TRB 86<sup>th</sup> Annual Meeting, Compendium of Papers, 2007, pg. 12.

## Use of Bus vs. Distance to Bus Stop, Hampton Roads, 2006



prep of modal related variables.xls

Ms. Weinstein also found that actual walking distances to public transit are longer than previously assumed:

“A paper from the mid-1990s looking at how far transit agencies and transportation modelers assume that pedestrians will walk to light rail stations found very short distances, most well under a half mile. The results of our study suggest quite differently, at least for walk trips to access rail transit. The median trip distance was 0.47 miles, showing that fully half the people surveyed walked *at least* a half mile to access the train station. These results suggest that transportation and land-use planners designing transit-oriented developments should assume many train riders will walk considerably farther than they may have previously thought, at least for commute trips.”<sup>37</sup>

Ms. Weinstein’s findings concerning longer distances for walking to rail transit are comparable to the HRPDC staff findings concerning longer distances for walking to bus transit.

<sup>37</sup> “How Far, by Which Route, and Why? A Spatial Analysis of Pedestrian Preference”, Asha Weinstein (corresponding author), TRB 86<sup>th</sup> Annual Meeting, Compendium of Papers, 2007, pg. 12.

## Summary of Key Findings

In accordance with the basic purpose of this study effort—to directly measure the mobility impact of living near transit and living within walking distance of destinations—the key findings of this study are:

- 1) Bus infrastructure increases non-driver mobility
  - i. For lesser-walking non-drivers, the odds of getting out of the home on a given day increase for each additional bus stop within a 5 mile radius of their home.
  - ii. For better-walking non-drivers, living within one mile of a bus stop doubles the odds of getting out of the home.
- 2) Living within a half-mile of destinations increases non-driver mobility
  - iii. Better-walking non-drivers living in High Activity Locations in Hampton Roads have odds of leaving home five times higher than those living away from activities.

## **RECOMMENDATIONS**

The findings from the regression of local survey and GIS data led staff to the following recommendations for local governments desiring to improve non-driver mobility.

### **BUS INFRASTRUCTURE**

Given the demonstrated improvement in the mobility of non-drivers living near bus stops:

Local governments can measurably increase the mobility of non-drivers by directing resources to improve the bus infrastructure.

Given the finding that local bus riders are walking up to one mile to bus stops, and given the measured impact on non-driver mobility of living within one mile of a bus stop:

New 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.

### **PEDESTRIAN INFRASTRUCTURE**

Given the demonstrated importance of walking (for both walking and bus trips) to the mobility of non-drivers:

Local governments may be able to increase the mobility of non-drivers by directing resources to improve pedestrian infrastructure (sidewalks, street furniture, pedestrian overpasses, etc.).

### **GOVERNMENT FACILITIES**

Given the demonstrated improvement in the mobility of non-drivers living near destinations:

Local governments can measurably increase the mobility of non-drivers by locating government facilities near existing and planned locations of large numbers of residences.

For example, locating recreation centers, schools, and libraries near higher-density residential areas will improve the mobility of many non-drivers.

### **ZONING AUTHORITY**

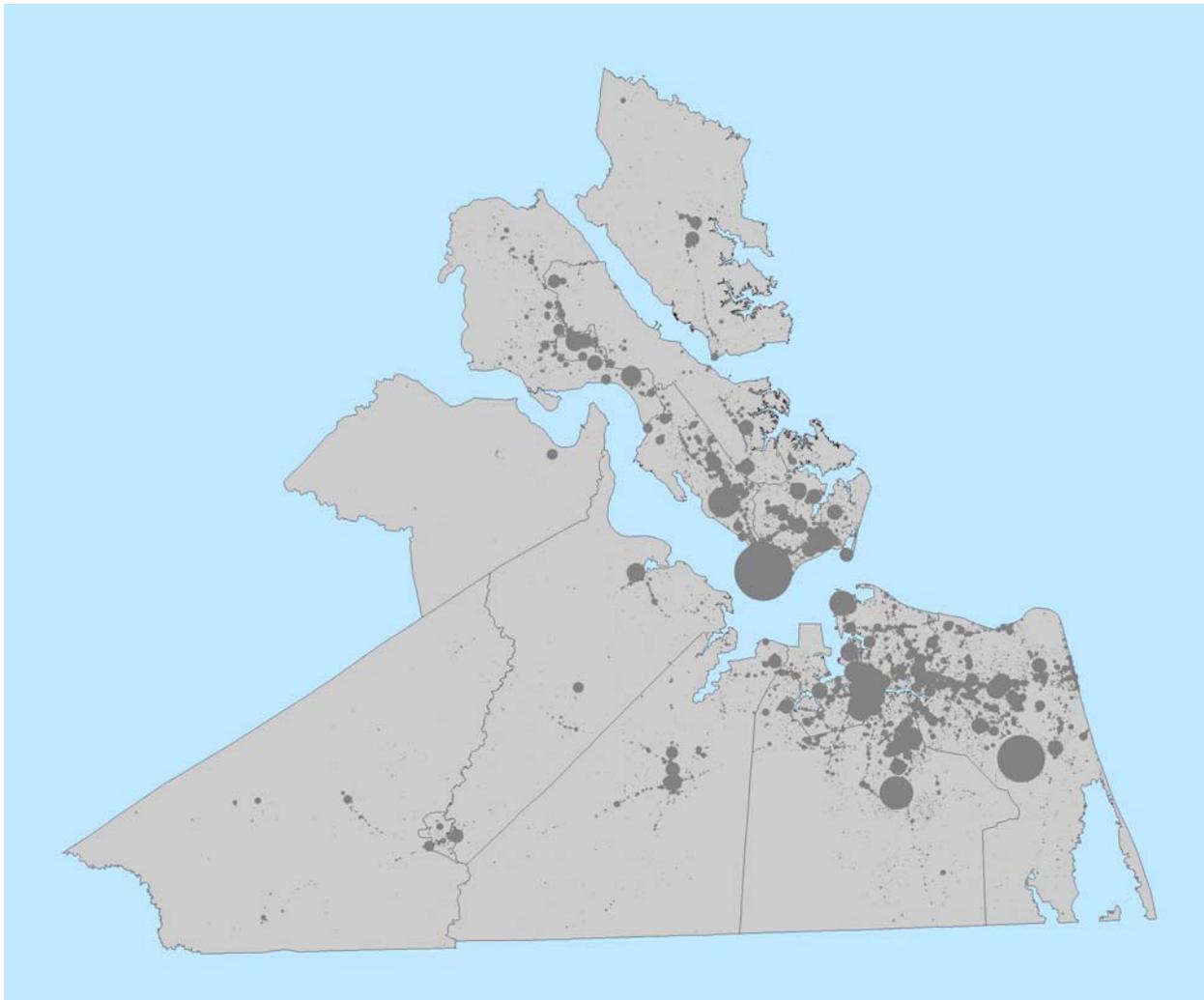
Given the demonstrated improvement in the mobility of non-drivers living near destinations:

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 in existing High Activity Locations
- 2) Adequate numbers of activity locations (businesses, institutions, etc.) are allowed to be built near existing high-density residential locations
- 3) New developments containing a mixture of both activity locations and residences are allowed to be built

Concerning recommendation #1 above, allowing many residences to be built near the activity locations shown below will improve non-driver mobility.

### Activity Location Units in Hampton Roads



HR- emp attr units.jpg

Key: The largest dot (NN Shipbuilding) contains 18,000 Activity Location Units.

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.

## APPENDICES

## APPENDIX A- REGRESSION PROCESS

The regression models presented in this document emanated from an extensive regression process.

First, HRPDC staff conducted a forward regression on the whole data set. The resulting model contained only one geographic variable (“percent of workers in local traffic analysis zone who used ‘other’ modes [taxi, motorcycle, etc.] to work in 2000 census”), and that one variable seemed unrelated to real mobility.

Throughout the modeling process, on finding unsatisfactory results (such as those for the first model above), staff returned to improving the input data set. In an attempt to reveal the explanatory power of the proximity variables (i.e. those variables which measure proximity to destinations and proximity to bus routes), new variables were added to the candidate variable data set. Some of these new variables came from new factors considered possibly important. For example, understanding that non-drivers may be reluctant to walk to stores and stand at bus stops in high crime areas, various crime-related variables were developed and added as candidate variables. Other new variables came from re-working existing variables. For example, the regression was originally run using geographic variables which measured the attractiveness of destinations within one-quarter mile and one-half mile of the surveyed non-drivers’ home. However, considering the finding that non-drivers walk up to one mile to bus stops (discussed above), additional variables were developed using larger buffers (1 mile and 5 miles).

In an attempt to account for interaction between variables that could mask the impact of the geographic effects being investigated by the study (i.e. proximity to destinations and proximity to public transit), staff split the data set into subsets (two at a time) based on various variables expected to have an impact on mobility (e.g. age, income, health, gender, access to vehicles, and ability to walk). The models resulting from the split based on the ability to walk—the Lesser Walkers model and the Better Walkers model—contained variables logically related to mobility, contained logical variable coefficient signs, and measured the impact of proximity. Therefore, these two models were retained for usage in the development of recommendations to improve non-driver mobility.

## APPENDIX B- 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 coefficient signs
- Influence points
- Normality
- Homoscedasticity
- Linearity
- Independence of error terms

#### Logical Coefficient Signs

HRPDC staff examined the signs (i.e. positive vs. negative) of the independent variable coefficients (“B” values in above tables) for reasonableness and found them to be logical. For example, in the Lesser Walkers model it is reasonable that mobility decreases with age (all other variables being held constant).

#### Influence Points

Influence points are individual outliers in the data which have an inordinate (and therefore undesirable) impact on the model results. The Lesser Walkers model contained only two scalar independent variables (i.e. variables of concern for influence): “Years Over 35” and “# of Bus Stops within 5 miles”. Plots of both of these variables revealed no outliers, eliminating the concern over influence points for this model.

The Better Walkers model also contained two scalar variables: an age variable (“age squared”) and a proximity variable (“Activity Location Units within a Half-Mile”). Concern over influence points in the age variable was eliminated based on the lack of outliers noted above, but a plot of the proximity variable revealed outliers. In order to test the influence of the outliers, regressions were performed both with and without the outliers, and then the results were compared. Finding similar results, concern over influence points for this model was eliminated.

#### Normality

The validity of regression analyses is subject to the normality of the variables involved. According to Hair et al in their textbook *Multivariate Data Analysis*:

“...larger sample sizes reduce the detrimental effects of nonnormality.”  
“For sample sizes of 200 or more...these same effects [on the results] may be negligible.”

“Thus, in most instances, as the sample sizes become large, the researcher can be less concerned about nonnormal variables....”<sup>38</sup>

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.

### Homoscedasticity

The validity of regression analyses is subject to homoscedasticity, i.e. equal variance of the population error over the range of predictor values. For this analysis, the dependent variable (“Leaving the Home on Survey Day”) being dichotomous (and therefore having no range of values), homoscedasticity is not a concern.

### Linearity

The validity of regression analyses is subject to the linearity of the relationship between the independent variables (IV) and the dependent variable (DV). The Lesser Walkers model contains two variables of concern for linearity due to their metric nature (i.e. having a range of values). (The other IVs in this model are dichotomous variables and therefore not subject to linearity concerns.) The metric variable “# of Bus Stops within 5 miles” was checked for linearity by preparing a model without that variable and then examining a plot of residuals (the difference between predicted and actual values of the DV) vs. “# of Bus Stops within 5 miles”. No evidence of non-linearity was evident for this variable. Staff allowed for non-linearity in the other metric variable in the Lesser Walker model (“Years Over 35”) by including an “age squared” variable in the set of candidate IVs.

As in the case of the Lesser Walkers model, the Better Walkers model contains two metric variables. “Activity Location Units within Half-mile” was checked via a plot of residuals (as described above for the other model) and no evidence of non-linearity was found. Non-linearity in the effects of age were accounted for by the other metric variable in this model, “Age<sup>2</sup>” (age squared).

### Independence of Error Terms

The validity of regression analyses is subject to the independence of error terms. According to Hair, “we can best identify such an occurrence [independence] by plotting the residuals against any possible sequencing variable.”<sup>39</sup> Therefore staff plotted residuals vs. travel date for each model. The residuals of the later surveys tending to have lower values than those from earlier surveys provided some evidence that the date of the surveys had an impact on the survey data. This concern was assuaged, however, by the inclusion of the candidate variable “Post-Revision Survey” which

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<sup>38</sup> *Multivariate Data Analysis*, Hair et al, pg's 80,81.

<sup>39</sup> *Multivariate Data Analysis*, Hair et al, pg. 207.

indicated whether or not the subject survey was taken after the survey script was slightly revised.<sup>40</sup>

## 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<sup>41</sup>, it is important to examine the degree to which the models reflect the data by measuring percentage correct, goodness-of-fit, and reduction in errors, as follows:

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 can be measured by R-Square<sup>42</sup> ( $R^2$ ) as follows:

- Lesser Walkers model:  $R^2 = 0.23$
- Better Walkers model:  $R^2 = 0.33$

The reduction in errors is measured by “Tau”, the percentage of fewer errors achieved via the subject model than by chance, as follows:

- Lesser Walkers model: Tau=30%
- Better Walkers model: Tau=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 many variables which are statistically-significant 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.

## Overall Assessment of the Model

Given the high level of statistical significance of the variables included in the models (as shown by “Sig.” values in the “Models Emerging” section above), the logical nature of the sign of the coefficients of the variables in the models, the satisfactory survey of the threats to model validity, and the degree to which the model outputs match the input data, it appears that the models are reliable for use in developing ways of improving the mobility of non-drivers.

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<sup>40</sup> Due to privacy concerns, the income and religious-affiliation questions were made optional in the midst of the multi-week process of collecting surveys.

<sup>41</sup> See “Sig.” values in “Models Emerging” section above for actual significance levels.

<sup>42</sup> “Nagelkerke R Square” is used to measure the goodness-of-fit of binary logistic models.