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Formulating Older Driver Licensing Policy: An Evaluation of Older Driver Crash History and Performance

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FORMULATING OLDER DRIVER LICENSING POLICY:
AN EVALUATION OF OLDER DRIVER CRASH HISTORY AND PERFORMANCE

A Dissertation Presented

by

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DEDICATION

For my father. Who instilled in me a great appreciation for the value of education. And who insisted that speed limits were maximum speeds and in no way a suggestion of what speed one should actually travel.

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ABSTRACT

FORMULATING OLDER DRIVER LICENSING POLICY:
AN EVALUATION OF OLDER DRIVER CRASH HISTORY AND PERFORMANCE

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This research sought to understand the relationship between licensing policy and the opportunity for the development of a scientifically-based approach to identifying high risk older drivers based on prior driving history. This research focused on five tasks: 1) review of the literature, 2) compilation of information on licensing policy for use by decision-makers, 3) assessment of charges and payer source for older driver crashes using linked crash and hospital data , and 4) the development and 5) validation of an older driver crash prediction model. There is relatively little available in the way of information for policymakers regarding licensing, and there is even less information available on evaluation of licensing practice effectiveness. Emergency department charges for older males were lower than females even though males accounted for a larger percentage of the injured population. Older drivers were no more likely to be covered by public insurance than the comparison group. Crash and citation data used to develop a driver history showed no differences between drivers in injury causing crashes and drivers in non-injury crashes. Logistic regression, Poisson regression, and negative binomial regression models were unable to effectively predict crash involvement based on driver history. This is likely due to self-selection bias for older drivers and truncated distribution of count variable (injury causing crashes). Recommendations resulting from this research include Massachusetts and national policy recommendations and additional research. Massachusetts should expand beyond its referral-based system for reviewing older drivers, consider restriction rather than only revocation, review medical advisory board practices, conduct evaluation of any policies it does implement, and conduct a thorough review of alternative transportation options. Nationally, efforts should focus on developing effective cognitive/functional testing by licensing agents, identification of effective second phase of testing, determination of a mechanism for determining when to retest, and assessment of the differences between older males and females for potential use in training, education, and testing. Research recommendations include continued exploration of the potential for systematic identification of high risk drivers using administrative data and in-depth analyses of the differences between males and females in terms of aging and driver safety.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAMVA: American Association of Motor Vehicle Administrators

AARP: American Association of Retired Persons

ADA: Americans with Disabilities Act

CODES: Crash Outcome Data Evaluation System

CDP: Comprehensive Driver Profile

DLPP: Driver Licensing Policy and Practice

EMS: Emergency Medical Services

FHWA: Federal Highway Administration

ICCD: Injury-Causing Crash Driver

IIHS: Insurance Institute for Highway Safety

JOL: Junior Operator Law

NHTSA: National Highway Traffic Safety Administration

MAB: Medical Advisory Board

OR: Odds Ratio

RMV: Registry of Motor Vehicles

ROC: Receiver Operating Characteristic

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, there has been increased attention paid to older drivers and their role in highway safety. High publicity crashes, increases in older driver fatality rates, and other similar factors have been the basis for policy revisions, educational campaigns, and additional research aimed at reducing the safety risks associated with older drivers. What is too-often absent from the dialogue around older drivers is the fact that unlike some other high-risk drivers, older drivers pose the greatest hazard to themselves (1).

Several studies have indicated that older drivers are not necessarily associated with higher crash rates. A 2006 study showed that if the use of miles driven is used as the exposure measure, older driver crash rates are higher than may actually be reasonable for use in comparison to drivers in other age groups (2). Another study published in 2003 indicates that older drivers are not necessarily overrepresented in terms of crash frequency. Instead, it is the fragility associated with an older person's physiology that contributes to the high rate of crash fatalities (3). The rate of non-driver deaths per 100 million miles in 1995 was similar for older road users when compared to adult road users and was lower than the rate for teen and young adult road users (1). However, the death rate per mile begins to increase for drivers age 60 to 64; for the 75 to 79 year old age group, the death rate for drivers is four times higher than the rate for drivers age 30 to 59 years old. More recent data show similar trends around the severity of older road user injuries. In 2004, five percent of people injured in crashes in the US were age 70 or over, however they represented 11 percent of all vehicle occupant fatalities (4).

The need for greater attention to older driver safety is supported not only by the issue of injury severity, but also by the growing population of older adults in the US. According to projection data from the US Census Bureau, in 2000 people age 65 or older accounted for 12 percent of the US population; by 2050, this figure will grow to 20 percent. The percent of the population that is 85 or older will quadruple during the same timeframe (5). The proportion of the driving population that is older is increasing as well. Between 1993 and 2003, the number of drivers age 70 or older increased 27 percent to 19.8 million (3). By 2030, drivers age 65 or older will account for 20 percent of licensed drivers, compared to 13 percent in 2004 (6).

Massachusetts injury severity trends for older vehicle occupants reflect those found at the national level. In 2004, the oldest vehicle occupants (85+) had a higher rate of fatalities per 100,000 population (8.4) than adult (25-64) or older (65-84) occupants (6.0 and 5.7 respectively). In addition when considering all injuries suffered by vehicle occupants, the percentage of injuries that are most severe (fatal or incapacitating) increases as age increases. For occupants age 25-64, 10 percent of injuries are fatal or incapacitating compared to 12 percent for occupants age 65-84 and 15 percent for occupants age 85+ (7).

Massachusetts population growth trends also reflect those of the nation as a whole. According to the US Census Bureau, in 2000, persons age 65 and older represented 13.5 percent of the total population; by 2030, this number will increase to 21 percent. This is slightly higher than the national percentages of 12 percent in 2000 and 20 percent in 2030. The population of Massachusetts residents age 65 or older is projected to increase 70 percent between 2000 and 2030, compared to an increase of only 10 percent for the general Massachusetts population over the same period of time (5).

Older people are becoming increasingly reliant on the use of private automobiles. Approximately 90 percent of all trips made by those over the age of 65 are by automobile; for people age 85 and older, 80 percent of trips are made by automobile (8). There have been a variety of efforts undertaken to improve safety for older drivers, (including design guidelines to be used in building older-driver-friendly roads, guidelines to help physicians assess and counsel older drivers, and cues for enforcement officers to use in determining the safe operational needs of older drivers) state licensing agencies are in the unique position of being able to develop policies that can improve older driver safety by limiting the exposure of older drivers to dangerous driving situations through revised license renewal procedures.

Reviews of licensing practices have been undertaken to some extent in several states and at the national level. However, policy issues associated with licensing practices for older drivers that are cost-effective, feasible, and non-discriminatory have made the implementation of older-driver specific licensing practices difficult. The development of a method for identifying high risk older drivers and implementing policy changes at the state level that would allow for the use of such methods in the licensing process would represent significant progress in the area of improving older driver safety.

1.2 Research Problem Statement

The development of licensing practices specifically aimed at improving older driver safety requires careful thought to ensure the methods are effective in identifying high risk older drivers and that the rights of older drivers are protected throughout the process. This careful balance between the practice and policy associated with revised older driver licensing programs points to the need for the development of a scientific method for identifying high risk older drivers and the implementation of policies that support the use of these scientific methods. Simultaneously, it is imperative to identify and support alternative means for maintaining a certain level of mobility for older drivers who no longer drive.

Older drivers have low rates of police-reported crash involvements per capita, but per mile traveled crash rates start increasing for drivers over 75 (3) and increase markedly after age 80 (9). Drivers over 65 are disproportionately involved in fatal crashes compared to police-reported crash rates (10). Because each driver loses skills and abilities at a different rate, some people are no longer safe drivers at 65 and others are competent well past age 85. While some older drivers self-limit their driving (i.e., dry conditions, daytime only, surface streets only) as their skills diminish (11), others fail to recognize their driving safety has waned. As the driving population is aging, jurisdictions are struggling to find ways to re-assess older driver competency in an equitable and cost effective manner that successfully preserves safety on the roadways. Thus far, only in-person license renewal for those over 85 has been related to a reduced fatality rate; vision testing, other in-person renewal, (12) and on road re-testing has failed to significantly decrease the risk of fatality (13).

Crash prediction modeling is a logical mechanism for identifying high-risk older drivers. In order to address roadway safety, the unit of inquiry should be the risk of an injury causing crash. Evidence of recent driving performance such as citation and crash data should be considered as potential variables for model development. Reliably identifying a group of high risk drivers would allow re-screening or re-testing based on objective data – recent driver performance – rather than on age or medical conditions alone. This inherently makes targeting a subgroup of drivers more politically palatable since they have demonstrated their risk. In addition, the factors contributing the greatest weight to the model will likely identify potential areas for focused retraining.

1.3 Research Hypotheses

The research hypotheses consider the ability to develop a scientifically-based approach for identifying high risk older drivers and for implementing policies and licensing procedures that use this type of information to improve older driver safety. The ultimate goal of this research is to provide quantitative support and qualitative review that can be applied to policy initiatives associated with improving older driver safety. There are five hypotheses associated with this research; these hypotheses and background information for each are included in this section.

1. *An improved method for sharing information on older driver licensing practices at the state level can be identified to improve policy and program decision making.*

2. *Older drivers who are involved in injury crashes exhibit risky driving behaviors prior to becoming older drivers.*

3. *Charges associated with treating the injuries of these older vehicle occupants (drivers and passengers) are higher than charges associated with treating injuries for non-older occupants of vehicles involved in the same crash. Additionally, treatment for these injuries are more likely to be charged to public insurers placing the fiscal burden for older vehicle occupant on society in general.*

4. *Statewide crash, driver licensing, and citation datasets can be used to derive and validate a crash prediction model that will identify a subgroup of older drivers at high risk for a near term injury causing crash.*

5. *State level legislation regarding the licensing process can be modified to allow for the use of an effective crash prediction model for identifying high risk older drivers in a manner that is not considered blanket discrimination towards all older drivers.*

The following sections provide relevant background information regarding the development of the five proposed research hypotheses.

1.3.1 Research Hypothesis 1

An improved method for sharing information on older driver licensing practices at the state level can be identified to improve policy and program decision making.

Licensing practices and the provision of alternative means of transportation for older persons is the responsibility of each individual state. As such, it may be difficult to identify and understand not only what states may have implemented special licensing or alternative transportation programs aimed at improving older driver safety, but also which have been successful and what challenges have been presented during the course of implementation. The Insurance Institute for Highway Safety provides an overview of licensing practices for older drivers in each state. However, information on the policy hurdles associated with implementing these practices and the perceived success of these practices at the state level are not included in this overview. There exists a need for state-level policy makers to have additional information available to them to help them understand not only what practices exist but how they were implemented and how effective they have been.

1.3.2 Research Hypothesis 2

Older drivers who are involved in injury crashes exhibit risky driving behaviors prior to becoming older drivers.

Existing research indicates that drivers involved in crashes do so repeatedly. Studies have shown that while some crashes may be "accidents", drivers who are in more than one crash tend to be "accident-prone" with their involvement in a crash being associated with a human factor. To date, this research has considered repeated involvement in crashes from both the general involvement and culpability perspectives (14). However, these studies have not looked specifically at correlations between repeated crash involvement and risky driving behavior specifically for older drivers. The aging process impacts the physical (vision, mobility) and cognitive abilities required to effectively drive, potentially compounding how "accident prone" a driver who exhibits risky driving behavior prior to age 65 becomes as they get older.

1.3.3 Research Hypothesis 3

Charges associated with treating the injuries of these older vehicle occupants (drivers and passengers) are higher than charges associated with treating injuries for non-older occupants of vehicles involved in the same crash. Additionally, treatment for these injuries are more likely to be charged to public insurers placing the fiscal burden for older vehicle occupant on society in general.

Older persons involved in motor vehicle crashes are more likely to sustain injuries due to their fragility (1). As important as this information is, it may be difficult to quantify in terms that are practical for policy and program initiatives. However, the use of hospital charges associated with the treatment of provides the opportunity to understand how the more serious injuries sustained by older road users translate into more costly hospital treatment. This is especially important since a larger percentage of older persons are likely to be covered by some type of publicly funded insurance program. It is necessary to understand the charges associated with crash injuries sustained by older drivers as well as the payer source for treatment to quantify not only the impact of injuries on the older person but on society at large.

1.3.4 Research Hypothesis 4

Statewide crash, driver licensing, and citation datasets can be used to derive and validate a crash prediction model that will identify a subgroup of older drivers at high risk for a near term injury causing crash.

Crash prediction modeling has been effectively used in a variety of highway safety capacities. It has been used to predict crashes at rural intersections (15) and to identify high risk drivers based on prior involvement in crashes, prior citations, etc (14). When considering older drivers, crash prediction models have been used to understand the influence of certain medical treatments (drugs) and reduced physical and cognitive capacities on crash involvement. However, there has not yet been a crash prediction model that can be used by state licensing agencies to identify high risk older in an effort to address these drivers prior to their involvement in an injury crash as they age. The ability to identify high risk older drivers prior to their involvement in an injury causing crash could provide the foundation for the development of revised licensing procedures, educational programs, and the provision of alternative modes of transport for older drivers who pose a significant risk.

1.3.5 Research Hypothesis 5

State level legislation regarding the licensing process can be modified to allow for the use of an effective crash prediction model for identifying high risk older drivers in a manner that is not considered blanket discrimination towards all older drivers.

Using the crash prediction model developed during the research associated with hypotheses 2 and 4, recommendations can be made for revisions to state level legislation regarding older driver licensing. Using Massachusetts as an example, opportunities to apply scientifically established crash prediction models to state policy can initiate change not only in Massachusetts, but serve as a resource for other states seeking to revise existing older driver licensing practices.

1.4 Research Objectives

The objective of the proposed research was achieved by evaluating the five identified research hypotheses associated with implementation of older driver licensing policies and the development of an older driver crash prediction model. The overall objective was achieved by providing quantitative and/or qualitative responses to evaluate each hypothesis.

1.5 Scope

The intent of the proposed research was to address to the specific research hypotheses previously stated. As a result, other potential means or measures associated with improving older driver safety was not considered. This research focused on initiatives and applications at the state level rather than those that might be implemented at the national level. Additionally, this research does not consider older pedestrians in the injury or crash prediction model, but focuses on older vehicle occupants, specifically older drivers.

1.6 Organization of Dissertation

This dissertation is comprised of eight chapters. The first chapter provides background information on older driver safety and presents the research questions to be examined. The second chapter provides a review of the literature regarding older driver safety, licensing policy, and the use of crash prediction models in highway safety efforts. The third chapter outlines the research methodologies employed. The fourth through seventh chapters include the results associated with the work conducted. The final chapter presents the conclusions and recommendations resulting from the comprehensive research effort.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 General Information

Older driver safety is becoming an issue of increasing importance and relevance as the aging population in the United States grows. According to 2000 US Census data, approximately 35 million people age 65 or older were living in the United States. Members of the baby boom generation (those born between 1946 and 1964) will turn 65 beginning in 2011 and the number of these older persons living in the United States is expected to double by the year 2030 (16). An increase in older persons translates to an increase in older drivers. Currently, approximately 50 percent of women and 80 percent of men age 85 or older still drive (17). The increase in the number of older drivers, coupled with increased fragility as one ages, has drawn the attention of transportation safety professionals worldwide to the issue of older drivers and how best to address their safety while accounting for the mobility needs inherent to an older person's general well-being.

Efforts aimed at improving older driver safety include initiatives instituted at the policy and program level, as well as by older drivers themselves. This background section will outline the physical limitations associated with older drivers that impact their ability to drive, discuss some of the self-regulating behaviors used by older drivers, and will provide an overview of both program and policy based efforts. Finally, the background section will discuss the use of crash prediction modeling for other areas of highway safety with a focus on how it can be applied to older driver safety.

2.2 Physical Limitations

The act of driving requires several skill sets including visual, cognitive and physical abilities (18). Impairments in these skills as one ages, coupled with the impact of medical conditions and related medication on driving abilities, have the potential to greatly affect safety and performance in older drivers.

Vision is the sense that is most critical to driving tasks, regardless of age (17). Approximately 90 percent of the information needed to drive is related to the ability to see clearly. Visual acuity may be the visual measure most often considered in relation to driving. It is the test most commonly used during the licensing process and research conducted by Burg in the 1960s, and reconsidered in the 1970s by Hills and Burg has shown that there is an association between visual acuity and crash rates for older drivers (18). Though this relationship is acknowledged, they also noted that though statistically significant, the magnitude was low; a link between poor visual acuity as a causal factor in crashes could not be established based on this work and visual acuity should not be identified as a good test for identifying high risk older drivers. Specifically, dynamic visual acuity plays a role in the relationship between vision and driving. Dynamic visual acuity is the ability to see a moving object, especially in conditions with limited light such as dawn, dusk, or fog. Dynamic visual acuity is reduced by age (17).

Although visual acuity is the test most commonly used during the licensing process, there is relatively little literature to support the concept that acuity tests can identify high-risk drivers; there are several explanations for why this may be the case (18). First, letter-acuity tests were designed for clinical diagnosis of eye disease but not to be used during the evaluation of complex tasks such as driving. Severe visual acuity impairment is likely to have an impact on the ability of a driver to safely maneuver a vehicle. However, other visual impairments are likely to impact one's ability to drive and acuity tests would fail to identify those impairments, especially in the presence of satisfactory acuity (18). Another explanation for the lack of literature supporting the relationship between visual acuity and accident rates is that many drivers with poor visual acuity are not able to obtain licenses and are therefore not "eligible" to be involved in crashes. This limits the amount of information that can be collected on the relationship between acuity and crash involvement. In states where vision re-screening is not required, there is the opportunity to collect this information, though drivers with severe acuity impairment (such as older drivers) are more likely to voluntarily surrender their license or limit their driving to less risky, more familiar situations. This would, again, limit the opportunity to effectively tie impaired visual acuity to crash involvement (18).

Other visual issues that have been considered in relationship to driving are field of vision, contrast sensitivity, and color discrimination. Field of vision is the total area that one can see and respond to (17). As one ages, the field of vision decreases and peripheral vision is lost creating what is commonly referred to as "tunnel vision". Several studies have shown that there is a relationship between loss of peripheral vision and crash and violation rates. However, many other studies were unable to identify a link between visual field impairments and higher crash rates. In studies conducted on closed courses or in a driving simulator, researchers found that visual field impairment impacts some aspects of driving such as the ability to read road signs or identify obstacles, but not others such as speed or stopping distance. These findings may be difficult to correlate to real-world driving tasks since these environments tend to be less complex than actual driving and do not allow for the observation of critical situations such as crashes. Several real-world studies showed that drivers with visual field impairments were not more likely to be prone to driving performance problems (18).

Studies examining contrast sensitivity, a visual impairment tied to the presence of cataracts which are common in older persons, are less prevalent than those considering acuity or visual field (18). Contrast sensitivity is the ability to discern between two similarly colored objects which can affect the ability to judge distance or identify objects (17). Several studies have shown a relationship between contrast sensitivity and crash rates; the limited availability of research in this field and the findings to date indicate the need for additional study in this area (18).

Color discrimination is tested in both personal and commercial licensing practices, not so much as a measure for potential crash involvement but to determine whether the driver can obey color-based traffic signals. Color discrimination has been found to be less important since the information that may be gathered through color can often be accrued using other means such as luminance, position, and pattern. As such, it can be reasonably assumed that color discrimination is not a significant challenge for older drivers (18).

Other visual impairments that have been raised as potential areas for consideration in older driver safety research include glare and eye-movement disorders. These, however, have not been addressed in the literature to the same extent that others have (18).

The above visual-sensory impairments are not the only relationship between vision and safe driving. There are visual-cognitive tasks that are also important to consider. In the late 1980s, the Useful Field of View Test was developed to examine the visual field area where information that is rapidly presented is used. This test, unlike other measures of visual field, included higher-order processing such as selective and divided attention, and rapid visual-processing speed (18). Several research studies have found relations between impairment identified using this test and increased crash rates. This test has also been found to effectively identify high-risk older drivers suffering from Alzheimer's disease. Generally, the strength of the relationship between visual-cognitive impairment and crash rates is stronger than the relationship between crash involvement and visual-sensory function alone (18).

Dementia, which results in a decrease in cognitive understanding, is not a "normal" part of aging but can have a significant impact on safe driving behaviors (17). Dementia is a progressive, incurable disease which was first linked to driver safety issues by Waller in 1967, and subsequently specifically studied by Johns Hopkins University researchers in 1988 and others later (19). Several studies have shown that older drivers with cognitive impairments, regardless of the cause, are at least twice as likely to be involved in a crash (18). Some of the specific challenges associated with cognitive impairment and safe driving are centered around attention problems, visual search impairment, and spatial memory (18). Interestingly, while older drivers with Alzheimer's disease had a slightly higher crash rate than older drivers without it, the crash rate for older drivers with Alzheimer's disease is within the range of what is deemed acceptable for other age groups, especially young drivers (18). As a result, it is important to consider not only the impact of cognitive impairment on older drivers in relation to themselves, but also in relation to the driving population as a whole; are they any more dangerous on the road than other drivers? The existing body of research has resulted in varying positions on the relationship between cognitive impairment in older drivers and driver safety as a general public health issue, pointing to the need for continued monitoring at the individual level by licensing agencies, clinicians, and others (19).

In addition to being able to see and understand the driving environment, safe driving requires the physical ability to maneuver and control the vehicle. Specifically, some of the important physical skills associated with driving are coordination, range of motion (head, neck, arms, legs, etc), balance, and gait. There has been relatively little research done on the relationship between physical function and safety for older drivers. For example, there is almost no information on minimum levels of physical performance needed for driving safely. There are many new vehicles with controls that are aimed at meeting the needs of drivers with varying degrees of physical ability (18), as well as assistive devices that may be added to vehicles to address some of the issues raised by physical impairment (17).

2.3 Older Driving Self-Monitoring

In many cases, the first line of activity in safety for older drivers is older drivers themselves. A survey conducted in 1999 by the Insurance Research Council found that 77 percent of people age 70 and older who were surveyed supported annual vision tests. Other provisions supported by older drivers surveyed included training programs for older drivers and mandatory annual physicals (20). Older drivers have been known to employ adaptive strategies – both conscious and unconscious – in response to declining function and existing mobility needs (21).

The adaptive strategies employed by older drivers may be categorized into three areas: 1) strategic behaviors, 2) tactical behaviors, and 3) operational behaviors. Strategic behaviors are considered knowledge-based behaviors and include decision-making such as whether to drive in the rain. These decisions are generally made over time, not on an instant basis. The best strategic adaptation to be made by an older driver would be to live someplace where there is the greatest diversity of mode choice. Living in a city would increase the availability of means of transportation, reducing the impact on mobility associated with aging and driver safety. Older drivers, however, do not generally make this decision. Research has shown that people tend to choose to age in the same areas they lived for most of their lives; as populations tend to move towards the suburbs, this trend is evident in the aging population as well (21). The primary strategic adaptation employed by older drivers is to limit driving exposure. It is common to find that with an increase in age comes a decrease in driving exposure. An Australian study found that approximately one-third of the older drivers they surveyed drove less than they did five years prior to the survey (22). Older drivers are not only likely to reduce their overall driving, but are even more likely to limit their exposure to high-risk driving situations such as driving in the in the winter, during the rain, during high traffic (peak hour) conditions, and at night (21). Additionally, older drivers indicated that they avoid certain types of roads such as highways and those in urban areas.

In addition to general strategic adaptation by older drivers, those who have visual or attention impairments were even more likely to report avoidance than those without similar impairments. It is interesting to note, though, that those with cognitive impairments did not report the same level of avoidance as those with visual or attention impairments. This may be due to the lack of insight regarding their own behavior. Additionally, those drivers with crashes within the five years prior were more likely to report avoidance behaviors than those with clean records indicating that the crash may have triggered these avoidance tactics (21).

The Australian study found that the following characteristics were associated with a driver age 65 or older who avoided any specific driving situation: age 75 or older, female, drivers who were not confident with their driving skills, drivers who rated their health as less than excellent (good/fair/poor) (22).

The most extreme case of avoidance is the surrendering of the driver license. A Finnish study of drivers who did not renew their licenses indicated that less than seven percent did so as the result of professional advice. Men were more likely to continue driving until health prevented it, while women were more likely to give up their licenses as a result of the stress associated with driving (23).

Tactical adaptations that may be employed by older drivers include driving more slowly and allowing larger gaps when following other vehicles. Wasielewski and Evans studied this in two separate studies (24, 25). The results of this research indicated that drivers age 50 and older adopted mean headways that were 15 percent longer than drivers age 20 and older, as well as a decline in mean speed with increase in age. On average, drivers age 75 traveled 6.5km/hr slower than 20 year old drivers.

Intersections present another opportunity for older drivers to employ tactical adaptations. Several studies, including one by Staplin, have shown that older drivers are less able to judge closing speed for approaching vehicles in an intersection and therefore rely largely on distance judgment. This puts them at a greater risk when dealing with vehicles that are moving more quickly than the rest of the traffic stream (26). As a result, older drivers lengthened the gap they were willing to accept to complete a left-turn maneuver. In some cases, adaptive tactical behaviors are not necessarily suitable given the situation. The same research study conducted by Staplin indicated that older women were less likely to pull into an intersection to improve the view around opposing traffic prior to completing a left turn. Their lack of willingness to pull into the intersection not only put them at a disadvantage in terms of view, but also lengthened the time required to complete the turning movement.

Operational adaptations are far less common among older drivers, probably because they are unable to make these adaptations (21). In both simulator and on-road experiments, older drivers performed more poorly than younger or adult drivers when asked to complete a specific task. Though many studies found that older drivers responded poorly compared to younger or adult drivers, one study by Hakamies-Blomqvist et al. found that older drivers were likely to use three controls (ex. steering, clutch, accelerator, and brake) simultaneously, while the middle age drivers were more likely to use four or more (27). Generally speaking, the tasks that require operational adaptation often require rapid response and do not allow the older drivers the time they need to adapt appropriately.

2.4 Older Driver Safety and Policy

Adaptation by older drivers is one method for addressing some of the safety issues faced by older drivers. However, in some cases adaptation may be counterproductive, and relying on the older driver to be able to assess potential challenges and respond effectively in all cases is unreasonable. As such, efforts have been made at several levels to provide guidance and a more systematic method for improving older driver safety while maintaining mobility.

A 2002 draft of *Safe Mobility for a Maturing Society: a National Agenda* was published as part of the 2004 conference proceedings for Transportation in an Aging Society: A Decade of Experience. This draft agenda, which was developed based on information gathered through a series of regional forums, focus groups, conferences, and stakeholder roundtables, has as its organizing tenet "to enable safe driving as late in life as possible and to offer other convenient transportation options when walking and driving are not feasible" (28). This agenda focuses on seven areas where professionals should focus efforts to provide safe transportation for the aging population:

- Develop state and local safe-mobility action plans;
- Promote safer, easier-to-use roadways;
- Create safer, easier-to-use automobiles;
- Improve older driver competency;
- Promote better, easier-to-use public transportation services;
- Better public information; and
- Basic and social research needs.

These focus areas include elements of design, policy, and program initiatives. This background section will focus on policy initiatives, specifically around licensing.

Transportation policy regarding older persons' safe mobility is an interdisciplinary issue that is based on the relationships between transportation professionals, public safety and human service providers, interest groups, and others (29).

The competing issues presented mirror some of the issues identified as part of the National Agenda. These include improved older driver licensing and testing methods, development of safer vehicles, practical transit systems, paratransit opportunities, and communities that promote aging in place (29). The nature of the issues facing those working towards safer mobility for older drivers implies the inherent involvement of government at either the state or Federal level. However, competing priorities such as health care or education have limited the sustained attention received by the issue of older driver safety. Older driver safety programs and policy have been largely marked by incremental support offered by individual agencies rather than a comprehensive government-wide approach.

There are four pieces of key legislation related to older drivers that have defined access as a right, funded services and infrastructure improvement, and promoted research. The Americans with Disabilities Act of 1990 (ADA) served to redefine access to transportation as a civil right, requiring access to key bus and rail routes for persons with disabilities (29). The relationship between access for older persons and access for disabled persons can be seen as there is a relative growth in disability as a person ages. The Intermodal Surface Transportation Equity Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21) funds national surface transportation efforts. Each of these two pieces of legislation provided funding for research on driver safety, intelligent transportation systems (ITS), and transit resources. In ISTEA, Section 5310 specifically provided funding for private, nonprofit organizations or public agencies that coordinate transportation for older persons. The Older Americans Act (OAA) reauthorization of 1992 identified transportation as a priority service that is critical to the well-being of older people; however most of the transportation funding in this act was related to the transportation needs associated with other programs such as nutrition and health. Funds spent through related programs are significant transportation investments but address mobility needs rather than services that are associated with the experiences of the healthy aging (such as social trips) (29). Although there are a variety of policy efforts that address some aspect of older driver safety and mobility, the remainder of this background policy section will focus on licensing practices. Focusing on licensing does not indicate the need to review only licensing policies but also alternative transportation that addresses the needs of older persons who may no longer be "fit to drive".

A document prepared by the Insurance Institute for Highway Safety outlines the license renewal procedures for older drivers in all 50 states as well as the District of Columbia (30). In most cases, the renewal process includes a review of the driving record to ensure there are no suspensions/revocations, appearance in person, passing a vision test, and payment of a fee. In 26 states and the District of Columbia, in addition to the requirements for drivers of any age regarding physical and mental capacity, older drivers are governed by a shorter renewal cycle, the requirement to pass additional tests not required of other drivers (vision or road tests), and/or appearance in person rather than renewal by mail or electronically. In cases where the person's ability to drive is in doubt, clinicians, police, and others can notify the licensing agency that may then refer the case to a medical review board. This review board considers individuals on a case by case basis and may recommend retaking standard licensing tests (written, road, or vision), or may require physical or mental examination. Following review of the person's fitness to drive, the agency may choose to renew the license, refuse renewal, suspend, revoke, or restrict the license. Restriction might include nighttime driving, requiring additional mirrors on the vehicle, or restriction to driving in specified places (such as within a certain radius of the drivers home). In states where the renewal cycle is not shorter for older drivers, agencies have the authority to reduce the renewal cycle for individual cases where they feel it is warranted. The success of these measures in identifying hazardous drivers has been difficult to document. Studies have shown mixed results, and there is question about the effectiveness of license restrictions on limiting unsafe driving (29).

In Massachusetts, the standard renewal cycle length is five years. It is the same for older drivers and there are no additional safety provisions for older drivers. This is due to state licensing laws that specifically prohibit treating people differently based solely on advanced age (30).

If policy initiatives are going to consider licensing practices that may limit older persons' mobility through the use of personal vehicles, there must also be consideration regarding how to provide supplemental transportation. There is increased attention being paid to the issue of maintaining mobility while implementing licensing restriction policies. In New Hampshire, the State's Transportation Safety Task Force review of a proposed graduated delicensing for older drivers noted that New Hampshire has almost no public transportation to supplement travel by personal vehicle (31). There has been some work by the Federal Transit Administration (FTA) to provide public transit through their Nonurbanized Area Formula Program, though these efforts tend to be underfunded (29). In Metropolitan areas, federal program funds have been allocated to improving fixed routes and providing transportation to health-related trips, nutritional support, and other necessities.

Paratransit and other door-to-door services continue to exist in a format where demand far exceeds supply. Challenges with door-to-door services include cost, quality, and availability. Combined funds from the Department of Health and Human Services and Department of Transportation represent a significant contribution to non-fixed-route transit. However, car and van services that run below capacity do no optimize time and vehicle productivity and providing trips for the range of demands can be beyond the technological and personnel resources available (29).

Another option for providing alternative transportation is considering walking and community design. Community layout and connectivity by walkways can be challenging to consider from a policy perspective since it is greatly governed at the local level by zoning, permit processes, and local history (29). Massachusetts has a program that has been highlighted as a strategy for making pedestrian movement safer. The Boston Indicators Project selected transportation as a critical element for a livable community and developed performance measures that would improve the walking experience of Boston residents. Rapid growth in many suburban areas has led to diminishing sidewalk and open space.

2.5 Assessments and Predictors for High Risk Older Drivers

To focus programs and policy where they are likely to be most effective, efforts have been made to develop systems for identifying high-risk older drivers. Many of the attributes that may make older persons high risk drivers are often associated with the physical impairments associated with aging. The focus on medical and physical indicators may also be common because there is some opportunity for intervention by individuals involved in their care (physicians or family) or by the licensing agency (vision tests). A fair amount of research has been conducted regarding efforts to use medical and physical assessment to identify high risk older drivers.

Eby, Molnar, Shope, and Dellinger worked to develop and pilot test an assessment battery for older drivers. They sought to develop a battery of tests that could be administered easily and inexpensively for use in longitudinal studies (32). The goal of this work was not to assess crash risk associated with the areas being assessed but rather to provide a mechanism for measuring several aspects of health and driving behaviors that would be easy and inexpensive to administer. The tests evaluated in the battery included tests of sensitivity, visual acuity, walking ability, reach, clock reading, ruler drop, hand strength, stereoacuity test, motor free visual perception, mental state exam, three questionnaires on driving, health and demographics, as well as several others. The battery took, on average, less than one hour to complete and was well-received by participants and test-administrators alike. Although this assessment battery was inexpensive, transportable, and provided acceptable results from a data collection perspective, it is important to note that it is designed specifically for data collection in a longitudinal study rather than crash risk assessment as part of the licensing process.

In research similar to that conducted by Eby et al., a Canadian study examined the acceptability of components of a clinical assessment battery that might predict involvement in a motor vehicle crash that could be used in a clinical setting (33). The study was conducted by study nurses in the homes of 10 patients who had sought emergency department treatment. Patients underwent a 90 minute assessment that could be used in front-line clinical settings rather than in the patient's home. The tests used for this assessment included the Older American Resources and Services questionnaire to understand pre-crash daily living activities, Timed Up and Go balance and mobility test, the Geriatric Depression Scale score, Mini-mental State Examination, Clock Drawing Test, a visual acuity test, a hearing test, as well as several other tests. Several new tests were developed to assess peripheral vision, neck rotation, rapid foot movement, and reaction time. Since the research was conducted as a pilot study and the sample size was small, no definitive conclusions could be reached. However, patients generally found the tests acceptable to participate in and several of the tests warranted further consideration to be used as mechanisms for identifying older drivers likely to be involved in a crash. Specifically, tests of physical examination measures, such as the Timed Toe Tap, Neck Rotation, and Coin-Catch Reaction Time tests could be linked to the ability to measure fitness to drive. The Mini-mental State Examination, Driving Habits Questionnaire, and dementia questionnaire also provided valuable information for further consideration.

Another study sought to examine the relationship between medical contacts and crash risk (34). This study used logistic regression analysis to determine the odds ratios for involvement in a crash based on medical contact within the month prior to the crash. Results showed a weak but statistically significant increased risk of collisions being associated with this medical contact (OR=1.10, 95% CI 1.08 to 1.11).

Researchers are not the only transportation professionals who are documenting the relationship between physical ability and crash risk for older drivers. In July, 2005, the National Highway Traffic Safety Administration (NHTSA) published *Strategies for*

Medical Advisory Boards (MABs) and Licensing Review to document the medical review practices of 51 driver licensing agencies in the United States and to develop strategies for addressing drivers with medical conditions and functional impairments (35). Some of the recommendations made in this report included the following:

- Use of Medical Advisory Boards (MABs) for fitness to drive determinations as well as appeals for licenses already denied;
- Use of MAB guidelines to achieve some level of consistency with review on a case-by-case basis;
- Requirement of older drivers to appear in person to renew with a shortened renewal cycle for older persons;
- Education of police officers in identifying at-risk drivers with medical conditions or functional impairments;
- Implementation of functional screenings at license renewal for drivers over a specified age;
- Use of restrictions that allow drivers to maintain some driving privileges in safe conditions; and
- Recognition of the importance of licensing agencies not only in ensuring public safety but also supporting safe mobility of drivers with functional impairments or medical conditions.

2.6 Crash Prediction Modeling

To date, a great deal of the efforts focused on improving older driver safety through the licensing practice have been centered around assessment of fitness to drive, physical impairment, and medical conditions. There is, however, the opportunity to consider older driver crash risk in relation to prior driving history. Crash prediction modeling has been used to identify high-risk drivers and driving environments, though it has not been directly applied to older drivers in terms of driver history.

Crash prediction modeling has been widely applied to efforts to better understand two lane rural highways. Landge, Parida, and Jain found that negative binomial regression modeling was most effective in understanding the relationships between fatality rate and volume, intersection density, and shoulder width on Indian two lane rural roads (36). Their models also indicated that the use of road signs were effective in improving overall safety. They concluded that the models they developed could be used in the field to predict the probability of a certain number of crashes in areas with similar geometric design characteristics.

The Federal Highway Administration (FHWA) has published several reports based on the use of accident prediction models. In one case, an algorithm that used base models developed using Poisson and negative binomial modeling (37) were modified with accident modification factors (38). The base model provided a prediction of safety performance for a road or intersection for a base set of conditions that are then adjusted using accident modification factors that account for the effects of lane width, shoulder width, shoulder type, horizontal curves, grades, driveway density, left turn lanes, passing lanes, and roadside design as well as other design elements. The final algorithm includes a calibration process that allows it to be adapted to meet the needs and circumstances of various highway organizations. Additionally, the algorithm includes a method for employing Empirical Bayes analysis to combine the algorithm with actual site-specific crash history information for the areas being considered. In related work, similar methods were employed to validate and calibrate an algorithm for crash prediction at five types of rural intersections, for ultimate use in the Interactive Highway Safety Design Module (39).

Crash prediction modeling has not been used only to attempt to predict crash rates based on roadway environment. Kentucky driver history data were used to develop a crash prediction model that identified high risk drivers based on previous driving behaviors (40). This study used multiple logistic regression to consider as crash predictors total number of previous crashes (at-fault and not-at-fault), citations, time gap between the most recent two crashes, crash type, and demographic factors. The factors deemed most highly associated with future crash involvement were number of previous at-fault crash involvements and having previous license suspensions. This study found that very young and very old male drivers with both speeding and non-speeding citations were most likely to be at fault in a crash.

Crash prediction modeling has also been used to examine older driver safety issues, though the focus was on medical issues and impairment rather than driver history (41). This research found that factors associated with an older drivers probability of being involved in a crash were demographic attributes, limitations in performing physical activities, chronic conditions, physical features, psychosocial characteristics, symptoms, drug use, and other health related factors. The risk factors that were identified for women were different than those identified for men. For female drivers, significant odds ratios (>1.0) indicating an increased risk of crash involvement were found for annual miles driven (odds ratio increases as annual miles driven increases) and difficulty extending arms. Male drivers had significant odds ratios (>1.0) for annual miles driven, living alone, being employed, history of glaucoma, low score on word-recall tests, and taking antidepressants.

The success of newer crash prediction model methods such as negative binomial modeling to understand crash risk based on roadway environment, coupled with the success of other methods in identify high risk drivers based on history, and high risk older drivers based on impairment and medical conditions indicate that there is a prime opportunity to use crash prediction modeling to examine older driver safety, with a special focus on the development of a model that can be applied at the state level for licensing purposes.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

A series of tasks was developed to successfully meet all of the research objectives and evaluate each of the developed hypotheses. Evaluating each of the five defined hypotheses constitutes a majority of the project tasks and each consists of multiple subtasks.

3.1 Task 1: Review of the Literature

A comprehensive literature review was conducted as the first task of this research project. The completed literature review ensures that existing research has been discussed and that the relevance of the research conducted is clearly outlined.

3.2 Task 2: Compilation of Resources for State-Level Decision Makers Regarding Older Driver Policies

Using the existing Insurance Institute for Highway Safety overview of older driver policies in each state as a guideline, this task seeks to provide additional information that may be used by policy makers in understanding what policies exist regarding older driver licensing and what challenges may be associated with developing and implementing licensing policies.

An overview of information regarding the processes associated with older driver licensing were compiled. The policies considered included the following:

- Current renewal procedures used for licensing older drivers including the length of renewal cycles;

- Older driver restrictions included as part of the licensing process;
- Requirements imposed on physicians to report unfit drivers (for drivers of all ages);
- Challenges associated with perceived discrimination in older driver licensing policies; and
- Changes in fatality rates associated with older drivers in states that have implemented older driver licensing policy.

The research was conducted and documentation prepared with a focus on how the information may be useful to Massachusetts decision-makers.

3.3 Task 3: Assess Charges and Payer Source for Injuries Sustained by Older Vehicle Occupants

Research has shown that due to their fragility, older persons involved in a crash are more likely to sustain injuries. This task focuses on further examination of this issue through several subtasks: 1) linkage of crash and hospital data, 2) assessment of charges associated with treatment of injuries sustained by older vehicle occupants in both emergency department and inpatient settings, 3) evaluation of payer source for older vehicle occupants, and 4) compilation of results so they may be used by policy makers for benefit cost analysis and other decision making processes.

3.3.1 Task 3A: Linkage of Crash and Hospital Data

Traditionally, analysis of crashes has been centered upon the use of police-reported information collected on state-specific crash report forms. However, the series of events surrounding a crash are more complex than the data on a crash report form can accurately record. Ideally, data should cover the events immediately preceding a crash, the characteristics of the crash itself, and the outcomes associated with the crash. The primary purpose of the Crash Outcome Data Evaluation System (CODES) is to link multiple datasets in an effort to create a more robust dataset that more effectively captures crash events. Specifically, CODES focuses on linking crash data to emergency medical services (EMS) and hospital data, to understand injuries and charges associated with crashes; other safety datasets including citation, roadway inventory, and insurance data may also be linked to provide a more comprehensive overall picture. Recognizing that this type of data collection and linkage was best possible at the state level, CODES was established by NHTSA in 1992. CODES employs probabilistic linkage to link datasets with common information but no common unique identifier. Crash characteristics (i.e. time, location, object struck), person characteristics (i.e. age, sex), and vehicle characteristics (i.e. type of vehicle) that are common across data sets can be used to link person level records.

All subtasks associated with Task 3 are based on the use of Massachusetts CODES data for 2005. Three datasets were used: crash, emergency department, and hospital inpatient. Prior to linkage, fields from each dataset were analyzed and standardized, followed by a "self-match" process conducted on each dataset to assess and address the issue of duplicate records within each dataset. Once the standardization and self-match were complete, the actual linkage was carried out.

Although the linkage requires person-level records, due to confidentiality issues, unique identifiers such as social security number are not provided with hospital data. As a result, the probabilistic linkage strategy is based on the probability that if two records match in similar fields across data sets, the records that match are the same person. The CODES data linkage is conducted using CODES2000, an Access-based software that implements Fellegi and Sunter's statistical theory of record linkage as extended by McGlincy, Newcombe, Jaro, Winkler, Belin, Kelley and others (42, 43). Two statistical properties of comparison fields – reliability and discriminating power – are used to calculate the likelihood ratio for a true match. The logarithm of likelihood ratios is the match weight; match weight is a uniformly powerful test statistic for determining the correct disposition of candidate record pairs. Reliability (defined as *m*) is the probability that a common field agrees on a matched pair. Discriminating power (identified as *u*) is the probability that a common field agrees on an unmatched pair. These probabilities can be estimated for each field from the data. All candidate records are then compared field by field, with a linkage weight assigned to each record pair. This linkage weight measures how well the data elements improve the ability to match two records accounting for the fact that there is always the possibility of a random true match (42). These concepts are further explained in TABLE 3.1.

TABLE 3.1 Probabilistic Linkage Concepts

Concept	Definition	Calculation
Reliability	Probability that a linkage field agrees on a true matched pair	$m_i = 1 - (error \quad rate)$
Discriminating Power	Probability that a linkage field agrees on a true unmatched pair	$u_i = \frac{1}{(number \;\; of \;\; values \;\; in \;\; field \;\; i)}$
Linkage Weights	For each field comparison, a weight is computed based on whether the two fields are a match or a non-match	$W_i = \begin{cases} \log_2\left(\frac{m_i}{u_i}\right) & \text{Agreement Weight} \\ \log_2\left(\frac{1-m_i}{1-u_i}\right) & \text{Disagreement Weight} \end{cases}$
Match Weight	Likelihood that the two records refer to the same individual and crash and event	$\sum_i W_i$ over all fields *i*

The linkage of Massachusetts data was based on three match passes. Within each match pass, fields from each data set were used for two sets of linkage specifications. Match specifications were the same for each pass and were used to calculate match weights and probabilities; these specifications define the fields for comparison. Join specifications, which were different for each pass, identify candidate pairs. Each pass was run independently, and passes were merged to obtain a resulting set of linked data. Figure 3.1 outlines the fields used for the Massachusetts linkage.

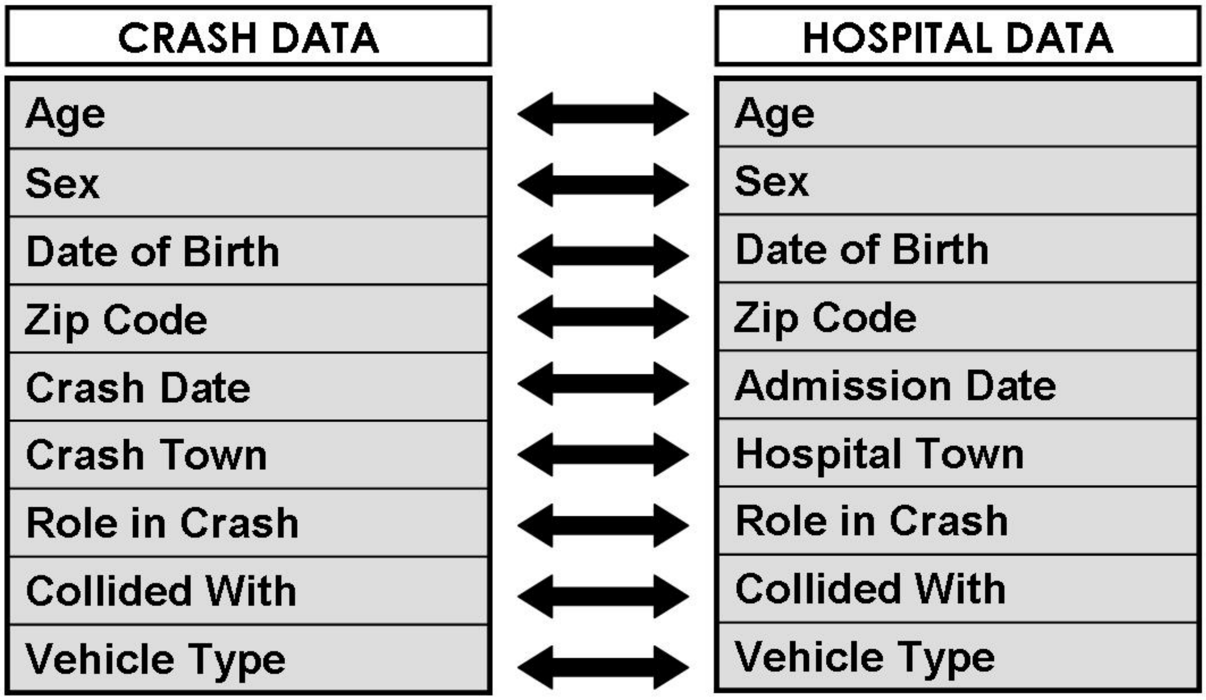

Figure 3.1 Fields used for Massachusetts CODES linkage.

It should be noted that the practice of imputing missing links was used for this linkage. As part of the linkage process, each pair was assigned a probability of being a true match. If only high probability matches were used, the data may lead to inaccurate conclusions. Missing values and systematic errors in data collection processes may result in false field disagreements that lead to low probabilities assigned to true matches. These false negatives can make datasets unrepresentative of the total population of true linked pairs. Imputing missing links accounts for these low probability matches (43).

This process resulted in five distinct datasets (one for each imputation) that are then analyzed individually and combined. For the purpose of this analysis, an older vehicle occupant is defined as age 65 or older.

3.3.2 Task 3B: Evaluation of Charges Associated with Injury Treatment

Using the CODES dataset described in Task 3A, charges associated with the treatment of injuries sustained by older occupants and other occupants involved in the same crash were analyzed. Data for the analysis of charges was kept separate for emergency department and inpatient because of the difference in scale for each. In emergency department data, total charges are lower than for inpatient records. It should also be noted that only those vehicle occupants who are injured in the crash were included in the CODES data set.

3.3.3 Task 3C: Assessment of Payer Source

In addition to injury and charge information, the primary payer source can be obtained through the use of CODES linked data since this information is included in health care data. Since older persons are often insured by public insurance programs, payer source is perhaps more critical for an evaluation of older drivers than any other age group. As such, payer source for older driver crash injury treatment was examined and an overview of charges billed to public and private insurance programs was developed. The following payer sources are included in health care data and were classified as shown in TABLE 3.2 (44).

TABLE 3.2 Categorization of Payer Types in Health Care Data

Payer Type	Payer Type Category
Self Pay	Self Pay
Workers Comp	Private
Medicare	Public
Medicare Managed Care	Public
Medicaid	Public
Medicaid Managed Care	Public
Other Government Payment	Public
Blue Cross	Private
Blue Cross Managed Care	Private
Commercial Insurance	Private
Commercial Managed Care	Private
Health Maintenance Organization	Private
Free Care	Public
Other Non-Managed Care Plans	Private
PPO and Other Managed Care Plans not Elsewhere Classified	Private
Point-of-Service Plan	Private
Exclusive Provider Organization	Private
Auto Insurance	Private
None	None

3.3.4 Task 3D: Compilation of Results into Cost Report

The information gathered during the completion of Task 3 was compiled with a focus on the financial outcomes associated with the treatment of injuries associated with older vehicle occupants.

3.4 Task 4: Examine the Relationship between Injury Causing Crashes Involving an Older Driver and Previous Driving History

Older drivers who are involved in crashes that result in injury may have exhibited driving behaviors prior to crash involvement that might serve as early warning signs that these are high risk drivers. This driving history includes involvement in crashes as well as the receipt of violations for potentially risky driving behaviors. For this task, 2006 and 2007 crashes involving a driver age 65 or older were examined and the crash and citation history for those older drivers were outlined using standard summary statistics. This included information on number and types of previous crashes as well as number and types of previous citations. This serves to provide a preliminary understanding of the relationship between crash involvement and high risk driving behavior, further developed in Task 5.

It should be noted that originally, it was anticipated that a driver history file would be available through the Registry of Motor Vehicles (RMV) that would allow for the consideration of all older drivers regardless of crash involvement and would provide individual-specific driver history that might include information beyond crash and citation information. However, this was not possible and an alternate approach was undertaken.

A comprehensive driver profile was developed based on the use of two administrative datasets collected by the Massachusetts Registry of Motor Vehicles (RMV): crash data and citation data. These data were obtained from the University of Massachusetts traffic safety data warehouse that houses 14 data sets, as shown in Figure 3.2. Once data are transferred from the RMV to UMass, they are cleaned and formatted for storage in the data warehouse. All data in the warehouse are accessible using SQL.

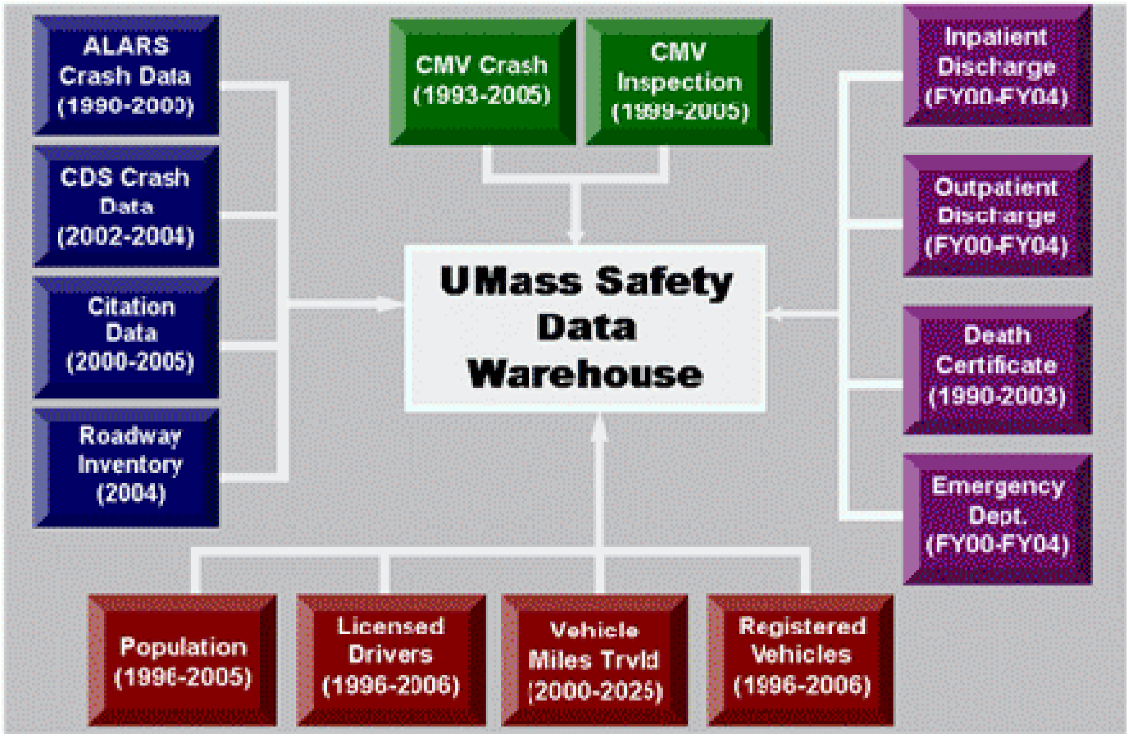

Figure 3.2 Datasets in UMass safety data warehouse.

To prepare the data for the analysis and the subsequent modeling process, a Comprehensive Driver Profile (CDP) for each driver age 65 or older was established. The CDP was created by linking crash and citation data using common fields across datasets. This linkage process was based the use of driver license number to link records across crash and citation databases, with the use of name (first and last) and date of birth to verify that linked drivers were the same person. While this process yielded datasets with sufficient records for analysis, there are several limitations that should be noted.

- There may be missing information for drivers due to changes in license numbers or typos in license number in any of the datasets.
- Only older drivers involved in a crash in the year being considered could be included. Drivers who were not involved in a crash that year would not appear in the database and therefore cannot be considered. As such, drivers in injury-

causing crashes were considered with drivers in non-injury causing crashes as a point of comparison.

- Only crash and citation history could be included as possible indicators of risk for involvement in a future injury-causing crash. Driver history data might have provided additional information regarding years licensed, prior suspensions, etc.

3.4.1 Task 4A: Development of Driver Crash Profiles

The preparation of data for use in the crash prediction model began with the development of a crash profile for drivers age 65 or older (older drivers) who were involved in a crash in 2006 or 2007. Older drivers involved in injury crashes in 2006 were profiled for use in the development of the model and those in 2007 for testing the model. The process below describes preparation of crash profiles for older drivers involved in an injury causing crash in 2006. The process was replicated identically to create the 2007 crash profiles.

The process of developing the crash profile began with two data tables: 1) drivers age 65 or older involved in any crash in 2006 and 2) all people involved in a crash between 2002 and 2006 involving drivers age 55 or older. The lower age definition for the second table was to account for the fact that a 65 year old driver involved in a crash in 2006 would fall outside the 65 or older boundary if they were involved in a crash in 2002; their involvement in that crash, even though they were 61 when it occurred would be considered in their crash profile. The first table was queried to identify all injury crashes regardless of driver age. This was linked to a table of older driver crashes in 2006 using crash number. Each older driver was identified as an injury causing crash driver (ICCD) or non ICCD. The number of injury crashes for each older driver involved in any crash in 2006 was totaled and ranged from zero to three. Those with unknown driver license numbers were excluded since this number would be necessary to link to crashes in other years and to citation records. In 2006, 20,684 older drivers were involved in at least one crash, with 5,780 being involved in at least one injury crash.

The driver license numbers from the list of 2006 older ICCDs were linked to license numbers in the table of crashes that took place between 2002 and 2005, and divided by crash year. Additionally, driver name (first and last) and date of birth were used to verify the linkage to ensure that a single crash number was not associated with more than one driver, for example. In addition, for each year, the following crash characteristics were compiled into a system of "flags" to indicate whether each prior year crash could be identified as having that particular characteristic. The flags, and the definitions associated with each flag, are described in TABLE 3.3.

TABLE 3.3 Aggregated Crash Characteristics Used in Crash Profile Development

Intersection	Yes	Four way, T-intersection, Y-Intersection, Traffic Circle, Five-Point or More
	No	Not at Intersection, On Ramp, Off Ramp, Driveway, Railway Grade Crossing, Unknown
Manner of Collision	Single Vehicle Crash	Single Vehicle Crash
	Rear Crash	Rear End, Rear to Rear
	Angle Crash	Angle Crash
	Sideswipe Crash	Sideswipe Same Direction, Sideswipe Opposite Direction
	Head On	Head On
First Harmful Event	Vehicle	Motor Vehicle in Traffic, Parked Motor Vehicle
	Non-Motorist	Pedestrian, Cyclist
	Fixed Object	Curb, Tree, Utility Pole, Light Pole, Guardrail, Median Barrier, Ditch, Embankment, Bridge, Bridge Overhead Structure, Unknown Fixed Object
	Non-Collision	Overturn/Rollover, Jacknife, Other Non-Collision, Unknown Non-Collision
	Other	Animal-Deer, Animal-Other, Moped, Workzone Maintenance Equipment, Railway, Other Movable Object, Other

A field was created for each driver license number to count the number of crashes associated with that driver per year as well as the number of injury crashes per year.

The final crash profile table combined the crash characteristics described in TABLE 3.3 and added a category for driver age at the time of the 2006 injury-causing crash grouped in 5 year blocks for ages 65 to 84 and one category for 85 and over. For those drivers who were involved in more than one injury-causing crash in 2006, their age at the time of the first crash was used. Additionally, driver sex was added to the profile. Below is a list of the fields included for each of the 2006 older ICCDs.

- Driver License Number,
- Age Group (at time of 2006 crash),
- Sex,
- Number of crashes between 2002 and 2005,
- Number of injury-causing crashes between 2002 and 2005,
- Number of intersection crashes between 2002 and 2005,
- Number of single vehicle crashes between 2002 and 2005,
- Number of rear crashes between 2002 and 2005,
- Number of angle crashes between 2002 and 2005,
- Number of sideswipe crashes between 2002 and 2005,
- Number of head on crashes between 2002 and 2005,
- Number of crashes with another vehicle between 2002 and 2005,
- Number of crashes with a non-motorist between 2002 and 2005,
- Number of crashes with a fixed object between 2002 and 2005,
- Number of non-collision crashes between 2002 and 2005, and
- Number of crashes associated with other first harmful event between 2002 and 2005.

Once this process was complete for drivers age 65 or older involved in an injury causing crash, the same process was used to create a crash profile for older drivers involved in a crash where there was no injury since these drivers would also be part of the model, as the point of comparison.

3.4.2 Task 4B: Development of Driver Citation Profiles

Using the list of older driver license numbers developed during the previous step, a citation profile was developed for each of the older drivers involved in a crash. These driver license numbers were linked to the driver licenses numbers in records from the citation database. The citation dataset includes information on the violator (age, sex, date of birth, name, and license number) and violation (chapter/section, description of offense, and citation number). It should be noted that these records were examined at the violation level rather than the citation level; one citation may be issued for up to three separate and unrelated violations.

For 2006 older drivers in a crash, citations issued between 2002 and 2005 were considered; for 2007, this was expanded to include 2006. Violations were aggregated based on the description of offense into meaningful categories described in TABLE 3.4 through TABLE 3.6.

TABLE 3.4 Grouping of Violation Descriptions in Citation Data-Alcohol/Drug, Belt, Flee, General, and Lane Offenses

Category	Offense Description
Alcohol/Drug	Dwi Drugs
	Liq Trans By Minor
	Illegal Poss Class D
	Dwi Liquor
	Dwi Serious Injury
	Dwi Drug Program
	Dwi Alcohol Program
	Drink Open Container
Belt	No Child Restraint
	Seat Belt Violation
Flee	Leave Scene Pers Inj
	Leave Scene Prop Dam
	Fail To Rpt Name/Add
	Fail To Rpt Accd
	Abandonment Of Veh
General	Minor Traffic
	Fail To Use Safety
	Traffic/Safety Viol
	Rmv/Fed Safety Regs
	St Hway Violation
	Mun Bylaw Pass Vehs
	Dpw State Hway Regs
	Illegal Operation
Lane	Lane Violation
	Keep Right No View
	Improper Passing
	Keep In Right Lane
	Left Lane Exclusion
	Fail To Keep Right

TABLE 3.5 Grouping of Violation Descriptions in Citation Data-License/Registration/Equipment Offenses

Lic/Reg/Equip	Learner Permit
	License Restriction
	License Suspended
	Jol Pass Restriction
	INSPECTION STK VIOL
	Impropr Equipment Ns
	Improper Equipment
	FALSE LIC/REG
	LIMIT/PROHIBITED USE
	EXPIRED REG STICKER
	Display Number Plate
	Conceal Identity
	Attaching Plates
	ATTACH IMPROPR PLATE
	Allow Unlic Operate
	False Lic/Reg,Etc.
	REG STKR NO DISPLAY
	Unreg/Improper Equip
	TRUCK OWNR VIOLATION
	Tire Tread
	SCHL BUS OPER/EQUIPT
	REGISTRAR RULE/REG
	License Revoked
	Reg Suspend/Revoked
	Load No Cover/Escape
	Refuse Give Name/Adr
	OVERWEIGHT VEHICLE
	OVERSIZE VEHICLE
	Operator Unlicensed
	No Inspection Stcker
	NO TRANSPARENT WINDO
	No Reg/Lic In Posses
	No Liability Policy
	Mv Reg Misrepresent
	MODIFY VEH HEIGHT

TABLE 3.6 Grouping of Violation Descriptions in Citation Data-Other, Serious, Speeding, and Stop/Yield Offenses

Other	One Way Street
	FAIL PAY/EVADE TOLL
	FAIL DIM LIGHTS
	Safety Standards
	Fail To Give Signal
	Mdc Excluded Vehicle
	FAIL RPT INJ DOG/CAT
	DPW/EXCLUSION ST HWY
	Trespass With Mv
	Using W/O Authority
	Theft/Concealment Mv
	FLARE VIOLATION
	Motor Carrier Act
	PARKING PROHIBITIONS
	Refuse Obey Police
	Rules/Reg Violation
Serious	Vehicular Homicide
	Operating Recklessly
	Driving To Endanger
	Mv Homicide/Negl Op
	Mv Homicide/Liq&Negl
Speeding	Speeding
	Speed Drag Racing
	MASS PIKE SPEED
Stop/Yield	FAIL STOP SCHOOL BUS
	Impede Emerg Vehicle
	Impeding Operation
	Yield To Pedestrian
	Failure To Stop
	Rt Of Way Intersectn
	Yield Blind Person
	Stop At RR Crossing

Each violation was flagged as falling into one of these categories and the final dataset included the following information for each driver:

- Driver License Number,
- Number of total violations,
- Number of alcohol violations,
- Number of belt violations,
- Number of fleeing violation,
- Number of general violations,
- Number of lane violations,
- Number of license/registration/equipment violations,
- Number of other violations,
- Number of serious violations,
- Number of speeding violations, and
- Number of stop/yield violations.

As was the case with the creation of the crash profile, once this process was complete for drivers age 65 or older involved in an injury causing crash, the same process was used to create a citation profile for older drivers involved in a crash where there was no injury.

Two citation profiles were developed for each driver. One included violations issued between 1995 and 2001; these are referred to as prior violations. Additionally, a "recent" citation profile was developed for each driver. For drivers in a crash in 2006, this included violations issued between 2002 and 2005; for drivers in a 2007 crash this included violations issued between 2002 and 2006.

It should be noted that during the development of these citation profiles, some data quality questions arose. Specifically, drivers in all four driver groups (2006 ICCD and non-ICCD, an 2007 ICCD and non-ICCD) were associated with what appeared to be an unreasonable number of violations. For 2006 drivers, for example, the number of violations issued between 1995 and 2001 was as high as 268,800 violations for a single driver and 2,608 were issued to a single (different) driver between 2002 and 2005. There was also a driver in 2007 who was associated with 268,800 violations between 1995 and 2001; 1,600 violations were issued to a 2007 crash driver between 2002 and 2006. Based on these unrealistic violation counts, the decision was made to eliminate citation histories with more than 5 violations issued per year. This resulted in the elimination of 30 recent citation history records for 2006 older drivers in crashes and 29 recent citation history records for older drivers in 2007 crashes. It also resulted in the elimination of 74 prior citation history records for older drivers in 2006 crashes and 60 prior citation history records for older drivers in 2007 crashes. These drivers are still included in the dataset and may have crash histories associated with them. They may also have an element of the citation history that did not require deletion. For example, if a driver has unrealistic violation counts for the recent citation history, this does not automatically mean that they were associated with unrealistic violation counts for the prior citation history.

Appendix A provides an overview all of the variables included in the final comprehensive drive profile dataset including number of observations, mean, standard deviation, minimum, maximum, and variance for each field. Additionally, the distribution within each variable is included.

3.5 Task 5: Develop an Older Driver Crash Prediction Model

Crash prediction modeling is a logical mechanism for identifying high-risk older drivers. In order to address roadway safety, the unit of inquiry should be the risk of an injury causing crash. Evidence of recent driving performance such as citation and crash data should be considered as potential variables for model development. Reliably identifying a group of high risk drivers would allow re-screening or re-testing based on objective data – recent driver performance – rather than on age or medical conditions alone. This inherently makes targeting a subgroup of drivers more politically palatable – they have demonstrated their risk. In addition, the factors contributing the greatest weight to the model will likely identify potential areas for focused retraining. This task focused on the development and validation of a crash prediction model.

The development of a crash prediction model for older drivers took place in three steps: acquisition and preparation of data, development of model, and validation of the model. An overview of this process is shown in Figure 3.3.

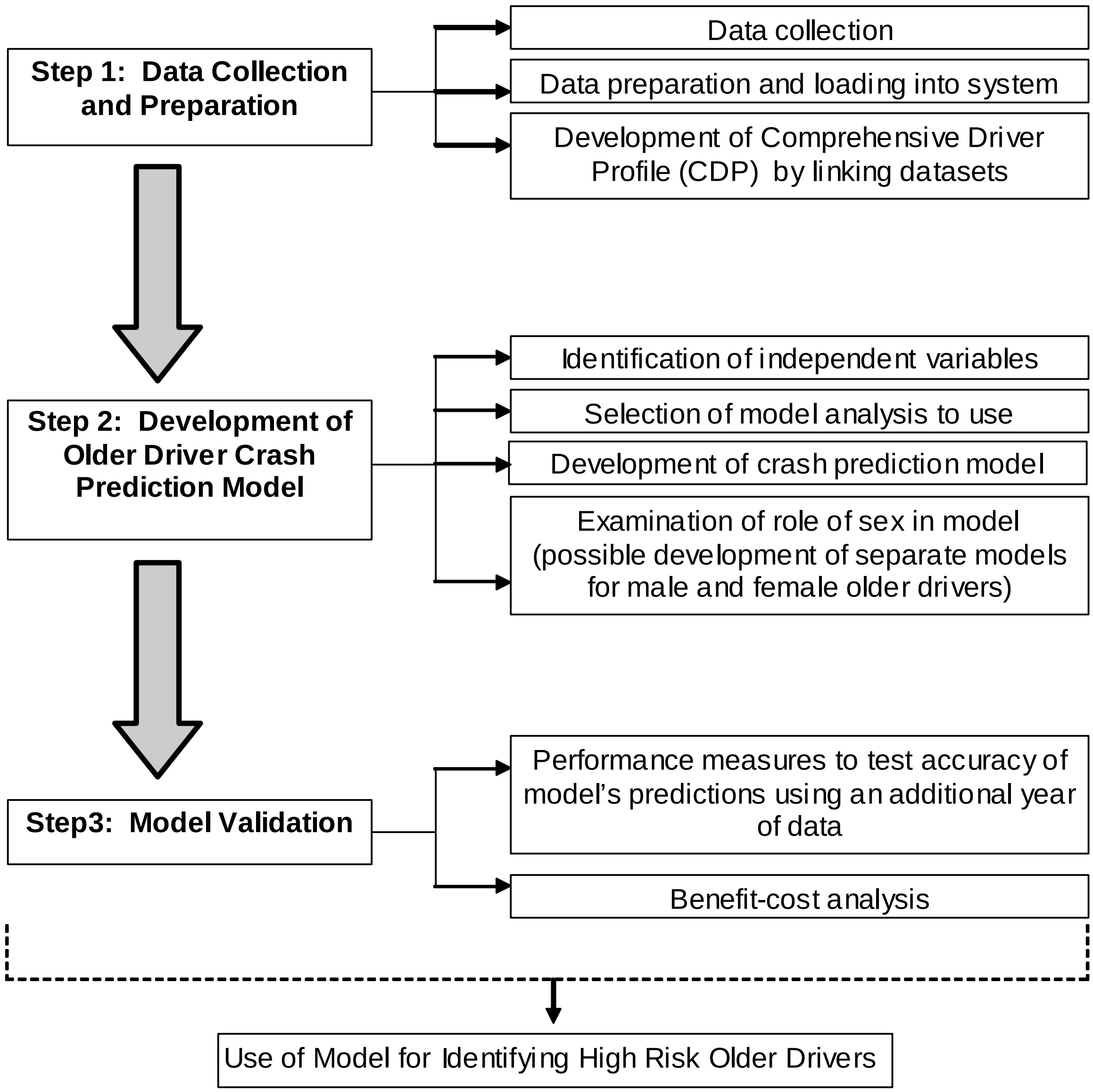

Figure 3.3 Overview of crash prediction model development process.

3.5.1 Task 5A: Acquisition and Preparation of Data:

The development of the older driver crash prediction model was based on the CDP developed during Task 4. Although the initial datafile imported into SAS for the development of the crash prediction model included all of the fields described in Task 4, analyses were conducted to identify potential correlation between fields. This was done using Kendall's tau-b correlation coefficient. Kendall's tau-b is a nonparametric measure of correlation that takes into consideration the number of concordances and discordances in paired observations (45). The formula for Kendall's tau-b is the following:

$$\tau = \frac{\sum i < j(sgn(x_i - x_j)sgn(y_i - y_j))}{\sqrt{(T_o - T_1)(T_o - T_2)}}$$

where $T_0=n(n-1)/2$, $T_1=\sum_k t_k(t_k-1)/2$, and $T_2=\sum u_l(u_l-1)/2$. The t_k is the number of tied x values in the kth group of tied x values, u_l is the number of tied y values in the lth group of tied y values, and n is the number of observations. Additionally, sgn(z) is the following:

$$sgn(z) = \begin{cases} 1 & if\ z > 0 \\ 0 & if\ z = 0 \\ -1 & if\ z < 0 \end{cases}$$

Probability values for Kendall's tau-b are computed on the basis that:

$$\frac{s}{\sqrt{V(s)}}$$

coming from a standard normal distribution where

$$s = \sum_{i<j}(sgn(x_i - x_j)sgn(y_i - y_j))$$

And V(s), the variance of s, is the following:

$$V(s) = \frac{v_0 - v_t - v_u}{18} + \frac{v_1}{2n(n-1)} + \frac{v_2}{9n(n-1)(n-2)}$$

where

$v_0=n(n-1)(2n+5)$
$v_t=\sum_k t_k(t_k-1)(2t_k+5)$
$v_u=\sum_l u_l(u_l-1)(2u_l+5)$
$v_1=(\sum_k t_k (t_k-1))(\sum u_i(u_l-1))$
$v_2=(\sum_l t_i(t_k-1)(tk-2))(\sum u_l(u_l-1)(u_l-2))$

where t_i is the number of tied x values and u_i is the number of tied y values.

The test for correlation using Kendall's tau-b was conducted in two phases. In the first phase, correlation was tested for each of the variables within the three groups: crash profile, recent violation profile, and prior violation profile. Those with Kendall's tau-b values higher than 0.30 were eliminated. For crash profile data, this led to the elimination of number of crashes between 2002 and 2005, number of rear crashes between 2002 and 2005, number of crashes with another vehicle between 2002 and 2005, and number of crashes with a fixed object between 2002 and 2005. Results of Kendall's tau-b tests for crash profile fields are shown in TABLE 3.7 with the values over the 0.30 cutoff in bold. Similarly, TABLE 3.8 and TABLE 3.9 show results for recent violation and prior violation profile fields. For both violation profiles (recent and prior), the only fields that were eliminated were those that counted the total number of violations issued.

The second phase of correlation testing combined the fields that were not eliminated during the first phase were tested for correlation. TABLE 3.10 provides the results of these correlation tests. None of these variables had a value over 0.30; therefore all remained for inclusion in the model.

TABLE 3.7 Kendall's Tau-B Results for Crash Profile Data, 2006 Older Drivers in Crashes

	crashes_ 0205	injcrashes_ 0205	int_ 0205	svc_ 0205	rear_ 0205	angle_ 0205	side_ 0205	headon_ 0205	veh_ 0205	nonmot_ 0205	fixed_ 0205	noncoll_ 0205	otherfhe_ 0205
crashes_ 0205													
injcrashes_ 0205	**0.3828**												
int_ 0205	**0.7025**	0.2954											
svc_ 0205	0.2846	0.1669	0.1617										
rear_ 0205	**0.5556**	0.2629	**0.352**	0.047									
angle_ 0205	**0.641**	0.2564	**0.6123**	0.036	0.0694								
side_ 0205	**0.3617**	0.064	0.2207	0.0283	0.0288	0.061							
headon_ 0205	0.1672	0.1696	0.1214	0.002	0.0193	0.0413	0.0187						
veh_ 0205	**0.8206**	**0.3559**	**0.6578**	0.0919	**0.5008**	**0.663**	**0.3001**	0.1637					
nonmot_ 0205	0.148	0.0207	0.1218	0.2986	0.025	0.0471	0.0232	0.0529	0.0249				
fixed_ 0205	0.204	0.1811	0.0939	**0.6547**	0.028	0.0381	0.043	0.011	0.0394	0.0043			
noncoll_ 0205	0.0592	0.022	0.045	0.1531	0.0126	0.018	0.0101	-0.0017	0.0181	-0.0015	-0.002		
otherfhe_ 0205	0.1059	0.0142	0.0347	0.2477	0.0241	0.027	0.0158	0.0443	0.0168	-0.0027	-0.0037	-0.0011	

TABLE 3.8 Kendall's Tau-B Results for Recent Violation Profile Data, 2006 Older Drivers in Crashes

	viol_0205	alc_0205	belt_0205	flee_0205	gen_0205	lane_0205	lic_0205	other_0205	ser_0205	speed_0205	stp_0205
viol_0205											
alc_0205	0.1049										
belt_0205	**0.3667**	0.0067									
flee_0205	0.1337	0.0865	0.0296								
gen_0205	**0.3935**	0.0047	0.0941	0.04							
lane_0205	**0.3319**	0.078	0.1193	0.0319	0.099						
lic_0205	**0.4243**	0.0229	0.1546	0.0522	0.0933	0.0871					
other_0205	0.1742	0.043	0.0468	0.051	0.0513	0.0932	0.048				
ser_0205	0.08	0.2477	-0.0033	0.2353	0.0356	0.0283	0.0084	0.0287			
speed_0205	**0.6369**	0.0167	0.2607	0.0192	0.089	0.1348	0.1433	0.0741	-0.0061		
stp_0205	**0.5324**	0.015	0.1636	0.0731	0.1112	0.117	0.143	0.0968	0.034	0.1093	

TABLE 3.9 Kendall's Tau-B Results for Prior Violation Profile Data, 2006 Older Drivers in Crashes

	viol_9501	alc_9501	belt_9501	flee_9501	gen_9501	lane_9501	lic_9501	other_9501	ser_9501	speed_9501	stp_9501
viol_9501											
alc_9501	0.1415										
belt_9501	**0.3378**	0.0231									
flee_9501	0.1078	0.1256	0.0136								
gen_9501	**0.3864**	0.0328	0.1151	0.0707							
lane_9501	**0.312**	0.212	0.0987	0.0726	0.1258						
lic_9501	**0.3996**	0.0677	0.141	0.0368	0.1104	0.1287					
other_9501	0.1714	0.0358	0.0413	0.0227	0.0763	0.121	0.1057				
ser_9501	0.1115	0.2994	0.0201	0.1009	0.0646	0.1781	0.0653	0.0355			
speed_9501	**0.696**	0.0351	0.2671	0.0328	0.1335	0.1347	0.1735	0.102	0.0382		
stp_9501	**0.5404**	0.0329	0.1975	0.0546	0.1237	0.1147	0.1538	0.058	0.0292	0.174	

TABLE 3.10 Kendall's Tau-B Results for Combined Comprehensive Driver Profile, 2006 Older Drivers in Crashes

	injcrashes_0205	**int_0205**	**svc_0205**	**side_0205**	**headon_0205**	**nonmot_0205**	**noncoll_0205**	**otherfhe_0205**	**alc_0205**
injcrashes_0205									
int_0205	0.2954								
svc_0205	0.1669	0.1617							
side_0205	0.0640	0.2207	0.0283						
headon_0205	0.1696	0.1214	0.0020	0.0187					
nonmot_0205	0.0207	0.1218	0.2986	0.0232	0.0529				
noncoll_0205	0.0220	0.0450	0.1531	0.0101	-0.0017	-0.0015			
otherfhe_0205	0.0142	0.0347	0.2477	0.0158	0.0443	-0.0027	-0.0011		
alc_0205	0.0205	0.0194	0.0999	0.0222	0.0025	-0.0022	0.0547	-0.0016	
belt_0205	0.0248	0.0272	0.0269	0.0204	0.0262	-0.0009	-0.003	0.0214	0.0067
flee_0205	0.0134	0.0263	0.0496	0.0589	-0.0032	0.0145	0.0430	-0.0020	0.0865
gen_0205	0.0695	0.0962	0.0384	0.0595	0.0619	0.0489	0.0112	-0.0062	0.0047
lane_0205	0.0534	0.0423	0.0634	0.0471	0.0658	0.0068	0.0320	0.0044	0.0780
lic_0205	0.0205	0.0259	0.0348	0.0290	0.0093	0.0127	0.0244	0.0384	0.0229
other_0205	0.0117	0.0223	0.0211	0.0364	0.0195	0.0495	-0.0014	-0.0027	0.043
ser_0205	0.0309	0.0394	0.0587	0.0454	0.0241	-0.0017	0.0739	-0.0012	0.2477
speed_0205	0.0126	0.0398	0.0352	0.0378	0.0263	0.0009	0.0134	0.0154	0.0167
stp_0205	0.0526	0.0883	0.0282	0.0286	0.0369	0.0359	0.0067	0.0034	0.015
alc_9501	0.0101	0.0139	0.0007	0.0174	-0.0043	0.0087	-0.0015	-0.0028	0.0191
belt_9501	0.0218	0.0438	0.0198	0.0263	0.0288	0.0073	0.0105	-0.0008	0.0318
flee_9501	0.0054	0.0238	0.0030	0.0069	0.0263	0.0134	-0.0012	-0.0022	0.0261
gen_9501	0.0258	0.0561	0.0185	0.0407	0.0118	0.0065	0.0068	0.0102	0.0163
lane_9501	0.0293	0.0606	0.0372	0.0340	0.0159	0.0138	0.0112	0.0169	0.0336
lic_9501	0.0210	0.0322	0.0167	0.0148	0.0237	0.0115	0.0071	0.0040	0.0398
other_9501	0.0086	0.0110	0.0019	0.0105	0.0041	0.0160	-0.0019	0.0108	0.0324
ser_9501	0.0052	0.0232	0.0029	0.0272	-0.0033	-0.0030	0.0401	-0.0022	-0.0018
speed_9501	0.0394	0.0558	0.0259	0.0395	0.0272	0.0108	-0.0015	0.0103	0.0019
stp_9501	0.0237	0.0638	0.0255	0.0551	0.0270	0.0168	-0.0062	0.0112	-0.0034
	belt_0205	**flee_0205**	**gen_0205**	**ane_0205**	**lic_0205**	**other_0205**	**ser_0205**	**speed_0205**	**stp_0205**
belt_0205									
flee_0205	0.0296								
gen_0205	0.0941	0.0400							
lane_0205	0.1193	0.0319	0.0990						
lic_0205	0.1546	0.0522	0.0933	0.0871					
other_0205	0.0468	0.0510	0.0513	0.0932	0.0480				

TABLE 3.10 Kendall's Tau-B Results for Combined Comprehensive Driver Profile, 2006 Older Drivers in Crashes (cont)

	belt_0205	flee_0205	gen_0205	ane_0205	lic_0205	other_0205	ser_0205	speed_0205	stp_0205
ser_0205	-0.0033	0.2353	0.0356	0.0283	0.0084	0.0287			
speed_0205	0.2607	0.0192	0.089	0.1348	0.1433	0.0741	-0.0061		
stp_0205	0.1636	0.0731	0.1112	0.1170	0.1430	0.0968	0.0340	0.1093	
alc_9501	0.0051	0.0146	0.02	0.0097	0.0284	-0.0036	-0.0017	0.0113	0.0184
belt_9501	0.0877	0.0085	0.0491	0.0554	0.0787	0.0323	0.0086	0.0936	0.0868
flee_9501	0.0108	-0.0022	0.0084	0.0215	0.0144	0.0148	0.0361	0.0266	0.0412
gen_9501	0.0549	0.0228	0.0693	0.0505	0.0553	0.0179	0.0054	0.0512	0.0836
lane_9501	0.0748	0.0482	0.0807	0.062	0.0807	0.0282	0.022	0.0851	0.0826
lic_9501	0.0923	0.017	0.0546	0.0490	0.1566	0.0330	-0.0049	0.0877	0.0911
other_9501	0.0277	-0.0034	0.0227	0.0199	0.0527	0.0067	-0.0021	0.0463	0.0215
ser_9501	0.0188	0.0202	0.0373	0.0034	0.0212	-0.0028	-0.0013	0.0077	0.0075
speed_9501	0.0865	0.0184	0.0789	0.0760	0.0843	0.0375	0.0148	0.1774	0.1082
stp_9501	0.0852	0.0248	0.0745	0.0678	0.0799	0.0456	0.0005	0.1058	0.1379

	alc_9501	belt_9501	flee_9501	gen_9501	lane_9501	lic_9501	other_9501	ser_9501	speed_9501
alc_9501									
belt_9501	0.0231								
flee_9501	0.1256	0.0136							
gen_9501	0.0328	0.1151	0.0707						
lane_9501	0.2120	0.0987	0.0726	0.1258					
lic_9501	0.0677	0.1410	0.0368	0.1104	0.1287				
other_9501	0.0358	0.0413	0.0227	0.0763	0.1210	0.1057			
ser_9501	0.2994	0.0201	0.1009	0.0646	0.1781	0.0653	0.0355		
speed_9501	0.0351	0.2671	0.0328	0.1335	0.1347	0.1735	0.1020	0.0382	
stp_9501	0.0329	0.1975	0.0546	0.1237	0.1147	0.1538	0.0580	0.0292	0.174

3.5.2 Task 5B: Development of Crash Prediction Model for Older Drivers

The primary outcome of interest was driver participation in an injury crash in 2006. Three modeling approaches were considered for the development of this model: Poisson regression, negative binomial, and logistic regression.

3.5.2.1 Logistic Regression Model

Logistic regression modeling serves a purpose similar to other approaches to statistical modeling – to develop the best fitting model that is also reasonable given a broader understanding of the data being used (46). Logistic regression modeling is different from other modeling approaches in that the dependent variable is binary rather than continuous. In the case of the development of an older driver crash prediction model, the dependent variable becomes whether or not the older driver was involved in an injury causing crash (0=no, 1=yes), rather than the number of injury causing crashes in which the older driver was involved. With the logistic regression model, the conditional mean of the regression equation has to fall between zero and one since the outcome variable upon which this mean is calculated is zero or one. Additionally, distribution associated with the errors that will be the distribution on which the model is based is binomial rather than normal. Other principles that are associated with other regression model types may be applied to logistic regression as well.

Logistic regression is based on the following logistic function:

$$f(z) = \frac{1}{1 + e^{-z}}$$

where z accounts for the risk factors and f(z) is the outcome associated with exposure to those risk factors. The value of z is described as the following:

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \ldots + \beta_k x_k$$

Estimates for the values of βn are the regression coefficients that define the contribution of that risk factor. A positive regression coefficient means a that risk factor is associated with an increased likelihood of the outcome and negative regression coefficients are risk factors associated with a decreased likelihood of the outcome.

The results of logistic regression analysis are often described in terms of odds ratios. The odds of the outcome being present among individuals where the independent variable is present (x=1) is $\pi(1)/[1-\pi(1)]$ while the odds of the outcome being present among individuals where the independent variable is not present (x=0) is $\pi(0)/[1-\pi(0)]$. The odds ratio is the ratio of these two terms. An odds ratio of 1.0 indicates that there is no difference between the impact of the independent variable on those where the variable is present and those where it is not. The results of the logistic regression analysis are included in Chapter 7.

The Hosmer-Lemeshow goodness of fit test was used using the LACKFIT option in the MODEL line of the SAS code. This goodness of fit test divides observations into 10 equal-sized groups based on their probabilities. The following formula is then applied.

$$G^2_{HL} = \sum_{j=1}^{10} \frac{(O_j - E_j)^2}{E_j(1 - E_j/n_j)}$$

where n is the number of observations in the j group, O_j is the observed number of cases, and E_j is the expected number of cases. The results of the model defined using this process are further described in Chapter 7.

3.5.2.1 Poisson Regression Model

The Poisson regression model is based on the Poisson distribution and posits that each count y_i is based on the Poisson distribution with parameter μ_i, related to regressors. (15,47). The primary equation is the following:

$$\text{Prob } (y_i) = \frac{\exp(-\mu_i)(\mu_i)^{y_i}}{y_i!}$$

There has been some criticism of the use of the Poisson regression model because it assumes the variance of y_i is equal to its mean. However, count data are often found to have greater variation than indicated in the Poisson model. In a case where the variation is not adequately represented by the Poisson model, negative binomial regression analysis may be used.

The Poisson regression analysis was conducted using the PROC GENMOD procedure in SAS with the dist=poisson specification. Further detail on the process and results of the analysis are presented in Chapter 7.

3.5.2.2 Negative Binomial Regression Model

Negative binomial regression analysis is, generally speaking, an extension of the Poisson model that allows for variation beyond the mean (46). In a traditional negative binomial regression analysis, the number of accidents might be represented by:

$$\text{EXPO } \exp(aX + bY + \ldots)$$

where EXPO is a measure of exposure, X and Y are measures of characteristics considered in the model and a and b are regression coefficients (48).

An expanded version of the negative binomial regression analysis allows the model to account for subsegments rather than having to consider the entire segment in terms of "averages". Extended negative binomial regression analysis allows for variation within the segment as shown in the form

$$w_1 \exp(aX_1) + w_2 \exp(aX_2) + \ldots + w_m \exp(aX_m)$$

where x_i represents a characteristic for a subsegment of the total being considered and w_i represents the proportion of the segment to which x_i applies. In the case of engineering factors, x_i might be the vertical curvature for a roadway subsegment and w_i represents the length of that subsegment.

Negative binomial regression analysis has been used previously in crash prediction modeling that examines the safety performance of engineering attributes where the subsegments considered were smaller distances of road.

Negative binomial regression analysis was conducted in SAS using PROC GENMOD with link=log, dist=negbin specifications. Further detail of the process and results are described in Chapter 7.

3.5.3 Task 5C: Validation of Crash Prediction Model for Older Driver

Validation of the older driver crash prediction model was anticipated to be conducted using additional years of data not used in the original development of the model. Specifically, the model(s) derived in previous step were to be validated using 1995to 2006 data to retrospectively "predict" 2007 crashes. However, due to challenges associated throughout the modeling process, and the results disussed in Chapter 7, it became apparent that an effective model could not be developed using the methodologies employed. As such, there was no opportunity to validate the model.

3.6 Task 6: Documentation of Findings

The results of the previous tasks have been compiled in this doctoral dissertation in accordance with the University of Massachusetts - Amherst Policy and Guidelines (49).

CHAPTER 4

OLDER DRIVER LICENSING POLICIES: BEST PRACTICES AND MASSACHUSETTS APPLICABILITY

This chapter focuses on research related to Hypothesis 1: *An improved method for sharing information on older driver licensing practices at the state level can be identified to improve policy and program decision making*. This is done through an examination of existing licensing policies related to older drivers across the United States, with a focus on how the information can be used by Massachusetts in developing licensing policy.

4.1 Background on Older Driver Licensing Policies

Although research suggests that today's older drivers are more cautious than previous cohorts of older drivers, and that they are willing to self-regulate (drive in less congested conditions, avoid night-time driving, etc), there is also the perception that this generation of older drivers are so accustomed to the mobility afforded by driving that they may not be willing to change their driving behavior in ways that will significantly impact that mobility (50). The literature reminds us that one of the roles that a state Department of Motor Vehicle plays is to "ensure that drivers are capable of driving safely, and to restrict, suspend or revoke licenses when drivers demonstrate that they are incapable" (51). However, there is less consensus regarding how this should be done in reference to older drivers. Across the United States, and in other countries, age-based restrictions have been implemented. What these restrictions are and how they are carried out varies greatly but it points to the idea that though they may not be consistent, they are politically viable (50).

In many states, age-based restrictions include more frequent or different vision, performance, and driving tests. As described in the Review of the Literature, these tests are not particularly effective as tools for assessing an older person's ability to safely drive. Some would argue that a road test is the most effective mechanism for assessing driver safety; however, road tests fail to expose drivers to hazardous driving situations, behavior behind the wheel during a driving test may differ from behavior behind the wheel under daily driving conditions, and it rests on the idea that some of the factors considered during this test (vision, cognition, physical ability) will not change as the driver continues to age (51).

Research has shown that age-based restrictions are not effective in reducing crash rates for older drivers (50). Many countries, and some states in the US, are moving away from strictly age-based restrictions and moving towards behavior-based restrictions. These behavior based restrictions are commonly associated with additional testing that takes place due to a driver's high crash frequency or at the recommendation of friends or family (50).

Whether the restrictions are age-based or behavior-based, there are challenges associated with the testing procedures. Essentially, whether an older person is retested, and the results of those tests, are at the discretion of the examiner. In some cases, examiners reported deciding who to retest based on how they looked and some in rural states reported their inclination to allow older people to keep their licenses even if they were deemed unsafe because they knew that there were no alternative transportation options (50). It is necessary for states to identify ways to implement licensing tools that are reliable, efficient, and cost effective. These tools should balance scientific foundation with the need to be fair and respectful (51).

4.2 State Licensing Practice and Policy

Licensing of drivers is a practice overseen at the state level. Although it is the responsibility of the state, and ultimately decisions are made at the state level, there are opportunities for states to learn from each other, and from national experts, in terms of what is likely to be most effective around older driver licensing. The licensing of young novice drivers, through junior operating licensing policies, is one example of the opportunity for states to successfully implement best practices. Although there is no single uniform junior operator licensing law, most states have similar common elements such as restrictions on night driving, passenger restrictions, and the requirement for certain levels of driving experience before they can move on to the next level of licensure. To better understand how states may adopt successful elements of licensing policies from other states or national guidelines, it is important to understand current licensing practices regarding older driver licensing.

4.2.1 Older Driver Licensing Attitudes at the Licensing Agency Level

As part of the National Highway Traffic Safety Administration (NHTSA) Model Driver Screening and Evaluation Program, the licensing officials in 50 US states and 12 Canadian Provinces responded to a questionnaire regarding feasibility of licensing practices in their state (52). Specifically, they were asked to consider the cost and time required to implement the model program and how that might impact their willingness to do so. Of the agencies asked to participate, 60 ultimately responded including 47 states, the District of Columbia, and 12 Canadian Provinces.

When asked how new/increased screening procedures should be applied, six respondents indicated they should be applied to everyone over a certain age who applied for license renewal, 28 (including Massachusetts) felt they should be applied only to a subset of "high risk" drivers that would likely include a disproportionate share of older drivers – who have been referred through a variety of mechanisms, and 26 indicated that both groups (over a certain age and "high risk") should undergo the additional screening. Respondents were then asked to set aside consideration of cost or time associated with additional screening procedures to answer the additional questions. The great majority of respondents felt the following licensing practices were feasible:

- Graduated de-licensing (though in some cases it would require changes in legislation);
- Public outreach/community education program for drivers to educate them about aging and safe driving practices;
- Modification of existing vision screening to incorporate more reliable/accurate techniques;
- Modification of practices so lower levels of vision test performance (20/80 or 20/100) would result in license restrictions rather than revocation;
- Incorporation of testing for vision skills other than static visual acuity (such as dynamic visual acuity and contrast sensitivity);

- Testing for additional measures beyond vision that might include measures of attention, perception, memory, decision-making, and situational awareness;
- Testing to asses functional capabilities of someone based on referral without having to wait for the end of the renewal cycle for license revocation/restrictions based on test results (Massachusetts was one of only two states who said this would not be feasible);
- Conforming to a set of uniform standards for referral of drivers to a screening process based on diagnosis of medical conditions;
- Tailor retesting nature and frequency to address specific medical conditions such as dementia, stroke, Parkinson's etc.;
- Allow for friends or family of an older person to refer them for screening, even if they have not been diagnosed by a doctor as being functionally impaired;
- Implement a referral mechanism to be used by counter staff at licensing agencies based on a checklist, questions, etc. that could be applied to those who appear before them for relicensing; and
- Tailor road-tests to specifically consider the driving skills that are likely to be most impacted by the type(s) of functional impairment identified for the driver being tested.

Just over half of licensing agencies indicated that the cost of additional efforts would have to be substantially or completely offset by other savings within the department; the remaining agencies were relatively evenly divided between those who felt that half of the costs would need to be offset and would be supplemented by safety benefits and those who felt the safety benefits alone were justification enough for implementing such measures. Additionally, the responding agencies were evenly divided across four categories when identifying the greatest amount of time that these additional measures could take for practical implementation: 1) under 15 minutes, 2) 15 to 30 minutes, 3) 30 to 45 minutes, or 4) 45 minutes to one hour (or more).

4.2.2 Current State Policies for Older Driver Licensing

While it is important to continue to work towards an understanding of what licensing agencies might be willing to implement, it is also important to understand what practices and policies are currently in place for licensing older drivers.

The Insurance Institute for Highway Safety monitors the licensing practices in place for each state (30). TABLE 4.1 and TABLE 4.2 provide an overview of practices implemented by each state and the District of Columbia. Twenty-four states have no special safety provisions for older drivers. They are licensed under essentially the same regulations and policies licensing all drivers regarding renewal processes. In most of these states, the renewal cycle is 4 or 5 years. The one exception is Wisconsin where the renewal cycle is eight years. These states are the following: Alabama, Arkansas, Connecticut, Delaware, Kentucky, Massachusetts, Michigan, Minnesota, Mississippi, Nebraska, Nevada, New Jersey, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Vermont, Washington, West Virginia, Wisconsin and Wyoming.

There are several notes to consider for these states. In Connecticut drivers over the age of 65 may choose either a two or six year renewal cycle (compared to four or six years for non older drivers) and are asked to appear in person to renew. However, they may cite hardship in appearing and can then renew by mail. Both Minnesota and Massachusetts have licensing laws that specifically prohibit licensing agencies from treating drivers differently based solely on age. Nevada has similar laws, though drivers over the age of 70 who are renewing by mail must include a medical report. In Oklahoma, drivers age 62 to 64 pay a reduced fee and drivers over the age of 65 pay no fee. Licenses for Tennessee drivers over the age of 65 do not expire.

Ten states have an accelerated renewal process as the only special provision for older drivers. In these states, the renewal cycle is one to four years less than for other drivers; the age at which the accelerated renewal process is applied ranges between 63 and 75 years old. In some states, drivers have a choice regarding the length of their renewal cycle but older drivers are required to renew at the most frequent interval. For example, Idaho allows drivers age 21 to 62 to renew every four or eight years, while drivers age 63 or older are required to renew every four years. States with only accelerated renewal processes for older drivers are the following: Hawaii, Idaho, Indiana, Iowa, Kansas, Missouri, Montana, New Mexico, North Carolina, and Rhode Island.

Nine states and the District of Columbia have no accelerated renewal processes but do have other provisions associated with licensing older drivers. Three states require the older driver to appear in person to renew (cannot renew by mail); five states require the older driver to pass a vision test; one state requires a road test for drivers age 75 or older; and the District of Columbia requires a vision test and statement from a physician certifying the driver as competent to drive and may require a reaction test. The ages at which these special provisions are instituted range across states from 50 to 80. States with no accelerated renewal but other provisions are the following: Alaska, California, District of Columbia, Florida, Louisiana, Maryland, New Hampshire, Oregon, Utah and Virginia.

It should be noted that Maryland licensing law prohibits licensing agencies from treating older drivers different and the age requirement for vision testing at the time of licensing in Maryland is 40 or older. Additionally, there are special provisions for older drivers age 70 or older who are applying for an initial license (rather than renewing).

The remaining seven states have accelerated renewal processes as well as other provisions for older drivers. Of these seven states, three have accelerated renewal and prohibit renewal by mail, three have accelerated renewal cycles and require a vision test, and one has accelerated renewal and requires a road test. The renewal cycles for these states are accelerated by 2 to 5 years and the ages to which these accelerated renewals are applied range from 60 to 85. States that have accelerated renewal as well as other special provisions are the following: Arizona, Colorado, Georgia, Illinois, Maine, South Carolina, and Texas.

TABLE 4.1 Summary of Practices by Scope of Safety Provisions

Scope of Provisions	Number of States	States	Ages Provision Takes Effect	Notes
No Special Provisions for Older Drivers	24	AL NY AR ND CT OH DE OK KY PA MA SD MI TN MN VT MS WA NE WV NV WI NJ WY	NA	• MN, MA, and NV have laws prohibiting age-based provisions. • OK and TN reduce fees for older drivers.
Accelerated Renewal Only	10	HI MO ID MT IN NM IA NC KS RI	63 to 75	In some cases, accelerated renewal simply requires drivers to abide by most frequent renewal cycle option when other drivers have choice of renewal cycle length.
No Accelerated Renewal but Other Provisions	10	AK MD CA NH DC OR FL UT LA VA	50 to 80	• 3 require appearance in person to renew. • 5 require vision test. • 1 requires road test. • 1 requires vision test & physician statement of competency to drive.
Accelerated Renewal and Other Provisions	7	AZ ME CO SC GA TX IL	60 to 85	• 3 accelerate renewal and require appearance in person. • 3 accelerate renewal and require vision test. • 1 accelerates renewal and requires road test.

TABLE 4.2 Summary of Practices by Type of Safety Provisions

Type of Provision	Number of States	States	Ages Provision Takes Effect	Notes
No Special Provisions for Older Drivers	24	AL NY AR ND CT OH DE OK KY PA MA SD MI TN MN VT MS WA NE WV NV WI NJ WY	NA	• MN, MA, and NV have laws prohibiting age-based provisions. • OK and TN reduce fees for older drivers.
Accelerated Renewal	17	AZ CO GA HI ID IL IN IA KS ME MO MT NM NC RI SC TX	60 to 85	In some cases, accelerated renewal simply requires drivers to abide by most frequent renewal cycle option when other drivers have choice of renewal cycle length.
Vision Testing	8	DC MD FL OR GA UT ME VA	50 to 80	Some allow vision test conducted by physician.
Required to Appear in Person for Renewal	5	AK CA CO LA TX	61 to 79	None
Road Test Required	2	IL NH	75	None
Other	1	FL	70	• May be required to take a reaction test. • Requires statement from physician certifying physical and mental competency to drive.

4.2.3 Massachusetts Licensing Policy

Massachusetts licensing policy is governed by Massachusetts General Laws (MGL) Chapter 90, Section 8. The law states that anyone may apply for a driver license unless their license has been suspended or revoked. Beyond minimum age requirements, the law specifically states "Before a license is granted pursuant to this section, the applicant shall pass such examination as to his qualifications as the registrar, without discriminating as to age, shall require…(53)"

While the law specifies that age cannot be used in licensing, the most obvious exception to this language has been the implementation of junior operating licensing policy that outlines the process and age milestones at which young drivers may progress through the licensing process from initial permitting at age 16 to full licensure at 18.

The Junior Operator License (JOL) law which introduced graduated licensing for young novice drivers was initially implemented in 1998 in Chapter 220 of the Acts of 1998 (56). In addition to including restrictions that are gradually removed as the new, young driver gains experience, drivers operating under JOL are subject to stricter penalties for some violations such as speeding, racing, and alcohol or drug violations (54). Enhanced penalties associated with alcohol or drug related violations continue between the ages of 18 and 21 even though the driver is eligible for full licensure at 18. Restrictions associated with the JOL as it was passed in 1998 included passenger restrictions (no passengers under age 18 for the first 6 months), time restrictions (no driving between the hours of 12:30 and 5:00 AM), vehicle restrictions (no operation of a vehicle requiring a commercial drivers license), and license suspension for speeding, racing, alcohol or drug violations. In January 2007, a revised Junior Operator Bill was signed into law. This law enhanced penalties associated with failure to comply with JOL rules and also placed responsibility for oversight of driving schools under the purview of the Registry of Motor Vehicles (55).

4.3 Possible Practices for Older Driver Licensing Policy

Though there may be little in the way of consensus as to the exact mechanisms that should be implemented for the effective and fair assessment of older driver safety at the point of licensure, there seems to be agreement on the need for a two-tier system. The first tier, screening, should be implemented to uniformly identify drivers who should undergo further evaluation (50, 51). Screening should not be used to make final licensing decisions (51). The second tier should consist of more detailed, more expensive tests that can be used to determine driving impairment, make licensing decisions, recommend or require additional training, and identify opportunities for remediation (50, 51).

A great deal of the research focused on effective driver licensing policy focuses on the physical and mental capacity of older drivers. The recommended use of MABs, programs that allow friends and family to recommend review of an older person's driving capacity, and other similar practices pay special heed to the second tier of older driver licensing practices. There is less information available on models for screening processes. For example, the AAA Foundation for Traffic Safety's North American Licensing Policies Workshop yielded "Best Practices Guidelines" that included standardized education and guidelines for clinicians, police, and licensing personnel on fitness-to-drive issues; incentives for and training to MAB members; and resources to assist older drivers in sustaining mobility even after they are no longer able to drive (51).

It may be that recommendations for medically-based fitness-to-drive tests are more plentiful than other options because there is more research in this area. This is evident from the same document's identification of "Research Needs" which include designing and testing assessment tools, determining whether the results yielded from assessment tools are clinically meaningful, and understanding how applicable these assessment tools may be at the individual driver level (51). Medically-based assessments are specific to individuals and require a detailed understanding of the physical and mental conditions being assessed. Screening tools, by nature, cannot employ that level of detail or require similar skill sets and are therefore more difficult to relate at the individual driver level.

4.3.1 National Highway Traffic Safety Administration (NHTSA) Model Driver Screening and Evaluation Program

In 1996, NHTSA undertook a research project to identify the limitations associated with aging and normal disease pathologies that might impact an older person's ability to drive and to identify test procedures that could be feasibly implemented by licensing agencies (52). This research project, much like others that have sought to identify mechanisms for identifying high risk older drivers, focused on medical and psychological impairment associated with aging. Specifically, the project relied on a panel of experts to define a list of critical issues related to safe driving (sensory function, attention/perception, and medical factors including dementia). In addition, these experts were asked to identify gaps in existing research that should be considered as part of this program. Subsequently, a survey was completed to 62 licensing jurisdictions (50 states and 12 Canadian provinces) to identify which of the previously identified research areas may have had scientific merit but little or no practical application.

Based on the information gathered, a pilot program was designed and tested in Maryland, through a collaboration with the Maryland Motor Vehicle Administration, MAB, and the Maryland Research Consortium which included representatives from Government, universities, non-profit organizations, and the private sector. In this pilot, specially trained staff implemented a battery of tests at licensing outlets and community locations; data collected included older persons who were visiting the licensing agencies for license renewal, older persons who were referred for medical evaluation because of suspected impairment, and some who lived in a residential community for older persons who used a mobile licensing facility in their residential development.

The safety measures considered to evaluate effectiveness of the screening processes were three types of crashes (all crashes, at-fault and unknown fault crashes, and at-fault only crashes) and three type of violations (all moving violations, all moving violations except speeding, and all moving violations except speeding and occupant restraint). Results indicate that screening methods could be used effectively and efficiently, especially in four areas: 1) directed visual search, 2) information processing speed for divided attention tasks, 3) ability to visualize missing information in an image, and 4) working memory. Lower limb strength and head/neck mobility were also identified as critical measures. The research also reinforced the need to identify mechanisms for addressing functional loss and providing alternative means of mobility for those who are no longer able to drive.

4.3.2 Medical Advisory Boards (MABs)

NHTSA, through the American Association of Motor Vehicle Administrators (AAMVA), conducted a survey of the 51 licensing agencies in the United States to understand the medical review processes used in each state (56). Licensing agencies were asked to complete a survey and to participate in a follow-up telephone interview. Based on the information gathered during this process, as well as from a review of state licensing statutes, a qualitative review and comparison of 45 licensing agencies medical review processes was conducted and barriers for implementation of certain strategies were identified.

Although absolute consensus was not generally reached regarding the roles, responsibilities, and best practices for MAB, there was general agreement on several issues specifically related to the roles and responsibilities of state sanctioned agencies, practices, and review boards.

Medical Advisory Board (MAB) Structure and Responsibilities

- MABs should review individual cases for fitness to driver and establish guidelines for licensing, rather than only reviewing case where a license has been denied and an appeal has been filed. Review recommendations should be individual, rather than requiring consensus of the panel.
- Guidelines should be used to ensure some level of consistency but case review by physicians should be used for more complex cases.
- MAB physicians should be compensated at a rate commensurate with the hourly rates they would charge for services elsewhere, rather than the minimal compensation

currently associated with review in many states. Ideally, the physicians associated with MABs should be employed as full time staff members at the state licensing agency.

- In-person and video interviews between members of the MAB and drivers should be considered as part of the process making fitness to drive decisions.

Licensing Review Rules and Policies

- Rules associated with medical review of drivers should not be in statute, but should be part of the Code of State Regulations to allow for ease of changes based on the release of new information and medical data.
- Restricted licenses should be considered to allow drivers to drive in safer conditions (daylight, limited area, and limited speeds).
- After a certain age, drivers should be required to appear in person for license renewal and the renewal cycle should be shortened based on driver age.
- Drivers over a certain age should be subject to functional screening at license renewal. Where resources prevent this type of screening, subpopulations (for example, reexamination drivers) should be screened or partnerships should be formed to provide outside screening with results reported to the MAB.

Licensing Agency Responsibilities and Scope of Services

- Licensing agencies should expand their scope beyond traditional responsibility for public safety to include mobility for drivers with medical conditions and functional impairments. Services provided by licensing agencies for counseling, education or other aid should be locally-based rather than state based.

- State licensing agencies should work with police departments to provide education for police officers to aid them in identifying at-risk drivers based on medical conditions and functional impairment.
- Drivers with mild dementia who are allowed to keep their driving privileges should be retested every three to six months and should be required to pass several road tests to maintain driving privileges.

Although absolute consensus was not reached, these concepts should be used as the foundation for developing guidelines and programs at the state and national levels.

4.3.3 Driver Licensing Policies and Practices Database

In June 2009, a project report for the AAA Foundation for Traffic Safety project on "Driver Licensing Policies and Practices: Gearing up for an Aging Population" was finalized (57). This report outlines the process associated with the development of a database that includes information on older driver licensing programs across the United States. Initially designed to identify best practices, the project quickly shifted direction upon the realization that more important than best practices was the documentation of programs and policies currently in place across the United States. Researchers found that there was no single place for licensing agents and others involved in the development of older driver safety policy and programs to understand what had been implemented in other states.

The outcome of the project is two Driver Licensing Policies and Practices (DLPP) databases with a target audience of licensing agencies. One database includes current licensing policies and practices while the other identifies "Noteworthy Initiatives". The database includes 48 programs that were classified into six areas: 1) Identifying at risk drivers, 2) Driver assessment and remediation, 3) Driver education and awareness, 4) Support to non-drivers, 5) Comprehensive programming and collaborations, and 6) Program evaluation.

Several initiatives associated with driver licensing practices at the licensing agency level may be of special interest. The most comprehensive driver testing system appears to be in California (58). The California Three-Tier Pilot Driver Assessment Program is based on three levels of testing regardless of driver age. The first consists of screenings for visual, cognitive, and physical function. The second, which is taken by those who fail the first, is a computer-based test of perception-response time and also includes a written knowledge test. Those who badly fail the first or moderately fail both the first and second may take a third behind-the-wheel driving test. This program is based largely on research and has been extensively evaluated at each step. Full evaluation reports are expected in September 2009 (Process Analysis Report) and December 2011 (Outcome Analysis Report). Maryland also implemented a multi-tiered approach as part of the NHTSA Model Driver Screening and Evaluation Program previously described.

Several states have policies that require additional road tests (58). In Iowa, any driver (regardless of age), may be required to take a driving test to renew their license. In Minnesota and Kansas, drivers deemed medically-at-risk may be required to take an additional road test. One of the challenges associated with these road tests is that many older drivers limit their driving to familiar streets. In states such as these with large rural areas, testing centers are often in more densely populated areas. A driving test for an older driver who is most familiar with – and limits their driving to – rural roads may be an unreasonable assessment of their fitness to drive. Some states have addressed this challenge by allowing drivers to be tested near their homes.

Other approaches to addressing licensing for older drivers focus more on assessment of medical (physical, cognitive, etc) ability to drive and include education for licensing agents, training for the enforcement community, and public education campaigns/information.

4.3.4 Graduated Licensing for Older Drivers

The concept of licensing individuals in stages is a practice that has been widely accepted and applied to young drivers through graduated licensing programs. A similar practice, graduated licensing for older drivers, has been presented as an option for restricting driving as drivers age to limit older driver exposure to the riskiest driving situations. The idea of graduated driver licensing was defined by the American Association for the Advancement of Retired Persons (AARP) in their 1993 booklet "a driver's license that for one reason or another has a restriction attached to it. To operate a motor vehicle holders of such a license must… restrict their driving practices in some well-specified fashion (60)." This of graduated licensing for older drivers was initially introduced by Dr. Patricia Waller in 1988 (61).   Interestingly, there has been relatively little research conducted on the effectiveness of graduated licensing for older drivers or the use of license restrictions rather than revocation.

The implementation of this method of older driver licensing has been applied in some states. A study was conducted in California in 1997 of a small sample (65) of older drivers who were reexamined and 59 of their friends and family (62). Twenty-five of those re-examined were allowed to keep their licenses, 30 had their licenses revoked and 10 received license restrictions. The study considered what level of difficulty these drivers indicated in reaching six categories of “necessary” destinations, as well as the reactions associated with the decision made regarding their license status. Overall, the study found that restriction was less stressful than revocation for the driver as well as friends and family. However, the study also noted that a larger study was necessary to draw add more definitive information on types of restrictions, restriction practices, etc.

Restricted licensing for older drivers was also studied by the University of North Carolina Highway Safety Research Center in 2000 (61). This study found that very few older drivers (approximately two percent) had restrictions on their licenses beyond corrective lenses, and that many of those restrictions were the result of a failed vision test or MAB recommendations rather than license examiner recommendations. Those older drivers that did have restrictions beyond corrective lenses had a higher proportion of crashes than those who did not. Researchers concluded that there was potential benefit in terms of safety associated with restricting older drivers, though it should happen in conjunction with older driver education, evaluation, and training (61).

A 2008 report published by the AAA Foundation for Traffic Safety examined the effectiveness of a voluntary state reporting law in Missouri (63). This report noted the possible use of license restriction over license revocation in some cases, especially since this has the potential to more specifically address the weaknesses of older drivers without having to apply a universal pass/fail approach to licensing.

The DLLP database identifies the types of restrictions used by licensing agencies (57). According the table on types of conditions or restrictions on license, 46 states and the District of Columbia apply some sort of restriction. It should be noted that the table is unclear as to who may be restricted though it appears these apply to those issued conditional licenses based on medical fitness. The following is an overview of the types of restrictions they may issue and the number of states who issue that type of restriction:

- Daytime/daylight (46),
- Lower speed/No freeway or limited access (32),
- Within specified distance from home (32),
- For specified length of time (12),
- Specified destinations or trip purpose (13),
- Passenger presence required (15),
- Passenger presence prohibited (4), and
- Required vehicle equipment (44).

Massachusetts' only restrictions are daytime/daylight driving, passenger presence required, and required vehicle equipment.

4.4 Recommendations for Older Driver Licensing Policy in Massachusetts

Based on the information gathered regarding existing licensing policy for older drivers in Massachusetts and practices employed by other states, it becomes apparent that there is opportunity for the Massachusetts Registry of Motor Vehicles to examine the Commonwealth's licensing practices around older drivers. Prior to reviewing the potential opportunities for changes to licensing practice, it is important to note several factors that should be considered.

- Current Massachusetts legislation prohibits special licensing practices based solely on age. Though this has been used as a reason for the lack of older driver specific policies to date, it is evident that there are mechanisms for developing age-based licensing policy. Graduated licensing for teen drivers is a prime example of this.
- These opportunities for changes to licensing practice may require additional resources for implementation. Consideration of how they may be implemented require examination not only of their effectiveness, but also feasibility.
- Screening practices that may be used in the application of any license policy changes should be standardized and should include extensive training for license examiners.
- Any practice that may restrict or all together revoke and older drivers driving privileges must be considered in conjunction with the means necessary to ensure the maintenance of mobility. This is important not only because maintaining older person mobility is critical for quality of life, but also because the perceived mobility of an older driver may influence the license examiner's decision-making process.
- None of these opportunities should be considered as independent solutions. They are most effective when implemented in conjunction with ongoing education and program evaluation.

- Recent research has led to a compilation of potential practices associated with licensing policy and program. This database is rich with information not only regarding licensing but also addressing mobility and education initiatives.

Given these, the following practices should be considered for potential implementation in Massachusetts.

- The current MAB practices and policies should be reviewed in relation to the recommendations outlined in the NHTSA Model Program report. Subsequently, changes to Massachusetts MAB practices should be made in accordance.
- An in-depth review of all of the programs include in the DLLP database should be conducted and assessed for feasibility of implementation in Massachusetts given current restrictions on age-based licensing practice. Consideration should be given to the need for research-based programs as well as the importance of program evaluation.
- The opportunity to implement "de-graduated" or restricted licensing for older drivers should be examined. This examination should include determinations not only regarding what the restrictions might be, but also who will be responsible for making decisions about when and to whom they will be applied. The implementation of the Massachusetts graduated licensing program for teen novice drivers may be used as a foundation for understanding how age-based practices can be implemented given the legislative framework currently in place.
- In accordance with recommendations in the NHTSA Model Program report, older drivers should be required to appear in person for license renewal.

These recommendations all work towards the implementation of licensing practices that account for an individual older driver's needs and skills rather than attempting to implement standard practices based solely on age.

In addition to understanding licensing policy, it is important to understand the relationship between injuries sustained by older people involved in crashes and potential responsibility borne by the public for the treatment of those injuries. This is especially important given the fragility of older persons (and therefore greater likelihood of injury) and the potential for publicly funded insurance being responsible for treatment of those injuries. This will be explored in the following chapter.

CHAPTER 5

HOSPITAL CHARGES FOR VEHICLE OCCUPANTS IN OLDER DRIVER CRASHES

This chapter focuses on the analysis and results associated with the consideration of Hypothesis 3: *Charges associated with treating the injuries of older vehicle occupants (drivers and passengers) are higher than charges associated with treating injuries for non-older occupants of vehicles involved in the same crash. Additionally, treatment for these injuries are more likely to be charged to public insurers placing the fiscal burden for older vehicle occupants on society in general.* These analyses are important as policy is often based on an understanding of cost and benefit. Examining charges associated with the treatment of older vehicle occupants provides an initial foundation for such an understanding.

5.1 Analysis and Results

As described in Chapter 3, Massachusetts crash and hospital data for 2005 were linked using probabilistic linkage methodologies through the use of NHTSA's CODES program. The resulting linked pairs included crash participants who were linked either to an emergency department record or to an inpatient record; if someone is initially treated in an emergency department and then admitted for inpatient care, their hospital record appears only as an inpatient record but includes information on all treatment. TABLE 5.1 provides an overview of the number of linked pairs for each of the five imputations along with how many crash participants linked to an emergency department record and how many linked to an inpatient record. It should be noted that this includes all crash participants regardless of age or role.

TABLE 5.1 Massachusetts 2005 CODES Linkage Imputation Overview

Imputation Number	Total Linked Records	Crash Participants Linked to Emergency Department Record	Crash Participants Linked to Inpatient Record
1	43,040	40,742	2,298
2	42,911	40,591	2,320
3	42,965	40,649	2,316
4	42,886	40,593	2,293
5	42,973	40,669	2,304

From these linked records, a subset of data was selected for analysis. This set included drivers only from crashes involving an older driver. Two age groups were considered: older drivers (age 65 to 98) and a comparison group (drivers age 25 to 49). By limiting the subset to only those crashes involving an older driver, it ensures that the drivers, regardless of age, were involved in the same crashes, removing the possibility that differences in charges or payer source may be related to differences in the crash circumstances (crash type, severity, etc). Additionally, by selecting only drivers, the possibility that differences in injuries are associated with seating position is eliminated. Any records that had null values for any of the following fields were removed from the analysis subset: sex, age, payer type, charge, maximum driver age (used to identify older driver crashes), and person type (to identify drivers). TABLE 5.2 outlines the number of linked records for each of the age groups included in the analysis subset. Note that there were insufficient number of inpatient records for older drivers, so these data sets include only emergency department hospital data.

TABLE 5.2 Number of Records in Analysis Subset

Imputation Number	Older Driver Emergency Department Linked Records		Comparison Driver Emergency Department Linked Records	
Sex	Female	Male	Female	Male
1	1,032	876	640	532
2	1,028	974	632	524
3	1,023	871	635	517
4	1,025	868	637	522
5	1,024	870	641	520

5.2 Evaluation of Charges Associated with Injury Treatment

Using the CODES dataset previously described, charges associated with the treatment of injuries sustained by vehicle occupants in older driver crashes were examined. Older vehicle occupants were defined as those age 65 to 98. The comparison group of vehicles occupants involved in older driver crashes were those age 25 to 49. Due to the insufficient number of inpatient records, focus was placed on emergency department charges. It should also be noted that only those vehicle occupants who are injured in the crash will be included in the CODES data set. However, there may be some occupants involved in the crash who are not injured and they are not included in the assessment.

5.2.1 Emergency Department Charges for Older Drivers by Payer Source

When examining emergency department charges for older drivers by payer source type and sex, several notable findings emerge. The first is that while older drivers are eligible for Medicare, the great majority of those included in the analysis dataset we associated with private insurance; public insurance actually accounted for the fewest cases of the three payer source types including self pay.

The second notable finding is that for all three payer source types, median emergency department charges associated with female older drivers were significantly higher than the emergency department charges for males in the same payer source type and for all three groups, more females were injured than males. For older drivers under private payer types, the difference between male and female median charges was statistically significant but small ($933 for females and $913 for males). The difference between median emergency department charges for males and females was far greater for those under public payer sources ($919 for females and $777 for males). This may be due, in part, to the smaller sample size for public payer source cases; however, the more notable difference between females and males covered by public payer sources is still worthy of further consideration. Figure 5.1 provides an overview of findings while TABLE 5.3 and TABLE 5.4 show median charges for males and females by imputation.

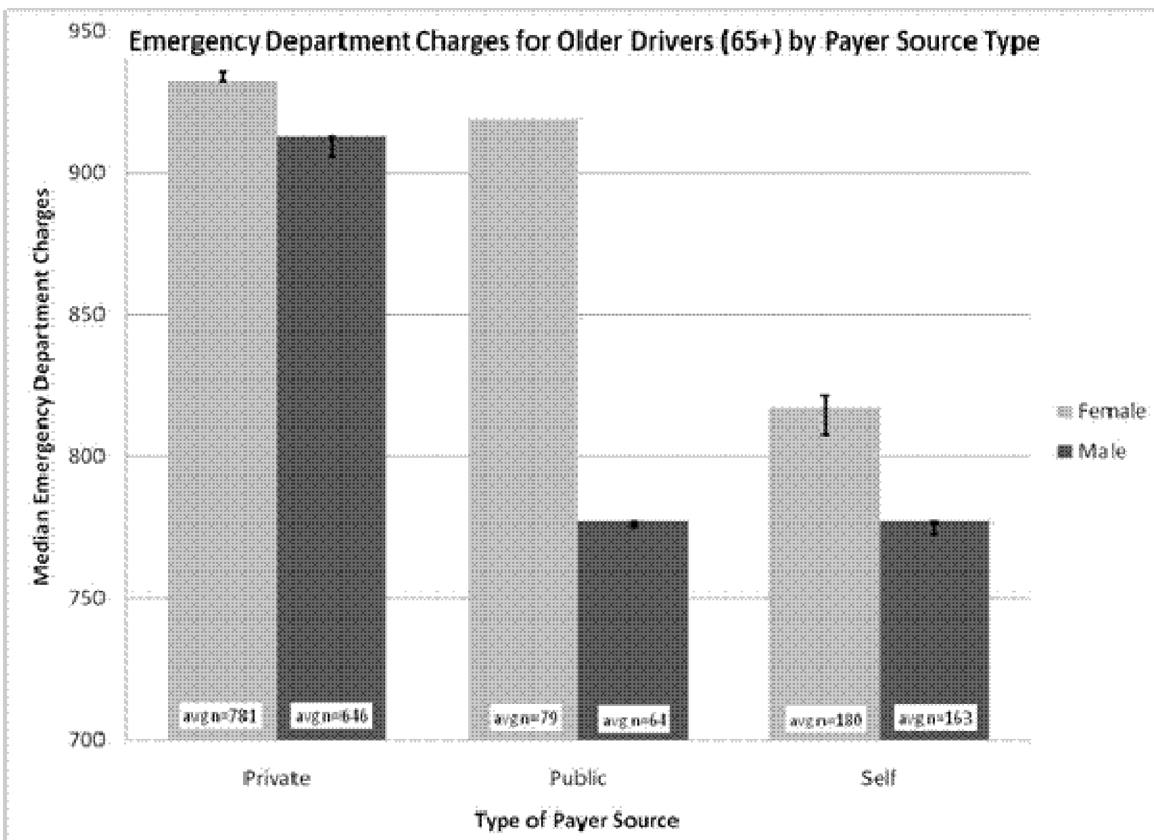

Figure 5.1 Emergency Department Charges for Older Drivers by Payer Source Type

TABLE 5.3 Median Emergency Department Charges for Older Female Drivers by Imputation

Female								
Payer Source Type	Imputation					Median	25th Percentile	75th Percentile
	1	2	3	4	5			
Private	$932.50	$936.00	$936.00	$932.00	$932.00	$932.50	$932.50	$936.00
Public	$919.00	$900.50	$919.00	$941.00	$919.00	$919.00	$919.00	$919.00
Self	$825.00	$808.00	$817.00	$808.00	$822.00	$817.00	$808.00	$822.00

TABLE 5.4 Median Emergency Department Charges for Older Male Drivers by Imputation

Male								
Payer Source Type	Imputation					Median	25th Percentile	75th Percentile
	1	2	3	4	5			
Private	$913.00	$906.50	$913.00	$906.50	$913.00	$913.00	$906.50	$913.00
Public	$777.00	$777.00	$775.50	$792.00	$775.50	$777.00	$775.50	$777.00
Self	$769.00	$777.00	$782.00	$773.00	$777.00	$777.00	$773.00	$777.00

5.2.2 Emergency Department Charges for Comparison Group Drivers by Payer Source

When conducting the same analysis reported in Section 4.4.1 for the comparison group, the results were different. Like the older drivers, most of the cases included in the analysis dataset were associated with private payer source. However, unlike the older drivers, males had significantly higher median emergency department charges for private and self payer source types. This is especially interesting for private payer source cases where more females were injured than males, yet the median emergency department charge was lower for females than for males. Interestingly, for public payer source cases, females had higher emergency department charges. Figure 5.2 provides an overview of findings while TABLE 5.5 and

TABLE **5.6** show median charges for males and females by imputation.

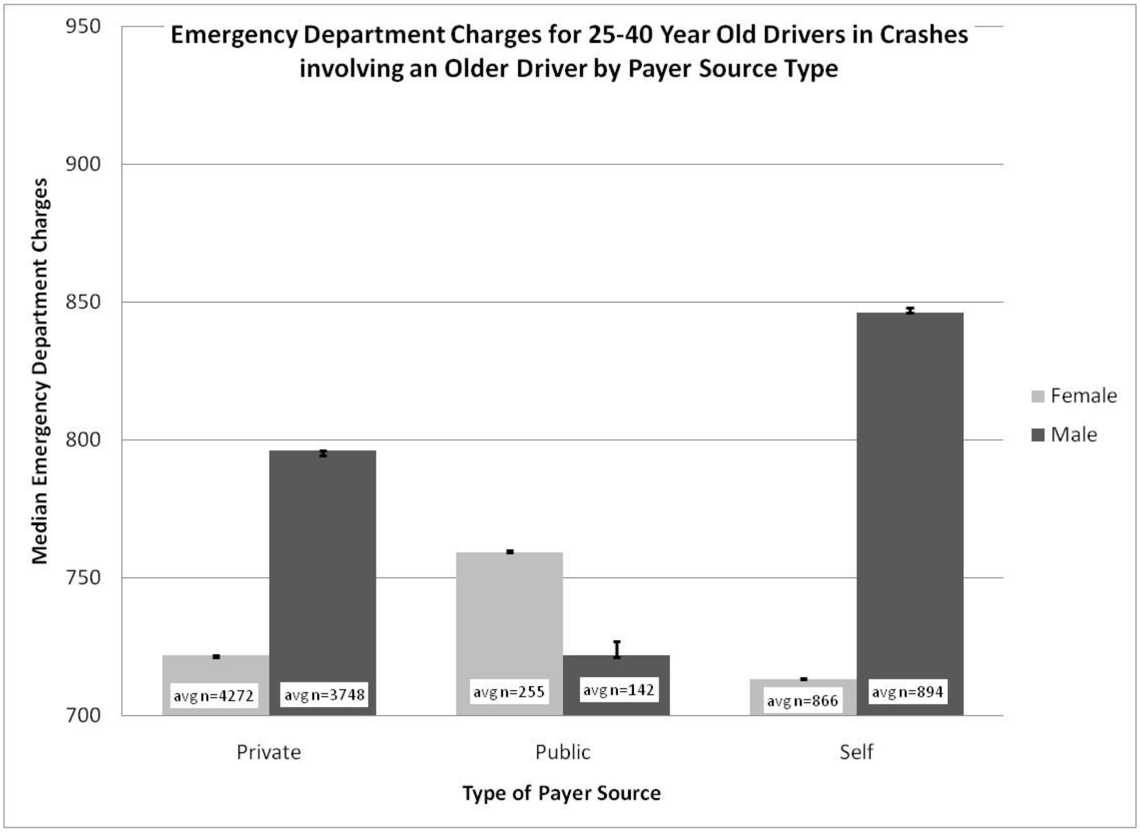

Figure 5.2 Median emergency department charges for comparison drivers.

TABLE 5.5 Median Emergency Department Charges for Comparison Female Drivers by Imputation

Female								
Payer Source Type	Imputation					Median	25th Percentile	75th Percentile
	1	2	3	4	5			
Private	$722.00	$721.00	$722.00	$721.00	$722.00	$722.00	$721.00	$722.00
Public	$759.00	$760.00	$761.00	$759.00	$759.00	$759.00	$759.00	$760.00
Self	$713.00	$713.50	$713.50	$713.00	$713.00	$713.00	$713.00	$713.50

TABLE 5.6 Median Emergency Department Charges for Comparison Male Drivers by Imputation

Male								
Payer Source Type	Imputation					Median	25th Percentile	75th Percentile
	1	2	3	4	5			
Private	$793.00	$796.00	$796.00	$796.00	$794.50	$796.00	$794.50	$796.00
Public	$722.00	$720.50	$727.00	$741.00	$721.00	$722.00	$721.00	$727.00
Self	$848.00	$846.00	$846.00	$850.00	$843.00	$846.00	$846.00	$848.00

5.2.3 Assessment of Emergency Department Charges for Older and Comparison Drivers Groups Drivers

In addition to the results noted in the previous two sections, comparing the older and comparison driver groups more directly yields additional findings worth noting. As shown in, for all combinations of payer source and sex except self-pay males, median charges for older drivers were higher than for comparison drivers. In some cases, such as males with public payer sources, the difference between the older driver and comparison groups though significant, are less notable. For other groups, such as females with private payer source, the difference is far more noteworthy. For all three payer source types, the difference between female older and comparison drivers was greater than the difference between male older and comparison drivers. These results are shown in Figure 5.3 and TABLE 5.7.

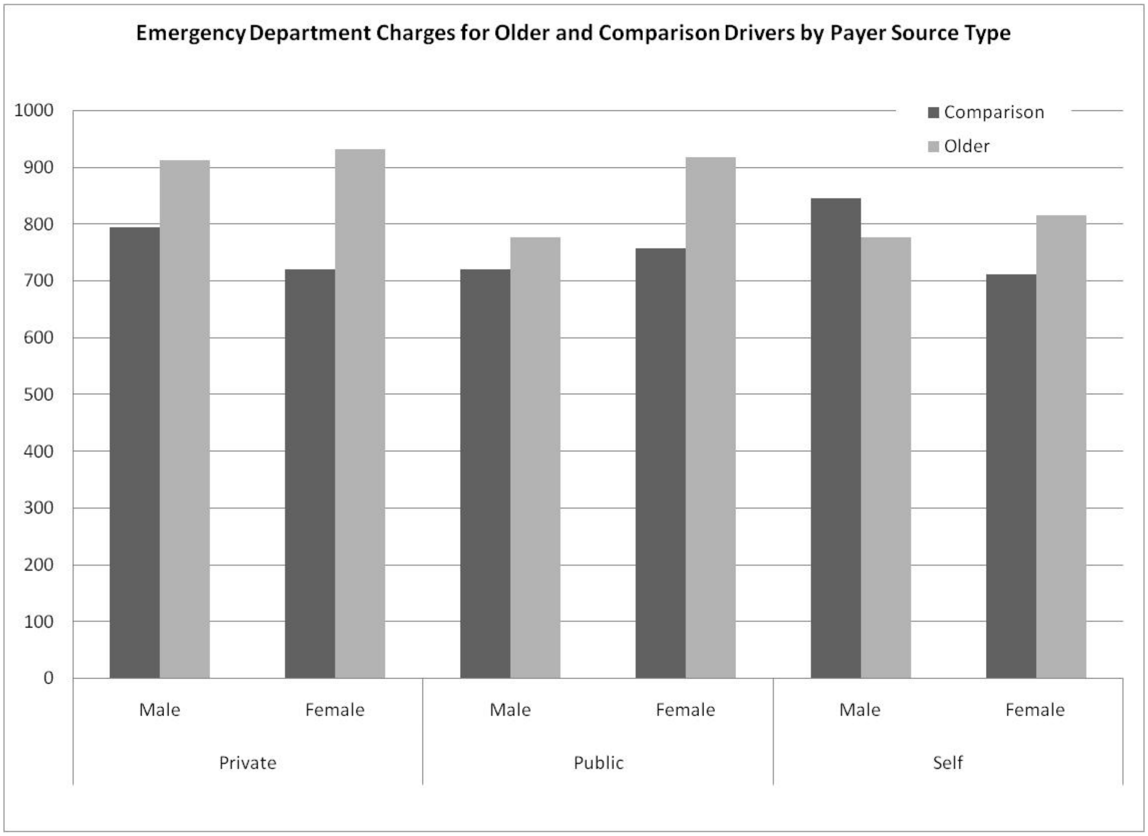

Figure 5.3 Emergency department charges for older and comparison driver groups.

TABLE 5.7 Median Emergency Department Charges for Comparison and Older Drivers by Sex and Payer Source

Payer Source Type	Sex	Median		25th Percentile		75th Percentile	
		Comparison	Older	Comparison	Older	Comparison	Older
Private	Male	$796.00	$913.00	$794.50	$906.50	$796.00	$913.00
	Female	$722.00	$932.50	$721.00	$932.50	$722.00	$936.00
Public	Male	$722.00	$777.00	$721.00	$775.50	$727.00	$777.00
	Female	$759.00	$919.00	$759.00	$919.00	$760.00	$919.00
Self	Male	$846.00	$777.00	$846.00	$773.00	$848.00	$777.00
	Female	$713.00	$817.00	$713.00	$808.00	$713.50	$822.00

5.3 Summary of Findings

The probabilistic linkage of crash and health care data, and subsequent analysis of the resulting dataset, yielded several statistically significant findings. Generally speaking, they pointed to less notable differences across payer sources between the older driver and comparison groups than might have been expected given the availability of public insurance for older drivers. The results also pointed to noteworthy differences between charges associated with males and females.

- Though most older drivers are eligible for public insurance (Medicare), the great majority of older drivers included in the analysis dataset were covered by private insurance.
- For all three payer source types (private, public, and self), more older female drivers were injured than older male drivers and the median emergency department charges for females were higher than for males. This is different than for the comparison group where more females were injured than males but the median emergency department charges were higher for males than for females, except when covered by a public payer source.
- Median emergency department charges were higher for older drivers than for the comparison drivers for all combinations of payer source and sex except self-pay males. For all three payer sources, the difference in median emergency department charges for the older drivers versus comparison drivers was greater for females than for males.

With some understanding of the impact of crashes on injury outcomes for older persons, it then becomes important to focus on older drivers and the opportunity to identify high risk older drivers. This is especially important since, unlike other high risk populations, older drivers are most likely to do harm to themselves. The following chapter begins to examine the relationship between driver history and crash involvement as a first step in identifying high risk older drivers.

CHAPTER 6

RELATIONSHIP BETWEEN INJURY CAUSING CRASHES AND DRIVER CRASH AND CITATION HISTORY

This chapter focuses analyses designed around Hypothesis 2: *Older drivers who are involved in injury crashes exhibit risky driving behaviors prior to becoming older drivers.* Using crash and citation data to understand how older drivers involved in a crash behaved prior to that crash involvement may provide an understanding not only of the general relationship between driving history and crash involvement, but of what specific elements of driving history have the closest relationship to crash involvement.

6.1 Driver Crash History

Prior to the development of the formal crash prediction model, data preparation was necessary that also allowed for the opportunity to establish a base understanding of the relationship between participation in an injury causing crash and crash history. The data preparation process is described in Section 3.4. The results provided in the following sections are based on standard summary information for both 2006 and 2007 data.

TABLE 6.1 provides an overview of the demographic characteristics associated with older ICCDs and non-ICCDs in 2006 and 2007. There are no notable differences for the demographic distributions between 2006 and 2007. Similarly, there are no notable differences between the distributions associated with ICCDs and non-ICCDS. Overall, however, there is a higher percentage of males involved in crashes than females. This is noteworthy since the licensed driver population for Massachusetts drivers age 65 or older is split almost evenly in half.

TABLE 6.1 Demographic Characteristics of Older ICCDs and Non-ICCDs

	2006				2007			
	ICCD		Non ICCD		ICCD		Non ICCD	
	Freq	Per	Freq	Per	Freq	Per	Freq	Per
Age Group								
65 to 69	1,685	29.15%	4,639	31.13%	1,693	31.52%	4,693	32.41%
70 to 74	1,424	24.64%	3,557	23.87%	1,227	22.84%	3,345	23.10%
75 to 79	1,208	20.90%	3,069	20.59%	1,085	20.20%	2,959	20.43%
80 to 84	948	16.40%	2,337	15.68%	839	15.62%	2,182	15.07%
85 or older	515	8.91%	1,302	8.74%	528	9.83%	1,302	8.99%
Sex								
Female	3,273	56.63%	8,375	56.19%	2,950	54.91%	7,981	55.11%
Male	2,457	42.51%	6,370	42.74%	2,315	43.09%	6,245	43.13%
Unknown	50	0.87%	159	1.07%	107	1.99%	255	1.76%

Given the differences in distribution between males and females in this analysis, and the variation between emergency department charges for older males and females, further examination was undertaken of the relationship between sex, crash involvement, and crash history. TABLE 6. 2 shows the distribution of older drivers involved in a 2006 crash by age and sex. There are no notable differences between the age distributions by sex.

TABLE 6. 2 Distribution of Older Drivers in 2006 Crash by Age and Sex

Sex	Age Group	Number of Drivers in 2006 Crash	Percentage of Drivers of that Sex in 2006 Crash
Male	65 to 69	2584	29.3%
	70 to 74	2116	24.0%
	75 to 79	1884	21.3%
	80 to 84	1450	16.4%
	85 or older	793	9.0%
Female	65 to 69	3672	31.5%
	70 to 74	2807	24.1%
	75 to 79	2360	20.3%
	80 to 84	1807	15.5%
	85 or older	1002	8.6%

Figure 6.1 shows the frequency of older drivers involved in a crash in 2006 by age, sex, and number of crashes between 2002 and 2005. For both males and females, approximately 85 percent of the drivers involved in a 2006 crash had not been involved in a crash between 2002 and 2005. Although older females were involved in more crashes in 2006 than older males, the distribution of prior crash history considering age and sex combined is very similar. This is further evidence that while there appear to be differences between crash involvement between males and females, considering age and sex in combination shows little in the way of variation between the two sexes.

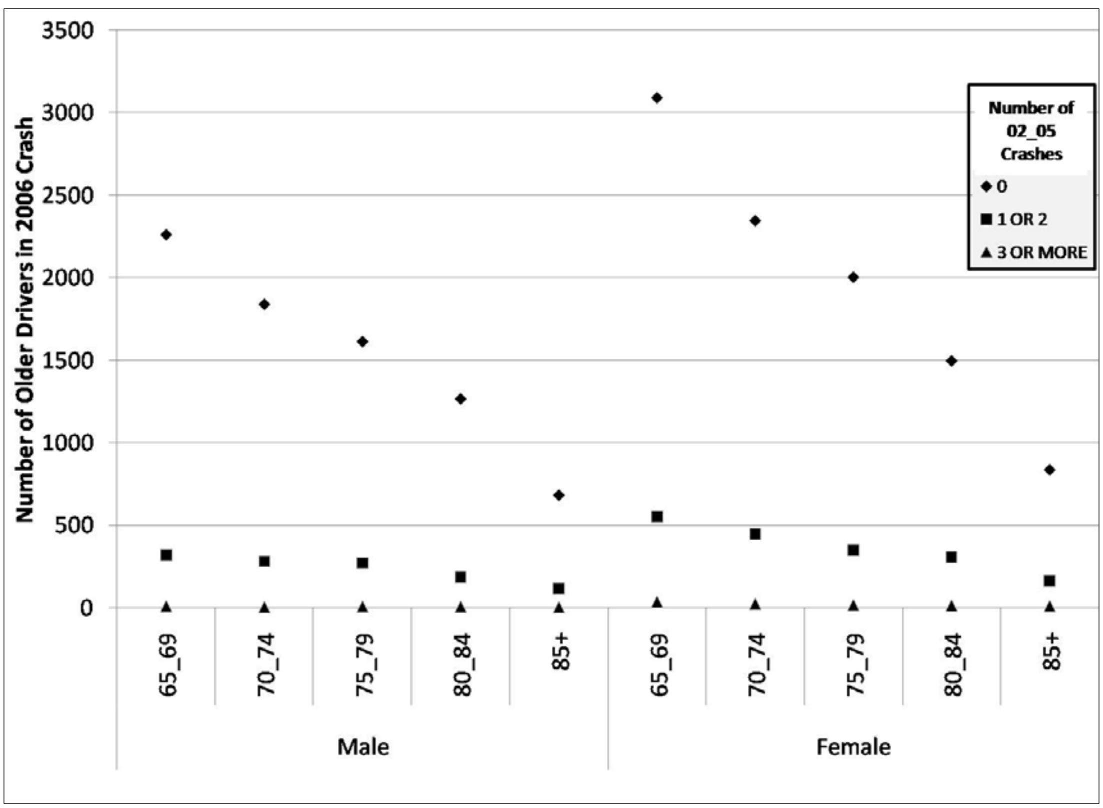

Figure 6.1 Number of older drivers in a 2006 crash by age, sex, and involvement in 2002-2005 crashes.

In addition to these demographic characteristics, the crash profiles provide information on crash characteristics associated with crashes involving these older drivers prior to their crash in either 2006 or 2007. TABLE 6.3 provides an overview of these crash characteristics for drivers age 65 or older involved in a crash in 2006 or 2007. The table provides information for drivers in both injury-causing and non-injury-causing crashes. Recent past for drivers in a 2006 crash includes 2002 to 2005; for 2007 drivers recent past includes 2002 to 2006. As was the case when considering demographic distributions for each of the four drivers categories (2006 ICCD and non-ICCD and 2007 ICCD and non-ICCD), there are no notable differences in recent past crash characteristics.

TABLE 6.3 Crash Characteristics for Recent Past Crashes for 65+ Drivers in 2006 and 2007 Crashes

	2006				2007			
	ICCD		Non ICCD		ICCD		Non ICCD	
	Freq	Percent of Total Crashes	Freq	Percent of Total Crashes	Freq	Percent of Total Crashes	Freq	Percent of Total Crashes
General Crash Information								
Total Crashes	1,158	NA	2,725	NA	1,176	NA	3,242	NA
Injury Crashes	179	15.46%	377	13.83%	198	16.84%	411	12.68%
Intersection Crashes	550	47.50%	1,348	49.47%	544	46.26%	1,512	46.64%
Manner of Collision								
Single Vehicle	101	8.72%	198	7.27%	102	8.67%	251	7.74%
Rear-End	345	29.79%	812	29.80%	360	30.61%	1,003	30.94%
Angle	483	41.71%	1,087	39.89%	457	38.86%	1,268	39.11%
Sideswipe	146	12.61%	357	13.10%	139	11.82%	393	12.12%
Head-On	24	2.07%	78	2.86%	27	2.30%	78	2.41%
First Harmful Event								
Crash with Another Vehicle	778	67.18%	1,827	67.05%	816	69.39%	2,138	65.95%
Crash with Non-Motorist	22	1.90%	56	2.06%	15	1.28%	73	2.25%
Collision with Fixed Object	47	4.06%	103	3.78%	53	4.51%	123	3.79%
Non-Collision	5	0.43%	8	0.29%	1	0.09%	3	0.09%
Other	11	0.95%	32	1.17%	10	0.85%	46	1.42%

TABLE **6.4** provides an overview of the frequency of crash characteristics associated with 2006 and 2007 older ICCDs and non-ICCDs who were involved in at least one crash during prior years. Prior years older drivers in a 2006 crash are 2002 to 2005; for older drivers in a 2007 crash are 2002 to 2006. Percentages are reported as the portion of the total 2006 or 2007 older ICCDs or non-ICCDs (not just those who were involved in a prior year crash). It is interesting to note that one driver, for example, was involved in 24 crashes during the years prior to participating in an injury-causing crash in 2006. As was the case with other examinations of crash history for older drivers in a 2006 or 2007 crash, there were no notable differences across years or in the distributions of ICCDs compared to non-ICCDs.

TABLE 6.4 Crash Characteristics for 2006 and 2007 Older ICCDs

	2006				2007			
	ICCD		Non ICCD		ICCD		Non ICCD	
	Freq	Perc	Freq	Per	Freq	Perc	Freq	Per
Number of Crashes								
1	752	13.01%	1,803	12.10%	727	13.53%	1,856	12.82%
2	126	2.18%	301	2.02%	140	2.61%	435	3.00%
3 to 6	30	0.52%	70	0.47%	36	0.67%	94	0.65%
More than 6	2	0.03%	4	0.03%	2	0.04%	10	0.07%
Number of Injury Causing Crashes								
1	156	2.70%	316	2.12%	159	2.96%	345	2.38%
More than 1	10	0.17%	28	0.19%	14	0.26%	27	0.19%
Number of Intersection Crashes								
1	452	7.82%	1,011	6.78%	399	7.43%	1,087	7.51%
2	24	0.42%	108	0.72%	49	0.91%	138	0.95%
3 to 6	11	0.19%	30	0.20%	10	0.19%	35	0.24%
More than 6	1	0.02%	1	0.01%	1	0.02%	2	0.01%
Number of Single Vehicle Crashes								
1	83	1.44%	184	1.23%	82	1.53%	210	1.45%
More than 1	8	0.14%	7	0.05%	9	0.17%	14	0.10%
Number of Rear-End Crashes								
1	299	5.17%	680	4.56%	296	5.51%	749	5.17%
More than 1	18	0.31%	57	0.38%	25	0.47%	104	0.72%
Number of Angle Crashes								
1	380	6.57%	864	5.80%	362	6.74%	962	6.64%
2	30	0.52%	66	0.44%	30	0.56%	105	0.73%
More than 2	12	0.21%	26	0.17%	9	0.17%	26	0.18%
Number of Sideswipe Crashes								
1	120	2.08%	301	2.02%	121	2.25%	325	2.24%
More than 1	7	0.12%	24	0.16%	9	0.17%	26	0.18%
Number of Head On Crashes								
1	24	0.42%	73	0.49%	25	0.47%	76	0.52%
More than 1	0	0.00%	2	0.01%	1	0.02%	1	0.01%
Number of Collisions with Another Vehicle								
1	573	9.91%	1,335	8.96%	569	10.59%	1,445	9.98%
2	55	0.95%	146	0.98%	81	1.51%	208	1.44%
More than 2	20	0.35%	52	0.35%	22	0.41%	62	0.43%
Number of Collisions with a Non-Motorist								
1	22	0.38%	56	0.38%	12	0.22%	65	0.45%
2	0	0.00%	0	0.00%	1	0.02%	2	0.01%
Number of Collisions with a Fixed Object								
1	45	0.78%	95	0.64%	44	0.82%	111	0.77%
More than 1	1	0.02%	4	0.03%	4	0.07%	6	0.04%
Number of Non-Collision Crashes								
1	3	0.05%	8	0.05%	1	0.02%	3	0.02%
2	1	0.02%	0	0.00%	0	0.00%	0	0.00%
Number of Crashes with Another First Harmful Event								
1	11	0.19%	28	0.19%	10	0.19%	38	0.26%
More than 1	0	0.00%	2	0.01%	0	0.00%	3	0.02%

6.2 Driver Citation History

In addition to identifying the relationship between involvement in an injury-causing crash and crash history, data were prepared for inclusion in the model that examine the relationship between involvement in an injury-causing crash and citation history. The citation data were considered in two time periods. Recent citations were those issued to drivers between 2002 and 2005 for 2006 ICCDs; recent citations for 2007 ICCDs were those issued between 2002 and 2006. Prior citations were 1995 to 2001 for both 2006 and 2007 ICCDs. In addition, citation history for older drivers in non-injury causing crashes were also included in the analysis since they are included in the model.

TABLE 6.5 provides an overview of violations issued to the four groups of drivers. As was the case with crash history, there are no notable differences between the two years or in terms of the distributions for ICCDs compared to non-ICCDS.

TABLE 6.5 Citation History for Older Drivers in 2006 and 2007 Crashes

	2006				2007			
	ICCD		Non ICCD		ICCD		Non ICCD	
	Freq	Percent of Total Crashes	Freq	Percent of Total Crashes	Freq	Percent of Total Crashes	Freq	Percent of Total Crashes
Recent Violations (2002-2005 or 2002-2006)								
Total Violations	1,389	NA	3,189	NA	1,639	NA	3,568	NA
Alcohol	12	0.86%	18	0.56%	16	0.98%	40	1.1%
Belt	134	9.65%	359	11.26%	199	12.14%	380	10.7%
Fleeing Crash Scene	16	1.15%	37	1.16%	10	0.61%	32	0.9%
General	144	10.37%	365	11.45%	183	11.17%	402	11.3%
Lane	104	7.49%	227	7.12%	123	7.50%	290	8.1%
License/Registration/Equipment	220	15.84%	503	15.77%	292	17.82%	537	15.1%
Serious	4	0.29%	12	0.38%	10	0.61%	15	0.4%
Speeding	426	30.67%	969	30.39%	455	27.76%	1,068	29.9%
Stop/Yield	302	21.74%	639	20.04%	318	19.40%	729	20.4%
Other	27	1.94%	60	1.88%	33	2.01%	72	2.0%
Prior Violations (1995-2001)								
Total Violations	2,564	NA	7,170	NA	2,264	NA	5,634	NA
Alcohol	27	1.05%	88	1.23%	35	1.55%	73	1.30%
Belt	160	6.24%	489	6.82%	165	7.29%	394	6.99%
Fleeing Crash Scene	20	0.78%	50	0.70%	14	0.62%	42	0.75%
General	263	10.26%	691	9.64%	237	10.47%	547	9.71%
Lane	194	7.57%	388	5.41%	122	5.39%	328	5.82%
License/Registration/Equipment	345	13.46%	921	12.85%	322	14.22%	824	14.63%
Serious	14	0.55%	47	0.66%	11	0.49%	33	0.59%
Speeding	906	35.34%	2,736	38.16%	876	38.69%	2,187	38.82%
Stop/Yield	584	22.78%	1,470	20.50%	454	20.05%	1,119	19.86%
Other	51	1.99%	132	1.84%	29	1.28%	87	1.54%

The following two tables provide information on the frequency of violations for older drivers in 2006 and 2007 crashes. Consistent with previous information, there are no notable differences between years or between the distributions for ICCDs when compared to non-ICCDs.

TABLE 6.6 focuses on prior violations, defined as those issued between 1995 and 2001. TABLE 6.7 focuses on recent violations. For older drivers in a 2006 crash, this includes violations issued between 2002 and 2005; for older drivers in a 2007 crash, this includes violations issued between 2002 and 2006.

TABLE 6.6 Frequency of Prior Violations for Older Drivers

	2006 Crash Drivers				2007 Crash Drivers			
	ICCD		Non ICCD		ICCD		Non ICCD	
	Freq	Per	Freq	Per	Freq	Per	Freq	Per
Number of Total Violations								
1	582	10.07%	1,599	10.73%	464	8.64%	1,311	9.05%
2 to 6	407	7.04%	1,020	6.84%	324	6.03%	837	5.78%
More than 6	61	1.06%	283	1.90%	56	1.04%	144	0.99%
Number of Alcohol Violations								
1	16	0.28%	48	0.32%	25	0.47%	46	0.32%
More than 1	4	0.07%	13	0.09%	3	0.06%	8	0.06%
Number of Belt Violations								
1	95	1.64%	257	1.72%	84	1.56%	249	1.72%
2	7	0.12%	38	0.25%	12	0.22%	25	0.17%
3 or more	13	0.22%	36	0.24%	9	0.17%	23	0.16%
Number of Fleeing Violations								
1	10	0.17%	26	0.17%	6	0.11%	21	0.15%
More than 1	5	0.09%	7	0.05%	4	0.07%	7	0.05%
Number of General Violations								
1	165	2.85%	370	2.48%	125	2.33%	330	2.28%
2 to 6	32	0.55%	98	0.66%	30	0.56%	79	0.55%
More than 6	2	0.03%	6	0.04%	2	0.04%	2	0.01%
Number of Lane Violations								
1	98	1.70%	216	1.45%	69	1.28%	159	1.10%
2	20	0.35%	44	0.30%	13	0.24%	35	0.24%
3 or more	12	0.21%	21	0.14%	6	0.11%	26	0.18%
Number of License/Registration/Equipment Violations								
1	113	1.96%	311	2.09%	93	1.73%	216	1.49%
2	35	0.61%	94	0.63%	26	0.48%	70	0.48%
3 to 6	24	0.42%	59	0.40%	29	0.54%	57	0.39%
More than 6	7	0.12%	20	0.13%	6	0.11%	22	0.15%
Number of Other Violations								
1	28	0.48%	62	0.42%	14	0.26%	50	0.35%
More than 1	9	0.16%	22	0.15%	5	0.09%	13	0.09%
Number of Serious Violations								
1	11	0.19%	30	0.20%	1	0.02%	19	0.13%
2	1	0.02%	7	0.05%	0	0.00%	5	0.03%
Number of Speeding Violations								
1	389	6.73%	1,136	7.62%	334	6.22%	910	6.28%
2 to 6	127	2.20%	359	2.41%	105	1.95%	325	2.24%
More than 6	11	0.19%	52	0.35%	17	0.32%	31	0.21%
Number of Stop/Yield Violations								
1	265	4.58%	678	4.55%	213	3.97%	561	3.87%
2 to 6	100	1.73%	208	1.40%	56	1.04%	167	1.15%
More than 6	4	0.07%	20	0.13%	7	0.13%	8	0.06%

TABLE 6.7 Frequency of Recent Violations for Older Drivers

	2006 Crash Drivers				2007 Crash Drivers			
	ICCD		Non ICCD		ICCD		Non ICCD	
	Freq	Per	Freq	Per	Freq	Per	Freq	Per
Number of Total Violations								
1	405	7.01%	1,040	6.98%	416	7.74%	1,100	7.60%
2 to 6	240	4.15%	536	3.60%	246	4.58%	623	4.30%
More than 6	29	0.50%	57	0.38%	40	0.74%	57	0.39%
Number of Alcohol Violations								
1	10	0.17%	14	0.09%	10	0.19%	30	0.21%
More than 1	1	0.02%	2	0.01%	2	0.04%	4	0.03%
Number of Belt Violations								
1	54	0.93%	124	0.83%	60	1.12%	153	1.06%
2	33	0.57%	75	0.50%	32	0.60%	73	0.50%
3 or more	7	0.12%	17	0.11%	19	0.35%	18	0.12%
Number of Fleeing Violations								
1	11	0.19%	26	0.17%	6	0.11%	18	0.12%
More than 1	1	0.02%	5	0.03%	3	0.06%	6	0.04%
Number of General Violations								
1	93	1.61%	244	1.64%	92	1.71%	289	2.00%
2 to 6	17	0.29%	41	0.28%	25	0.47%	43	0.30%
More than 6	4	0.07%	1	0.01%	5	0.09%	1	0.01%
Number of Lane Violations								
1	69	1.19%	165	1.11%	83	1.55%	176	1.22%
2	13	0.22%	15	0.10%	16	0.30%	24	0.17%
3 or more	6	0.10%	7	0.05%	5	0.09%	17	0.12%
Number of License/Registration/Equipment Violations								
1	92	1.59%	218	1.46%	103	1.92%	231	1.60%
2	26	0.45%	49	0.33%	31	0.58%	66	0.46%
3 to 6	14	0.24%	29	0.19%	18	0.34%	21	0.15%
More than 6	6	0.10%	7	0.05%	10	0.19%	9	0.06%
Number of Other Violations								
1	21	0.36%	46	0.31%	17	0.32%	43	0.30%
More than 1	4	0.07%	4	0.03%	9	0.17%	10	0.07%
Number of Serious Violations								
1	4	0.07%	10	0.07%	8	0.15%	10	0.07%
2	0	0.00%	1	0.01%	1	0.02%	2	0.01%
Number of Speeding Violations								
1	248	4.29%	601	4.03%	221	4.11%	664	4.59%
2 to 6	44	0.76%	102	0.68%	66	1.23%	119	0.82%
More than 6	9	0.16%	9	0.06%	9	0.17%	10	0.07%
Number of Stop/Yield Violations								
1	165	2.85%	420	2.82%	170	3.16%	438	3.02%
2 to 6	42	0.73%	78	0.52%	41	0.76%	92	0.64%
More than 6	6	0.10%	0	0.00%	5	0.09%	6	0.04%

6.3 Summary of Findings

Based on the preparation of the crash and citation profiles for older drivers involved in a crash in 2006 or 2007, several findings of note become evident.

- Although the older driver population is defined as 65 to 100 for this analysis, the great majority (three-quarters) of the drivers included are between the ages of 65 and 79. This three-quarters of the dataset population are relatively evenly spread across the three age groups (65 to 69, 70 to 74, and 75 to 79).
- The population of older drivers involved in a crash in 2006 or 2007 have a slightly higher percentage of females than males (approximately 55 percent compared to just over 40 percent). This is of special interest when considering the fact that the licensed driver population for Massachusetts drivers age 65 to 100 is split almost exactly in half in terms of sex.
- There appears to be little in the way of interaction between age and sex. The distribution of crash involvement across age groups was similar for males and females.
- Drivers in injury-causing crashes do not appear to account for a notably higher portion of crashes or violations in comparison to drivers in non-injury causing crashes. Injury-causing crash drivers accounted for approximately 27 percent of drivers in a crash and accounted for between 27 and 32 percent of drivers involved in crashes or issue violations during previous years considered.
- There appears to be a data quality issue that warrants further consideration for future efforts. Specifically, it appears that some driver license numbers were

associated with an unreasonable number of violations given the time period considered.

- This analysis allowed only for consideration of drivers involved in a crash in 2006 or 2007. Had driver history data been available, this analysis could have been expanded to include all drivers rather than just those involved in a crash.

This initial study of the relationship between driving history and crash involvement yielded limited information in terms of prior crash involvement, citation history, and involvement in an injury-causing crash. A more in-depth analysis using statistical modeling to identify potential predictors for involvement in an injury-causing crash is discussed in the following chapter.

CHAPTER 7

OLDER DRIVER CRASH PREDICTION MODEL

This chapter describes the results from the use of three regression models considered in the development of the older driver crash prediction model. This analysis was conducted in relation to Hypothesis 4: *Statewide crash, driver licensing, and citation datasets can be used to derive and validate a crash prediction model that will identify a subgroup of older drivers at high risk for a near term injury causing crash*; and Hypothesis 5: *State level legislation regarding the licensing process can be modified to allow for the use of an effective crash prediction model for identifying high risk older drivers in a manner that is not considered blanket discrimination towards all older drivers.*

7.1 Logistic Regression Model

Initially, a logistic regression model was developed using PROC LOGISTIC in SAS with a flag for involvement in an injury crash in 2006 as the dependent variable, including all of the variables in Table 3.8. This model yielded only two variables with statistically significant odds ratios; that is there were only two odds ratios with 95 percent confidence intervals that did not cross 1.0. Number of lane violations from 1995-2001 had an odds ratio of 1.180 (95% CI 1.033, 1.347) and number of speed violations from 1995-2001 had an odds ratio of 0.944 (95% CI 0.901, 0.988). Though these were statistically significant, they were not remarkable. Subsequently, the model was run with age as a continuous variable indicating the driver’s actual age rather than the categorical variable of age group. This did not impact the model’s results.

To better understand the nature of variables included in the model, logistic regression was run for each of the variables independently. Based on the results from that, a logistic regression model including only those with p values <0.25 was run. These variables were age, number of belt violations between 1995 and 2001, number of lane violations between 1995 and 2001, number of speed violations between 1995 and 2001, number of alcohol violations between 2002 and 2005, number of speed violations between 2002 and 2005, and number of stopping/yield violations between 2002 and 2005. The only variable that yielded a statistically significant odds ratio was the number of speed violations between 1995 and 2001 (0.949, 95% CI 0.908, 0.991).

Using these variables, purposeful selection (46) was used. Results from the inclusion of all the variables indicated that age had p<0.05. The first variable that had a large p value was number of belt violations between 1995 and 2001. As such, the process of purposeful selection dictates that the model should be run omitting this variable. Results from the logistic regression including all of the variables are shown in TABLE 7.1.

TABLE 7. 1 Logistic Regression Results, Inlcusion of All Variables

Parameter	Estimate	Standard Error	Wald Chi-Sqaure	Pr>ChiSq
AGE	0.00453	0.00229	3.9228	0.0476
BELT_9501	-0.0509	0.0665	0.5862	0.4439
LANE_9501	0.147	0.0634	5.3794	0.0204
SPEED_9501	-0.0528	0.0225	5.5309	0.0187
ALC_0205	0.4215	0.3425	1.5145	0.2185
SPEED_0205	0.0761	0.039	3.7982	0.0513
STP_0205	0.0784	0.0579	1.8378	0.1752

Running the logistic regression omitting BELT_9501 yielded results where there was no notable difference in the estimate (no change greater than nine percent). However, two of the variables had p values greater than 0.10: number of alcohol violations between 2002 and 2005 as well as number of stop/yield violations between 2002 and 2005. These results are presented in TABLE 7. 2.

TABLE 7. 2 Logistic Regression Results, Omitting BELTS_9501

Parameter	Estimate	Standard Error	Wald Chi-Sqaure	Pr>ChiSq
AGE	0.00457	0.00229	3.9897	0.0458
LANE_9501	0.1447	0.0632	5.2339	0.0222
SPEED_9501	-0.0574	0.0217	6.9891	0.0082
ALC_0205	0.4111	0.3421	1.4438	0.2295
SPEED_0205	0.0757	0.039	3.7562	0.0526
STP_0205	0.0753	0.0578	1.7008	0.1922

Subsequently, the logistic regression model was run omitting number of belt violations between 1995 and 2001, number of alcohol violations between 2002 and 2005, and number of stop/yield violations between 2002 and 2005. The resulting model yielded reasonable p values and statistically significant odds ratios.

The final logistic regression model included only four variables: age, number of lane violations between 1995 and 2001, number of speed violations between 1995 and 2001, and number of speed violations between 2002 and 2005. There were no noteworthy point estimates as they were only slightly higher than or slightly lower than one. For three of the variables, $p<0.05$. The p-value for age was slightly higher than 0.05 and the confidence interval lower limit is 1.000. These results are outlined in TABLE 7. **3**. The Hosmer-Lemeshow goodness of fit test for this model yielded a chi-square=13.3726 and p=0.0997.

TABLE 7. 3 Logistic Regression Model Results

Variable	Point Estimate	95% Wald Confidence Limits		Pr > ChiSq
Age	1.004	1.000	1.009	0.0531
Lane_9501	1.172	1.037	1.325	0.0109
Speed_9501	0.945	0.906	0.986	0.0093
Speed_0205	1.087	1.008	1.172	0.313

While the model is reasonable, the c value for this model is 0.516 indicating that the model cannot predict involvement in an injury crash. This c value measures the area under the Receiver Operating Characteristic (ROC) curve. This curve was developed as part of signal detection theory to plot the probability of detecting a true signal and a false signal. The closer the area under the ROC curve is to 1.0, the better the discriminating power of the model. An ROC of 0.5 indicates that there is no discrimination. Further investigation of opportunities for improving this model would include investigation of interactions between variables.

7.2 Poisson Regression Model

Examination of the use of the Poisson regression model began by assessing the Poisson distribution of the data using the PROC NLMIXED command in SAS. This examination estimated a Poisson model and estimate probabilities for number of injury crashes being equal to 0, 1, or 2 or more. Number of injury crashes more than 2 were grouped to ensure sufficient number of observations. The results of the test here indicated that the test was statistically significant ($p<0.001$) and that the number of observed zeros was not greater than the number of expected zeros. The observed frequency distributions were similar to the expected distributions; a zero-inflated model is not necessary.

Initially, a Poisson regression model was developed using GENMOD in SAS with number of injury crashes in 2006 as the independent variable. This model included all of the variables in Table 3.8. This model yielded only two variables with statistically significant estimates ($p<0.05$). Number of single vehicle crashes between 2002 and 2005 had an estimate of 0.4347 and number of speed violations from 1995-2001 had an estimate of -0.0678.

To better understand the nature of variables included in the model, the Poisson regression model was run for each of the variables independently. Based on the results from that, a Poisson regression model including only those with p values <0.25 was run. These variables were age, number of injury crashes between 2002 and 2005, number of single vehicle crashes between 2002 and 2005, number of lane violations between 1995 and 2001, number of speed violations between 1995 and 2001, number of alcohol violations between 2002 and 2005, number of speed violations between 2002 and 2005, and number of stopping/yield violations between 2002 and 2005. The only variable that yielded a statistically significant estimate was the number of speed violations between 1995 and 2001. Results from the Poisson regression including all of the variables are shown in TABLE 7. 1.

TABLE 7. 4 Poisson Regression Results, Inlcusion of All Variables

Parameter	Estimate	Standard Error	Wald Chi-Sqaure	Pr>ChiSq
Age	0.0029	0.0019	2.30	0.1296
INJCRASH_0205	0.1078	0.0690	2.44	0.1183
SVC_0205	0.1406	0.0932	2.27	0.1315
LANE_9501	0.0925	0.0491	3.56	0.0593
SPEED_9501	-0.0425	0.0188	5.19	0.0227
SPEED_0205	0.0490	0.0309	2.51	0.1134
STP_0205	0.0502	0.0464	1.17	0.2789

Using these variables, further exploration of useful variables was undertaken. Initially, driver age was omitted from the model. Running the Poisson regression omitting age yielded results where there was no notable difference in the estimate (no change greater than five percent). However, all but two of the variables had p values greater than 0.10. The only two that did not were number of lane violations between 1995 and 2001, and number of speed violations between 1995 and 2001. These results are shown in TABLE 7. 5.

TABLE 7. 5 Poisson Regression Results, Omitting Age

Parameter	Estimate	Standard Error	Wald Chi-Sqaure	Pr>ChiSq
INJCRASH_0205	0.1086	0.0690	2.48	0.1154
SVC_0205	0.1394	0.0932	2.24	0.1346
LANE_9501	0.0918	0.0491	3.50	0.0616
SPEED_9501	-0.0450	0.0188	5.72	0.0167
SPEED_0205	0.0466	0.0310	2.27	0.1321
STP_0205	0.0476	0.0464	1.05	0.3046

The same process was repeated, ultimately eliminating all variables from inclusion in the model. It should be noted that in the model where age and number of injury crashes between 2002 and 2005 were omitted, the p value for number of single vehicle crashes between 2002 and 2005 indicated significance. However, the change in the estimate was 19 percent indicating reason for omission of that from the model as well (any change greater than 15 percent warrants exclusion). These results are shown in TABLE 7. 6 and TABLE 7. 7.

TABLE 7. 6 Poisson Regression Results, Omitting Age and INJCRASH_0205

Parameter	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq
SVC_0205	0.167	0.0912	3.35	0.067
Lane_9501	0.0922	0.049	3.54	0.06
Speed_9501	-0.0443	0.0188	5.56	0.018
Speed_0205	0.0474	0.0309	2.35	0.125
STP_0205	0.0500	0.0463	1.17	0.28

TABLE 7. 7 Poisson Regression Results, Omitting Age, INJCRASH_0205, and SVC_0205

Parameter	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq
Lane_9501	0.0947	0.0488	3.77	0.0523
Speed_9501	-0.0439	0.0188	5.47	0.0194
Speed_0205	0.0483	0.0309	2.45	0.1174
STP_0205	0.0513	0.0462	1.23	0.2671

Although the results when including only number of lane violations between 1995 and 2001 and number of speed violations between 1995 and 2001 yield p values <0.05 (Table 7.8), the percent change for the lane violations estimate was above the 15 percent threshold. The final Poisson regression model was run with only the number of speed violations between 1995 and 2001. The resulting $p=0.0925$ indicates that it is not statistically significant on its own.

TABLE 7. 8 Poisson Regression Results, Omitting Age, INJCRASH_0205, SVC_0205, and STP_0205

Parameter	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq
Lane_9501	0.1082	0.0482	5.03	0.0249
Speed_9501	-0.0392	0.0184	4.56	0.0328

The resulting conclusion is that the Poisson regression model is not effective for modeling the relationship between driver history and involvement in involvement in an injury-causing crash.

7.3 Negative Binomial Regression Model

The development of the negative binomial employed the PROC GENMOD procedure in SAS. Initially, a model including all of the variables outlined in Table 3.8 was run. This process produced a warning that the convergence criterion (Hessian convergence criterion <0.0001) had not been met (0. 8718989886). Subsequently, other variables were removed from the model. Those variables found to be relevant during the exploration of data conducted as part of the logistic regression and Poisson regression modeling were included in a negative binomial regression model. This model, which included only age, number of injury crashes between 2002 and 2005, number of single vehicle crashes between 2002 and 2005, number of lane violations between 1995 and 2001, number of speed violations between 1995 and 2001, number of speed violations between 2002 and 2005, and number of stop/yield violations between 2002 and 2005 resulted in a lower Hessian convergence criterion (0. 3769155558); this is still far from the convergence criterion required. Subsequently, each of the variables included in the model were removed to identify potential opportunities for improving convergence. As shown in TABLE 7. 9, none of these omissions resulted in a satisfactory convergence criterion.

TABLE 7. 9 Hessian Convergence Criteria with Omission of Variables

Parameter Omitted	Hessian Convergence Criterion
Age	0.2658233068
InjCrash_0205	0.2640270159
SVC_0205	0.2636352108
Lane_9501	0.2637343528
Speed_9501	0.2615543403
Speed_0205	0.263227190
Stp_0205	0.2640292778

Although SAS continues to run the negative binomial model, without convergence (indicating questions regarding model fit), the results of the model are unreliable.

7.4 Conclusions

The effort to develop an older driver crash prediction model that would allow for the prediction of involvement in an injury crash based on elements of driver history focused on three types of model: logistic regression, Poisson regression, and negative binomial regression. None of these three model types yielded a model that was both valid and meaningful.

- The logistic regression model ultimately included only four parameters. While the odds ratios associated with these variables were statistically significant, the ability of the model to effectively predict involvement in an injury causing crash was poor.
- The Poisson regression model attempt yielded no variables that were associated with statistically significant estimates.

- The negative binomial regression model was unsuccessful because it failed to meet convergence criterion.

Some reasons for the failure of these models to yield significant meaningful results include the following:

- Self-selection bias exists as older drivers who have exhibited poor driving behaviors (crash involvement or violation issuance) may choose to stop driving or may be mandated to stop driving through the decision of an MAB. This would preclude the highest risk drivers from being potentially present in the count variable (involvement in at least one injury causing crash).
- Due to challenges with data acquisition, the population considered included only those drivers who were in a crash, with the model aimed as discerning between those in an injury causing crash and those in a crash where no one was injured. Inclusion of all older drivers, including those involved in no crashes, may impact the success of the models.
- Given the unique characteristics of this dataset, other model types may yield more successful models. The use of zero inflated Poisson and zero inflated negative binomial models were considered. They were initially eliminated as options due to the distribution of the count variable. Most (more than 99 percent) of the cases were associated with either zero or one injury crashes. This does not allow for sufficient distribution upon which those models could be built. However, revisions to the dataset or the inclusion of additional data might warrant further consideration of these models. Additionally, truncated Poisson regression models might be considered.

However, these should be approached cautiously as it appears that attempting to model older driver behavior in this way may not be possible.

Although these three models may not have been successful in their original intent (to predict injury-causing crash involvement based on prior driving history), the process provided valuable information for consideration in future efforts to address older driver safety through the use of administrative datasets such as crash and citation data.

- Older drivers behave differently than other potentially high risk driver populations. Research has shown that they self-impose limits on their driving to reduce exposure to high-risk driving situations such as nighttime driving, driving in inclement weather, etc. Additionally, they are more likely to identify a crash or violation receipt as an indicator for the need to self-regulate. As a result, those with a less-than-perfect driving history may already be reducing their potential crash-involvement.
- Crashes are infrequent events. This is especially true when considering a population that may already be reducing their own exposure to potentially crash-risky driving situations. The resulting distribution (primarily 0 or 1 crash over any given period of time) renders it difficult to apply prediction models that have been successful in other efforts, including those that focus on high crash locations or populations.
- While a systematic approach to identifying high risk older drivers may be feasible using a different modeling approach or an expanded dataset, it is evident from this effort that there will not be the strength of results – statistically or practically speaking – for it to be the only mechanism through which high risk older drivers are

identified and licensing decisions are made. Continued efforts in the area of cognitive and functional testing as well as medically based decision-making are necessary.

Given the challenges and processes associated with the development of the crash prediction model, and the information gathered as part of other tasks associated with this research, the final chapter provides a summary of findings as well as conclusions and recommendations.

CHAPTER 8

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Existing research has identified older drivers as an area for consideration in the development of highway safety programs and policies. Although there is general consensus among the highway safety community regarding the importance of addressing the issues surrounding older road users, there appears to be significantly less agreement in terms of how best to implement programs and policies that improve older driver safety while also accounting for the importance of continued mobility for older persons who no longer drive. To date, efforts have focused largely on the use of medically based indicators for assessing older persons' ability to safely drive. While the use of physical and physiological indicators for a person's ability to drive safely can be successful in identifying high risk drivers, the process requires the skilled assessment of individual drivers by a panel or group of trained professionals. It also requires that potentially risky drivers be referred to these medical advisory boards for review. There exist no systematic mechanisms for referring drivers for review. The projected increase in the population over 65, which will also lead to an increase in the number of older drivers, indicates the need for standardized and systematic means for identifying high risk older drivers, ensuring that as their safety is assessed, their mobility needs continue to be met.

This research sought to identify opportunities for combining existing data with advanced analysis methods to provide the foundation for effective older driver licensing policy initiatives. Specifically, this research considered existing licensing policies implemented nationally, and data traditionally available at the state level to understand the outcomes of crashes involving older road users and identify high risk older drivers in a manner that, because of its standardized and systematic approach, can be replicated in other states. The following sections outline the tasks associated with this research and provide an overview of the findings associated with each. Additionally, the research hypotheses presented at the beginning of this document are addressed in light of the research findings.

8.1 Compilation of Resources for State Level Decision Makers

Research has shown that older drivers are often the first line of screening in terms of their own safety as drivers. They limit their driving based on their own perceived skills and abilities. For example, many older drivers limit night driving, driving on certain types of roads, in certain weather conditions, etc. However, this generation of older drivers is heavily reliant on personal automobiles as a means of travel and are accustomed to the level of mobility afforded by automobile travel (47). As such, we cannot rely solely on older drivers to monitor their own driving. State licensing agencies are in a unique position to play a critical role in the older driver safety from the licensing perspective.

In some states, licensing agencies have implemented age-based restrictions or licensing practices. These practices are generally applied based solely on age and there is little evidence to suggest that they are effective in improving older driver safety. These age-based restrictions include practices such as accelerated renewal cycles, additional vision testing, requirement to appear in person for license renewal, and additional road testing. Some would argue that of these, road tests are most effective in identifying high risk drivers. This argument is countered, though, by those who say that these tests do not expose drivers to high risk conditions and that ability at the time of the test may change as the driver ages (48). Given the inability to show effectiveness of age-based restrictions, licensing agencies are moving towards more behavior-based restrictions.

Whether the licensing agencies choose age-based or behavior-based practices, one of the greatest challenges comes in terms of testing procedures. Relying on examiners at the licensing agency to make decisions regarding whether an older person is retested, and what the results of those tests are, minimizes standardization.

Consideration of the standardization of licensing practices at the point of licensure provides a basis to further consider the opportunity to standardize older driver licensing practices across states. Although licensing decisions are made at the state level, there is a prime opportunity to share best practices and provide guidelines and models for effective older driver licensing policies. The information gathered during this task provides some insight for state licensing agencies and also points to opportunities for further research.

- There is general consensus that it is necessary for states to identify ways to implement licensing tools that are reliable, efficient, and cost effective. There is less consensus, though, on how to define reliable, efficient and cost effective. The NHTSA Model Driver Screening and Evaluation Program began to address these issues and provides some framework, but further examination of this area is required.
- MABs are a generally accepted element of older driver licensing practices. Although there has not be general consensus reach regarding all best practices associated with MABs, there are some areas where consensus has been reached. These areas of consensus include the importance of consistency across review

while maintaining the individuality associated with the case-by-case review process; the need for MABs to be part of the development of licensing guidelines rather than just reviewing cases where licenses have been denied; and the need for members of MABs to compensated appropriately.

- Information gathered from licensing agencies across the United States' also points to agreement in terms of the need for additional practices for older drivers including appearance in person for license renewal and functional testing at the time of renewal.
- Licensing agencies should also play a role in the insurance of mobility options for older persons who are no longer able to drive.

Perhaps the greatest opportunity for further exploration identified during this task is the use of graduated licensing, or graduated de-licensing, for older drivers. Similar to the idea of graduated licensing employed for new teen drivers, graduated licensing for older drivers would limit their driving activity gradually. These limits, similar to those employed for teens, would aim to reduce their exposure to high risk situations and might include limits on time of day, area, road types, etc. This idea, originally introduced in 1988, has seen little in the way of implementation or evaluation. What limited evaluation of this potential practice has been conducted points to some success in terms of improving driver safety when conducted in conjunction with driver education and training (55). In addition, another study indicated that older persons and their caretakers found the use of license restrictions, rather than revocation, less stressful for the driver and friends and family (56).

When specifically considering Massachusetts, there are opportunities for improving older driver licensing policy based on existing best practices in the area of the use of the MAB, appearance in person for license renewal, and the opportunity for implementation of graduated "de-licensing" for older drivers. There will also need to be consideration of the challenges associated with MGL language that prohibits licensing practices that discriminate on the basis of age. Graduated licensing for new teen drivers may be a basis for identifying opportunities to implement age-based licensing policies within the framework of existing law.

8.2 Assessment of Charges and Payer Source for Injuries Sustained by Older Vehicle Occupants

The need for older driver licensing policy and a thoughtful approach to addressing safety issues related to older drivers are generally accepted tenets in the highway safety community. The ability to quantify the impact of older drivers and older road users in general, not only on themselves in terms of injury, but also on society in terms of treatment of injuries, has the potential to be a useful tool in the discussions surrounding older driver safety. Since driver licensing happens at the state level, the ability for states to consider the impact of older drivers "at home" lends of level of credibility to data presented to policy makers. National-level information provides a general framework for understanding older drivers but state-based data analyses provides the foundation for discussing the issue at the level where licensing decisions are made.

State crash and hospital data can be linked to understand not only crashes involving older drivers, but the outcomes of those crashes in terms of treatment of injuries. The lack of common unique identifiers in datasets collected by a variety of state agencies leads to the need for advanced approaches to data linkage. CODES, developed by NHTSA and implemented at the state level, provides the software and analysis applications to understand crash outcomes in a manner that crash data alone does not. For this research, 2005 crash, inpatient, and emergency department data were probabilistically linked. Charges and payer source for emergency department treatment of older drivers (65 or older) and a comparison group (ages 25-40) were considered.

Though most older drivers are eligible for public insurance (Medicare), the great majority of older drivers included in the analysis were covered by private insurance. More older female drivers were injured than older male drivers and the median emergency department charges for females were higher than for males, regardless of payer source (private, public, or self). This was different than the results for the comparison group where more females were injured than males but where the median emergency department charges for males were higher than females. Overall, median emergency department charges were higher for older drivers than for comparison drivers for all combinations of payer source and sex except for self-pay males.

While the lack of difference between charges by payer source may be surprising, there is evidence that consideration of crash outcomes, especially where older vehicle occupants are concerned, needs to take sex into consideration. Most dialogue around older drivers refers to a population defined by age (65 or older, for example) but pays less attention to sex. When sex does enter the conversation, it is, more often than not, regarding the differences in driving behaviors and willingness to self regulate. It is critical that older driver safety efforts consider the differences in crash outcomes by sex, as well.

8.3 Examination of the Relationship between Injury Causing Crashes and Driver History

The ability to identify high risk older drivers prior to their involvement in a crash brings with it the potential to implement programs such as driver training, reeducation, or retesting that might prevent the involvement in that crash. The first step in attempting to identify high risk older drivers is to examine the relationship between crash involvement and prior driving history.

Though the work associated with this element of the research was originally intended to be conducted using driver history data, the lack of availability of this dataset required the use of alternate methods for considering crash history. Crash and citation data, which were available, were linked using common fields across the two datasets (driver license number, checked against name and date of birth). Comprehensive driver profiles included information in three general areas for drivers age 65 or older who were involved in a crash in 2006 or 2007. The crash drivers were group into two categories for each year: ICCD (they were involved in an injury causing crash that year) or non-ICCD (the crash they were in resulted in no injuries to anyone in the crash). Crash history included information on the frequency, severity, and characteristics of crashes for these drivers from 2002 to the year prior to their involvement in a crash (2005 for drivers in a 2006 crash or 2006 for drivers in a 2007 crash). Recent violation history provided information on the frequency and types of violations that were issued between 2002 and the year prior to their involvement in a crash. Prior violation history included in the same information as recent violation history except that the years included were 1995 to 2001.

Although the older driver population was defined as anyone 65 or older, the great majority of drivers involved in crashes were between the ages of 65 and 79. Crash drivers were more likely to be male than female, which is of special interest since the licensed driver population age 65 or older for Massachusetts is almost evenly divided between males and females.

There were no notable differences in driver history (crash, recent violation, or prior violation) between ICCDs and non-ICCDs. There were also no notable differences between older drivers involved in a crash in 2006 compared to those in 2007. This indicates that, at this level of analysis, prior driver history may not be an effective mechanism for identifying high risk older drivers.

In addition to the finding regarding driver sex for older drivers in crashes, there were two data issues that should be noted. The first is that had driver history data been available, additional fields including number of years licensed and prior suspensions, etc could have been considered as indicators of a potentially high risk older driver. The other is that data quality issues in the citation data warrant further consideration. Specifically, some driver license numbers were associated with an unreasonable number of violations given the time period considered. Those unreasonably high violation counts were eliminated from the analysis but the source of the problem warrants examination.

8.4 Development of Older Driver Crash Prediction Model

In an attempt to identify high risk older drivers on the basis of prior driving history (crash and violation), three model types were used: Poisson regression, negative binomial, and logistic regression. None of these yielded significant results. The datasets included sufficient cases for analysis, and substantial investigation of the data was conducted to understand why the models were ineffective. Through this process, questions were raised about the issues that using prior driving history to identify high risk older drivers failed to acknowledge. Specifically, the use of driving history ignores several basic tenets associated with aging drivers.

Involvement in an injury crash may be more related to the impact of aging on skills and abilities than to a person's driving history or experience. The age at which the effects of aging become a concern, as well as the speed at which the aging process impacts a person (and continues to degrade their fitness as a driver) will also vary.

Additionally, if effective mechanisms are in place for reducing the exposure of high risk older drivers to involvement in a crash, then history of these events would preclude future exposure. These mechanisms may include formal ones such as MABs. The involvement of an older person in a crash or the issuance of violations may encourage the recommendation of their review by an MAB, who may then revoke their license. If this is true, they are no longer exposed to the very measure the models attempted to count (involvement in an injury crash). These mechanisms may also be less formal. Older drivers have been known to self regulate, limiting their exposure to high risk driving situations. If they are more likely to do this following involvement in a crash or the receipt of a violation, they are also reducing their exposure to the measure the models sought to count.

The use of additional fields available through datasets such as driver history data may strengthen the model, and may even yield statistically significant results. Even if this were to be true, it is critical to acknowledge the individual nature of the aging process, the reduction of exposure to crashes associated with mechanisms such as MABs and selfregulation, and the impact of these concepts on the use of statistical models to identify high risk older drivers.

8.5 Conclusions of Research Hypotheses

The following section provides a summary of results specifically addressing the hypotheses outlined at the outset of this research.

8.5.1 Hypothesis 1

An improved method for sharing information on older driver licensing practices at the state level can be identified to improve policy and program decision making.

While agencies and organizations such as NHTSA and IIHS provide overview information on state licensing policies regarding older drivers and reports on work completed to date to better understand licensing policy for older drivers, there is an untapped opportunity for states to share information with each other. Since older driver licensing policies are still very much in development, and likely to continue to evolve in the near future, states would greatly benefit from the opportunity to share information on what has been successful, what challenges were faced in terms of implementing older driver licensing policies, and how those challenges were addressed. While the needs and difficulties associated with licensing teens and licensing older driver vary greatly, the framework within which licensing policies are implemented at the state level are similar. There is the common need for standardization of practice, feasibility of implementation, and evaluation of effectiveness. One of the greatest differences, perhaps, is the need to address mobility issues for older drivers once they can no longer drive.

8.5.2 Hypothesis 2

Charges associated with treating the injuries of these older vehicle occupants (drivers and passengers) are higher than charges associated with treating injuries for non-older occupants of vehicles involved in the same crash. Additionally, treatment for these injuries are more likely to be charged to public insurers placing the fiscal burden for older vehicle occupant on society in general.

The first element of this research hypothesis has proven to be true. Emergency department charges for older vehicle occupants involved in a crash were higher than charges for comparison age group (25 to 40) occupants involved in the same crashes. However, there were no notable differences in terms of payer source for older vehicle occupants than the payer sources associated with vehicle occupants in the comparison group.

The more notable differences were found when considering the sex of the vehicle occupant. Unlike comparison age group females who had lower median emergency department charges than males in the same age group, older females had higher emergency department charges than males in the same group.

8.5.3 Hypothesis 3

Older drivers who are involved in injury crashes exhibit risky driving behaviors prior to becoming older drivers.

Initial analysis of the driving history – crash and violation – for older drivers involved in crashes in 2006 and 2007 did not point to any notable indicators of risky driving behaviors in years prior to involvement in an injury causing crash. There were no differences between ICCDs and non-ICCDS for either 2006 or 2007 in terms of the frequency or distribution of crash frequency or severity, crash characteristics, violation frequency, or violation types.

8.5.4 Hypothesis 4

Statewide crash, driver licensing, and citation datasets can be used to derive and validate a crash prediction model that will identify a subgroup of older drivers at high risk for a near term injury causing crash.

Three separate modeling approaches were used to attempt to develop a crash prediction model that would effectively identify high risk older drivers based on their prior driving history: logistic regression, Poisson regression, and negative binomial. None of these models were able to produce results that indicated that any of the predictors considered (prior crash severity, crash characteristics, or violation types) with any statistical significance. Though one or two of the variables may have yielded statistically significant results, such as number of lane violations or speed violations issued between 1995 and 2001, the magnitude of their relationship to involvement in an injury causing crash was very small. Additionally, statistically significant results for one or two variables do not translate into a model that effectively identifies high risk older drivers based on crash history. It is not possible to use driver history, in the manner attempted in this research, to identify high risk older drivers based on their prior driving history.

8.5.5 Hypothesis 5

State level legislation regarding the licensing process can be modified to allow for the use of an effective crash prediction model for identifying high risk older drivers in a manner that is not considered blanket discrimination towards all older drivers.

Given the results associated with Hypothesis 4, and the inability to identify high risk older drivers using driving history in the manner described in this research, there does exist the opportunity to modify state level legislation in a manner that is likely to best serve older drivers as well as other road users who may be affected by older drivers. These opportunities are further described in Section 7.6.

8.6 Recommendations

A great deal of the work associated with this research was focused on the development of a crash prediction model that would identify high risk older drivers based on their previous driving history. Although the approach used in this research did not yield a model that could be used in this manner, the research process and results do provide the foundation for recommendations for policy and program implementation, as well as for additional research.

8.6.1 Policy and Program Recommendations

Policy-related recommendations based on this research are categorized into those that should be considered for implementation in Massachusetts and those that should be considered for implementation at a national level.

8.6.1.1 Massachusetts Policy and Program Recommendations

Currently, Massachusetts licensing provisions for older drivers are based on a system of review by referral and minimum requirements for fitness to drive. This means that a driver's ability is considered only when that person is brought to the attention of the Registry of Motor Vehicles by someone who knows the driver (doctor, caretaker, etc) or because of their involvement in a safety-related event (such as fault in a crash). Upon referral, minimum standards must be met (vision tests, heart health, etc). If the driver does not meet any one of these minimum standards, they are deemed unfit to drive and their license is revoked. There are two critical opportunities for improving Massachusetts licensing around older drivers.

Massachusetts should institute a mechanism for screening older drivers that does not rely primarily on referral. Waiting until the older person is considered a potential risk either by caretakers or by licensing agents is too late. It leaves open an unnecessary window of opportunity for these drivers to be involved in a crash. Unfortunately, there appear to be no current "best practices" for identifying a subset of older drivers who should potentially be considered for additional review. Given this, the following steps should be considered.

1. Institute an age-based policy for retesting older drivers. Existing research indicates that using a strictly age-based policy may not be most effective. This age-based measure should be considered temporary until research or best practices have identified a more effective mechanism for identifying a subset of the driving population that should be considered for further evaluation of driving

ability. Although current MGL language prohibits licensing policies based solely on age, the exception has been made for teen drivers. This framework for exception should also be applied to older drivers.

2. Continue to monitor policies implemented by other states to identify potentially high risk drivers and consider implementation in Massachusetts. Simultaneously, Massachusetts should continue to explore its own options for identifying high risk drivers which may include the potential use of administrative data (crash, citation, driver history).

Massachusetts should move away from a system that is based on revocation of licenses and towards a system that uses license restrictions. Although research evaluating the effectiveness of licensing practices on improving older driver safety is relatively limited, there have been some small-scale studies that have shown that the use of a system of restrictions, rather than full license revocation, can limit an older drivers exposure to high risk driving situations while allowing them to maintain a level of mobility not afforded when they become reliant on others for transportation. Restrictions may include time of day, distance from home, roadway type, and weather conditions among others. The use of restrictions rather than revocation is also less stressful than revocation for both the older driver and their family and friends.

In addition to these licensing practices, there are other efforts that Massachusetts should undertake in the process of establishing an overall system for addressing older driver safety at the licensing agent level. These should happen concurrently to the each other and to the development of actual licensing practices. These should also be considered ongoing efforts rather than tasks to be completed once.

Massachusetts should conduct a thorough review of its MAB practices. Using the results of the survey conducted by NHTSA through AAMVA, Massachusetts should identify opportunities to strengthen its MAB. For example, Massachusetts' current MAB is a volunteer Board; recommendations have been made that MABs should be full-time agents of the Registry of Motor Vehicles. Whether or not they are full time, they should be compensated for their time at a rate comparable to what their pay would be elsewhere. Although this may be deemed a costly measure, the growing size of the older population dictates that additional resources be allocated to addressing their needs; this is one place that resource allocation may be most effective since aging is an individual process that is largely associated with the decline of physical and cognitive health.

Massachusetts should focus heavily on the evaluation of any programs or policies implemented. This evaluation serves two purposes. First, it will provide foundations for the development or alteration of state-level policy and programming in the future. Second, because older driver licensing policy has been under-evaluated to date, it provides the opportunity for Massachusetts to be seen as a national leader in older driver policy development and, perhaps more importantly, evaluation.

There are several resources currently available to Massachusetts policy makers that should be considered. Although there is other information available, three key works should be examined:

- Driver License Policies, Practice, and Noteworthy Programs Database (AAA Foundation for Traffic Safety)
- Strategies for Medical Advisory Boards and Licensing Review (NHTSA)
- Model Driver Screening Program (NHTSA)

Massachusetts should explore alternative transportation options for older persons who can no longer drive. These options may include transit, rideshare, taxi cab vouchers, etc. This should be an ongoing process. It is critical that this process incorporate planners as well as policy makers since ultimately a great deal of this alternative transportation will be implemented at the local or regional level. It is also critical that personal safety be considered. For example, suggesting an older person begin using public transit when they never have before ignores concerns for their physical ability to navigate transit stations or the transit system as a whole. It will also be important to assess the relationship between smart growth, smart transportation, and older person mobility. Smart transportation, which focuses on community-based processes for developing context-specific transportation solutions (64) has the potential provide older persons with transportation options that have not been available in the past. However, many of the solutions often considered involve transit, pedestrian activity, and the relationship between where people live and how they move. These solutions may present some challenges for older persons who have been shown to prefer aging in place and who may have difficulty with walking or transit use. The community-involvement aspect does have a great potential for improving older person mobility as they may take a more active role in making transportation decisions. This is one example of the importance of planners in the process of considering alternate mobility options since planning and smart transportation are both associated with implementation on a scale smaller than state-level licensing practices.

8.6.1.2 National Policy and Program Recommendations

The development of older driver licensing policy is in its infancy. Although licensing policy is implemented at the state level, there exists the opportunity for national level support to be provided to state decision makers. As has been the case with teen driver licensing, national guidance can support state licensing policy, encouraging states to adopt comprehensive policies that have been proven effective. To that end, the following recommendations are made for older driver licensing policy initiatives as the national level.

Resources should be allocated to the development of functional and cognitive testing that can be conducted at the licensing agency. There has been some initial work on this front, such as the NHTSA Model Driver Screening Program. However, findings from program, which was conducted in 1996, should be updated in light of the availability of new information on the impact of aging and tests to assess driver fitness. Given the growing number of older drivers anticipated with the aging of the Baby Boom generation, any testing conducted at the licensing agent level must be both effective in its ability to assess driver fitness and feasibly implemented. In this case, feasibility includes consideration of 1) the time it will take for testing to be conducted, 2) the ability of the test to be conducted by counter staff who may receive some training but are not medical professionals, 3) the cost of implementation, and 4) whether the testing process will be politically palatable and socially accepted. This type of testing should only serve as a first step in the licensing process. Failure of these types of tests should not automatically result in license revocation or restriction.

An effective second step for older driver license decision making should be identified. There several approaches that have been taken in assessing driver fitness, especially given failure in a first step test. These include additional testing at the licensing agency (computer based, for example), road testing, or case review by an MAB. Challenges have been raised associated with these methods and there is little in the way of evaluation. Road tests may not effectively measure the ability of an older driver to safely navigate hazardous situations. Case-by-case MAB review may be too costly. Similar to the development of functional and cognitive testing to be conducted by counter staff, a combination of effectiveness, cost, benefit, and political/social palatability must be considered in the identification of best practice "second steps".

Determination should be made regarding the best mechanism for determining when to retest. Existing research indicates that age based approaches to licensing policy may not be ideal. However, there is little in the way of alternatives for identifying a subset of all licensed drivers who should undergo additional testing. This mechanism may ultimately be age, since it is standard and easy to assess. There may be some challenges, though, regarding perceptions of age discrimination and the process of deciding what that age should be. While this research was unable to identify a purely systematic method for identify a subset of potentially high risk drivers, there still exists opportunities to further explore this possibility with the use of additional data or alternative models. However, given the challenges identified with using only a systematic, administrative data approach, great caution should be taken in reliance only on these data. Ultimately, it is likely that a combined approach that is both age and data driven will provide the most effective and feasible option for determining when to retest.

There is a need for further consideration of the differences between males and females in relation to aging and driving. It is a disservice to the older population to continue the dialogue around licensing without acknowledging, and further investigation of, the relationship between sex and older driver safety. Although it may be difficult (or impossible) to develop licensing policy specific to driver sex, additional research is necessary that could be used for retraining, public outreach, education, etc. In addition, information on the differences in aging processes for men and women could become a consideration in the development of functional and cognitive testing where males are tested for those challenges more commonly associated with the aging process for men, and females for those more commonly associated with the aging process for women.

8.6.2 Recommendations for Additional Research

The following recommendations are associated with potential future research topics.

Further examination of the potential for use of systematic approaches for identifying drivers who may be candidates for individual assessment is necessary.

Although none of the three models were able to develop a systematic approach for identifying high risk older drivers based on their previous driving history, the use of state level data for older driver licensing policy should not be abandoned. However, several points have become evident as part of this research. There may still be opportunity for developing a successful model using additional information included in the driver history data that was not available for this model development. The development of a model using these additional variables should be explored.

If the use of additional variables does yield a successful model, the results of that model should be used in the process of identifying candidates for additional assessment. A successful statistical model alone should not serve as the basis for decision-making regarding and older person's fitness to drive. This is especially true given the limited ability and success of model development efforts outlined in this research. This points to the idea that data alone are not likely to yield overwhelming results in identifying high risk drivers.

There exists a need for additional information regarding variation in older driver risk, ability, and crash outcomes based on sex.

Both the analysis of crash outcomes and the analysis of the relationship between driver history and crash involvement highlighted notable differences between males and females. A great deal of the focus in the area of older safety has been placed on age. However, it is clear that male and female older drivers are affected differently and policy and programs should be developed with this in mind. Specifically, additional research in the following areas would yield helpful information:

- Why are older females associated with higher emergency department charges than older males when this is the opposite of the case for adult drivers? Are there issues around vehicle design that have a greater impact on older drivers than they do on adults, specifically where the relationship between vehicle design and biomechanics are concerned?
- Knowing that older females are associated with higher emergency department charges than older males, what is the nature of crash outcomes in terms of long-term care for older persons injured in a crash? Emergency department information addresses immediate treatment. Given the fragility of older persons, the need to consider long-term care is even greater than may be the case for other driver populations. Is there a difference between long-term care outcomes for older males and females?
- What is the relationship between crash involvement and sex? Although males and females each account for one-half of the licensed older driver population, males are involved in a higher proportion of crashes than females. How does this compare to the driver population in general (regardless of age)? If the difference between licensed driver proportion and crash driver proportion is different for older drivers than other drivers, further research should be conducted to determine why.

APPENDIX

SUMMARY STATISTICS FOR 2006 COMPREHENSIVE DRIVER PROFILE

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	Minimum	Maximum	Variance
NumInjCr	NumInjCr	20684	0.2851963	0.4642948	0	3.0000000	0.2155697
AGE	AGE	20684	74.3519145	6.8257379	65.0000000	100.0000000	46.5906984
AGE_GRP	AGE_GRP	20684	2.4822085	1.3061256	1.0000000	5.0000000	1.7059640
SEX	SEX	20475	1.5688889	0.4952437	1.0000000	2.0000000	0.2452663
Crashes_0205	Crashes_0205	20684	0.1877296	0.5489194	0	24.0000000	0.3013125
InjCrashes_0205	InjCrashes_0205	20684	0.0268807	0.1774197	0	4.0000000	0.0314778
Int_0205	Int_0205	20684	0.0917617	0.3520776	0	8.0000000	0.1239586
SVC_0205	SVC_0205	20684	0.0144556	0.1272057	0	4.0000000	0.0161813
Rear_0205	Rear_0205	20684	0.0559370	0.2577692	0	5.0000000	0.0664450
Angle_0205	Angle_0205	20684	0.0759041	0.3110272	0	6.0000000	0.0967379
Side_0205	Side_0205	20684	0.0243183	0.1874524	0	12.0000000	0.0351384
HeadOn_0205	HeadOn_0205	20684	0.0049313	0.0727603	0	3.0000000	0.0052941
Veh_0205	Veh_0205	20684	0.1259428	0.4367293	0	20.0000000	0.1907324
NonMot_0205	NonMot_0205	20684	0.0037710	0.0612943	0	1.0000000	0.0037570
Fixed_0205	Fixed_0205	20684	0.0072520	0.0876540	0	2.0000000	0.0076832
NonColl_0205	NonColl_0205	20684	0.000628505	0.0269228	0	2.0000000	0.000724838
OtherFHE_0205	OtherFHE_0205	20684	0.0020789	0.0476243	0	2.0000000	0.0022681
VIOL_9501	VIOL_9501	20610	0.4675400	1.8137712	0	32.0000000	3.2897658
ALC_9501	ALC_9501	20610	0.0055798	0.1110950	0	8.0000000	0.0123421
BELT_9501	BELT_9501	20610	0.0314896	0.2716275	0	12.0000000	0.0737815
FLEE_9501	FLEE_9501	20610	0.0033964	0.0858131	0	6.0000000	0.0073639
GEN_9501	GEN_9501	20610	0.0462882	0.3261190	0	12.0000000	0.1063536
LANE_9501	LANE_9501	20610	0.0282387	0.2442572	0	8.0000000	0.0596616
LIC_9501	LIC_9501	20610	0.0643377	0.5723288	0	30.0000000	0.3275602
OTHER_9501	OTHER_9501	20610	0.0088792	0.1473355	0	8.0000000	0.0217078
SER_9501	SER_9501	20610	0.0029597	0.0678298	0	4.0000000	0.0046009
SPEED_9501	SPEED_9501	20610	0.1767103	0.8584189	0	26.0000000	0.7368830
STP_9501	STP_9501	20610	0.0996604	0.5439265	0	18.0000000	0.2958561
VIOL_0205	VIOL_0205	20654	0.2216520	0.9709198	0	20.0000000	0.9426852
ALC_0205	ALC_0205	20654	0.0014525	0.0417250	0	2.0000000	0.0017410

BELT_0205	BELT_0205	20654	0.0238695	0.2403648	0	12.0000000	0.0577753
FLEE_0205	FLEE_0205	20654	0.0025661	0.0648527	0	5.0000000	0.0042059
GEN_0205	GEN_0205	20654	0.0246441	0.2122542	0	9.0000000	0.0450519

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	Minimum	Maximum	Variance
LANE_0205	LANE_0205	20654	0.0160260	0.1589340	0	6.0000000	0.0252600
LIC_0205	LIC_0205	20654	0.0350053	0.3310679	0	14.0000000	0.1096059
OTHER_0205	OTHER_0205	20654	0.0042123	0.0859673	0	7.0000000	0.0073904
SER_0205	SER_0205	20654	0.000774668	0.0295118	0	2.0000000	0.000870944
SPEED_0205	SPEED_0205	20654	0.0675414	0.4057866	0	13.0000000	0.1646627
STP_0205	STP_0205	20654	0.0455602	0.2975169	0	13.0000000	0.0885163

The FREQ Procedure

NumInjCr

NumInjCr	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	14904	72.06	14904	72.06
1	5663	27.38	20567	99.43
2	115	0.56	20682	99.99
3	2	0.01	20684	100.00

Frequency Missing = 1

The FREQ Procedure

AGE

AGE	Frequency	Percent	Cumulative Frequency	Cumulative Percent
65	1529	7.39	1529	7.39
66	1322	6.39	2851	13.78
67	1272	6.15	4123	19.93
68	1136	5.49	5259	25.43
69	1065	5.15	6324	30.57
70	1025	4.96	7349	35.53
71	1021	4.94	8370	40.47
72	981	4.74	9351	45.21
73	988	4.78	10339	49.99
74	966	4.67	11305	54.66
75	862	4.17	12167	58.82
76	923	4.46	13090	63.29
77	869	4.20	13959	67.49
78	881	4.26	14840	71.75
79	742	3.59	15582	75.33
80	801	3.87	16383	79.21
81	717	3.47	17100	82.67
82	666	3.22	17766	85.89
83	585	2.83	18351	88.72
84	516	2.49	18867	91.22
85	450	2.18	19317	93.39
86	360	1.74	19677	95.13
87	257	1.24	19934	96.37
88	228	1.10	20162	97.48
89	168	0.81	20330	98.29
90	124	0.60	20454	98.89
91	71	0.34	20525	99.23
92	59	0.29	20584	99.52
93	35	0.17	20619	99.69
94	20	0.10	20639	99.78
95	15	0.07	20654	99.85

The FREQ Procedure

AGE

AGE	Frequency	Percent	Cumulative Frequency	Cumulative Percent
96	12	0.06	20666	99.91
97	9	0.04	20675	99.96
98	6	0.03	20681	99.99
99	2	0.01	20683	100.00
100	1	0.00	20684	100.00

Frequency Missing = 1

SEX

SEX	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	8827	43.11	8827	43.11
2	11648	56.89	20475	100.00

Frequency Missing = 210

The FREQ Procedure

Crashes_0205

Crashes_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	17596	85.07	17596	85.07
1	2555	12.35	20151	97.42
2	427	2.06	20578	99.49
3	27	0.13	20605	99.62
4	56	0.27	20661	99.89
6	17	0.08	20678	99.97
8	2	0.01	20680	99.98
9	3	0.01	20683	100.00
24	1	0.00	20684	100.00

Frequency Missing = 1

InjCrashes_0205

InjCrashes_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20174	97.53	20174	97.53
1	472	2.28	20646	99.82
2	31	0.15	20677	99.97
3	6	0.03	20683	100.00
4	1	0.00	20684	100.00

Frequency Missing = 1

The FREQ Procedure

Int_0205

Int_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19046	92.08	19046	92.08
1	1463	7.07	20509	99.15
2	132	0.64	20641	99.79
3	19	0.09	20660	99.88
4	15	0.07	20675	99.96
5	4	0.02	20679	99.98
6	3	0.01	20682	99.99
8	2	0.01	20684	100.00

Frequency Missing = 1

SVC_0205

SVC_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20402	98.64	20402	98.64
1	267	1.29	20669	99.93
2	14	0.07	20683	100.00
4	1	0.00	20684	100.00

Frequency Missing = 1

The FREQ Procedure

Rear_0205

Rear_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19630	94.90	19630	94.90
1	979	4.73	20609	99.64
2	55	0.27	20664	99.90
3	14	0.07	20678	99.97
4	4	0.02	20682	99.99
5	2	0.01	20684	100.00

Frequency Missing = 1

Angle_0205

Angle_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19306	93.34	19306	93.34
1	1244	6.01	20550	99.35
2	96	0.46	20646	99.82
3	22	0.11	20668	99.92
4	13	0.06	20681	99.99
5	2	0.01	20683	100.00
6	1	0.00	20684	100.00

Frequency Missing = 1

The FREQ Procedure

Side_0205

Side_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20232	97.81	20232	97.81
1	421	2.04	20653	99.85
2	22	0.11	20675	99.96
3	6	0.03	20681	99.99
4	2	0.01	20683	100.00
12	1	0.00	20684	100.00

Frequency Missing = 1

HeadOn_0205

HeadOn_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20585	99.52	20585	99.52
1	97	0.47	20682	99.99
2	1	0.00	20683	100.00
3	1	0.00	20684	100.00

Frequency Missing = 1

The FREQ Procedure

Veh_0205

Veh_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	18503	89.46	18503	89.46
1	1908	9.22	20411	98.68
2	201	0.97	20612	99.65
3	32	0.15	20644	99.81
4	28	0.14	20672	99.94
5	4	0.02	20676	99.96
6	5	0.02	20681	99.99
8	1	0.00	20682	99.99
9	1	0.00	20683	100.00
20	1	0.00	20684	100.00

Frequency Missing = 1

NonMot_0205

NonMot_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20606	99.62	20606	99.62
1	78	0.38	20684	100.00

Frequency Missing = 1

The FREQ Procedure

Fixed_0205

Fixed_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20539	99.30	20539	99.30
1	140	0.68	20679	99.98
2	5	0.02	20684	100.00

Frequency Missing = 1

NonColl_0205

NonColl_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20672	99.94	20672	99.94
1	11	0.05	20683	100.00
2	1	0.00	20684	100.00

Frequency Missing = 1

OtherFHE_0205

OtherFHE_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20643	99.80	20643	99.80
1	39	0.19	20682	99.99
2	2	0.01	20684	100.00

Frequency Missing = 1

The FREQ Procedure

VIOL_9501

VIOL_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	16753	81.29	16753	81.29
1	2181	10.58	18934	91.87
2	881	4.27	19815	96.14
3	178	0.86	19993	97.01
4	227	1.10	20220	98.11
5	11	0.05	20231	98.16
6	130	0.63	20361	98.79
8	60	0.29	20421	99.08
9	26	0.13	20447	99.21
10	9	0.04	20456	99.25
12	70	0.34	20526	99.59
15	1	0.00	20527	99.60
16	24	0.12	20551	99.71
18	15	0.07	20566	99.79
20	8	0.04	20574	99.83
24	23	0.11	20597	99.94
27	3	0.01	20600	99.95
30	5	0.02	20605	99.98
32	5	0.02	20610	100.00

Frequency Missing = 75

The FREQ Procedure

ALC_9501

ALC_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20529	99.61	20529	99.61
1	64	0.31	20593	99.92
2	9	0.04	20602	99.96
3	3	0.01	20605	99.98
4	4	0.02	20609	100.00
8	1	0.00	20610	100.00

Frequency Missing = 75

BELT_9501

BELT_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20164	97.84	20164	97.84
1	352	1.71	20516	99.54
2	45	0.22	20561	99.76
3	17	0.08	20578	99.84
4	20	0.10	20598	99.94
5	8	0.04	20606	99.98
8	3	0.01	20609	100.00
12	1	0.00	20610	100.00

Frequency Missing = 75

The FREQ Procedure

FLEE_9501

FLEE_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20562	99.77	20562	99.77
1	36	0.17	20598	99.94
2	8	0.04	20606	99.98
4	3	0.01	20609	100.00
6	1	0.00	20610	100.00

Frequency Missing = 75

GEN_9501

GEN_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19937	96.73	19937	96.73
1	535	2.60	20472	99.33
2	77	0.37	20549	99.70
3	34	0.16	20583	99.87
4	9	0.04	20592	99.91
5	1	0.00	20593	99.92
6	9	0.04	20602	99.96
7	1	0.00	20603	99.97
8	5	0.02	20608	99.99
9	1	0.00	20609	100.00
12	1	0.00	20610	100.00

Frequency Missing = 75

The FREQ Procedure

LANE_9501

LANE_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20199	98.01	20199	98.01
1	314	1.52	20513	99.53
2	64	0.31	20577	99.84
3	15	0.07	20592	99.91
4	9	0.04	20601	99.96
5	1	0.00	20602	99.96
6	5	0.02	20607	99.99
8	3	0.01	20610	100.00

Frequency Missing = 75

The FREQ Procedure

LIC_9501

LIC_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19947	96.78	19947	96.78
1	424	2.06	20371	98.84
2	129	0.63	20500	99.47
3	38	0.18	20538	99.65
4	21	0.10	20559	99.75
5	10	0.05	20569	99.80
6	14	0.07	20583	99.87
7	4	0.02	20587	99.89
8	7	0.03	20594	99.92
9	2	0.01	20596	99.93
10	4	0.02	20600	99.95
12	3	0.01	20603	99.97
14	2	0.01	20605	99.98
15	1	0.00	20606	99.98
16	1	0.00	20607	99.99
18	1	0.00	20608	99.99
27	1	0.00	20609	100.00
30	1	0.00	20610	100.00

Frequency Missing = 75

The FREQ Procedure

OTHER_9501

OTHER_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20489	99.41	20489	99.41
1	90	0.44	20579	99.85
2	18	0.09	20597	99.94
3	6	0.03	20603	99.97
4	3	0.01	20606	99.98
6	2	0.01	20608	99.99
7	1	0.00	20609	100.00
8	1	0.00	20610	100.00

Frequency Missing = 75

SER_9501

SER_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20561	99.76	20561	99.76
1	41	0.20	20602	99.96
2	5	0.02	20607	99.99
3	2	0.01	20609	100.00
4	1	0.00	20610	100.00

Frequency Missing = 75

The FREQ Procedure

SPEED_9501

SPEED_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	18536	89.94	18536	89.94
1	1525	7.40	20061	97.34
2	267	1.30	20328	98.63
3	105	0.51	20433	99.14
4	55	0.27	20488	99.41
5	25	0.12	20513	99.53
6	34	0.16	20547	99.69
7	12	0.06	20559	99.75
8	13	0.06	20572	99.82
9	7	0.03	20579	99.85
10	4	0.02	20583	99.87
11	2	0.01	20585	99.88
12	5	0.02	20590	99.90
13	1	0.00	20591	99.91
14	5	0.02	20596	99.93
15	1	0.00	20597	99.94
16	3	0.01	20600	99.95
17	2	0.01	20602	99.96
18	2	0.01	20604	99.97
19	1	0.00	20605	99.98
20	1	0.00	20606	99.98
21	1	0.00	20607	99.99
22	2	0.01	20609	100.00
26	1	0.00	20610	100.00

Frequency Missing = 75

The FREQ Procedure

STP_9501

STP_9501	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19335	93.81	19335	93.81
1	943	4.58	20278	98.39
2	164	0.80	20442	99.18
3	71	0.34	20513	99.53
4	45	0.22	20558	99.75
5	10	0.05	20568	99.80
6	18	0.09	20586	99.88
7	2	0.01	20588	99.89
8	13	0.06	20601	99.96
9	1	0.00	20602	99.96
10	1	0.00	20603	99.97
11	1	0.00	20604	99.97
12	3	0.01	20607	99.99
13	1	0.00	20608	99.99
17	1	0.00	20609	100.00
18	1	0.00	20610	100.00

Frequency Missing = 75

The FREQ Procedure

VIOL_0205

VIOL_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	18347	88.83	18347	88.83
1	1445	7.00	19792	95.83
2	465	2.25	20257	98.08
3	134	0.65	20391	98.73
4	96	0.46	20487	99.19
5	31	0.15	20518	99.34
6	50	0.24	20568	99.58
7	10	0.05	20578	99.63
8	19	0.09	20597	99.72
9	8	0.04	20605	99.76
10	7	0.03	20612	99.80
12	21	0.10	20633	99.90
13	2	0.01	20635	99.91
14	2	0.01	20637	99.92
15	2	0.01	20639	99.93
16	6	0.03	20645	99.96
18	7	0.03	20652	99.99
20	2	0.01	20654	100.00

Frequency Missing = 31

The FREQ Procedure

ALC_0205

ALC_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20627	99.87	20627	99.87
1	24	0.12	20651	99.99
2	3	0.01	20654	100.00

Frequency Missing = 31

BELT_0205

BELT_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20347	98.51	20347	98.51
1	178	0.86	20525	99.38
2	108	0.52	20633	99.90
3	5	0.02	20638	99.92
4	11	0.05	20649	99.98
5	2	0.01	20651	99.99
6	1	0.00	20652	99.99
12	2	0.01	20654	100.00

Frequency Missing = 31

The FREQ Procedure

FLEE_0205

FLEE_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20611	99.79	20611	99.79
1	37	0.18	20648	99.97
2	4	0.02	20652	99.99
3	1	0.00	20653	100.00
5	1	0.00	20654	100.00

Frequency Missing = 31

GEN_0205

GEN_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20258	98.08	20258	98.08
1	337	1.63	20595	99.71
2	31	0.15	20626	99.86
3	14	0.07	20640	99.93
4	8	0.04	20648	99.97
5	3	0.01	20651	99.99
6	2	0.01	20653	100.00
9	1	0.00	20654	100.00

Frequency Missing = 31

The FREQ Procedure

LANE_0205

LANE_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20382	98.68	20382	98.68
1	234	1.13	20616	99.82
2	28	0.14	20644	99.95
3	4	0.02	20648	99.97
4	3	0.01	20651	99.99
5	1	0.00	20652	99.99
6	2	0.01	20654	100.00

Frequency Missing = 31

The FREQ Procedure

LIC_0205

LIC_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20217	97.88	20217	97.88
1	310	1.50	20527	99.39
2	75	0.36	20602	99.75
3	16	0.08	20618	99.83
4	17	0.08	20635	99.91
5	2	0.01	20637	99.92
6	7	0.03	20644	99.95
7	2	0.01	20646	99.96
8	3	0.01	20649	99.98
9	2	0.01	20651	99.99
12	1	0.00	20652	99.99
13	1	0.00	20653	100.00
14	1	0.00	20654	100.00

Frequency Missing = 31

The FREQ Procedure

OTHER_0205

OTHER_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20581	99.65	20581	99.65
1	67	0.32	20648	99.97
2	3	0.01	20651	99.99
3	1	0.00	20652	99.99
4	1	0.00	20653	100.00
7	1	0.00	20654	100.00

Frequency Missing = 31

SER_0205

SER_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	20639	99.93	20639	99.93
1	14	0.07	20653	100.00
2	1	0.00	20654	100.00

Frequency Missing = 31

The FREQ Procedure

SPEED_0205

SPEED_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19645	95.11	19645	95.11
1	849	4.11	20494	99.23
2	83	0.40	20577	99.63
3	24	0.12	20601	99.74
4	25	0.12	20626	99.86
5	6	0.03	20632	99.89
6	7	0.03	20639	99.93
7	4	0.02	20643	99.95
8	5	0.02	20648	99.97
9	1	0.00	20649	99.98
11	2	0.01	20651	99.99
12	2	0.01	20653	100.00
13	1	0.00	20654	100.00

Frequency Missing = 31

The FREQ Procedure

STP_0205

STP_0205	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	19943	96.56	19943	96.56
1	585	2.83	20528	99.39
2	73	0.35	20601	99.74
3	30	0.15	20631	99.89
4	13	0.06	20644	99.95
5	3	0.01	20647	99.97
6	4	0.02	20651	99.99
8	2	0.01	20653	100.00
13	1	0.00	20654	100.00

Frequency Missing = 31

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