FACTORS AFFECTING FATAL CRASH INVOLVEMENT OF OLDER DRIVERS IN THE U.S.

by

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Abstract

Rapid increases are estimated in the percentage of elderly among the U.S. population starting in 2010. A majority of the older Americans depend on automobiles to meet their transportation needs either because of lack of public transportation or by choice. Ninety percent of total trips made by the elderly are by personal vehicle and seventy percent of this number involves the elderly driving the vehicles. However due to the aging process, older drivers experience a natural decline in sensory, cognitive, and other mental and physical capabilities as compared to younger drivers. This situation, combined with an imperfect highway infrastructure is making older drivers one of the most critical groups in terms of highway safety, thus demanding safer driving conditions.

Safety concern for older drivers arises when the fatality rate per mile driven is considered, as exposure is one of the crucial factors contributing to increased fatality risk of older drivers. Hence, exposure reported in Billion Vehicle Miles Traveled (BVMT) was considered for this study. Crash data and exposure data were used to compute the fatality rates. Sources for this data are the Fatality Analysis Reporting System (FARS) and National Household Travel Survey (NHTS).

A basic characteristics study was completed to compare the fatality risk of younger (16-24 yrs), middle-aged (25-64 yrs), and older drivers (65+ yrs). Crash details were screened to study the characteristics of older drivers involved in fatal crashes. Risk for older drivers due to other involved drivers of all ages divided into groups was studied to understand their distribution. A number of statistical methods like the chi-square test of independence, odds ratio

and double paired comparison estimates were applied to study contributing factors of older driver's increased fatal crash involvement.

Results from the characteristics study for the elderly indicate that a majority of fatal crashes occur under daylight conditions with relatively higher seatbelt usage and non-alcoholic driving on straight level roads, which are generally considered as safer driving conditions. Other factors studied include vehicle-related variables like body type; manner of collision; roadway-related variables like roadway function class, month of the crash, and day of the week; and driver-related variables like race. Roadway functional class, vehicle body type, travel speed, number of drunk drivers, and the month in which the fatality occurred were found to have strong correlation with age of the older driver. Results from paired comparisons were used to estimate the fatality risk of older occupants as drivers and passengers under two different conditions considered simultaneously. Older drivers were found to have more fatality risk compared to older passengers. Recommended measures are also discussed to enhance older driver safety in the U.S.

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Dedication

I would like to dedicate this thesis to my grandparents, Late Rallabandi Satyanarayana and Rallabandi Annapurna and Late Dasaka Seshaih Sastry and Late Dasaka Satyavati. I would like to sincerely dedicate this work to my parents, Rallabandi Sarma and Rallabandi Lakshmi, to my sisters, Malladi Karthika and Yenamandra Sirisha and to my brother in-laws Malladi Chandrashekar and Yenamandra Kiran, without whom my journey to a Master's degree would not have been possible. A very special dedication goes to all my teachers who helped me in getting to this stage.

CHAPTER 1 - Introduction

1.1 Background

Highway safety is an important public health issue for many organizations. Annually, 518 billion U.S. dollars are estimated to be spent for materials, healthcare, and other expenditures in road traffic collisions globally (*1*). One of the primary causes for fatalities of all age groups in the U.S is traffic crashes making safety of road users of utmost concern (*2*). Crash distribution, based on the severity of crashes in the United States for some selected years, is given in Table 1.1. The percentage of fatal crashes among total number of crashes shows a consistency since 1990. Though fatal crashes are fewer in number compared to non-fatal crashes and property damage only crashes, the loss occurred due to a fatal crash is irreparable.

Table 1.1 Crashes by Severity in the United States for Selected Years from 1990 to 2006

Item	*1990*	*1995*	*2000*	*2005*	*2006*
Crashes (1,000)	6,471	6,699	6,394	6,159	5,973
Fatal	39.8	37.2	37.5	39.2	38.6
Non-fatal injury	2,122	2,217	2,070	1,816	1,746
Property damage only	4,309	4,446	4,286	4,304	4,189
Percent of total crashes					
Fatal	0.6	0.6	0.6	0.6	0.6
Non-fatal injury	32.8	33.1	32.4	29.5	29.2
Property damage only	66.6	66.4	67.0	69.9	70.1

Source: U.S. Census Bureau (3)

There are about 38,000 fatal crashes every year, leading to more than 40,000 fatalities in the United States. As per 2008 statistics, 37,261 people died and an additional 2.5 million were injured as a result of motor vehicle crashes on U.S. roadways (*4*). Various common studies like percentages and risk ratio calculations play a vital role in analyzing traffic trends and improving safety for specific age groups. Accordingly, distributions of crash fatalities by age group and gender from year 2002 through 2006 are presented in Table 1.2. A complete table with number of crash fatalities for the years 1996-2006 is provided in Appendix A.

Table 1.2 Distribution of Total Crash Fatalities by Sex, Age Group, and Year

Females						
Year	2006	2005	2004	2003	2002	Total
< 16 yrs	964	1,017	1,142	1,071	1,065	5,259
16-25 yrs	3,006	3,079	3,151	3,171	3,207	15,614
26-55 yrs	5,125	5,216	5,191	5,271	5,343	26,146
56-65 yrs	1,229	1,263	1,238	1,190	1,156	6,076
≥ 65 yrs	2,399	2,553	2,636	2,809	2,731	13,128
Total	***12,747***	***13,155***	***13,387***	***13,532***	***13,529***	***66,350***
Males						
Year	2006	2005	2004	2003	2002	Total
< 16 yrs	1,206	1,340	1,480	1,508	1,483	7,017
16-25 yrs	8,302	8,187	8,129	8,050	8,334	41,002
26-55 yrs	14,085	14,349	13,713	13,741	13,700	69,588
56-65 yrs	2,708	2,707	2,463	2,399	2,204	12,481
≥ 65 yrs	3,315	3,674	3,577	3,582	3,654	17,802
Total	***29,722***	***30,347***	***29,443***	***29,346***	***29,466***	***148,324***

Source: FARS 2002-2006 (5)

Crash fatalities are higher for males of all age groups, while the male population is equal to or less than the female population for the five-year study period considered (*3*). Females above 65 yrs have the highest number of fatalities, followed by the 16-20 yrs group. Among males, younger (< 25 yrs) and older (≥ 65 yrs) age groups have a higher number of fatalities.

Percentage distribution of fatalities by young, middle, and older age groups for the years 2002 to 2006 is given in Fig 1.1. Younger (< 25 yrs) and middle-aged (25-64 yrs) groups contribute to 32 percent and 52 percent of total traffic fatalities respectively, whereas elderly (≥ 65 yrs) contribute to 16 percent of the total.

According to a National Highway Traffic Safety Administration (NHTSA) report, when considering fatality rates based on exposure in vehicle miles traveled or population, older and younger age groups have higher rates (*5*). Based on vehicle miles traveled (VMT), fatal crash rates increase starting at age 75 and increase markedly after age 80 (*6*). This makes the safe mobility of the older age group a major concern in the United States.

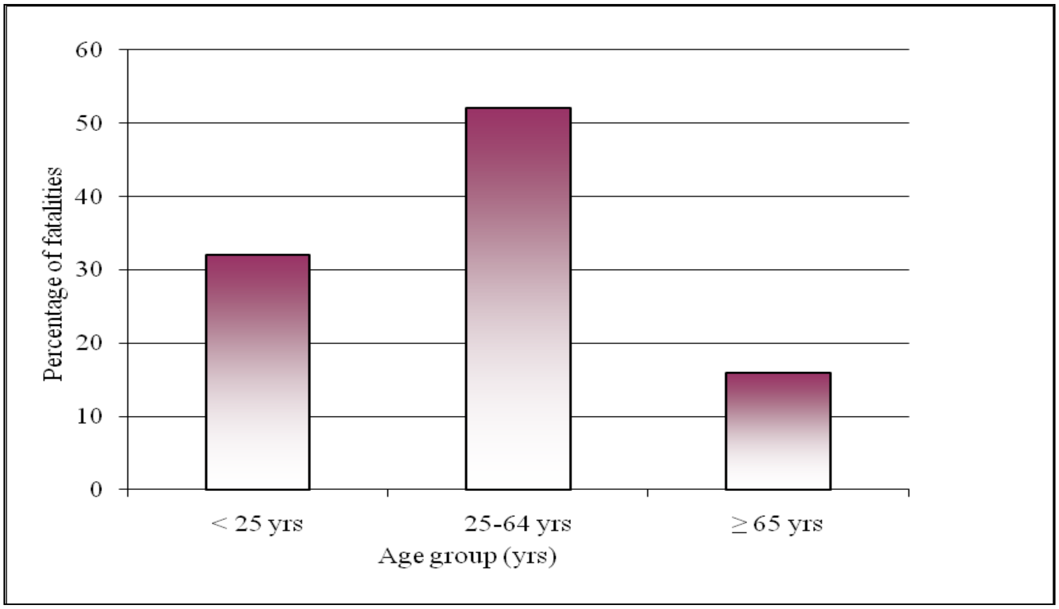

Figure 1.1 Percentage Distribution of Fatalities in the U.S based on Age Group

Older people (≥ 65 yrs) contributed to 12 percent of the total U.S. population in 2006. According to U.S. census estimates, a considerable increase will occur in the older population during the 2010 to 2030 period, after the first baby boomers (people born between 1946 and 1964) start turning 65 yrs in 2011. There was a rapid increase of eleven-fold in older population from 3.1 million in 1900 to 35.0 million in 2000, in comparison to the total population which increased threefold. The older population is anticipated to be 70.1 million, i.e. twice that by 2030. The estimated growth in elderly population for the year 2050 given by the U.S. Census Bureau is shown in Fig 1.2 (*7*). The growth is projected until year 2050 by using census data available up to 2006.

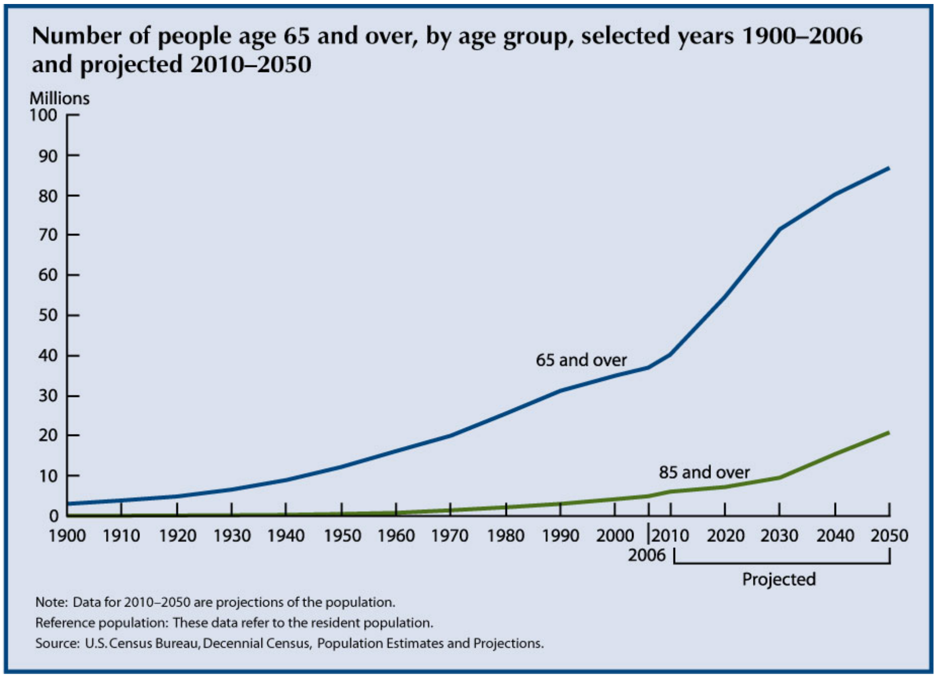

Figure 1.2 Projected Growth in Older Population for the Year 2030
(Source: U S. Census Bureau) (7)

Older road users are comprised of drivers, passengers, pedestrians, bicyclists, and motorcyclists. Elderly individuals accounted for 8 percent of all traffic crashes during 2007 and 14 percent of all traffic fatalities during the same year (*8*). Involvement of older road users in fatal crashes as drivers, occupants, and pedestrians in 2007 is shown in Table 1.3. Comparing younger, middle, and older age road users, older drivers and occupants accounted for 13.8 percent of fatalities whereas pedestrians had 19.4 percent of the total.

Table 1.3 Younger, Middle-aged, and Older Road Users Involved in Fatal Crashes in 2007

Item	*16-24 yrs (%)*	*25-64 yrs (%)*	*≥ 65 yrs (%)*	*Unknown (%)*	*Total (%)*
Drivers involved in fatal crashes	13,346 (23.9)	35,547 (63.9)	5,880 (10.6)	908 (1.6)	55,681 (100)
Driver fatalities	6,416 (24.2)	16,387 (61.9)	3,656 (13.8)	21 (0.1)	26,480 (100)
Total traffic fatalities	11,890 (29.0)	23,109 (56.3)	5,932 (14.4)	128 (0.3)	41,059 (100)
Occupant fatalities	10,735 (30.2)	19,858 (55.8)	4,928 (13.8)	34 (0.2)	35,555 (100)
Pedestrian fatalities	937 (20.1)	2,770 (59.5)	903 (19.4)	44 (1.0)	4,654 (100)

Mobility of the older population has increased more than in the past (*9*). Distribution of daily trips made by the elderly population by mode is shown in Figure 1.3 (*10*). They are mostly on the road as drivers. As indicated by data from the National Household Travel Survey (NHTS), the older population makes a greater percentage of their trips as drivers compared to younger people. With the increase in elderly population estimated, there might be an increase in older drivers correspondingly. It is also likely that growth of number of older drivers will be higher compared to the growth of the older population itself (*11*). This growth may account for an increase in the number of crashes and fatalities involving older drivers.

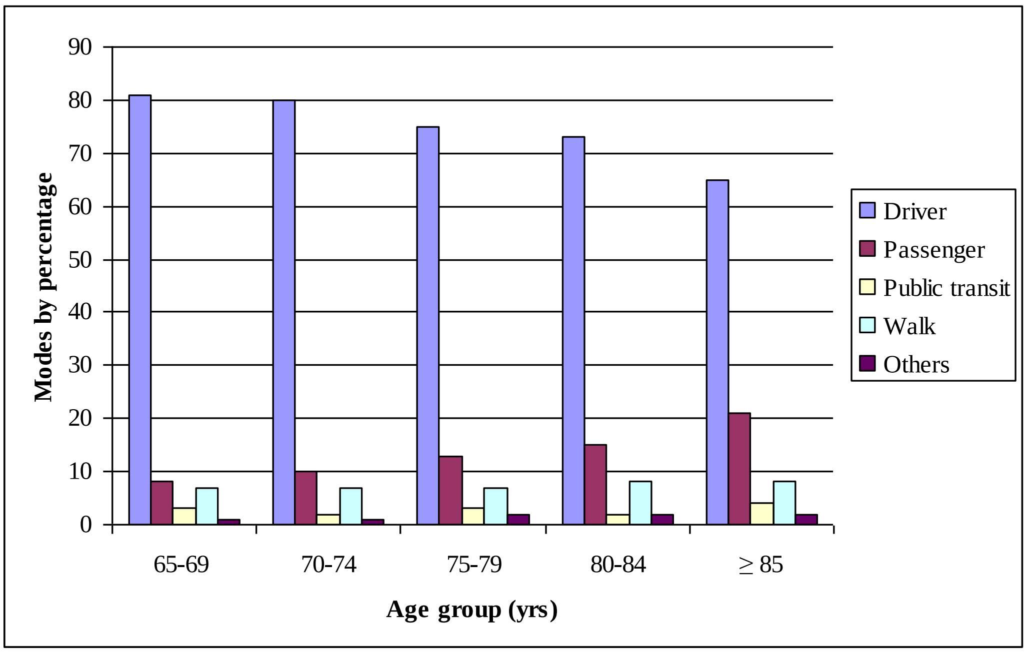

Figure 1.3 Mode of Travel for All Daily Trips by Age

Number of licensed older drivers was around 30 million in 2006, contributing to an 18 percent increase from 1996, whereas the increase in total number of licensed drivers was only 13 percent during the same period. With the natural aging process leading to decreased mental and physical capabilities, combined with imperfect highway infrastructure, older drivers are more prone to traffic injuries. Although licensed older drivers have fewer crashes when compared to the total population, they have higher fatal crash rates per miles driven (*12*).

According to NHTSA, fatality rates for older drivers are much higher than rates for middle-aged (25-64 yrs) drivers. Older drivers have second highest crash rates after younger drivers, but older drivers are of major interest because of their fragility to injury, along with increasing numbers of licensed drivers and their experience in driving (*13*). The risk of the older population is not only a factor of crashes but also the amount of travel in number of miles or number of trips. Based on travel data collected between April 2001 and March 2002, the rate of passenger vehicle fatal crash involvements per 100 million vehicle miles traveled was higher for drivers 80 yrs and older, than it was for drivers of any other age group except teenagers. Fatal crash rates for elderly drivers calculated by the U.S. Department of Transportation for 2001 are shown in Figure 1.4 (*14*). Fatal crash rates based on a per mile driven basis increase starting at age 75 and increase significantly after 80 yrs.

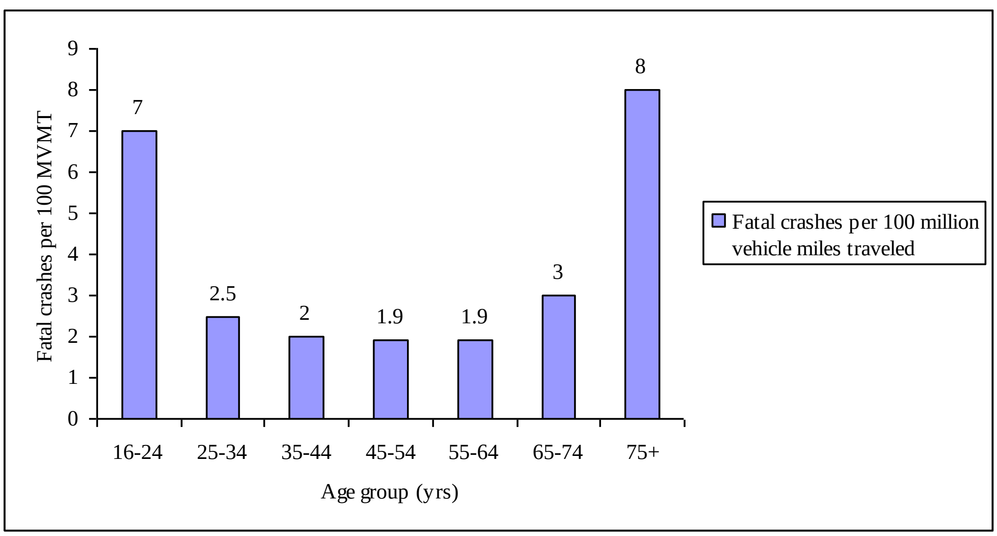

Figure 1.4 Fatal Crashes by Driver Age Group per 100 Million Vehicle Miles Traveled (2001)
Source: GAO analysis of NHTSA and USDOT data

Fragility begins to increase at ages 60-64 yrs. At age 75, older drivers begin to be markedly over involved in crashes, but fragility is the predominant factor explaining the elevated deaths per mile driven among older drivers (*15*).The reason for older driver crashes could be due to the aging process as the reaction time of an older driver decreases with increasing age. Fragility being the leading factor, it is important to investigate the other driver, vehicle, and environmental related factors contributing to the fatal crash involvement of older drivers. A systematic approach to this has been made by various institutes by addressing four E's of safety: engineering, education, enforcement, and emergency medical services to improve highway traffic safety (*16*).

1.2 Problem Statement

The majority of the elderly are dependent on the automobile for their transportation needs. With the increase in older driver population and their involvement in higher severity crashes, their highway safety concerns have taken the front seat. The desire of the older population to be independent necessitates them to drive more, making them more susceptible to severe injuries. Deterioration in vision, perception reaction time, and hearing impairment are some of the common problems of the elderly which makes their driving more unsafe to themselves and other road users (*17*). Older drivers have low risk when rates are measured in fatalities per licensed driver, but they have a very high risk when rates are considered in fatalities per mile driven.

Older drivers might have fatality risk under different driver, vehicular, environmental, and roadway related conditions. Hence, it becomes necessary to find out the factors contributing to the fatality risk of older drivers.

1.3 Objectives

The primary objective of this study is to identify critical characteristics of elderly drivers' fatal crash involvement, while considering their actual amount of driving. Causes and situations under which older drivers are more likely to be fatally injured are investigated. This study also attempts to predict the correlation between various driver, vehicle, and crash-related factors and age of the driver. The amount of risk involved for older occupants is identified using the double pair comparison method and the distribution of other involved drivers with older drivers is analyzed.

Suggested measures are discussed to improve the overall highway safety situation for elderly drivers.

1.4 Organization of the Thesis

This thesis consists of six chapters and three appendices. Chapter one contains background information, problem statement, and objectives of this study. Chapter two provides a summary of the previous studies conducted in relation to the current research. Chapter three presents details of the data and databases used to facilitate this study. Chapter four presents the methodologies used in achieving the objectives of this study, while chapter five summarizes the results. Chapter six details the summary, conclusions, and recommendations for improving older driver safety.

CHAPTER 2 - Literature Review

Extensive research has been conducted on safety of the older population (65 yrs and older) in the recent past, precipitated by the increased number of fatalities for both occupants of motor vehicles and non-occupants like pedestrians, bicyclists, and others. Various organizations like the National Highway Traffic Safety Administration, the American Association for Retired Persons, the American Medical Association, and the American Automobile Association have been working on policies and improvement of elderly driving conditions. Most of the studies have focused on number of fatalities, calculation of risk ratios, and percentages, but very few studies have been performed on the risk posed based on vehicle miles traveled. A literature review on some of the important findings related to older driver safety is provided in this chapter.

2.1 Age and Gender Based Studies

Evans, L. (*18*), after an extensive research, found that age and gender of the occupant are two of the most important factors to be considered in the occurrence of a fatal injury. Risk of dying in a crash is based on the ability of the human to tolerate its impact, which is technically termed as fragility. Fragility increases with increase in age and also varies with gender for different types of crashes. The double pair comparison method was introduced by Evans, which was used to study the effects of age and gender on the fatality risk in a fatal crash using the FARS database. Irrespective of age of the occupant, females were found to be more fragile compared to males in fatal crashes.

Baker et al. (*19*) analyzed the special characteristics of female drivers older than 70 yrs involved in fatal crashes. Results indicated that older female drivers were overrepresented in good weather, daylight, dry roads, and low traffic, which were supposed to be the safest driving conditions. With increase in age, visual, cognitive, and perceptual functions deteriorate and thus become contributing causes of resulting crashes.

2.2 Factors Responsible for Fatalities

According to studies conducted by NHTSA, the risk of being involved in fatal crashes varies depending on different crash characteristics like driver, vehicle, roadway, and environment related (*20*).

A driver's notion of ideal driving conditions would be a car with antilock breaks, clear sky, and dry roadway with low traffic. Evans, L. (*18*) study showed that 84 percent of fatal crashes occurred on dry roads and 88 percent of them occurred under non-adverse atmospheric conditions. More than half of fatal crashes occurred under daylight conditions. Rural road conditions accounted for 60 percent of traffic fatalities, with the highest number of fatalities on local roads and the lowest on Interstates.

Braitman et al. (*21*) studied factors leading to over involvement of older drivers in intersection crashes compared to younger drivers. The study was conducted in the state of Connecticut, which is similar to the United States as a whole in terms of older people and their crash statistics. Crash reports submitted by police agencies to the Connecticut Department of Transportation were used for the analysis. Subjects considered were of the age group 70-79 yrs and 80 and older, and the comparison group of drivers were of the age 35-54 yrs. The study excluded property damage only crashes and crashes involving fatal injuries. Telephone interviews were conducted as the final effort, and coding for factors leading to the crash was done based on a detailed summary provided by the subject. The oldest drivers (80 yrs and older) experienced fewer rear-end crashes and run-off-the-road crashes compared to middle-aged drivers (35-54 yrs). Failure to yield while turning left or right at stop signs was of highest occurrence for older drivers. These increased with an increase in age and reasons were contributed to misjudging the gap and problems in scanning the busy intersection. To reduce failure- to-yield crashes countermeasures like roundabouts, protected left turn lanes to detect oncoming traffic, crash avoidance technologies, driver retraining, and screening tests were suggested.

Dissanayake and Lu (*22*) analyzed various factors influencing injury severity to older drivers in fixed object passenger car crashes. The source database for this study was the Florida Traffic Crash Database obtained from the State Data Program for the period 1994-1996. Binary logistic regression was applied to model the conditional crash and injury severity, with the dependent variable being crash severity and driver injury severity. Severity levels varied from no injury to fatality. All selected explanatory variables were divided into four categories: driver related, vehicle related, roadway related and environment related. Apart from controlling factors like age of the driver and fixed-object crashes, considering a relationship between the properties of the vehicle and the crash severity, only passenger cars were considered in this study. Travel speed and restraint device usage were found to be the important parameters for all crash severity and injury severity models. Gender, urban/rural nature, presence of roadway curvature, and having a front-impact point in the crash were also identified as the other important factors resulting in higher severity crashes. The injury-severity model was found to have higher predictive power compared to a crash-severity model. Older drivers in good personal condition succumbed to less-severe injuries, and older male drivers were comparatively safer than female drivers. Crashes in rural areas and places with curves or grades had a higher probability of crashes resulting more severe injuries.

Kweon et al. (*23*) studied the importance of exposure data and overall risk to different drivers across vehicle classes. Datasets considered were the 1999 General Estimates System (GES) for crash data and the 1995 Nationwide Personal Travel Survey (NPTS) for exposure data. The GES is a nationally represented dataset and contains all types of crashes including fatal, injury, and property damage only crashes. Data is extracted only for drivers from both datasets. The number of miles driven by males and females varies much with increase in age. Among findings, young and middle aged men are slightly more involved in accidents than their female counterparts, but older women are slightly more involved than men. Drivers of passenger cars are involved in more crashes than those driving light-duty trucks, and males are involved in more crashes when driving passenger cars. SUV and PU drivers are more likely to experience a rollover crash and younger drivers are more involved in such crashes. Crash risks are estimated using probability values for different driver and vehicle types. The ordered probit method was used to model the probability of injury severity conditioned on crash occurrence. Results indicated that younger drivers are at more risk driving passenger cars, female drivers are more at risk driving light-duty trucks and older drivers are relatively at lower crash risk than younger drivers based on miles driven. The differences are striking between age groups and lower between genders when considering the vehicle miles driven. Vehicle design features can be improved and some of the important crash-causing factors are to be attended for higher risk drivers.

Mortimer et al. (*24*) studied major problems involved in night driving for older drivers (65yrs and older). Datasets considered were FARS for crash data and NPTS for exposure. The risk measure for older drivers was made by calculating rates and comparing them with younger and middle-aged groups at various times of the day. It was found that fatal crash involvement rates of older drivers were not as high as those of younger drivers. Crash rates were lowest during daylight hours and then increased in the night for all age groups. Older male drivers driving at nighttime (12-6 AM) had higher fatal crash rates compared to females, and these rates were higher only in case of fatal crashes. For all the other type of crash severities, females had higher crash involvement rates for both middle- and older-age groups. Also, multi-vehicle crashes were overrepresented in cases of nighttime driving for older drivers. Though younger drivers were at higher risk compared to older drivers, performance of older males indicated an extensive increase in crash involvement in darkness. These trends are expected to increase with the baby boomers. Improvement in driving, environment and vehicle characteristics were suggested such as; increasing reflectivity of roadway delineation, providing exterior mirrors on motor vehicles, and reducing the maximum permissible mounting height of headlamps on all vehicles to reduce glare were suggested.

McGwin et al. (*25*) made an effort for countermeasure development of traffic crash characteristics for the riskiest group among young, middle-aged and older drivers. Police-reported crashes in the year 1996 for the state of Alabama were considered for this study. This was provided by Crash Analysis Reporting Environment (CARE), an online crash data analysis system designed to assist traffic safety professionals. Data pertaining to driver, vehicle, and roadway characteristics were analyzed for each crash. Crash rates were calculated based on two exposure measures, i.e. based on per licensed driver and per person miles of travel. Rates based on age and gender was calculated for all crashes, crashes resulting in a fatality or an injury, and fatal crashes. Age groups of the drivers were divided into three categories: 16-34 yrs, 35-54 yrs, and 55 yrs and older. Given a crash, older drivers and younger drivers had almost equal probability of involvement when considered per mile driven, and older drivers were more likely to be injured. The higher crash rate for women was attributed to their having less travel relative to men. Higher rates per licensed driver prevailed among younger drivers and rates decreased with increase in age. The exception was for fatal crashes where there was a slight increase for drivers 75 yrs and older. Younger and older drivers were more likely to be considered at-fault. Older drivers were less likely to have crashes involving driver fatigue and were overrepresented in crashes at intersections, while turning or changing lanes, and failure to yield right-of-way. Older drivers were less likely to be involved in crashes due to higher Blood Alcohol Content percentages. Further study of the relation between driver, vehicle, roadway, and environmental-related factors in crash causation, was recommended.

Brown et al. (*26*) evaluated the difference in rural and urban motor vehicle crash death rates. FARS data was used to aid this study for a period of 20 yrs, i.e. 1977-1996. Total population and percentage of those living in rural and urban areas was obtained from the U.S. Census Bureau. Estimates for annual vehicle miles traveled were obtained from the U.S. Department of Transportation/ NHTSA Highway Statistic Summaries. Crash death rates were calculated in three forms: population based as deaths per 100,000 population, vehicle miles traveled based as deaths per 100 MVMT, and frequency with which crash deaths occur. These rates were calculated to answer eight study questions: 1) Is the rural motor vehicle crash death rate higher than the urban rate? 2) Has the rural motor vehicle crash death rate changed over the past 20 yrs? 3) Has the urban motor vehicle crash death rate changed over the past 20 yrs? 4) Has the combined (rural and urban) motor vehicle crash death rate changed over the past 20 yrs? 5) Is the rural dead-at-scene rate higher than the urban dead-at-scene rate? 6) Has the rural dead-at-scene rate changed over the past 20 yrs? 7) Has the urban dead-at-scene rate changed over the past 20 yrs? 8) Has the combined (rural and urban) dead-at-scene rate changed over the past 20 yrs? Chi-square, t-test, and odds ratio were used to make the comparison study between rural and urban crash rates. It was found that the rural motor vehicle crash death rate is consistently higher than urban rate for the considered 20-year period. This is similar to the case with the dead-at-scene rate. The population-based, combined motor vehicle crash death rate did not differ much for the two 10-year periods, but the VMT-based rate was found to be lower in the second 10-year period. The combined rates showed a converse result in the case of dead-at-scene rates. These remained unchanged for VMT-based, dead-at-scene rates but showed an increase in the population-based rates. The author stated that law enforcement activities and public awareness campaigns could be reasons for the change in crash rates. Further impact can be made by introducing seat belt laws, improving road construction techniques, and other things like automatic crash notification and location identification technology.

2.3 Older Driver Safety Research in Other Countries

Ryan et al. (*27*) studied age and gender differences in the rates of crash involvement of Western Australian drivers. Research was conducted at the Road Accident Prevention Research Unit at the University of Western Australia using a Road Injury Database. Subjects considered were all drivers of cars, station wagons, and related vehicles involved in property damage, injury, and fatal crashes in Western Australia; the analysis period was four years (1989-1992). Results showed that drivers under 25 years had the highest crash rates on population and license basis, but when the distance traveled was taken into account, rates of crash involvement for the 75 or more age group were as high as those of the youngest age group. Drivers over 70 years were involved in relatively more crashes involving fatalities and hospital admissions than younger drivers. Younger drivers were more involved in single-vehicle crashes, middle-aged drivers in same-direction crashes, and older drivers in right-angle crashes. These patterns observed are consistent with changes in exposure to risk of crash involvement with age, and also with changes in ability, experience, and psychological function, which are also related to age.

Hutchinson, T. (*28*) studied the difficulty in grading injury severity in the crash database of England. Each of three categories-- fatal, serious, and slight -- had large variations within themselves. Considering drivers and front seat passengers in single-vehicle crashes, cross-tabulation of injury severities was done to study the dependency. A probabilistic model was developed to study the relative frequencies of injury severities of two persons in the same accident. Results showed that presence of a passenger affects the driver injury severity. Passengers tended to be more seriously injured than drivers in non-overturning accidents. It also found it practicable to base analysis of injury severity on the notion of a continuous scale divided into categories.

Keall et al. (*29*) studied the reasons for higher than average rate of involvement in injury crashes for older drivers. This study was a case-control design of driver kilometers conducted in New Zealand for the years 1997-1998. Only light, four-wheel vehicles were considered for consistency in the driving patterns. SAS procedure GENMOD, using the REPEATED statement, was used for modeling crash risk. Modeling was done using age as a continuous variable, as risk was expected to vary smoothly with age. Hierarchical logistic regression was the method used to model data. Results showed that age had linear and quadratic effects in predicting injury severity. Effects of air bags and restraint systems were also studied.

2.4 Improving Traffic Safety

Traffic safety is an outcome of broader cultural conventions, norms, attitudes, and behaviors (*30*). Aggressive driving, drunk driving, running red lights, etc. are some of the serious issues that led to attempts to change the traffic culture into a traffic safety culture. The Federal

Highway Administration (FHWA) has made an effort in preparing a “Highway Design Handbook for Older Drivers and Pedestrians.” It is designed in such a way to help not only older persons but all road users. This can be used in designing safer new roads and identifying and rectifying problems with existing roads before statistics reveal a crash problem. (*31*) This handbook can also be used to reduce the risk and severity of crashes and for remedial works after construction, reducing the whole-life cost of projects.

Other handbooks like “A Guide for Reducing Collisions Involving Older Drivers,” “Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians,” and “Pocket Guide to Improve Traffic Control and Mobility for Our Older Population,” aid transportation professionals in making decisions and taking into account unique needs of the nation’s older road users (*32*). Various other ways of promoting safety issues related to older road users include Federal and State Older Road User Programs, Community Resources for Promoting Older Road User Safety, and Articles on Older Road Users and Pedestrians published in Public Roads Magazine. The Highway Safety Improvement Program (HSIP) was designed to achieve a significant reduction in traffic fatalities and injuries on all public roads through the implementation of infrastructure-related highway safety improvements (*33*). To ensure that the benefits are achieved through the HSIP, it is carried out in three major steps: planning, implementation, and evaluation. The Strategic Highway Safety Plan (SHSP) releases implementation guides regularly under the Roadway Departure Safety Program to ensure the safety of context-sensitive solutions and to provide a safe driving, riding, and walking environment (*34*). There are various other organizations and programs which consider safety as their primary issue, strive to improve the safety performance of roadways, and make safety their first consideration in every investment decision (*35*).

CHAPTER 3 - Data

The following section provides a detailed discussion about crash and exposure data used to evaluate the fatality risk for older drivers.

3.1 Crash Data

The Fatality Analysis Reporting System (FARS) database was used in this study for obtaining fatal crash data. It contains details of fatal crashes in all 50 states, District of Columbia, and Puerto Rico. This database was conceived, designed, and developed by the National Center for Statistics and Analysis (NCSA) to aid the traffic safety community in identifying traffic safety problems and providing countermeasures for better driving standards (*36*). NCSA is a division of the National Highway Traffic Safety Administration (NHTSA), providing a wide range of analytical and statistical support to NHSTA. NCSA responds to requests for data from various sources like state and local governments, research organizations, private citizens, auto and insurance industries, Congress, and the media. NHTSA has a contract with an agency in each state to obtain information on fatal crashes. This information from all the states is compiled and put in a standard format by FARS analysts who are state employees specially trained for this job. Fatal motor vehicle traffic crash data obtained from various state agencies are assembled and coded on standard FARS forms. Various forms used in assembling the information are Police Accident Reports (PARS), state vehicle registration files, state driver licensing files, state highway department data, vital statistics, death certificates, coroner/medical examiner reports, hospital medical records, and emergency medical service reports.

FARS was established in 1975 and data since then is available in several formats. It is broadly used within NHTSA to answer many queries on the safety of vehicles, drivers, traffic conditions, and roadways. Fatal crash reports can be accessed at national and state levels by a FARS analyst acting in response to overall traffic safety issues.

In order to make an entry in the database, a crash must involve a motor vehicle traveling on a trafficway customarily open to the public, and result in the death of an occupant of a vehicle or non-motorist within 30 days of the crash. The FARS database includes details of each and every fatal crash reported. Each crash is characterized in terms of crash, vehicle, roadway, and people involved with the help of more than 100 coded variables. All these variables are reported on accident, vehicle, driver, and person forms, respectively. The accident form contains information about the crash such as time and location, first harmful event, weather conditions under which the crash occurred, number of vehicles and people involved. Vehicle and driver forms record details like vehicle type, impact points, most harmful event, and driver's license status. The person form contains details about each individual involved in the crash such as age and gender of the person; whether the person is the driver, passenger, or non-motorist; injury severity; and restraint use. Individual privacy is maintained by protecting details such as name, address, and any other personal information. Overall alcohol estimates which describe the contribution of the alcohol factor in fatal crashes as well as driver and non-occupant Blood Alcohol Content (BAC) estimates, are present in the FARS alcohol files which are an add-on to the data files when no alcohol information would otherwise be available.

FARS Encyclopedia is a Web-based tool that facilitates in downloading the data and generating results through queries. It also consists of reports and fact sheets drawn from published FARS data for the relevant year and state. The reports are classified under trends, crashes, vehicles, and people sections. The trends section covers motor vehicle crashes and fatalities over a range of years. Reports under crashes present statistics about motor vehicle crashes based on injury severity of the person, and those under vehicles present details about kinds of vehicles involved in fatal motor vehicle crashes. Reports under the people section provide data on the kinds of people, i.e. drivers, passengers, or non-motorists involved in motor vehicle crashes. FARS Query System is a Web interface that allows users to perform their own custom queries such as case listings and univariate and cross tabulations. FARS data files are available in an archive as a public resource to download in file transfer protocol (FARS FTP). This Website enables us to process the data using our own computer system.

3.2 Exposure Data

The National Household Travel Survey (NHTS) 2001 database was used in obtaining exposure-related data in this study. Exposure is measured in person trips, person miles of travel, vehicle trips, and vehicle miles of travel (VMT). NHTS is an endeavor by the U.S. Department of Transportation (DOT), sponsored by the Bureau of Transportation Statistics (BTS) and the Federal Highway Administration (FHWA), to gather data on both long-distance and local travel by the American public. All data related to a trip, such as number of miles traveled, time of travel, duration of the trip, purpose of the trip, weather conditions during the trip, etc., are considered in the survey to aid policy makers and transportation planners in their work on travel. This survey is typically conducted every five years on average, and travel data has been available since 1969. Surveys have been conducted in 1969, 1977, 1983, 1990, 1995 and 2001. From 1969 through 1983, the survey was called the Nationwide Personal Transportation Survey (NPTS), which was conducted for U.S.DOT by the Census Bureau as face-to-face surveys and respondents reporting about their travel by recall. The 1990 NPTS was a telephone survey that used the same recall method for collection of travel data by household members older than five years. The 1995 NPTS was also a telephone survey but used a travel diary to collect trip reports from each household above the considered age. The 2001 NHTS survey was conducted from March 2001 to May 2002. The 2001 NHTS is updated with delimitations of some variables from previous years travel data like 1969, 1977, 1983, 1990 and 1995 Nationwide Personal Transportation Surveys and American Travel Survey conducted in 1977 and 1995. This was a telephone survey with a travel diary collecting trip reports from every household member. For 2001, 69,817 households and 160,758 people were interviewed (*37*). A seventh series of the NHTS survey was conducted from March 2008 to April 2009 representing the largest household travel survey in the world. Efforts were made by the U.S.DOT in improving the design and methods of the 2008 NHTS. Nearly 155,000 households were interviewed and public use of the dataset will be available in late fall of 2009 (*38*).

Exposure in VMT is useful in calculating crash rates which is an important tool when evaluating traffic safety. NHTS 2001 helped in preparing the *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report* by providing data to the FHWA and the Federal Transit Administration (*39*). It also enabled BTS and NHTSA, in calculating fatal crash rates and exposure rates, to provide a better understanding of the risks. Travel data for 2001 is available in the Person file, Travel Day file, and Household file, which are easily accessible by the public. The Household file contains data on household demographics, socio-economic characteristics, and residence location of the 26,038 households included in the survey. The Person file contains data on personal and household characteristics, attitudes about transportation, and general travel behavior characteristics such as usual modes of transportation to travel to work for 60,282 persons. The Travel Day file contains trip-based data on trip purposes, modes, trip lengths in terms of time and distance, and trip start times for 248,517 trips (*40*).

With the availability of NPTS and NHTS data over time, many trends have been established about American's travel that have alerted need for required measures. Some of them are as follows:

- growth of the suburbs and associated growth of personal travel,
- increase in household vehicle ownership,
- broad range in the household vehicle fleet and impact on safety with fleet's aging,
- impact of baby boomer generation on travel,
- increase in women's travel and
- growth in average trip length and greater mobility of specific age groups like younger and older age groups.

Among the issues listed, impact of the baby boomer generation on travel has been quite significant and various studies are being conducted for their safety measures. Calculation of crash rates as fatalities per vehicle miles traveled facilitates studying fatalities in the context of amount of driving done, and thus shows the real picture of risks posed for different age groups.

3.3 Data Preparation

FARS data was obtained from NHTSA for the period from 1990 to 2007 in compact discs through a mail request. It is available in three major files: Accident file, Person file, and Vehicle file, and the period considered for analysis is 1997-2007. Data used in this study for different purposes was prepared by merging the three files (person, vehicle, and accident file) using a common field (State_case) in Statistical Analysis Software (referred to as SAS from now on). Entries with unknown value for variables used in the three files were discarded in this study to avoid errors in results. Personal injury severity in FARS is divided into five major categories measured on the KABCO scale: K-Fatal Injury, A-Incapacitating Injury, B-Non-incapacitating Evident Injury, C-Possible Injury, O-No Injury. Injured severity unknown, died prior to accident, and unknown were the other minor categories. When estimating rates and fatality risk using the double pair comparison method only fatal injuries were considered. All types of injuries except no injury in fatal crashes were considered for all other analyses. Various customized datasets were formed by incorporating certain sets of variables. These datasets were used to estimate the fatal crash/fatality risk for older drivers using various methodologies.

At the time of this study, exposure data available for the latest year was 2001 NHTS. Also, it corresponded with the midpoint of fatal crash data considered for 10 yrs, from 1997-2006, facilitating an estimation of Average Annual Fatality Rates. It was used with the fatal crash data from FARS to calculate rates based on age, gender, and various crash-causing conditions. Only fatal injuries were considered in the exposure data. Unknown entries in the NHTS database were also discarded while estimating rates to obtain more accurate results.

CHAPTER 4 - Methodology

This chapter focuses on methods used to evaluate risk involved and factors responsible for fatal crash involvement of older drivers. It is divided into six subsections:

1. Analysis of driving characteristics of elderly
2. Average Annual Fatality Rates
3. Chi-square test of independence
4. Odds ratio
5. Double pair Comparison Method
6. Other involved drivers in fatal crashes with older drivers

4.1 Analysis of Characteristics of Older Drivers

Older drivers involved in fatal crashes are the subject group of people considered for this study. Characteristic study for the subject group was carried out for the five year period, from 2003 to 2007. All personal injury severities, i.e. fatal, incapacitating, non-incapacitating, and possible injury were considered. Vehicular, driver, and crash-related characteristics were chosen from vehicle, person, and accident files in FARS. All three files were then merged into one file using the common variable State Case (ST_CASE). Details of all factors studied are given in Appendix B. All variables and their corresponding codes used for fatally and non-fatally injured older drivers in fatal crashes are given in Appendix C. Various vehicle, driver, environmental, and roadway-related variables like air-bag deployment, hospital, Hispanic status, fatal injury at work, died at scene/enroute, rollover, route signing, related to junction, related to roadway, speed limit, construction maintenance zone, number of drunk drivers, travel speed, deformed, impacts, and vehicle maneuver were chosen for this study. Older drivers were categorized into five subgroups based on age, i.e. 65-69 yrs, 70-74 yrs, 75-79 yrs, 80-84 yrs, and ≥85 yrs. Also, involvement of older drivers in fatal crashes with younger and middle-aged groups was compared using few selected variables like restraint use, drinking, race, manner of collision, body type, roadway alignment, roadway function class, roadway profile, month of death, light conditions, and day of the week.

4.2 Average Annual Fatality Rates (AAFR)

Among younger, middle, and older-aged groups, older drivers have the highest percentage of fatalities compared to non-fatalities. Along with various driving conditions, exposure in vehicle miles traveled also plays an important role in contributing to the higher fatality rates of older drivers. Risk can be evaluated using the Average Annual Fatality Rate (AAFR), which is used to assess the fatality risk for an older driver under different driving conditions. Crash data and exposure data were used to evaluate AAFR for all age groups and gender. Fatality risk was assessed for driver-related factors like age, gender, and race; environmental related factors like light conditions; roadway-related factors like urban and rural conditions; and vehicle-related factors like vehicle type. A 10-year time period was considered for crash data from 1997 to 2006 where the midpoint, 2001, corresponded with NHTS (exposure) data. Therefore, no growth rates were necessary to be considered in the case of amount of travel.

The Average Annual Fatality Rate (AAFR) was calculated as the ratio of the average number of fatalities per year to the number of miles driven for each category. Age groups considered for analysis were 65-69 yrs, 70-74 yrs, 75-79 yrs, 80-84 yrs, and older than 85 yrs. The AAFR was defined as given in Equation 1:

$$\text{Average Annual Fatality Rate} = \frac{\text{Average annual fatalities}}{\text{Estimated annual miles driven in } 10^9 \text{ VMT}} \quad (1)$$

Average annual fatalities were calculated using crash data for the 10-year period from 1997 to 2006. The person file of FARS database was used to estimate the number of fatalities for each year. Fatal injury was the injury severity considered to calculate AAFR.

Number of vehicle miles traveled was estimated using NHTS data. The NHTS database contains a sample of people interviewed to represent the entire driving population in the US. Accordingly, total number of miles driven by each elderly driver group was estimated as shown below:

The number of miles traveled by the 65-69 yrs age group, as obtained from NHTS 2001 database, was 49,730,499 for 6,721drivers. The number of 65-69 yr old drivers in the U.S. as per Highway Statistics 2001, was 8,436,274 (*41*). So, the estimated annual miles driven by the 65-69 yrs group was given as

$$= \textit{Number of drivers} \times \frac{\textit{Miles traveled by NHTS sample drivers}}{\textit{Number of NHTS sample drivers}} \qquad (2)$$

$$= 8{,}436{,}274 \times \frac{49{,}730{,}499}{6{,}721} = 62 \times 10^{9} \text{ VMT (Or) 62 Billion Vehicle Miles Traveled (BVMT)}$$

Using the average annual fatalities and estimated miles driven, AAFR was calculated using Equation 1. AAFR was calculated for five factors which are:

1. Age and gender of the driver
2. Light conditions under which crashes occurred
3. Urban/Rural nature of the roadway
4. Vehicle type
5. Race of the driver

AAFR based on age and gender was calculated by considering the age groups chosen for males and females individually.

Categories considered for light conditions were daylight and dark conditions. Number of fatalities from crash data was sorted using the variable LGT_COND. The death month variable was based on months given in FARS, which in turn was divided into three periods with four months each, i.e. December to March, April to July, and August to November. Daylight conditions were considered as 7 am to 5 pm for the period December to March, 6 am to 8 pm for the April to July period, and 7 am to 6 pm for August to November. The remaining times of the day were considered as dark conditions.

Since light conditions vary for different seasons, they were considered accordingly using travel day date, and end hour and start hour variables from NHTS data. The same variables were considered to classify the death month.

AAFR calculated for the 65-69 yrs age group driving in daylight conditions was given in Equation 3 as follows:

$$\left.\begin{matrix} AAFR\ under \\ daylight\ \ condition \end{matrix}\right\} = \frac{Average\ \ annual\ \ fatalities\ \ for\ \ 65\text{-}69\ \ yrs\ \ group\ \ under\ \ daylight\ \ condition}{Estimated\ \ miles\ traveled\ \ by\ \ 65\text{-}69\ \ yrs\ \ group\ \ under\ \ daylight\ \ condition} \qquad (3)$$

Similarly, fatality rates for the elderly driving in dark conditions were also calculated using Equation 3.

Fatality rates based on road conditions were estimated to study the fatality risk of older drivers in urban and rural conditions. AAFR for elderly drivers based on urban or rural nature of the roadway was calculated using URBRUR (Urban/Rural) variable from the NHTS file and the ROAD_FNC (Roadway Function Class) variable from FARS**.** Rates were estimated for the elderly driving on different road types using Equation 3.

Different vehicle types like automobiles, vans, SUVs, pickup trucks, heavy trucks, motorcycles, and other vehicles like snowmobiles, construction equipment were used in different percentages by older drivers. BODY_TYP and VEHTYPE were the variables used in FARS and

NHTS to get the number of fatalities and vehicle miles traveled based on vehicle type. For usage of vehicle types by older drivers, automobiles are first and pickup trucks are second. Fatality rates are estimated by substituting average annual fatalities and estimated vehicle miles traveled in different vehicle types by fatally injured older drivers.

Race for this study was considered in five sub categories: White, African American, American Indian, Asian, and others. The variable used in FARS and NHTS to get the number of fatalities and vehicle miles traveled was RACE. AAFR was calculated by substituting the average annual fatalities and estimated vehicle miles traveled in Equation 3.

4.3 Chi-Square Test of Independence

The chi-square test of independence is a statistical test commonly used to determine whether there is a significant association between two variables. The chi-square test, also known as the test of independence or goodness-of-fit test, was performed between older drivers' age group and all other variables defining driver, vehicle, and environmental characteristics. The hypothesis assumed was;

H_o: There is no relationship between age group and the variable (ex: restraint use).

$H_{a:}$ There is a relationship between age group and the variable considered.

The chi square value was calculated using the formula

$$\chi^2 = \sum \frac{(Observed\ \ frequency - Expected\ \ frequency)^2}{Expected\ \ frequency} \qquad (4)$$

where observed frequency is the frequency obtained for a sample and expected frequency is the one which is expected to occur under similar conditions.

The expected frequency, $F_{e,}$ for the case where there exists two or more categories for both row and column (two way classification), is calculated as follows:

$$F_e = \frac{Row\,Subtotal \times Column\ Subtotal}{Total} \qquad (5)$$

The assumptions that are to be satisfied to perform the chi square test are as follows:

- There must be a representative sample.
- The data must be in frequency form or greater.
- Individual observations must be independent of each other.
- Sample size must be adequate i.e. expected value must be greater than 1.
- The sum of observed frequencies must equal the sum of expected frequencies (*42*).

The chi-square test was performed using SAS. In SAS, the "chisq" option was used to obtain the test statistic and its associated p-value (*43*) at a 95% confidence interval. A sample code used for chi-square test is given in Appendix D.

4.4 Odds Ratio

The odds ratio is the measure of effect size describing the strength of association between two binary data values (*44*). Odds of an event E is defined as the ratio of the probability of the event happening to the probability of the event not happening. The odds ratio defined using conditional probabilities was, if E is any event with probabilities P(E|group 1) and P(E| group 2), then

$$Odds\,ratio = \frac{P(E|group\,1)/[1-P(E|group\,1)]}{P(E|group\,2)/[1-P(E|group\,2)]} \qquad (6)$$

A ratio greater than 1 indicates that the condition is more likely in the first group (i.e. the group in numerator), and ratio less than 1 indicates that the condition is less likely in the first group. Groups used in calculating the odds ratio were the independent variables chosen for this study.

The odds ratio in this analysis was used to estimate the fatality risk for five selected independent variables: gender, light conditions, road conditions, day, and month. An example for values taken by variables in the estimation of the odds ratio based on gender is illustrated below.

Considering event E as the occurrence of fatality, odds in favor and odds not in favor for occurrence of fatality take values of E =1 and 0. Gender of the driver defined by p takes the value of 1 for males and 0 for females. Results of the odds ratio analysis are presented in section 5.4.

4.5 Double Pair Comparison Method

The double pair comparison method was applied in this study to determine how occupant characteristics affected the elderly when they are involved in fatal crashes. The double pair comparison method introduced by Evans L. (*18*) was utilized in this study to make inferences about fatal crashes from FARS data. It has been used by many researchers to estimate the effectiveness of seat belts (*45*).

The double pair comparison method focuses on vehicles containing two occupants with at least one fatal injury. The two occupants in a vehicle are referred to as subject occupant and control occupant. Subject occupant is the person whose characteristics are used to determine the fatality risk. The control occupant standardizes the conditions to estimate the fatality risk of the subject occupant without directly entering into the result. In this study, two cases considered for calculating the eight estimates in order to observe the fatality risk for an older driver compared to an older passenger are as follows:

1. Subject occupant is an older driver and control occupant is the front right passenger; and
2. Subject occupant is an older passenger and control occupant is the driver.

The analysis period for this study was five years, from 2003 to 2007, and FARS was the source data. All cases with two occupants in passenger cars, i.e. driver and front right passenger with at least one of them being an older person and with at least one person fatally injured, were chosen.

Considering the first case, where the subject occupant is an older driver and control occupant is the front right passenger (referred to as passenger from now), Table 4.1 shows the hypothetical case used to estimate the risk for older drivers based on gender of the subject and control occupants.

Table 4.1 Hypothetical Case Used to Estimate Risk for Elderly

Category	Number of driver fatalities	Number of passenger fatalities
Male driver, Male passenger	a	b
Female driver, Male passenger	c	d

The procedure to estimate the fatality risk was initiated with the calculation of risk ratios between the subject and control occupant groups. The number of older male drivers killed when accompanied with male passengers of any age is “a”, and “b” is the number of male passengers killed traveling with older male drivers. Likewise, “c” and “d” are the case with a female driver.

Fatality risk ratio of male driver to male passenger r_1 is given as

$$r_1 = a/b \qquad (7)$$

Similarly, fatality risk ratio of female driver to male passenger is given by r_2 as

$$r_2 = c/d \qquad (8)$$

Using fatality risk ratios r_1 and r_2, male to female older driver risk ratio is given by fatality ratio $R_{1,}$ as

$$R_1 = r_1/r_2 \qquad (9)$$

The standard error in the estimate of R_1 is given as follows:

$$\Delta R_1 = R_1 \times \left(\sigma^2 + 1/a + 1/b + 1/c + 1/d \right)^{1/2} \qquad (10)$$

As suggested by Evans, L., the value of σ^2, is taken as 0.05 (*18*). It is the value used in consideration of the confounding effects that limit the accuracy, even for large samples.

The weighted average of the ratio between male and female drivers was calculated using the following equation:

$$\overline{R} = exp\left[\frac{\sum_{i=1}^{2} \left\{ \left(R_i / \Delta R_i \right)^2 \ x \ log\left(R_i \right) \right\}}{\sum_{i=1}^{2} \left\{ \left(R_i / \Delta R_i \right)^2 \right\}} \right] \qquad (11)$$

The standard error in the estimate of $\overline{R}$ is given as

$$\Delta\overline{R} = \frac{\overline{R}}{\left(\sum_{i=1}^{2} \left\{ \left(R_i / \Delta R_i \right)^2 \right\} \right)^{1/2}} \qquad (12)$$

The percentage risk for subject occupants is given as

$$\%\ risk = 100(1- \overline{R}) \pm 100(1- \Delta\overline{R}) \qquad (13)$$

All values for the eight estimates are given in Table 5.25 of section 5.5.

4.6 Other Drivers Involved in Fatal Crashes with Older Drivers

Vast research has been done on older drivers involved in fatal crashes but very limited research has been done on the characteristics of other drivers involved in fatal crashes with older drivers. Older drivers are more susceptible to higher severity injuries compared to other age groups. Hence, the distribution of other involved drivers based on age and gender in fatal crashes was analyzed. The two primary conditions taken into consideration in this analysis were as follows:

- Only two vehicle crashes with at least one older driver involved.
- All types of injury severities.

Analysis was done for a five-year period, from 2003 to 2007, using FARS data. In two-vehicle crashes, if the older driver was considered the primary driver then the secondary driver was termed as the other driver. To facilitate the analysis, other drivers were divided into six categories based on age. These were: 16-24 yrs, 25-34 yrs, 35-44 yrs, 45-54 yrs, 55-64 yrs, and ≥65 yrs. Results are developed for the six groups based on gender of the other drivers.

CHAPTER 5 - Analysis Results and Findings

Results of methods applied to evaluate fatality risk involvement of older drivers and analysis of various factors contributing to their fatal crash involvement are discussed in this chapter. Statistics of fatalities, based on state, for older drivers and fatal crash facts in 2007 are presented in sections 5.1 and 5.2. A characteristic analysis comparing younger, middle-aged, and older drivers is discussed in section 5.3. A detailed characteristic analysis for fatally injured older drivers is presented in section 5.4. Results of risk evaluated using Average Annual Fatality Rates is given in section 5.5. Relationship between various categories using the chi-square test of independence, odds ratio, and double pair comparison method are discussed in subsequent sections. Analysis results based on other drivers involved in fatal crashes with older drivers are presented in the last section.

5.1 Fatalities Based on State

In this section, fatality facts based on region is presented for drivers of all ages and older drivers. All 50 states of the U.S. (excluding Puerto Rico and Virgin Islands) and the District of Columbia are classified by the U.S. Census Bureau into Northeast, Midwest, South, and West regions (*41*). Figure 5.1 depicts the distribution of fatalities based on region for all age groups. Fatality distribution based on region considering all ages for the combined period from 2003 to 2007 is in the following order:

South > West > Midwest > Northeast

Fatality distribution for the older population in descending order is as follows:-

South > Midwest > West > Northeast

Number of fatalities was highest in the Southern and Western regions of the U.S for all age groups, whereas they were found to be highest in Southern and Midwestern regions for the older population.

Appendix E provides details of fatalities in all states for population of all ages and older population. Fatalities of the older population are around 14 percent in the South and West regions. They are 19 and 16 percent for Northeast and Midwestern regions, respectively. California, Texas, Florida, Georgia, and Pennsylvania are five states with highest number of fatalities in descending order in comparison to all 50 states and the District of Columbia.

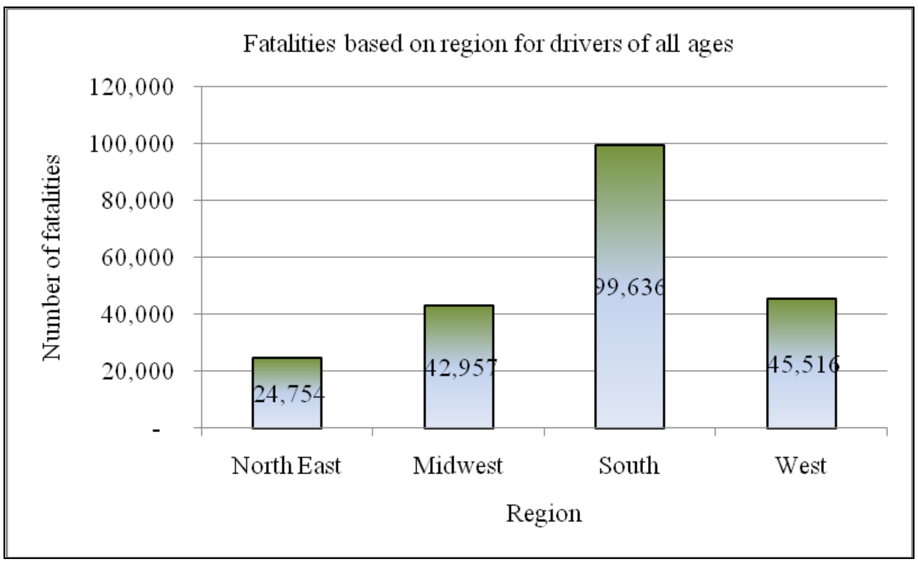

Figure 5.1 Fatalities for All Age Groups Based on Regions

Figure 5.2 presents fatalities based on region for the older population. Though the number of fatalities for the older population is highest in the Southern region, California ranks first based on state. In the Midwestern region, Kansas is ninth in descending order of fatalities among 12 other states.

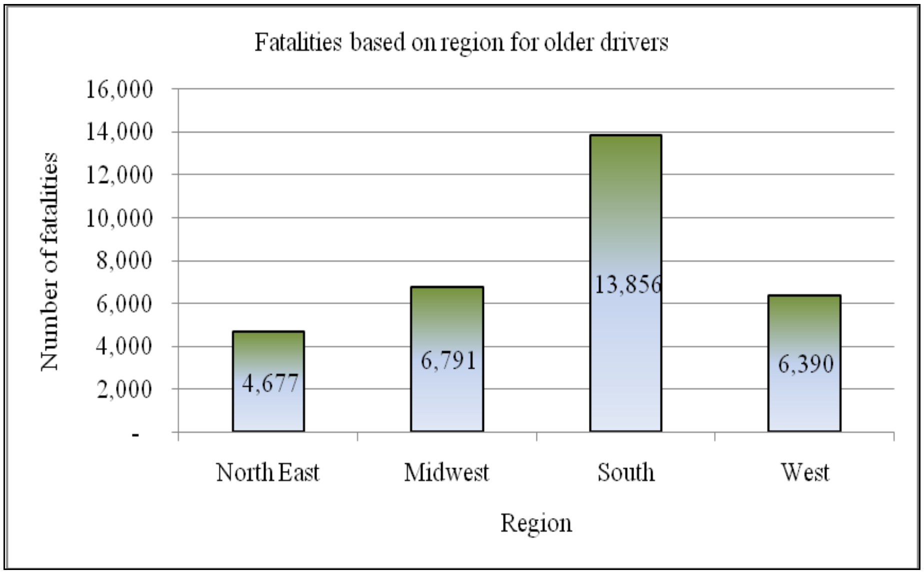

Figure 5.2 Fatalities for Older Population Based on Regions

5.2 Fatal crash facts for the year 2007

A brief summary of fatal crash statistics for the year 2007 is presented in this section. This analysis was carried out by considering both occupants and non-occupants of all age groups using FARS. There were 37,248 fatal crashes and 41,059 traffic fatalities reported in 2007. Table 5.1 presents the summary of fatality and non-fatality statistics for all occupants and non-occupants involved in fatal crashes during 2007.

Table 5.1 Fatally and Non-Fatally Injured Elderly in Fatal Crashes Based on Age

Age group (yrs)	***Fatalities (%)***	***Non-fatalities (%)***	***Total (%)***
< 15	1,670 (30.5)	3,806 (69.5)	5,476 (100)
15-24	10,220 (50.4)	10,051 (49.6)	20,271 (100)
25-34	6,796 (56.3)	5,283 (43.7)	12,079 (100)
35-44	6,082 (59.1)	4,210 (40.9)	10,292 (100)
45-54	6,130 (64.7)	3,352 (35.3)	9,482 (100)
55-64	4,101 (65.1)	2,195 (34.9)	6,296 (100)
65-74	2,602 (69.3)	1,152 (30.7)	3,754 (100)
75-84	2,318 (75.1)	770 (24.9)	3,088 (100)
≥ 85	1,012 (84.7)	183 (15.3)	1,195 (100)
Total	***40,931 (56.9)***	***31,002 (43.1)***	***71,933 (100)***

There was a decrease in number of fatalities with increase in age. However percentage of fatalities increased with increase in age. The highest percentage was reported by the 85 yrs and older group. Occupants and non-occupants together accounted for 57 percent of fatalities and 43 percent of non-fatalities during 2007.

Table 5.2 presents a brief summary of fatally and non-fatally injured drivers in fatal crashes in 2007. The highest percentage of fatalities was observed for the oldest group of drivers. Numerically, fatalities decreased with an increase in age, but fatality risk increased with an increase in age. On average, 63 percent of fatalities and 37 percent of non-fatalities occurred for drivers in the U.S.

Table 5.2 Fatally and Non-Fatally Injured Drivers Involved in Fatal Crashes Based on Age

Age group (yrs)	***Fatalities (%)***	***Non-fatalities (%)***	***Total (%)***
< 15	68 (70.1)	29 (29.9)	97 (100)
15-24	6,348 (59.7)	4,282 (40.3)	10,630 (100)
25-34	4,841 (61.1)	3,083 (38.9)	7,924 (100)
35-44	4,338 (61.5)	2,717 (38.5)	7,055 (100)
45-54	4,254 (65.8)	2,213 (34.2)	6,467 (100)
55-64	2,954 (67.0)	1,453 (33.0)	4,407 (100)
65-74	1,699 (71.0)	693 (29.0)	2,392 (100)
75-84	1,089 (58.9)	757 (41.1)	1,846 (100)
≥ 85	547 (85.3)	94 (14.7)	641 (100)
Total	***26,138 (63.1)***	***15,321 (36.9)***	***41,459 (100)***

A brief summary of passengers injured in fatal crashes is given in Table 5.3. Fatality and non-fatality risk for passengers was observed as highest for oldest and youngest age groups, respectively. On average 37 percent of fatalities and 63 percent of non-fatalities occurred for passengers in fatal crashes in the U.S.

Table 5.3 Fatally and Non-Fatally Injured Passengers Involved in Fatal Crashes Based on Age

Age group (yrs)	*Fatalities (%)*	*Non-fatalities (%)*	*Total (%)*
< 15	1,183 (24.1)	3,717 (75.9)	4,900 (100)
15-24	3,102 (35.4)	5,651 (64.6)	8,753 (100)
25-34	1,231 (36.7)	2,125 (63.3)	3,356 (100)
35-44	853 (37.5)	1,419 (62.5)	2,272 (100)
45-54	797 (42.1)	1,096 (57.9)	1,893 (100)
55-64	543 (43.1)	717 (56.9)	1,260 (100)
65-74	458 (58.9)	320 (41.1)	778 (100)
75-84	492 (60.4)	323 (39.6)	815 (100)
≥ 85	321 (79.3)	84 (20.7)	405 (100)
Total	***8,980 (36.8)***	***15,452 (63.2)***	***24,432 (100)***

Summary statistics for fatally and non-fatally injured non-occupants (i.e. pedestrians, bicyclists, and others) in fatal crashes is given in Table 5.4. The number of fatalities increased with increase in age till 54 yrs and then there was a considerable decrease. Older non-occupants (≥ 65 yrs) had the highest fatality risk. Non-occupants have a higher fatality risk due to their easy exposure to the intensity of crashes. In 2007, 94 percent of fatalities and 6 percent of non-fatalities occurred on average for non-occupants.

Table 5.4 Fatally and Non-Fatally Injured Non-Occupants Involved in Fatal Crashes Based on Age

Age group (yrs)	*Fatalities (%)*	*Non-fatalities (%)*	*Total (%)*
< 15	416 (87.8)	58 (12.2)	474 (100)
15-24	736 (89.4)	87 (10.6)	823 (100)
25-34	697 (91.7)	63 (8.3)	760 (100)
35-44	876 (93.0)	66 (7.0)	942 (100)
45-54	1,072 (96.4)	40 (3.6)	1,112 (100)
55-64	599 (96.0)	25 (4.0)	624 (100)
65-74	444 (96.9)	14 (3.1)	458 (100)
75-84	414 (97.6)	10 (2.4)	424 (100)
≥ 85	143 (96.6)	5 (3.4)	148 (100)
Total	***5,397 (93.6)***	***368 (6.4)***	***5,765 (100)***

As the older population is more dependent on personal mode of travel as drivers, detailed analysis is done in the subsequent sections comparing older drivers with younger and middle-aged drivers and their involvement in fatal crashes.

5.2 Characteristics of Younger, Middle-aged and Older Drivers Involved in Fatal Crashes

Characteristics of older drivers were compared with younger (16-24 yrs) and middle-aged (25-64 yrs) drivers involved in fatal crashes. Drivers traveling in passenger cars sustaining both fatal and non-fatal injuries were considered in this analysis. The analysis period was combined data from five years, 2003 to 2007. Several driver, vehicle, roadway, and environmental related variables were used in the analysis as follows:

- Driver related
    - Restraint use, drinking alcohol, and race
- Vehicle related
    - Manner of collision and body type
- Roadway related
    - Roadway alignment, roadway function class, and roadway profile
- Environment related
    - Month of fatality, light conditions and day of the week

Figure 5.3 presents the percentage distribution of fatal and non-fatal injuries comparing younger, middle-aged, and older drivers' involvement in fatal crashes during 2003 to 2007. Fatality risk for older drivers in fatal crashes was highest, with 74 percent of fatal injuries. Younger and middle-aged drivers had the same percentage of non-fatalities (44.3 percent).

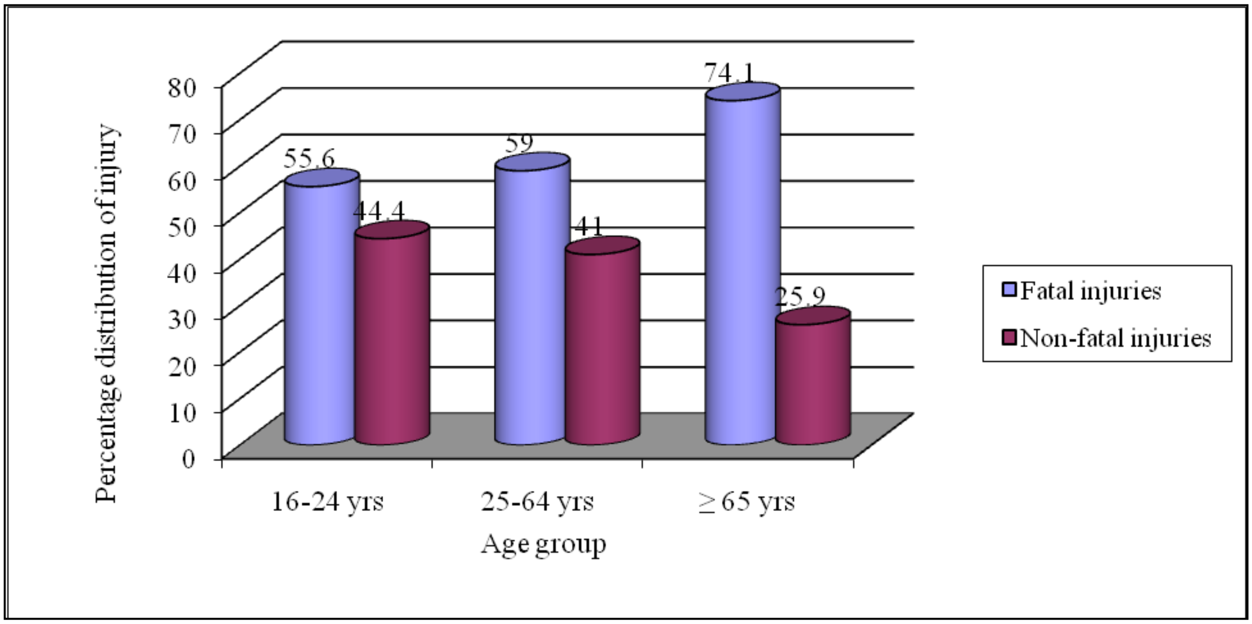

Figure 5.3 Percentage Distribution of Fatal and Non-Fatal Injuries for Drivers Based on Age

Table 5.5 presents the comparison of driver-related variables among the three age groups. Comparison across columns, using individual column percentages makes the most sense as row percentage is always highest for middle-aged drivers due to the wide gap between the minimum and maximum limits (i.e. 25yrs and 64 yrs).

Among the drivers involved in fatal crashes, older drivers were the most likely to be wearing seat belts (67 percent), followed by middle-aged drivers (54.9 percent). In comparison, only 48.8 percent of younger drivers involved in fatal crashes were wearing seat belts. Younger drivers sustained an equal percentage of injuries in fatal crashes with or without restraint use.

Around 40 percent of younger and middle-aged drivers and 58 percent of older drivers were not drunk when involved in fatal crashes. Younger drivers reported the highest percentage of positive results for the BAC test. Many cases were either not reported or unknown due to unwillingness of the driver to give the test or inability of the person due to higher injury severity.

Table 5.5 Number and Percentages of Injuries Sustained by Younger, Middle-aged and Older Drivers in Fatal Crashes Based on Driver-related Characteristics for the Period 2003 to 2007

RESTRAINT USE				
Age group	***16-24 yrs (%)[a] (%)[b]***	***25-64 yrs (%) (%)***	***≥ 65 yrs (%) (%)***	***Total (%) (%)***
None used	22,059 (32.2) (43.8)	39,998 (58.3) (38.3)	6,525 (9.5) (26.8)	68,582 (100.0) (38.3)
Belt used	24,535 (25.0) (48.8)	57,308 (58.4) (54.9)	16,298 (16.6) (67.0)	98,141 (100.0) (54.8)
Unknown	3,727 (30.3) (7.4)	7,078 (57.5) (6.8)	1,501 (12.2) (6.2)	12,306 (100.0) (6.9)
Total	50,321(28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
DRINKING ALCOHOL				
No	19,576 (25.4) (38.9)	43,377 (56.3) (41.6)	14,097 (18.3) (58.0)	77,050 (100.0) (43.0)
Yes	11,215 (34.9) (22.3)	20,193 (62.8) (19.3)	758 (2.4) (3.1)	32,166 (100.0) (18.0)
Not reported	11,691 (27.3) (23.2)	24,664 (57.5) (23.6)	6,508 (15.2) (26.8)	42,863 (100.0) (23.9)
Unknown	7,839 (29.1) (15.6)	16,150 (59.9) (15.5)	2,961 (11.0) (12.2)	26,950 (100.0) (15.1)
Total	50,321(28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
RACE				
Whites	18,257 (26.0) (36.3)	39,311(56.0) (37.7)	12,656 (18.0) (52.0)	70,224(100.0) (39.2)
African Americans	2,323 (23.6) (4.6)	6,480 (65.9) (6.2)	1,033 (10.5) (4.2)	9,836 (100.0) (5.5)
Other	923 (30.6) (1.8)	1,871 (62.1) (1.8)	220 (7.3) (0.9)	3,014 (100.0) (1.7)
Not Applicable	22,368 (31.2) (44.5)	42,920 (59.9) (41.1)	6,314 (8.8) (26.0)	71,602 (100.0) (40.0)
Unknown	6,450 (26.5) (12.8)	13,802 (56.7) (13.2)	4,101 (16.8) (16.9)	24,353 (100.0) (13.6)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)

Race is reported for persons who sustained fatal injuries only and hence, more than half of the entries are under not applicable category. The highest percentage of injuries occurred for

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[a] Row percentage
[b] Column percentage

older whites (52 percent). Middle-aged African American drivers had higher involvement in fatal crashes compared to younger and older age groups. Also, a higher percentage of fatal injuries for older drivers is justified by the fewer “not applicable” cases as race is reported only for fatal injuries.

Table 5.6 presents the number of injuries sustained by the three age groups based on vehicle-related characteristics. Considering manner of collision, front-to-side collisions were highly predominant. Older drivers had the highest percentage of front-to-side type collisions. Younger and middle-aged drivers had more non-motor vehicle collisions. Among the three age groups, middle-aged drivers had the highest percentage (58.3%) of injuries among those involved in fatal crashes. Younger and middle-aged drivers have almost similar involvement in front-to-side and front-to-front collisions. Order of occurrence of injuries based on manner of collision for older drivers is as follows:

Front to side > No collision > Front to front > Front to rear > Sideswipe

Based on body type, most of the injuries occurred in passenger cars for all three age groups: 62 percent of injuries for older drivers, 58 percent for younger, and 38 percent for middle-aged drivers occurred in passenger cars; 18 percent of injuries for everyone on average, occurred in pickup trucks. The order of type of vehicles contributing to the occurrence of injuries in fatal crashes for all age groups is as follows:

Automobiles > Pickup trucks > SUVs > Others > Vans > Heavy trucks > RVs

Vehicles under the “Others” category include buses, motor homes, mopeds, snowmobiles, farm equipment, and construction equipment, which contribute very little to fatal crashes.

Table 5.6 Number and Percentages of Injuries Sustained by Younger, Middle-aged and Older Drivers in Fatal Crashes Based on Vehicle-related Characteristics for the Period 2003 to 2007

MANNER OF COLLISION				
Age group	***16-24 yrs (%) (%)***	***25-64 yrs (%) (%)***	***≥ 65 yrs (%) (%)***	***Total (%) (%)***
No Collision	25,541 (34.5) (50.8)	41,983 (56.7) (40.2)	6,557 (8.9) (27.0)	74,081(100.0) (41.4)
Front to rear	2,581 (19.7) (5.1)	8,616 (65.7) (8.3)	1,917 (14.6) (7.9)	13,114 (100.0) (7.3)
Front to front	7,701 (24.1) (15.3)	20,165 (63.1) (19.3)	4,076 (12.8) (16.8)	31,942 (100.0) (17.8)
Front to side	12,917 (24.1) (25.7)	29,600 (55.3) (28.4)	10,979 (20.5) (45.1)	53,496 (100.0) (29.9)
Sideswipe	1,341 (24.3) (2.7)	3,468 (62.9) (3.3)	702 (12.7) (2.9)	5,511(100.0) (3.1)
Rear to side	104 (31.4) (0.2)	192 (58.0) (0.2)	35 (10.6) (0.1)	331 (100.0) (0.2)
Rear to rear	6 (31.6) (0.0)	13 (68.4) (0.0)	-	19 (100.0) (0.0)
Other	130 (24.3) (0.3)	347 (64.9) (0.3)	58 (10.8) (0.2)	535 (100.0) (0.3)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
BODY TYPE				
Automobiles	32,598 (33.1) (58.0)	49,936 (50.7) (37.8)	16,028 (16.3) (61.7)	98,562 (100.0) (46.0)
SUV's	7,340 (24.9) (13.1)	20,042 (68.0) (15.2)	2,088 (7.1) (8.0)	29,470 (100.0) (13.8)
Vans	1,461 (12.1) (2.6)	8,674 (71.7) (6.6)	1,960 (16.2) (7.5)	12,095 (100.0) (5.6)
Pick up trucks	8,917 (22.8) (15.9)	25,901 (66.3) (19.6)	4,244 (10.9) (16.3)	39,062 (100.0) (18.2)
Heavy trucks	412 (4.6) (0.7)	8,118 (90.2) (6.2)	466 (5.2) (1.8)	8,996 (100.0) (4.2)
Recreational vehicles	9 (4.9) (0.0)	99 (53.8) (0.1)	76 (41.3) (0.3)	184 (100.0) (0.1)
Other	5,463 (20.8) (9.7)	19,158 (72.9) (14.5)	1,123 (4.3) (4.3)	26,274 (100.0) (12.3)
Total	56,200 (26.2) (100.0)	131,946 (61.6) (100.0)	25,985 (12.2) (100.0)	214,131 (100.0) (100.0)

Table 5.7 presents results for the study based on roadway-related variables. Based on roadway alignment, more than 80 percent of older drivers and 70 percent of younger and middle-

aged drivers were involved in fatal crashes on straight roads. Around 27 percent of injuries for younger and middle-aged drivers occurred on curved roads.

Table 5.7 Number and Percentages of Injuries Sustained by Younger, Middle-aged and Older Drivers in Fatal Crashes Based on Roadway-related Characteristics for the Period 2003 to 2007

ROADWAY ALIGNMENT				
Age group	***16-24 yrs (%) (%)***	***25-64 yrs (%) (%)***	***≥ 65 yrs (%) (%)***	***Total (%) (%)***
Straight	35,430 (26.7) (70.4)	77,189 (58.2) (73.9)	19,990 (15.1) (82.2)	132,609 (100.0) (74.1)
Curve	14,644 (32.1) (29.1)	26,721 (58.6) (25.6)	4,246 (9.3) (17.5)	45,611(100.0) (25.5)
Unknown	247 (30.5) (0.5)	474 (58.6) (0.5)	88 (10.9) (0.4)	809 (100.0) (0.5)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
ROADWAY FUNCTION CLASS				
Urban	19,764 (28.5) (39.3)	39,664 (57.1) (38.0)	9,978 (14.4) (41.0)	69,406 (100.0) (38.8)
Rural	29,833 (27.9) (59.3)	63,124 (59.1) (60.5)	13,904 (13.0) (57.2)	106,861 (100.0) (59.7)
Unknown	724 (26.2) (1.4)	1,596 (57.8) (1.5)	442 (16.0) (1.8)	2,762 (100.0) (1.5)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
ROADWAY PROFILE				
Level	34,937 (27.6) (69.4)	73,838 (58.3) (70.7)	17,830 (14.1) (73.3)	126,605 (100.0) (70.7)
Grade	12,776 (29.1) (25.4)	25,750 (58.6) (24.7)	5,388 (12.3) (22.2)	43,914 (100.0) (24.5)
Hill crest	1,486 (32.4) (3.0)	2,549 (55.5) (2.4)	554 (12.1) (2.3)	4,589 (100.0) (2.6)
Sag	190 (31.7) (0.4)	325 (54.2) (0.3)	85 (14.2) (0.3)	600 (100.0) (0.3)
Unknown	932 (28.1) (1.9)	1,922 (57.9) (1.8)	467 (14.1) (1.9)	3,321 (100.0) (1.9)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)

Roadway function class is classified into urban and rural categories. Older drivers involvement in fatal crashes based on roadway classification was 57 percent in rural areas and 41 percent in urban areas. For younger and middle-aged drivers, around 60 percent of injuries occurred in rural and 40 percent in urban areas.

Considering roadway profiles, all three age groups had the highest number of injuries on level roads. Around 70 percent of injuries occurred on level roads and 25 percent occurred on graded roads.

Table 5.8 presents the summary of injuries for three age groups based on environmental related characteristics. Based on death month, no record cases were highest as this variable is reported only for fatal injuries. Within an age group, a higher percentage of injuries for older drivers occurred during August to November. Distribution is quite similar for younger and middle-aged groups with an average of 19 percent of injuries occurring during the periods April to July and December to March.

Based on light conditions, the highest number of injuries occurred for middle-aged drivers under dark conditions. More than 80 percent of injuries for older drivers involved in fatal crashes occurred during daylight hours, which is supposed to be safer than dark conditions. Younger drivers were more involved in crashes during dark conditions and middle-aged drivers were around 46 percent involvement during darkness.

Considering the day of the week, the highest percentage of injuries occurred on Saturday with an 18 percent average. Comparing the three age groups, a higher number of injuries occurred for middle-aged drivers. Older drivers were highly involved in crashes on Fridays, whereas younger and middle-aged drivers had higher involvement on Saturdays. From the comparison study, it is inferred that among the three age groups, older drivers were highly involved in some of the safest driving conditions and had a higher fatality risk involving fatal crashes. Hence an effort was made to study the factors contributing to fatal crashes of older drivers in more detail.

Table 5.8 Number and Percentages of Injuries Sustained by Younger, Middle-aged and Older Drivers in Fatal Crashes Based on Environment-related Characteristics for the Period 2003 to 2007

DEATH MONTH				
Age group	***16-24 yrs (%) (%)***	***25-64 yrs (%) (%)***	***≥ 65 yrs (%) (%)***	***Total (%) (%)***
Apr-July	9,635 (26.9) (19.1)	20,262 (56.6) (19.4)	5,907 (16.5) (24.3)	35,804 (100.0) (20.0)
Aug-Nov	9,428 (26.2) (18.7)	20,524 (57.0) (19.7)	6,052 (16.8) (24.9)	36,004 (100.0) (20.1)
Dec-March	8,559 (25.0) (17.0)	19,917 (58.2) (19.1)	5,758 (16.8) (23.7)	34,234 (100.0) (19.1)
No Record	22,699 (31.1) (45.1)	43,681 (59.8) (41.8)	6,607 (9.1) (27.2)	72,987 (100.0) (40.8)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
LIGHT CONDITION				
Daylight	21,487 (22.2) (42.7)	55,663 (57.6) (53.3)	19,488 (20.2) (80.1)	96,638 (100.0) (54.0)
Dark	28,685 (35.0) (57.0)	48,378 (59.1) (46.3)	4,780 (5.8) (19.7)	81,843 (100.0) (45.7)
Unknown	149 (27.2) (0.3)	343 (62.6) (0.3)	56 (10.2) (0.2)	548 (100.0) (0.3)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)
DAY OF THE WEEK				
Sunday	9,326 (33.1) (18.5)	16,120 (57.2) (15.4)	2,729 (9.7) (11.2)	28,175 (100.0) (15.7)
Monday	5,979 (26.2) (11.9)	13,354 (58.4) (12.8)	3,521 (15.4) (14.5)	22,854 (100.0) (12.8)
Tuesday	5,505 (25.4) (10.9)	12,672 (58.4) (12.1)	3,528 (16.3) (14.5)	21,705 (100.0) (12.1)
Wednesday	5,636 (25.2) (11.2)	13,091 (58.4) (12.5)	3,681 (16.4) (15.1)	22,408 (100.0) (12.5)
Thursday	5,908 (25.2) (11.7)	13,835 (59.1) (13.3)	3,684 (15.7) (15.1)	23,427 (100.0) (13.1)
Friday	7,877 (27.5) (15.7)	16,770 (58.6) (16.1)	3,988 (13.9) (16.4)	28,635 (100.0) (16.0)
Saturday	10,090 (31.7) (20.1)	18,542 (58.3) (17.8)	3,193 (10.0) (13.1)	31,825 (100.0) (17.8)
Total	50,321 (28.1) (100.0)	104,384 (58.3) (100.0)	24,324 (13.6) (100.0)	179,029 (100.0) (100.0)

5.3 Analysis of Characteristics of Older Drivers

Analysis carried out with the intention of identifying factors contributing to fatal crashes of older drivers is presented in this section. Table 5.9 gives the details of various predominant characteristics for older drivers involved in fatal crashes. Complete tables for the analysis are given in Appendix B. Row percentages which represent the percentage comparison of a characteristic between age groups is highest for 65-69 yrs drivers compared to all other age groups of older drivers in most of the cases. This can be attributed to the reason that the number of miles driven by older drivers decreases with increase in age. Hence column percentages which represent the distribution within an age group are used for better comparison. Around 70 percent of older drivers involved in fatal crashes were wearing seat belt. Air bag deployment was around 45 percent, whereas non-deployment and non-availability of airbags in passenger cars was around 26 percent for all age groups.

Older drivers' involvement in fatal crashes was high in speed limit areas of 50-65 mph and travel speeds of 51-60 mph. Not many cases were reported for travel speed as data for this variable is collected after fatal crashes occur and is often a judgment rather than a measurement. Older drivers were highly involved in fatal crashes using automobiles (66 percent). The next higher involvement by older drivers was in pickup trucks with a 15 percent average. Automobile usage increased with increase in age. Order of usage of other types of vehicles by older drivers during their fatal crash involvement is as follows:

Pickups (15%) > SUVs (8%) > Vans (8%)> Others (4%)> Heavy trucks (2%)> RVs (1%)

The "others" category includes vehicles like mopeds and motorhomes. More than 50 percent of collisions were front-to-side type, which increased with an increase in age.

Table 5.9 Predominant Driver, Vehicle, Environment and Roadway Related Characteristics of Older Drivers Involved in Fatal Crashes

Variable	***Predominant category***
Speed limit	50mph-65mph
Rollover	No Rollover
Body type	Automobiles
Vehicle Maneuver	Going Straight
Impacts	Right front at 30 degrees
Deformed	Disabling (Severe)
Travel Speed	Not Reported
Gross Vehicle Weight Rating	Not Applicable
Restraint Use	Seat belt used
Air Bag	Deployed
Manner of collision	Front to side
Registered Owner of the vehicle	Driver (of This Vehicle) Was Registered Owner
Drinking	No
Taken to hospital	Yes
Race	White
Hispanic	No
Number of drunk drivers	0
Died at Scene/En Route	Not Applicable
Death Month	No Record
Light Condition	Daylight
Day of the Week	Friday
Fatal injury at work	No
Roadway Function Class	Rural Principal Arterial - Other
Route Signing	State Highway
Related to Junction	Non-Junction
Related to Roadway	On Roadway
Roadway Alignment	Straight
Construction Maintenance Zone	None
National Highway System	Section not on highway system
Special Jurisdiction	No Special Jurisdiction

Drivers 75-79 yrs had the highest percentage of front-to-side type collisions. Front-to-front and no collisions (i.e. single vehicle crash) were next in order. Ninety percent of the vehicles involved in fatal crashes during the five-year analysis period did not rollover. Drivers 65-69 yrs were highly involved in rollovers among all age groups. Maneuver of the vehicle was straight in 70 percent of the cases and around 7 percent were negotiating a curve during crashes. Around 52 percent of older drivers had impact on the vehicle's right front side at 30 degrees, and 40 percent of the drivers had impact at 45 degrees. Very few cases were reported for vehicles entering in and exiting a parked position. Vehicle deformity level was severe for more than 80 percent of older drivers involved in fatal crashes. Around 7 percent of the vehicles were 26,000 lbs or more in weight, and more than 90 percent of the cases were not applicable under Gross Vehicle Weight Rating category.

On average, 69 percent of older drivers drove registered vehicles. Seventeen percent of the drivers were driving vehicles with private owners and 10 percent were driving vehicles registered as business/company/government. Sixty percent of older drivers injured in fatal crashes were not drunk. The highest percentage of drunk drivers reported were 65-69 yrs old. Their drinking percentage decreased gradually with increase in age. Around 10 percent of the cases reported involved at least one drunk driver and 89 percent of the cases reported had no drunk drivers. Number of older drivers taken to hospital after crash occurrence increased with increase in age. On average, 66 percent were taken to hospital and 32 percent were not hospitalized. Twenty-nine percent of older drivers died at scene of the crash and only 1 percent of the total died enroute to the hospital. Seventy percent of the cases were not applicable as this variable is recorded only for fatal injuries.

Race of the person is also recorded in FARS when the type of injury is fatal. Hence, the number of entries under "not applicable" category was maximum. Around 51 percent of the injured older drivers were whites and 4 percent were African Americans. Whites 75-79 yrs and African Americans 65-69 yrs were highly involved in fatal crashes. Non-Hispanics were highest with an average of 54 percent, and Hispanics were highest in the 65-69 yrs group.

Death month was recorded only for fatal injuries and hence no record cases were high in number for all age groups. Ages of 65-69 yrs, 70-74 yrs, and 75-79 yrs were equally involved during the year. Older drivers of 80-84 yrs had the highest involvement in August thru November, whereas drivers older than 85 yrs were highly involved between April and July. Based on light conditions, older drivers had the highest percentage of injuries in daylight and the percentage increased with increase in age. Injuries in dark conditions were highest for 65-69 yrs drivers. Considering the distribution of injuries based on day of the week, older drivers had highest crash involvement on Fridays. Though the percentage distribution was almost the same for all days of the week, a higher number of fatalities prevailed on Thursdays and Fridays.

Fatal injuries at work were very rare for older drivers. It decreased with an increase in age and was highest for the 65-69 yrs age group. Based on roadway function class, the highest number of injuries occurred at rural principal arterials. Older drivers had higher fatal crash risk in rural areas than in urban areas. Fatal crash risk was more on minor arterials and major collectors compared to local roads and minor collectors. Based on route signing, older drivers were more involved in fatal crashes on state highways compared to U.S. highways and county roads.

The junction-related variable is classified into two sub-categories, interchange and non-interchange areas. Roadways are at different levels in interchange areas, whereas all roadways are at the same level in non-interchange areas .Non-junction-related crashes were significant for 65-69 yrs, 70-74 yrs, 75-79 yrs groups, and intersection-related crashes were more for 80-84 yrs and ≥ 85 yrs groups. Fatal crash risk for older drivers was higher at interchange areas. The roadway-related variable involves details of position of the vehicle related to the road. Eighty-five percent of older drivers were involved in “on road” crashes, whereas only 8 percent of them were involved in roadside crashes. Crashes occurring on shoulders and medians also had significant numbers. More than 85 percent of fatal crashes occurred on straight roads. Fatal crash involvement on curved roads decreased with increase in age. Only 2-3% of crashes occurred in construction maintenance zones. Based on the National Highway System, only 35 percent of crashes occurred on sections which were part of national highways. Only 1 percent of crashes occurred in special jurisdiction areas.

It is observed from the analysis that older drivers have higher fatal crash risk under safe driving conditions; hence the fatality risk was evaluated only for a few limited characteristics based on data availability in the following section.

5.4 Average Annual Fatality Rates

Older drivers have the highest percentage of fatalities compared to non-fatalities among younger, middle, and older-aged groups involved in fatal crashes. Since exposure plays an important role in evaluating crash/fatality risk, Average Annual Fatality Rates (AAFR) were calculated for older drivers considering exposure in vehicle miles traveled. AAFR calculated based on age, gender, light conditions, vehicle type, road conditions, and race of the driver are discussed in this section.

5.4.1 Based on Age and Gender

Older drivers were categorized into five sub groups with a 5-yr span starting from 65 yrs. The 65-69 yrs group is referred to as the youngest group and the ≥ 85 yrs group is referred to as the oldest group in this section. Table 5.10 presents the miles driven by older drivers from the NHTS 2001 database and estimated annual miles using U.S. Census Bureau data.

Number of miles driven decreased with increase in age. The 65-69 yrs group drove 41 percent of the total miles whereas the oldest group of drivers contributed only 2 percent. As per the U.S. Census Bureau, the female older driver population was higher compared to males in 2001. Total of female older drivers included in the 2001 NHTS dataset was more in number than males, but miles driven by older male drivers was around 60 percent more than females for the same year. Average annual fatalities and estimated miles driven by older drivers are represented in Figures 5.4 and 5.5.

Table 5.10 Estimation of Total Miles Driven by Older Drivers during 2001, by Age & Gender

All Drivers				
	NHTS data		***Estimated total miles***	
Age group (yrs)	***Number of drivers***	***Miles driven***	***Number of drivers***	***Miles driven (BVMT)***
65-69	6,721	49,730,499	8,436,274	62.00
70-74	5,955	36,298,414	7,464,825	45.50
75-79	4,320	21,690,095	5,912,286	29.70
80-84	2,415	10,079,730	3,653,273	15.20
≥85	990	2,778,780	2,106,116	5.90
Male Drivers				
	NHTS data		***Estimated total miles***	
Age group (yrs)	***Number of drivers***	***Miles driven***	***Number of drivers***	***Miles driven (BVMT)***
65-69	3,256	35,800,633	4,193,804	45.00
70-74	2,908	26,290,122	3,650,960	33.00
75-79	2,086	15,343,683	2,825,231	20.80
80-84	1,162	7,421,590	1,723,275	11.00
≥85	496	2,010,226	981,746	3.97
Female Drivers				
	NHTS data		***Estimated total miles***	
Age group (yrs)	***Number of drivers***	***Miles driven***	***Number of drivers***	***Miles driven (BVMT)***
65-69	3,465	13,929,866	4,242,470	17.00
70-74	3,047	10,008,292	3,813,865	12.50
75-79	2,234	6,346,412	3,087,055	8.80
80-84	1,253	2,658,140	1,929,998	4.09
≥85	494	768,554	1,124,370	1.75

Based on gender, average annual fatalities were highest for males, whereas number of fatalities for females was around one-third to that of males. Fatalities decreased with increased age and were lowest for the oldest age group. Estimated miles driven by males and females varied largely. They decreased gradually with an increase in age and were almost the same for the oldest group of male and female drivers. AAFR estimates based on age and gender are given in Table 5.11.

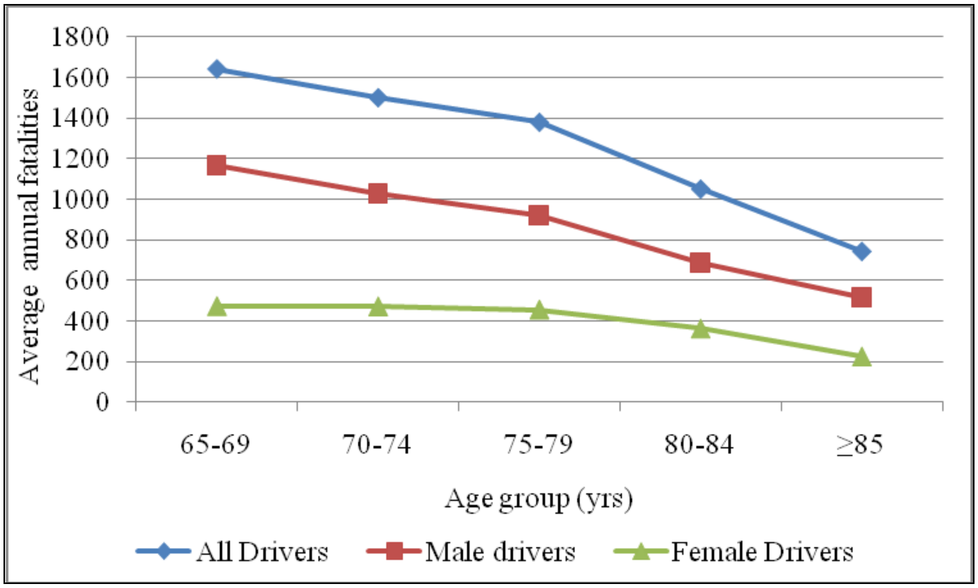

Figure 5.4 Average Annual Fatalities for Older Drivers Based on Age and Gender

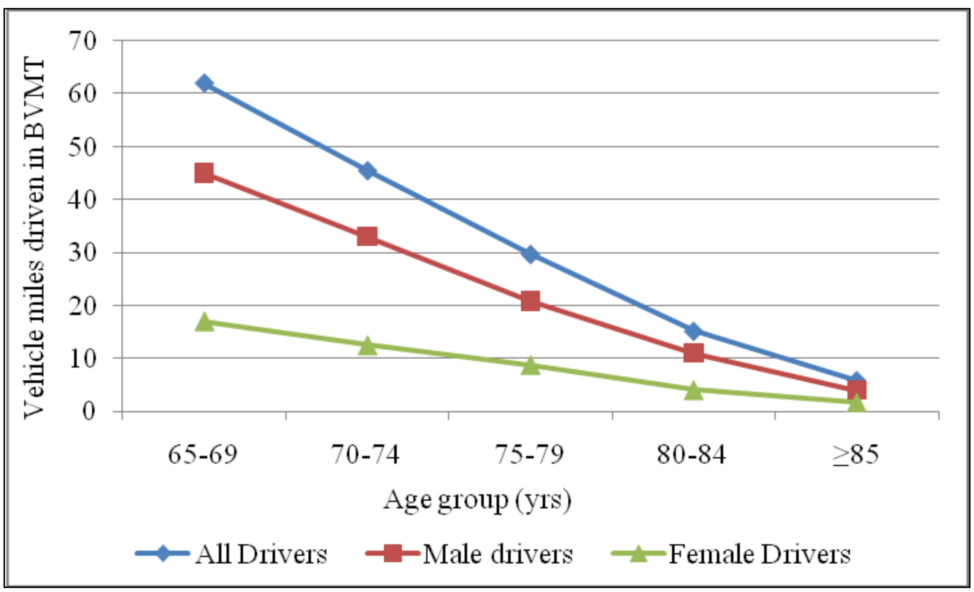

Figure 5.5 Estimated Miles Driven by Older Drivers for the Year 2001

Table 5.11 AAFR for Older Drivers Based on Age and Gender

All Drivers			
Age group (yrs)	***Average yearly fatalities (a)***	***Estimated miles driven in BVMT (b)***	***AAFR (c=a/b)***
65-69	1640.1	62	26.45
70-74	1498.8	45.5	32.94
75-79	1378.3	29.7	46.41
80-84	1050.3	15.2	69.10
≥85	743.8	5.9	126.07
Male Drivers			
Age group (yrs)	***Average yearly fatalities (a)***	***Estimated miles in BVMT (b)***	***AAFR (c=a/b)***
65-69	1167.6	45.0	25.33
70-74	1027.2	33	31.13
75-79	922.2	20.8	44.34
80-84	687.2	11	62.47
≥85	517.3	3.97	130.30
Female Drivers			
Age group (yrs)	***Average yearly fatalities (a)***	***Estimated miles in BVMT (b)***	***AAFR (c=a/b)***
65-69	472.2	17	27.78
70-74	471.3	12.5	37.70
75-79	455.6	8.8	51.77
80-84	362.9	4.09	88.73
≥85	225.9	1.75	129.09

AAFR increased with increase in age, though there was a decrease in average annual fatalities and estimated miles driven. Figure 5.6 represents AAFR for older drivers based on age and gender. The lowest AAFR was observed for the 65-69 yrs age group. Fatality risk for the oldest group of drivers was five times the risk posed for the youngest older group. Female older drivers had higher fatality risk in terms of AAFR, compared to males.

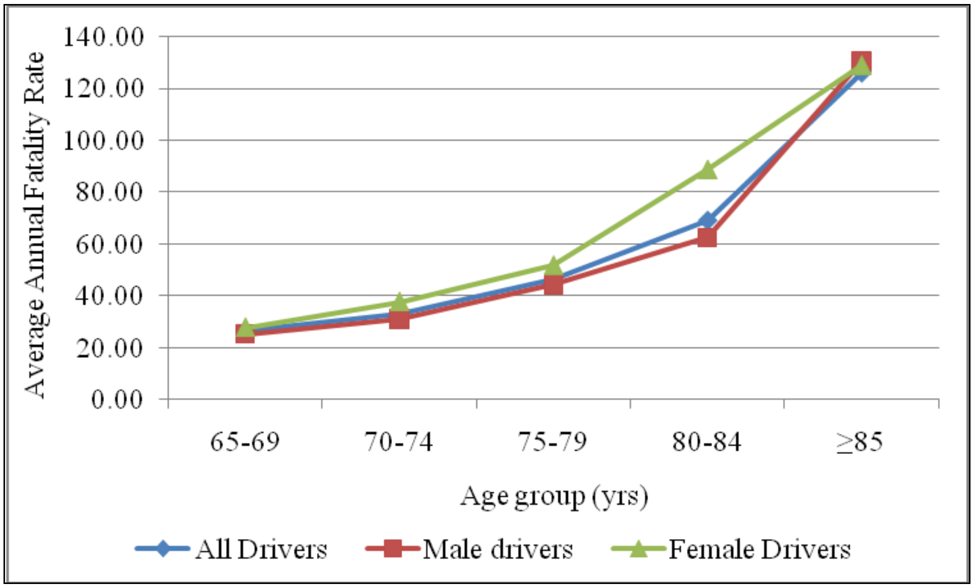

Figure 5.6 AAFR for Older Drivers Based on Age and Gender

5.4.2 Light Conditions

Figures 5.7 and 5.8 represent average annual fatalities under daylight and dark conditions. Fatalities for older drivers were the highest under daylight conditions. Number of fatalities based on gender was highest for older male drivers of 65-69 yrs and older female drivers of 75-79 yrs. There was a significant decrease in number of fatalities from the 75-79 yrs group to the oldest age group. Fatalities under dark conditions were highest for 65-69 yrs drivers. There was a gradual decrease in number of fatalities with increasing age for older females, whereas a sudden decrease was observed for older males.

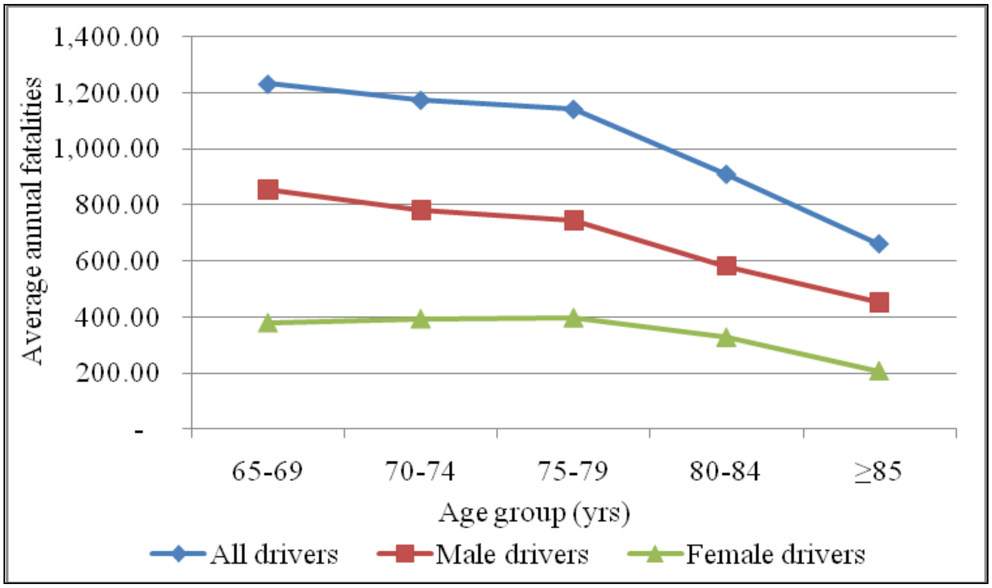

Figure 5.7 Average Annual Fatalities for Older Drivers in Daylight

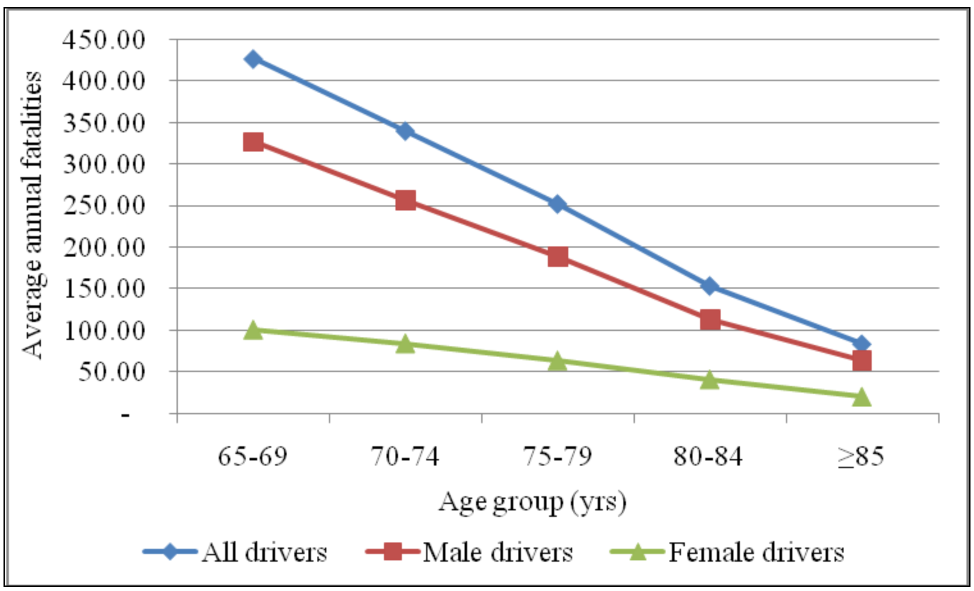

Figure 5.8 Average Annual Fatalities for Older Drivers in Dark

The estimated number of miles driven based on light conditions is depicted in Figures 5.9 and 5.10. These varied greatly for males and females. The highest number of miles was driven under daylight conditions. Miles driven by older males were about seven times that of older females in both daylight and dark conditions.

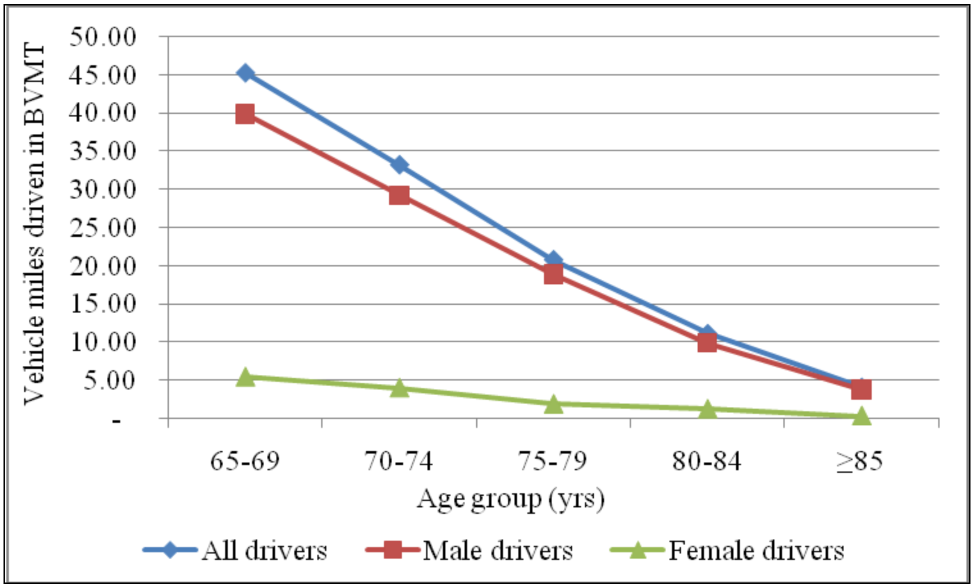

Figure 5.9 Estimated Miles Driven by Older Drivers in Daylight Conditions

Eighty percent of the miles driven in daylight were by older males. Number of miles driven by females was around 20 percent and was highest for the 65-69 yrs age group. Approximately 90 percent of the miles driven in dark conditions were by older males.

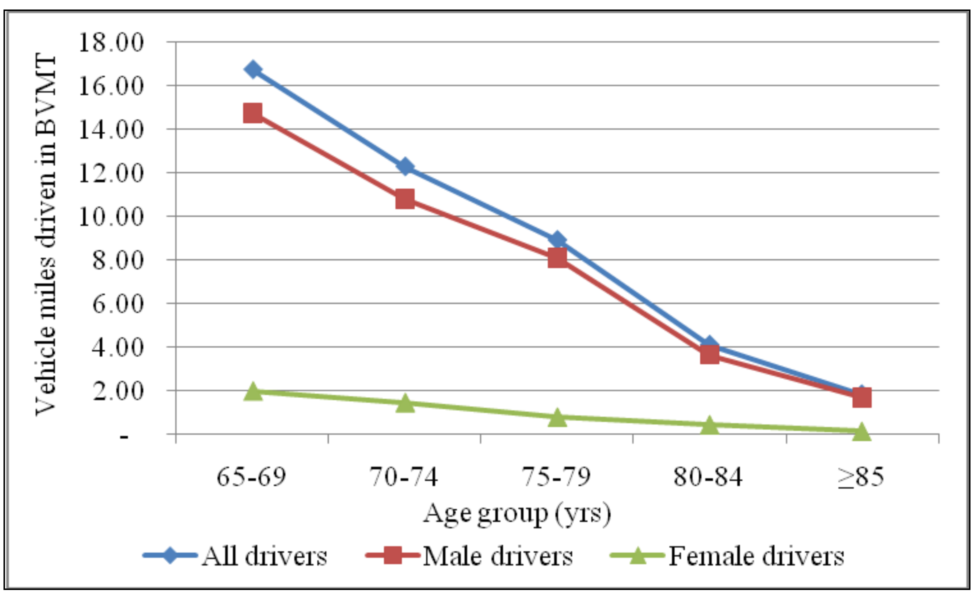

Figure 5.10 Estimated Miles Driven by Older Drivers in Dark Conditions

Average annual fatalities, calculated miles driven, and AAFR calculated based on light conditions are shown in Table 5.12.

Table 5.12 AAFR for Older Drivers Based on Light Conditions

All Drivers						
	Average yearly fatalities (a)		***Estimated miles driven in BVMT (b)***		***AAFR (c=a/b)***	
Age Group (yrs)	***Daylight conditions***	***Dark conditions***	***Daylight conditions***	***Dark conditions***	***Daylight conditions***	***Dark conditions***
65-69	1,231.70	427.20	45.26	16.74	27.21	25.52
70-74	1,174.50	340.30	33.22	12.28	35.36	27.70
75-79	1,141.50	252.20	20.79	8.91	54.91	28.31
80-84	908.90	153.30	11.10	4.10	81.91	37.35
≥85	659.30	83.00	4.07	1.83	161.95	45.38
Male Drivers						
	Average yearly fatalities (a)		***Estimated miles driven in BVMT (b)***		***AAFR (c=a/b)***	
Age Group (yrs)	***Daylight conditions***	***Dark conditions***	***Daylight conditions***	***Dark conditions***	***Daylight conditions***	***Dark conditions***
65-69	852.80	326.80	39.83	14.73	21.41	22.18
70-74	781.50	256.30	29.23	10.81	26.74	23.71
75-79	744.30	188.70	18.92	8.11	39.34	23.27
80-84	581.90	112.70	9.88	3.65	58.93	30.85
≥85	452.90	63.30	3.75	1.68	120.93	37.61
Female Drivers						
	Average yearly fatalities (a)		***Estimated miles driven in BVMT (b)***		***AAFR (c=a/b)***	
Age Group (yrs)	***Daylight conditions***	***Dark conditions***	***Daylight conditions***	***Dark conditions***	***Daylight conditions***	***Dark conditions***
65-69	378.90	100.40	5.43	2.01	69.77	49.98
70-74	393.00	84.00	3.99	1.47	98.60	56.99
75-79	397.20	63.50	1.87	0.80	212.29	79.18
80-84	327.00	40.60	1.22	0.45	267.81	90.02
≥85	206.40	19.70	0.33	0.15	633.13	134.93

Fatality rates of female older drivers are overrepresented as the number of miles driven by them was much less than those driven by males. Rates varied from 21 to 121 fatalities per billion vehicle miles traveled for males and 50 to 633 fatalities per billion vehicle miles traveled for females. Females have a higher fatality risk than males both in daylight and dark conditions. Figures 5.11 and 5.12 show fatality rates for older drivers based on light conditions.

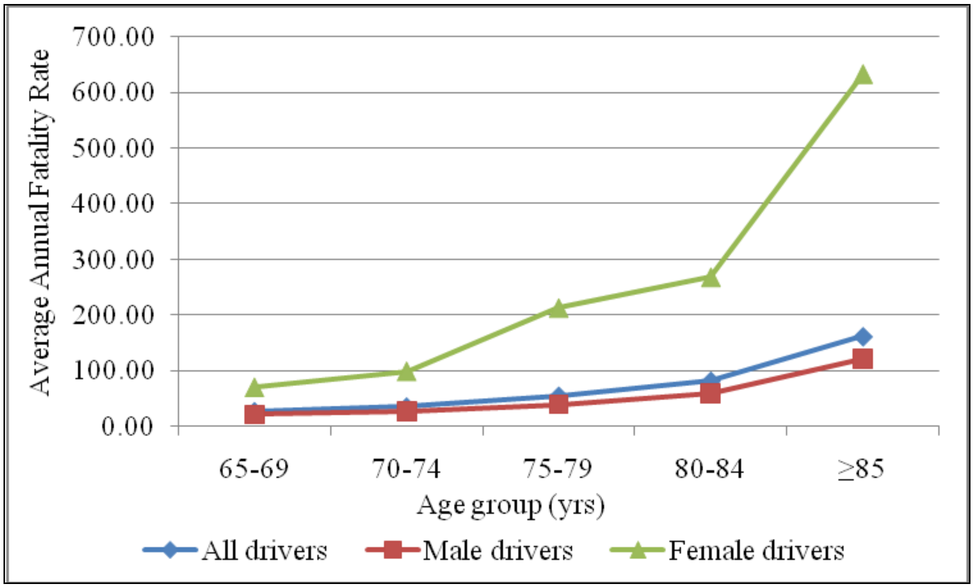

Figure 5.11 AAFR for Older Drivers in Daylight Conditions

Fatality risk for older drivers in different light conditions increased with increase in age. There was a consistent increase in rates for older male drivers, whereas a haphazard increasing trend was observed for females. Older female drivers had a similar increasing trend of fatality rates in both daylight and dark conditions.

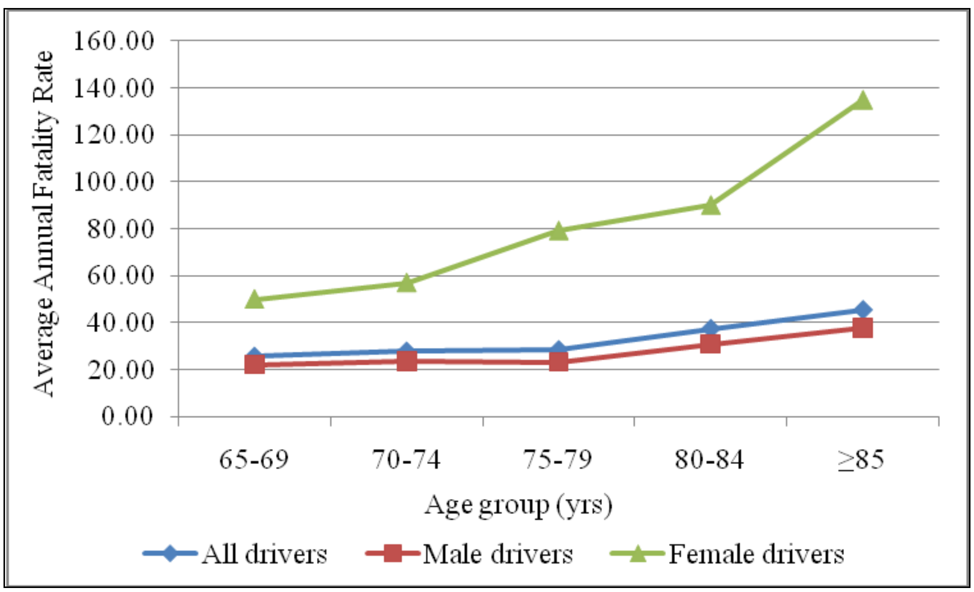

Figure 5.12 AAFR for Older Drivers in Dark Conditions

5.4.3 Road Conditions

Number of fatalities and miles driven based on gender in urban and rural areas are represented in Figures 5.13 and 5.14. Average annual fatalities in rural areas were high for all age groups. The oldest group of drivers had similar fatal crash involvement in both urban and rural areas. Miles driven by older males was almost thrice that of females.

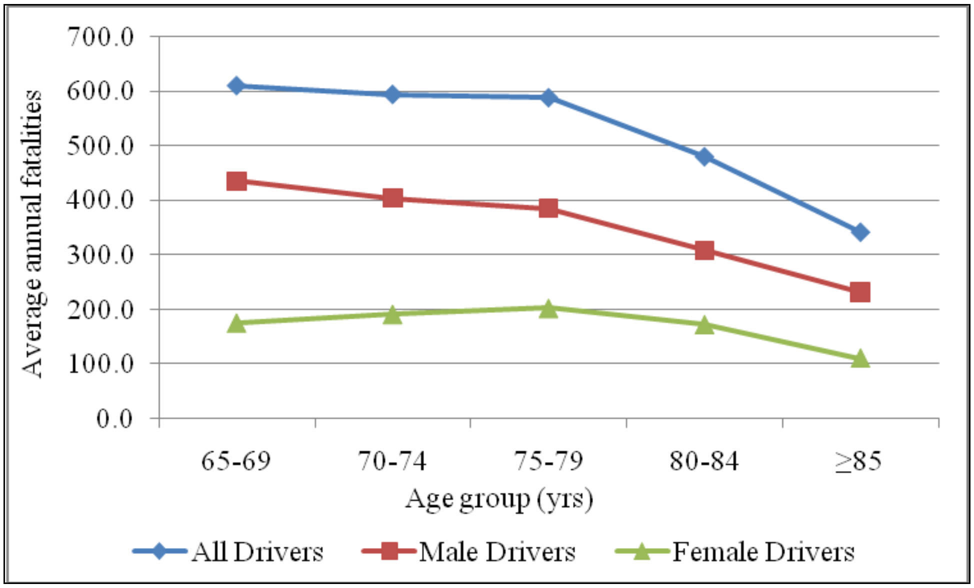

Figure 5.13 Average Annual Fatalities for Older Drivers in Urban Areas

Around 70 percent of fatalities in urban areas involved older male drivers. Percentage of fatalities for female drivers was highest for the 75-79 yrs group.

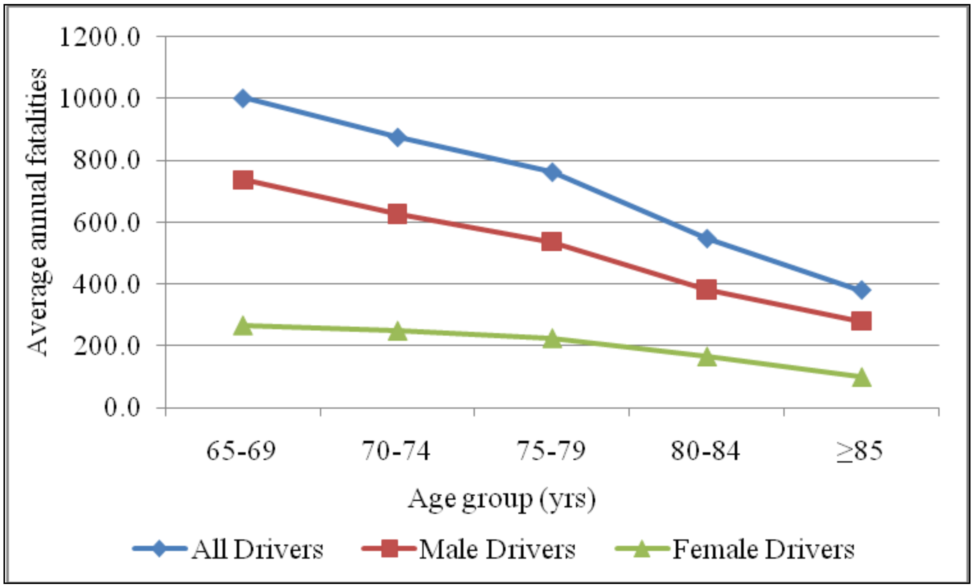

Figure 5.14 Average Annual Fatalities for Older Drivers in Rural Areas

Fatalities in rural areas were highest for the 65-69 yrs group and continuously decreased with increased age. These dropped drastically for 75-85 yr old males. There was a wide gap in miles driven by the youngest and oldest group of male older drivers in urban areas, but it did not vary much for females.

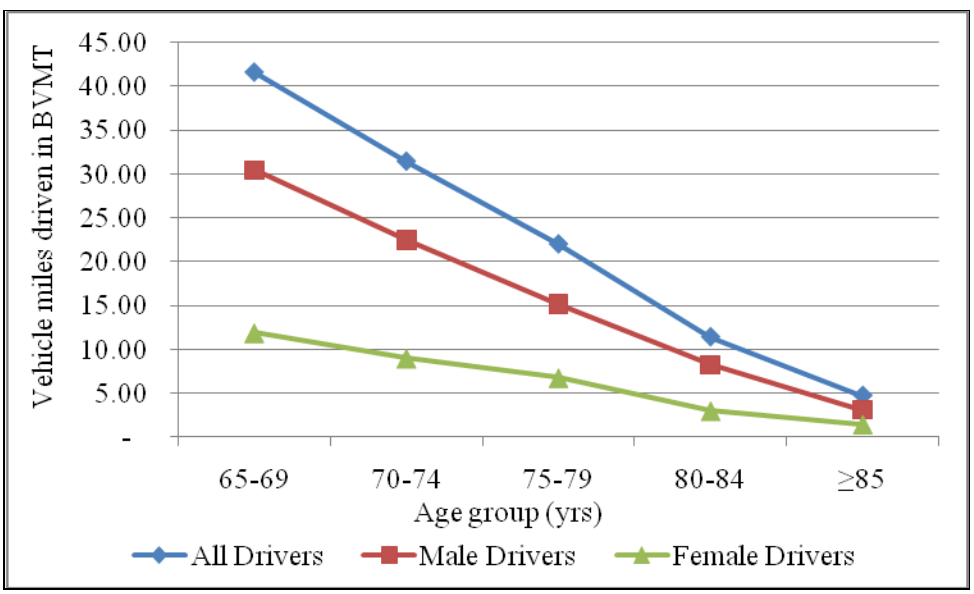

Figure 5.15 Estimated Miles Driven by Older Drivers in Urban Areas

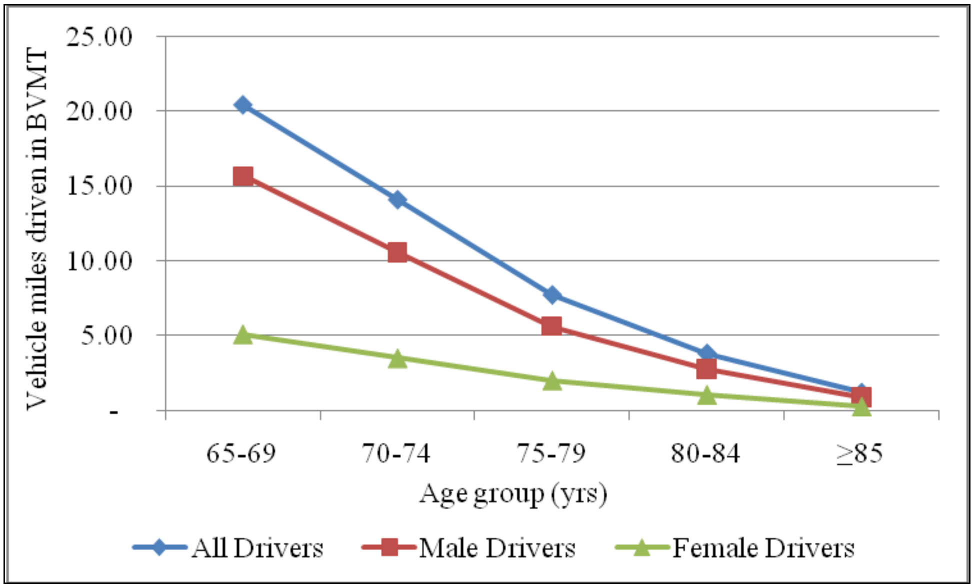

Figure 5.16 Estimated Miles Driven by Older Drivers in Rural Areas

The graph for miles driven by males is almost similar in rural and urban areas. More miles were driven by females in urban areas than in rural. From Table 5.12, it can be seen that fatality rates for elderly driving in rural conditions are higher and there is a sudden increase in fatality rates due to lesser amounts of travel and road conditions. Figures 5.17 and 5.18 represent the AAFR evaluated in urban and rural areas separately.

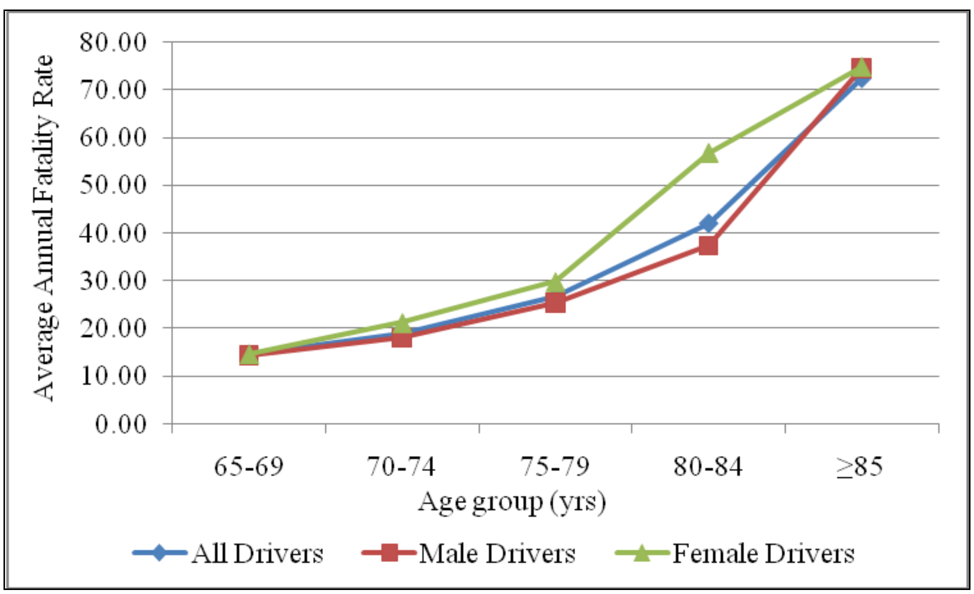

Figure 5.17 AAFR for Older Drivers in Urban Areas

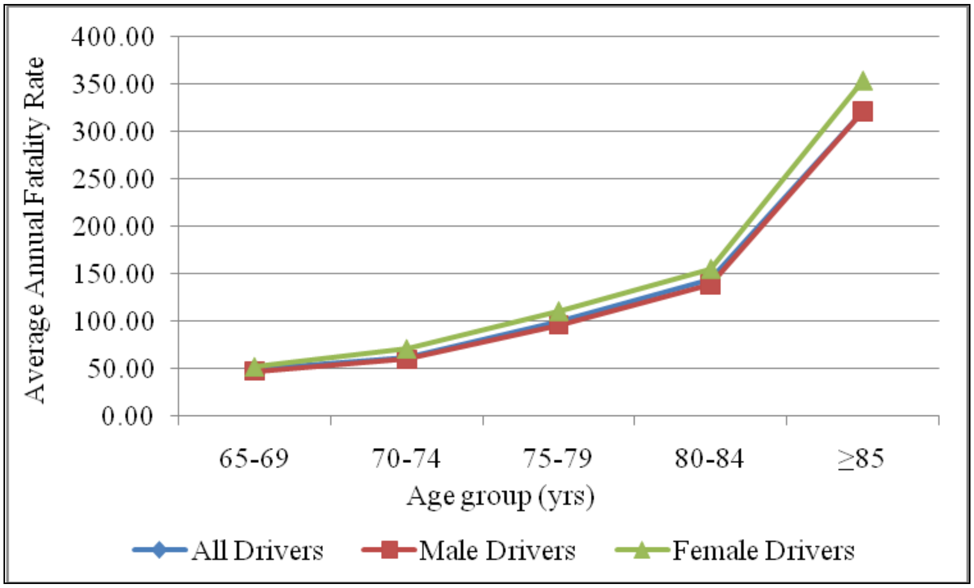

Figure 5.18 AAFR for Older Drivers in Rural Areas

Average annual fatalities, estimated annual vehicle miles driven, and AAFR evaluated based on road conditions for older drivers are shown in Table 5.13. Fatality rates in urban areas are higher for older female drivers. Rates increased consistently till 84 yrs for males and 79 yrs for females in urban areas, and there was a sudden increase observed for the oldest group of males and females. Fatality rates for older drivers in rural areas are nearly thrice the rates for the elderly driving in urban areas. There was a sudden increase in rates for the oldest group of drivers in rural areas, indicating higher fatality risk.

Table 5.13 AAFR for Older Drivers Based on Road Conditions

All Drivers						
	Average yearly fatalities (a)		***Estimated miles driven in BVMT (b)***		***AAFR (c=a/b)***	
Age Group	***Urban***	***Rural***	***Urban***	***Rural***	***Urban***	***Rural***
65-69	610.0	1002.0	41.54	20.46	14.68	48.97
70-74	594.0	875.0	31.40	14.11	18.92	62.00
75-79	588.0	762.0	21.98	7.72	26.75	98.67
80-84	480.0	546.0	11.40	3.80	42.10	143.68
≥85	342.0	379.0	4.72	1.18	72.45	321.18
Male Drivers						
	Average yearly fatalities (a)		***Estimated miles driven in BVMT (b)***		***AAFR (c=a/b)***	
Age Group	***Urban***	***Rural***	***Urban***	***Rural***	***Urban***	***Rural***
65-69	435.0	737.0	30.43	15.67	14.29	47.02
70-74	404.0	627.0	22.44	10.56	18.00	59.38
75-79	385.0	537.0	15.18	5.62	25.35	95.62
80-84	308.0	381.0	8.25	2.75	37.33	138.55
≥85	231.0	280.0	3.10	0.87	74.58	320.73
Female Drivers						
	Average yearly fatalities (a)		***Estimated miles driven in BVMT (b)***		***AAFR (c=a/b)***	
Age Group	***Urban***	***Rural***	***Urban***	***Rural***	***Urban***	***Rural***
65-69	175.0	265.0	11.90	5.10	14.70	51.96
70-74	191.0	248.0	9.00	3.50	21.22	70.86
75-79	202.0	224.0	6.78	2.02	29.81	110.67
80-84	172.0	165.0	3.03	1.06	56.82	155.22
≥85	110.0	99.0	1.47	0.28	74.82	353.57

5.4.4 Vehicle Type

Average annual fatalities, estimated annual vehicle miles driven, and AAFR for older drivers based on vehicle type are shown in Table 5.14. Older drivers were mostly involved in fatal crashes in automobiles during the analysis period. In 2001, the highest number of elderly-driven miles was also in automobiles. The order of occurrence of fatalities for older drivers based on vehicle type is as follows:

Automobiles > Pickup trucks > Sport utility vehicles > Vans > Motorcycles

Table 5.14 AAFR for Older Drivers Based on Vehicle Type

All Drivers															
	Average yearly fatalities (a)					***Estimated miles driven in BVMT (b)***					***AAFR (c=a/b)***				
Age Group (yrs)	Autos	Vans	SUV's	Pickup trucks	Motor cycle	Autos	Vans	SUV's	Pickup trucks	Motorcycle	Autos	Vans	SUV's	Pickup trucks	Motorcycle
65-69	1382.5	244.3	268.2	588.7	121.2	37.81	5.90	4.54	11.07	0.95	36.57	41.42	59.03	53.19	128.12
70-74	1390.1	219.1	223.5	508.4	86.2	28.12	4.61	2.86	8.20	0.59	49.44	47.52	78.10	62.00	146.79
75-79	1394.1	191.5	205	448.7	56.9	18.82	3.18	1.81	5.20	0.09	74.07	60.16	113.06	86.36	633.92
80-84	1125.9	135.3	148.1	315.1	36.1	11.29	1.36	0.60	1.55	0.08	99.73	99.71	247.65	203.20	478.03
≥85	818.6	85.8	103.1	224.6	21.1	5.04	0.30	0.13	0.32	0.04	162.50	286.92	781.50	700.84	591.10
Male Drivers															
	Average yearly fatalities (a)					***Estimated miles driven in BVMT (b)***					***AAFR (c=a/b)***				
Age Group (yrs)	Autos	Vans	SUV's	Pickup trucks	Motor cycle	Autos	Vans	SUV's	Pickup trucks	Motorcycle	Autos	Vans	SUV's	Pickup trucks	Motorcycle
65-69	868.5	172.5	189.1	470.1	99.7	24.20	4.86	4.10	10.24	0.96	35.88	35.48	46.13	45.90	103.39
70-74	858	156.4	152.8	398.6	67.5	20.29	3.41	2.14	5.91	0.42	42.28	45.93	71.28	67.43	159.30
75-79	851.1	139	139.1	348.8	41.7	13.80	1.77	1.30	3.37	0.09	61.69	78.64	106.78	103.61	454.03
80-84	683.2	97	100.6	237	25.7	7.71	1.16	0.46	1.30	0.07	88.59	83.56	219.25	181.68	364.06
≥85	543.3	60	71.1	178	16.1	3.32	0.23	0.10	0.22	0.03	163.60	261.15	700.46	827.26	483.35
Female Drivers															
	Average yearly fatalities (a)					***Estimated miles driven in BVMT (b)***					***AAFR (c=a/b)***				
Age Group (yrs)	Autos	Vans	SUV's	Pickup trucks	Motor cycle	Autos	Vans	SUV's	Pickup trucks	Motorcycle	Autos	Vans	SUV's	Pickup trucks	Motorcycle
65-69	514	71.8	79.1	118.6	21.5	11.44	1.86	1.06	2.31	0.10	44.95	38.58	74.68	51.34	208.04
70-74	532	62.6	70.7	109.7	18.7	9.10	0.92	0.69	1.41	0.09	58.46	68.22	102.27	77.91	207.36
75-79	542.9	52.5	65.9	99.9	15.2	7.13	0.60	0.28	0.68	0.03	76.19	87.85	233.52	146.08	520.65
80-84	442.7	38.3	47.5	78	10.4	3.56	0.16	0.13	0.21	0.00	124.38	237.12	361.93	372.03	4803.24
≥85	275.1	25.8	32	46.4	5	1.57	0.06	0.02	0.10	0.00	174.94	459.24	1299.93	485.39	0.00

Older drivers reported higher number of miles driven using pickups and vans after automobiles. Number of fatalities and estimated miles driven are plotted for automobiles in Figures 5.19 and 5.20. Only automobiles are considered as they have significant numbers. Number of fatalities was consistent till 79 yrs and there was a drop for 80-84 yrs and ≥85 yrs age groups. Older males driving automobiles were involved twice that of older female drivers in fatal crashes.

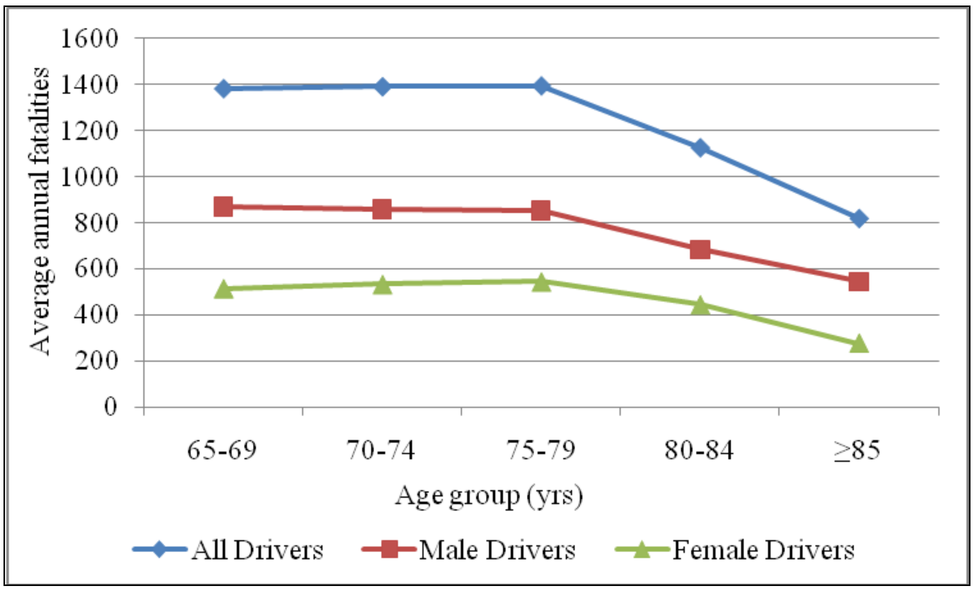

Figure 5.19 Average Annual Fatalities for Elderly Driving Automobiles

Miles driven by older males using automobiles was higher than that of females and this decreased with increase in age. There was a significant drop in number of miles driven by males compared to females. Fatality rates for older drivers driving automobiles are represented in Figure 5.21. Older females driving automobiles had higher fatality rates than males due to the lesser number of miles driven by them with increasing age. The increase in rate is nearly similar for both genders. Within an age group, older females driving automobiles had a 50 percent higher risk than older male drivers.

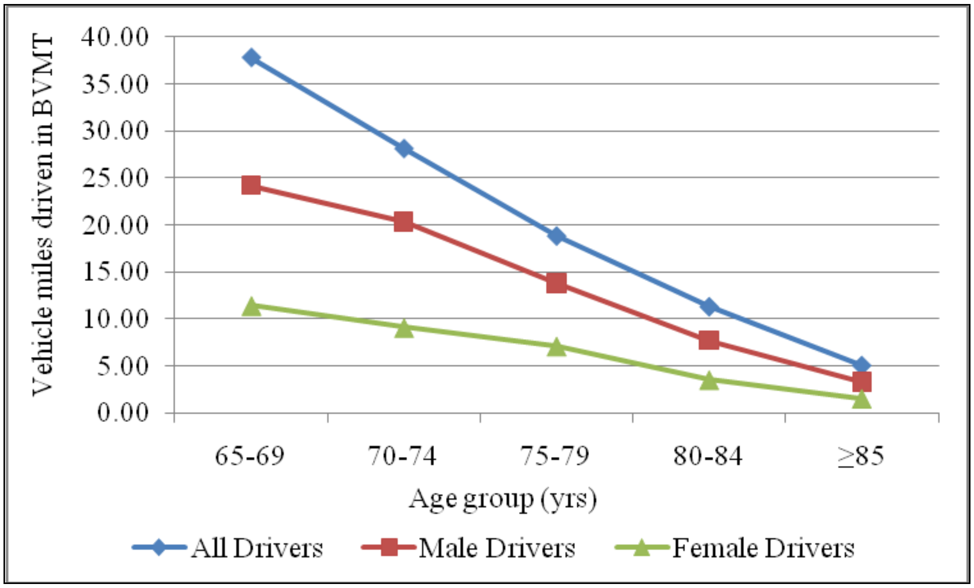

Figure 5.20 Estimated Miles Driven by Elderly in Automobiles

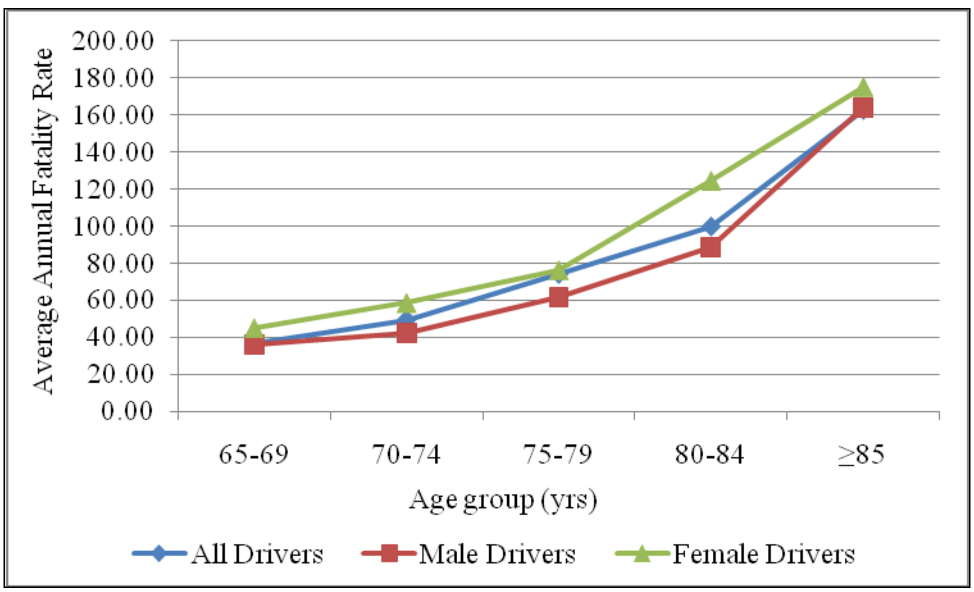

Figure 5.21 AAFR for Elderly Driving Automobiles

From Table 5.14, it can be seen that females had higher fatality rates than males when considering vans and SUVs also. Fatality rates of heavy trucks are significantly high because of lesser data points and miles driven. Motorcycle fatality rates are the highest since frequency of motorcycles driven by older drivers is very low, which is in turn reflected in the rates. These were highest for females. Fatality rates for females driving heavy trucks were zero as the number of miles was not reported.

5.4.5 Race

Fatality risk evaluated based on race using AAFR is presented in this section. Average annual fatalities and estimated annual miles driven based on race are represented in Figures 5.22 and 5.23. The number of fatalities decreased for males and increased for females with an increase in age from 65 yrs to 75 yrs. Starting from 75 yrs, fatalities decreased with an increase in age for both males and females. Miles driven by older males was thrice that of older females, but fatality rates were higher for females.

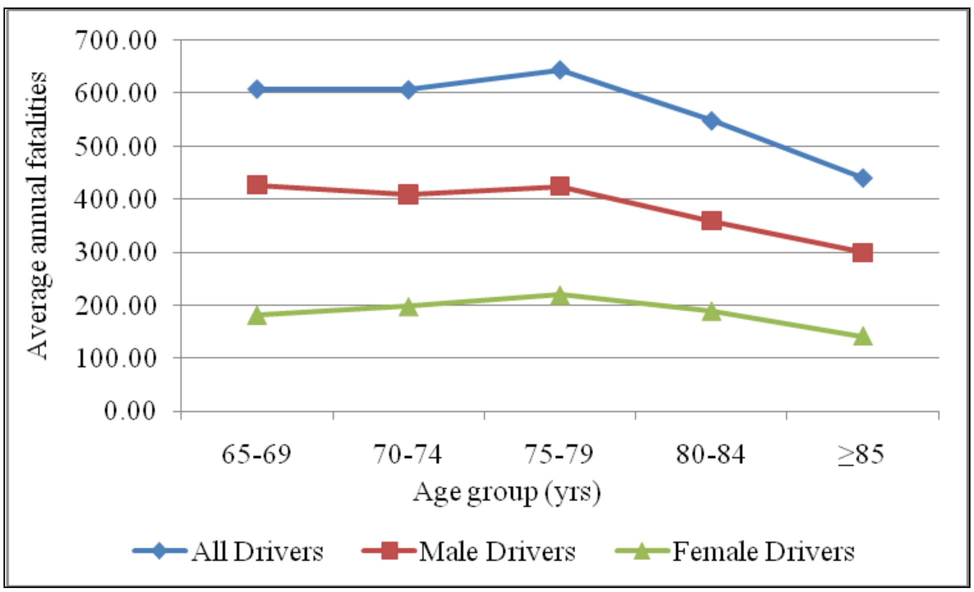

Figure 5.22 Average Annual Fatalities for Older Whites

Average annual fatalities, estimated vehicle miles driven, and AAFR calculated based on race of the driver are shown in Table 5.15**.** The order of fatality rates based on race of the driver is as follows:

African Americans > Whites > American Indian > Asian > Others

Since fatality rates, fatalities, and miles driven were reported highest for whites, rates are depicted for that particular group in Figure 5.24.

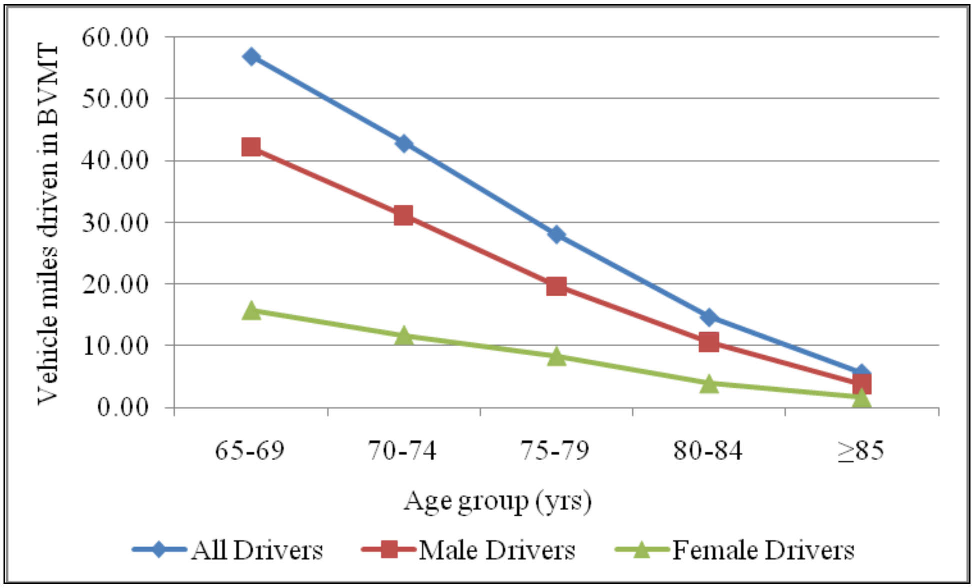

Figure 5.23 Estimated Miles Driven for Whites

Whites have lower fatality rates, whereas African Americans have a rapid increase in rates with increasing age. African Americans have fewer number of miles reported, resulting in higher fatality rates. Fatality rates among whites are highest for older female drivers. AAFR increases constantly with increase in age and the pattern is similar for both the genders.

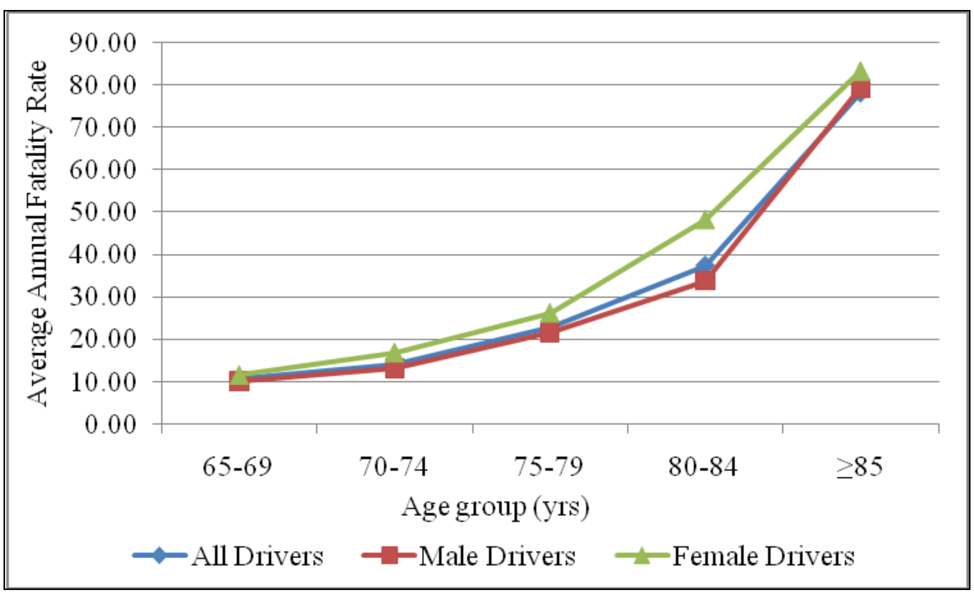

Figure 5.24 AAFR for Older White Drivers

Table 5.15 AAFR for Older Drivers Based on Race

All Drivers															
	Average yearly fatalities (a)					***Estimated miles driven in BVMT (b)***					***AAFR (c=a/b)***				
Age Group (yrs)	Whites	African American	American Indian	Asian	Others	Whites	African American	American Indian	Asian	Others	Whites	African American	American Indian	Asian	Others
65-69	608.1	69.0	4.7	3.0	5.6	56.9	1.3	0.2	1.2	2.5	10.7	54.4	27.8	2.6	2.2
70-74	606.9	52.7	5.3	4.1	2.9	42.8	0.7	0.1	0.8	1.1	14.2	78.9	99.3	4.9	2.6
75-79	644.3	49.3	5.0	2.9	3.7	28.1	0.3	0.1	0.7	0.5	22.9	162.1	42.4	4.3	7.4
80-84	548.4	28.0	1.4	1.4	1.3	14.7	0.1	0.03	0.2	0.2	37.4	258.2	43.8	5.9	7.9
≥85	440.9	19.4	0.9	0.7	0.7	5.7	0.04	0.0	0.04	0.2	78.1	446.6	0.0	20.1	4.1
Male Drivers															
	Average yearly fatalities (a)					***Estimated miles driven in BVMT (b)***					***AAFR (c=a/b)***				
Age Group (yrs)	Whites	African American	American Indian	Asian	Others	Whites	African American	American Indian	Asian	Others	Whites	African American	American Indian	Asian	Others
65-69	426.7	49.0	3.0	2.0	4.1	42.2	0.9	0.1	0.9	1.9	10.1	53.8	28.5	2.2	2.1
70-74	409.3	37.6	3.1	3.0	1.6	31.1	0.4	0.02	0.6	0.9	13.2	90.4	176.2	5.0	1.8
75-79	424.6	35.0	3.9	1.6	2.9	19.6	0.2	0.1	0.5	0.4	21.6	162.3	40.9	3.5	7.1
80-84	359.1	19.9	1.0	1.0	0.7	10.6	0.1	0.02	0.2	0.1	33.8	295.4	43.3	5.9	6.5
≥85	299.1	15.1	0.7	0.6	0.3	3.9	0.04	0.0	0.03	0.1	79.2	384.0	0.0	17.3	2.4
Female Drivers															
	Average yearly fatalities (a)					***Estimated miles driven in BVMT (b)***					***AAFR (c=a/b)***				
Age Group (yrs)	Whites	African American	American Indian	Asian	Others	Whites	African American	American Indian	Asian	Others	Whites	African American	American Indian	Asian	Others
65-69	181.4	20.0	1.7	1.0	1.4	15.7	0.4	0.1	0.3	0.6	11.5	52.9	25.9	3.9	2.5
70-74	197.6	15.1	2.1	1.1	1.3	11.7	0.3	0.04	0.2	0.3	16.9	60.3	61.2	4.8	5.1
75-79	219.4	14.3	1.1	1.3	0.9	8.4	0.1	0.02	0.2	0.1	26.2	163.4	49.9	5.9	8.6
80-84	189.3	8.1	0.4	0.4	0.6	3.9	0.04	0.01	0.1	0.1	48.3	199.2	46.1	6.1	11.4
≥85	141.6	4.3	0.1	0.1	0.4	1.7	0.0	0.0	0.0	0.1	83.3	0.0	0.0	0.0	8.8

5.3 Chi-Square Test of Independence

The existence of a relationship between age of the driver and various variables defining environmental, roadway, vehicle, and driver-related characteristics of older drivers was tested using the chi-square test of independence. Results were obtained in terms of chi-square values, *p*-values, and degrees of freedom using SAS.

Table 5.16 presents the chi-square and probability values. A chi-square value can never be less than zero; the larger the value of chi-square, the stronger the evidence against the null hypothesis that there is a relationship between the two variables. Chi-square values for all the variables were greater than zero and probabilities were less than 0.05, indicating a significant relationship between the selected variable and age of the driver.

From the table, race of the driver, number of drunk drivers involved in fatal crashes, month of death, roadway function class describing the type of the road, manner of collision, type of the vehicle, travel speed, and vehicle maneuver were found to have higher chi-square values making them as the most influential variables among all the other variables.

Age of the driver had strong relation with some other factors and characteristics like light conditions under which crash occurred, speed limits, route signing, fatal injury at work, whether the subject was drunk, rollover/non-rollover crash, whether the person was taken to hospital immediately after the crash, Hispanic or non-hispanic status, whether the road was straight or aligned, and whether the crash occurred on/off road.

Table 5.16 Chi-square Values Determining Relation between Age of Older Drivers and Various Driver, Vehicle, Environment and Roadway related Characteristics

Variable	*p-value*	*Chi-square value*	*Degrees of freedom*
Drinking	<.0001	308.78	4
Taken to Hospital	<.0001	430.04	4
Race	*<.0001*	*849.20*	*12*
Hispanic	<.0001	585.71	8
Drunk drivers	*<.0001*	*903.95*	*8*
Fatal injury at work	<.0001	800.54	8
Died at scene/En route	<.0001	258.11	8
Month of death	*<.0001*	*1069.27*	*12*
Light conditions	<.0001	760.02	16
Day of the week	<.0001	96.53	24
Roadway function class	*<.0001*	*812.08*	*48*
Route signing	<.0001	538.62	28
Interchange area	<.0001	81.25	20
Non-interchange area	<.0001	86.64	28
Related to roadway	<.0001	197.94	28
Roadway alignment	<.0001	244.17	8
Restraint use	0.006	14.44	4
Air bag deployment	< .0001	171.25	8
Manner of collision	*<.0001*	*1150.13*	*24*
Body type	*<.0001*	*3047.29*	*16*
Rollover	<.0001	353.82	8
Speed limit	<.0001	584.36	20
Travel speed	*<.0001*	*1278.02*	*36*
Deformed	<.0001	65.92	16
Impacts	<.0001	152.01	16
Vehicle maneuver	*<.0001*	*867.41*	*52*

Though all the factors were found to have significant relationship with age of the driver, type of the vehicle was very strongly correlated with the highest chi-square value indicating its impact and relation with the age of older drivers involved in fatal crashes.

5.4 Odds Ratio

Odds ratios were calculated for a few selected variables which were found to have strong relation with age of the driver from the chi-square test and a few other crash-related variables. Odds ratios calculated for five variables by considering a five-year analysis period, from 2003 to 2007, are presented in Tables 5.17-5.21.

Table 5.17 Odds and Odds Ratio for Older Drivers Based on Gender

	Odds				***Odds ratio***
Age group (yrs)	***Male driver fatalities (A)***	***Male driver non-fatalities (B)***	***Female driver fatalities (C)***	***Female driver non-fatalities (D)***	***(A*D)/(B*C)***
65-69	0.53	0.47	0.55	0.45	0.90
70-74	0.57	0.43	0.61	0.39	0.88
75-79	0.64	0.36	0.66	0.34	0.93
80-84	0.70	0.30	0.71	0.29	0.92
≥ 85	0.77	0.23	0.80	0.20	0.86

Odds and odds ratio computed based on gender are presented in Table 5.17. It shows that risk of fatality occurrence was more for female drivers (C>A) and that non-fatality occurrences were more for male drivers (B>D). Based on the odds ratio, female drivers had a higher fatality risk. Male drivers had an average of 10 percent lesser fatality risk compared to female drivers. Drivers 75-79 yrs had the highest risk among all other age groups.

Table 5.18 presents results based on light conditions. Odds computed show that older drivers have higher fatality risk in daylight conditions and non-fatality risk in dark conditions. The odds ratio shows that fatality risk for older drivers in daylight varies from 3-54% more than the risk of driving in dark.

Table 5.18 Odds and Odds Ratio for Older Drivers Based on Light Conditions

	Odds				***Odds ratio***
Age group (yrs)	***Fatalities in daylight (A)***	***Non-fatalities in daylight (B)***	***Fatalities in dark (C)***	***Non-fatalities in dark (D)***	***(A*D)/(B*C)***
65-69	0.55	0.45	0.54	0.46	1.03
70-74	0.60	0.40	0.52	0.48	1.42
75-79	0.66	0.34	0.56	0.44	1.54
80-84	0.73	0.27	0.68	0.32	1.24
≥ 85	0.79	0.21	0.75	0.25	1.23

Odds and odds ratio based on road conditions are given in Table 5.19. Fatality risk for older drivers is high in rural areas (A<C) and non-fatality risk in urban areas (B>D). The odds ratio computed show that there is 23-38 % lesser risk for older drivers driving in urban areas compared to rural.

Table 5.19 Odds and Odds Ratio for Older Drivers Based on Road Conditions

	Odds				***Odds ratio***
Age group (yrs)	***Fatalities in urban areas (A)***	***Non-fatalities in urban areas (B)***	***Fatalities in rural areas (C)***	***Non-fatalities in rural areas (D)***	***(A*D)/(B*C)***
65-69	0.48	0.52	0.58	0.42	0.68
70-74	0.52	0.48	0.63	0.37	0.64
75-79	0.59	0.41	0.70	0.30	0.62
80-84	0.66	0.34	0.74	0.26	0.67
≥ 85	0.76	0.24	0.80	0.20	0.77

Table 5.20 shows results based on day of the month. It indicates involvement of older drivers in fatal crashes during first or second half of the month. The odds ratio shows that fatality risk for age groups 65-69 yrs, 70-74 yrs, and 80-84 yrs is high during the first half of the month, and for 75-79 yrs and ≥ 85 yrs age groups fatality risk is predominant during the second half of the month.

Table 5.20 Odds and Odds Ratio for Older Drivers Based on Day of the Month

	Odds				***Odds ratio***
Age group (yrs)	***Fatalities in first half of the month (A)***	***Non-fatalities in first half of month (B)***	***Fatalities in second half of the month (C)***	***Non-fatalities in second half of the month (D)***	***(A*D)/(B*C)***
65-69	0.54	0.46	0.53	0.47	1.05
70-74	0.59	0.41	0.58	0.42	1.06
75-79	0.65	0.35	0.65	0.35	0.98
80-84	0.70	0.30	0.70	0.30	1.02
≥ 85	0.77	0.23	0.79	0.21	0.90

The odds ratio computed based on the month is presented in Table 5.21. Fatality risk for older drivers is high during the first half of the year for all age groups except 80-84 yrs. Non-fatality risk for older drivers is high during the second half of the year.

Table 5.21 Odds and Odds Ratio for Older Drivers Based on Month

	Odds				***Odds ratio***
Age group (yrs)	***Fatalities in first half of the year (A)***	***Non-fatalities in first half of the year (B)***	***Fatalities in second half of the year (C)***	***Non-fatalities in second half of the year (D)***	***(A*D)/(B*C)***
65-69	0.54	0.46	0.54	0.46	1.01
70-74	0.60	0.40	0.57	0.43	1.13
75-79	0.66	0.34	0.64	0.36	1.08
80-84	0.69	0.31	0.71	0.29	0.93
≥ 85	0.80	0.20	0.77	0.23	1.17

5.5 Double Pair Comparison Method

Double pair estimates calculated to find the fatality risk for older occupants in a passenger car are given in Table 5.22. Fatality risk ratios show that older male drivers accompanied by male or female passengers have higher risk than older female drivers. Older male passengers with a male as the driver have more risk than female passengers, whereas older female passengers have more risk than older male passengers accompanied by female drivers. Paired estimate results show that fatality risk for an older driver due to a passenger is

13.5 ± 7.2 % , whereas fatality risk for an older passenger due to a driver is 3.5 ± 6.6 %. Hence, fatality risk for an elderly as a driver is more than that as a passenger.

Table 5.22 Estimation of Fatality Risk for Elderly as Driver and Passenger

Subject occupant	***Category***	***Driver fatalities***	***Passenger fatalities***	***r***	***R***	***ΔR***	$\overline{R}$	$\Delta\overline{R}$	***% risk***
Older driver	Male driver Male passenger	497	336	1.48 (r_1)	1.87 (R_1)	0.189	1.135	0.072	13.5 ± 7.2
	Female driver Male passenger	642	815	0.79 (r_2)					
	Male driver Female passenger	2,476	2,463	1.01 (r_1)	1.08 (R_2)	0.088			
	Female driver Male passenger	560	603	0.93 (r_2)					
Older passenger	Male passenger Male driver	574	282	2.04 (r_1)	1.67 (R_1)	0.155	1.035	0.066	3.5 ± 6.6
	Female passenger Male driver	2,556	2,096	1.22 (r_2)					
	Male passenger Female driver	1,076	619	1.74 (r_1)	0.74 (R_2)	0.065			
	Female passenger Female driver	1,303	554	2.35 (r_2)					

Applying the paired estimates formulae for older drivers, it was found that male drivers traveling with male passengers are 31.3±13.3 % more likely to be killed than female drivers, whereas male drivers traveling with female passengers are 3.4±8.4 % more likely to be killed than female drivers.

Number of passengers involved in fatal crashes with older drivers based on age and gender is given in Figures 5.25-5.28. Figures 5.25 and 5.26 depict the number of male passengers involved in fatal crashes with older drivers based on gender. From five yrs of fatal crash data, younger and middle-aged male passengers were more involved with older male drivers, whereas older male passengers were involved more with older female drivers. Older male passengers were involved four times more with older female drivers compared to older male drivers.

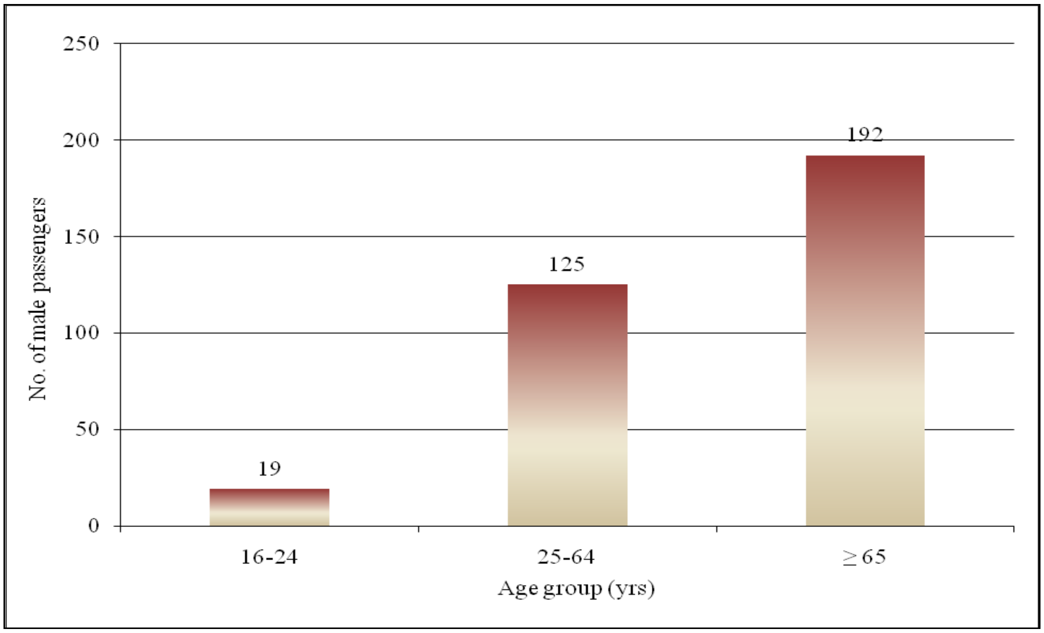

Figure 5.25 Number of Male Passengers Involved Based on Age in Fatal Crashes with Older Male Drivers

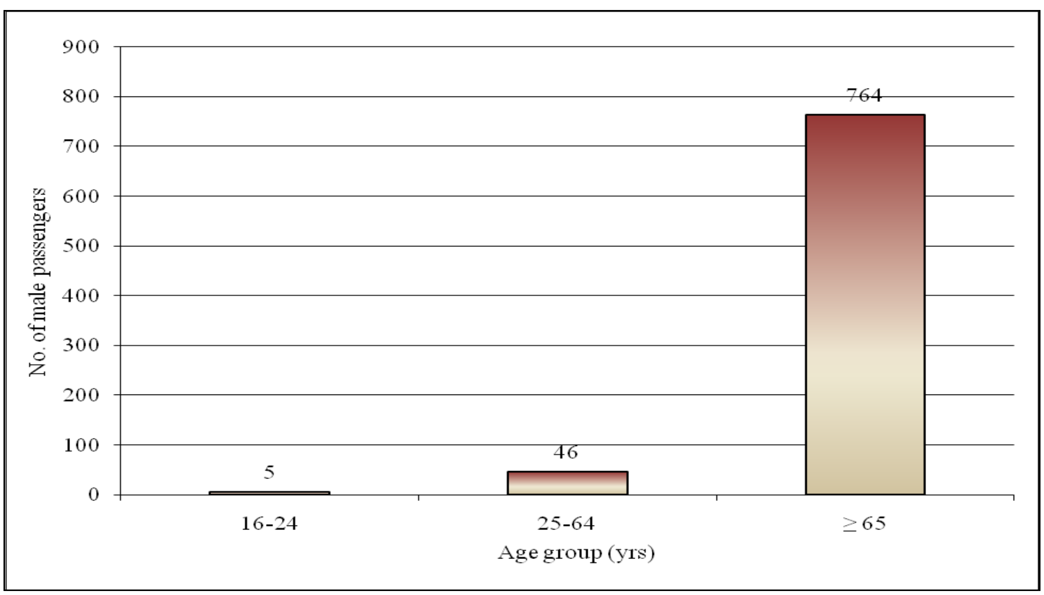

Figure 5.26 Number of Male Passengers Involved Based on Age in Fatal Crashes with Older Female Drivers

Figures 5.27 and 5.28 present the number of female passengers involved in fatal crashes of older drivers based on gender. Numbers of younger female passengers involved were almost all same with older male and female drivers. Middle-aged and older female passengers involved with male drivers were around four times that of their involvement with female drivers. In brief, older male drivers were more involved in fatal crashes with older female passengers whereas older female drivers were more involved with older male drivers.

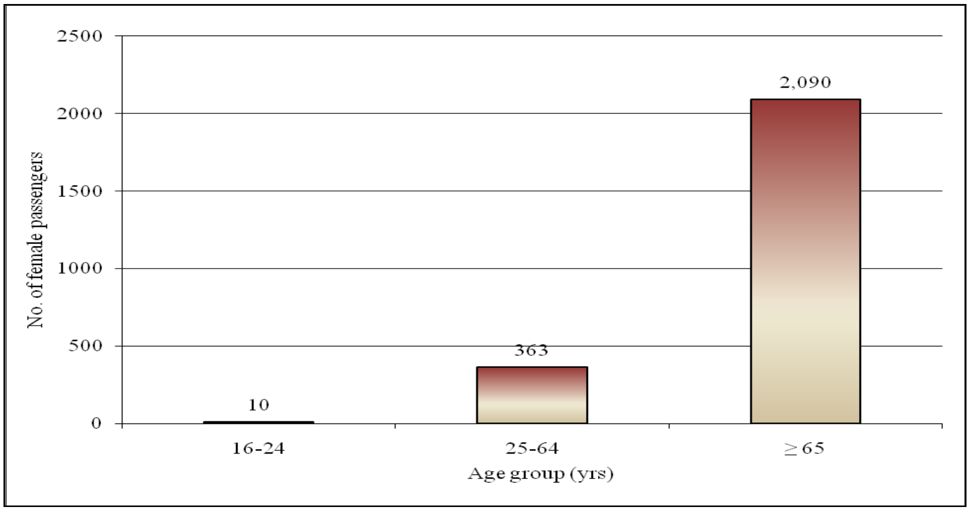

Figure 5.27 Number of Female Passengers Involved Based on Age in Fatal Crashes with Older Male Drivers

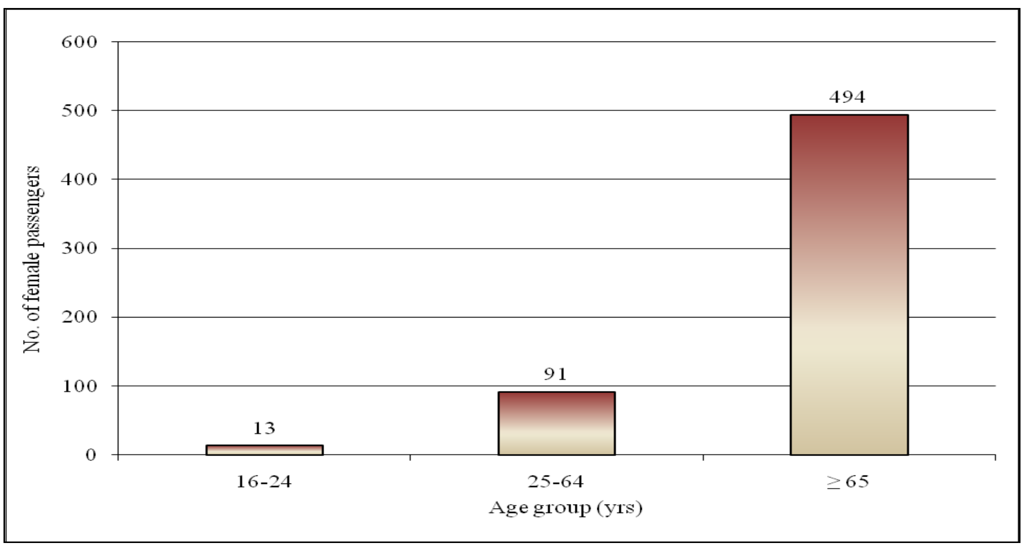

Figure 5.28 Number of Female Passengers Involved Based on Age in Fatal Crashes with Older Female Drivers

5.6 Other Drivers Involved in Fatal Crashes with Older Drivers

Results of analysis for other involved drivers (other drivers) in fatal crashes with older drivers are discussed in this section. Table 5.23 presents data for other drivers involved during 2003 to 2007.

Table 5.23 Number of Other Drivers Involved Based on Age for Five Years

Age (yrs)	***Year***				
	2003	***2004***	***2005***	***2006***	***2007***
16-24	759	766	730	691	671
25-34	734	698	684	614	611
35-44	752	722	664	643	606
45-54	626	615	639	605	563
55-64	414	366	431	381	415
≥65	237	239	209	226	217

Number of other drivers involved in fatal crashes with older drivers decreased for each year starting from 2003. Table 5.24 presents data for other drivers classified based on age and gender. Younger (16-24 yrs) and middle-aged (35-44 yrs) male drivers were highly involved as other drivers in fatal crashes with older drivers.

Table 5.24 Other Drivers Involved in Fatal Crashes of Older Drivers Based on Age and Gender

Age (yrs)	***Males (%) (%)***	***Females (%) (%)***	***Total (%) (%)***
16-24	2,458 (67.9) (20.8)	1,159 (32.1) (24.7)	3,617 (100.0) (21.9)
25-34	2,384 (71.4) (20.1)	957 (28.6) (20.4)	3,341 (100.0) (20.2)
35-44	2,493 (73.6) (21.0)	894 (26.4) (19.1)	3,387 (100.0) (20.5)
45-54	2,301 (75.5) (19.4)	747 (24.5) (15.9)	3,048 (100.0) (18.5)
55-64	1,475 (73.5) (12.5)	532 (26.5) (11.4)	2,007 (100.0) (12.1)
≥65	729 (64.6) (6.2)	399 (35.4) (8.5)	1,128 (100.0) (6.8)
Total	***11,840 (71.6) (100.0)***	***4,688 (28.4) (100.0)***	***16,528 (100.0) (100)***

Figure 5.29 shows the percentage of involvement of other drivers based on age, which reveals that the youngest group was the highest involved and the oldest group was the least involved with older drivers in fatal crashes.

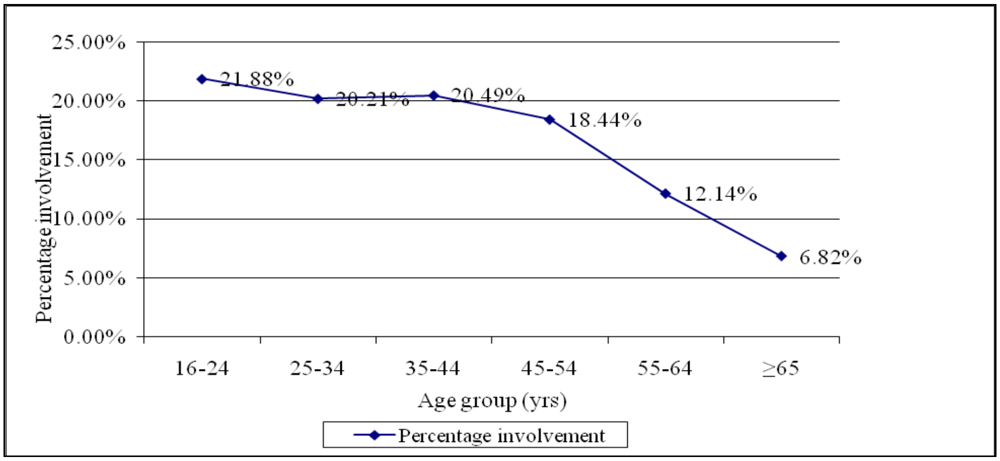

Figure 5.29 Percentage of Other Involved Drivers Based on Age

Percentages of other drivers involved in fatal crashes with older drivers based on gender and age group are given in Figure 5.30. Male other driver's involvement is an inverse U-shaped curve, which shows that their involvement increases and then decreases with an increase in age. It is vice versa for female other drivers.

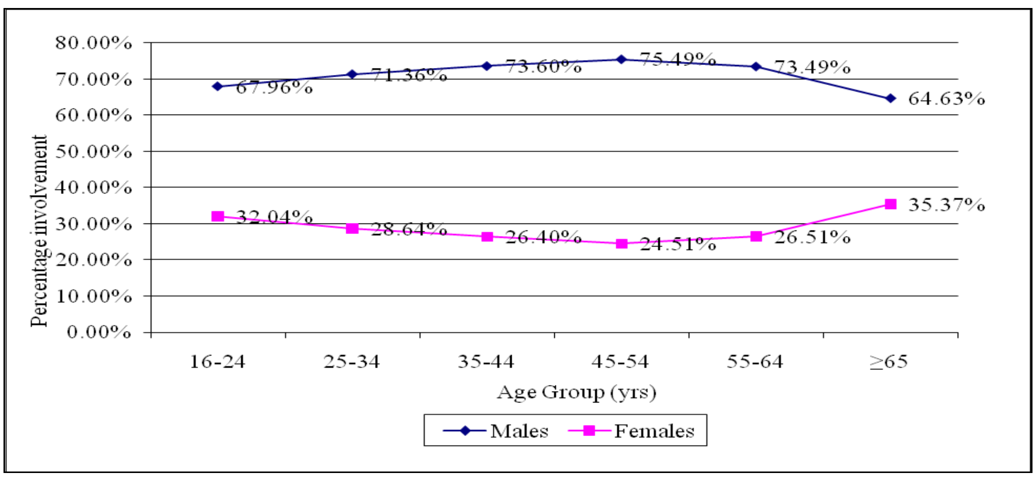

Figure 5.30 Percentage of Other Involved Drivers Based on Gender

Percentages within age groups are compared for male and female other drivers separately in Figures 5.31 and 5.32.

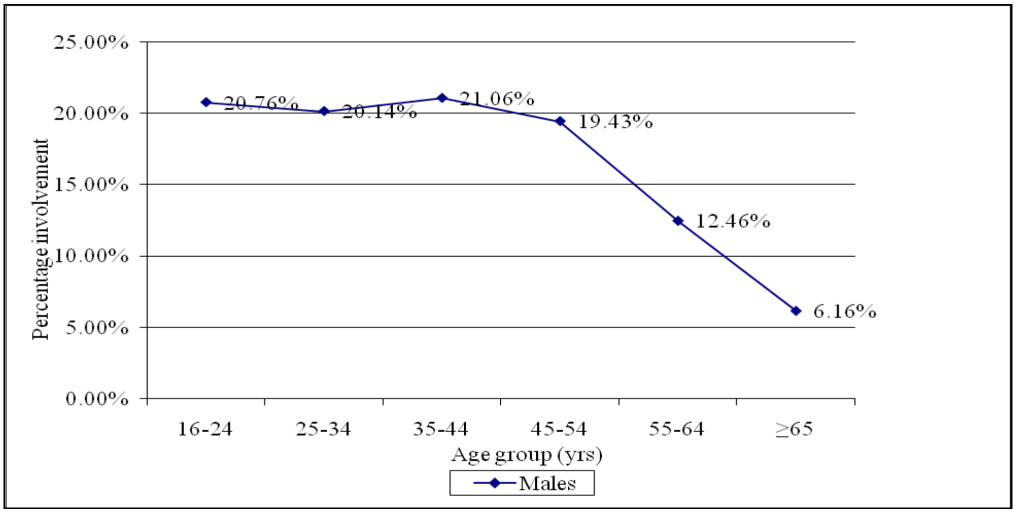

Figure 5.31 Percentage of Other Involved Male Drivers

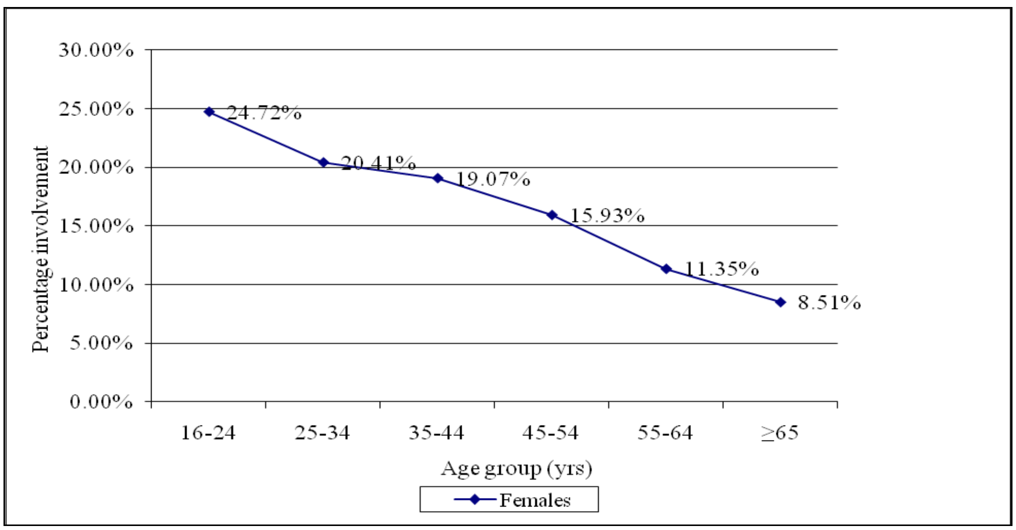

Figure 5.32 Percentage of Other Involved Female Drivers

From the figures, it can be seen that younger and older female drivers are more involved in fatal crashes than their male counterparts, and middle-aged male drivers are more involved than female drivers in fatal crashes with older drivers.

CHAPTER 6 - Summary, Conclusions & Recommendations

6.1 Summary and Conclusions

This study explored the characteristics of older drivers involved in fatal crashes and evaluated the fatality risk posed for them in relation to a few of the selected driver, vehicle, environmental, and roadway-related variables. Fatal crash data obtained from NHTSA and exposure data from NHTS were used for this analysis. Analysis of the characteristics of older drivers involved in fatal crashes was carried out in detail, and a comparison study with younger and middle-aged drivers was performed to identify risk factors for older drivers in fatal crashes. Fatality rates in terms of average annual fatality rates (AAFR) were estimated to evaluate the risk for older drivers involved in fatal crashes under different conditions and situations. Statistical applications like the chi-square test and odds ratio were used to find the relationship and strength of association between age of the driver and various other variables, whereas the double pair comparison method was used to estimate the fatality risk for the older population as occupants of passenger cars. The analysis period was 10 yrs, from 1997 to 2006 with 2001 as the mid yr corresponding to exposure for rate calculations; and 5 yrs, from 2003 to 2007, for all other calculations. Older drivers were divided into five age groups to match the standard grouping followed by NHTSA. These are 65-69 yrs, 70-74 yrs, 75-79 yrs, 80-84 yrs, and 85 yrs and older. Each factor was individually studied for all age groups based on gender to identify the effect of increasing age for males and females separately.

Fatal crash facts for the most recent year for which crash data is available (2007) shows that there were 37,248 fatal crashes resulting in 40,931 fatalities of known age and 128 of unknown age. The 15-24 yrs population had the highest number of fatalities and non-fatalities. The number of fatalities and non-fatalities decreased with increased age, but the percentage of fatalities in fatal crashes prevailed as highest for the older population, i.e. ≥ 65 yrs. The percentage of fatal injuries among the driving population was highest for 85 yrs and older drivers, whereas that of non-fatal injuries was highest for 15-24 yrs drivers. On average, 63 percent of fatalities and 37 percent of non-fatalities were among older drivers involved in fatal crashes. The oldest group of passengers (≥ 85 yrs) had the highest percentage of fatalities, whereas the youngest group of passengers (≤ 15 yrs) had the highest percentage of non-fatalities. Non-occupants had the highest percentage of fatalities with increasing age. Because the older population are the road users more as drivers than non-occupants, a detailed analysis of characteristics was performed for older drivers comparing them with younger and middle-aged drivers considering various factors of fatal crashes.

Younger (16-24 yrs), middle-aged (25-64 yrs), and older drivers (≥ 65 yrs) were classified based on standard age groupings by NHTSA. Both fatal and non-fatal injuries were considered for the analysis, and percentages were used to make the comparisons. They were calculated as row and column percentages, which are explained as percentages among the three age groups and within an age group. Findings showed that the percentages among the three groups for various factors considered was always highest for the middle-aged group as the age range between the minimum and maximum limit was highest (64-25 = 39 yrs). Hence, percentages within an age group were considered for genuine comparisons. Older drivers involved in fatal crashes had a seat belt usage of 67 percent, whereas younger and middle-aged drivers had 49 and 55 percent, respectively. Older drivers had the highest percentage of non-drinkers and younger drivers had the highest percentage of drinkers reported in fatal crashes. The number of injuries for older drivers involved in fatal crashes was highest for whites and second for African Americans. Based on manner of collision, older drivers had the highest numbers of front-to-side type collisions, whereas the other two groups had higher numbers of single vehicular collisions. All three groups were highly involved in fatal crashes in automobiles. The highest percentage of crashes involving pickup trucks and SUVs also involved middle-aged drivers. Fatal crashes on straight and curved roads were predominant for older drivers and younger drivers, respectively. All three groups had higher involvement in rural areas compared to urban. Crashes on level roadway profiles were more in number than on graded profiles. Middle-aged and older drivers had higher involvement in daylight and during the months of August to November, whereas younger drivers were more involved in dark conditions and during April to July. Younger and middle-aged drivers were more involved in fatal crashes on Saturdays, whereas older drivers were more involved on Fridays.

Among older drivers, the 65-69 yrs group was highly involved in fatal crashes. An average of 45 percent of older drivers deployed airbags and the other 55 percent consisted of non-deployment and non-availability of airbags equally. Twenty-nine percent of older drivers died at the scene, whereas 66 percent were taken to hospital when fatal crashes occurred. Only 11 percent of the crashes were rollover and 35 percent of them occurred on state highways. Older drivers had more involvement in interchange areas and on roadways traveling at speeds of 51-60 mph. Only 3 percent of injuries occurred in construction maintenance zones and 1 percent of fatal injuries occurred at work. Highest number of crashes included drivers maneuvering straight and impact on the vehicle at right front with highest severity of vehicle deformation. Older drivers also had problems in making left turns and negotiating curves. The highest number of crashes occurred on dry bituminous, two-lane two-way roads physically undivided. Not applicable cases were predominant for categories like race, drinking, hospital, death month, Hispanics, and travel speed, as they were reported only for fatal injuries.

Fatality rates were calculated for driver-related factors like age, gender, and race, vehicle-related factors like body type; environment related like light conditions; and roadway-related like roadway function class. These factors were chosen based on data availability. Rates calculated showed that risk for older drivers increased with increase in age. The number of older male drivers involved in crashes was more than older females, but fatality rates were higher for female older drivers. Based on age, AAFR ranged from 25 fatalities per BVMT to 130 fatalities per BVMT. Fatality rates in daylight conditions were higher than in dark conditions for older drivers. Daylight fatality rates significantly increased with increasing age and this can be attributed to more than 90 percent of driving and fatal crash involvement in daylight conditions. Percentage of the elderly driving in the dark decreased with an increase in age, and hence, fatality rates were higher for dark conditions. Based on gender, fatality rates were around three times higher for females. Older drivers had high fatality risk in rural areas. Previous studies and governmental reports showed that the number of crashes occurring in rural areas was higher than in urban areas, and hence fatality rates were higher by three times to those in urban areas. Rate of licensed drivers was higher in rural areas by 2%. The value for AAFR ranged from 15.0 to 75.0 fatalities per BVMT in urban areas and 45.0 to 350.0 fatalities per BVMT in rural areas. The range for rates varied from three to five times in rural areas.

Vehicles were categorized into seven major types and fatality rates were highest for automobiles. Older drivers had a higher percentage of vehicle miles traveled using automobiles. Unlike younger drivers, they had a very small percentage of involvement in fatal crashes using motorcycles. So the crash rates were well explained in the case of automobiles involvement being more than any other type of vehicle. Vehicle miles traveled for heavy trucks were insignificant and hence, fatality rates shot up rapidly. Females had an excessive increase and a sharp drop to zero in rates for vehicles like heavy trucks and RVs due to the lesser amount of travel in those vehicles. Based on race of the driver, African Americans had higher rates than whites, which is again an over projection due to their small population and lesser amount of travel. Fatality rates increased with increase in age, from 10.0 to 80.0 crashes per BVMT in the case of whites and 50.0 to 500.0 crashes per BVMT in the case of African Americans. The range was wide in the case of African Americans because of fewer number of observations reported to NHTS. This study was limited to these five factors because of the non-availability of common variables in crash and exposure data. It can be further extended if data for some of the important variables such as travel speed, intersection-related, and junction-related were available in both the databases, aiding the rate calculations and evaluations of fatality risk for older drivers based on speed and maneuvers.

According to chi-square test results, a significant relationship was observed between age of the driver and various driver, environmental, roadway, and vehicle-related variables. The number of drunk drivers involved in a crash, death month, roadway function class, and vehicle type were found to have the strongest relation supported with the evidence of highest chi-square value. Race of the driver, light conditions, fatal injuries at work, and travel speed were other variables having a relation with the age of the driver.

The odds ratio, which determines strength of association between two groups, showed that female older drivers had a 10 percent higher fatality risk than males. Older drivers had a 30 percent higher risk in daylight conditions than in the dark and 32 percent higher risk in rural areas than urban. They also had higher fatality risks in the first half of the month and in the first half of the year.

Estimates of the double paired comparison were used to evaluate and estimate risk for older occupants in fatal crashes as drivers and passengers. According to the results, older occupants as drivers had 10 percent more fatality risk than passengers when involved in fatal crashes. Older male drivers were more involved in fatal crashes with older female passengers whereas based on the number of fatalities older female drivers were more involved in fatal crashes with older male passengers. From the paired comparison estimates, it was found that older male drivers had a 31 percent fatality risk accompanied by a male passenger, whereas they had just a 3 percent risk when accompanied by a female passenger.

In two-vehicle crashes with at least one older driver fatally injured, an analysis was carried out to find the age group of the other drivers involved in the crash. It was concluded from the results that the youngest group of drivers (16-24 yrs) were involved most in fatal crashes with older drivers (≥ 65 yrs). Older drivers were the least involved as other drivers. Based on gender, middle-aged males and older females were more involved.

6.2 Suggested measures

It was found from the results that the older population involved in fatal crashes have more risk compared to younger and middle-aged groups due to the frailty that comes with age. The older population have more risk both as occupants and non-occupants, but older road users are mostly comprised of drivers and hence this study was carried out with subject occupant as the older driver. From the older drivers' perspective, physical, visual, and cognitive abilities may decline with increasing age, making it difficult to drive safely. Also, they are more easily prone to injuries than younger age groups. With an increasing older population, licensed drivers, and increased involvement in fatal crashes, countermeasures should be suggested from both the engineering and medical perspectives.

Recommendations from a medical perspective include self-regulation of driving behavior and monitoring health. Older drivers may suffer with dementia, which results in cognitive and sensory functions impairment. The U.S. Government Accountability Office (U.S. GAO) has stated that many states have applied stricter rules on older drivers than that of younger drivers regarding licensing requirements. But since these in-person renewals demand only vision testing and do not include assessment of physical and cognitive functions, they do not attain desired results for improvement of older drivers' safety. Developments in this process may result in assessing a driver's ability to recognize traffic conditions, and to see traffic signals, pedestrians, lane markings, and other vehicles. Older drivers have to stringently monitor their health to make a decision on continuing their driving, particularly those aged 85 yrs and older.

Recommendations from an engineering perspective involve implementing licensing requirements, using larger letters on traffic signs for good visibility, regular usage of FHWA handbooks such as "Highway Design Handbook for Older Drivers and Pedestrians," placing advance street name signs before intersections, improving intersection layouts for the design and better operation of the roadways, and public awareness programs. These practices can aid in improvement of safety situations for older drivers. The GAO has been keeping track of efforts taken by some states in developing policies to improve older driver safety in the areas of strategic planning, education and awareness, licensing and driver fitness assessment, roadway engineering, and data analysis. It has also recommended that FHWA and NHSTA administrators implement a system to allow states to share information regarding older driver safety practices. Further research can be conducted to find out details about other factors responsible for higher involvement of older drivers and suggest recommendations accordingly.

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Appendix A - Distribution of Total Crash Fatalities by Sex, Age Group and Year

Table A-6.1 Distribution of Total Crash Fatalities by Sex, Age Group, and Year

Sex and Age Group	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Females										
<16	1,365	1,258	1,234	1,223	1,094	1,065	1,071	1,142	1,017	964
16-20	1,877	1,825	1,934	1,816	1,859	1,963	1,921	1,899	1,786	1,755
21-25	1,176	1,072	1,135	1,186	1,150	1,244	1,250	1,252	1,293	1,251
26-30	990	928	913	892	841	828	846	879	844	868
31-35	1,041	973	903	866	832	833	813	840	824	788
36-40	1,057	1,111	1,068	1,019	1,063	996	975	856	870	857
41-45	892	950	938	951	935	1,055	996	959	1,006	983
46-50	767	829	777	812	764	851	857	880	867	867
51-55	634	649	682	669	734	780	784	777	805	762
55-60	619	584	581	604	588	575	635	632	685	691
61-65	562	543	562	519	492	581	555	606	578	538
>65	3,159	3,141	2,920	2,806	2,822	2,731	2,809	2,636	2,553	2,399
Total*	***14,168***	***13,885***	***13,667***	***13,396***	***13,205***	***13,529***	***13,532***	***13,387***	***13,155***	***12,747***
Males										
<16	1,802	1,736	1,708	1,608	1,509	1,483	1,508	1,480	1,340	1,206
16-20	3,915	3,904	3,985	4,149	4,204	4,336	4,109	4,024	3,933	3,883
21-25	3,528	3,470	3,505	3,622	3,892	3,998	3,941	4,105	4,254	4,419
26-30	2,705	2,553	2,644	2,723	2,685	2,683	2,549	2,622	2,786	2,780
31-35	2,461	2,421	2,281	2,308	2,329	2,328	2,335	2,290	2,420	2,379
36-40	2,362	2,380	2,433	2,464	2,432	2,440	2,298	2,224	2,286	2,158
41-45	2,028	2,086	2,231	2,381	2,444	2,416	2,572	2,467	2,493	2,387
46-50	1,713	1,790	1,837	1,934	1,976	2,118	2,166	2,275	2,329	2,386
51-55	1,368	1,401	1,432	1,549	1,634	1,715	1,821	1,835	2,035	1,995
55-60	1,044	1,046	1,142	1,198	1,213	1,217	1,393	1,436	1,537	1,564
61-65	878	891	855	895	915	987	1,006	1,027	1,170	1,144
>65	3,948	3,862	3,923	3,630	3,671	3,654	3,582	3,577	3,674	3,315
Total*	***27,827***	***27,608***	***28,040***	***28,545***	***28,986***	***29,466***	***29,346***	***29,443***	***30,347***	***29,722***

Source: FARS 1996-2005 (Final), 2006 (ARF)

Appendix B - Characteristic Analysis Tables for Older Drivers

Table B-1 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers

Variable	*Age groups*					
Speed limit	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
No Statutory Limit	*30.0%*	17.5%	25.0%	7.5%	20.0%	100.0%
10mph-25mph	16.3%	19.2%	*22.8%*	*22.8%*	18.8%	100.0%
30mph-45mph	21.0%	20.2%	*22.6%*	20.4%	15.8%	100.0%
50mph-65mph	*26.3%*	22.9%	22.4%	16.2%	12.2%	100.0%
70mph-85mph	*30.3%*	26.4%	20.9%	13.8%	8.6%	100.0%
Unknown Speed	20.0%	19.4%	*22.2%*	19.9%	18.6%	100.0%
Rollover						
No Rollover	*23.0%*	21.6%	22.6%	18.4%	14.5%	100.0%
First event	*37.0%*	26.8%	18.5%	10.5%	7.2%	100.0%
Subsequent event	*31.6%*	23.6%	19.9%	14.1%	10.8%	100.0%
Body type						
Automobiles	19.6%	20.3%	*23.1%*	20.3%	16.7%	100.0%
SUVs	*37.4%*	24.6%	18.6%	12.7%	6.6%	100.0%
Vans	*30.2%*	26.3%	23.9%	11.8%	7.8%	100.0%
Pickup trucks	*32.4%*	24.7%	20.1%	13.2%	9.6%	100.0%
Heavy trucks	*64.1%*	24.3%	7.5%	3.9%	0.2%	100.0%
Recreational vehicles	*40.3%*	29.0%	18.5%	9.7%	2.4%	100.0%
Others	*48.8%*	25.1%	15.1%	6.5%	4.5%	100.0%
Unknown	*24.3%*	*24.3%*	*24.3%*	16.8%	10.3%	100.0%
Special Jurisdiction						
No Special Jurisdiction	*24%*	22%	22%	18%	14%	100.0%
National Park Service	23%	13%	*32%*	25%	8%	100.0%
Military	23%	0%	*62%*	0%	15%	100.0%
Indian Reservation	*32%*	26%	21%	12%	10%	100.0%
College/University Campus	*0%*	*0%*	*0%*	*0%*	*0%*	100.0%
Other Federal Properties (since 1977)	*57%*	0%	14%	0%	29%	100.0%
Other (since 1976)	11%	11%	*67%*	11%	0%	100.0%
Unknown	0%	*32%*	*32%*	11%	26%	100.0%

Table B-2 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers, continued.

Variable	***Age groups***					
Vehicle Maneuver	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
Going Straight	*24.2%*	22.1%	22.5%	17.6%	13.6%	100.0%
Slowing or Stopping in Traffic Lane	*34.9%*	19.8%	21.7%	13.5%	10.2%	100.0%
Starting in Traffic Lane	13.2%	20.7%	*23.6%*	21.3%	21.2%	100.0%
Stopped in Traffic Lane	*27.0%*	22.3%	23.3%	16.0%	11.4%	100.0%
Passing or Overtaking Another Vehicle	*32.9%*	23.0%	24.0%	11.8%	8.3%	100.0%
Leaving a Parked Position	9.4%	25.0%	18.8%	18.8%	*28.1%*	100.0%
Parked	0.0%	25.0%	50.0%	*25.0%*	0.0%	100.0%
Entering a Parked Position	12.5%	18.8%	18.8%	*25.0%*	25.0%	100.0%
Maneuvering to Avoid	*28.0%*	26.2%	17.4%	16.5%	11.9%	100.0%
Turning Right: Right Turn on Red Permitted	12.0%	8.0%	16.0%	*40.0%*	24.0%	100.0%
Turning Right: Right Turn on Red Not Permitted	33.3%	0.0%	0.0%	0.0%	*66.7%*	100.0%
Turning Right: Right Turn on Red Not Applicable or Not known if permitted	15.3%	20.5%	20.9%	*27.4%*	15.8%	100.0%
Turning Left	15.2%	18.0%	22.5%	*23.6%*	20.7%	100.0%
Making a U-Turn	17.3%	*24.6%*	19.0%	21.8%	17.3%	100.0%
Backing Up (not parking)	23.3%	15.6%	*27.8%*	14.4%	18.9%	100.0%
Changing Lanes or Merging	*33.0%*	24.1%	21.4%	13.7%	7.7%	100.0%
Negotiating a Curve	*31.4%*	24.4%	20.4%	14.2%	9.5%	100.0%
Other	*24.6%*	23.0%	18.2%	19.3%	15.0%	100.0%
Unknown	22.2%	13.6%	*23.5%*	19.8%	21.0%	100.0%
Impacts						
Non-collision	*36.5%*	26.0%	18.9%	10.9%	7.7%	100.0%
Right front at 30 degrees	*24.0%*	22.0%	22.2%	17.9%	13.9%	100.0%
Right front at 45 degrees	*23.1%*	21.4%	22.6%	18.2%	14.7%	100.0%
Right centre	*27.1%*	22.3%	23.1%	16.2%	11.3%	100.0%
Left centre	*27.0%*	23.0%	12.2%	27.0%	10.8%	100.0%
Deformed						
None	*29.2%*	18.6%	19.0%	16.4%	16.8%	100.0%
Other (Minor)	*25.2%*	22.4%	22.7%	17.0%	12.7%	100.0%
Functional (Moderate)	21.9%	20.0%	*22.7%*	19.4%	16.0%	100.0%
Disabling (Severe)	*24.3%*	22.1%	22.2%	17.7%	13.7%	100.0%
Unknown	20.6%	21.9%	*23.5%*	16.2%	17.8%	100.0%

Table B-3 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers, continued.

Variable	*Age groups*					
Travel Speed	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
Stopped Motor Vehicle In-Transport	*27.2%*	22.5%	23.3%	15.8%	11.3%	100.0%
1 mph- 20 mph	*44.1%*	13.3%	15.3%	14.9%	12.4%	100.0%
21 mph-30 mph	18.8%	19.6%	*23.6%*	20.7%	17.3%	100.0%
31 mph - 40 mph	21.5%	20.2%	*24.2%*	18.6%	15.5%	100.0%
41 mph- 50 mph	23.8%	*24.3%*	22.1%	17.1%	12.7%	100.0%
51 mph- 60 mph	*28.3%*	24.3%	21.6%	15.7%	10.0%	100.0%
61 mph- 70 mph	*32.5%*	24.2%	20.6%	14.5%	8.2%	100.0%
71 mph- 80 mph	*31.9%*	25.2%	21.1%	13.4%	8.4%	100.0%
81 mph- 90 mph	*37.0%*	27.0%	22.0%	9.0%	5.0%	100.0%
91 mph- 96 mph	*36.8%*	26.3%	5.3%	10.5%	21.1%	100.0%
Ninety-Seven MPH or Greater	*30.2%*	17.0%	41.5%	3.8%	7.5%	100.0%
Not Reported	*23.4%*	21.6%	22.0%	18.4%	14.6%	100.0%
Unknown	*25.0%*	20.7%	22.4%	17.2%	14.7%	100.0%
Gross Vehicle Weight Rating						
Not Applicable	*23.9%*	21.6%	22.2%	18.3%	13.9%	100.0%
10,000 lbs or less	33.3%	*46.7%*	13.3%	0.0%	6.7%	100.0%
10,000 lbs-26,000 lbs	19.3%	*24.7%*	23.8%	18.8%	13.4%	100.0%
26,000 lbs or more	24.0%	21.5%	*23.8%*	17.9%	12.8%	100.0%
Unknown	15.8%	21.1%	*22.8%*	21.1%	19.3%	100.0%
Restraint Use						
None used	*24.8%*	21.2%	22.4%	17.4%	14.2%	100.0%
Belt or helmet used	*23.6%*	21.9%	22.2%	18.5%	13.8%	100.0%
Unknown	*23.7%*	22.0%	21.8%	19.0%	14.0%	100.0%
Air Bag						
Deployed	*24.4%*	23.2%	22.4%	17.7%	12.3%	100.0%
Not Deployed	*25.1%*	22.2%	22.6%	17.4%	12.8%	100.0%
Not Available	*22.3%*	21.0%	21.0%	18.9%	16.9%	100.0%
Unknown	20.3%	19.4%	*30.5%*	15.7%	14.2%	100.0%
Drinking						
No	*23%*	22%	22%	18%	14%	100.0%
Yes	*41%*	26%	20%	9%	4%	100.0%
Not reported	*24%*	21%	22%	18%	15%	100.0%
Unknown	*26%*	23%	24%	16%	12%	100.0%

Table B-4 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers, continued.

Variable	***Age groups***					
Manner of collision	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
No Collision	*28.8%*	23.0%	21.1%	15.7%	11.1%	100.0%
Front to rear	*28.5%*	24.4%	22.8%	14.0%	10.3%	100.0%
Front to front	*28.1%*	24.4%	22.5%	14.5%	10.5%	100.0%
Front to side	19.3%	19.9%	*22.5%*	21.0%	17.3%	100.0%
Sideswipe	*29.6%*	23.7%	22.2%	13.8%	10.6%	100.0%
Rear to side	*30.4%*	8.7%	33.3%	20.3%	7.2%	100.0%
Rear to rear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
other	*37.3%*	19.4%	23.9%	11.9%	7.5%	100.0%
Unknown	*58.8%*	10.8%	10.8%	7.8%	11.8%	100.0%
Registered Owner of the vehicle						
Not Applicable, Vehicle Not Registered	*27%*	21%	18%	20%	14%	100.0%
Driver (of This Vehicle) Was Registered Owner	*23%*	21%	23%	19%	15%	100.0%
Driver (of This Vehicle) Not Registered Owner (other private owner)	*27%*	23%	21%	17%	12%	100.0%
Vehicle Registered as Business/Company/Government Vehicle	*25%*	22%	23%	17%	13%	100.0%
Vehicle Registered as Rental Vehicle	*34%*	24%	16%	16%	9%	100.0%
Vehicle Was Stolen (reported by police)	*27%*	18%	23%	18%	14%	100.0%
Driverless Vehicle	*28%*	25%	16%	25%	6%	100.0%
Unknown	*24%*	22%	23%	17%	13%	100.0%
Hospital						
No	*28%*	24%	22%	15%	11%	100.0%
Yes	*22%*	21%	*22%*	19%	15%	100.0%
Unknown	*28%*	*28%*	18%	15%	11%	100.0%
Race						
Whites	20%	21%	*23%*	20%	17%	100.0%
African Americans	*32%*	24%	21%	13%	10%	100.0%
Others	*31%*	24%	30%	11%	5%	100.0%
Not Applicable	*32%*	25%	21%	14%	8%	100.0%
Unknown	21%	20%	*22%*	20%	17%	100.0%
National Highway System						
Section not on highway system	*23%*	21%	22%	19%	15%	100.0%
Section on highway system	*26%*	23%	23%	16%	12%	100.0%
Unknown	21%	*24%*	23%	17%	15%	100.0%

Table B-5 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers, continued.

Variable	***Age groups***					
Hispanic	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
Yes	*28%*	26%	18%	20%	9%	100.0%
No	21%	21%	*23%*	19%	17%	100.0%
Not a fatality	*32%*	25%	21%	14%	8%	100.0%
Unknown	21%	20%	*22%*	20%	17%	100.0%
Number of drunk drivers						
0	22%	21%	*23%*	19%	15%	100.0%
1	*38%*	26%	20%	11%	6%	100.0%
2	*49%*	19%	21%	7%	3%	100.0%
3	*33%*	29%	13%	16%	9%	100.0%
Died at Scene/En Route						
Not Applicable	*23%*	21%	22%	19%	15%	100.0%
Died at scene	*27%*	23%	23%	15%	11%	100.0%
Died En Route	22%	*23%*	22%	20%	13%	100.0%
Unknown	*24%*	22%	20%	20%	14%	100.0%
Death Month						
April thru July	20%	20%	*23%*	19%	17%	100.0%
August thru November	21%	21%	*22%*	20%	16%	100.0%
December thru March	21%	21%	*23%*	19%	16%	100.0%
No Record	32%	25%	21%	14%	8%	100.0%
Unknown	19%	21%	*22%*	20%	18%	100.0%
Light Condition						
Daylight	22%	21%	*23%*	19%	15%	100.0%
Dark	*35%*	23%	20%	13%	9%	100.0%
Dark but Lighted	*32%*	24%	21%	16%	8%	100.0%
Dawn	*37%*	20%	20%	12%	10%	100.0%
Dusk	27%	23%	21%	18%	11%	100.0%
Unknown	12%	*38%*	24%	14%	12%	100.0%
Day of the Week						
Sunday	*26%*	22%	22%	18%	13%	100.0%
Monday	*23%*	22%	22%	18%	15%	100.0%
Tuesday	23%	21%	*24%*	18%	15%	100.0%
Wednesday	*24%*	21%	23%	18%	13%	100.0%
Thursday	*23%*	*23%*	21%	18%	14%	100.0%
Friday	*24%*	21%	22%	19%	14%	100.0%
Saturday	*26%*	23%	22%	16%	13%	100.0%

Table B-6 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers, continued.

Variable	***Age groups***					
Fatal injury at work	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
No	20%	21%	*23%*	19%	17%	100.0%
Yes	*41%*	22%	26%	8%	4%	100.0%
Not Applicable	*32%*	25%	21%	14%	8%	100.0%
Unknown	*22%*	21%	22%	19%	16%	100.0%
Roadway Function Class						
Rural Principal Arterial - Interstate	*32%*	27%	21%	12%	7%	100.0%
Rural Principal Arterial - Other	*26%*	22%	22%	17%	14%	100.0%
Rural Minor Arterial	*25%*	22%	23%	17%	12%	100.0%
Rural Major Collector	*26%*	23%	22%	16%	12%	100.0%
Rural Minor Collector	24%	*25%*	21%	15%	15%	100.0%
Rural Local Road or Street	*26%*	24%	21%	16%	13%	100.0%
Rural Unknown	23%	*27%*	21%	18%	11%	100.0%
Urban Principal Arterial - Interstate	*33%*	24%	20%	14%	9%	100.0%
Urban Principal Arterial - Other	*25%*	24%	22%	16%	13%	100.0%
Urban Principal Arterial	19%	20%	*23%*	21%	17%	100.0%
Urban Minor Arterial	20%	20%	*22%*	20%	18%	100.0%
Urban Collector	18%	19%	*24%*	21%	18%	100.0%
Urban Local Road or Street	*22%*	19%	22%	21%	17%	100.0%
Urban Unknown	*35%*	12%	21%	25%	7%	100.0%
Unknown	21%	*25%*	23%	17%	15%	100.0%
Route Signing						
Interstate	*32%*	26%	21%	13%	7%	100.0%
U.S. Highway	*24%*	21%	23%	18%	14%	100.0%
State Highway	*24%*	22%	23%	17%	14%	100.0%
County Road	*24%*	22%	21%	18%	14%	100.0%
Township	21%	20%	*22%*	20%	18%	100.0%
Municipality	20%	19%	*21%*	*21%*	18%	100.0%
Frontage Road	28%	*31%*	18%	10%	13%	100.0%
Other	*24%*	20%	22%	19%	14%	100.0%
Unknown	*23%*	23%	22%	15%	18%	100.0%
Roadway Alignment						
Straight	*23%*	21%	*23%*	18%	15%	100.0%
Curve	*29%*	24%	20%	16%	10%	100.0%
Unknown	*30%*	19%	19%	18%	13%	100.0%

Table B-7 Comparison of Driver, Roadway, Vehicle, and Environmental Characteristics of Five Subgroups of Older Drivers, continued.

Variable	*Age groups*					
Related to Junction	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs	Total
Interchange area						
Non-Junction	*30%*	24%	21%	15%	10%	100.0%
Intersection	18%	19%	*23%*	21%	18%	100.0%
Intersection Related	*23%*	22%	22%	19%	15%	100.0%
Driveway, Alley Access, etc.	16%	17%	*27%*	20%	19%	100.0%
Entrance/Exit Ramp Related	*23%*	37%	14%	14%	13%	100.0%
Rail Grade Crossing	19%	*25%*	21%	18%	16%	100.0%
Crossover-Related	18%	20%	*24%*	20%	17%	100.0%
Driveway Access Related	16%	17%	*24%*	23%	20%	100.0%
Unknown, Non-Interchange	20%	0%	*40%*	20%	20%	100.0%
Non-interchange area						
Intersection	*21%*	19%	*21%*	19%	19%	100.0%
Intersection Related	*25%*	19%	22%	23%	12%	100.0%
Driveway Access	14%	0%	18%	*46%*	21%	100.0%
Entrance/Exit Ramp Related	*26%*	21%	19%	19%	16%	100.0%
Crossover-Related	0%	10%	43%	*48%*	0%	100.0%
Other location in Interchange	*33%*	23%	23%	13%	9%	100.0%
Unknown, Interchange Area	*60%*	40%	0%	0%	0%	100.0%
Unknown	*50%*	21%	7%	14%	7%	100.0%
Related to Roadway						
On Roadway	*23%*	22%	*23%*	18%	14%	100.0%
Shoulder	*27%*	*27%*	20%	16%	11%	100.0%
Median	*33%*	27%	19%	14%	8%	100.0%
Roadside	*29%*	23%	22%	15%	11%	100.0%
Outside Trafficway/Outside Right-of-Way	*26%*	20%	20%	20%	14%	100.0%
Off Roadway – Location Unknown	*28%*	23%	20%	18%	12%	100.0%
In Parking Lane	22%	16%	12%	*26%*	24%	100.0%
Gore	*33%*	12%	28%	21%	7%	100.0%
Separator	24%	24%	*35%*	0%	18%	100.0%
Two-way Continuous Left-Turn Lane	*37%*	14%	29%	11%	9%	100.0%
Unknown	23%	8%	*38%*	0%	31%	100.0%
Construction Maintenance Zone						
None	*24%*	22%	22%	18%	14%	100.0%
Construction, Maintenance, Utility, Work Zone, and Unknown type	*29%*	24%	20%	16%	11%	100.0%

Table B-8 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers

Variable	***Age groups***				
Speed limit	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
No Statutory Limit	0.1%	0.1%	0.1%	0.1%	0.1%
10mph-25mph	1.9%	2.5%	2.9%	3.6%	3.8%
30mph-45mph	33.5%	35.5%	38.8%	43.9%	43.2%
50mph-65mph	*55.1%*	*52.8%*	*50.5%*	*45.6%*	*43.7%*
70mph-85mph	7.9%	7.5%	5.8%	4.8%	3.8%
Unknown Speed	1.5%	1.6%	1.8%	2.0%	2.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Rollover					
No Rollover	*85.1%*	*87.9%*	*90.4%*	*91.9%*	*92.2%*
First event	3.6%	2.9%	1.9%	1.4%	1.2%
Subsequent event	11.2%	9.2%	7.6%	6.8%	6.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Body type					
Automobiles	*50.5%*	*58.1%*	*67.0%*	*75.5%*	*79.3%*
SUV's	11.5%	8.5%	6.5%	5.7%	3.7%
Vans	9.5%	9.2%	8.4%	5.3%	4.5%
Pick up trucks	20.7%	17.6%	14.5%	12.2%	11.3%
Heavy trucks	4.6%	2.0%	0.6%	0.4%	0.0%
Recreational vehicles	0.4%	0.3%	0.2%	0.2%	0.0%
Others	7.2%	4.1%	2.5%	1.4%	1.2%
Unknown	0.2%	0.3%	0.3%	0.2%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Special Jurisdiction					
No Special Jurisdiction	*99%*	*99%*	*99%*	*100%*	*100%*
National Park Service	0%	0%	0%	0%	0%
Military	0%	0%	0%	0%	0%
Indian Reservation	0%	0%	0%	0%	0%
College/University Campus	0%	0%	0%	0%	0%
Other Federal Properties (since 1977)	0%	0%	0%	0%	0%
Other (since 1976)	0%	0%	0%	0%	0%
Unknown	1%	1%	1%	0%	0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-9 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	***Age groups***				
Vehicle Maneuver	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
Going Straight	*69.6%*	*70.0%*	*69.6%*	*68.0%*	*67.4%*
Slowing or Stopping in Traffic Lane	2.5%	1.5%	1.7%	1.3%	1.2%
Starting in Traffic Lane	1.0%	1.8%	2.0%	2.2%	2.8%
Stopped in Traffic Lane	5.3%	4.8%	4.9%	4.2%	3.9%
Passing or Overtaking Another Vehicle	1.6%	1.2%	1.3%	0.8%	0.7%
Leaving a Parked Position	0.0%	0.1%	0.1%	0.1%	0.1%
Parked	0.0%	0.0%	0.0%	0.0%	0.0%
Entering a Parked Position	0.0%	0.0%	0.0%	0.1%	0.1%
Maneuvering to Avoid	0.9%	0.9%	0.6%	0.7%	0.6%
Turning Right: Right Turn on Red Permitted	0.0%	0.0%	0.0%	0.1%	0.1%
Turning Right: Right Turn on Red Not Permitted	0.0%	0.0%	0.0%	0.0%	0.0%
Turning Right: Right Turn on Red Not Applicable or Not known if permitted	0.3%	0.5%	0.5%	0.8%	0.6%
Turning Left	6.5%	8.4%	10.3%	13.6%	15.2%
Making a U-Turn	0.5%	0.7%	0.6%	0.8%	0.8%
Backing Up (not parking)	0.2%	0.1%	0.3%	0.2%	0.3%
Changing Lanes or Merging	1.9%	1.5%	1.3%	1.0%	0.7%
Negotiating a Curve	9.1%	7.8%	6.4%	5.6%	4.8%
Other	0.4%	0.4%	0.3%	0.5%	0.5%
Unknown	0.2%	0.1%	0.2%	0.2%	0.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Impacts					
Non-collision	2.6%	2.1%	1.5%	1.1%	1.0%
Right front at 30 degrees	*52.5%*	*52.9%*	*52.3%*	*52.8%*	*52.5%*
Right front at 45 degrees	38.6%	39.3%	40.5%	41.0%	42.1%
Right center	6.1%	5.5%	5.6%	4.9%	4.4%
Left center	0.2%	0.2%	0.1%	0.3%	0.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Deformed					
None	0.6%	0.4%	0.4%	0.5%	0.6%
Other (Minor)	4.9%	4.8%	4.7%	4.4%	4.2%
Functional (Moderate)	12.0%	12.1%	13.4%	14.3%	15.0%
Disabling (Severe)	*81.9%*	*82.0%*	*80.7%*	*80.2%*	*79.2%*
Unknown	0.6%	0.7%	0.8%	0.6%	0.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-10 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	***Age groups***				
Travel Speed	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
Stopped Motor Vehicle In-Transport	4.8%	4.4%	4.5%	3.8%	3.4%
1 mph- 20 mph	21.3%	7.0%	7.9%	9.7%	10.3%
21 mph-30 mph	2.2%	2.5%	2.9%	3.2%	3.4%
31 mph - 40 mph	5.1%	5.3%	6.2%	5.9%	6.3%
41 mph- 50 mph	8.4%	9.4%	8.3%	8.1%	7.6%
51 mph- 60 mph	10.4%	9.9%	8.6%	7.8%	6.3%
61 mph- 70 mph	5.8%	4.8%	4.0%	3.5%	2.5%
71 mph- 80 mph	1.3%	1.1%	0.9%	0.7%	0.6%
81 mph- 90 mph	0.3%	0.3%	0.2%	0.1%	0.1%
91 mph- 96 mph	0.1%	0.1%	0.0%	0.0%	0.1%
Ninety-Seven MPH or Greater	0.2%	0.1%	0.2%	0.0%	0.1%
Not Reported	*37.8%*	*38.3%*	*38.3%*	*39.9%*	*40.4%*
Unknown	18.6%	17.0%	18.0%	17.2%	18.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Gross Vehicle Weight Rating					
Not Applicable	*92.4%*	*92.1%*	*91.8%*	*92.4%*	*92.8%*
10,000 lbs or less	0.0%	0.1%	0.0%	0.0%	0.0%
10,000 lbs-26,000 lbs	0.8%	1.1%	1.0%	1.0%	0.9%
26,000 lbs or more	6.7%	6.6%	7.1%	6.5%	6.1%
Unknown	0.1%	0.1%	0.1%	0.1%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Restraint Use					
None used	25.2%	23.6%	24.5%	23.1%	24.7%
Belt or helmet used	*68.7%*	*70.1%*	*69.4%*	*70.4%*	*69.1%*
Unknown	6.2%	6.3%	6.1%	6.5%	6.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Air Bag					
Deployed	*46.3%*	*46.1%*	*46.0%*	*44.6%*	*39.6%*
Not Deployed	28.0%	27.2%	27.1%	26.1%	24.6%
Not Available	24.5%	25.5%	24.9%	28.0%	32.0%
Unknown	1.2%	1.2%	1.9%	1.2%	1.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-11 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	***Age groups***				
Manner of collision	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
No Collision	19.3%	16.8%	15.1%	14.1%	12.7%
Front to rear	12.9%	12.1%	11.1%	8.5%	8.0%
Front to front	21.8%	20.8%	18.8%	15.1%	14.0%
Front to side	*40.4%*	*45.8%*	*50.7%*	*59.0%*	*62.1%*
Sideswipe	4.7%	4.1%	3.8%	3.0%	2.9%
Rear to side	0.2%	0.1%	0.2%	0.2%	0.1%
Rear to rear	0.0%	0.0%	0.0%	0.0%	0.0%
other	0.2%	0.1%	0.2%	0.1%	0.1%
Unknown	0.6%	0.1%	0.1%	0.1%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Registered Owner of the vehicle					
Not Applicable, Vehicle Not Registered	2%	1%	1%	2%	1%
Driver (of This Vehicle) Was Registered Owner	*66%*	*68%*	*71%*	*72%*	*73%*
Driver (of This Vehicle) Not Registered Owner (other private owner)	20%	18%	16%	16%	15%
Vehicle Registered as Business/Company/Government Vehicle	11%	10%	10%	9%	9%
Vehicle Registered as Rental Vehicle	1%	1%	1%	1%	0%
Vehicle Was Stolen (reported by police)	0%	0%	0%	0%	0%
Driverless Vehicle	0%	0%	0%	0%	0%
Unknown	1%	1%	1%	1%	1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Drinking					
No	*57%*	*59%*	*59%*	*61%*	*61%*
Yes	5%	3%	2%	1%	1%
Not reported	26%	25%	26%	27%	28%
Unknown	13%	12%	12%	10%	10%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Hospital					
No	37%	35%	32%	27%	25%
Yes	*61%*	*63%*	*67%*	*72%*	*74%*
Unknown	2%	2%	1%	1%	1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-12 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	***Age groups***				
Race	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
Whites	*42%*	*48%*	*52%*	*56%*	*62%*
African Americans	5%	4%	4%	3%	3%
Others	1%	1%	1%	1%	0%
Not Applicable	37%	32%	27%	22%	16%
Unknown	15%	15%	16%	18%	19%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Hispanic					
Yes	2%	2%	1%	2%	1%
No	*46%*	*50%*	*55%*	*57%*	*63%*
Not a fatality	37%	32%	27%	22%	16%
Unknown	15%	16%	17%	19%	20%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Number of drunk drivers					
0	*83%*	*88%*	*91%*	*93%*	*96%*
1	15%	11%	9%	6%	4%
2	1%	1%	1%	0%	0%
3	0%	0%	0%	0%	0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Died at Scene/En Route					
Not Applicable-0	*66%*	*67%*	*69%*	*74%*	*75%*
Died at scene-7	33%	31%	30%	25%	24%
Died En Route-8	1%	1%	1%	1%	1%
Unknown	1%	1%	1%	1%	1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Death Month					
April thru July	20%	22%	*24%*	25%	29%
August thru November	*21%*	*23%*	*24%*	*27%*	*28%*
December thru March	21%	22%	24%	25%	26%
No Record	37%	32%	27%	22%	16%
Unknown	1%	1%	1%	1%	1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-13 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	***Age groups***				
Light Condition	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
Daylight	*73%*	*79%*	*82%*	*84%*	*88%*
Dark	16%	11%	10%	8%	7%
Dark but Lighted	8%	6%	5%	5%	3%
Dawn	2%	1%	1%	1%	1%
Dusk	2%	2%	2%	2%	2%
Unknown	0%	0%	0%	0%	0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Day of the Week					
Sunday	12%	11%	11%	11%	10%
Monday	14%	15%	14%	14%	15%
Tuesday	14%	14%	15%	15%	15%
Wednesday	15%	14%	16%	15%	14%
Thursday	14%	*16%*	15%	16%	16%
Friday	*17%*	*16%*	*17%*	*18%*	*17%*
Saturday	14%	14%	13%	11%	13%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Fatal injury at work					
No	*50%*	*55%*	*60%*	*63%*	*70%*
Yes	1%	0%	1%	0%	0%
Not Applicable	37%	32%	27%	22%	16%
Unknown	12%	12%	13%	14%	15%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Route Signing					
Interstate	12%	11%	9%	7%	5%
U.S. Highway	23%	23%	24%	23%	23%
State Highway	*33%*	*34%*	*35%*	*33%*	*34%*
County Road	14%	14%	13%	14%	14%
Township	3%	3%	3%	4%	4%
Municipality	11%	11%	12%	15%	16%
Frontage Road	0%	0%	0%	0%	0%
Other	3%	2%	3%	3%	3%
Unknown	1%	1%	1%	1%	1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-14 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	***Age groups***				
Roadway Function Class	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
Rural Principal Arterial - Interstate	7%	6%	5%	4%	2%
Rural Principal Arterial - Other	*18%*	*17%*	*17%*	*16%*	*16%*
Rural Minor Arterial	14%	13%	14%	12%	11%
Rural Major Collector	13%	13%	12%	11%	10%
Rural Minor Collector	2%	3%	2%	2%	3%
Rural Local Road or Street	6%	6%	5%	5%	5%
Rural Unknown	0%	0%	0%	0%	0%
Urban Principal Arterial - Interstate	5%	4%	4%	3%	2%
Urban Principal Arterial - Other	3%	4%	3%	3%	3%
Urban Principal Arterial	13%	15%	17%	19%	20%
Urban Minor Arterial	9%	9%	10%	12%	13%
Urban Collector	2%	3%	3%	4%	4%
Urban Local Road or Street	5%	5%	6%	7%	7%
Urban Unknown	0%	0%	0%	0%	0%
Unknown	2%	2%	2%	2%	2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Related to Junction					
Interchange area					
Non-Junction	*60%*	*54%*	*46%*	*39%*	*34%*
Intersection	29%	35%	41%	47%	51%
Intersection Related	4%	4%	4%	4%	4%
Driveway, Alley Access, etc.	1%	2%	3%	3%	3%
Entrance/Exit Ramp Related	0%	0%	0%	0%	0%
Rail Grade Crossing	0%	1%	0%	0%	1%
Crossover-Related	0%	0%	0%	0%	0%
Driveway Access Related	2%	2%	3%	4%	4%
Unknown, Non-Interchange	0%	0%	0%	0%	0%
Non-interchange area					
Intersection	1%	1%	1%	1%	1%
Intersection Related	0%	0%	0%	0%	0%
Driveway Access	0%	0%	0%	0%	0%
Entrance/Exit Ramp Related	1%	0%	0%	1%	1%
Crossover-Related	0%	0%	0%	0%	0%
Other location in Interchange	1%	1%	1%	1%	1%
Unknown, Interchange Area	0%	0%	0%	0%	0%
Unknown	0%	0%	0%	0%	0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table B-15 Analysis of Driver, Vehicle, Environmental, and Roadway Characteristics of Each Age Group of Older Drivers, continued.

Variable	*Age groups*				
Related to Roadway	65-69yrs	70-74yrs	75-79 yrs	80-84 yrs	≥85 yrs
On Roadway	*82%*	*83%*	*85%*	*86%*	*87%*
Shoulder	3%	3%	2%	2%	2%
Median	2%	2%	1%	1%	1%
Roadside	9%	8%	8%	7%	7%
Outside Trafficway/Outside Right-of-Way	1%	1%	1%	1%	1%
Off Roadway – Location Unknown	3%	2%	2%	2%	2%
In Parking Lane	0%	0%	0%	0%	0%
Gore	0%	0%	0%	0%	0%
Separator	0%	0%	0%	0%	0%
Two-way Continuous Left-Turn Lane	0%	0%	0%	0%	0%
Unknown	0%	0%	0%	0%	0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Roadway Alignment					
Straight	*81%*	*83%*	*86%*	*86%*	*89%*
Curve	19%	17%	14%	14%	11%
Unknown	0%	0%	0%	0%	0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Construction Maintainance Zone					
None	*97%*	*97%*	*98%*	*98%*	*98%*
Construction, Maintainance, Utility, Work Zone, and Unknown type	3%	3%	2%	2%	2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
National Highway System					
Section not on highway system	*61%*	*62%*	*64%*	*68%*	*68%*
Section on highway system	37%	36%	34%	31%	30%
Unknown	2%	2%	2%	2%	2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix C - FARS Codes for Variables Used for Analysis

Table C-1 FARS Codes for Variables Used in Various Analyses

Variable	***Defined in FARS by***	***Code***
Automobiles	BODY_TYP	1-13
Fatal injury	INJ_SEV	4
Non-fatal injuries	INJ_SEV	01-03,05
Older drivers	AGE	≥65
Driver	PER_TYP	01
Front right passenger	PER_TYP	02
Motorists	PER_TYP	01,02,09
Non-motorists	PER_TYP	03-08,19
Daylight	LGT_COND	01
Dark	LGT_COND	02-05
Urban	ROAD_FNC	11-19
Rural	ROAD_FNC	01-09

Appendix D - SAS Code for Chi-Square Test

The data filtered for the number of older drivers fatally and non-fatally injured in fatal crashes during the five-year period 2003-2007 is used as the frequency in the data lines. This is a sample code for variable restraint use. Likewise, it was applied for 38 other variables to find the relation with the age of the driver.

```
roc format; value age 1='65-69' 2='70-74' 3='75-79' 4='80-84' 5='>=85';
data abhi; do restraint = 'none' , 'borh', 'unkn'; do agegrp= 1 to 5;
input n @@; output;
end; end; format agegrp age.;
datalines;
2662   2272         2405         1802         1519 7258   6741         6814
5539   4249 652     603    598    510    384
;
proc freq;
table restraint*agegrp/Chisq; weight n;
title "Chisquare test for restraint and agegroup";
run;
```

Appendix E - Fatality Distribution Based on States and Region

Table E-1 Fatalities for Population of All Ages and Elderly in the Northeast and South Regions During 2003-07

	Population of all ages	*Older population*
Northeast		
Maine	941	192
New Hampshire	720	121
Vermont	393	73
Massachusetts	2,227	416
Rhode Island	424	69
Connecticut	1,444	208
New York	7,206	1,483
Pennsylvania	7,699	1,424
New Jersey	3,700	691
Total	***24,754***	***4,677***
South		
Delaware	675	103
Maryland	3,172	448
District of Columbia	239	23
Virginia	4,802	764
West Virginia	2,019	305
North Carolina	7,894	1,194
South Carolina	5,211	648
Georgia	8,300	1,159
Florida	16,544	2,701
Kentucky	4,654	710
Tennessee	6,299	924
Mississippi	4,498	567
Alabama	5,606	701
Oklahoma	3,766	529
Texas	17,862	2,177
Arkansas	3,306	444
Louisiana	4,789	459
Total	***99,636***	***13,856***

Table E-2 Fatalities for Population of All Ages and Elderly in the West and Midwest Regions During 2003-07

	Population of all ages	***Older population***
West		
Idaho	1,347	225
Montana	1,282	289
Wyoming	844	79
Nevada	1,995	280
Utah	1,473	203
Colorado	3,004	355
Arizona	5,800	775
New Mexico	2,345	272
Alaska	429	41
Washington	3,012	443
Oregon	2,388	409
California	20,883	2,901
Hawaii	714	118
Total	***45,516***	***6,390***
Midwest		
Wisconsin	3,935	609
Michigan	5,744	1,008
Illinois	6,673	1,037
Indiana	4,515	652
Ohio	6,378	991
North Dakota	550	98
South Dakota	923	124
Nebraska	1,348	237
Kansas	2,240	374
Minnesota	2,779	478
Iowa	2,165	436
Missouri	5,707	747
Total	***42,957***	***6,791***