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THE EFFECTS OF AGE ON THE DRIVING HABITS OF THE ELDERLY:

Evidence from the 1990 NPTS

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16. Abstract

This report examines the effects of age on the driving habits of the elderly, using the 1990 Nationwide Personal Transportation Survey (NPTS). Elderly is defined as persons 65 years or older. Six aspects are considered: the amount of daily driving exposure, driving by time of day, driving speed, driving by type of roadways, vehicle size, and the number of passengers carried. The scope of analysis is limited to the content of the 1991 NPTS and those aspects of driving habits that are hypothesized to have safety implications for the elderly. The scale of analysis is limited to urban residents. Regression is used to isolate the effects of being elderly while holding constant a set of personal, household, and location characteristics of the drivers, as well as a set of trip characteristics. Elderly drivers show an increased effort of self-protection in their driving habits relative to mid-aged drivers (persons between the ages of 25 and 64 years). Being elderly not only makes elderly drivers reduce daily driving exposure, avoid driving at night, avoid driving during peak hours, and avoid driving on limited-access highways, but also make them drive at lower speeds, drive larger automobiles, and carry fewer passengers. Despite their effort of self-protection, however, the elderly still show a higher risk of crash and injury per unit of exposure than the mid-aged. If policies induce the elderly to further adjust their driving habits to offset the external risks of their driving, their risk of crash and injury would be reduced and society as a whole would be better off. The elderly, however, are likely to be worse off as a consequence of reduced mobility. The challenge to policy-making is to balance these consequences of any policy concerning the mobility and traffic safety of the elderly.

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ABSTRACT

The Effects of Age on the Driving Habits of the Elderly:
Evidence from the 1990 NPTS

This report examines the effects of age on the driving habits of the elderly, using the 1990 Nationwide Personal Transportation Survey (NPTS). Elderly is defined as persons 65 years or older. Six aspects are considered: the amount of daily driving exposure, driving by time of day, driving speed, driving by type of roadways, vehicle size, and the number of passengers carried. The scope of analysis is limited to the content of the 1991 NPTS and those aspects of driving habits that are hypothesized to have safety implications for the elderly. The scale of analysis is limited to urban residents. Regression is used to isolate the effects of being elderly while holding constant a set of personal, household, and location characteristics of the drivers, as well as a set of trip characteristics. Elderly drivers show an increased effort of self-protection in their driving habits relative to mid-aged drivers (persons between the ages of 25 and 64 years). Being elderly not only makes elderly drivers reduce daily driving exposure, avoid driving at night, avoid driving during peak hours, and avoid driving on limited-access highways, but also make them drive at lower speeds, drive larger automobiles, and carry fewer passengers. Despite their effort of self-protection, however, the elderly still show a higher risk of crash and injury per unit of exposure than the mid-aged. If policies induce the elderly to further adjust their driving habits to offset the external risks of their driving, their risk of crash and injury would be reduced and society as a whole would be better off. The elderly, however, are likely to be worse off as a consequence of reduced mobility. The challenge to policy-making is to balance these consequences of any policy concerning the mobility and traffic safety of the elderly.

Chapter 1
INTRODUCTION

The mobility and traffic safety of elderly drivers are of great concern to the public.[1] Much of this concern is due to the fast growth in the number of elderly drivers and their driving. This report examines the effects of age on the driving habits of the elderly in the United States, as revealed in the 1990 Nationwide Personal Transportation Survey (NPTS).[2] Six aspects of driving habits are considered that are hypothesized to have safety implications for the elderly. A good understanding of the driving habits of the elderly is essential not only to the provision of public transportation to the elderly but also to the design of policies that address the mobility and traffic safety of the elderly.

BACKGROUND

Between 1985 and 1989, three national conferences were held to discuss issues on the mobility and traffic safety of elderly drivers.[3] Initiated in 1986 by the Transportation Research Board (TRB), the U.S. Congress requested in the Surface Transportation Assistance Act of 1987 "a comprehensive study and investigation of (1) problems which may inhibit the safety and mobility of elderly drivers using the Nation's roads and (2) means of addressing these problems."[4] In 1987, Congress asked the U.S. Department of Transportation to implement a pilot program of highway safety improvements to enhance the mobility and traffic safety of elderly drivers.[5] In addition, elderly drivers frequently make headlines in major magazines and newspapers across the nation.[6]

The number of elderly drivers grew from 8.6 million in 1970 to 22.3 million in 1990, an increase of 148 percent, while the number of all drivers grew by 50 percent during the same period. The number of elderly drivers as a proportion of all drivers also increased from 8.0 percent in 1970 to 13.3 percent in 1990.[7] These increases reflect the growth in the elderly population as well as in its licensure rate. The elderly population grew from 20.0 million in 1970 to 31.1 million in 1990, an increase of 56 percent, while the population of age 15 years or older grew by 34 percent during the same period.[8] The licensure rate of the elderly population increased from 45 percent in 1970 to 72 percent in 1990, while the licensure rate of the population of age 15 years or older increased from 77 percent in 1970 to 86 percent in 1990.[9]

The number of miles driven by the elderly has grown more than the elderly population and its licensure rate. The elderly drove 42.2 billion miles in 1969 and 153.7 billion miles in 1990, an increase of 264 percent. The rate of growth for all drivers was 142 percent. The share of miles driven by the elderly increased from 4.9 percent in 1969 to 7.1 percent in 1990.[10]

These trends are expected to continue. By the year 2020, the elderly population is expected to reach 20 percent of all persons. The number of elderly drivers is likely to exceed 20 percent of all drivers.[11]

ISSUES AND HYPOTHESES

This report considers six aspects of driving habits. These aspects include the amount of daily driving exposure, driving by time of day, driving speed, driving by type of roadways, vehicle size, and the number of passengers carried. The scope of analysis is limited to the content of the 1990 NPTS and to those aspects of driving habits that are hypothesized to have safety implications for the elderly. The scale of analysis is limited to urban residents.

In addition to age, other personal, household, and location characteristics of the elderly also may influence their driving habits. Personal characteristics include educational attainment and labor force participation. Household characteristics include race, annual income, composition (size, children), and vehicle ownership. Location characteristics include the household location in an urban area (central city vs. suburbs), the household location in the nation (the West vs. other regions), the size of an urban area, and the population density of an urban area.

Many of these characteristics may differ systematically between the elderly and others. Labor force participation changes with aging. Household income may decline with retirement from the labor force. Household composition may change with aging. For example, the elderly are less likely to live with young children than are younger persons. Vehicle ownership may change with aging due to changes in household composition and income. Household location may change with aging. For example, the elderly may be more likely to live in the suburbs and in the South. The elderly have more time available for travel during the day.

The elderly also may differ from others in their activity patterns. The elderly may choose to participate in activities that occur less frequently (e.g., once a month instead of once a week). They may choose to participate in activities that are closer to their homes. Or they may move closer to activities in which they choose to participate. They also may choose to participate in activities that occur during the day or off-peak hours. However, the literature provides no evidence of these hypothetical changes in the activity patterns of the elderly.

It is important to control for the characteristics that differ systematically between the elderly and others in order to isolate the effects of age on the driving habits of the elderly. It is also important to control for these characteristics in order to draw conclusions about the driving habits of the future's elderly from the driving habits of today's elderly because many of these characteristics may change in the future for the elderly. For example, the future's elderly may have higher vehicle ownership than today's elderly. The future's elderly also may be more likely to live in the suburbs than today's elderly.

The elderly differ from others in two other important characteristics that have not been discussed. First, the majority of the elderly are not employed and will remain unemployed for the rest of their lives. The elderly, therefore, would lose less than younger persons in future labor earnings from an injury. According to the foregone-labor-earnings approach to measuring motor vehicle crash costs, elderly drivers are likely to have lower costs of injuries than younger drivers.[12]

Second, cognitive and physical abilities generally decline with aging.[13] One consequence of this decline is that the driving skills of the elderly are reduced. As a result, elderly drivers are more likely to be involved in crashes than all drivers, except those under the age of 25 years.[14] In the majority of crashes in which elderly drivers were involved, they were at fault for failing to yield the right-of-way, turning improperly, ignoring traffic signals, or starting improperly into traffic.[15] Another consequence of the decline in their physical abilities is that the elderly are more likely to be injured than younger persons in a crash.

These two important characteristics of the elderly may have two opposite effects on their driving habits. On the one hand, elderly drivers may be more willing than younger drivers to take risks because of their reduced costs of injuries. On the other hand, elderly drivers may compensate for their increased crash and injury risks. This behavior of risk compensation can manifest itself in many ways. The elderly may drive fewer miles to reduce exposure. They may feel less comfortable with carrying passengers. They may find certain driving conditions difficult, such as driving at night, during peak hours, at high speeds, or on limited-access highways. They also may feel vulnerable to the low crashworthiness of small vehicles.

While this study controls for many of the personal, household, and location characteristics of the elderly discussed earlier, it does not, however, control for the two important characteristics just discussed. It is hypothesized that the relative strengths of these two characteristics determine the effects of age on the driving habits of the elderly.

PREVIOUS STUDIES

No known previous study exists that looks at the size of vehicles that the elderly drive or the number of passengers they carry. Previous studies on the amount of driving exposure, driving speed, driving by time-of-day, and driving on limited-access highways by the elderly have one drawback: they often fail to control simultaneously for many factors that may influence the driving habits of the elderly. This drawback has two implications. On the one hand, any observed difference in the driving habits between the elderly and others may be a mix of the differences in age and other personal, household, and location characteristics of the drivers that are not controlled for in these studies. On the other hand, any difference observed in the driving habits of today's elderly and others is unlikely to hold true in the future because those personal, household, and location characteristics of the drivers that are not controlled for may change in the future.

The evidence from previous studies is mixed. Studies have found "no evidence that elderly drivers who exhibit poor performance on driving simulators make any compensating adjustment in the amount of driving exposure."[16] One reason given is that elderly drivers are unaware of the changes in their cognitive and physical abilities and those driving conditions that become more difficult as age advances. The other reason given is that elderly drivers are unwilling to admit lack of driving competence or to significantly reduce exposure. Several U.S. studies, however, find that elderly drivers reduce exposure more as they age and tend to avoid high-risk conditions, such as driving at night and during peak hours.[17] A Canadian study concludes that "increased driver risk due to medical conditions among elderly drivers was more than offset by their adoption of new, less risky driving patterns."[18]

APPROACH AND ORGANIZATION OF THE REPORT

This study uses regression analysis to isolate the effects of age on the driving habits of the elderly. Regression analysis accomplishes this isolation by including variables measuring the age as well as a set of other personal, household, and location characteristics of the drivers. It is important to control for factors that aging may affect. It is also important to control for factors that aging does not affect, such as gender and race. Under this regression framework, this study attempts to determine whether or not age affects the driving habits of the elderly and, if so, what the size and nature of the effects are.

This report is organized into six chapters. Chapter 1 is this introduction. Chapter 2 describes the 1990 NPTS and the variables that are used in this study. Chapter 3 examines the effects of age on how much the elderly drive. The aspects examined include the number of daily vehicle miles driven by individual drivers, the number of daily vehicle trips taken by individual drivers, and the distance of individual vehicle trips. Chapter 4 examines the effects of age on when the elderly drive. The aspects examined include driving at night and during peak hours. Chapter 5 examines the effects of age on how the elderly drive. The aspects examined include driving speed, driving on limited-access highways, vehicle size, and the number of passengers carried. Chapter 6 summarizes the main results and discusses policy implications of these results.

Chapter 2
THE 1990 NATIONWIDE PERSONAL TRANSPORTATION SURVEY (NPTS)

This chapter describes the 1990 NPTS and defines the variables that are used in this study. The 1990 NPTS compiles data on a cross-section of personal travel in the United States for all purposes and surface modes of transportation in 1990-1991.

SURVEY

The 1990 NPTS was conducted between March 1990 and March 1991 using random-digit dialing and computer-assisted telephone interviewing. The sample was stratified by geography, quarter-of-year, month-of-quarter, and day-of-week. A total of 73,579 telephone numbers was randomly selected to identify 26,172 households. Each of the identified households was contacted for an interview. A total of 21,869 households participated. Each of the participating households was assigned a 24-hour "travel day" and a 14-day "travel period."

For each participating household, a household-level interview was conducted with an adult resident of the household. This interview obtained information on the number of household vehicles, household location, and household income. In addition, a roster containing person data for each resident of the household was completed.

A person-level interview was attempted for each resident of the participating households who was five years or older. The person-level interview was completed for 47,499 household residents. Each resident older than 13 years was asked to report all trips they had taken during the travel day, as well as trips of 75 miles or longer taken during the travel period. A "knowledgeable" household resident, older than 13 years, was asked to report all trips taken by household residents between the ages of 5 and 13 years.

The 1990 NPTS data for this study are contained in four files in the Statistical Analysis System (SAS) format. The four files are the Household File, Person File, Vehicle File, and Travel Day File. The Household File contains household characteristics for 22,317 observations. The information collected includes household race, household income, household size, and household location, such as census region, the location in an urbanized area, the size of an urbanized area, and the population density of a zip-code area. Also included are the sunrise and sunset times associated with the travel day.

The Person File contains the person-level attributes for 48,385 residents of the participating households. The information collected includes the age, educational attainment, driver's license status, and labor force participation of each household resident. Participating in the labor force means being employed or actively looking for employment. The Person File also contains the number of vehicle miles and the number of vehicle trips taken by each resident on the travel day.

The Vehicle File contains the attributes for 41,178 vehicles in the participating households. The information collected includes the model year, make, model, and main driver of each vehicle.

The Travel Day File contains the attributes of 149,546 trips taken by residents of the participating households on the travel day. The information collected includes the purpose, mode, occupancy, length (both duration and distance), time-of-day, day-of-week, and month-of-year of each trip. The survey also randomly selected a private-vehicle trip for each resident of the participating households (if any) to collect information on the various types of roadways that were used on this trip. A total of 31,015 such trips was sampled. The distance for each of these trips was broken down by roadway classification.

Weights were developed in the 1990 NPTS to reflect the sample design and selection probabilities, and survey non-response or non-coverage. The Household and Vehicle Files have the same weight variable. The Person and Travel Day Files have separate weight variables. A weight variable was also developed for the randomly selected private-vehicle trips.

VARIABLES

The variables used in this study are defined in Table 2.1. They are organized into five groups: personal, household, location, trip, and vehicle characteristics.

Table 2.1 Definition of variables

Variable	Definition
Personal Characteristics	
Age>=65	1 for persons age 65 years or older; 0 otherwise
Age<=24	1 for persons age 24 years or younger; 0 otherwise
Male	1 for males; 0 otherwise
Education>high school	1 for persons with above high school education; 0 otherwise
Worker	1 for persons in the labor force; 0 otherwise
Household Characteristics	
White	1 for White households; 0 otherwise
Black	1 for Black households; 0 otherwise
Hispanic	1 for Hispanic households; 0 otherwise
Single	1 for persons from single-person households; 0 otherwise
Household size	number of household residents
# adults	number of adult household residents
# old children	number of household residents age 5 to 22 years
# young children	number of household residents age 5 years or younger
# vehicles	number of household automobiles and trucks
No vehicle	1 for households with no automobiles or trucks; 0 otherwise
Income category	level of household income on a scale from 1 to 17
Location Characteristics	
Central city	1 for households in central cities; 0 otherwise
Urbanized-area size	size of an urbanized area on a scale from 1 to 5
Population density	persons per 1000 square miles for household zip-code area
North East	1 for households in the North East region; 0 otherwise
North Central	1 for households in the North Central region; 0 otherwise
South	1 for households in the South region; 0 otherwise
Trip Characteristics	
Dark	1 if started after sunset and before sunrise; 0 otherwise
Peak hours	1 if started from 6:30-9:00 a.m. or 3:30-6:00 p.m.; 0 otherwise
Weekend	1 if made from 4:00 AM Saturday-3:59 AM Monday; 0 otherwise
Carpool	1 if there are more than one occupant; 0 otherwise
Distance	reported distance in miles
Winter	1 if made in December, January, or February; 0 otherwise
Speed	ratio of reported distance and duration in miles per hour (mph)
Work-related	1 for commuting and other work-related purposes; 0 otherwise
Shopping	1 for shopping purpose; 0 otherwise
Other family/personal	1 for other family or personal business; 0 otherwise
Medical	1 for medical purpose; 0 otherwise
Visiting friends/relatives	1 for purposes of visiting friends or relatives; 0 otherwise
Other social/recreational	1 for other social or recreational purposes; 0 otherwise
Vehicle Characteristics	
Vehicle age	the difference between 1990 and vehicle model year
Import status	1 for vehicles with foreign brand names; 0 otherwise

Chapter 3
THE EFFECTS OF AGE ON HOW MUCH THE ELDERLY DRIVE

This chapter examines the effects of age on the amount of driving exposure by the elderly. Three measures of driving exposure are considered. These measures are the number of vehicle miles driven by individual drivers on the travel day, the number of vehicle trips taken by individual drivers on the travel day, and the distance of individual vehicle trips on the travel day. Each of these measures is first tabulated by driver age group and labor force participation. Regression analysis is then used to isolate the effects of age on each of these measures.

NUMBER OF DAILY VEHICLE MILES DRIVEN

TABULATION

Table 3.1 tabulates the average number of vehicle miles driven on the travel day by driver age group and labor force participation. On average, elderly persons in the labor force drive about 19 miles a day and those not in the labor force drive about 10 miles a day. In comparison, mid-aged persons in the labor force drive about 29 miles a day, and those not in the labor force drive about 16 miles a day; and young persons in the labor force drive about 27 miles a day, and those not in the labor force drive about 3 miles a day.

Table 3.1 Average number of daily vehicle miles driven by driver age group

Driver Age Group	All Drivers	In Labor Force	Not in Labor Force
All	19.23	28.02	8.07
Young (Age<=24)	9.45	26.70	2.73
Mid-Aged (25<=Age<=64)	25.87	28.63	15.82
Elderly (Age>=65)	11.44	19.27	10.29

Source: Computed from the Person File as the weighted average of total vehicle miles driven by each responding driver on the travel day.

REGRESSION

Regression analysis is used to isolate the effects of age on the number of vehicle miles driven by individual elderly drivers on the travel day. Regression analysis isolates these effects by including age and other personal, household, and location characteristics of the elderly drivers as control variables. The number of vehicle miles driven by individual drivers is the dependent variable. The age and other characteristics of individual drivers are the explanatory variables.

Model

The first candidate model for this regression analysis would be the standard linear regression model. This model can be defined as follows:

$$y_i = \beta' x_i + u_i \qquad (1)$$

where y_i is the dependent variable; i indicates an observation in the data; β is a column vector of unknown parameters; x_i is a column vector of known values of the explanatory variables for observation i; and u_i is a disturbance term for observation i that is independently and normally distributed across observations with a zero mean and common variance. If the assumptions of this model are not met, parameters estimated from the ordinary least squares method may not have properties such as consistency or efficiency.

The current problem violates the assumption that the disturbance term has a zero mean. About 40 percent of the responding drivers reported no vehicle miles driven on the travel day. This situation fits the Tobit model, which originally was formulated to analyze survey data of consumer expenditures on durable goods. Most households report zero expenditures on major durable goods during any year. Among those households that report any such expenditures, however, the amounts vary widely. The Tobit model can be defined as follows:

$$\begin{aligned} y_i &= \beta' x_i + u_i \quad \text{if RHS} > 0 \\ y_i &= 0 \quad \text{otherwise} \end{aligned} \qquad (2)$$

where RHS refers to the right hand side and the other symbols are as defined in the standard linear regression model in equation (1). The ordinary least squares method in this situation leads to inconsistent estimates of the unknown parameters. Consistent estimates in the Tobit model can be obtained with the maximum likelihood or Heckman two-stage method. The Heckman method is easier to compute, but less efficient.[1] Therefore, the maximum likelihood method is used for this analysis.[2]

Results

Many factors could affect the number of vehicle miles driven on a given day by individual drivers. These factors include the characteristics associated with the drivers as well as the cost of driving. While the 1990 NPTS contains a set of personal, household, and location characteristics of the drivers, it does not, however, include information on the cost of driving. As a result, the cost of driving is approximated by the statewide average refiner/reseller sales price of motor gasoline plus state gasoline tax in 1990.[3] This cost of driving ignores any variation in the refiner/reseller sales price of motor gasoline within a state and in non-state local gasoline taxes. This cost of driving also ignores other components of driving costs. This cost of driving, in cents per gallon, will be referred to as gasoline price.

The results are shown in Table 3.2. The first column lists the explanatory variables by category. The second column lists the estimated coefficients, measuring the marginal effects

Table 3.2 Tobit analysis of daily vehicle miles driven

Explanatory Variables	Coefficients	χ^2-Statistics
Personal Characteristics		
Age>=65	-3.8392	5.74▪
Age<=24	-18.7563	315.00
Male	8.0405	104.79
Education>high school	11.8649	193.71
Worker	33.1366	1080.74
Household Characteristics		
White	5.6748	9.19
Black	-0.0913	0.00•
Hispanic	0.2098	0.01•
Income category	0.2194	5.02▪
Single	4.4484	8.03
# adults	-0.6361	1.24•
# old children	-3.6891	87.12
# young children	3.9341	21.60
No vehicle	-57.3373	184.10
Location Characteristics		
Central city	-2.7091	9.93
Urbanized-area size	-0.2500	0.66•
Population density	-0.5677	104.20
North East	-1.3290	1.00•
North Central	1.2319	1.07•
South	1.2448	1.07•
Winter	-2.4424	7.44
Weekend	-6.7313	61.38
Gasoline Price	-0.1587	3.83▪
Constant	-3.1058	0.15•
Log Likelihood at convergence		-64021
Number of observations		19,024
Proportion of observations with zero vehicle miles		40%

Source: Estimated from the Person File using the maximum likelihood method with the SAS LIFEREG procedure. The dependent variable is total number of vehicle miles driven on the travel day by each responding driver. Whether a coefficient differs from zero is labeled as follows: ▪ significant at the 5 percent level; • insignificant at the 10 percent level; others significant at the 1 percent level.

of an explanatory variable on the dependent variable while holding constant other explanatory variables. The last column lists the corresponding chi-square (χ^2) statistics, indicating the statistical significance of the explanatory variables. At the bottom are the log likelihood at convergence, the number of observations used in the estimation, and the proportion of observations with zero miles.[4]

Two issues are involved in the interpretation of the results. First, the sign of a coefficient in a Tobit model measures the direction of changes in the dependent variable from a change in the corresponding explanatory variable. But to compute the magnitude of these changes in the dependent variable is not straightforward. The interpretation here focuses on the signs.[5]

The second issue involved in the interpretation of the results concerns dummy variables. Since the model includes a constant term, the dummy variable coefficients are interpreted relative to the omitted category. For example, the dummy variable for male drivers is included, but the dummy variable for female drivers is omitted. The omitted category becomes a benchmark. The dummy variable coefficients for the remaining categories tell whether or not each of the remaining categories differ from this benchmark and, if so, by how much.

There are two types of dummy variables: those involving two categories and those involving more than two categories. The two-category dummy variables include gender, educational attainment, labor force participation, Hispanic status, single status, location in an urbanized area, month-of-year, and day-of-week. The multi-category dummy variables include age, race, and census region. The omitted category for age includes those persons between the ages of 25 and 64 years; the remaining categories include those persons age 24 years or younger and those persons age 65 years or older. The omitted category for race includes those persons who are neither White nor Black; the remaining categories include White persons and Black persons. The omitted category for census region is the West; the remaining categories include the North East, North Central, and South regions.

The results indicate that the coefficient of the elderly dummy variable is -3.8392 and differs from zero at the 5 percent level. Thus, other things being equal, the elderly drive fewer miles than the mid-aged.

The other variables are organized into two groups for interpretation. The first group includes those variables whose coefficients differ from zero at up to the 10 percent level. The results indicate that, other things being equal, persons in the labor force drive more miles than those not in the labor force; males drive more miles than females; Whites drive more miles than drivers who are neither White nor Black; Blacks drive fewer miles than Whites; persons with higher household incomes drive more miles; and persons from households with more children under five years old drive more miles. In addition, the young drive fewer miles than the mid-aged; persons from households without vehicles drive fewer miles than those with vehicles; persons living in areas with higher population densities drive fewer miles; persons living in central cities drive fewer miles than those living outside central cities; and the number of daily vehicle miles driven by individual persons decreases with an increase in gasoline price.

The second group includes those variables whose coefficients do not differ from zero at the 10 percent level. The results indicate that, other things being equal, Blacks drive the same number of daily vehicle miles as those who are neither White nor Black; Hispanics drive the same number of daily vehicle miles as non-Hispanics; the size of an urbanized area does not affect the number of daily vehicle miles driven by individual persons; and census region does not make a difference in the number of daily vehicle miles driven by individual persons.

NUMBER OF DAILY VEHICLE TRIPS

The number of vehicle miles driven combines the number and distance of vehicle trips. The previous section has shown that the elderly drive fewer miles than the mid-aged. Does this result imply that the elderly take shorter trips as well as make fewer vehicle trips than the mid-aged? The literature provides mixed evidence.[6] The number of vehicle trips taken on the travel day by individual drivers and the distance of individual vehicle trips are examined separately using both tabulation and regression analysis.

TABULATION

Table 3.3 tabulates the average number of vehicle trips taken on the travel day by driver age group and labor force participation. On average, elderly persons in the labor force drive 2.56 vehicle trips per day and those not in the labor force drive 1.64 vehicle trips per day. Mid-aged persons in the labor force drive 2.99 vehicle trips per day and those not in the labor force drive 2.22 vehicle trips per day. Young persons in the labor force drive 2.92 vehicle trips per day and those not in the labor force drive 0.35 vehicle trips per day.

Table 3.3 Average number of daily vehicle trips by driver age group

Driver Age Group	All Drivers	In Labor Force	Not in Labor Force
All	2.17	2.97	1.15
Young (Age<=24)	1.07	2.92	0.35
Mid-Aged (25<=Age<=64)	2.83	2.99	2.22
Elderly (Age>=65)	1.76	2.59	1.64

Source: Calculated from the Person File as the weighted average of the number of vehicle trips driven by each responding driver on the travel day.

REGRESSION

This regression analysis is similar to that for the number of vehicle miles driven by individual persons in the previous section. The unit of observation is individual drivers. The same set of explanatory variables are used. As mentioned in the previous section, about 40 percent of the responding drivers reported no vehicle miles on the travel day. Thus, the Tobit model in equation (2) is used along with the maximum likelihood method for estimation. The results are shown in Table 3.4.

The results indicate that the coefficient of the elderly dummy variable does not differ from zero at the 10 percent level. Thus, other things being equal, the elderly drive just the same number of vehicle trips per day as the mid-aged.

The other explanatory variables are organized into three groups for interpretation. The first group includes those variables whose coefficients differ from zero at up to the 10 percent level. The results indicate that, other things being equal, persons in the labor force drive more vehicle trips than those not in the labor force; persons with more than a high school education drive more vehicle trips than those with less education; Whites drive more vehicle trips than those who are neither White not Black; Blacks drive fewer vehicle trips than Whites; persons living with children under five years old drive more vehicle trips than those not living with children under five years old; and persons from single-resident households drive more vehicle trips than those from multi-resident households. In addition, the young drive fewer vehicle trips than the mid-aged; persons from households without vehicles drive fewer vehicle trips than those from households with vehicles; people drive fewer vehicle trips on weekend days than on weekdays; the number of daily vehicle trips taken by individual drivers decreases with an increase in the number of adults in a household; the number of daily vehicle trips taken by individual drivers decreases with an increase in the population density of a zip-code area; and the number of daily vehicle trips taken by individual drivers decreases with an increase in the size of an urbanized area.

The second group includes those variables whose statistical significance changes in explaining the number of vehicle miles driven and vehicle trips taken by individual drivers on the travel day. The results in Tables 3.2 and 3.4 indicate that, other things being equal, males drive more miles than females, but not more vehicle trips; household income affects the number of miles driven, but not the number of vehicle trips; gasoline price affects the number of miles driven, but not the number of vehicle trips; and living in central cities affects the number of miles driven, but not the number of vehicle trips taken. In addition, the size of an urbanized area has no effect on the number of miles driven, but affects the number of vehicle trips taken by individual drivers.

The third group includes those variables whose coefficients that do not differ from zero at the 10 percent level in explaining both the number of vehicle miles driven and the number of vehicle trips taken by individual drivers on the travel day. The results in Tables 3.2 and 3.4 indicate that, other things being equal, Blacks drive the same number of miles and take the same number of vehicle trips as those who are neither White nor Black; Hispanics drive the same number of miles and take the same number of vehicle trips as non-Hispanics; and census region does not make a difference in explaining the number of miles driven or the number of vehicle trips taken by individual drivers.

Table 3.4 Tobit analysis of number of daily vehicle trips

Explanatory Variables	Coefficients	χ^2-Statistics
Personal Characteristics		
Age>=65	-0.0737	0.40●
Age<=24	-1.8436	572.58
Male	-0.0237	0.17●
Education>high school	1.0692	292.43
Worker	2.6303	1284.15
Household Characteristics		
White	0.2849	4.36■
Black	0.0225	0.02●
Hispanic	-0.1387	0.91●
Income category	-0.0062	0.76●
Single	0.4019	12.21
# adults	-0.0760	3.33●
# old children	-0.1542	28.91
# young children	0.3227	18.50
No vehicle	-5.2585	295.10
Location Characteristics		
Central city	-0.0535	0.73●
Urbanized-area size	-0.0835	13.88
Population density	-0.0495	148.53
North East	-0.0026	0.00●
North Central	0.2678	9.45
South	0.1948	4.89■
Winter	-0.1429	4.78■
Weekend	-0.9011	205.86
Gasoline Price	-0.0031	0.27●
Constant	0.7806	1.74●
Log Likelihood at convergence		-35432
Number of observations		19,024
Proportion of observations with zero vehicle miles		40%

Source: Estimated from the Person File using the maximum likelihood method with the SAS LIFEREG procedure. Whether a coefficient differs from zero is marked as follows: ■ significant at the 5 percent level; ● insignificant at the 10 percent level; others significant at the 1 percent level.

DISTANCE OF DAILY VEHICLE TRIPS

TABULATION

Table 3.5 tabulates the average distance of vehicle trips taken on the travel day by driver age group and trip purpose. For elderly drivers, the average distances are 6.55 miles for all trips, 8.30 miles for work trips, and 6.43 miles for non-work trips. For mid-aged drivers, the average distances are 9.25 miles for all trips, 11.54 miles for work trips, and 8.22 miles for non-work trips. For young drivers, the average distances are 8.91 miles for all trips, 9.98 miles for work trips, and 8.54 miles for non-work trips. For all drivers, the average distances are 8.98 miles for all trips, 11.23 miles for work trips, and 8.10 miles for non-work trips.

Table 3.5 Average distance of daily vehicle trips by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	8.98	11.23	8.10
Young (Age<=24)	8.91	9.98	8.54
Mid-Aged (25<=Age<=64)	9.25	11.54	8.22
Elderly (Age>=65)	6.55	8.30	6.43

Source: Calculated from the Travel Day File as the weighted average of distances of individual vehicle trips on the travel day in miles.

REGRESSION

As with the models developed for the number of vehicle miles driven and the number of vehicle trips taken by individual drivers on the travel day, the purpose of this regression analysis is to isolate the effects of age on the distance of individual vehicle trips taken by elderly drivers on the travel day.

Model

The regression analysis in this section differs from those in the previous sections in two important aspects. First, while a large proportion of responding drivers reported no vehicle trips on the travel day, the variable measuring the distance of vehicle trips does not have this problem. Instead of the Tobit model in (2), the standard linear regression model in (1) is used along with the weighted least squares method for estimation. Second, while the unit of observation in the previous sections is individual drivers, the unit of observation in this section is individual vehicle trips. As a result, an additional set of explanatory variables measuring trip characteristics is also included. These additional variables include time-of-day, whether the driver carried any passengers, day-of-week, month-of-year, and the purpose of a vehicle trip.

Results

The results are shown in Table 3.6. The interpretation of the standard linear model is straightforward. The coefficient of an explanatory variable measures the expected change in the value of the dependent variable from one unit change in the explanatory variable, while holding other explanatory variables constant. Another issue of interpretation is the set of dummy variables that measures trip purposes. The 1990 NPTS classifies trip purposes into ten categories. Four of these categories are omitted from the model: trips for school or church, trips for vacation, trips for pleasure driving, and trips for other purposes. The remaining six categories are included in the model. As a result, the coefficients of the dummy variables for these remaining categories are interpreted relative to the omitted categories.

The results indicate that the coefficient of the elderly dummy variable is -1.0471 and differs from zero at the 0.01 percent level. Thus, other things being equal, the elderly drive about one mile shorter per trip than the mid-aged.

The other variables are organized into two groups for interpretation. The first group includes those variables whose coefficients differ from zero at up to the 10 percent level. The results indicate that, other things being equal, male drivers take longer trips than female drivers; drivers in the labor force take longer trips than those not in the labor force; White drivers take longer trips than those who are neither White nor Black; Blacks take trips of shorter distances than those taken by Whites; drivers with higher household incomes take longer trips; and drivers living in larger urbanized areas take longer trips. In addition, drivers living in central cities take shorter trips than those living outside central cities; the distance of vehicle trips decreases with an increase in gasoline price; drivers living in areas with higher population densities take shorter trips; trips for work-related purposes and for visiting friends or relatives are longer than trips for those purposes that are omitted from the model; and trips for other remaining purposes are shorter than trips for those purposes that are omitted from the model.

The second group includes those variables whose coefficients do not differ from zero at the 10 percent level. The results indicate that, other things being equal, young drivers take trips that are just as long as those taken by mid-aged drivers; winter trips are just as long as non-winter trips; night trips are just as long as day trips; peak trips are just as long as off-peak trips; Black drivers take trips that are just as long as those taken by drivers who are neither White nor Black; Hispanic drivers take trips that are just as long as those taken by non-Hispanic drivers; and drivers in the North East or South regions take trips that are just as long as trips taken by those in the West.

Table 3.6 Weighted regression of distance of daily vehicle trips

Explanatory Variables	Coefficients	t-Statistics
Personal Characteristics		
Age>=65	-1.0471	-2.76
Age<=24	-0.2702	-1.18●
Male	2.2187	13.01
Education>high school	0.6365	3.58
Worker	0.5928	2.46■
Household Characteristics		
White	1.2739	3.19
Black	0.6191	1.29●
Hispanic	-0.0445	-0.11●
Income category	0.1030	5.09
Location Characteristics		
Central city	-0.3041	-1.63◆
Urbanized-area size	0.3978	5.92
Population density	-0.0406	-2.39■
North East	-0.0529	-0.19●
North Central	-0.6060	-2.49■
South	-0.1080	-0.47●
Gasoline Price	-0.0400	-2.19
Trip Characteristics		
Dark	0.2013	0.95●
Peak hours	0.2131	1.17●
Weekend	1.4526	7.20
Winter	-0.2125	-1.08●
Carpool	2.1489	11.38
Work-related	0.7136	1.84◆
Shopping	-5.6096	-14.52
Other family/personal	-3.4523	-9.11
Medical	-1.5511	-1.74◆
Visiting friends/relatives	1.2935	2.98
Other social/recreational	-1.4867	-3.56
Constant	7.8105	54.34
F-Statistic		56.61
Mean of dependent variable		8.30
Number of observations		43,936

Source: Estimated by Author from the Travel Day File using the weighted least squares method. Whether a coefficient differs from zero is labeled as follows: ■ significant at the 5 percent level; ◆ significant at the 10 percent level; ● insignificant at the 10 percent level; others significant at the 0.01 percent level.

Chapter 4
THE EFFECTS OF AGE ON WHEN THE ELDERLY DRIVE

This chapter examines the effects of age on driving at night or during peak hours by the elderly. Night includes the hours after sunset and before sunrise. Peak hours include 6:30-9:00 a.m. and 3:30-6:00 p.m. Whether a vehicle trip was taken at night or during peak hours is determined by its start time. Driving at night is examined first, followed by an examination of driving during peak hours. For each analysis, the percent of vehicle miles driven by time of day is first tabulated by driver age group and trip purpose. Logit analysis is then used to isolate the effects of age on the elderly's probability of driving at night or during peak hours.

DRIVING AT NIGHT

TABULATION

Table 4.1 tabulates the percent of vehicle miles driven at night by driver age group and trip purpose. The elderly drive about 18 percent of their miles at night for both work and non-work trips, while the mid-aged drive about 29 percent of their miles at night for work trips and 23 percent for non-work trips. The young drive about 29 percent of their miles at night for work trips and 25 percent for non-work trips.

Table 4.1 Percent of miles driven at night by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	24.62%	28.66%	23.51%
Young (Age<=24)	26.12%	29.03%	25.74%
Mid-Aged (25<=Age<=64)	24.62%	28.84%	22.94%
Elderly (Age>=65)	18.34%	18.43%	18.31%

Source: Calculated from the Travel Day File. Each number represents total miles driven by drivers of a given group at night as a percentage of total miles driven by these drivers all day.

REGRESSION

The purpose of this regression analysis is to isolate the effects of age on driving at night by the elderly, while holding constant a set of the elderly's personal, household, and location characteristics.

Model

Similar to the regression analysis of the distance of vehicle trips in the previous section, the unit of observation is individual vehicle trips. This regression analysis, however, differs from that for the distance of vehicle trips in four aspects. First, the dependent variable here is binary, indicating whether a vehicle trip on the travel day started at night. One commonly used regression model for a binary choice problem is the logit model, in which the probability of choosing to drive at night has the logit form. If P is the probability of driving at night, x is a column vector of the values of explanatory variables, and β is a column vector of parameters, then:

$$P = \frac{e^{\beta' x}}{1 + e^{\beta' x}} \tag{3}$$

Second, speed may differ systematically by time of day. In addition to a similar set of explanatory variables used in the model for the distance of vehicle trips, speed is also included in this analysis. Third, the ordinary least squares method does not apply here. Instead, the maximum likelihood method is used for estimation. Fourth, several variables are excluded because convergence could not be reached when these variables are included. These excluded variables are Black, Hispanic, and the census regions. The reason that these particular variables are chosen to be excluded is that they are thought to be less important than others in the decision of driving by time of day.

Results

The results are shown in Table 4.2. The coefficients in this model are interpreted differently from those in a standard linear or Tobit model. First, an increase in a variable with a negative coefficient decreases the odds ratio of driving at night. The odds ratio of driving at night is $P/(1-P)$, where P is the probability of driving at night. Second, the exponential value of the coefficient of an explanatory variable determines the percent change in the odds ratio of driving at night from one unit change in that explanatory variable. For example, the dummy variable for male drivers has a coefficient of 0.3070. Its effect on the odds ratio of driving at night is $100^*(e^{0.3070} - 1) = 36$ percent. That is, males' odds ratio of driving at night is 36 percent higher than females' odds ratio of driving at night.

The results indicate that the coefficient of the elderly dummy variable is -0.2183 and differs from zero at the 0.01 percent level. Thus, other things being equal, the elderly are less likely to drive at night than the mid-aged. In fact, the elderly's odds ratio of driving at night is 20 percent lower than the mid-aged's odds ratio of driving at night.

The other variables are organized into two groups for interpretation. The first group has positive coefficients. The results indicate that, other things being equal, the young are more likely to drive at night than the mid-aged; males are more likely to drive at night than females; persons in the labor force are more likely to drive at night than those not in the labor force;

Table 4.2 Logit analysis of driving at night

Explanatory Variables	Coefficients	χ^2-Statistics
Personal Characteristics		
Age>=65	-0.2183	22.02
Age<=24	0.3124	134.87
Male	0.3070	223.85
Education>high school	-0.1193	33.03
Worker	0.3630	149.07
Household Characteristics		
White	-0.1122	14.90
Income category	0.0013	23.57
Location Characteristics		
Central city	0.0851	15.56
Urbanized-area size	0.0281	13.09
Population density	0.0046	6.66■
Trip Characteristics		
Weekend	0.2940	140.46
Winter	0.8139	1381.84
Work-related	0.1946	17.14
Shopping	-0.1376	7.97■
Other family/personal	-0.1615	11.46
Medical	-1.0784	51.13
Visiting friends/relatives	0.6065	137.20
Other social/recreational	0.6568	174.73
Speed	0.0051	63.91
Constant	-2.6550	1086.12
χ^2-Statistics		3499
Number of observations		57,312
Number of observations driving at night		14,135

Source: Estimated from the Travel Day File using the maximum likelihood method with the SAS LOGISTIC procedure. Whether a coefficient differs from zero is marked as follows: ■ significant at the 1 percent level; others significant at the 0.01 percent level.

persons living in central cities are more likely to drive at night than those living outside central cities; the probability of driving at night increases with an increase in household income, the size of an urbanized area, and the population density of a zip-code area; and trips for work-related purposes, visiting friends or relatives, and other social or recreational purposes are more likely to be taken at night than trips for those purposes that are omitted from the model.

The second group has negative coefficients. The results indicate that, other things being equal, persons with more than a high school education are less likely to drive at night than those with less education; Whites are less likely to drive at night than non-Whites; and trips for shopping, other family or personal business, and medical purposes are less likely to be taken at night than trips for those purposes that are omitted from the model. Note that the omitted category for race in this analysis is non-Whites.

DRIVING DURING PEAK HOURS

TABULATION

Table 4.3 tabulates the percent of vehicle miles driven during peak hours by driver age group and trip purpose. The elderly drive about 28 percent of their miles during peak hours for non-work trips, 57 percent for work trips, and 30 percent for all trips. The mid-aged drive about 31 percent of their miles during peak hours for non-work trips, 59 percent for work trips, and 39 percent for all trips. The young drive about 38 percent of their miles during peak hours for non-work trips, 50 percent for work trips, and 40 percent for all trips.

Table 4.3 Percent of miles driven during peak hours by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	38.71%	57.39%	33.51%
Young (Age<=24)	39.67%	49.84%	38.36%
Mid-Aged (25<=Age<=64)	39.26%	58.84%	31.36%
Elderly (Age>=65)	30.02%	56.69%	28.16%

Source: Calculated from the Travel Day File. Each number represents total miles driven by drivers of a given group during peak hours as a percentage of total miles driven by these drivers all day.

REGRESSION

The regression analysis of driving during peak hours is similar to that for driving at night. Again, the dependent variable is binary, indicating whether a vehicle trip on the travel day started during peak hours. The same set of explanatory variables are included as in the regression analysis for driving at night. The logit model is used along with the maximum likelihood method for estimation. The results are shown in Table 4.4.

The results indicate that the coefficient of the elderly dummy variable is -0.1251 and differs from zero at the 1 percent level. Thus, other things being equal, the elderly are less likely to drive during peak hours than the mid-aged. In fact, the elderly's odds ratio of driving during peak hours is about 12 percent lower than the odds ratio of driving during peak hours by the mid-aged. This difference in the odds ratio of driving during peak hours between the elderly and mid-aged is smaller than that for the odds ratio of driving at night. This change in the difference is consistent with that the elderly find driving at night more problematic than driving during peak hours.

The other variables are organized into three groups for interpretation. The first group includes those variables whose coefficients are positive and differ from zero at the 10 percent level. The results indicate that, other things being equal, persons in the labor force are more likely to drive during peak hours than those not in the labor force; persons with more than a high school education are more likely to drive during peak hours than those with less education; weekend trips are more likely to be taken during peak hours than weekday trips; and work trips are more likely to be taken during peak hours than trips for those purposes that are omitted from the model.

The second group includes those variables whose coefficients are negative and differ from zero at the 10 percent level. The results indicate that, other things being equal, the young are less likely to drive during peak hours than the mid-aged; males are less likely to drive during peak hours than females; trips for shopping, other family or personal business, medical, visiting friends or relatives, and other social or recreational purposes are less likely to be taken during peak hours than trips for those purposes that are omitted from the model.

The last group includes those variables whose coefficients do not differ from zero at the 10 percent level. The results indicate that, other things being equal, Whites are just as likely as non-Whites to drive during peak hours; household income or the size of an urbanized area does not affect the probability of driving during peak hours; persons living in central cities are just as likely as those living outside central cities to drive during peak hours; and winter trips are just as likely as non-winter trips to be taken during peak hours.

Table 4.4 Logit analysis of driving during peak hours

Explanatory Variables	Coefficients	χ^2-Statistics
<u>Personal Characteristics</u>		
Age>=65	-0.1257	10.15
Age<=24	-0.1678	41.81
Male	-0.0803	18.73
Education>high school	0.0448	5.66■
Worker	0.1332	26.49
<u>Household Characteristics</u>		
White	-0.0153	0.32●
Income category	-0.0001	0.30●
<u>Location Characteristics</u>		
Central city	0.0082	0.18●
Urbanized-area size	-0.0110	2.51●
Population density	-0.0031	3.13■
<u>Trip Characteristics</u>		
Weekend	0.2967	172.88
Winter	-0.0022	0.01●
Work-related	0.7208	320.42
Shopping	-0.4303	108.54
Other family/personal	-0.2020	25.45
Medical	-0.3750	16.08
Visiting friends/relatives	-0.4746	98.67
Other social/recreational	-0.4631	106.06
Speed	-0.0033	31.60
<u>Constant</u>	-0.8658	151.75
χ^2-Statistics		
41270 Number of observations		
55,610		
Number of observations driving at night		21,604

Source: Estimated by from the Travel Day File using the maximum likelihood method with the SAS LOGISTIC procedure. Whether a coefficient differs from zero is labeled as follows: ■ significant at the 10 percent level; ● insignificant at the 10 percent level; others significant at the 1 percent level.

Chapter 5
THE EFFECTS OF AGE ON HOW THE ELDERLY DRIVE

Chapters 3 and 4 have shown that age affects how much, as well as when the elderly drive. This chapter examines the effects of age on how the elderly drive. Four aspects are considered. These include driving speed, driving on limited-access highways, vehicle size, and the number of passengers carried.

SPEED

This section examines the effects of age on the driving speeds of the elderly. Do the elderly drive at lower speeds than others? If they do, do they drive on roads with lower speed limits? Or do they drive slower than others on roads with the same speed limits? The 1990 NPTS can be used to shed light on whether the elderly drive slower than others on limited-access highways. The 1990 NPTS does not, however, include the information necessary to test whether the elderly drive on roads with lower speed limits than others.

In the following analysis, speed is first tabulated by driver age group and trip purpose. Regression is then used to isolate the effects of age on the driving speeds of the elderly. This analysis is done separately for all roadways combined and for limited-access highways.

TABULATION

Table 5.1 tabulates the average speed for vehicle trips using all roads by driver age group and trip purpose. The elderly drive at an average speed of 22 mph for all trips, 24 mph for work trips, and 22 mph for non-work trips. The mid-aged drive at an average speed of 29 mph for all trips, 31 mph for work trips, and 28 mph for non-work trips. The young drive at an average speed of 32 mph for all trips, 34 mph for work trips, and 31 mph for non-work trips.

Table 5.1 Average speed on all roads by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	28.69	31.58	27.55
Young (Age<=24)	31.83	34.39	30.93
Mid-Aged (25<=Age<=64)	28.79	31.29	27.66
Elderly (Age>=65)	22.05	24.35	21.89

Source: Calculated from the Travel Day File as the weighted average of the speeds of individual vehicle trips. The speed of a trip is measured as the ratio of its reported distance and duration in miles per hour (mph).

Table 5.2 tabulates the average speed for vehicle trips using limited-access highways by driver age group and trip purpose. As expected, the average speeds for trips using limited-access highways are higher than those for trips using all roadways. On average, the elderly drive at about 34 mph for all purposes, 36 mph for work trips, and 33 mph for non-work trips. The mid-aged drive at about 39 mph for work trips, non-work trips, and all purposes. The young drive at about 44 mph for all trips, 44 mph for work trips, and 42 mph for non-work trips. All persons as a group drive at about 39 mph for both work and non-work trips.

Table 5.2 Average speed on limited-access highways by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	39.22	39.16	39.31
Young (Age<=24)	43.96	44.47	42.31
Mid-Aged (25<=Age<=64)	38.92	38.73	39.07
Elderly (Age>=65)	33.77	36.45	33.45

Source: Calculated from the sample of private-vehicle trips in the Travel Day File as the weighted average of the speeds for individual trips in this sample. The distance of each trip in this sample is broken down by roadway classification.

REGRESSION

This regression analysis is similar to that for the distance of vehicle trips in Chapter 3. The unit of observation is individual vehicle trips. The dependent variable is the speed of individual vehicle trips, measured as the ratio of reported distance and duration in miles per hour. The same set of explanatory variables are included as in the analysis of the distance of vehicle trips except gasoline price. The standard linear regression model in equation (1) is used along with the ordinary least squares method for estimation. The results are presented in Table 5.3. The model for trips using limited-access highways is shown in the second and third columns. The model for trips using all roadways is shown in the last two columns.

The results indicate that the elderly drive at lower speeds than the mid-aged for trips using all roads as well as for trips using limited-access highways. The model for all roadways indicates that, other things being equal, the elderly drive 3.9 mph slower than the mid-aged for trips using all roadways. The model for limited-access highways indicates that, other things being equal, the elderly drive 3.7 mph slower than the mid-aged for trips using limited-access highways.

The other variables are organized into four groups for interpretation. Those in the first group have a positive effect in both models. The results indicate that, other things being equal, the young drive at higher speeds than the mid-aged for both trips using all roadways and trips

Table 5.3 Weighted regression of speed of vehicle trips

Explanatory Variables	Limited-Access Highways		All Roads	
	Coefficients	t-Statistics	Coefficients	t-Statistics
Personal Characteristics				
Age>=65	-3.7258	-2.24■	-3.8598	-11.30
Age<=24	5.1825	6.46	2.9221	14.13
Male	2.6885	4.60	1.3154	8.55
Education>high school	0.9070	1.47●	1.0727	6.69
Worker	3.6277	3.84	1.7807	8.19
Household Characteristics				
White	3.3632	2.62	1.7256	4.81
Black	5.0459	3.35	0.6354	1.47●
Hispanic	3.1640	2.25■	-0.3465	-0.94●
Income category	0.1313	1.90◆	0.2054	11.25
Location Characteristics				
Central city	1.0178	1.64◆	-0.8086	-4.80
Urbanized-area size	0.0541	0.21●	0.1829	3.03
Population density	-0.3490	-5.76	-0.2660	-17.14
North East	-0.1813	0.21●	-1.2205	-5.24
North Central	-0.4542	-0.54●	-0.4757	-2.17■
South	-1.6494	-2.28■	0.3476	1.70◆
Trip Characteristics				
Dark	0.3544	0.49●	1.3667	7.17
Peak hours	-2.3635	-3.76	-0.5709	-3.47
Weekend	2.5473	3.59	1.7567	9.62
Carpool	-0.5986	-0.87●	1.2350	7.24
Winter	-0.4823	0.73●	-0.4734	-2.68
Work-related	1.8450	1.44●	2.6185	7.48
Shopping	0.7108	0.49●	-3.0883	-8.84
Other family/personal	1.7029	1.26●	-1.1646	-3.40
Medical	8.4012	2.78	2.1862	2.72
Visiting friends/relatives	6.7746	4.66	2.4156	6.14
Other social/recreational	2.3077	1.56●	0.0315	0.08●
Constant	27.2783	11.82	21.3926	35.67
F-Statistic		9		110
Mean of dependent variable		38.36		27.64
Number of observations		2,431		43,431

Source: Estimated from the Travel Day File using the weighted least squares method. Whether a coefficient differs from zero is labeled as follows: ■ significant at the 5 percent level; ◆ significant at the 10 percent level; ● insignificant at the 10 percent level; others significant at the 1 percent level.

using limited-access highways. Similarly, males drive at higher speeds than females; persons with higher household incomes drive at higher speeds; weekend trips have higher speeds than weekday trips; and trips for medical and visiting friends or relatives have higher speeds than trips for the purposes that are omitted from the models.

The variables in the second group have a negative effect in both models. The results indicate that, other things being equal, persons living in areas with higher population densities drive at lower speeds for both trips using all roadways and trips using limited-access highways. Similarly, peak trips have lower speeds than off-peak trips.

The variables in the third group have a positive effect in the model for all roadways, but have no effect in the model for limited-access highways. The results indicate that, other things being equal, persons with more than a high school education drive at higher speeds than those with less education for all roadways, but at similar speeds on limited-access highways. The size of an urbanized area increases the speeds for trips using all roadways, but has no effect for trips using limited-access highways. Since limited-access highways generally have higher speeds than local roadways, the positive relationship between the size of an urbanized area and the speeds for trips using all roadways may imply that trips in larger urbanized areas are more likely to use limited-access highways. In fact, the analysis of driving on limited-access highways in the next section confirms this implication. Similarly, night trips have higher speeds than day-time trips on all roadways, but have similar speeds on limited-access highways; and work trips on all roadways have higher speeds than trips for those purposes that are omitted from the models, but have similar speeds on limited-access highways. Also, carpool trips have higher speeds than single-occupant trips on all roadways, but have similar speeds on limited-access highways. It is reasonable that carpool trips have higher speeds than single-occupant trips on all roadways because carpool trips may be more likely to use limited-access highways.

The variables in the last group have a negative effect in the model for all roadways, but have no effect in the model for limited-access highways. The results indicate that, other things being equal, persons living in central cities drive at lower speeds than those living outside central cities for all roadways, but drive at similar speeds on limited-access highways. Similarly, persons in the North East or North Central regions drive at lower speeds than those in the West on all roadways, but drive at similar speeds on limited-access highways. Also shopping trips and trips for other family or personal business have lower speeds than trips for the omitted trip purposes on all roadways, but have similar speeds on limited-access highways.

LIMITED-ACCESS HIGHWAYS

This section examines the effects of age on the elderly's choice of driving on limited-access highways. It is unclear, at the outset, how age may affect the elderly's use of limited-access highways. Limited-access highways have the lowest fatal crashes per mile driven.[1] But they are also likely to have higher injury risks from crashes due to the high speeds. As discussed in Chapter 1, however, driving on limited-access highways is one of the commonly mentioned conditions that the elderly find difficult.

The percent of vehicle miles driven on limited-access highways is first tabulated by driver age group and trip purpose. Logit analysis is then used to isolate the effects of age on the elderly's probability of driving on limited-access highways.

TABULATION

Table 5.4 tabulates the percent of vehicle miles driven on limited-access highways by driver age group and trip purpose. The elderly drive 21 percent of their miles on limited-access highways for work trips and 15 percent for non-work trips. The mid-aged drive 28 percent of their miles on limited-access highways for work trips and 26 percent for non-work trips. The young drive 22 percent of their miles on limited-access highways for work trips and 24 percent for non-work trips.

Table 5.4 Percent of miles driven on limited-access highways by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	25.5%	27.2%	24.6%
Young (Age<=24)	23.5%	22.1%	24.1%
Mid-Aged (25<=Age<=64)	26.6%	28.1%	25.7%
Elderly (Age>=65)	15.3%	20.7%	14.7%

Source: Calculated from the Travel Day File. The 1990 NPTS randomly selects a private-vehicle trip for each respondent (if any), and breaks down its distance by roadway classification.

REGRESSION

This regression analysis is similar to that for driving at night or during peak hours. The dependent variable is binary, indicating whether a vehicle trip uses any limited-access highways. The logit model is used along with the maximum likelihood method for estimation. Two models are estimated in order to examine how controlling for speed affects the elderly's choice of driving on limited-access highways. The results are shown in Table 5.5. Model 1 includes speed; Model 2 does not include speed.

The results in both models indicate that, other things being equal, the elderly are less likely to drive on limited-access highways than the mid-aged. The coefficients of the elderly dummy variable are -0.5618 in Model 1 and -0.7364 in Model 2 and both differ from zero at the 0.1 percent level. Thus, when speed is not held constant (Model 2), the elderly's odds ratio is 52 percent lower than the mid-aged's odds ratio of driving on limited-access highways. When speed is also held constant (Model 1), the elderly's odds ratio is 49 percent lower than the mid-

Table 5.5 Logit analysis of driving on limited-access highways

Explanatory Variables	Model 1		Model 2	
	Coefficients	χ^2-Statistics	Coefficients	χ^2-Statistics
<u>Personal Characteristics</u>				
Age>=65	-0.5618	26.23	-0.7364	48.24
Age<=24	-0.2785	18.32	-0.1686	7.32■
Male	0.2960	42.38	0.3366	59.42
Education>high school	0.2547	30.36	0.2979	44.91
Worker	0.0927	1.73●	0.1501	4.90■
<u>Household Characteristics</u>				
White	-0.0628	0.35●	0.0075	0.01●
Black	0.0616	0.22●	0.1107	0.79●
Hispanic	-0.0996	0.73●	-0.0809	0.53●
Income category	-0.0013	4.43■	-0.0014	5.65■
<u>Location Characteristics</u>				
Central city	-0.0387	0.65●	-0.0772	2.79♦
Urbanized-area size	0.1361	60.15	0.1254	55.18
Population density	0.0007	5.14■	-0.0001	0.00●
North East	-0.4725	54.34	-0.4951	64.83
North Central	-0.4926	54.44	-0.4891	58.23
South	-0.2388	13.11	-0.2237	12.54
<u>Trip Characteristics</u>				
Dark	-0.0411	0.60●	0.0361	0.51●
Peak hours	-0.0068	14.36	-0.0067	15.06
Weekend	0.0632	1.27●	-0.0341	0.40●
Winter	0.0892	2.96♦	0.0247	0.25●
Carpool	0.1059	3.75	0.1554	8.81
Work-related	0.1948	3.88■	0.2247	5.58■
Shopping	-0.5261	22.96	-0.5916	31.33
Other family/personal	-0.1891	3.22♦	-0.1657	2.68♦
Medical	0.0477	0.05●	0.0947	0.20●
Visiting friends/relatives	-0.0160	0.02●	0.1275	1.39●
Other social/recreational	-0.0965	0.77●	-0.0288	0.07●
Speed	0.0430	829.04		
<u>Constant</u>	-3.1177	227.49	-1.6083	70.88
χ^2-Statistic		1543		653
Mean of dependent variable		12,984		12,999
Number of observations		3,095		3,100

Source: Estimated from the sample of trips for which distances are broken down by roadway classification. Whether a coefficient differs from zero is labeled as follows: ■ significant at the 5 percent level; ♦ significant at the 10 percent level; ● insignificant at the 10 percent level; others significant at the 0.1 percent level.

aged's odds ratio of driving on limited-access highways. So, the elderly's odds ratio of driving on limited-access highways decreases slightly (from 52 to 49 percent) when speed is controlled. This slight decrease seems to indicate that the elderly avoid driving on limited-access highways mainly for reasons other than high speeds.

The other variables are organized into three groups for interpretation. The first group includes variables whose coefficients differ from zero at the 10 percent level in both models. The results indicate that, other things being equal, males are more likely to drive on limited-access highways than females; persons with more than a high school education are more likely to drive on limited-access highways that those with less education; the probability of driving on limited-access highways increases with an increase in the size of an urbanized area; limited-access highways are more likely to be used for carpool trips than for non-carpool trips; limited-access highways are more likely to be used for works trips than for trips for purposes that are omitted from the models. In addition, the probability of driving on limited-access highways decreases with an increase in household income; persons in other census regions are less likely to drive on limited-access highways than those in the West; limited-access highways are less likely to be used for peak trips and for off-peak trips; and limited-access highways are more likely to be used for shopping and other family or personal business than for trips for the purposes that are omitted from the models.

The second group includes those variables that do not differ from zero at the 10 percent level in either models. The results indicate that, other things being equal, race makes no difference in the choice of driving on limited-access highways; limited-access highways are more likely to be used for night trips than for day trips; limited-access highways are as likely to be used for weekend trips as for weekday trips; limited-access highways are as likely to be used for trips for medical, visiting friends or relatives, and other social or recreational purposes as for trips for those purposes that are omitted from the models.

The last group includes variables whose statistical significance changes between the two models. The results indicate that, other things being equal, greater population density increases the probability of driving on limited-access highways when speed is held constant, but shows no effect when speed is not held constant; living in central cities increases the probability of driving on limited-access highways when speed is not held constant, but shows no effect when speed is also held constant; and persons in the labor force are more likely than persons not in the labor force to drive on limited-access highways when speed is not held constant, but are as likely to drive on limited-access highways when speed is also held constant.

AUTOMOBILE SIZE

This section examines the effects of age on the size of automobiles that the elderly drive. Do the elderly drive larger automobiles than others? The answer is not straightforward. As discussed in the introduction, the increased injury risk and reduced injury costs of the elderly may have two opposite effects on the elderly's choice of automobile size. In addition, if one assumes that the elderly value comfort or prestige more than others, one may argue that the elderly may drive larger automobiles for these reasons rather than for their crashworthiness. The literature, however, provides no evidence that the elderly value comfort or prestige more than others. Also, the fact that elderly drivers take trips that are shorter in distance, as shown in Chapter 3, suggests that the comfort of an automobile is less important for the elderly than for others.

The 1990 NPTS associates each vehicle used on the travel day with a main driver. This association allows one to link the characteristics of the main drivers with the attributes of the vehicles that they drive. The 1990 NPTS measures vehicle size according to the National Accident Sampling System.[1] The size of an automobile is based on its wheelbase length and is coded on a scale from one to six. For example, the size of a Ford Escort is one and the size of a Toyota Camry is three. Only automobiles are included in the analysis. Non-household-owned automobiles are excluded because they cannot be related to household attributes of the main drivers.

The following analysis starts with a tabulation of automobile size by age group of the main drivers and labor force participation. Regression is then used to isolate the effects of age on the size of automobiles that the elderly drive.

TABULATION

Table 5.6 tabulates the average size of automobiles by age group of the main drivers and labor force participation. For persons not in the labor force, the average sizes of the automobiles they drive are 3.16 for the elderly, 2.85 for the mid-aged, 2.52 for the young, and 2.88 for all. For those in the labor force, the average sizes are 2.90 for the elderly, 2.61 for the mid-aged, 2.35 for the young, and 2.58 for all.

Table 5.6 Average size of automobiles by age group of main drivers

Driver Age Group	All Drivers	In Labor Force	Not in Labor Force
All	2.68	2.58	2.88
Young (Age<=24)	2.42	2.35	2.52
Mid-Aged (25<=Age<=64)	2.66	2.61	2.85
Elderly (Age>=65)	3.12	2.90	3.16

Source: Calculated from the Vehicle and Person Files as the weighted average of automobile sizes. The size of an automobile is based on its wheelbase length, and is on a scale from one to six.

REGRESSION

The dependent variable is the size of an automobile measured on a scale from one to six. Unlike the regression analyses so far, where the unit of observation is either individual drivers or vehicle trips, the unit of observation here is individual automobiles. This analysis is similar, however, to those for the distance and speed of vehicle trips in that the standard linear regression model in equation (1) is used along with the weighted least squares method for estimation.[2] The results are shown in Table 5.7. Two models are estimated. Model 1 includes a set of personal, household, and location characteristics of the main drivers. In addition to these characteristics, Model 2 also includes two vehicle attributes: vehicle age and import status (whether a vehicle is foreign-made).

The results indicate that the coefficients of the elderly dummy variable are 0.4039 in Model 1 and 0.2574 in Model 2, and both differ from zero at the 0.01 percent level. Thus, other things being equal, the elderly drive larger automobiles than the mid-aged.

The other explanatory variables are organized into three groups for interpretation. The first group includes variables whose coefficients differ from zero at the 10 percent level in both models. The results indicate that, other things being equal, the young drive smaller automobiles than the mid-aged; persons with more than a high school education drive smaller automobiles than those with less education; persons in the labor force drive smaller automobiles than those not in the labor force; the size of an automobile increases with an increase in household income, but decreases with an increase in the size of an urbanized area; and persons in the South drive larger automobiles than those in the West.

The second group includes variables whose coefficients do not differ from zero at the 10 percent level in either model. The results indicate that, other things being equal, living in central cities does not affect the size of an automobile one drives and persons in the South East drive automobiles that are as large as those driven by persons in the West.

The third group includes variables whose statistical significance changes between the two models. The results indicate that, other things being equal, males are shown to drive larger automobiles than females when vehicle age and import status are not held constant (Model 1). But once vehicle age and import status are held constant (Model 2), males drive automobiles that are the same size as those driven by females. Similar changes in statistical significance are also observed for Whites, Blacks, household size, and persons living in the North Central region. On the other hand, when vehicle age and import status are not held constant (Model 1), Hispanics are shown to drive automobiles that are the same size as those driven by non-Hispanics. Once vehicle age and import status are given (Model 2), however, Hispanics are shown to drive smaller automobiles.

Two qualifications are in order. First, these models do not include owning and operating costs as an explanatory variable, though there is no reason to believe that including such a cost variable would necessarily change the results. It is possible to estimate these costs using other sources with the information on vehicle make and model.[3] However, estimating these costs would require additional resources and is beyond the scope of this study.

Table 5.7 Weighted regression of automobile size

Explanatory Variables	Model 1		Model 2	
	Coefficients	t-Statistics	Coefficients	t-Statistics
Personal Characteristics				
Age>=65	0.4039	9.94	0.2574	7.05
Age<=24	-0.3380	-11.71	-0.2579	-9.95
Male	0.0722	3.40	-0.0019	-0.10●
Education>high school	-0.2009	-8.85	-0.0618	-3.01■
Worker	-0.2091	-7.67	-0.1579	-6.46
Household Characteristics				
White	0.1321	2.90■	-0.0162	0.40●
Black	0.1493	2.72■	0.0601	1.22●
Hispanic	-0.0693	-1.41●	-0.1536	-3.49■
Income category	0.0072	2.74■	0.0248	10.46
Household size	0.0493	6.15	0.0104	1.45●
Location Characteristics				
Central city	0.0153	0.65●	0.0114	0.55●
Urbanized-area size	-0.0286	-3.40■	-0.0146	1.94◆
Population density	-0.0003	-0.20●	0.0019	1.20●
North East	0.0404	1.25●	-0.0022	-0.08●
North Central	0.1467	4.79	0.0325	1.16●
South	0.1386	4.80	0.1172	4.50
Vehicle Characteristics				
Vehicle age			0.0460	24.71
Import status			-0.8733	-40.99
Constant	2.5012	34.95	-84.9974	-23.89
F-Statistic		40		178
Mean of dependent variable		2.56		2.56
Number of observations		9,965		9,916

Source: Estimated from the Vehicle and Person Files with the weighted least squares method. Whether a coefficient differs from zero is labeled as follows: ■ significant at the 1 percent level; ◆ significant at the 10 percent level; ● insignificant at the 10 percent level; others significant at the 0.01 percent level.

NUMBER OF PASSENGERS CARRIED

This section examines the effects of age on the number of passengers that the elderly carry. Given that the elderly show increased crash involvements per unit of exposure, one might hypothesize that they feel less comfortable with carrying passengers than younger persons. The following analysis first tabulates the average automobile occupancy by driver age group and trip purpose. Regression is then used to isolate the effects of age on the number of passengers carried in each vehicle trip on the travel day.

TABULATION

Table 5.8 tabulates the average occupancy of automobile trips by driver age group and trip purpose. The elderly's average occupancies are 1.39 for all purposes, 1.08 for work trips, and 1.41 for non-work trips. The mid-aged's average occupancies are 1.54 for all purposes, 1.14 for work trips, and 1.71 for non-work trips. The young's average occupancies are 1.44 for all purposes, 1.10 for work trips, and 1.56 for non-work trips.

Table 5.8 Average occupancy of automobile trips by driver age group

Driver Age Group	All Trips	Work Trips	Non-Work Trips
All	1.51	1.13	1.65
Young (Age<=24)	1.44	1.10	1.56
Mid-Aged (25<=Age<=64)	1.54	1.14	1.71
Elderly (Age>=65)	1.39	1.08	1.41

Source: Calculated from the Travel Day File as the weighted average of occupancies of individual automobile trips on the travel day.

REGRESSION

The dependent variable is the number of occupants in an automobile trip on the travel day. This regression analysis is similar to those for the distance and speed of vehicle trips in two ways. First, the unit of observation is individual vehicle trips. Second, the standard linear regression model in equation (1) is used along with the weighted least squares method for estimation. This analysis differs, however, from those for the distance and speed of vehicle trips in that this analysis includes additional variables that measure household composition and vehicle ownership. The results are shown in Table 5.9.

The results indicate that the coefficient of the elderly dummy variable is -0.0558 and differs from zero at the 1 percent level. Thus, other things being equal, the elderly carry fewer passengers than the mid-aged.

Table 5.9 Weighted regression of occupancy of automobile trips

Explanatory Variables	Coefficients	t-Statistics
Personal Characteristics		
Age>=65	-0.0558	-2.98■
Age<=24	-0.1087	-9.52
Male	0.0136	1.59●
Education>high school	0.0007	0.07●
Worker	-0.0543	-4.58
Household Characteristics		
White	-0.0232	-1.18●
Black	-0.0583	-2.48
Hispanic	0.0121	0.58●
Single	-0.2625	-19.40
# old children	0.1487	48.21
# vehicles	-0.0635	-12.52
Income category	-0.0038	-3.45■
Location Characteristics		
Central city	0.0084	0.90●
Urbanized-area size	-0.0132	-3.95
Population density	0.0034	4.24
North East	-0.0588	-4.32
North Central	-0.0935	-7.65
South	-0.0543	-4.62
Gasoline Price	0.0010	1.10●
Trip Characteristics		
Dark	0.0437	4.13
Peak hours	-0.0185	-2.04◆
Weekend	0.1601	16.05
Winter	-0.0101	-1.04●
Distance	0.0031	12.10
Work-related	-0.5085	-27.19
Shopping	-0.1607	-8.54
Other family/personal	-0.0305	-1.66◆
Medical	-0.1720	-3.98
Visiting friends/relatives	-0.1067	-5.03
Other social/recreational	0.2463	12.14
Constant	1.6987	18.75
F-Statistic		278
Mean of dependent variable		1.50
Number of observations		37,097

Source: Estimated from the Travel Day File with the weighted least squares method. Whether a coefficient differs from zero is labeled as follows: ■ significant at the 1 percent level; ◆ significant at the 10 percent level; ● insignificant at the 10 percent level; others significant at the 0.01 percent level.

The other variables are interpreted by category of characteristics. Among the personal characteristics, the young carry fewer passengers than the mid-aged and persons in the labor force carry fewer passengers than those not in the labor force. In addition, males carry just as many passengers as females.

Among the household characteristics, automobile occupancy decreases with an increase in household income and vehicle ownership; persons from household with more children between the ages of 5 and 22 years carry more passengers; persons from single-resident households carry fewer passengers than those from multi-person households; and Blacks carry fewer passengers than non-Blacks. Also, Whites carry as many passengers as those who are neither White nor Black; and Hispanics carry as few passengers as non-Hispanics.

Among the location characteristics, automobile occupancy increases with an increase in population density, but decreases with an increase in the size of an urbanized area; automobile occupancy is lower in the other census regions than in the West. In addition, living in central cities does not affect automobile occupancy. Gasoline price, as measured in this analysis, has a positive but statistically insignificant effect on automobile occupancy.

Among the trip characteristics, night trips have higher occupancies than day trips; weekend trips have higher occupancies than weekday trips; and long distance trips have higher occupancies than short distance trips. In addition, trips for other social or recreational purposes have higher occupancies than trips for those purposes that are omitted from the model; and trips for the other remaining purposes included in the model (work-related, shopping, other family/personal business, medical, and visiting friends/relatives) have lower occupancies than trips for the omitted purposes. The omitted purposes include trips for school or church, trips for vacation, trips for pleasure driving, and trips for other purposes.

Chapter 6
SUMMARY AND POLICY IMPLICATIONS

This report has examined the effects of age on six driving habits of the elderly (persons age 65 years or older). This chapter summarizes the main results and discusses the implications of these results to policy-making in areas concerning the mobility and traffic safety of the elderly.

SUMMARY

Elderly drivers show an increased effort of self-protection in their driving habits relative to mid-aged drivers (persons between the ages of 25 and 64 years). Elderly drivers not only reduce daily driving exposure, avoid driving at night, avoid driving during peak hours, and avoid driving on limited-access highways, but also drive at lower speeds, drive larger automobiles, and carry fewer passengers. The following summarizes the results for each of the six driving habits examined.

- **Daily Driving Exposure**. The elderly reduce their daily driving exposure by reducing not the frequency but the distance of vehicle trips. The elderly drive fewer vehicle miles than the mid-aged. They take as many vehicle trips as the mid-aged, but their vehicle trips are shorter in distance than those taken by the mid-aged.

- **Driving By Time of Day**. The elderly are less likely to drive at night and during peak hours than the mid-aged. In addition, the elderly are lesser likely to drive at night than to drive during peak hours. This is consistent with the fact that the elderly find driving at night more problematic than driving during peak hours.

- **Driving By Roadway Type**. The elderly are less likely to drive on limited-access-highways than the mid-aged. This avoidance behavior by the elderly can be due to many characteristics of limited-access-highways, such as high speeds. When speed is held constant, however, the elderly still are found to be less likely to drive on limited-access highways. In addition, the elderly's likelihood of driving on limited-access-highways decreases only slightly when speed is held constant. This slight decrease seems to suggest that the elderly avoid driving on limited-access-highways mainly due to characteristics of limited-access-highways other than high speeds.

- **Driving Speed**. The elderly drive at lower speeds than the mid-aged. They drive about 4 miles per hour (mph) slower than the mid-aged for all trips. This is either because the elderly are more likely to drive on roadways with lower speed limits or because they drive slower on roadways with the same speed limits. The evidence indicates that both possibilities occur with the elderly. When only vehicle trips that use limited-access highways are considered, the elderly are found to drive about 4 mph slower than the mid-aged. As indicated earlier, the elderly also are less likely to drive on limited-access-highways.

- **Automobile Size.** The elderly drive larger automobiles than the mid-aged. When the size of an automobile is measured by wheelbase size on a scale from one to six, the average size of automobiles driven by the elderly is 0.40 smaller then that by the mid-aged when automobile age and import status are not held constant and is 0.26 smaller when automobile age and import status are held constant.

- **Number of Passengers Carried.** The elderly carry fewer passengers than the mid-aged. In fact, the elderly carry an average number of passengers that is about 0.05 lower than the mid-aged.

These differences in the driving habits between the elderly and mid-aged reflect the marginal effects of age difference between the two groups. These differences do not reflect any effects of the differences between the two groups in other personal, household, location, and trip characteristics that are held constant in this study.

POLICY IMPLICATIONS

Despite their increased effort of self-protection in their driving habits, as summarized above, the elderly still show a higher risk of crash and injury per unit of exposure than the mid-aged.[1] When the elderly adjust their driving habits, they consider the risks they face, but not the external risks they impose on others when they drive. If the elderly are forced to adjust their driving habits further to offset the external risks of their driving, their risk of crash and injury would be reduced and society as a whole would be better off. Any further adjustment in the elderly's driving habits, however, is likely to make the elderly worse off due to reduced mobility. The challenge to policy-making is to balance these consequences of any policy concerning the mobility and traffic safety of the elderly. The following discusses four existing policy options.

- **Removing Hazardous Elderly Drivers from Roadways.**[2] Removing elderly drivers through the use of stricter licensing laws is controversial. First, the removed drivers are forced to pay a large price--loss of automobile mobility. Second, elderly drivers have the lowest severe crash involvement per driver. If the purpose is to reduce the maximum number of severe crashes per removed driver, then removing younger drivers would be far more effective than removing elderly drivers. Third, the physical and cognitive abilities vary widely among the elderly. Forth, such removal has the appearance of discriminating against elderly drivers. As a result, the higher the proportion of elderly drivers that a state has, the harder to implement such an option. The best example is Florida, where the elderly population as a share of the total population is the highest in the nation. Three attempts by Florida's legislature to pass stricter licensing laws for elderly drivers have failed in the past several years.[3]

- **Making Alternatives to Driving Available.**[4] This option accommodates the option of removing elderly drivers from roadways. Alternatives to driving include walking, public transit, specialized transportation, and the use of taxis. As more elderly persons live in suburbs where the population density is low, these alternatives become less feasible. Walking is difficult for elderly persons in low density areas, and it is extremely costly to expand public transit for the elderly in these areas. Expanding specialized transportation to low density areas is also expensive. Subsidizing the use of taxis may be more expensive than specialized transportation.

- **Improving Vehicle and Roadway Design and Operation.**[5] This option attempts to accommodate the reduced physical and cognitive abilities of elderly drivers. There is, however, strong evidence that drivers become more risk-taking when the driving environment becomes safer.[6] There is no reason to believe that elderly drivers do not have such a behavior. This behavior would off-set many of the intended benefits of improving vehicle and roadway design and operation.

- **Re-Educating Elderly Drivers.**[7] Re-educating elderly drivers would be an appropriate policy if elderly drivers were not fully aware of their reduced cognitive and physical abilities and the consequences to their traffic safety.

As the number of elderly drivers continues to grow, the welfare of the society as a whole becomes increasingly dependent upon the mobility and traffic safety of elderly drivers. While this study has implications to policy-making, policy recommendation is beyond the scope of this report. Future research needs to examine the impacts of existing policies, as well as to develop new policy options that would better balance the effects on the elderly and society as a whole.

ENDNOTES

CHAPTER 1

1. Elderly is defined as age 65 years or older. This is the most commonly used definition in the literature on the mobility and safety of elderly persons.

2. Federal Highway Administration, *1990 Nationwide Personal Transportation Survey: User's Guide for the Public Use Tapes*, Advance Copy (Washington, D.C.: U.S. Department of Transportation, 1991).

3. *Summary of Findings and Recommendations: Highway Mobility and Safety of Older Drivers and Pedestrians* (Washington, D.C.: Highway Users Federation for Safety and Mobility, 1985); Transportation Research Board, "Executive Summary," in *Transportation in an Aging Society: Improving the Mobility and Safety of Older Persons*, Vol. 1, *Committee Report and Recommendations* (Washington, D.C.: National Research Council, 1988); and *Conference on Research and Development Needed to Improve Safety and Mobility of Older Drivers* (Washington, D.C.: National Highway Traffic Safety Administration, 1990?).

4. The TRB effort and Congressional request resulted in a two-volume report by TRB, *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons*, Special Report 218, Vol. 1: *Committee Report and Recommendations*, Vol. 2: *Technical Papers* (Washington, D.C.: National Research Council, 1988).

5. The result is a report BY THE U.S. Department of Transportation, *Older Driver Pilot Program: Report of the Secretary of Transportation to the United States Congress* (Washington, D.C.: Federal Highway Administration, 1990).

6. For example, Max Israelite, "Take Away My License: I Would Rather Stop Driving Too Soon Than Too Late (Elderly Automobile Drivers)" in *Newsweek* (May 9, 1994): 11; Joan E. Rigdon, "Car Trouble: Older Drivers Pose Growing Risk On Roads As Their Numbers Rise; They Crash More Than Many, Yet Taking Away Wheels Leads To Isolation, Anger; A Man Runs Over His Wife" in *Wall Street Journal* (October 29, 1993): A1; Lisa J. Moore, "Drive on Miss Daisy (older automobile drivers)" in *U.S. News & World Report* (June 22, 1992): 83-84; Alan L. Otten, "Older Drivers Appear Safer But More Frail (National Institute On Aging Study Reveals Older Drivers More Likely To Die In Auto Accidents Than Younger Drivers)" in *Wall Street Journal* (June 1, 1992): B1; "Safety And The Older Driver: When Difficult Issues Collide (Federal And State Authorities Struggle To Identify Aged Drivers Who Pose A Hazard While Not Discriminating Against Those Who Do Not)" in *New York Times* (May 4, 1992): A1; Sandy Rovner, "Driving Difficulties Increase With Age" in *Washington Post*

(October 30, 1990): WH16; and James Carney, "Can A Driver Be Too Old? Fender Benders And Fatalities Raise Fears Over Elderly Motorists" in *Times* (January 16, 1989): 28.

7. U.S. Federal Highway Administration (FHWA), *Highway Statistics, 1990* (Washington, D.C.: FHWA, 1991), Table DL-20; and FHWA, *Highway Statistics, Summary to 1985* (Washington, D.C.: FHWA, 1987), Table DL-220.

8. U.S. Bureau of the Census, *Statistical Abstract of the United States, 1992* (Washington, D.C.: U.S. Government Printing Office, 1992), Table 14.

9. FHWA, *Highway Statistics, 1990*, Table DL-20; and FHWA, *Highway Statistics, Summary to 1985*, Table DL-220.

10. Ruth H. Asin, *Characteristics of 1977 Licensed Drivers and Their Travel: Report 1, 1977 NPTS* (Washington, D.C.: FHWA, 1980), Table 16; and Ezio C. Cerrelli, *Crash Data and Rates for Age-Sex Groups of Drivers, 1990* (Washington, D.C.: National Center for Statistics & Analysis, 1992), Table C.

11. The elderly population is expected to reach 20 percent of all persons by the year 2020, according to Census Bureau, *Projections of the Population by Age, Sex, and Race for the United States, 1983-2080* (Washington, D.C.: Government Printing Office, 1984), No. 952, Series P-25, cited by TRB, *Transportation in an Aging Society*, Vol. 1: 22. In 1990, the elderly population was 12.5 percent of all persons, while the number of elderly drivers was 13.3 percent of all drivers.

12. Finn Jørgensen and John Polak, "The Effect of Personal Characteristics on Drivers' Speed Selection," *Journal of Transport Economics and Policy*, 27 (September 1993): 237-252.

13. TRB, *Transportation in an Aging Society*, Vol. 1: 61, 72.

14. *Ibid.*: 39-40.

15. J. Peter Rothe, *The Safety of Elderly Drivers: Yesterday's Young in Today's Traffic* (New Brunswick: Transaction Publishers, 1990), p. 64.

16. S.J. Flint, K.W. Smith, and D.G. Rossi, "An Evaluation of Mature Driver Performance," paper presented at the 14th International Forum on Traffic Records Systems, San Diego (1988), cited by J. Peter Rothe, *The Safety of Elderly Drivers*, 127.

17. P.A. Brainn, *Safety and Mobility Issues in Licensing and Education of Older Drivers* (Washington, D.C.: NHTSA, U.S. Department of Transportation, 1980), cited by Sandra Rosenbloom, "The Mobility Needs of the Elderly," in *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons*, Special Report 218, Vol. 2, *Technical Papers* (Washington, D.C.: National Research Council, 1988), 40.

18. R. Risser and C. Chaloupka, "Elderly Drivers: Risks and Their Causes," in *Proceedings of the Second International Conference on Road Safety,* ed. by J.A. Rolhengatter and R.A. de Bruin (Assen, Netherlands: Van Gorcum, 1987), cited by Sandra Rosenbloom, "The Mobility Needs of the Elderly," 40.

CHAPTER 3

1. G.S. Maddala, *Limited-Dependent and Qualitative Variables in Econometrics*, Econometric Society Monographs, No. 3 (Cambridge, Mass.: Cambridge University Press, 1983): 149-165.

2. *SAS/STAT® User's Guide*, Version 6, Fourth Edition (Cary, NC: SAS Institute Inc., 1989): 1005-6.

3. Bureau of Census, *Statistical Abstract, 1991* (Washington, D.C.: U.S. Department of Commerce, 1992), No. 762. Refiner/Reseller Sales Price of Motor Gasoline, by Grade and State: 1989 to 1991; and No. 998. State Gasoline Tax Rates, 1990 and 1991, and Motor Fuel Tax Receipts, 1990.

4. The SAS procedure used for estimation, LIFEREG, does not report the log likelihood at zero (i.e., when all explanatory variables are excluded).

5. For more on the interpretation of Tobit models, see John F. McDonald and Robert A. Moffitt, "The Uses of Tobit Analysis," *The Review of Economics and Statistics* 62 (1980): 318-321.

6. Rosenbloom, "The Mobility Needs of the Elderly," Vol. 2: 33-34.

CHAPTER 5

1. FHWA, *User Guide to the 1990 Nationwide Personal Transportation Survey*, Appendix J: National Accident Sampling System Vehicle Make and Model Coding Dictionary (Washington, D.C.: Department of Transportation, 1991).

2. A more appropriate tool would be grouped data regression or ordered probit regression (William H. Green, *Econometric Analysis*, New York: MacMillian Publishing Company, 1990).

3. Kenneth Train, *Qualitative Choice Analysis: Theory, Econometrics, and an Application to Automobile Demand*, MIT Press Series in Transportation Studies, Marvin L. Manheim, ed. (Cambridge, Mass.: M.I.T. Press, 1986): 143-144.

CHAPTER 6

1. See Chapter 1.

2. TRB, *Transportation in an Aging Society*, Vol. 1: 76-103.

3. A.D. Burch, "Bill Targets Old, Young For Added Driving Tests" in *The Orlando Sentinel* (March 3, 1994): C-1.

4. TRB, *Transportation in an Aging Society*, Vol. 1: 76-103.

5. *Ibid.*

6. Sam Peltzman, "The Effects of Automobile Safety Regulation," *Journal of Political Economy*, 83 (June 1975): 677-725.

7. TRB, *Transportation in an Aging Society*, Vol. 1: 76-103.