ABSTRACT

FACTORS THAT IMPACT SEAT BELT USAGE AND INJURY SEVERITY OF BELTED FRONT SEAT OCCUPANTS

by

Siri Konje Lawrencia Nukenine

Factors influencing seat belt usage have been extensively researched in the safety analysis literature. Most of this research has focused on factors that influence seat belt usage for a driver and front seat passenger in a vehicle. Few research studies have investigated factors that impact seat belt usage for back seat occupants. This research investigates the factors associated with seat belt usage for front-seat as well as back-seat occupants of vehicles in the state of New Jersey. Using logistic regression, seat belt usage models were developed to examine the contribution of several variables on seat belt usage for five vehicle occupants.

The age of the occupant was found to be a significant factor for influencing the seat belt usage of both the driver and the right-back passenger. Gender was determined to be a significant variable for all of the models, with the exception of the right-back seat occupant model. The models show that in general male occupants in the front-seat tend to be less likely to wear a seat belt compared to female occupants. The results are just the opposite for back seat occupants. The results showed that a driver traveling alone is less likely to be belted than if he or she was driving with another passenger. The results also indicated that more occupants in the vehicle increase the likelihood that the back-seat occupants are buckled. Occupants on urban principal arterials were found to be more likely to be belted than on other roadways.

The driver's seat belt usage was found to be significant for all the non-driver seat belt usage models.

Essentially, research and enforcement campaigns on seat belt usage have been focus on front seat occupants. Seat belt usage for back seat occupant is also very important. Unbelted back seat occupants put themselves and other occupants at serious risk when riding unbuckled. A comprehensive literature review on back seat passenger seat belt usage was conducted in this research. Injury severity models were developed in this research to obtain injury severity level of drivers and right-front seat occupants in motor vehicle crashes, using several independent variables. Using SPSS version 10.00 Statistical software, ordinal logistic regression models were developed. The results showed among other variables that seat belt usage by back seat occupants has an impact on the injury severity of front seat occupants. In particular, the impact is greater as the number of back seat occupants in the vehicle during a crash increases.

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by
Siri Konje Lawrencia Nukenine

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FACTORS THAT IMPACT SEAT BELT USAGE AND INJURY SEVERITY OF BELTED FRONT SEAT OCCUPANTS

Siri Konje Lawrencia Nukenine

Dr. Janice R. Daniel, Dissertation Advisor — Date
Associate Professor of Civil and Environmental Engineering, NJIT

Dr. Lazar Spasovic, Committee Member — Date
Professor of Civil and Environmental Engineering, NJIT

Dr. Steven I. Chien, Committee Member — Date
Professor of Civil and Environmental Engineering, NJIT

Dr. Athanassios K. Bladikas , Committee Member — Date
Associate Professor of Industrial and Manufacturing Engineering, NJIT

Dr. Rongfang (Rachel) Liu, Committee Member — Date
Associate Professor of Civil and Environmental Engineering, NJIT

BIOGRAPHICAL SKETCH

Author: Siri Konje Lawrencia Nukenine

Degree: Doctor of Philosophy

Date: January 2011

Undergraduate and Graduate Education:

- Doctor of Philosophy in Civil and Environmental Engineering,
  New Jersey Institute of Technology, Newark, NJ, USA, 2011

- Master of Science in Mathematics,
  University of Ibadan, Ibadan, Nigeria, 1998

- Bachelor of Science in Mathematics,
  Ahmadu Bello University, Zaria, Nigeria, 1995

Major: Civil Engineering

Presentations and Publications:

Janice Daniel, Siri Konje L. Nukenine,
"Impact of Rear-seat Occupant Belt Use on the Injury Severity of Belted Drivers,"
Submitted for the
90th Annual Meeting of Transportation Research Board Annual Meeting
Washington D.C., July 2010.

Janice Daniel, Yang He, and Siri Konje L. Nukenine,
"Rear Seat Belt Use Models Using FARS and Field Data,"
Submitted for the
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Washington D.C., July 2010.

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This Dissertation is dedicated to my darling husband: Elias Nukenine (Eliboy), and my lovely babies: Charlotte “Princess Mama Cherie”, Justin “Prince Popsi Papa”, and Engelbert “My little One, Angel”

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CHAPTER 1

INTRODUCTION

Car crashes are the leading cause of death, as well as loss of work time in the United States. In particular traffic accidents are the number one cause of death for Americans age 1 to 34 (Briggs et al., 2006). In 2008 an estimated 37,261 people died in motor vehicle traffic crashes, and it was projected that traffic fatalities for the first quarter of 2009 would be 7,689 people (NHTSA, 2009a). According to the National Highway Traffic Safety Administration (NHTSA) traffic crashes are not “accidents,” but are both predictable and preventable.

Numerous studies have been done for decades to show the importance of seat belt in traffic safety. These studies have all proved that wearing seat belts by motor vehicle occupants reduce injuries and also save lives. NHTSA identified that the quickest, easiest, and most effective way to prevent traffic injuries and fatalities is to make certain that every vehicle occupant is properly buckled up on every trip. According to NHTSA lap-shoulder belt systems reduce the risk of fatality and serious injury by 50 percent when used by drivers and front-seat passengers. Public health officials insist that up to half the number of deaths could be saved if everyone wore seat belts (Westlake-Kenny, 1998). Among passenger vehicle occupants 5 and older in 2008, seat belts saved an estimated 13,250 lives and an estimated 75,000 people for the 5 year period of 2004-2008 (NHTSA 2009a).Kenneth Mann Ph.D. of University of Alabama’s (UAB) Biomedical Engineering Department says that the three-point safety-belt restraint, which includes a combination of lap belt and shoulder-to-hip belt, “protects the internal organs in a crash as it controls the forward motion of the body and the accompanying rotation of the pelvis.” The device, he says, also minimizes head contacts and excessive neck motion, preventing head and neck injuries (Westlake-Kenny, 1998).

The use of safety belts has also been identified as the single and most effective means of reducing fatal and nonfatal injuries in motor vehicle crashes (Dinh-Zarr, 2001). Studies and surveys on the subject of the importance of seat belts by other researchers, the press, radio and television, have also concluded that seat belts have a great positive impact on safety and that effective seatbelt usage reduces mortality and morbidity among traffic crash victims. Seatbelts are effective in protecting occupants from ejection, one of the most injurious results of a motor vehicle crash.

The following seat belt statistics for drivers and right-front passengers of passenger vehicles was released by the National Occupant Protection Use Survey (NOPUS) for NHTSA in 2009:

- Fifty-five percent of those killed in passenger vehicle occupant crashes in 2008 were not wearing a seat belt.
- Seat belt use stood at 84% in 2009, up from 83 % in 2008.
- Seat belt use has been increasing steadily since 1994 accompanied by steady decline in the percentage of unrestricted passenger vehicle occupant fatalities during daytime.
- Seat belt use for occupants travelling during weekends increased from 83% to 86% from 2008 to 2009, while weekdays stay same 83%.
- Seat belt use continues to be higher in states with Primary laws (88%) compared with states with secondary laws (77%).

Other seat belt usage statistics previously released by NHTSA in 2008 were as follows

- Seat belt use in 2008 increased to 90% on expressways and remained at 80% for surface streets.

- In states where rear seat belt use was not required in 2008, only 66% of adult passengers wore their seat belts while sitting in the backseat.

- Among 16-24-year-olds, seat belt use continued to be lower than other age groups.

- Seat belt use is lower among drivers driving alone than among drivers with passengers.

- Females wore their seat belt more than males in 2007.

Despite the steady increase in seat belt usage since 1994, the national target usage rate of 90 percent is yet to be attained. In fact according to NHSTA increasing the national seat belt use rate to 90 percent would prevent an estimated 5,536 fatalities, 132,670 injuries and save the nation $8.8 billion annually. The new seat belt usage rate by NHTSA is 92% by the end of 2010. Achieving this goal will require a careful and intensive study on the factors influencing seat belt usage for both front seat and back seat vehicle occupants. A good understanding of factors that influence vehicle occupants' seat belt usage would assist state and local administrators in determining strategies for improving seat belt usage. The different factors identified to influence seat belt usage could then be compared, and those with very high influence could then be the focus of seat belt usage campaigns designed to encourage motorists to buckle up.

Much of the research that has been conducted on seat belt usage has been focused on front seat occupants. Not much has been studied on the seat belt usage of back seat occupants. However studies have shown that unbelted back seat occupants place both themselves and front seats occupants at greater risk during crashes. This is because an unbelted back seat occupant could be catapulted to the front of the vehicle during a crash causing more severe injuries to front seat occupants as well as themselves. Although primary child restraint belt use laws exist in all states, adult rear seat belt laws do not exists in all the states. However, some states do have secondary rear seat belt laws. There is therefore a need for seat belt laws for adult back seat occupants and most importantly a need to make these laws primary seat belt laws.

1.1 Problem Statement

Factors influencing seat belt usage has been extensively researched in the safety analysis literature. Most of this research has focused on factors that would influence seat belt usage for a driver and front seat passenger in a vehicle. However, very little work has been done to determine those factors that impact seat belt usage for back seat occupants. In several studies, the seating positions of the motorists are not specified. Factors that have been associated with seat belt usage for drivers and front-seat occupants include but not limited; gender, age, income, educational level, and race. It is not clear whether these factors are identical for back-seat occupants.

When determining the impact of backseat occupant seat belt usage on a front seat occupant injury severity, it is necessary to distinguish the impact if the front seat occupant were belted or not. Existing research that have been carried out to observe the impact of back seat occupant seat belt usage on front seats occupant injury severity have been limited in specifying whether the front occupant was belted or not.

In the State of New Jersey, over 2000 unbelted drivers and front-seat passengers died in motor vehicle crashes over the last ten years (NJ Division of Highway Traffic Safety, 2010). Also, 700 unbelted drivers were ejected from their vehicles and died in motor vehicle crashes over the last ten years. New Jersey seat belt laws (NJS 39:3-76.2f) requires all drivers, front-seat passengers, and all passengers of age 8 to 18 years old to wear a properly adjusted and fastened seat belt system. In January, 2010, legislation was signed into law requiring all occupants, not just those previously stated, to wear a seat belt regardless of their seating position in a vehicle. The new law is a secondary law allowing the police to issue summons on unbuckled back seat occupants, 18 years of age and older, when the vehicle they are riding in is stopped for another violation.

Although it is known that back-seat unbelted passenger impacts the safety of front- seat passenger, it is not clear the level of impact. Laws enacted requiring back seat passengers to be belted may provide an improvement in the safety of front-seat passengers. This however, has yet to be demonstrated.

1.2 Research Objectives

The objective of this research is to identify factors that significantly influence the seat belt usage of front-seat as well as back-seat occupants of vehicles in the State of New Jersey. Using binary logistic regression models, the factors to be considered include roadway, occupants', and physical variables that influence seat belt usage. The second objective of this research is to identify the factors that influence the injury severity of belted front-seat occupants with and without rear-seat occupants. The factors will be identified by developing a relationship between the injury severity of a belted front-seat occupant and a set of independent variables, including seat belt usage of back seat occupants. The research will determined whether a back-seat occupant's seat belt usage has an impact on the injury severity of a belted front-seat occupant. The results of this research will assist both the State of New Jersey and the country at large in developing programs aimed at increasing seat belt usage through strategies, techniques and educative programs that can be used to increase seat belt usage for unbuckled American motorists.

To better understand how back-seat passengers seat belt use impact front-seat occupants injury severity, the physics of the movement of occupants in motor vehicles will be further studied and a better understanding of why certain types of crashes and certain seating positions may be more dangerous than others.

The research will also evaluate whether back-seat passenger laws result in reduction of fatality and injury rates. The number of lives saved by the enactments of such laws will also be studied. Research has shown that seat belt usage for younger occupants can result in more severe injuries. This research will investigate the impact of a back-seat passenger seat belt law by age of the occupant. Based on the overall findings, a back-seat passenger campaign will be developed fro use in increasing seat belt usage of these vehicle occupants.

1.3 Dissertation Organization

This dissertation is organized into five chapters. Chapter 1 presents an introduction to the dissertation, stating the specific problem to be solved in the study and the research objectives. In Chapter 2, previous studies on the factors that influence seat belt usage and injury severity of vehicle occupants is reviewed. The different methodologies used to develop the seat belt and injury severity models in the research are presented and discussed in Chapter 3. Chapter 4 presents the model results and interpretation. Finally, the conclusions from the models developed and future work that could be done from this research are contained in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

In this chapter a literature review will be presented on the following: (1) The importance of seat belt usage; (2) Social and Economic impacts of non-use of seat belts; (3) Strategies that have been used in the country for increasing seatbelt usage; (Primary verses Secondary Seat Belt Laws, Selective Traffic Enforcement Programs (sTEPs), Innovative Programs related to seat belt use; (4) Existing research that has been done to identify factors that impact seatbelt usage; (5) Impact of seat belt usage; (Impact of seat belt usage on injury severity of vehicle occupants, and Impact of rear-seat occupants' seat belt usage on injury severity of front seat occupants with emphasis on the impact on belted front seat occupants).

2.1 Importance of Seat Belt Usage

What is universally acknowledged is that seat belt usage is a very important factor in traffic safety. Seat belt saves lives. According to NHTSA, seat belts are the best defense against motor vehicle injuries and fatalities. Seat belts have saved over 75,000 lives during the 5-year period from 2004 to 2008. In particular, among passenger vehicle occupants 5 years and older in 2008, seat belts saved an estimated 13,250 lives. An additional 4,152 lives could have been saved if seat belts were worn at the time of every crash. Seventy six percent of passenger vehicle occupants who were totally ejected from their vehicles were killed. But only three percent of passenger vehicle occupants killed in fatal crashes who were wearing seat belts were totally ejected. Seat belts also reduce the risk of fatal injury severity. Lap and shoulder seat belts, when properly used, reduce the risk of fatal injury to front-seat passenger by 45 percent and reduce the risk of moderate-to-critical injury by 50 percent (NHTSA, 2009a). A study by Cummings in 2004 looked at the seatbelt effectiveness as part of a study of the effectiveness of airbags. It was found that use of a seat belt alone reduces fatality risk by 65 percent. Wearing a seat belt decreases a vehicle occupant's risk of a severe injury when a collision occurs (Broughton et al., 2007). Seat belt can help a passenger survive a crash. A motorist can increase the odds of survival in a rollover crash in a light truck by nearly 80 percent by wearing a seat belt (NHTSA, 2009a). In 2007, 72 percent of passenger vehicle occupants who were involved in fatal crash and were bucked up survived.

Although most drivers and occupants know the importance of seat belt use many still do not realize the danger of not wearing a seat belt when an occupant is in the back seat. In crashes at 30mph, an unrestrained back seat occupant involved in a crash can be projected into the front seat, with a force of 30 to 60 times body weight of the back seat occupant. This could result in death or serious injury to both the back seat occupant and to those sitting in the front seat (DOE Road Safety, UK DOT, 2007). This fact is further confirmed in a study by Mayrose (2005) on the effect of unrestrained rear seat passengers on driver mortality. The study concluded that unrestrained rear seat passengers place themselves, as well as their driver at great risk of serious injury when involved in a head-on crash. A related study performed by Ichikawa (2002), concluded that if rear seat belts had been used, almost 80 percent of deaths of belted front-seat occupants could have be avoided. Traffic crash mortality can be reduced for rear occupants by approximately 55-75 percent if they use seat belts (Zhu, 2005).

2.2 Social and Economic Impact of Seat Belts Usage

To discuss the social and economic impacts of non-use of seat belt, the Fatality Analysis Reporting Systems (FARS) was used. FARS is used because it is the most widely used data source on Highway Safety within the 50 states and the District of Columbia used by numerous studies focusing on the impact of occupant restraint system in vehicles.

2.2.1 Social Impact of Seat Belt Usage

The non-use of seat belts accounts for serious injuries and lost of lives of unbuckled vehicle occupants. These have serious social impacts not only on the lives of the crash victims but on their families and the entire society as well. The social impacts of seat belt use include health lost and live lost. The following section presents the social impact of seat belt usage.

- In 2008 alone seat belt save an estimated 13,250 lives (NHTSA, 2009b) and in 2007 an estimated 15,147 lives were saved by seat belts (NHTSA, 2008).
- Research has shown that lap and shoulder seat belts, when used properly, reduce the risk of fatal injuries to front-seat passengers by 45 percent and reduce the risk of moderate-to-critical injuries by 50 percent. For light truck occupants, seat belts reduce the risk of fatal injury by 60 percent and moderate to critical injury by 65 percent (DOT State of Hawaii, 2003).

- Passenger not wearing seat belts face a higher risk of brain injury in a crash than belted drivers (DOT State of Hawaii, 2003).
- Seat belts should always be worn, even when riding in vehicles equipped with airbags. Air bags are designed to work with seat belts and not alone. Air bags, when not used with safety belts, have a fatality-reducing effectiveness rate of only 12 percent (DOT, State of Hawaii, 2003).

2.2.2 Economic Impact of Seat Belt Usage

The cost of deaths and injuries from the non-use of seat belts accounts not only for the lost of lives of the unbuckled drivers and passengers, but also includes huge economic costs to the entire society. The costs components include: productivity losses, medical costs, rehabilitation costs, legal and court costs, emergency services (such as medical, police and fire service), insurance administration costs, and the costs to employers. Motor vehicle related deaths and injuries cost the United States a total of $230 billion per year (in year 2000 dollars) of which:

- $34 billion was spent on medical and emergency service cost;
- $61 billion was a result of lost productivity in the workplace; and
- $5 billion was due to workplace administrative costs (in year 2000 dollars) (NHTSA, 2002).

Seat belt use saved an estimated $96 billion in economic cost, and about 19 thousand lives as of 2007 when the National Occupant Protection Use Survey (NOPUS) national belt use was 82 percent (NHTSA, 2008). NOPUS projected that if belt use increased to 90 percent an additional $5.2 billion and 1,652 lives would have been saved.

2.3 Strategies for Increasing Seatbelt Usage

There has been a steady increase in seat belt usage in United States. Seat belt usage rate stood at 84 percent as of the end of the year 2009, up by one percent from 2008. This successful achievement happened due to the coordinated efforts of government, law enforcement, concerned citizens and many other private and public agencies. Statistic still shows that 1 out of 5 Americans is not belted. Therefore there is a need to develop strategies that will help in the very difficult task of convincing the remaining unbuckled vehicle occupants to buckle up. The following section presents the different strategies that have been used for increasing seat belt usage.

2.3.1 Seat Belt Laws (Primary-Law vs. Secondary-Law States)

Seat belt laws were adopted in the United States in 1984, with New York being the first state to do so (Cohen, 2003). Two types of seat belt laws (Primary and Secondary) exist in the U.S. Primary state laws allows a motorists to be stopped and cited solely for violating a seat law, while secondary state laws are applicable when a motorist can be cited for violating a seat belt law only if stopped for another offense. As of July 2009 thirty states have primary laws and nineteen have secondary laws. The State of New Hampshire does not have an adult seat belt law. States with primary laws averaged 88 percent belt use, while states with secondary laws averaged 77 percent belt use (NHTSA, 2009a). These usage rates are higher than the present national seat belt usage rate of 84%.

These laws have played a very serious role in increasing belt usage. While both types of seat belt law enforcement increase seat belt use, primary laws have proved to be more effective (NHTSA, 2009b). States with primary seatbelt laws saved an estimated cost of $74.4 billion and15, 147 lives from seat belt usage, while those with secondary laws saved $21.6 billion and 4,401 lives from seat belt usage (NHTSA, 2009b). A good number of studies have been done to show the impact of seatbelt laws on seat belt usage rate and, the advantage of primary seatbelt laws over secondary seat belt laws (Briggs et al, 2006, Levine et al, 2006, and Houston et al, 2006). The sections that follow will discuss the following: (1) the impact of seat belt laws on seat belt usage rate and traffic fatalities, (2) advantages of primary seat belt laws over secondary seat belt laws, and (3) seat belt usage disparities in terms of race, gender, and age in states with seat belt laws,

2.3.1.1 Impacts of a Seat Belt Law on Seat Belt Usage Rate. Public awareness of a safety belt law, particularly when accompanied by a perceived risk of detection and punishment, is hypothesized to increase safety belt use (Dinh-Zarr et al., 2001).Several studies have been conducted to show the positive impact of seat belt laws on seat belt usage rate. Curtis et al. (2007) investigated the relationship between opinions, behaviors, and the presence or absence of a restraint law. This was done by the Dartmouth-Hitchcock Medical Center (DHMC) which has an annual Emergency Department (ED) volume of 30,000 patients and an annual trauma volume of 1200. The Medical center serves residents and travelers from two states: Vermont, which has a restraint law, and New Hampshire, which has no Law. The study found that with respect to overall belt use, a 84% of patients from Vermont used seat belts compared to the 73% of patients from New Hampshire. The results also showed that seat belt use rate was similar (87%) when residents of both states drove in states with seat belt laws. These results show that states with restraint laws had higher belt usage rates than those without. It also proves that vehicle occupants tend to use seat belts more in states which have restraint laws even if they are from states without these laws.

Cohen et al. (2003**)** examined the effects of mandatory seat belt laws on driving behavior and traffic fatalities and empirically investigated the effectiveness of these laws on reducing traffic fatalities. The data set for this study contained panel data for 50 U.S states and the District of Columbia for the years 1983 to 1997, obtained from FARS on annual number of occupants and non-occupants traffic fatalities.

Overall, they found that with implementation of seat belt laws traffic fatalities caused by non-usage of seat belt reduced. Results from the study estimated that an increase usage of one percent point saves 136 lives, and a 1% increase usage would reduce occupant fatalities by about 0.13%. It also illustrated that moving to the 90% target level of 2005 will save annually about 1500-3000 lives (4% to 8% of all traffic fatalities).

Dinh-Zarr et al. (2001) reviewed evidence regarding interventions to increase the use of safety belts. Using the Guide to Community Preventive Services' methods for systematic reviews the study evaluated the effectiveness of three interventions to increase seat belt use in which effectiveness of seat belt laws was one of them. Effectiveness was assessed in terms of changes in seat belt use and number of crash-related injuries. Results showed strong evidence for the effectiveness of seat belt laws. Out of a total of 46 studies of the effectiveness of safety belt laws 33 revealed consistent increases in seat belt use and consistent decrease in fatal and non-fatal injuries. Increase in safety belt use was found in three outcomes as follows: (1) Observed seat belt use increase was between 20-36%; (2) Police reported seat belt use increase was 26%; and (3) Self-reported seat belt use increase was between 13-19%. Decrease in fatal and was also found in this study. Fatal injuries decrease 25-18%, non-fatal injuries decrease from 15 % to 11%, and fatal and non-fatal injuries combined decreased 3%-20%.

Other earlier related research by Maguire et al., 1996, Asch et al., 1991, and Dee, 1998**,** support the fact that enactment of seat belt laws increase safety belt use rate and reduce number of fatal injuries and nonfatal injuries, thus eventually reducing mortality rates of motor vehicle crashes. From the studies mentioned above, strong evidence that safety belt laws are effective in increasing safety belt use and decreasing injuries and death is very clear.

2.3.1.2 Advantages of Primary Seat Belt Laws over Secondary Seat Belt Laws. The following section describes the advantages of primary seat belt laws over secondary seat belt laws in terms of comparing seat belt usage rate in states with primary laws to states with secondary seat belt laws and advantages of upgrading from primary to secondary laws.

Briggs et al. (2006) conducted multivariate logistic regression analysis using SAS to compared seat belt usage racial disparities among motorists in states with primary seat belt laws and secondary seat belt laws. Using data extracted from the Fatality Analysis Reporting System (FARS) in 2005, the findings showed that seat belt use in primary–law states was 15.2% higher among whites compared with seat belt use for whites in secondary–law states, and 17.9% higher for blacks in primary law states than those in secondary law states. The results confirm the fact that seat belt usage in primary law state is higher than in secondary law states. In a related study, Houston et al. (2005) examined annual state seat belt use rate over the period 1991-2001. The results showed that seat belts use laws are associated with higher seat belt usage rate and in particular primary law states experience seat belt use rates that are on the average 9.15 points higher than secondary law states. The study further recommended that to further increase seat belt use, states should adopt primary enforcement and impose fines of at least $50 for violating seat belt law.

Whereas, Briggs and Houston use higher seat belt rates to prove the advantage of primary seat belt laws over secondary seat belt laws, Levine et al. (2006) used a different approach. His was to show the impact of on seat belt use by upgrading a secondary law state to a primary law state. They performed a study to compare mortality rates between two states; Louisiana characterized by a primary law and Mississippi characterized by a secondary Law. The objective of the research was to prove that primary enforcement of state seatbelt laws saves more lives than secondary enforcement laws. Before 1995 both states were secondary– law states. Louisiana upgraded to a primary state law in 1995. They found that during the period of 1992 to 1994 when both states had secondary belt laws, the Mississippi (MS) black: white mortality ratio was not significantly different from 1.00, while Louisiana (LA) blacks had a lower risk of mortality than whites. However, in 1996 to 1998 when LA passed a primary law while MS remained a secondary state, the MS black: white ratio became significantly less than1.00, while LA remained the same. The black: white mortality ratio increased in MS (+0.21) was more than twenty times higher than that for LA (- 0.01). Related studies by Houston et al. (2006), Shults et al. (2004) also confirmed the fact that upgrading an existing secondary law to a primary one increases seat belt usage. They confirm that greater safety benefits exist when secondary laws are upgraded to primary laws as they would persuade higher risks drivers (young males, drinking drivers) to buckle up.

2.3.2 Seat Belt Use Selective Traffic Enforcement Programs (sTEPs)

When a seat belt enforcement law is passed in a state it is the first step in increasing seat belt use in that state or local jurisdiction. An initial boost in seat belt use is often observed once the law is passed. Many states have increased and sustained the impact of the law through effective, ongoing implementation programs of enforcement. A high-profile enforcement effort is one of the best ways to encourage seat belt use.

Occupant Protection Selective Traffic Enforcement Programs (sTEPs) are periods of highly visible safety belt law enforcement combined with extensive media support. These programs are a proven method to change motorists’ safety belt use behavior and do it quickly. Successful Occupant Protection sTEPs have been documented in Canada, Europe, and the United States (NHTSA, 2003a).

Highly visible enforcement of safety belt laws is at the core of any plan to increase safety belt use; no State or community has ever achieved a high safety belt use rate without strong enforcement of such laws. Strong enforcement of safety belt laws sends the message that the State takes safety belt use laws seriously. Ultimately, this leads to greater compliance (NHTSA, 2003a). Enforcement of safety belt laws is significantly more effective when it is combined with media saturation because the perceived risk of receiving a citation is increased. Research shows that people will buckle up if they believe the police are enforcing the law (NHTSA, 2003a).

One safety belt enforcement campaign program that has been used to encourage motorists to buckle up is the Click It or Ticket (CIOT) program. It was fully implemented and evaluated in May 2002. This initiative involved a partnership between the National Highway Traffic Safety Administration (NHTSA), the Air Bag & Seat Belt Safety Campaign, and hundreds of law enforcement agencies. CIOT is a law enforcement effort that gives people more of a reason to buckle up. This law encourages drivers who may only buckle up with a threat of a ticket. In CIOT programs, law enforcement agencies are asked to mobilize their efforts to focus on safety belt violations and publicize the stepped-up effort through media and advertising. It is the two-pronged approach that makes these campaigns powerful. These campaigns do not only issue tickets to unbelted motorists but the surrounding publicity ensures that people know they are more likely to get a ticket.

The campaigns have increased safety belt use in cities, states and even an entire region of the country. In 2002, ten states that conducted the most comprehensive CIOT efforts saw an increase in safety belt use by an average of 8.6% points from 68.5% to 77.1% over a four-week period; those that had partial implementation saw an increase by an average of 2.7; and states that use only law enforcement without publicizing the efforts only had an average gain of half a percent point (Solomon et al., 2004). These results are shown on Figure 2.1.

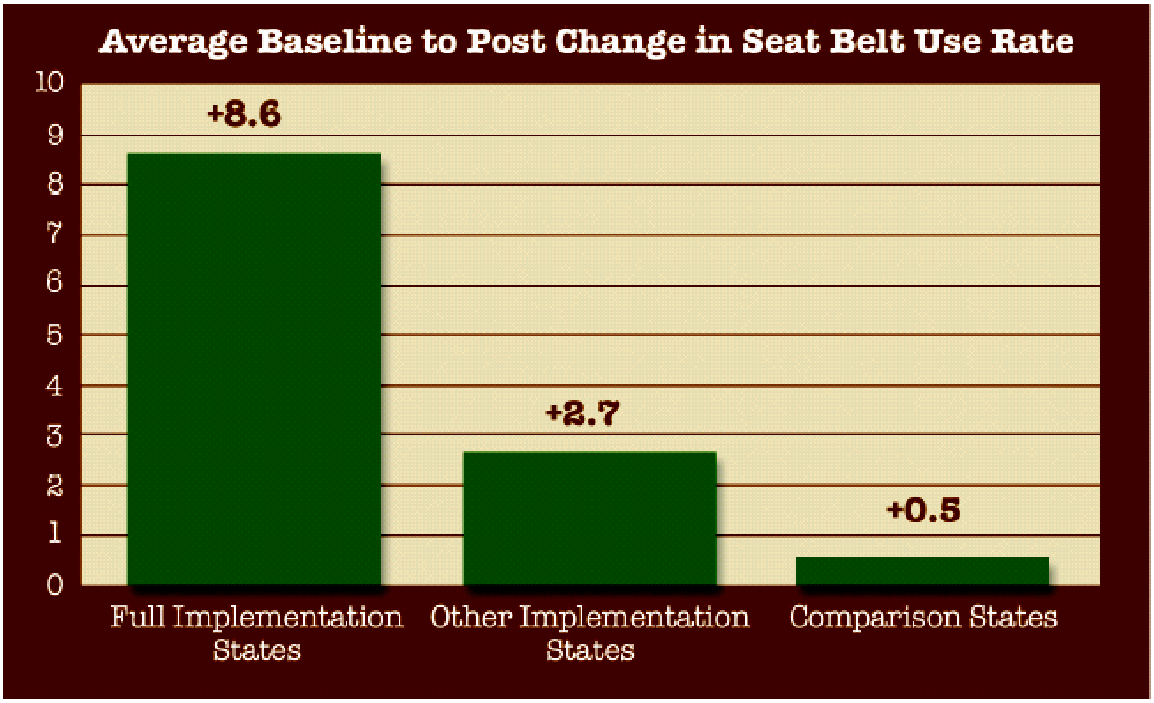


Figure 2.1 Click It or Ticket Campaign 2002.

(Source: DOT State of Hawaii, 2003)

Other enforcement campaigns that have been used are generally extensions of the Click It or Ticket program. The following show the different types of enforcement campaigns by some states.

North-Carolina used enforcement and promotion P methods to enforce seat belt usage. (NHTSA, 2003b) Promotion P is directed at advertising the new law and its legal consequences. In fall of 1993, the Click It or Ticket campaign in this state followed a combination enforcement education approach and seat belt use rate went up by 17 percent points. In spring 1994, when only the public information and education component were employed, belt use in this state went down eight percent points. Hence, the combination method was validated as the most effective strategy. North Carolina also found that leadership is crucial to success in the enforcement of the seat belt laws by committing the Governor and other state leaders to the success of the CIOT enforcement campaign. The Governor personally sent letters to enforcement, judicial, managerial and injury prevention officials. The *Traffic Safety Digest Spring* (2003) on North-Carolina's Four–County "Targeted Safety Belt Enforcement" campaign launched in April 2002, following the State's "Click it or Ticket" model, showed an increase in usage rate. The results of the campaign are shown in Table 2.1.

Table 2.1 Result of North Carolina Targeted Safety Belt Enforcement Campaign

County	Pre-Campaign %	Post Campaign	Difference
Buncombe	75.0	82.6	+8
Caldwell	76.0	89.4	+13
Mecklenburg	76.6	79.7	+3
Richmond	69.0	87.6	+19

Night-time Seat Belt Use Campaign

In Washington State, although seat belt use was 96.3 percent in 2006, highest in U.S and the world, a survey by the Washington State Traffic Safety Commission (WTSC) showed that nighttime belt use rate was 85 percent, 10 percent points below the daytime rate. The Governors Highway Safety Association (GHSA, 2008) stated that to enforce nighttime seat belt usage, WTSC received funds from the NHTSA for "Nighttime Seat Belt

Enforcement" (NTSBE) patrols to take place between May 21 through June 3, 2007, and October 2007 through May 2008.

Michigan State used partnership to help spread the word in both the planning and implementation phases of their enforcement campaigns. The approach in securing partners for its implementation campaign was "pitch a big tent-it's amazing how many people will see something in it for them." Several organizations were involved in the campaign. The Melody Farms Diary got involved because seat belt and safety seat save kids, their main consumers; the Michigan Petroleum Association because dead customers do not buy gasoline; the Automobile Manufacturers because they are the state's largest employees, a state representative from the inner city who could visualize increase safety for his own kids; the state Chamber of Commerce because cutting employer cost due to deaths and injuries is the same as raising profits. Other involved individuals also included: the President of the Detroit Conference of Baptist Ministers, although the organization did not support their program, the Detroit City Council President endorsed the standard law bill, although the Detroit City Council did not endorse it.

Another approach Michigan used to enforce seat belt usage was to ask a representative of the American Civil Liberties Union (ACLU) in the state to serve on the implementation term. ACLU participation helped to ensure that potential concerns could be addressed through public information and education activities and gave the ACLU the advantage to monitor enforcement of the law. ACLU also helped to communicate that the laws proponents would not tolerate harassment and to see to it that a three-year study amendment, a provision of the law, would be conducted.

To make it easy for law enforcement to participate, the “key 25” group of police chiefs and sheriffs around the state who are known to be committed to the seat belt enforcement and recognized as leaders within the law enforcement community were used. Each key chief or Sheriff was assigned a group of peers who headed departments in his/her area of state and, prior to mobilization, they wrote, call and visited the assigned peers to enlist their participation.

Enforcement Efforts for Targeted Groups

Some enforcement efforts have targeted specific groups of people who had low belt usage rate. Efforts were focused on young males, African Americans and pickup drivers. Staff in the Michigan office of the Highway Safety Planning studied available research messaging to these groups, including surveys by Meharry Medical College Report on seat belt use among African Americans (NHTSA, 2003c). They developed 15 different combinations of messages and signage designs and conducted three focus groups with African American males, pickup truck drivers and the general population. They discovered that the most effective message /signage combination was a black-on-yellow “Click it or Ticket” on a roadway advisory sign. For widespread media coverage of the new seat belt law and enforcement efforts, the Michigan office of Highway Safety Planning and its public relations firm used a variety of creative means: it released the results of a telephone survey on public perceptions of traffic stops, seat belt use and race; staged public “bucking up” of a popular singing group, a sports arena, and the state tree; held a “birthday celebration” featuring a huge cake to celebrate the 100 lives that the new law was projected to save each year; provided the media with local survivors and their stories; and conducted editorial board meetings with local print publication. They also used paid media carefully and judiciously to generate additional publicity.

To localize their messages of enforcement, the Michigan Highway Safety Planning office obtained 100 donated billboards in the urban area which printed “ Click it or Ticket” messages, made a partnership with the Michigan Petroleum Association to display “Click it or Ticket” on gasoline pump toppers, brochures, pins and peel-off stickers at thousands of gas stations across the state; worked with local diary to put “Click it or Ticket” on nearly one million milk cartons over a period of three months. They convinced Michigan AAA traffic broadcasters to use “Click it or Ticket” as the sign-off tag line; “Click it or Ticket” were displayed outside every police department, county sheriff’s office and state police troop headquarters reminding the public about the program, as well as every officer, deputy and trooper.

To enforce a new law to the fullest, the support of all officers, deputies and troopers in a state is necessary. This is due to the fact that unbuckled motorists must be persuaded that they will be stopped and ticketed everywhere, whether in interstate, rural road or a city street.

In New Jersey State to involve Law Enforcement, the New Jersey Division of Highway Traffic Safety (DHTS) hired a retired lieutenant from a local department. Through his years of enforcement, he had established himself across the state as a leading advocate for traffic safety and seat belt use in particular. He coordinated the statewide initiative, recruited local police departments to participate in mobilization efforts, provide technical assistance to them, and serve as a liaison between DHTS and the law enforcement community. For good media work, New Jersey DHTS has a public information officer (PIO). The PIO is dedicated to the media work needed to promote traffic safety and seat belt enforcement efforts. The PIO cultivates relationships with the media representatives to attract them to news events and minimize the likelihood that negative stories will appear without an opportunity for DHTS respond. The PIO has a strong history of working with the media, first as a reporter and then in the public relations. In May 20, 2004, the office of the Attorney General in collaboration with DHTS New Jersey joined Ocean County officials and launched the "101 Days of summer" safe driving initiative. The program was designed to promote traffic safety during the critical summer driving season between Memorial Day and Labor Day. This event announced a major state –wide seat belt enforcement campaign, "Click It or Ticket".

In New York State, "The Buckle Up New York" Campaign was launched in 2000 (Williams et al., 2000). The Campaign united law enforcement agencies statewide in zero tolerance enforcement of the state's mandatory seat belt laws. Compared with seat belt usage rate in 1999 when seat belt law was initiated, 1,444 deaths occurred in 2000 compared with 1,585 in 1999, a nearly 9 percent decline. Highway fatality rate was also 1.15 deaths per 100 million miles travel, down from 1.25 deaths in the previous year, 6,234 fewer motor vehicle injuries were reported to police in 2000 than in 1999. Elmira a medium-size community in upstate New York utilized the Selective Traffic Enforcement Program (STEP) model in 1999 to enforce its standard seat belt law. Results of observational surveys were posted on roadway feedback signs, which were updated everyday of the enforcement effort. This information was to show supporters and opponents alike that a standard law is a life saving law with significant benefits.

To determine public attitudes and perception in order to measure the level of community support for enforcement, a public relations firm was hired to coordinate the STEP in Elmira. The firm gathered information about changing public attitudes and perceptions through surveys conducted before and after the conclusion of the enforcement effort. Questions addressed residents' knowledge of the seat belt law, attitudes toward enforcement, awareness of the STEP effort and themes associated with it, perceived level of enforcement and reasons for not buckling up. Results of the survey were: 90 percent of people were aware of the seat belt enforcement program; perception that the law was being enforced increased from 34 percent to 77 percent afterwards; 61 percent reported going through at least one checkpoint; and 79 percent favored seat belt law enforcement.

To address the issue of harassing motorists during law enforcement especially to reach minority populations so as to avoid racial profiling, the New York State police conducted a Diversity Forum with a roundtable discussion on how to protect both lives and civil liberties enforcement efforts. Representatives from the State police, NHTSA, the Air Bag and Seat Belt Safety Campaign, National Organization of Black Law Enforcement Executives, Urban League, Hispanic Federation, ACLU, faith groups and other African American and Hispanic organizations from across the State participated in the forum. Discussions included minority over-representation in crashes, problems of racial profiling, effective ways of promoting the campaign to diverse audiences and ways to achieve public support for enforcement efforts. Most seat belt enforcement efforts center on a checkpoint approach to seeing if motorists are buckled up. Some states however prohibit check points.

In Indiana instead of checkpoints, the Marion County Traffic Safety Partnership created “Enforcement Zones.” Enforcement zones are not checkpoints, but are designated areas where police are stationed to stop cars whose drivers or passengers are not using seat belts or child restraints. Posted signs advise motorists that they are passing through an Enforcement Zone and other signs show the current seat belt use rate, as well as the highest previously recorded rate. Curbed lanes are coned off, violators are stopped and ticketed, safety materials are handed out and officers call dispatch on drivers without licenses, registrations or in other unusual situations. Each enforcement zone lasts two to four hours. They are held primarily at high-crash areas, school zones and areas with low seat belt usage. Seat belt use rate in Indiana increased five percentage points and pickup truck seat belt use rose 12 percentage points during the first six months of Enforcement Zones, in combination with public awareness, (NHTSA, 2000).

In California, beginning in 1994, all law enforcement agencies seeking traffic safety grants were required to include an occupant protection element, with the goal of increasing compliance with seat belt and child safety seat laws. By 1999, there were very few municipal agencies that did not consider the education and enforcement of occupant laws as very significant to their mission. City police departments report that they spend an average of 25 percent of their time on traffic law enforcement. The Sheriff’s departments report committed an average of 12 percent of resources to traffic law enforcement.

In South Carolina, as part of its “Click It or Ticket” checkpoint program in late 2000, the state spent nearly $500,000 on a statewide paid media campaign, in addition to extensive earned media efforts. The television and radio advertisement that ran over a two-week period before and during the effacement time were highly targeted and contained a clear enforcement message. Pre- and post-effort surveys showed that the paid media spots generated the most awareness. More people were aware of the campaign through TV commercials (63percent) than through TV news (25 percent), newspapers (25 percent) or radio ads (18 percent). All populations segments surveyed (urban/rural, black/white, male/female, low/high income) responded highest to paid television spots. Overall observed seat belt use in the state increased by eight percentage points, (Solomon et al., 2004).

The ultimate importance of successful implementation of the standard seat belt law is to get more people to buckle up. Enforcing a standard seat belt law is not a one-time thing that ends with the first implementation effort. States with high seat belt usage conduct visible high-profile enforcement campaigns at least twice per year, every year. Other states with standard laws move to an ongoing approach, making enforcement of the belt laws a normal and integrated part of an officer's day- to- day activities. Strong enforcement of the law must be combined with widespread promotion before, during and after to inform people of the law and let them know they will be ticketed if they don't buckle up.

2.3.3 Innovative Programs Related to Seat Belt Use

Innovative programs have been offered in terms of fiscal grants by NHTSA to states which have programs aimed at increasing seat belt usage and child restraint usage. The Fiscal Year 2010 budget includes $107.3 million, an increase of $1.8 million above the FY 2009 enacted level, in Highway Trust Funds for Highway Safety Research and

Development activities to reduce highway fatalities, prevent injuries, and significantly reduces their associated economic toll. The amount of each state's grant is based on savings in medical costs to the federal government from increased seat belt use, (USDOT, 2009).

Reports from DOT state of Hawaii, (2003) indicated that other opportunities for innovation exist, regardless of the State's current seat belt use rate or its ongoing efforts to increase it. The report showed that specific examples of various innovative activities that can be used in support of a core component of enforcement include: Expanding participation in the national seat belt enforcement mobilizations;

Implementing efforts to train, motivate, and recognize law enforcement officers for participation in the program; Implementing a training or orientation program for prosecutors and judges to make them aware of the program and of the importance of consistently prosecuting and adjudicating occupant protection law violations;

Strengthening public information efforts by adding a paid advertising component to support earned (i.e., news) and public service media efforts; Adopting a more focused message that brings attention to the ongoing enforcement effort (e.g., health care and medical groups, partnerships with diverse groups, businesses and employers); Initiating or expanding public awareness and outreach efforts to reach specific populations that have low seat belt use; and Initiating or expanding enforcement of other traffic laws (e.g., impaired driving laws) as a means for implementing highly visible enforcement of seat belt use laws (DOT State of Hawaii, 2003). Other innovations are seat belt alarms. Some vehicles have unique safety belt reminder system installed to remind drivers to buckle up. Examples are like those in Ford seat belt, Honda seat belts, etc.

2.4 Factors that Influence Seat Belt Usage

Despite the steady increase in seat belt use in the United States, and the several good strategies to continuously increase it, the country still lags significantly behind many developed countries such as Australia, United Kingdom, Germany, France and Canada, where the usage rates are above 90%.The U.S Administration has set a national seat belt goal of 92% by the end of 2010. The greatest problem in achieving this goal is how to improve existing seat belt programs so as to capture the remaining unbuckled vehicle occupants. The remaining motorists who ride unbuckled may be the most difficult to reach (Vivoda, 2004). Understanding factors that impact seat belt use will go a long way in helping authorities that be, in developing programs that would encourage unbelted occupants put on their seat belts.

Factors influencing seat belt usage has been extensively researched in the safety analysis literature. Common factors that have been identified to impact seat belt use are gender, age, socioeconomic status, geometric factors, seasonal factors, time, roadway functional class, etc. Most of this research has been focused on factors that would influence seat belt usage for a driver and front seat passenger in a vehicle. In some of these studies seating positions of the motorists are not specified. This section presents studies that have been carried out to identify factors that impact seat belt use.

Boontob et al. (2007) investigated the factors influencing seat belt use in Thailand through field observations and questionnaire survey. Statistical analysis from the questionnaire found that gender, age, education, income, vehicle type, seating position, seat belt installation, and average travel time, and interaction between age and seating position, education and income, and vehicle type and seating position significantly impact seat belt use. Another study by Briggs et al. (2006) to compared seat belt usage racial disparities among motorists in states with primary seat belt laws and secondary seat belt laws using multi obtained similar results like those of Boontob. Using data extracted from the Fatality Analysis Reporting System (FARS) in 2005 and conducting a multivariate logistic regression analyses the study also showed apart from the fact that there were racial disparities in seat belt use, gender, age, income level and region (urban or rural) of a driver or front seat occupant are some of the factors that could impact seat belt usage. In both states with primary and secondary seat belt laws, seat belt usage rate for men were less than that of women, older occupants used seat belt more than younger ones, occupants with higher incomes had higher usage rate than those with lower incomes, and occupants living in urban area used seat belts more than those living in rural areas.

A different approach to determine factors that impact seat belt use was done by Lerner et al. (2001).The objective of the research was to determine demographic factors associated with reported seat belt use among injured adults admitted to a trauma center. The study conducted a retrospective chart review including all patients admitted to a trauma center for injuries from motor vehicle crashes between January 1995 and December 1997. Forward logistic regression was used to identify significant factors that impact seat belt use. The result revealed that age, female gender, Caucasian race, income, and driver were all significant factors that impact seat belt usage. The results indicated that seat belt use rate was higher for older persons, women, Caucasians, individuals with higher income, and with drivers. Thus, confirming earlier results obtained by Boontob and Briggs.

Other related research that observed gender, age, income and educational level as factors that influence seat belt usage were done by Nelson et al. (1998), Braver (2003), Kizer et al. (1991), Lund (1985), Martin et al. (2004), Shin et al. (1999), March et al. (2003), and Harper et al. (2000). Although these studies were done using different types of data sets, some state wise and some nation wise, the female drivers and passengers always had a higher seat belt usage rate than males. This is with the exception of Lund's (1985) study that observed that men and women drivers generally had similar use rates. In that study drivers less than 25 years of age had lower belt usage rate than older drivers

In addition to the factors discussed above some other studies were done that showed that race was a factor that impact seat belt usage. Vivoda et al. (2004) in a direct observation survey of drivers and front-outboard passenger through out Michigan tried to identify daytime differences in seat belt use by race. In addition to age and gender factors that were found to impact seat belt use,, result of this study also showed that race significantly impact seat belt usage. Seat belt usage in this study was significantly lower for occupants identified as Black when compared to White and other race counterparts. This was observed for both seating positions combined. However with among front-right passengers this significance was only noted among Whites when compared to Blacks passengers, but statistical differences were not observed between other passengers and Black race. A similar result was obtained by Wells et al. (2002) in a study to determine seat belt use among African Americans, Hispanics, and Whites in two states with primary seat belt laws and two states with secondary seat belt laws. However the result of this study showed that although Black males and females had lower seat belt usage rate compared to Hispanic and White males and females in states with secondary seat belt laws, race was not found to be a significant factor impacting seat belt use in state with primary seat belt laws.

The above literature clearly indicates that very little has been done to determine factors that impact back seat occupants' seat belt usage. In addition other factors such as geometric factors, seasonal factors, time, number of occupants in a vehicle, and Driver's seat belt usage have not yet been exploited in the identification of those factors that would impact seat belt usage.

Vivoda et al. (2004) in a study of seat belt use in the state of Michigan determined that females had a higher belt use than males. Overall seat belt use for males in that study was 75.6 ± 1.5 % and 85.5 ± 1.4% for female. The study also found a general increase in belt use with increase in age. They observed that the age group 23 – 29 had the lowest use rate (75.1 ± 2.2%) compared with the other age groups; (16 – 22 with 75.6 ± 3.0%, 30 – 64 with usage rate of 81.6 ± 1.2 %, and 65+ having a rate of 82.9 ± 2.2.).

In a related study by Wells et al. (2001) on seat belt use among African Americans, Hispanics, and whites in two states with primary seat belt laws and two states with secondary seat belt laws, it was found that safety belt use was strongly related to gender. Although the study showed a lower usage rate for men than women, the overall usage rate for male drivers was 58% compared to 75.6 ± 1.5 % for male drivers in earlier work done by Vivoda and 72% for female drivers compared to 85.5 ± 1.4% for female drivers in Vivoda's research.

In relation to race, Wells et al. (2001) determined that black males and females in secondary seat belt law states had lower seat belt usage compared to Hispanic, and whites' males and females. Race was not found to be a significant factor impacting seatbelt usage in a state with primary seat belt law.

Gender and age disparity in seat belt usage was also observed by Lerner (2001), where they investigated the influence of demographic factors on seatbelt use among injured adults admitted to a trauma center. The research found that 455 of men patients used seatbelts compared with 635 for women patients. The study classified age into two groups: less than 25 years with a belt use rate of 45 % and greater than 24 years with a usage rate of 52%. This is different to Vivoda who classified age into four groups.

Related studies showed that Black and Hispanic drivers generally had lower seat belt usage rates compared to white drivers, drivers with low income families had lower usage rates than those from higher income families, and occupants with at least high school diplomas used seat belt more than those with less than high school diplomas.

Very little work has been done to determine those factors that impact seat belt usage for back seat occupants in a vehicle. Also, most of the studies carried out to determine factors that could impact seat belt usage for occupants have not extensively considered other factors like geometric factors and seasonal factors, time, number of occupants in a vehicle and Driver's seat belt usage. This research will also study those factors that would impact seat belt usage of back seat occupants and above mentioned factors.

2.5 Impact of Rear Seat Occupant Seatbelt Usage

This part of the research presents existing research on the impact of seat belt usage by right back seat occupant, middle back seat occupant and left back seat occupant seat belt usage on the injury severity of belted driver and belted right front seat occupant.

Much research has been carried out on the injury severity of occupants in a vehicle during crashes. Seatbelt use has been identified amongst others as one of the contributing factors that impact the injury severity of vehicle occupants during crashes. Since this research deals with the impact of back seat occupants' seat belt usage on the injury severity of belted front seat occupants, this review will attempt to present the most relevant and rigorous study in this area.

2.5.1 Impact of Seat Belt use on Injury Severity of Vehicle Occupants

There is quiet a good number of research that has been carried out to proved that seat belt use by vehicle occupants during crashes has an impact on their injury severity.

Kazuaki et al. (2004) used a chi-squared (χ^2) test to observe what most influences the severity of patient's injuries involved in crashes. Using the 1985 version of the Injury Severity Scale (AIS-85) to evaluate the severity of patients injuries and the 1985 version of Injury Severity Score (ISS-85) commonly used in emergency rooms, they observed that the mortality rate and the rate of injury (AIS>=3) in each part of the body, was significantly lower in belted patients than unbelted patients. Their findings reveal that belted patients would be prevented from being thrown out of the car, and would prevent body trunk injury. In addition results from their study identified that the use of a seatbelt is what most influences the decrease of patient's injury severity. These findings were also confirmed by Delen et al. (2006) study where they identified significant predictors of injury severity in traffic accidents using a series of artificial neural networks.

Hitosugi and Takatsu (2000) in another study performed a retrospective analysis of injury severity and the effect of seat belt use from forensic autopsies of 50 persons who had died in motor vehicle accidents. The research analyzed the cause of death, survival time, mechanism of injury, and estimation of injury severity, of forensic autopsies of persons who had died from injuries sustained in motor vehicle crashes. The results indicated that chest and abdominal injuries were less severe in vehicle occupants wearing some form of restraint. In particular, the study showed that the three-point seat belt significantly decreases the injury severity of drivers' chest and abdominal injuries most. This study concluded that injury severity is related to seat belt use.

Related studies were also carried out but with a focus on the driver's injury severity. Awadzi et al. (2008) performed univariate analyses, bivariate analyses, and a multinomial logistic regression to identify predictors of injury among younger (35-54 years) and older (65 years and older) drivers in fatal motor vehicle crashes. They found out that seat belt use was amongst the most risky factors that are significantly associated with injury and/or fatality for both younger and older drivers.

These findings were also confirmed in a strong study performed by Abdel-Aty (2003) where the analysis of driver injury severity levels at multiple locations was done using probit models. Yamamoto et al. (2008) also used an ordered-response probit model to confirm that proper use of restraint system by drivers tends to be associated with less severe injury. Also Kim et al. (1995) identified lack of seat belt use to greatly increase the odds of more severe crashes and injuries for drivers. They carried out this work using techniques of categorical data analysis on crashes in Hawaii during 1990.

2.5.2 Rear-seat Occupants' Belt Usage Impact on Front Occupant's Injury Severity

The above works do identify seat belt usage as one of the factors that influence the injury severity of occupants during crashes, but they do not discuss the impact of back seat occupant seat belt usage on the injury severity of front seat occupants. Not much research has been carried out to determine the impact of back seat occupants' belt usage on the injury severity of front seat occupants. The following presents work that has been done in that area.

In a study by Mayrose et al. (2005) on the influence of unbelted rear-seat passenger on driver mortality, logistic regression revealed that the odds of fatality for a belted driver in a head-on crash was 2.27 times greater with an unbelted rear-seat passenger than if seated in front of a restrained passenger.. This study was limited to whether an unrestrained left rear-seat passengers increase the risk of death of belted driver involved in serious crashes. This research was a retrospective cohort study of fatal crash data from the Fatality Analysis Reporting Systems (FARS) database for 1995 – 2001 involving belted drivers with a rear-seat passenger seated directly behind them.

In yet another study four sled test experiments were performed at General Dynamics' HYGE Sled Test facility in Buffalo, New York to examine the effect of unrestrained rear-seat passengers on driver mortality (Mayrose, 2006).Three of these tests simulated a full-frontal impact and one mimicked an angled driver-side crash. Results from this study quantified the relationship between rear-seat passenger restraint use and driver mortality for the case of several selected test conditions. It generated compelling empirical data indicating that unrestrained passengers pose a greater risk of injury or fatality during frontal crash to both themselves as well as the driver seated in front of them. Mayrose concluded that this study could be extended by examining other frontal and side-impact test conditions, such as a fully restrained passenger-side front-seat occupant could be evaluated for the case of an unrestrained passenger seated directly behind that position, and that the mortality-related implications of unrestrained and restrained rear-seat passengers next to one another.

Cummings et al. (2004) used a matched cohort study design to estimate the association between the death of a car occupant and the restraint use of another occupant in the same car. Data for the study was obtained from FARS for 1988-2000. According to match-pair cohort study results of comparing the outcomes of two target occupants in the same passenger car that crashed, the risk of death was greater for a restrained front target occupant in front of an unrestrained occupant compared with a restrained front target in front of a restrained occupant (adjusted risk ratio(RR), 1.20; 95 % confidence interval[CI], 1.10-1.31).For a restrained rear target occupant behind an unrestrained occupant compared with a restrained rear target occupant behind a restrained occupant, the adjusted RR was 1.22 (95 % CI, 1.10-1.36). For a restrained side target occupant sitting next to an unrestrained occupant compared with a restrained side target occupant sitting next to a restrained occupant, the adjusted RR was 1.15 (95% CI, 1.08-1.22). Among unrestrained target occupants, the adjusted RRs were, for front targets, 1.04 (95% CI, 0.97-1.12), rear targets, 1.22 (95% CI, 1.10-1.36), and side targets, 0.85 (95% CI, 0.80-0.92). In a similar study a matched cohort study approach was used to examine the association of rear seat safety belt use with death in traffic crash (Zhu et al. 2005). According to a match- cohort regression method result the risk of death for a passenger car occupant who used a seat belt was less compared with a similar occupant who was not belted. FARS 1990-2001 crash data was used in this study.

Masao et al. (2002) conducted a study to compare the risk of death and severe injury of belted front-seat occupant in a car crash with belted or unbelted rear-seat passenger. Crash data from the Institute for Traffic Accident Research and Data Analysis of Japan was used. Using odds ratios to estimate the risk of death, or severe injury to front-seat occupants, caused by unbelted rear-seat occupants, the results indicated that the risk of death of belted drivers and front-seat passengers was increased about five-fold when rear-seat occupants were unrestrained. Risk of death was not significantly raised for unbelted front-seat occupants. They recommended that rear-seat use should be made compulsory. This is because most deaths and severe injuries of front-seat occupants of cars would be averted by rear seat belt use.

This work would be differentiated from those referenced in this section by considering both belted drivers and belted right front seat occupants. The impact of seat belt usage by the left-back seat occupants, middle-back seat occupants, and right-back seat occupant on the driver’s injury severity and the right-front occupant injury severity would be considered. The probability of each injury severity level sustained by the belted driver and belted right-front occupant would be calculated. Ordinal logistic regression method would be used in this study.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Two sets of models will be developed in this study: seat belt models and injury severity models. Seat belt models are developed to examine the contribution of several variables to seat belt usage for drivers, front seat occupants, and back seat occupants in motor vehicles. Seat belt usage (the dependent variable) in this study is a binary (or dichotomous variable) with two categories: usage and non-usage. Since the dependent variable is of a binary nature, a logistic approach is found suitable.

A second set of models that are developed are injury severity models. These models examine the impact of rear-seat occupants' seat belt usage on front-seat occupants' (driver and front right occupants) injury severity. The KABCO injury scale is used to categorize injury severity into five levels. A KABCO injury scale is a measure of the functional injury level of a victim at a crash scene. The codes are selected based on the on-site judgment of the investigating police completing the crash report, with

K = killed, A = Incapacitating Injury, B = Non-Incapacitating Injury, C = possible Injury, and O = No Injury. The objective of this model is to examine whether unrestrained rear seat occupants increase the injury severity of belted front seat occupants during motor vehicle crashes.

3.2 Statistical Approach

3.2.1 Logistic Regression

Many mathematical techniques have been developed and used to derive models from sets of experimental data or observations. Amongst them are linear regression and logistic regression. From a statistical point of view, logistic regression is different from Ordinary Linear Regression (O.L.R). The underlying mathematics in the two methods is different and computation details are different. The distinction between logistic regression model and O.L.R is that the outcome (or dependent) in logistic regression is “binary or dichotomous”, while in linear regression it is continuous (Hosmer and Lemesshow, 1989). This difference is reflected both in the choice of parametric model and in the assumptions.

The first difference concerns the nature of the relationship between the outcome variable and the independent variable. In ordinary linear regression it is assumed that the conditional mean is expressed as

$$\mathrm{E}(Y|x) = \beta_0 + \beta_1 x \qquad (3.1)$$

Where Y denotes the outcome variable, x denotes a value of the independent variable, and the β_i values denote the model parameters, and theses variables take any values as x ranges from $-\infty$ and $+\infty$. With dichotomous data, the conditional mean is between 0 and 1. That is

$$0 \le E(Y|x) \le 1 \tag{3.2}$$

The conditional mean approaches zero and one gradually. The change in $E(Y|x)$ per unit change in x becomes progressively smaller as the conditional mean gets closer to zero or one, hence the s-shape of a logistic distribution.

The second difference between the O.L.R and logistic regression concerns the conditional distribution of the outcome variable. In a linear regression model it is assumed that an observation of the outcome variable maybe expressed as:

$$y = E(Y|x) + \varepsilon \tag{3.3}$$

Where ε is called the error and expresses an observation's deviation from the conditional mean. The most common assumption is that ε follows a normal distribution with mean zero and some variance that is constant across levels of the independent variables. Therefore the conditional distribution of the outcome variable Y given x will be normally distributed with mean $E(Y/x)$, and a variance that is constant. This is the assumption of Homoscedasticity. Homoscedasticity is the assumption in ordinary linear regression in which the conditional distribution of the outcome variable y is normal with a variance that is constant across the levels of the independent variables x_i. In a logistic regression the outcome variable may be expressed as

$$y = \Pi(x) + \varepsilon \tag{3.4}$$

ε may assume one or two possible values. If y = 1, then $\varepsilon = 1 - \Pi(x)$ with the probability $\Pi(x)$, and if y = 0, then $\varepsilon = -\Pi(x)$ with the probability $1 - \Pi(x)$. Therefore ε has a distribution with mean zero and variance equal to $\Pi(x)\,[1 - \Pi(x)]$. That is conditional distribution of the outcome follows a binomial distribution with probability given by the conditional mean $\Pi(x)$.

In ordinary linear regression there is a linear least square regression equation which can be solved explicitly, using a stated formula. Logistic regression equations are solved iteratively. The iterations stop when the improvement from one step to the next is suitably small. Both the ordinary least square regression and logistic regression produce prediction equations. In both cases the regression coefficients measure the predictive capability of the independent variables. However, an ordinary linear regression model has a limitation in that the independent variable is numerical (or quantitative) and must be able to assume any value between – ∞ and ∞, rather than categorical. Many interesting variables in life are however categorical. For example, a student may “Pass” or “Fail” an exam, a sick person may “live” or “die.”

In this research the independent variables for both the seat belt model and the injury severity model are either continuous or categorical. The dependent variables in both models are categorical: “use” or “non-use” of seat belt for the seat belt model, and ‘killed,” “incapacitated,” “moderate injury”,” minor injury”, and “no injury” for the injury severity model. For these reasons categorical models are chosen as the methodology for this research.

Categorical models are models whose dependent variables are not continuous. They may be dichotomous (having two levels) like the seat belt model, or polytomous, (having more than two levels) as in the injury severity model. For example: an occupant uses a seat belt, Y=1 or does not use a seat belt Y=0, is a dichotomous independent variable in the seat belt model. In addition, the five levels of injury severity in the injury severity model represent a polytomous dependent variable.

Many techniques have been developed for analyzing data with categorical dependent variables. These include probit models, log-log models (or log-linear regression models) and logistic regression (Binomial /binary) or logit models. These form the class of models called generalized linear models. The various models are applicable in different situations. The logistic regression model, for example, is applicable in situations where the dependent variable is binary, and the ordinal regression model is used when the dependent variable is of ordered levels. The selected methods for this research are the logistic regression model and the Ordinal regression model.

3.2.2 Logistic Regression Model

Logistic regression falls in the class of models called generalized linear models. Generalized models are extensions of general linear models in which the assumptions of normality, linearity, and constant variance (Homoscedasticity) are removed. Logistic regression is used to: (1) predict a dependent variable on the basis of continuous and/ or categorical independent variables; (2) to determine the percent of variance in the dependent variable explained by the independent variables; (3) to assess interaction effects; and (4) to understand the impact of covariate control variables. Logistic regression models use maximum likelihood estimation after transforming the dependent variable into a logit variable (the natural log of the odds of the dependent variable occurring or not (Marija, 2007; Al-Ghamdi, 2002).The logistic function is given by:

$$F(Z)=\frac{1}{1+e^{-z}} \quad or \quad P=\frac{e^{a+bX}}{1+e^{a+bX}} \tag{3.5}$$

The input is Z and the output is F (Z). The output F (Z) takes values between 0 and 1. The variable Z represents the exposure to some set of risk factors. F (Z) represents the probability of a particular outcome, given a set of risk factors. The variable Z is the measure of the total contribution of all the risk factors used in the model and is known as the Logit**.** Z is defined as:

$$Z=\alpha+\beta_k X_k \tag{3.6}$$

α is called the intercept and the β_k are the regression coefficient of the X_k . That is β_1, β_2, β_3, …., β_k are coefficients of x_1, x_2, x_3, …, $x_{k..}$ The intercept is the value of Z when the values of all the risk factors are zero (i.e. the value of Z with no risk factors).

Substituting equation (3.6) into equation (3.5) yields:

$$F(Z)=\frac{1}{1+e^{-(\alpha+\beta_k X_k)}} \tag{3.7}$$

Suppose F (Z) is denoted as Y, then equation (3.7) becomes

$$Y = \frac{1}{1+e^{-(\alpha+\beta_k X_k)}} \tag{3.8}$$

Each β_k represents the size of the contribution of that risk factor. A positive regression coefficient implies that the risk factor increases the probability of the outcome, while a negative coefficient implies the risk factor decreases the probability of that outcome. A large regression coefficient implies the risk factor strongly influences the probability of that outcome; while a near zero value implies that the risk factor has little or no influence on the probability of that outcome.The specific form of the logistic regression model in equation (3.5) is

$$\Pi(x) = \frac{e^{\alpha+\beta_1 \mathrm{X}}}{1+e^{\alpha+\beta_1 x}} \tag{3.9}$$

Where $\Pi(x) = \mathrm{E}(Y/x)$

Equation (3.9) is transformed by using the natural log to develop a linear relationship between the dependent variable and the independent variables. The transformation of the $\Pi(x)$ function is known as the logit transformation:

$$g(x) = \ln\left[\frac{\Pi(x)}{1-\Pi(x)}\right] = \alpha + \beta_1 x \tag{3.10}$$

The importance of the transformation of the logit model (3.9) into (3.10) is that g(x) has most of the properties of a linear regression model. The logit, g(x), is linear in its parameters, may be continuous, and may range from $-\infty$ to $+\infty$. In logistic regression the slope coefficient, β_1 is equal to the difference between the values of the independent variable at x+1 and x for any value x. That is

$$\beta_1 = g(x+1) - g(x) \tag{3.11}$$

Therefore the slope coefficient represents the change in the logit for a change of one unit in the independent variable x.

Logistic regression calculates the probability of success over the probability of failure. Results are in the form of odds ratio. Odds ratio is the ratio of an event occurring to the likelihood of not occurring. An odd ratio also provides knowledge of the relationships and strengths among variables. The calculation for the odds ratio of the logistic regression coefficients with the situation where the independent variable is dichotomous would be developed to give a conceptual foundation for all other situations. Suppose the outcome variable Y is seat belt usage coded y = 1 for belted, and y = 0 for unbelted, and suppose sex is a dichotomous independent variable x coded male (x) = 1 and female (x) = 0.Therefore there will be two values of $\Pi(x)$ and two values of 1 - $\Pi(x)$ as shown in Table 3.1. The odds of the outcome for the male (x=1) is defined

$\Pi(1)/[1-\Pi(1)]$, and that of the outcome for female (x=0) is defined as $\Pi(0)/[1-\Pi(0)]$.

The log of the odds called the logit is defined as g(1) = ln $\{\Pi(1)/[1-\Pi(1)]\}$ for male, and ln $\{\Pi(0)/[1-\Pi(0)]\}$ for female. The odds ratio is the ratio of odds for male seat belt usage x = 1 to the odds for the female seat belt usage, and is given by the following equation:

Table 3.1 Logistic Regression Model Values for Dichotomous Independent Variable

Independent Variable(Sex)	**x(male) =1**	**x(female) = 0**
y(belted) =1	$\Pi(1) = \frac{e^{\alpha+\beta_1 X}}{1+e^{\alpha+\beta_1 x}}$	$\Pi(0) = \frac{e^{\beta_1}}{1+e^{\beta_1}}$
y(unbelted) = 0	1-$\Pi(1) = \frac{1}{1+e^{\alpha+\beta_1}}$	1- $\Pi(0) = \frac{1}{1+e^{\beta_1}}$
Total	1.0	1.0

$$\Psi = \{\Pi(1)/[1-\Pi(1)]\} / \{\Pi(0)/[1-\Pi(0)]\} \qquad (3.12)$$

The log of the odds ratio, called log-odds ratio, or log-odds, is given by the following equation:

$$\mathrm{Ln}(\Psi) = \ln\left[\{\Pi(1)/[1-\Pi(1)]\} / \{\Pi(0)/[1-\Pi(0)]\} \right]$$

$$= g(1) - g(0) \qquad (3.13)$$

Using the expressions for the logistic regression model shown in Table 3.1, the odds ratio is given as

$$\Psi = \frac{e^{\alpha+\beta_1}}{e^{\alpha}}$$

$$= e^{\beta_1} \qquad (3.14)$$

Hence the logit difference, or log odds, is

$$\mathrm{Ln}(\psi) = \ln(e^{\beta_1}) = \beta_1$$

Since y denotes belted or unbelted vehicle occupant and x denotes if the occupant is a male or female, then a value of $\Psi = 3$ indicates that seat belt usage is two times more often in males than females.

When the independent variables are polytomous, a set of design variables or dummy variables to represent the category of the variables is formed. The designed variables are specified by a method which sets all the variables equal to zero for the reference group of variables, and setting a single variable equal to 1 for each of the other groups (Hosmer and Lemeshow, 1989). In some computer programs like SPSS and SAS, the group with the largest code serves as the reference group.

SPSS version 10.0 Statistical Software is used to develop the seatbelt usage model. In the SPSS result output for a logistic regression, the odds ratio for each independent variable is calculated as the exponential of the coefficient of that variable.

3.2.3 Maximum Likelihood Estimation

In ordinary regression the ordinary least squares method is used to minimize the sum of the squared deviations of the observed values of Y from the modeled values. In logistic regression, the Maximum Likelihood Estimation (MLE) method is used to minimize the log- likelihood (LL) which reflects how likely it is (the odds) that observed values of the dependent variable may be predicted from the observed values of the independent variables. That is the probability under a specified hypothesis is determined. The idea behind MLE is to determine the parameters that maximize the probability (likelihood) of an outcome in the sample data. That is to assess the model's goodness -of- fit for the logistic regression model.

A brief review of fitting a logistic regression model presented by (Hosmer et.al, 1989; Agretsti, 1984; Feinberg, 1980) can be described as follows:

Suppose Y is a binary variable (coded 0 or 1), then the expression $\Pi(x)$ given in equation (3.9) gives the conditional probability that Y is equal to 1 given x, denoted P $(Y = 1|x)$, and the quantity 1-$\Pi(x)$ gives the conditional probability that y is equal to 0, denoted P $(Y = 0|x)$. Therefore, for those pairs (x_i, y_i) where $y_i = 1$, the contribution to the likelihood function is $\Pi(x_i)$, and for those pairs where $y_i = 0$, the contribution is 1-$\Pi(x_i)$. The quantity $\Pi(x_i)$ denotes the values $\Pi(x)$ computed at x_i. Mathematically, the maximum likelihood equation is expressed for a sample of pairs of data point as:

$$L(\beta) = \Pi(x_i)^{y_i}\,[1 - \Pi(x_i)]^{1-y_i} \qquad (3.15)$$

Since it is easier to work with the sum of series than the product, equation (3.15) is transformed using natural logarithms as follows:

$$\ln[l(\beta)] = \Sigma\{y_i \ln[\Pi(x_i)] + (1 - y_i)\ln[1 - \Pi(x_i)]\} \qquad (3.16)$$

The maximum β coefficients (or estimators) of the log-likelihood function in equation (3.17) are obtained by setting equations (3.15) and (3.16) to zero and taking partial derivatives of the log-likelihood function:

$$\sum_{1}^{n} [y_i - \Pi(x)] = 0 \qquad (3.17)$$

$$\sum x_i [y_i - \Pi(x)] = 0 \qquad (3.18)$$

Expressions (3.15) and (3.16) are called likelihood equations.A very useful property that is used in assessing the fit of the model is when the sum of the observed values of y is equal to the sum of the expected (predicted) values. This occurs when in equation (3.18) we have the following consequence:

$$\sum_{1}^{n} y_i = \sum_{1}^{n} \hat{\Pi}(x_i)$$

3.2.4. Goodness-of-fit of the Logistic Regression Model

Assessing the goodness- of- fit of the model is to determine how effective the model is in describing the outcome variable. This is done assessing the significance of the variables in the model. In ordinary linear regression, if y_i denotes the observed value and $\hat{y}_i$ denotes the predicted value for the i th individual under the model, the statistic used is:

$$SSE = \sum (y_i - \hat{y}_i)^2$$

The change in the values of SSE is due to the regression source of variability, denoted SSR, where SSR is the total Sum of Squares of Error term (SSE) and calculated as:

$$\text{SSR} = \left[\sum (y_i - \bar{y}_i)^2 \right] - \left[\sum (y_i - \hat{y}_i)^2 \right]$$

where $\bar{y}$ is the mean of the outcome variable. Interest is focus on the size of SSR (or R). A large value of R suggests that the independent variable is significant, whereas a small value indicates that the independent variable is not significant in explaining the variability in the outcome variable. In logistic regression the same principle is used to compare observed values of the outcome variable with the predicted values obtained from the model with and without the variable in question. This comparison is based on the log likelihood function defined in equation (3.16). The likelihood ratio is used to assess the goodness-of-fit. The likelihood ratio is given as follows:

$$D = -2\ln \left[\text{(Likelihood of the current model)/ (likelihood of the saturated model)} \right] \tag{3.19}$$

A saturated model is defined as one that contains as many parameters as there are data points. Using equations (3.16) and (3.19), the deviance is obtained:

$$D = -2\sum_{i=1}^{n}\left[y_i \ln\left(\frac{\widehat{\Pi}_i}{y_i}\right) + (1 - y_i)\ln\left(\frac{1-\widehat{\Pi}_i}{1-y_i}\right)\right] \tag{3.20}$$

where $\widehat{\Pi}_i = \widehat{\Pi}(x_i)$.

The deviance plays the same role that the residual sum of squares error SSE, plays in ordinary linear regression. To assess the significance of an independent variable in the logistic regression, the value of D is compared with and without the independent variable in the model. The change in D due to the inclusion of the independent variable is the difference between D for the model without the independent variable and D for the model with the independent variable. This difference is obtained as follows:

G = D(for the model without the variable) – D(for the model with the variable) .

The likelihood ratio for G is then expressed as:

$$G = -2\ln\left[\text{(likelihood without the variable)/ (likelihood with the variable)}\right] \tag{3.21}$$

Under the null hypothesis, β_1 = 0 and G follows a χ^2 distribution with one degree of freedom.

Another test statistic that can be used which is similar to G is known as the Wald statistic (W). Under the null hypothesis β_1 = 0 and W follows a standard normal distribution. The Wald statistic is computed by dividing the estimated value of the parameter by its standard error:

$$W = \frac{\hat{\beta}_1}{\widehat{SE}(\hat{\beta}_1)} \tag{3.22}$$

The Wald test sometimes fails to reject the null hypothesis when the coefficient is significant. In such cases the likelihood ratio should be used instead.

3.2.5 Ordinal Logistic Regression Model

An ordinal logistic regression model is a multivariate model that describes relationships between a dependent variable and a set of independent variables. The dependent variable in this model is an ordinal response using integers to represent an ordered sequence, however the distance between adjacent levels is not known.

By analyzing the marginal effects of the independent variables, ordinal logistic regression models can be used to determine whether the independent variables significantly influence the dependent variable. An ordinal regression model describing injury severity is generally expressed as follows:

$$Y^* = \ln\left(\frac{prob(event)}{(1 - prob(event))}\right) = \beta X + \varepsilon \tag{3.23}$$

Where:

Y*= an unobserved variable measuring the risk of the injury, also called a logit.
β = a vector of unknown coefficients
X = a vector of non-random independent variables, and
ε = a random error term (assumed to follow a standard normal distribution).

The observed and ordered injury severity Y is given by:

$$Y = k \text{ if } \mu_k \leq Y^* \leq \mu_{k+1} \qquad \text{for } k = 0, 1,2,3,4 \tag{3.24}$$

Where:

k denotes the ordered category of the injury severity,
μ_k s are the estimated thresholds

The independent variables can be expressed as follows:

$$Y = 0 \text{ if } -\infty \leq Y^* \leq \mu_1 \text{ (No injury)}$$
$$Y = 1 \text{ if } \mu_1 \leq Y^* \leq \mu_2 \text{ (Minor injury)}$$
$$Y = 2 \text{ if } \mu_2 \leq Y^* \leq \mu_3 \text{ (Moderate injury)}$$
$$Y = 3 \text{ if } \mu_3 \leq Y^* \leq \mu_4 \text{ (incapacitating injury)}$$
$$Y = 4 \text{ if } \mu_4 \leq Y^* \leq \infty \text{ (Killed)}$$

Where μ_k represent the injury severity thresholds estimated by the model. The probabilities between the unobserved and observed injury severity is therefore given as follows:

$$\rho(Y = 0) = \psi(-\beta X) \tag{3.25}$$

$$\rho(Y = 1) = \psi(\mu_1 - \beta X) - \psi(-\beta X) \tag{3.26}$$

$$\rho(Y = 2) = \psi(\mu_2 - \beta X) - \psi(\mu_1 - \beta X) \tag{3.27}$$

$$\rho(Y = 3) = \psi(\mu_3 - \beta X) - \psi(\mu_2 - \beta X) \tag{3.28}$$

$$\rho(Y = 4) = \psi(\mu_3 - \beta X) \tag{3.29}$$

Where ρ (Y = k) denotes the probability of an injury severity falling in the category k, and ψ denotes the cumulative distribution function of the standard normal distribution.

Instead of considering the probability of an individual event, which is done in binary logistic regression, the cumulative probability of that event is considered (or the probability of that event and all events that are ordered before it). Therefore in ordinal regression the event of interest is observing a particular event at a particular level or the event one level less than it in ranking, (Marija J. Norusis, 2007). For the rating of injury severities, the following odds are modeled:

ρ_0 = prob(injury severity of 0) / prob(injury severity greater than 0)
ρ_1 = prob(injury severity of 0 or 1) / prob(injury severity greater than 1)
ρ_2 = prob(injury severity of0,1,or 2) / prob(injury severity greater than 2)
ρ_3 = prob(injury severity of 0,1,2,or 3) / prob(injury severity greater than 3)
ρ_4 = prob(injury severity of 0,1,2,3,or 4) / prob(injury severity greater than 4)

The last category does not have an odds associated with it since the probability of injury severity up to and including the last level is 1.

The Maximum likelihood Estimation (MLE) is used to obtain the coefficients in the ordinal regression model. This method is used because the dependent variable is not continuous as in ordinary linear regression (OLS) where the ordinary least square estimation method would be more appropriate.

Significant variables that impact the injury severity of the front seat occupants are identified using the p-value associated with that variable. In this research, a variable is said to significantly impact injury severity if the variable has a p-value of 0.1, or has significance at a 90 percent confidence interval. As with continuous independent variables in linear regression models, a positive coefficient value in ordinal regression indicates a more severe injury as the magnitude of the variable increases, while a negative coefficient value indicates a less severe injury as the magnitude of the variable increases. Similarly, positive coefficient values of categorical independent variables indicate the variables would increase injury severity as the magnitude of the variables increase compared to a referral category, while a negative coefficient decreases injury severity. For example, the Light condition under the injury model is a categorical independent variable in the ordinal injury severity model. The variable would be interpreted relative to a referral category. For this variable the referral category is daylight or dark but lighted conditions.

CHAPTER 4

MODEL DEVELOPMENT

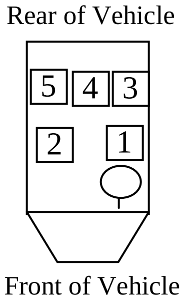
In this chapter the methodology described in Chapter 3 for the seat belt model and the injury severity model are implemented and the models developed are discussed. The development of these models is done using the following process: data collection, analysis, identification of significant variables, and formulation of the seatbelt and injury severity models. A total of fifteen models are developed; five seat belt models and ten injury severity models. These models are developed considering the different seating positions of occupants in vehicle.

4.1 Seat Belt Usage Model

Using the methodology described above for the seat belt usage model, five seat belt usage models are developed. These models are developed by considering the different seating positions of occupants in the vehicle. These models are described in Table 4.1. SPSS version 10.0 Statistical Software is used to develop the seatbelt usage model.

Table 4.1 Seat Belt Usage Models

Model Number	Model Description
1	Driver seat belt Usage
2	Right-front occupant seat belt usage
3	Lightt-back occupant seat belt usage
4	Middle-back occupant seat belt usage
5	Right-back occupant seat belt usage



The models examine the contribution of several variables that impact seat belt usage for each occupant in a passenger vehicle. The occupants for which models were developed include: driver (1), right-front occupant (2), left-back seat occupant (3), middle-back seat passenger (4), and right-back seat occupant (5), where ((1), (2), (3), (4), and (5) refer to the seating positions as shown in Table 4.1 Seatbelt usage, which is the dependent variable in the five models, is a binary or dichotomous variable with two categories: usage and non-usage. An occupant is considered belted if he or she used one of the following types of restraints: shoulder belt, lap belt, shoulder and lap belt, a child safety seat, used an unknown restraint type, used a safety belt improperly, or used a child safety seat improperly. An unbelted occupant is one who did not use any of the above restraint systems.

4.1.1 Data Collection for Seat Belt Usage Models

Study data for seat belt usage were extracted from the Fatality Analysis Reporting System (FARS) for the years 2004 through 2006 for the State of New Jersey. FARS database contains data for all motor vehicle crashes that result in at least one fatality within 30 days of the crash. The database is created and maintained by the National Highway Traffic Safety Administration (NHTSA) and contains information about the environment, road conditions, circumstances of the crash, characteristics of the vehicles (involved), and information on all the people involved in the crash.

FARS database was chosen for this study because it contains information on many factors during the crash. In addition it also contains restraint usage information for occupants during the crash. Other existing databases, such as the New Jersey Department of Transportation Crash Database, could not be used because it does not have information on restraint use for all occupants involved in each crash.

Five sets of data are extracted for use in the development of the models. The first dataset contains crash data information for drivers in passenger cars, vans, pick-ups, sport utility vehicles (SUV), and light trucks. This data set is developed to determine factors that would influence the seat belt usage of a driver in vehicles that have only the driver as the sole occupant. The second data set contains crash information for the same type of vehicles with at least a right-front occupant. This data set is developed to determine factors that will impact seat belt usage of right-front seat occupant. The data set contains, at minimum, a right-front seat occupant and may include other occupants. The third data set contains crash data for vehicles in which there was at least a left-back occupant. This set of data was developed in order to determine those factors that impact the seat belt usage of a left-back seat occupant. The fourth and fifth data sets consist of crash data for vehicles with at least a middle-back seat occupant and a right-back seat occupant, respectively. These sets of data were developed to determine those factors that influence seat belt usage for the middle-back seat occupant and the right-back seat occupant. Crashes involving large trucks, pedestrian crashes, bicyclists, motorcyclists were excluded from the study in order to minimize confounding factors.

4.1.2 Correlation Test for Speed and Roadway Functional Class

Correlation test was performed on the data to test the interrelation between speed limit and roadway functional class so as to avoid confounding effects. Bivariate correlation test was done and the result gave a negative correlation coefficient of 0.46. Although the correlation coefficient shows that the two variables are related, scatter plot diagrams showed (figure 4.1) that the two variables are however not linear, and hence no confounding effects exist. Therefore they were both incorporated into the analysis.

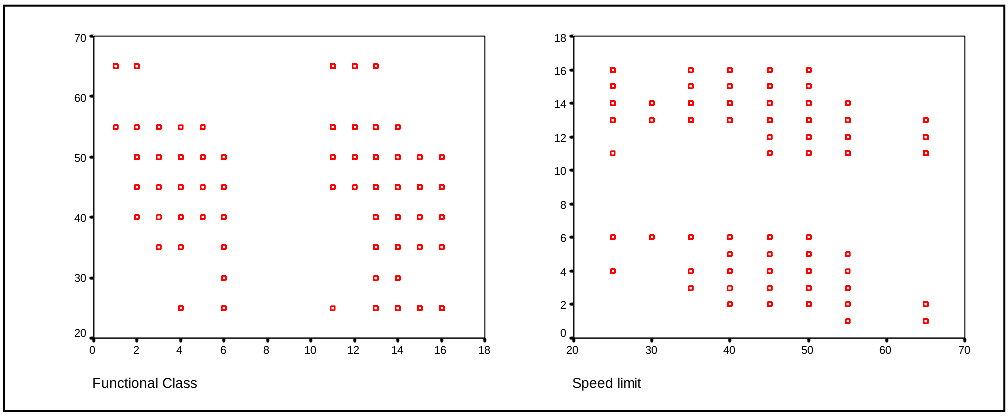


Figure 4.1 Scatter Plot graphs for Speed limit and Roadway Functional Class.

The variables used in the development of the logistic models are obtained from the FARS database. These variables are considered as independent variables in the models. Table 4.2 gives a description of the variables used and how they are coded in the models. A total of 18 independent variables are used in the models. The dependent variable, seat belt usage, is derived from the FARS information on “restraint system”. Table 4.3 shows a summary of belt usage for each of the seat belt usage models.

Table 4.4 provides a summary of the variables used in the development of the seat belt models.

Table 4.2 Model Variables for Seat Belt Usage Model

Variable	Description
Y (Seat belt usage as Dependent variable)	=1 If belted; =0 otherwise
Atmosphere Condition	=1 if no adverse Atmospheric condition; = 0 otherwise
Light	=1 if daylight/dark but lighted; = 0 otherwise
Crash Time	=1 if AM Peak, =2 if PM Peak, =3 if Off Peak
Crash Season	=1if Fall , =2 if Winter, =3 if Spring,= 4if Summer
Holiday	=1 If Holiday;= 0 otherwise
Number of Lanes	=1If <=2 ; =0 otherwise
Rural Arterial	=1 if Roadway functional class is Rural Arterial; = 0 otherwise
R(Coll/ Road /ST)	=1 if roadway functional class is rural(collector, road, street); = 0 otherwise
UPA	=1 if roadway functional class is urban principal arterial; = 0 otherwise
UMI-A	=1 if roadway functional is urban minor arterial; = 0 otherwise
Road Profile	=1 if roadway profile is straight; = 0 otherwise
Speed	=1 if posted Speed limit <50; = 0 otherwise
Gender	=1 if occupant is male; = 0 otherwise
Dry Surface Condition	=1 if roadway surface is dry;= 0 otherwise
AGE	=1if Occupants age <21; = 2 if >20<30; = 3if >29<50; = 4if >49<65; = 5if >=65
Number of Occupants (Driver seat belt model)	=1if number of occupants=1; =2 if =2:,=3 if >2
Belted Driver	=1 if Driver is belted; = 0 otherwise
Number of Occupants (Model,2,3,4,5)	=1 if number of occupants >2; = 0 otherwise

Table 4.3 Summary of Seat Belt Usage

Model	Occupant	Belted		Unbelted (%)		Total
		Total	%	Total	%	
1	Driver	1751	72.5%	663	27.5%	2414
2	Right-Front Passenger	587	74.1%	206	26%	793
3	Left-Back Passenger	111	48.9%	116	51.1%	227
4	Middle-Back Passenger	43	53.8%	37	46.3%	80
5	Right-Back Passenger	164	61.4%	103	38.6%	267

Table 4.4 Variable Distribution

Variable	Levels	Description of Levels	Model 1 (Driver)		Model 2 (Right-Front)		Model 3 (Left-Back)		Model 4 (Middle-Back)		Model 5 (Right-Back)	
Belt Usage	1	Occupant is belted	1751	72.5%	587	74.0%	117	50.2%	43	53.8%	164	61.4%
	0	Otherwise	663	27.5%	206	26.0%	116	49.8%	37	46.3%	103	38.6%
Atmosphere	1	No adverse Atmospheric condition;	2079	86.1%	685	86.4%	200	88.1%	68	88.3%	232	86.9%
	0	Otherwise	335	13.9%	108	13.6%	27	11.9%	9	11.7%	35	13.1%
Light	1	Daylight/Dark but lighted	1906	79.0%	624	78.7%	171	75.3%	58	75.3%	213	79.8%
	0	otherwise	508	21.0%	169	21.3%	56	24.7%	19	24.7%	54	20.2%
Crash Time	1	AM Peak,	230	9.5%	50	6.3%	15	6.6%	3	3.9%	18	6.7%
	2	PM Peak,	509	21.1%	173	21.8%	54	23.8%	17	22.1%	66	24.7%
	3	Off Peak	1675	69.4%	570	71.9%	158	69.6%	57	74.0%	183	68.5%
Season	1	Fall	699	29.0%	221	27.9%	69	30.4%	31	40.3%	79	29.6%
	2	Winter	555	23.0%	177	22.3%	46	20.3%	9	11.7%	48	18.0%
	3	Spring	558	23.1%	189	23.8%	46	20.3%	12	15.6%	56	21.0%
	4	Summer	602	24.9%	206	26.0%	66	29.1%	25	32.5%	84	31.5%
Holiday	1	Holiday	132	5.5%	61	7.7%	21	9.3%	7	9.1%	22	8.2%
	0	Otherwise	2282	94.5%	732	92.3%	206	90.7%	70	90.9%	245	91.8%
Lanes	1	Number of lanes is <=2	1668	69.1%	530	66.8%	143	63.0%	45	58.4%	265	99.3%
	0	Otherwise	746	30.9%	263	33.2%	84	37.0%	32	41.6%	2	0.7%
Ru Arterial	1	Roadway functional class is Rural Arterial	265	11.0%	97	12.2%	24	10.6%	9	11.7%	29	10.9%
	0	Otherwise	2149	89.0%	696	87.8%	203	89.4%	68	88.3%	238	89.1%
R(Coll/Rd/ST)							18		4			
	1	Roadway functional class is rural(collector, road, street)	180	7.5%	732	92.3%	209	100.0%	73	100.0%	22	8.2%
	0	Otherwise	2234	92.5%	61	7.7%		0.0%		0.0%	245	91.8%

Table 4.4 Variable Distribution (continued)

UPA	1	Roadway class is urban principal arterial	1165	48.3%	390	49.2%	113	49.8%	39	50.6%	140	52.4%
	0	Otherwise	1249	51.7%	403	50.8%	114	50.2%	38	49.4%	127	47.6%
UMI-A	1	Roadway functional is urban minor arterial	1983	82.1%	128	16.1%	34	15.0%	15	19.5%	39	14.6%
	0	Otherwise	431	17.9%	665	83.9%	193	85.0%	62	80.5%	228	85.4%
Road Profile							177		54		193	
	1	Roadway profile is straight	1831	75.8%	604	76.2%	50	100.0%	23	100.0%	74	100.0%
	0	Otherwise	583	24.2%	189	23.8%		0.0%		0.0%		0.0%
Speed	1	Posted Speed limit <50	1764	73.1%	245	30.9%	79	34.8%	44	57.1%	146	54.7%
	0	Otherwise	650	26.9%	548	69.1%	148	65.2%	33	42.9%	121	45.3%
Gender	1	Occupant is male	1659	68.7%	393	49.6%	111	48.9%	39	50.6%	143	53.6%
	0	Otherwise	755	31.3%	400	50.4%	116	51.1%	38	49.4%	124	46.4%
Dry Surface	1	Roadway surface is dry	1971	81.6%	655	82.6%	191	84.1%	64	83.1%	221	82.8%
	0	Otherwise	443	18.4%	138	17.4%	36	15.9%	13	16.9%	46	17.2%
AGE	1	Occupants age <21	287	11.9%	208	26.2%	140	60.1%	57	71.3%	149	55.2%
	2	Occupant age >20<30	512	21.2%	172	21.7%	39	16.7%	14	17.5%	47	17.4%
	3	Occupant age >29<50	861	35.7%	201	25.3%	25	10.7%	6	7.5%	39	14.4%
	4	Occupant age >49<65	416	17.2%	87	11.0%	17	7.3%	1	1.3%	14	5.2%
	5	Occupant age >=65	338	14.0%	125	15.8%	12	5.2%	2	2.5%	21	7.8%
Occupants	0	Number of occupants >2otherwise			480		219		70		17	
	1	Number of occupants =2			313		8		7		250	
Surface Type	1	Road Surface Concrete	80	3.3%	20	2.5%	7	3.1%	2	2.6%	9	3.4%
	0	Otherwise	2334	96.7%	773	97.5%	220	96.9%	75	97.4%	258	96.6%

The following describes the variables used in the data sets.

Roadway Related Information

For the driver seat belt usage model out of the five roadway functional classes that were used in the study, it was observed that most of the crashes 1970 (81.6%) occurred on urban principal arterial and urban minor arterials. Very few crashes, 444 (18.4%), occurred on rural arterial or on rural collector roads or streets. This can bee seen in Table 4.4.

A total of 1831 (75.8%) crashes occurred on level road profiles, 583 (24.2%) on hills, crest, or sag road profiles. A total of 2334 (96.7%) of crashes occurred on non-concrete surface road, while only a total of 80 (3.3%) crashes occurred on concrete surface roads. A total of 650 (26.9%) of the crashes occurred on roadways with a posted speed greater than 50 mph and 1764 (73.1%) on roadways with posted speed limits less than or equal to 50 mph.

Similar trends are observed in the data obtained for the development of models 2, 3, 4 and 5, with one exception. A greater number of crashes in models 2, right-front passenger, and 3, left-back passenger, occurred on roadways with a posted speed greater than 50 mph than on roadways with a posted speed less than or equal to 50 mph. For the right-front passenger model, (model 2), 548(69.1%) of the crashes occurred on roadways with posted speed limit of 50 mph or greater. For model 3, left-back passenger, 148 (65.2%) of crashes occurred on roadways with a speed limit of 50 mph or greater.

Environmental and Temporal Related Information

Environmental and temporal related information used in the development of the seat belt usage models included atmospheric conditions, light conditions, crash time, crash season, road surface conditions and holiday. In all five data sets information about weather characteristics shows that most of crashes occurred under no adverse atmospheric condition. For example in model 1 driver, 2079 (86.1%) of the crashes occurred under no adverse conditions and 335 (13.9%) and 108 (13.6%) of the crashes occurred during adverse conditions. For right-front passenger model, (model 2), 685 (86.4%) of crashes occurred under no adverse conditions and 108 (13.6%) of the crashes occurred under adverse conditions.

Most of the crashes also occurred when it was daylight or under dark but lighted conditions. This trend is observed in all five data sets. Table 4.4 shows that about 70 percent of the crashes occurred during off peak periods. Off –peak period is defined as the time of the day from 7:01pm to 6:59AM, and 10:01AM to 2:29PM. For crashes occurring during the peak period more crashes occurred during the PM peak period than the AM peak period. PM peak is defined as the time of the day between 3:00PM and 7:00PM and AM is the time between 7:00AM and 10:00AM. In all the data sets with the exception of data set for model 5 between 30 and 40 percent of fatal crashes occurred during the fall season. Finally most crashes occurred during periods which are not holidays as indicated in Table 4.4.

Occupant Related Information

For the driver seat belt model, drivers between the ages of 30-49 were most involved in crashes 861(35.7%). A total of 287 (11.9%) of crashes involved drivers who were less than 21 years old. Crashes involving drivers older than 64, between the ages of 21-29, and 50-64 made up 338 (14.0 %), 512 (21.2%), and 416 (17.2 %) of all crashes, respectively. In the back seat occupant seat belt models, models 3, 4, and 5, it is observed that most occupants are less than 21 years old. In model 3, 140 (61.7%) of the left-back seat occupants are less than 21 years, and in model 4, and 5, 57 (71.25%) and 149 (55.8%) of the middle-back and right-back occupants, respectively, are less than 21 years of age.

In model 1 most crashes involved male drivers 1659 (68.7%), compared with female drivers who made up 755(31.3%) of crashes. In model 5, 143 (53.6%) male right-back seat occupants were involved in all the crashes and 124(46.4%) were female occupants. A reverse trend is seen in model 2. A total of 400 (50.4%) of right-front occupants were females, while 393 (49.6%) were males. In model 4 the number of male middle-back occupants, 39, was just one more than that of the number of female middle-back occupants.

4.1.3 Seatbelt Usage Model and Result

Using data obtained from FARS for the years 2004 to 2006 for the state of New Jersey, five seat belt models are developed for driver's seat belt usage and occupants' seat belt usage. The driver's seat belt model predicts the probability of a driver wearing a seat belt, and the occupant models predict the probability of an occupant wearing a seat belt.

To predict the probability of a driver or occupant wearing a seat belt, the variables described in Table 4.3 are used. Results obtained from this model are presented in this section. Table 4.5 shows the goodness of fit for the driver and occupant seat belt models. This table shows that the models are all significant, with significance level of 0.00.

Table 4.5 Model–Fitting Information for Seat Belt Models

Parameter	**Models**				
	1	**2**	**3**	**4**	**5**
Chi-Square	105.08	344.87	41.45	21.89	81.82
Degree of Freedom	12	6	7	7	3
Significance	0.000	0.000	0.000	0.003	0.000

Table 4.6 shows the coefficient estimates and the p-values for each independent variable used in the driver and occupant seat belt usage models. Using a 90 percent confidence interval, independent variables are identified as significant.

4.1.4 Interpretation of Seat Belt Usage Models

Results from the Driver and occupants seat belt usage models are interpreted by examining the odds ratio and p-values for each of the model's independent variable. The Odds ratio is the ratio of the probability of an event occurring to the probability of that event not occurring. The following describes the odds ratio for significant independent variables in the driver seat belt usage model.

Table 4.6 Result of Driver and Occupant Seat Belt Usage Models

Variable	**Model 1 (Driver)**		**Model 2 (Right-Front)**		**Model 3 (Left-Back)**		**Model 4 (Middle-Back)**		**Model 5 (Right-Back)**	
	Coeff.	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**
Intercept	1.67	0.000	2.98	0.000	2.41	0.001	-3.20	0.95	0.09	0.911
Age	0.15	0.000							0.24	0.033
Gender (1)	-0.62	0.000	-0.50	0.023	0.81	0.007	0.94	0.080		
Speed(1)					-0.91	0.014				
No. Occupants		0.040								
No. of Occupants (1)	-0.26	0.118					2.14	0.087	1.25	0.121
No. of occupants (2)	-0.36	0.012								
Driver’s Belt Use			-3.60	0.000	-1.81	0.000	-1.46	0.088	-2.90	0.055
Urban Principal Arterial (1)	0.51	0.000			0.79	0.023				
Urban Minor Arterial	-0.29	0.045								
Rural Arterial	-0.38	0.025								
Rural(Collector, Road, Street			-1.30	0.000						
Light Condition(1)					0.61	0.092				
Surface Condition(1)					-0.97	0.014				
Crash Time		0.000								
Crash Time (1)	-0.08	0.641								
Crash Time (2)	0.39	0.037								
Crash Season		0.009		0.082						
Crash Season (1)	-0.29	0.031	-0.73	0.024						
Crash Season (2)	-0.20	0.132	-0.47	0.125						
Crash Season (3)	0.11	0.432	0.05	0.868						
Holiday(1)					-0.92	0.085	1.85	0.105		

Age

The age of the occupant was found to be a significant factor for both the driver and right-back passenger seat belt usage models. The sign of their coefficient estimates are both positive. For the driver seat belt usage model, the odds ratio for the age of the driver is 1.16. Thus the odds of a driver using seat belt are 1.16 times more with a unit increase in the age of a driver. For the right-back seat occupant, the odds ratio for age is 1.27. Therefore the odds of right-back seat occupant using seat belt are 1.27 times mores with a unit increase in the right-back seat occupant’s age. The higher odds ratio for the right-back occupant could also be due to the fact that a high proportion of right-back seat occupants are children under 12 who under law are required to be in a booster seat. This can be seen on Table 4 where 149 (55.2 %) of right-back occupants are below the age of 18.

Gender

In this research gender describes the sex of an occupant during a crash**.** This variable was classified into two categories: leve1 for male, and 0 for female. The female level is the reference class. Gender was determined to be a significant variable for all of the models, with the exception of model 5, the right-back seat occupant model. This indicates that the gender of he occupant influences whether the occupant will wear a seat belt or not. For the driver seat belt usage model, the odds ratio for gender is 0.54 and the coefficient estimate is -0.62. Therefore in crashes where the driver is a male, the odds of a driver wearing a seat belt is 0.54 times less than if the driver was a female.

For the right-front seat occupant model, the odds ratio for gender is 0.605 with a negative coefficient estimate of -0.50. This indicates that the odds of a right-front seat occupants wearing a seat belt is 0.605 times less if the right-front seat occupant is a male than if the occupant was a female. Result from the Left-back seat occupant model shows that the variable gender has a positive coefficient estimate value of 0.81, with an odds ratio 2.25. Thus the odds of a left-back seat occupant wearing a seat belt are 2.25 times more if the occupant is a male than if the occupant is a female. In the middle-back seat model the coefficient value for gender is 0.94. The odds ratio for this variable is 2.56. Therefore the odds of middle –back seat occupant being belted are 2.56 times more if the occupant is a male than if the occupant is a female. Gender was found not to be a significant variable for right back occupant model.

Number of Occupants

The number of occupants’ variable describes the number of occupants that were in the vehicle during a crash. This variable has three levels for the driver model as: “1” if the vehicle had no other occupant but the driver, “2” if number of occupants was two, and “3” if there were more than 2 occupants in the vehicle. In this model, the number of occupants was found to be significant with a p-value 0.04. However when the different levels are considered and compared with the reference level “3”, this variable was found to be significant only for vehicles that had two occupants, level “2”. The coefficient estimate for this level was -0.36, with an odds ratio of 0.70. This implies the odds of a driver being belted are 0.70 times less if there were 2 people in the vehicle than if there were more than two people in the vehicle during the crash.

For the other four models, the number of occupants was categorized into two levels; “1” if there were two occupants in the vehicle, and “2” if there were more than two occupants in the vehicle with “2” as the reference category. This variable was found to be significant only for the middle-back occupant model with a p-value 0.087. The estimate for this variable is 2.14 with an odds ratio 8.513. Therefore the odds of a middle-back seat occupant using a seat belt are 8.513 times more if there only two occupants in the vehicle than if there were more than two occupants in the vehicle.

Roadway Type

Four roadway types were evaluated to determine their impact on the seat belt usage of the occupants. The roadway types include: urban principal arterial, urban minor, rural arterial and rural collector roadway. The following describes the model results for each of these roadway types.

Urban Principal Arterial Roadway: Whether the roadway is an urban principal arterial was a significant factor in model 1, driver seat belt usage model and in model 3, left-back seat belt usage model. For the driver seat belt model the odds ratio for the urban principal arterial variable is 1.66 with a coefficient estimate value 0.51. This result indicates that the odds of a driver being belted when using an urban principal arterial is 1.66 times more than when he or she is not using an urban principal arterial. For the left-back seat occupant model, the odds ratio for urban principal arterial is 2.21, with a coefficient estimate of 0.79. Therefore the odds of a left-back seat occupant being belted in a vehicle travelling on an urban principal arterial is 2.21 times higher than if the crash occurred on a non- urban principal arterial.

Urban Minor Arterial: Whether the roadways is an urban minor arterial was a significant variable only in model 1, driver seat belt usage model. The results from model 1 show that the odds ratio for this variable is 0.75 and the coefficient estimate is -0.29. Thus the odds of a driver being belted are 0.75 times less if he is using an urban minor arterial than if he driving on a non- urban minor arterial.

Rural Arterial Roadway: Whether the roadway is a rural arterial was a significant variable only in model 1, driver seat belt usage model. The p-value for the variable is 0.025 with a coefficient estimate of -0.38. The odds ratio for this variable in this model is 0.68. Therefore the odds of a driver being belted are 0.684 times less when they are using a rural arterial roadway than when using a non-rural arterial roadway.

Rural Collector: Whether the roadway is a rural roadway (collector, road, or street) was a significant variable only in model 2, the right-front seat passenger seat belt usage model. The p-value for this variable is 0.00 with a coefficient estimate of -1.3.The odds ratio is 0.27. This result shows that the odds of a right-front seat occupant being belted in a vehicle on a rural roadway(collector, road, or street) are 0.27 times less than if he was in a vehicle on a non-rural roadway (collector, road, or street).

Crash Time

Crash time significantly impacts seat belt usage for a driver in model 1only, with an overall p-value of 0.00. This variable was categorized into three levels: Crash Time “1” for AM Peak times (7:00AM- 10:00AM); Crash Time “2” for PM Peak (3:00PM-7:00PM); and Crash Time “3” for off peak (7:01PM-6:59AM, 10:01AM-2:59PM). The off –peak level is the reference level. However if the variables Crash Time “1”and Crash Time “2”are considered individually only the coefficient for level 2, Crash Time “2”, is significant with a with a p-value of 0.037 and coefficient estimate of 0.39. The odds ratio for this level is 1.48. Therefore the odds of a driver being belted are 1.48 times more during PM peak hours than during off peak hours.

Crash Season

Crash season variable was categorized into 4 levels in this research; “1” for fall season, “2” for winter season, ‘3” for spring season, and “4” for summer season, with level “4” as the reference level. This variable is significant both in model 1, driver seat belt usage model with overall p-value 0.009, and model 2, right-front passenger seat belt usage model with an overall p-value of 0.082. However if the individual levels are considered separately, not all of the crash season levels significantly impact seat belt usage.

In the driver seat belt model the only season level that significantly impacts seat belt usage is fall with p-value 0.031 and an estimate value of -0.29. The odds ratio for fall season is 0.750. Therefore the odds of a driver being belted are 0.750 times less in the fall season than in the summer season. For the right-front seat occupant model, the fall season is also the only one that significantly impacts the right-front seat occupant’s seat belt usage. It has a p-value of 0.24 and a coefficient estimate of 0.73. The odds ratio for this level is 0.48. Hence the odds of a right-front seat occupant being belted in the fall season are 0.48 times less than being belted in the summer season.

Driver Seat Belt Usage

This variable describes the impact of a driver’s belt usage on belt usage of other occupants in a vehicle. It was categorized into two levels: ‘1” if the driver is belted, and ‘0’ if the driver is not belted. The reference category is driver being belted. The driver’s seat belt usage was found to be significant for all the non-driver seat belt usage models.

In the right-front seat occupant model this variable has a p-value of 0.00, with an estimate value of -3.6. The odds ratio is 0.03.This shows that the odds of a right-front seat occupant being belted are 0.03 times less when the driver is not belted than when the driver is belted. In the left-back seat occupant's model, the driver's seat belt usage was found to be significant with a p-value 0.00 and a coefficient estimate of -1.81. The odds ratio is 0.164. Therefore the odds of a left-back seat occupant being belted are 0.164 times less if the driver is not belted than if the driver is belted. For the middle-back seat model, the p-value for the driver seat belt usage is 0.09 with a coefficient estimate -1.46. The odds ratio is 0.23. This indicates that the odds of a middle-back seat occupant being belted are 0.23 times less if the driver is not belted than if the driver is belted. In the right-back seat occupant model, the driver seat belt usage has a p-value of 0.00 with an estimate value -2.9. The odds ratio is 0.06. Thus the odds of a right-back seat occupant being belted are 0.06 times less when the driver is not belted than when the driver is belted.

The results described above for the driver seat belt usage variable indicates that a belted driver has a great impact on seat belt usage of the middle-back and right-back seat occupants. This could be due to the fact that many middle-back and right back seat occupants are children and are required to be restrained.

Posted Speed Limit

The posted speed variable was classified into two levels: “1” when the posted speed is less than 50 mph, and “0” for posted speed of 50 mph or more, with “0” as the reference level. The posted speed limit was significant in only model 3, the left-back seat belt usage model. The p-value for this variable is 0.014 with a coefficient estimate of -0.91.

The odds ratio is 0.404. Therefore the odds of a left-back seat occupant being belted are 0.40 less if the crash occurred on a roadway with posted speed less than 50 mph than on a roadway with posted speed of 50 mph or more. Results of the other models show negligible differences between the seat belt usage and different posted speed limits**.** This could be due to the fact that the actual speeds of the vehicles were not recorded. Drivers could have been driving above or below posted speed.

Road Surface Condition

Road surface condition was categorized as “1” if the road surface was dry and “0” if it was not dry. The reference level is”0”.This variable is only significant for the left-back seat occupant model, having a p-value 0.17 and an estimate of -0.91. The odds ratio for this variable in this model is 0.38. Therefore the odd of a left-back seat occupant being belted are 0.38 times less if the road surface is dry than if the road surface is not dry.

Holiday

Holiday variable was classified into two levels: “1” for holidays and “0” for otherwise, with “0” as the reference category. The impact of holidays on seat belt usage was found to be significant for the left-back seat belt usage model only. Holiday was found to be significant with p-value 0.09 and a coefficient estimate of -0.92.The odds ratio for holiday is 0.398. Therefore the odds of a left-back seat occupant being belted are 0.398 times less if he was in a vehicle during a holiday than if it were not a holiday.

Light Condition

Light condition variable describes existing light conditions during the crash. It was classified into two categories: “1” if the crash took place during daylight or dark but lighted conditions, and “0” otherwise, with “0” as the reference level. The impact of light condition on seat belt usage was found to be significant for the left-back seat belt usage model only. In this model, the p-value for this variable was 0.09 with a coefficient value 0.61. The odds ratio for lighted conditions is 1.83.Therefore the odds of a left-back seat occupant being belted are 1.83 more during lighted or dark but lighted conditions than under dark conditions.

4.1.5 Predicted Logistic Regression Model

The predicted logistic regression model for the driver seat belt usage model, model 1 is given as:

$$\begin{aligned} Log\left(\frac{p}{1-p}\right) &= 1.67 + 0.146Age - 0.621Gnr - 0.36Occ(2) - 0.38RA + 0.51UPA \\ &\quad - 0.29UMA + 0.39PM - 0.29FALL + 0.93CT(2) \end{aligned} \tag{4.1}$$

Where: p = probability of wearing a seat belt
Age = Drivers age,
Gnr = Drivers gender,
Occ = number of occupants,
RA = Rural Arterial,
UPA = Urban principal arterial
UMA= Urban Minor Arterial
PM = PM peak time period,
FALL = Fall season of the year.
CT= crash time

The predicted logistic regression model for the right-front seat occupant belt usage model, model 2 is given as:

$$Log\left(\frac{p}{1-p}\right)=2.98-0.50Gnr-3.60DBU-1.30RuCRS-0.73CSE(1) \tag{4.2}$$

Where: p = probability of wearing a seat belt
Gnr = Right-front Occupant’s gender
DBU = Driver’s belt Usage
CSE(1) = Crash Season Fall.

The predicted logistic regression model for the left-back seat occupant belt usage model, model 3, is given as:

$$Log\left(\frac{p}{1-p}\right)=2.41+0.81Gnr-1.81DBU-0.92HOL+0..61LDN+0.79UPA-0.97DSC-0.91SPD \tag{4.3}$$

Where: p = probability of wearing a seat belt
Gnr = Left-back Occupant’s gender
DBU = Driver’s belt Usage
HOL = Holiday
LDN = Light Condition
PA = Urban Principal Arterial
DSC= Dry Roadway Surface Condition
SPD = Roadway Posted Speed Limit

The predicted logistic regression model for the middle-back seat occupant belt usage model, model 4, is given as:

$$Log\left(\frac{p}{1-p}\right)=-3.2+0.94Gnr-1.46DBU+2.14OCC(1) \tag{4.4}$$

Where: p = probability of wearing a seat belt
Gnr = middle-back seat occupant’s gender
DBU = Driver’s seat belt usage
OCC = Number of occupants

The predicted logistic regression model for the right-back seat occupant belt usage model, model 5, is given as:

$$Log\left(\frac{p}{1-p}\right) = 0.09 + 0.24RBAge - 2.9DBU + 1.25OCC(1) \qquad (4.5)$$

Where: p = probability of wearing a seat belt
RBAge = Right-back seat occupant’s age
DBU = Driver seat belt usage

OCC = Number of occupants

4.2 Injury Severity Model

Injury severity models were developed in this research to examine the impact of back seat occupants’ seat belt use and several other variables on the injury severity of belted front seat occupants. The injury severity for vehicle occupants studied included: belted drivers, belted right-front seat occupants, left-back seat occupants, middle-back seat occupants, and right-back seat occupants in passenger motor vehicles. Injury severity (the dependent variable) in the study is an ordinal response using integers to represent an ordered sequence. The injury severity used has five levels: Y = 4 if the front seat occupant is killed, Y = 3 if the front seat occupant suffers an incapacitated injury, Y = 2 if the front seat occupant is moderately injured, Y = 1 if the front seat occupant has a minor injury, Y = 0 if front seat occupant has no injury. The injury severity 4 indicates the most severe injury level and 0 indicates the least severe injury level. Since the dependent variable is of an ordinal nature, an ordinal logistic regression approach is found suitable.

4.2.1 Injury Severity Model Development

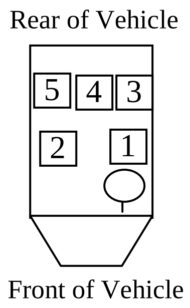
In this research, injury severity models are developed for injuries in crashes involving passenger cars, sport utility cars, light vans, and pickups, with left back, middle back and/or right back passengers. The intent of the analysis is to study the impact of back seat occupants' seat belt usage on the injury severity of front seat occupants in the state of New Jersey. Only vehicles in which the driver and the right front occupant were belted are considered in the development of the injury severity models. This was done because what is being studied is determining whether the injury severity of a belted front seat occupant is impacted by an unbelted back seat occupant.

Ten models are developed for the injury severity of the front seat occupants under varying scenarios. These models are described in Table 4.7. Models 6 through 9 and model 14 determine the injury severity for driver. Models 10 through 13 and model 15 determine the injury severity for the right-front occupant. Each model considers the presence of certain vehicle occupants. The occupants considered in each model are shown in Table 4.7. Table 4.8 describes the occupant seating positions considered in the models.

Table 4.7 Injury Severity Models

Model	Injury For	Occupants Considered	Number of Cases Studied
6	Driver	Left-back	185
7	Driver	Right-back	240
8	Driver	Left-back, right-back	105
9	Driver	Left-back, right-back , middle-back	117
10	Right Front Occupant	Left-back	185
11	Right Front Occupant	Right-back	240
12	Right Front Occupant	Left-back, right-back	105
13	Right Front Occupant	Left-back, right-back , middle-back	117
14	Driver	No back occupants	668
15	Right Front Occupant	No back occupants	668

Table 4.8 Seating Position for Vehicle Occupants

Seating Position	Description	
1	Driver	
2	Right-front occupant	
3	Left-back occupant	
4	Middle-back occupant	
5	Right-back occupant	

4.2.2 Data Collection for Injury Severity Models

Crashes from the Fatality Analysis Reporting System (FARS) for NJ for 2004 to 2006 were analyzed. Data obtained from FARS database were limited to crashes in which the driver and right front seat passenger were belted, with at least one back seat occupant seated in the row directly behind the driver or the right-front seat passenger. Occupants in large vehicles (buses, large vans, and trucks), motorcyclists and pedestrians were not considered in the study. The injury severity for the driver or the right front passenger in each crash case is chosen as the dependent variable for the injury severity model. The independent variables, which are both categorical and quantitative, are shown in Table 4.9. These variables are: Atmospheric condition, Light condition, Type of Crash, Roadway Class Function, Roadway Profile, Roadway Surface type, Roadway Surface condition, Posted Speed, Driver's gender, Driver's age, Right front passenger age, Right front passenger gender, Restraint use for Left back occupant, Restraint use for middle back occupant, and Restraint use for right back occupant.

The dependent variable, injury severity, is classified into five levels using the KABCO scale, where "K" is fatal injury, "A" is incapacitating injury, "B" is non-incapacitating injury, "C" is possible injury or complaint of pain and "O" represents no injury. All the categorical independent variables are dichotomized. Age and speed limit were the only two continuous variables. Speed was classified into two categories and age was classified into five categories.

4.2.3 Correlation Test for Speed Limit and Roadway Functional Class

Correlation test was also carried out on the data to test the interrelation between speed limit and roadway functional class so as to avoid confounding effects. Bivariate correlation test was done and the result gave a negative correlation coefficient of 0.46. Although the correlation coefficient shows that the two variables are related, scatter plot diagram shown in Figure 4.1 indicates that the two variables are linearly related, and hence confounding effects do not exist for these two variables.

4.2.4 Data Summary

Table 4.10 shows the number of cases considered in developing the injury severity models. A total of 105 vehicles with belted front occupants, that is a driver and right-front-seat occupant, and a left back occupant were involved in crashes. A total of 177 vehicles for belted front occupants and right back occupant crashes were obtained. 240 vehicles with belted front occupants with left back and right back occupant's crashes were recorded. A total number of 185 vehicles with belted front seat occupants, left back, middle back, and right back seat occupants were obtained. Finally 668 vehicles with belted front occupants and no back seat occupants' crashes were observed. This consisted of vehicles with a driver and front seat passenger only.

Table 4.9 Variable Description for Injury Severity Models

Variable	**Description**
Y	Injury Severity as dependent variable with 5 level
ATMP	=1 if no adverse Atmospheric condition; = 0 otherwise
LCD	=1 if daylight/dark but lighted; = 0 otherwise
NCV	=1 if no collision with another vehicle; = 0 otherwise
FRR	=1 if Front-to-Rear including Rear –End collision; = 0 otherwise
FFH	=1 if Front-to Front Collision including head-on; = 0 otherwise
FSRA	=1 if Front-to-Side Right Angle collision ; =0 otherwise
RA	=1 if road is Rural Arterial; = 0 otherwise
R(C/RD /ST)	=1 if road is rural(collector, road, street); = 0 otherwise
UPA	=1 if road is urban principal arterial; = 0 otherwise
UMIA	=1 if road is urban minor arterial; = 0 otherwise
RPSTRI	=1 if road is straight; = 0 otherwise
SL	=1 if posted Speed limit <50; = 0 otherwise
GNDR	=1 if driver gender is male; = 0 otherwise
GNRFO	=1 if Right front passenger gender is male;= 0 otherwise
AGEDR	=1if Driver age <21; = 2 if >20<30; = 3if >29<50; = 4if >49<65; = 5if >=65
AGERFO	=1 if Right Front passenger is <21; ; =2 if >20<30; =3 if >29<50; =4 if >49<65; =5if>=65
BLBO	=1 if left back occupant is belted; = 0 otherwise
BMBO	=1 if middle back occupant is belted; = 0 otherwise
BRBO	=1 if right back occupant is belted; =0 otherwise

Table 4.10 Summary of Observations by Occupant Position

Data Type	**Front occupants with left back occupant**	**Front Occupants with right back occupant**	**Front Occupants with left and right back occupants**	**Front Occupants with left back, middle back and right back occupants**	**Front Occupants only**
Total Number of Observations	105	117	240	185	668
Models developed	6(L) 10(L)	7(R) 11(R)	8(LR) 12(LR)	9(LMR) 13(LMR)	14(No) 15(No)

Note. 6-15: Model numbers
L: left-back occupant, M: Middle-back occupant, R: Right-back occupant, No: No back occupant.

Table 4.11 shows the injury severity distribution for a belted driver and belted right-front occupant. It can be seen in the table that a large majority of crashes did not cause injury to the driver. In the belted front seat occupants with left back passenger model, out of a total number of 108 drivers, 51(48.6%) of them had no injuries. For the belted front occupants with right back seat occupants' model, 51(28.8%) drivers out of a total number of 117 had no injuries. Out of a total number of 240 drivers with belted right-front occupants and left and right back seat occupants, 108(45 %) of drivers were not injured. In the belted right-front occupants, left back, middle back and right back occupants model, 50 (27.0%) drivers out of a total number of 185 did not sustain any injury. In the belted front occupants with no other occupants' model, 222 (33.2%) drivers had no injuries out of a total number of 668.Table 4.11 also shows that a large percentage of the crashes studied caused no injury to the right front occupant.

Table 4.11 Summary of Injury Severity Levels

	Model	Injury Level									
		0-No Injury		**1-Pain Only**		**2-Moderate**		**3- Incapacitated**		**4-Killed**	
		No.	%	No.	%	No.	%	No.	%	No.	%
Belted Driver Models	**6 (L)**	51	48.6%	15	14.3%	21	20.0%	6	5.7%	12	11.4
	7 (R)	51	28.8%	51	28.8%	36	20.3%	9	5.1%	30	16.9
	8(LR)	108	45.0%	32	13.3%	47	19.6%	20	8.3%	33	13.8
	9(LRM)	50	27.0%	60	32.4%	40	21.6%	25	13.5%	10	5.4
	14(No)	222	33.2%	99	14.8%	115	17.2%	74	11.1%	158	23.7
Belted Front-Seat Passenger Models	**10(L)**	54	51.4%	15	14.3%	18	17.1%	6	5.7%	12	11.4
	11(R)	72	40.7%	54	30.5%	18	10.2%	9	5.1%	24	13.6
	12 (LR)	100	41.7%	40	16.7%	48	20.0%	24	1%	28	11.7
	13(LRM)	70	37.8%	45	24.3%	25	13.5%	10	5.4%	35	18.9
	15(No)	205	30.6%	129	19.3%	102	15.3%	58	8.7%	174	26.0

Note. L: Left-back occupant; R: Right-back occupant; LR: left-back and Right-back occupants; LRM: left-back, Middle-back, and Right-back occupants; No- No back occupant

4.2.5 Injury Severity Model Result

To estimate the probability of an injury severity for a belted driver or belted right front seat occupant, the variables described in Table 4.9 are used. Using the data obtained from FARS, injury severity models are developed. A 90 percent confidence interval is used in this research to identify significant variables that impact the injury severity for drivers and right front-seat occupants. Before proceeding to examine the individual coefficients, the overall test of the null hypothesis that the estimate coefficients for all of the variables in all of the models are zero is examined. This is done using the loglikelihood ratio chi-square test. The results of this test are shown in Table 4.12. The table shows that for the ten scenarios the p-value for the test is significantly less than 0.005. This implies that the null hypothesis can be rejected in each scenario and the hypothesis that the model without independent variables is as good as the model with the independent variables is rejected.

Table 4.12 Model-fitting Information for Injury Severity Models

	Model	**Parameters**				
		Loglikelihood	**Restricted Loglikelihood**	**Chi-Square**	**Degree of Freedom**	**Significance**
Belted Driver Models	**6(L)**	270.6	203.9	66.688	19	0
	7(R)	488.1	447.7	40.4	19	0.003
	8(LR)	650.6	583	67.6	21	0
	9(LRM)	525.8	459.8	65.9	23	0
	14(No)	1571	1520.1	50.1	18	0
Belted Front-Seat Occupant Models	**10(L)**	261.6	171.1	90.5	19	0
	11(R)	327.4	246.8	80.6	19	0
	12(LR)	668.6	582.6	86.1	22	0
	13(LRM)	541.0	405.3	135.8	25	0
	15(No)	1573	1492.6	80.2	20	0

In addition to the null hypothesis test to examine the goodness-of-fit-statistics for the models, the Pearson Chi-square and the Deviance Chi-square tests are used. The Pearson Chi-square and Deviance Chi-square test are standard statistical tests to determine if a model fits well by comparing observed values of the response variable with the predicted values obtained from the models with and without the variable in question. This comparism in logistic regression is based on the log likelihood function. If a model is significant then the goodness-of-fit measure would have p-values greater than 0.05. Table 4.13 shows that when the Pearson chi-square test is used, six models (6, 7, 11, 12, 14, and

15) have large p-values. This indicates that only six out of the ten models are significant if the Pearson Chi-square tests used. When the Deviance Chi-square test is used, all the models are significant. As shown on Table 4.13 the p-values for the Deviance Chi-square are all greater than 0.05. Therefore the Deviance Chi-square could be used, since all the models are significant under this test.

Table 4.13 Goodness-of-Fit Statistics for Injury Severity Models

	Model	**Pearson Chi-Square**	**Deviance Chi-Square**	**Pearson P-value**	**Deviance P-Value**
Belted Driver Models	**6(L)**	341.3	191.6	0.3	1.0
	7(R)	558.0	416.9	0.6	1.0
	8(LR)	1032.2	549.6	0.004	1.0
	9(LRM)	2110.7	432.4	0.0	1.0
	14(No)	1498.9	1258.7	0.2	1.0
Belted Front-Seat Occupant Models	**10(L)**	445.0	155.9	0.0	1.0
	11(R)	339.2	225.9	0.99	1.0
	12(LR)	777.5	551.8	0.2	1.0
	13(LRM)	3118.6	386.5	0.0	
	15(No)	1525.5	1237.7	0.2	1.0

The results for the belted driver injury severity models are shown in Table 4.14. Interpretation of these results is based on practical inferences drawn from the coefficient estimates of the independent variables. These coefficients estimates represent the slope or rate of change of the dependent variable per unit of change in the independent variable. Therefore interpretation involves two issues: determining the functional relationship between the dependent variable, (i.e. the link function); and appropriately defining the unit change for the independent variable, (Al-Ghamdi, 2002). As described in Chapter 3, the link function in logistic regression is the logit transformation (Eq. (3.12)). The interpretation of a coefficient in a logistic regression is properly done by taking the difference between two logits. The exponential of this difference gives the odds ratio.

The odds ratio for an independent variable is defined as the ratio of the odds that the independent variable will occur to the odds that it will not occur. In the SPSS result output for an Ordinal logistic regression, the odds ratio for each independent variable is calculated as the negative exponential of the coefficient of that variable. That is the odds ratio is calculated as exp $(-\beta)$ where β is the coefficient estimate value. Table 4.15 shows the odd ratio for the significant variables in the Driver injury severity models.

Odds ratio is exp $(-\beta)$ where β is the coefficient estimate value.

Table 4.14 Injury Severity Models for Belted Driver

Parameter	**Model 6 (L)**		**Model 7 (R)**		**Model 8 (LR)**		**Model 9 (LRM)**		**Model 14 (No)**	
	Estimate	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**
Atmosph Cdn =0	**2.5**	**0.00**	0.3	0.50	0.037	0.90	-0.096	0.90	0.12	0.6
Light Cdn = 0	0.6	0.40	0.3	0.40	**0.9**	**0.01**	**1.3**	**0.00**	0.4	0.04
No coll with Veh = 0	**-2.4**	**0.02**	0.96	0.40	**0.9**	**0.08**	-0.7	0.20	-0.3	0.30
FRR= 0	-0.2	0.90	-0.7	0.60	-0.6	0.20	**-1.6**	**0.01**	**-0.5**	**0.12**
FFH = 0	-1.6	0.12	0.7	0.60	**-1.1**	**0.04**	**-1.3**	**0.04**	**-0.8**	**0.01**
FSRA = 0	**-2.2**	**0.04**	-0.3	0.80	-0.2	0.70	**-1.6**	**0.01**	**-0.7**	**0.01**
R(C/RD/ST) =0	-1.5	0.20	1.2	0.04	**-0.98**	**0.09**	**1.08**	**0.10**	**-0.7**	**0.07**
UPA = 0	**-2.2**	**0.01**	**0.9**	**0.01**	0.2	0.60	0.4	0.20	0.3	0.20
UMIA = 0	-0.5	0.50	**1.2**	**0.03**	0.051	0.95	-0.4	0.60	0.35	0.18
RDP = 0	0.065	0.93	-0.2	0.50	-0.021	0.95	**-0.8**	**0.08**	0.12	0.50
SL = 0	0.056	0.90	0.4	0.30	-1.2	0.001	-0.1	0.70	**-0.32**	**0.05**
AGEDR = 1	-0.6	0.70	0.8	0.20	0.049	0.90	0.354	0.70	-0.4	3.00
AGEDR = 2	-0.3	0.80	-0.9	0.20	0.6	0.30	1.596	0.06	**-0.4**	**0.20**
AGEDR = 3	-0.9	0.20	-0.2	0.60	-0.6	0.20	-0.045	0.90	**-0.9**	**0.002**
AGEDR = 4	-0.4	0.80	0.5	0.40	-0.9	0.30	-0.088	0.93	**-0.6**	**0.08**
GNDR = 0	1.1	0.20	-0.1	0.80	0.3	0.60	-0.6	0.40	**0.6**	**0.05**
Belt use(LB) = 0	-0.28	0.90			0.8	0.20	**1.6**	**0.008**		
Belt use(MB) = 0							1.44	0.03		
Belt use(RB) = 0			-0.193	0.82	0.7	0.30	**1.1**	**0.06**		

Table 4.15 Odds Ratio for Driver Injury Severity Models

Variable	**Model 6 (L)**		**Model 7 (R)**		**Model 8 (LR)**		**Model 9 (LRM)**		**Model 14 (No)**	
	Estimate	**Odds Ratio**	**Estimate**	**Odds Ratio**	**Estimate**	**Odds Ratio**	**Estimate**	**Odds Ratio**	**Estimate**	**Odds Ratio**
Atmosph Cdn	2.5	0.08								
Light Cdn					0.9	0.41	1.3	0.27	0.4	0.67
Single Vehicle Crash	-2.4	11.02			0.9	0.41				
Front-to-rear							-1.6	4.95		
Front-to-front head-on collision					-1.1	3.0	-1.3	3.67	-0.8	2.23
Front-to-side right- angle	-2.2	9.03					-1.6	4.95	-0.7	2.01
R(C/RD/ST)					-0.98	0.38	1.08	0.34	-0.7	2.01
Urban Principal Arterial	-2.2	9.03	0.9	0.41						
Urban Minor Arterial			1.2	0.30						
Posted Speed Limit					-1.2	3.3			-0.32	1.38
Age Driver = 3									-0.9	2.46
Age Driver = 4									-0.6	1.8
Gender Driver									0.6	0.55
Belt use(LB)							1.6	0.20		
Belt use(MB)							1.44	0.24		
Belt use(RB)							1.1	0.3		

4.2.6 Interpretation of Belted Driver Injury Severity Models

Table 4.13 indicates the coefficients for the variables of five models to determine the injury severity of a belted driver under different scenarios. The following provides a discussion of these variables for the scenarios studied.

Injury severity of Driver with no back occupants in Vehicle (Model 14)

Crashes involving vehicles that had no back seat occupants were first considered. The objective was to determine those variables that would impact the injury severity of a belted driver in crashes where the vehicles had no back seat occupants. The coefficient estimates for is shown in Model 14 on Table 4.14. Variables found to significantly impact the driver's injury severity in this model were light conditions with a p-value 0.04, front-to-front head-on collisions with a p-value 0.01, front-to -front right-angle collisions with a p-value of 0.01,rural roadways (collectors, local roads, or streets) with a p-value 0.01, speed limit with a p-value 0.05, driver's gender with a p-value 0.05, and driver's age with different p-values for the four categories as shown in Table 4.14.

The variable Light condition describes the light conditions that existed during the crash. In this research this variable is categorized into two levels: 1 if there was daylight/dark but lighted conditions, and 0 otherwise, with category 1 as the reference category. The positive coefficient value for light condition 0.4 indicates that dark condition is associated with higher injury severities for a driver. The odds ratio for light condition is exp(-0.4)= 0.67.This value indicates that the odds of a driver sustaining more severe injury severities in dark conditions are 0.67 times greater than in daylight or dark but lighted conditions.

The variable Front-to- Front collision including head-on collisions describes crashes that involved more than one vehicle colliding front-to-front or colliding head-on. This variable is categorized into two levels: 1 for crashes that were front-to-front including head-on collisions, and 0 for crashes that were not front-to-front, with 1 as the reference category. The coefficient for this variable is (-0.8). The coefficient indicates that crashes that were not front-to-front, including head-on collisions, are associated with lower injury severities for drivers. The odds ratio for this variable is 2.23.This value indicates that the odds of a driver sustaining more severe injuries are 2.23 times less if it is a non- front-to-front including head-on collision than if it is a front-to front including head-on collision.

The Front-to-side right angle variable describes crashes where the vehicles collided front-to-side at right angles. This variable was categorized as 1 if the crash was a front-to-side right angle type and 0 if it was otherwise. This variable has a negative coefficient of -0.7, indicating that non front-to-side right angle crashes are associated with lower injury severities for drivers. The odds ratio is 2.01; therefore the odds of higher injury severities for a driver in a front-to-front crash are 2.01 times less in a non-front-to front right- angle collision than if it is in a front-to-front right- angle crash.

The variable rural roadway (collectors, local roads, street) describe those crashes that occurred on collector roadways, local roads, and streets found in rural areas. This variable was dichotomized into two levels: 1 for crashes that occurred on rural roadways, and 0 for crashes that did not occur on rural collectors, rural local roads, or rural streets. The reference category is 1. In model 14 the estimate coefficient is -0.7. Therefore crashes that occurred on non-rural collectors, non-rural local roads, or non-rural streets are associated with less injury severity for drivers. The odds ratio is 2.01,indicating that the odds of sustaining more severe injuries by a driver are 2.01 times less on non-rural (collector, local roads, street) than on rural (collectors, local roads, streets).

The speed limit variable describes the posted speed limit on the roadway during a crash. This variable is categorized into two levels: 1 if posted speed limit was less than 50 mph and 0 if it was 50 mph or more. This variable is found to significantly impact the injury severity of a driver with a coefficient of -0.32. This shows that crashes that occurred on roadways with posted speed limit of 50 mph or more are associated with lower injury severities for drivers. The odds ratio for this variable is 1.38, indicating that the odds of a driver being more severely injured in a crash where posted speed limit is 50 mph or more are 1.38 times less than where posted speed is less than 50 mph.

The driver's gender variable describes the sex of the driver involved in a crash. This variable was categorized as 1 if the driver was male and 0 if the driver was female. The reference category was 1. The driver's gender significantly impacts his or her injury severity with a positive coefficient of 0.6. This result implies female drivers are associated with higher injury severities than male drivers. The odds ratio for driver gender is 0.55. This finding indicates that the odds of a driver sustaining more severe injuries are 0.55 times more if the driver is female driver than if the driver is male.

The age variable describes the age of the driver during a crash. This variable has five levels as shown on Table 4.14. The reference level is 5 is for drivers who were 65 years or older. The positive coefficient for age indicates that age is associated with higher injury levels. The odds ratio for age is 1.49. Thus the odds of a driver sustaining higher injury levels are 1.49 times more if the driver is younger than 65 than if the driver is 65 or older.

Injury severity of driver with left -back occupant (Model 6)

After developing a model to identify variables that impact the injury severity of a belted driver if there was no back seat passenger, another scenario is considered in which there was a left back seat occupant in the vehicle during the crash. The objective is to determine to what extent a left back seat occupant's seat belt usage during a crash would have on the injury severity of the driver, as well as to investigate whether there is a greater impact on the drivers injury severity if there is a passenger in the vehicle or not. Results for this model are shown on Table 4.14 for model 6(L).

The results show that four variables had significant impacts on the injury severity of the driver. This include atmospheric condition with a p-value of 0.0, single vehicle crashes with a p-value of 0.02, front-to-front-right angle collisions with a p-value of 0.04, and urban principal arterial with a p-value of 0.0.

The Atmospheric condition variable describes the existing atmospheric conditions during the crash. This variable was dichotomized into two levels: 1 if there were no adverse atmospheric conditions, and 0 if otherwise. The reference category for this variable is 1. Model results show that the coefficient for this variable is -2.5. The negative coefficient value indicates that non- adverse atmospheric conditions are associated with lower injury severities. The odds ratio is 0.08. This indicates that the odds of a driver sustaining higher levels of injury are 0.08 times less in non-adverse conditions than in adverse conditions.

The single vehicle crash variable relates to crashes that involved only one vehicle. The variable was categorized into two levels: 1 if it was a single vehicle crash and 0 if more than one vehicle was involved in the crash. The reference category is 1. The coefficient value for this variable is -2.4. This means crashes involving multiple vehicles are associated with less severe injuries for the driver in this model. The odds ratio for this variable is 11.02. Therefore the odds of a driver sustaining more severe injuries in multi-vehicle crash are 11.02 times less than in a single-vehicle crash. This confirms an earlier study performed by Jung (2009), for weather –related crash severity in Wisconsin for crash data from 1999 to 2006. Jung (2009) found that the proportion of serious crashes including fatalities and incapacitating injuries to total crashes was 10% for single-vehicle crash and only 4% for multiple-vehicle crashes.

Front-to-front-right angle collisions were also found to have an impact on the driver's injury severity, with a negative coefficient value of -2.2. The negative coefficient indicates that non-front-to-front -right angle rashes collisions are associated with less severe injuries. The odds ratio for this variable is 9.03. Therefore the odds of sustaining more severe injuries by a driver is 9.03 times less in non-front-to-front right angle collisions than if the crash is a front-to-front right angle collision.

The urban principal arterial variable is related to all crashes that occurred on the urban principal arterial roadway. Two categories were defined for this variable: 1 if the roadway was an urban principal arterial and 0 if it was not an urban principal arterial. The coefficient value for this variable is -2.2 with an odds ratio of 9.03. This implies crashes that occurred on roadways which were not urban arterials are associated with less injury severities for the driver. The odds of a driver sustaining higher injury severity levels is

9.03 times less in a crash that occurred on a non- urban principal arterial roadway than if the crash occurred on an urban principal arterial.

Injury severity of driver with right-back occupant (Model 7)

A third model was developed for crashes involving vehicles having a right back seat occupant seated directly behind the front seat occupants. The objective of this model is to determine the impact of the right back seat occupant's seat belt usage on the driver's injury severity. Two variables were found to significantly impact the injury severity of the driver in this model. These variables include urban principal arterial roadway with a p-value of 0.01 and urban minor arterial roadway with a p-value of 0.03.

The coefficient value for the urban principal arterial is 0.9. The odds ratio for this variable is 0.41. Therefore non- urban principal arterial roadways crashes are associated with higher injury severities for the driver. The odds ratio indicates that the odds of a driver sustaining more severe injuries is 0.41 times more with a crash that occurs on a non- urban principal arterial roadways than on an urban principal arterial roadway.

The urban minor arterial variable describes crashes that occurred on urban minor roadways. The variable is classified into two levels: 1 for crashes that occurred on urban minor arterial roadways and 0 otherwise. Level 1 is the reference category. The variable has a significant p-value of 0.03 and a positive coefficient of 1.2. Therefore crashes that occurred on roadways that were not urban minor arterials are associated with higher injury severity levels for the drivers. The odds ratio is 0.30. Hence the odds of a driver sustaining more severe injury severities are 0.30 times more on crashes that occur on a non- urban minor arterial roadway than crashes on urban minor arterial roadway. The results of this model show that the right-back seat occupant seat belt usage has no significant impact on the injury severity of a belted driver.

Injury severity of driver with left -back and right- back occupants (Model 8)

In this model, only crashes involving vehicles having both left back seat and right back seat occupants were considered. The objective of this model is to determine whether wearing seat belt or not by back seat occupants in vehicles with more than one back seat occupant would have an impact on the driver's injury severity. Results of this model are shown on Table 4.14 for Model 8(LR). Three variables were observed to significantly impact the injury severity of the driver. They are light condition with a p-value 0.01, Front-to-front including head-on collision with a p-value 0.04 and posted speed lit with a p-value 0.001.

For the light conditions variable, the coefficient value is 0.9. The positive coefficient value shows that dark conditions are associated with higher injury severities for the driver. The odds ratio for this variable is 0.41. This value indicates that the odds of a driver sustaining injuries of higher levels are 0.41 times more in darkness than in light or dark-but-lighted conditions.

Front-to-front including head-on collision has a negative coefficient value of -1.1. The negative coefficient indicates that collisions which are not Front-to-front including head-on are associated with less injury severities for the driver. The odds ratio for front-to-front head-on collision is 3.00. Therefore the odds of sustaining more severe injuries by a driver are 3.00 times less in a non-front-to-front including head-on collision than if the crash is a front-to-front including head-on collision.

The posted speed limit variable has a negative coefficient estimate of -1.2. This indicates that crashes that occurred on roadways with posted speed limits of 50 mph or more are associated with less injury severities for the driver. The odds ratio for this variable is 3.32. Hence the odds of a driver sustaining more severe injuries are 3.32 times less if the posted speed is 50 mph or more than if posted speed is less than 50 mph. This could be due to the fact that occupants travelling on roadways with higher speed limits buckled up more than those travelling on roadways with less posted speed limits.

Injury severity of driver with three back-seat occupants (Model 9)

After considering crashes with vehicles that had two occupants in the back seat, further studies were carried out to develop another injury severity model for crashes that took place with vehicles having three occupants (left back occupant, middle back occupant and right back occupant) in the back seat directly behind the front seat occupants. The coefficient estimates for model 9 (LRM) are presented in Table 4.13. Seven variables were found to significantly impact driver's injury in this model. These variables and their p-values are as follows: Light condition (0.00), Front-to-rear including rear-ends collisions (0.007), Front-to-front including head-on collisions (0.04), Front-to-side right angle collisions (0.01), Seat belt usage left- back occupant (0.008), Seat belt usage middle- back occupant (0.03) and Seat belt usage right- back seat occupant (0.06).

The Front-to-rear including rear-end collision variable is significant with a coefficient value of -1.6. The negative estimate value implies crashes with three back seat occupants that were not Front-to-rear including rear end collisions are associated with less injury severities. The odds ratio for this variable is 4.95. Hence the odds of higher level of injury severities for driver involved in a non- front-to- rear including rear-end collisions are 4.95 times less than if the collisions is front-to- rear including rear-end.

The front-to-front including head-on collision variable has a negative coefficient value -1.3. Thus crashes which are not front-to-front including head-on are associated with less injury severities. The odds ratio is 3.67. This indicates that the odds of higher injury severity levels for a driver involved in a non-front-to-front including head-on collision are 3.67 times less than if the crash is a front-to-front including head-on collision.

For front-to-front right-angle collision variable, the coefficient is -1.6 for this variable and indicates that non-front-to-front right angle crashes are associated with less injury severities. The odds ratio is 4.95. This shows that the odds of sustaining higher injury severity levels by a driver are 4.95 times less if the crash is not a front-to front right angle collision than if it is a front-to front right angle collision.

Light condition with a coefficient value of 1.3 indicates that crashes that occurred in dark conditions are associated with more severe injuries. The odds ratio for this variable is 0.27. This indicates that the odds of higher injury severity levels for a driver are 0.27 times more in dark conditions than in daylight or dark but lighted conditions.

Belt usage was categorized into 2 levels, with category 1 (occupant used seat belt) as the reference category. Seat belt usage by each back seat occupant was found to have a significant impact on the injury severity of the driver. Thus, confirming that the back seat occupant’s seat belt usage does have an impact on the injury severity of the driver. The coefficient values for the belt use of the left-back, middle- back seat occupant, and right- back seat occupant are 1.6, 1.44, and 1.1 respectively. These three variables each have a positive coefficient. Therefore non-seat belt usage by the left back seat occupant, the middle back seat occupant, or the right back seat occupant is associated with more severe injuries. The odds ratio for belt usage left- back occupant is 0.20. Therefore the odds of higher injury severity levels for a driver are only 0.20 times more if the left-back seat occupant is not belted than if the occupant is belted. Odds ratio for belt use middle back occupant is 0.24 and the odds ratio for the belt use right-back seat is 0.33. This indicates that the odds of higher injury severity levels for a driver are 0.24 times more if the middle- back seat occupant is not belted than if he or she is belted. Similarly the odds for higher injury level for the driver are 0.33 times more if the right-back seat occupant is not belted than if he or she is belted.

4.2.7 Interpretation of Belted Right Front Occupant Injury Severity Models

This section presents the interpretation of the results obtained from models that were developed to determine the variables that impact the injury severity of a right-front seat occupant. Table 4.16 indicates the coefficients for the five models to determine those variables that impact the injury severity of a belted right-front occupant under different scenarios. The odds ratios for the significant variables are shown on Table 14.17.

Injury severity right-front occupant with no back occupants (Model 15)

Similar to Model 14, the objective of this model is to determine those variables that impact the injury severity of a belted right-front seat occupant in crashes where the vehicles had no back seat occupants as shown on Table 4.16.

Table 4.16 Injury Severity Models for Belted Right Front-seat Occupant

Parameter	**Model 10 (L)**		**Model 11 (R)**		**Model 12 (LR)**		**Model 13 (LMR)**		**Model 15 (No)**	
	Estimate	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**
Atmosph Cdn =0	1.06	0.01	1.2	0.02	-0.2	0.60	1.3	0.03	0.0700	0.80
Light Cdn = 0	0.9	0.20	0.0650	0.90	1.08	0.001	0.4	0.20	-0.1	0.60
No coll with Veh = 0	2.04	0.10	0.18	0.90	2.2	0.00	-20.1	0.00	0.0570	0.80
FRR= 0	0.98	0.50	-0.3	0.80	1.3	0.01	21.4	0.00	-0.6	0.07
FFH = 0	-0.0430	0.97	-1.6	0.20	-0.3	0.50	-21.9	0.00	-0.8	0.01
FSRA = 0	-4.97	0.00	-3.4	0.002	0.3	0.50	-21.4	0.00	-0.6	0.05
R(C/RD/ST) =0	-1.5	0.10	-1.6	0.06	-1.3	0.03	1.3	0.07	-0.5	0.20
RA = 0									-0.4	0.10
UPA = 0	-1.6	0.09	-1.4	0.03	0.8	0.05	0.6	0.10	0.4	0.10
UMIA = 0	0.5	0.60	0.97	0.19	0.7	0.16	0.4	0.60	0.4	0.09
SL = 0	-4.8	0.00	-1.8	0.001	-0.0390	0.90	-2	0.00	-0.1	0.50
AGEDR = 1	0.4	0.70	3.5	0.00	17	0.00	-3.5	0.20	-0.5	0.60
AGEDR = 2	-1.3	0.50	-0.8	0.40	16.4	0.00	-1.3	0.10	-0.5	0.60
AGEDR = 3	-0.2	0.90	-0.2	0.80	16.3	0.00	-1.9	0.40	-0.5	0.60
AGEDR = 4	3.3	0.06	2.2	0.07	17.3	0.00	-3.8	0.10	-0.4	0.70
GNDR = 0	-0.2	0.80	0.301	0.70	-17.1	0.00	1.9	0.30	0.8	0.90
Belt use(LB) = 0	-0.4	0.70			1.03	0.60	1.4	0.02		
Belt use(MB) = 0							1.3	0.03		
Belt use(RB) = 0			-0.2	0.80	1.8	0.009	1.04	0.10		

Table 4.17 Odd Ratios for Injury Severity Models for Belted Right Front-seat Occupant

Parameter	**Model 10 (L)**		**Model 11 (R)**		**Model 12 (LR)**		**Model 13 (LMR)**		**Model 15 (No)**	
	Estimate	**Odds Ratio**	**Estimate**	**Odds Ratio**	**Estimate**	**Odds Ratio**	**Estimate**	**Odds Ratio**	**Estimate**	**Odds Ratio**
Atmosph Cdn =0	1.06	0.35	1.2	0.30			1.3	0.27		
Light Cdn = 0					1.08	0.34				
No coll with Veh = 0	2.04	0.13			2.2	0.11	-20.1	$5.3*10^{7}$		
FRR= 0					1.3	0.27	21.4	5.08	-0.6	1.82
FFH = 0							-21.9	$3.2*10^{7}$	-0.8	2.23
FSRA = 0	-4.97	144.2	-3.4	29.96			-21.4	$1.9*10^{7}$	-0.6	1.82
R(C/RD/ST) =0	-1.5	4.48	-1.6	4.95	-1.3	3.67	1.3	0.27		
RA = 0									-0.4	1.49
UPA = 0	-1.6	5.0	-1.4	4.06	0.8	0.45	0.6	0.55	0.4	0.67
UMIA = 0									0.4	0.67
SL = 0	-4.8	121.5	-1.8	6.05			-2	7.39		
AGEDR = 1			3.5	0.03	17	$3*10^{-7}$				
AGEDR = 2					16.4	$3*10^{-7}$	-1.3	3.67		
AGEDR = 3					16.3	$3*10^{-7}$				
AGEDR = 4	3.3	0.037	2.2	0.03	17.3	$3*10^{-7}$	-3.8	44.7		
GNDR = 0					-17.1	$26*10^{6}$				
Belt use(LB) = 0							1.4	0.25		
Belt use(MB) = 0							1.3	0.27		
Belt use(RB) = 0					1.8	0.17	1.04	0.35		

Variables that were found to significantly impact the right-front seat occupant's injury severity in this model were front-to rear including rear-end collisions with a p-value of 0.07 and a coefficient value -0.6, front-to-front head-on collisions with a p-value of 0.01 and coefficient value of -0.8, front-to-front right-angle collisions with a p-value of 0.05 and coefficient value of -0.6, rural arterial with a p-value of 0.10 and a coefficient value of -0.4, urban principal arterial with a p-value of 0.10 and coefficient value of 0.4, and urban minor arterial with a p-value of 0.09 and coefficient value of 0.4.

The variables with negative coefficient values indicate that they are associated with lower injury severity levels for the right-front seat occupant, and those with positive values are associated with higher injury severity levels for the right-front seat occupants. The odds ratio for front-to- rear including rear-end collisions is 1.82. This indicates that the odds of a belted right-front seat occupant sustaining more severe injuries are 1.82 times less if the collision is not a front-to-rear collision including rear-end collisions, than if the collision is a front-to-rear collision including rear-end collisions.

The odds ratio for front-to-front collision including head-on collisions is 2.23. Therefore the odds of a right-front seat occupant sustaining more severe injuries is 2.23 times less if the crash is not a front-to-front collision including head-on collision than if it is a front-to-front collision including head-on collision.

The odds ratio for front-to-front right angle collision is 1.8. Thus the odds of the right - front seat occupant sustaining higher injury severity levels are 1.8 times less if the crash is not a front-to-front right-angle collision than if the crash is a front-to-front right-angle collision.

The rural arterial variable has a coefficient value of -0.4. The odds ratio for rural arterial is 1.5. Therefore the odds of a right-front seat occupant being more severely injured in a crash that occurred on a non-rural arterial is 1.5 times less than if the crash occurred on a rural arterial.

For the urban principal arterial variable the coefficient value is 0.4. The odds ratio for this variable is 0.67. This indicates that the odds of sustaining higher injury levels for a right-front seat occupant is 0.67 times more in a crash on a non-urban principal arterial than on an urban principal arterial. Similarly the coefficient value for the urban minor arterial variable is 0.4, with odds ratio 0.67. Indicating that the odds of sustaining higher injury severities by a right-front seat occupant in a crash on a non- urban minor arterial is 0.67 more than on an urban minor arterial roadway.

Injury severity of right-front seat occupant with left -back occupant (Model 10)

In this model the injury severity of the right-front seat occupant is considered in which there was a left back seat occupant in the vehicle during the crash. The objective is to determine if a left back seat occupant's seat belt usage during a crash would have an impact on the injury severity of the right-front seat occupant. Results for this model are shown on Table 4.15 for model 10(L). Seven variables were found to have a significant impact on the injury severity of the right-front seat occupant. These variables include atmospheric condition with a p-value 0.01 and coefficient 1.06, single vehicle crashes with a p-value 0.10 and estimate coefficient 0.10, front-to-front-right angle collisions with a p-value 0.00 and estimate value -4.97, rural (collector/Road/Street) with a p- value 0.10 and coefficient -1.5, urban principal arterial with a p-value 0.09 and -1.6, posted speed limit with a p-value 0.00, and driver's age level 4 with a p-value 0.06 and coefficient 3.3. Variable with positive coefficient values indicate that they are associated with higher injury severity levels and variables with negative coefficients are associated with lower injury severity levels.

The odds ratio for atmospheric condition is 0.35. This implies the odds of a right-front seat occupant sustaining higher injury severity levels are 0.35 times more in adverse atmospheric conditions than in non-adverse atmospheric conditions. The odds ratio for single vehicle crashes is 0.13.This indicates that the odds of a right-front seat occupant sustaining more severe injuries are 0.13 times more in a multiple-vehicle crash than in single-vehicle crash. The odds ratio for driver's age is 0.04. Therefore the odds of driver between the ages of 49 and 65 of being more severely injured in a crash are 0.04 times more than if the driver was 65 or older.

The odds ratio for front-to-side right angle collision is 144.02. This indicates that the odds of a right-front occupant being more severely injured in a crash are 144.02 times less if the crash were a non-front-to-side right angle collision than if it was a front-to-side right angle collision. The odds ratio for rural roadway (collector, road, or street) is 4.48. Thus the odds of sustaining more severe injuries by a right-front seat occupant are 4.48 times less if the crash occurred on a non-rural roadway (collector, or roadway, or street) than if the crash occurred on a rural (collector, or road, r street). For urban principal arterial the odds ratio is 5. Indicating that the odds of a right-front seat occupant sustaining more severe injuries are 5 times less if the crash is on a non-urban principal arterial roadway than on an urban principal arterial roadway. Posted speed limit has an odds ratio of 121.5**.** This implies the odds of higher injury levels for a belted front seat occupant is 121.5 times less if posted speed is 50 mph or more than if posted speed limit is less than 50 mph.

Injury severity of right-front seat occupant with right -back occupant (Model 11)

In this scenario crashes which involved vehicles having a right back seat occupant seated directly behind front seat occupants were considered. The objective of this model is to determine the impact of the right back seat occupant's seat belt usage on the right-front seat occupant's injury severity. The variables that significantly impact the injury severity of the right-front seat occupant in this model are atmospheric condition with a p-value 0.02, Front-to-side right angle collision with a p-value 0.002, rural roadway(collector, or road, or street) with a p-value 0.06, urban principal arterial roadway with a p-value 0.03, posted speed limit with a p-value 0.001, driver's age level 1(<21 years) with a p-value 0.00, and driver's age level 4 (49-65) with a p-value 0.07.

The atmospheric condition variable has a positive coefficient value 1.2 indicating that adverse atmospheric conditions are associated with higher injury severity levels. The odds ratio for atmospheric condition is 0.30. Therefore the odds of a right-front seat occupant being more severely injured in a crash are 0.30 times more in adverse atmospheric conditions than in good atmospheric conditions.

Driver's age (1) has coefficient value 3.5. Therefore drivers less than 21 years are associated with higher injury severity levels compared to those drivers that are 65 or older. The odds ratio for this variable is 0.03.This shows that the odds of a right-front seat occupant sustaining higher injury severity levels is 0.03 times more if the driver is less than 21 than if the driver is 65 or older. Driver's age (4) has a coefficient value 2.2. The odds ratio for this variable is also 0.03. This also implies that the odds of a right-front seat occupant sustaining higher injury severity levels is 0.03 times more if the driver is between 49 and 65 than if 65 or older.

The front-to-side right-angle collision variable coefficient value is -3.4. This variable is therefore associated with less injury severity levels. The odds ratio is 29.96. Therefore the odds of a right-front seat occupant sustaining more severe injury severities are 29.96 times less if the collision type is not front-to-side right-angle than if it is a front-to-side right-angle collision.

Rural roadway (collector, road, or street) has a coefficient value -1.6. This variable is therefore associated with less severe injuries. The odds ratio is 4.95. The odds of a right-front-seat occupant being more severely injured are 4.95 times less if the roadway is not a rural roadway (collector, road, or street) than if it is a rural roadway (collector, road, or street).

The coefficient value for urban principal arterial variable is -1.4, indicating that this variable is associated with less severe injuries. The odds ratio for this variable is 4.06. Therefore the odds of the right-front seat occupant having more severe injuries are 4.06 times less if the crash occurred on a non-urban principal arterial than on an urban principal arterial. Finally posted speed limit has a coefficient value of -1.8. This shows that it is associated with less severe injuries. The odds ratio is 6.05. Hence the odds of the right-front seat occupant having more severe injuries are 6.05 times less if the posted speed limit is 50 mph or more than if the posted speed limit is less than 50 mph.

Injury severity of right-front seat occupant two back occupants (Model 12)

In this model only crashes in which all vehicles involved had both left back seat and right back seat occupants were considered. The objective of this model is the same as the previous models. However the aim is to determine if belt usage by back seat occupants in vehicles with more than one back seat occupant would have a greater impact on the right-front seat occupant's injury severity than if one back seat occupant is present. Eight variables were observed to significantly impact the injury severity of the right-front seat occupant. They are light condition with a p-value of 0.01, and a coefficient of 1.08, single vehicle crash with a p-value of 0.00 and a coefficient of 2.2, front-to-rear including rear-end collision with a p-value of 0.01 and a coefficient of 1.3, rural roadway (collector, road, or street) with a p-value of 0.03 and -1.3 coefficient value, urban principal arterial with a p-value of 0.05 and a coefficient of 0.8, driver's gender with p-value of 0.00 and a coefficient of -17.1, belt usage right-back occupant with a p-value of 0.009 and a coefficient of 1.8, and driver's age for level 1(<21) , level 2 (>20<30), Level 3 (>29<50), and level 4 (>49<65) with a p-value 0.00 and different coefficient values as shown on Table 4.16 .

Rural roadway (collector, road, or street) variable and driver's gender variables have negative coefficient values. They are therefore associated with lower injury severities for the right-front seat occupant. The other six variables (Light Condition, Single vehicle collision, front-to-front-rear end collision, urban principal arterial, driver's age for the 4 different levels, and Right-back occupant seat belt usage) have positive coefficients and so are associated with higher injury levels for the right-front seat occupants.

The odds ratio for rural roadway (collector, road, or street) is 3.67. Therefore the odds of a right-front seat occupant sustaining more severe injuries are 3.67 times less if the crash occurs on a non-rural roadway (collector, road, or street) than on rural roadway (collector, road, or street) roadway. The odds ratio for driver's gender is more than 26. Therefore the odds of a right-front seat occupant sustaining more severe injuries are more than 26 times less if the driver is female than if the driver is male.

The odds ratio for light condition is 0.34. These indicate that the odds of a right – front seat occupant sustaining more severe injuries are 0.34 times more if the crash occurred in dark conditions than if it occurred in daylight or dark but lighted conditions. The odds ratio for single-vehicle crash is 0.11. Thus the odds of a right-front seat occupant sustaining more severe injuries are 0.11 times more if it is a multi-vehicle crash than if it is a single-vehicle crash. The odds ratio for front-to-rear including rear-end collision is 0.27. This result shows that the odds of a right –front seat occupant sustaining more severe injuries are 0.27 times more if the collision is not a front-to-rear including rear-ends than if it is a front-to-rear including rear-end. Urban principal arterial has an odds ratio of 0.45. The odds of a right-front seat occupant sustaining more severe injuries are 0.45 times more if the crash occurs on a non-urban principal arterial than if it occurs on an urban principal arterial. The odds ratio for driver's age is 0. Therefore the odds of a right-front seat occupant sustaining more severe injuries are the same with any age.

Seat belt usage by right-back seat occupant has an odds ratio of 0.17. Thus the odds of a right-front seat occupant sustaining more severe injuries are 0.17 times more if the right-back seat occupant is not belted than if he or she is belted. This indicates that seat belt usage of a right-back seat occupant impacts the injury severity of a right-front seat occupant.

Injury severity of right-front seat occupant with three back occupants (Model 13)

The objective of this model is to determine the impact of seat belt usage of left-back seat occupant, middle-back seat occupant, and right-back seat occupant back seat occupant on the injury severity of a belted right-front seat occupant. The scenario considered in this case is that of crashes that involved vehicles that had three occupants in the seat directly behind the front seat occupants. Twelve variables were found to significantly impact right-front seat's injury severity in this model. These variables and their p-values are as follows: Atmospheric condition with a p-value of 0.03, single-vehicle crash with a p-value 0.00, front-to-rear including rear-ends collisions with a p-value of 0.00, front-to-front including head-on collisions with a p-value of 0.0, front-to-side right angle collisions with a p-value of 0.0, rural roadway(collector, road, or street) with a p-value of 0.07, urban principal arterial with a p-value of 0.10, speed limit with a p-value of 0.0, driver's age level 2 (>20<30) with a p-value of 0.10, driver's age level 4 (>49<65) with a p-value of 0.10, belt usage left- back occupant with a p-value of 0.02, belt usage middle-back occupant with a p-value of 0.03, and belt usage right- back seat occupant with a p-value of 0.10.

Five of these variables (single-vehicle crash, front-to front head –on collision, front-to-side right angle collision, speed limit, and driver's age), have negative coefficient values. They are therefore associated with lower injury severity levels. Seven significant variables (atmospheric conditions, front-to front including rear-end collision, rural roadway (collector, road, or street), urban principal arterial, belt usage left-back occupant. belt usage middle-back occupant, and belt usage right-back occupant) have positive coefficients. Thus are associated with higher injury severity levels.

The odds ratio for single vehicle crash is more than 53. This result shows that the odds of a right-front seat occupant sustaining more severe injuries are more than 53 times less in a multiple-vehicle crash than in single-vehicle crash. Front-to front head-on collision has an odds ratio of more than 32. Therefore the odds of a right-front seat occupant sustaining more severe injuries are more than 32 times less in a non-front-to-front including head-on collision than in a front-to-front including head-on collision. The odds ratio for front-to-side right-angles collision is more than19. Thus the odds of odds of a right-front seat occupant sustaining more severe injuries are more than 19 times less in a non-front-to- side right-angle collision than a front-to side right-angle collision. Posted speed limit has an odd ratio of 7.39. This result indicates that the odds of a right-front seat occupant sustaining more severe injuries are 7.39 times less when the posted speed limit is 50 mph or more than when the posted speed limit is less than 50 mph. The odds ratio for driver’s age is 3.67. Therefore the odds of a right-front seat occupant sustaining more severe injuries are 3.67 times less if the driver’s age is less than 65 than if the age is 65 or more.

The odds ratio for atmospheric conditions is 0.27. The odds of a right-front seat occupant sustaining more severe injuries are therefore 0.27 times more in adverse atmospheric condition than in non-adverse atmospheric conditions. The odds ratio for front-to front including rear-ends collision is 5.08. Therefore the odds of a right-front seat occupant sustaining more severe injuries are 5.08 times more with non-front-to front including rear-end collision than with front-to front including rear-end collision. This result is contrary to that obtained in other models. The rural roadway (collector, road, or street) variable odds ratio is 0.27. This shows that the odds of a right-front seat occupant sustaining more severe injuries are 0.27 times more on non- rural roadway (collector, road, or street) than on rural roadway (collector, road, or street). The odds ratio for urban principal arterial is 0.55, indicating that the odds of a right-front seat occupant sustaining more severe injuries are 0.55 times more on a non- urban principal arterial than on an urban principal arterial.

The left-back occupant belt usage variable has an odd ratio of 0.25. Therefore the odds of a right-front seat occupant sustaining more severe injuries are 0.25 times more if the left-back seat occupant is not belted than if he or she is belted. For the middle-back seat occupant seat belt usage variable, the odds ratio is 0.27. Hence the odds of a right-front seat occupant sustaining more severe injuries are 0.27 times more if the middle-back seat occupant is not belted than if he or she is belted. Seat belt usage by right-back occupant variable has an odds ratio of 0.35. This result indicates that the odds of a right-front seat occupant sustaining more severe injuries are 0.35 times more if the right-back seat occupant is not belted than if he or she is belted.

4.3 Model Validation

According to Harrell (2001) validation of a model is done to ascertain whether predicted values of the model are likely to accurately predict responses on future subjects or subjects not used to developed the model. That is model validation means establishing that a model works satisfactorily for cases other than those from whose data the model was derived.

Two main modes of validation exist: External and Internal validation.

External validation evaluates a model on new data collected from a different population from the original data that was used to develop the model. Internal validation evaluates a model on the same data, by splitting the data into parts. One part is used to develop the model, and the other part to validate the developed model.

The external mode of validation was used in this research to validate the Seat Belt Usage and Injury Severity models. These validations were done to prove certain statistical notions of correction, by making sure that the developed models passed the appropriate statistical checks, like goodness-of-fit, compatibility of variables coefficient estimates, and comparism of significant variables in the original data and the validation data. The models were validated using 3 years (2006-2008) of FARS data from the sate of New York.

4.3.1 Model Validation Seat Belt Usage Models

To validate the seat belt models developed in this research, three years (2006-2008) FARS data from the state of New York was used. Same variables that were used to develop the seat belt models for the original data were also used for the validation data. Table 4.18 shows that all five models developed were significant, with p-values less than 0.05 at 90 percent confidence level. Table 4.19 shows the coefficient estimate and p-values for each significant independent variable used in the seat belt usage models for New York State. Using a 90 percent confidence interval, independent variables were identified as significant.

Table 4.18 Model–Fitting Information for Seat Belt Models (New York State)

Parameter	**Models**				
	1	**2**	**3**	**4**	**5**
Chi-Square	186.05	353.92	39.19	37.09	85.09
Degree of Freedom	12	5	2	6	6
Significance	0.000	0.000	0.000	0.003	0.000

To validate the seat belt usage models developed the following qualitative and quantitative aspects proposed by Altman (73) were examined: if the same variables were still important and if the estimated regression coefficients were compatible in both data results. Table 4.20 is a comparism table indicating variables that were found to be significant in the original data and the validation data.

Table 14.19 Results of Driver and Occupant Seat Belt Usage Models (NY State)

Variable	Model 1 (Driver)		Model 2 (Right-Front)		Model 3 (Left-Back)		Model 4 (Middle-Back)		Model 5 (Right-Back)	
	Coeff.	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**	**Coeff.**	**P-value**
Intercept	-2.39	0.000	-0.934	0.007	1.047	0.02	-1.516	0.20	0.708	0.292
Age	0.37	0.003	0.211	0.003	0.383	0.002	0.991	0.001	0.594	0.000
Gender (1)	-0.60	0.000	0.673	0.001					0.741	0.009
Speed(1)										
No. Occupants		0.008								
No. of Occupants (1)	-0.38	0.800					1.653	0.07	1.214	0.05
No. of occupants (2)	-0.25	0.050								
Driver's Belt Use			-3.048	0.000	-2.237	0.000	-1.550	0.009	-2.091	0.000
Urban Principal Arterial (1)	-2.51	0.04								
Urban Minor Arterial	-0.26	0.06								
Rural Arterial	-0.26	0.02	0.780	0.001						
Light Condition(1)			0.482	0.013			-1.102	0.010		
Surface Condition(1)							-0.882	0.04		
Crash Time		0.002								0.004
Crash Time (1)	-0.114	0.44							-1.092	0.001
Crash Time (2)	0.285	0.09							-0.228	0.645
Atmospheric Cdn(1)							1.100	0.09		
Lanes(1)	-0.33	0.004								
Surface Type(1)	0.428	0.11								

Table 4.20 P-value Comparism of Seat Belt Usage Models

Variable	**Model 1 (Driver)**		**Model 2 (Right-Front)**		**Model 3 (Left-Back)**		**Model 4 (Middle-Back)**		**Model 5 (Right-Back)**	
	NJ	**NY**	**NJ**	**NY**	**NJ.**	**NY**	**NJ.**	**NY**	**NJ**	**NY**
Intercept	0.00	0.00	0.00	0.007	0.001	0.02	0.95	0.20	0.911	0.292
Age	0.00	0.003		0.003		0.002		0.001	0.033	0.00
Gender (1)	0.00	0.000	0.023	0.001	0.007		0.080		0.741	0.009
Speed(1)					0.014					
No. Occupants	0.04	0.008								
No. of Occupants (1)	0.118	0.800					0.087	0.07	0.121	0.05
No. of occupants (2)	0.012	0.050								
Driver's Belt Use			0.00	0.00	0.00	0.00	0.088	0.009	0.055	0.00
Urban Principal Arterial (1)	0.00	0.04			0.023					
Urban Minor Arterial	0.045	0.06								
Rural Arterial	0.025	0.02		0.001						
Rural(Collector, Road, Street			0.00							
Light Condition(1)				0.013	0.092			0.010		
Surface Condition(1)					0.014			0.04		
Crash Time	0.00	0.002								0.004
Crash Time (1)	0.641	0.44								0.001
Crash Time (2)	0.037	0.09								0.645
Atmospheric Cdn(1)								0.09		
Lanes(1)		0.004								
Surface Type(1)		0.11								
Holiday(1)					0.085					
Crash Season	0.009		0.082							
Crash Season(1)	0.031		0.024							
Crash Season(2)	0.132		0.125							
Crash Season(3)	0.432		0.868				0.105			

The results on Table 4.20 show that overall variables that were significant in the original data were also significant in the validation data. However, except for model 3, there were slyly more significant variables in models from the State of New York than the State of New Jersey. Differences in the number of significant variables are expected due to the fact that differences exist in the distribution of the variables in the original (New Jersey) data and validation (New York) data. This is confirmed by Alman [73].

Compatibility of the regression coefficients was done for the two data using the results shown on Table 4.21. Table 4.21 shows that regression coefficients value for significant variables in both data were compatible. For example the coefficient estimates for Driver Seat Belt Usage variable for models 2 to 5 were all negative in both data.

Table 4.21 Compatibility of Coefficients Estimates for Seat belt Usage Models

Variable	**Model 1 (Driver)**		**Model 2 (Right-Front)**		**Model 3 (Left-Back)**		**Model 4 (Middle-Back)**		**Model 5 (Right-Back)**	
	NY	**NJ**	**NY**	**NJ**	**NY**	**NJ**	**NY**	**NJ**	**NY**	**NJ**
Intercept	2.39	1.67	-0.934	2.98	1.047	2.41	-1.516	-3.20	0.708	0.09
Age	0.37	0,15	0.211		0.383		0.991		0.594	0.24
Gender (1)	-0.60	-0.62	-0.673	-0.50		0.81		0.94	0.741	0.009
Speed(1)						-0.91				
No. of Occupants (1)	-0.38	-0.26					1.653	2.14	1.214	0.121
No. of occupants (2)	-0.25	-0.36								
Driver’s Belt Use			-3.048	-3.60	-2.237	-1.81	-1.550	-1.46	-2.091	-2.90
Urban Principal Arterial (1)	2.51	0.51								
Urban Minor Arterial	-0.26	-0.29								
Rural Arterial	-0.26	-0.38	0.780							
Rural(Collector, Road, Street				-1.30						
Light Condition(1)			0.482				-1.102			
Surface Condition(1)							-0.882			
Crash Time (1)	-0.114	-0.08							-1.092	
Crash Time (2)	0.285	0.39							-0.228	
Atmospheric Cdn(1)							1.100			
Lanes(1)	-0.33									
Surface Type(1)	0.428									
Holiday(1)						-0.92		1.85		
Crash Season		-0.29		-073						
Crash Season(1)		-0.20		-0.47						
Crash Season(2)		0.11		0.05						
Crash Season(3)										

4.3.2 Model Validation for Injury Severity Models

The injury severity models were validated in a similar manner as the seat belt usage models. Three years (2006-2008) FARS data for the state of New York was used to validate the injury severity models. Table 4.22 shows the model- fitting information for the validation data. The results show that all 10 models were significant with p-values less than 0.05.

Table 4.22 Model-fitting Information for Injury Severity Models (New York State)

	Model	Parameters				
		Loglikelihood	**Restricted Loglikelihood**	**Chi-Square**	**Degree of Freedom**	**Significance**
Belted Driver Models	**6(L)**	407.80	357.48	50.32	20	0.00
	7(R)	602.17	571.66	30.47	21	0.08
	8(LR)	836.15	706.14	130.01	21	0.00
	9(LRM)	440.26	191.04	249.22	20	0.00
	14(No)	1454.30	1387.48	66.82	17	0.00
Belted Front-Seat Occupant Models	**10(L)**	410.95	369.47	41.49	20	0.003
	11(R)	605.91	561.81	44.10	21	0.002
	12(LR)	829.87	690.54	139.33	19	0.00
	13(LRM)	437.47	203.30	234.17	20	0.00
	15(No)	1377.61	1300.52	77.09	19	0.00

Tables 4.23 and 4.24 show the p-values and coefficient estimates of the variables when the data was analyzed for the New York driver injury severity models and right-front seat occupant injury severity models. To validate the developed injury severity models, significant variables and their coefficient estimates obtained from the original(New Jersey) and the validation(New York) data for the driver models were examined.

Table 4.23 Result Injury Severity Models for Belted Driver (New York State)

Parameter	**Model 14 (No)**		**Model 7 (R)**		**Model 8 (LR)**		**Model 9 (LRM)**		**Model 6 (L)**	
	Estimate	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**
Atmosph Cdn =0	0.136	0.54	0.164	0.62	**-1.019**	**0.002**	1.646	0.65	**2.178**	**0.00**
Light Cdn = 0	0.230	0.32	**0.822**	**0.02**	**-1.071**	**0.02**	**-17.705**	**0.00**	-0.632	0.25
No coll with Veh = 0	5.602	0.98	-0.128	0.75	**3.004**	**0.00**	**-5.274**	**0.12**	-0.322	0.57
FRR= 0	-0.531	0.19	**-0.862**	**0.070**	**2.747**	**0.02**	-0.490	0.87	-0.735	0.31
FFH = 0	**-0.383**	**0.18**	**-1.550**	**0.001**	**-1.786**	**0.02**	**4.801**	**0.11**	**-1.085**	**0.13**
FSRA = 0	1.226	0.96	**-1.322**	**0.008**	**3.394**	**0.00**	**12.832**	**0.00**	0.307	0.64
R(C/RD/ST) =0	-0.130	0.678	**1.135**	**0.11**	**-2.096**	**0.661**	-2.020	0.16	0.103	0.88
UPA = 0	3.799	0.89	-0.510	0.41	0.435	0.66	0.655	0.61	**-1.869**	**0.005**
UMIA = 0	8.904	0.78	**1.576**	**0.102**	**-2.621**	**0.02**	**-7.632**	**0.001**	0.869	0.37
RDP = 0	0.177	0.32	-0.204	0.55	-0.273	0.37	**-1.622**	**0.07**	0.364	0.38
SL = 0	-0.793	0.00	-0.199	0.57	**-1.158**	**0.002**	**-14.973**	**0.00**	0.413	0.31
AGEDR = 1	-0.299	0.24	-0.168	0.86	**-1.773**	**0004**	**10.649**	**0.00**	0.892	0.54
AGEDR = 2	**-0.646**	**0.013**	-0.476	0.65	0.764	0.30	**-6.133**	**0.007**	-0.293	0.85
AGEDR = 3	**-1.065**	**0.00**	-0.368	0.25	0.252	0.68	1.275	0.43	-0.271	0.85
AGEDR = 4	**-1.063**	**0.00**	-4.16	0.97	1.088	0.23	**-10.810**	**0.02**	8.8	0.99
GNDR = 0	1.1	0.20	0.300	0.74	0.775	0.004	**2.919**	**0.003**	0.147	0.92
Belt use(LB) = 0	0.217	0.23			**1.882**	**0.00**	**3.813**	**0.00**	0.425	0.48
Belt use(MB) = 0							**10.408**	**0.00**		
Belt use(RB) = 0			0.152	0.72	**-1.808**	**0.00**	**5.746**	**0.00**		

Table 4.24 Injury Severity Models for Belted Right Front-seat Occupant (New York State)

Parameter	**Model 10 (L)**		**Model 11 (R)**		**Model 12 (LR)**		**Model 13 (LMR)**		**Model 15 (No)**	
	Estimate	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**	**Estimate**	**P-Value**
Atmosph Cdn =0	0.553	0.24	**0.518**	**0.12**	**0.622**	**0.06**	**5.928**	**0.001**	-0.328	0.32
Light Cdn = 0	-0.578	0.20	-3.03	0.93	**-1.243**	**0.004**	**-9.811**	**0.00**	-8.70	0.72
No coll with Veh = 0	**-0.999**	**0.08**	**-1.165**	**0.005**	**1.211**	**0.002**	**-5.472**	**0.00**	0.231	0.38
FRR= 0	-0.701	0.34	**-1.268**	**0.009**	**1.905**	**0.02**	**3.877**	**0.006**	**0.760**	**0.08**
FFH = 0	**-1.256**	**0.07**	**-1.990**	**0.00**	**0.962**	**0.05**	1.557	0.31	-0.104	0.72
FSRA = 0	2.021	0.98	**-1.412**	**0.005**	0.630	0.20	**4.912**	**0.00**	9.332	0.73
R(C/RD/ST) =0	-0.445	0.49	**-1.494**	**0.03**	0.626	0.24	0.558	0.65	-9.96	0.76
Road Profile= 0	-5.81	0.89	**0.836**	**0.02**	**1.382**	**0.00**	**1.531**	**0.03**	**0.399**	**0.03**
UPA = 0	**1.183**	**0.07**	-0.698	0.26	**1.032**	**0.04**	-0.314	0.79	**0.674**	**0.03**
UMIA = 0	-1.101	0.23	**-2.611**	**0.006**	0.226	0.75	**-29.936**	**0.004**	**0.625**	**0.06**
SL = 0	-0.275	0.50	**-0.756**	**0.03**	**-1.875**	**0.00**	**-2.142**	**0.07**	**-0.512**	**0.01**
AGEDR = 1	0.876	0.44	**-1.572**	**0.07**	0.657	0.20	-2.058	0.37	**-1.103**	**0.00**
AGEDR = 2	-17.552	0.87	**-1.921**	**0.05**	0.248	0.66	**-8.972**	**0.001**	**-1,064**	**0.00**
AGEDR = 3	0.635	0.604	**-2.311**	**0.02**	-0.330	0.52	-1.816	0.29	**-1.358**	**0.00**
AGEDR = 4	1.649	0.242	-1.110	0.29	**1.929**	**0.004**	**-10.820**	**0.001**	**-1.365**	**0.00**
GNDR = 0	-0.453	0.70	**1.534**	**0.07**	**-1.133**	**0.00**	**0.920**	**0.07**	0.108	0.55
Belt use(LB) = 0	0.270	0.64			0.372	0.32	**1.810**	**0.03**		
Belt use(MB) = 0							**3.673**	**0.001**		
Belt use(RB) = 0			**0.763**	**0.08**	-0.497	0.19	**3.373**	**0.02**		

Table 4.25 is a comparism table indicating variables that were found to be significant in the original (New Jersey) driver injury severity data and the driver injury severity validation (New York) data. Overall, significant variables found in the original model were also significant in the validation models, except for model 8 and 9 where there were much more significant variables in the validation model than in the original model. Differences in the number of significant variables in models from both data could be due to the differences in variable distribution in the two data sets.

In Table 4.26 coefficient estimates for variables which were significant in both the original data and the validation data are compatible. For variables which were not significant in both sets of data the coefficient variables vary. Some are compatible and others are not.

Table 4.25 P-value Comparism of Driver Injury Severity Models

Parameter	**Model 14 (No)**		**Model 7 (R)**		**Model 8 (LR)**		**Model 9 (LRM)**		**Model 6 (L)**	
	NJ	**NY**	**NJ**	**NY**	**NJ**	**NY**	**NJ**	**NY**	**NJ**	**NY**
Atmosph Cdn =0	0.6	0.54	0.50	0.62	0.90	0.002	0.90	0.65	**0.00**	**0.00**
Light Cdn = 0	0.04	0.32	0.40	0.02	**0.01**	**0.02**	**0.00**	**0.00**	0.40	0.25
No coll with Veh = 0	0.30	0.98	0.40	0.75	**0.08**	**0.00**	0.20	0.12	0.02	0.57
FRR= 0	**0.12**	**0.19**	0.60	0.070	0.20	**0.02**	0.01	0.87	0.90	0.31
FFH = 0	**0.01**	**0.18**	0.60	0.001	**0.04**	**0.02**	**0.04**	**0.11**	**0.12**	**0.13**
FSRA = 0	0.01	0.96	0.80	0.008	0.70	0.00	**0.01**	**0.00**	0.04	0.64
R(C/RD/ST) =0	0.07	0.678	**0.04**	**0.11**	0.09	0.661	**0.10**	**0.16**	0.20	0.88
UPA = 0	0.20	0.89	0.01	0.41	0.60	0.66	0.20	0.61	**0.01**	**0.005**
UMIA = 0	0.18	0.78	**0.03**	**0.102**	0.95	**0.02**	0.60	0.001	0.50	0.37
RDP = 0	0.50	0.32	0.50	0.55	0.95	0.37	**0.08**	**0.07**	0.93	0.38
SL = 0	**0.05**	**0.00**	0.30	0.57	**0.01**	**0.002**	0.70	0.00	0.90	0.31
AGEDR = 1	0.3	0.24	0.20	0.86	**0.90**	**0004**	0.70	0.00	0.70	0.54
AGEDR = 2	0.20	0.013	0.20	0.65	0.30	0.30	0.06	0.007	0.80	0.85
AGEDR = 3	**0.002**	**0.00**	0.60	0.25	0.20	0.68	0.90	0.43	0.20	0.85
AGEDR = 4	**0.08**	**0.00**	0.40	0.97	0.30	0.23	0.93	0.02	0.80	0.99
GNDR = 0	0.05	0.20	0.80	0.74	**0.60**	**0.004**	0.40	0.003	020	0.92
Belt use(LB) = 0					**0.20**	**0.00**	**0.008**	**0.00**	0.90	0.48
Belt use(MB) = 0							**0.03**	**0.00**		
Belt use(RB) = 0			0.82	0.72	**0.30**	**0.00**	**0.06**	**0.00**		

Table 4.26 Compatibility of Coefficient Estimates for Driver Injury Severity Models

Parameter	**Model 14 (No)**		**Model 7 (R)**		**Model 8 (LR)**		**Model 9 (LRM)**		**Model 6 (L)**	
	NY	**NJ**	**NY**	**NJ**	**NY**	**NJ**	**NY**	**NJ**	**NY**	**NJ**
Atmosph Cdn =0	0.136	0.12	0.164	0.3	-1.019	0.037	1.646	0.65	**2.178**	**2.5**
Light Cdn = 0	0.230	0.4	0.822	0.3	**1.071**	**0.9**	**-17.705**	**1.3**	-0.632	0.6
No coll with Veh = 0	5.602	-0.3	-0.128	0.96	**3.004**	**0.9**	-5.274	-0.7	-0.322	-2.4
FRR= 0	**-0.531**	**-0.5**	-0.862	-0.7	2.747	-0.6	-0.490	-1.6	-0.735	-0.2
FFH = 0	**-0.383**	**-0.8**	-1.550	0.7	**-1.786**	**-1.1**	**4.801**	**-1.3**	**-1.085**	**-1.6**
FSRA = 0	1.226	-0.7	-1.322	-0.3	3.394	-0.2	**12.832**	**-1.6**	0.307	-2.2
R(C/RD/ST) =0	-0.130	-0.7	1.135	1.2	-2.096	-0.98	**-2.020**	**1.08**	0.103	-1.5
UPA = 0	3.799	0.3	-0.510	0.9	0.435	0.2	0.655	0.4	**-1.869**	**-2.2**
UMIA = 0	8.904	0.35	**1.576**	**1.2**	-2.621	0.05	-7.632	-0.4	0.869	-0.5
RDP = 0	0.177	0.12	-0.204	-0.2	-0.273	-0.02	**-1.622**	**-0.8**	0.364	0.065
SL = 0	**-0.793**	**-0.32**	-0.199	0.4	**-1.158**	**-1.2**	-14.973	-0.1	0.413	0.056
AGEDR = 1	-0.299	-0.4	-0.168	0.8	-1.773	0.05	10.649	0.354	0.892	-0.6
AGEDR = 2	-0.646	-0.4	-0.476	-0.9	0.764	0.60	-6.133	1.596	-0.293	-0.3
AGEDR = 3	**-1.065**	**-0.9**	-0.368	-0.25	0.252	-0.6	1.275	-0.045	-0.271	-0.9
AGEDR = 4	**-1.063**	**-0.6**	-4.16	0.5	1.088	-0.90	-10.810	-0.088	8.8	-0.4
GNDR = 0	1.1	0.6	0.300	0.74	0.775	0.3	2.919	-0.6	0.147	1.1
Belt use(LB) = 0					1.882	0.8	**3.813**	**1.6**	0.425	-0.28
Belt use(MB) = 0							**10.408**	**1.44**		
Belt use(RB) = 0			0.152	-0.193	-1.808	0.7	**5.746**	**1.1**		

CHAPTER 5

RESULT SUMMARY AND CONCLUSION

In this chapter, summary results obtained from the seat belt usage and injury severity models will be presented and conclusions drawn from these results are discussed. Furthermore, future work that could be performed as a consequence of results obtained from the dissertation will be presented.

The research had two main objectives: identify factor that significantly influence the seat belt usage of front-seat and back-seat occupants of vehicles in the State of New Jersey; and also identify the factors that impact the injury severity of belted front-seat occupants with and without rear-seat occupants. In particular, this research wanted to determine whether a back-seat occupant’s seat belt usage had an impact on the injury severity of a belted front-seat occupant.

Logistic regression models were developed to determine factors that would influence seat belt usage of front-seat and back-seat occupants, and Ordinal logistic regression models were developed to identify those factors that could impact injury severity of front-seat occupants with or without back-seat occupants.

5.1 Summary Results of Seat Belt and Injury Severity Models

This section summarizes the results obtained from the Seat Belt Usage models and the Injury Severity models. The summary is done for those variables that were found to be significant in the developed models.

5.1.1 Summary Results of Seat Belt Usage Models

The age of the occupant was found to be a significant factor for influencing the seat belt usage of both the driver model and the right-back passenger model. A large proportion of right-back seat occupants are children and are required to be in a booster seat which may be why age influences these occupants' seat belt usage.

Gender was determined to be a significant variable for all of the models, with the exception of the right-back seat occupant model. The models show that in general male occupants in the front-seat tend to be less likely to wear a seat belt compared to female occupants. The results are just the opposite for back seat occupants. The left-back occupant and middle-back occupants were found to be more likely to be belted if they were male compared to female occupants.

The number of occupants was found to be a significant variable for the driver, middle-back, and right-back seat belt usage models. The results showed that a driver traveling alone is less likely to be belted than if he or she was driving with another passenger. The results also indicated that more occupants in the vehicle increase the likelihood that the back-seat occupants are buckled. Although this seems counterintuitive, it is reasonable because most drivers feel their vehicle is more vulnerable to law enforcement officials scrutiny when there are more than one passenger in the vehicle.

Four roadway types were evaluated to determine their impact on the seat belt usage of the occupants. The roadway type was a significant variable for the driver, the right-front and the left-back seat belt usage models. Occupants on urban principal arterials were found to be more likely to be belted than on other roadways. Occupants on urban minor, rural arterial and rural collector were found to be less likely to be belted than on other roadways. This may be due to the fact that most drivers in these areas don't drive long distances and there is less traffic.

Crash time significantly impacts the seat belt usage for drivers. The results show that a driver while driving during the PM peak hours is more likely to be belted compared to driving during off peak hours. The crash season variable is significant both in the driver and in the right-front passenger seat belt usage models. For both the driver and right-front occupant models, it is less likely that the occupant would be belted while driving during the fall season than in the summer season. This may be due to the fact that during peak hours there is more traffic control by law enforcement officials and traffic volume is high. This is also true for the summer season.

The driver's seat belt usage was found to be significant for all the non-driver seat belt usage models. The results show that the right-front and left-back seat occupants have a slightly higher likelihood of wearing a seat belt because the driver is belted. For the middle-back and right-back the likelihood increases significantly. The increase for these occupants may be due to the fact that many middle-back and right back seat occupants tend to be children and are required to wear a restraint.

The posted speed limit was significant in the left-back seat belt usage model. The results show a negligible impact of the posted speed limit on the left-back seat belt usage**.** This could be due to the fact the actual speeds of the vehicles were not recorded. The study showed a negligible impact of the roadway surface condition on seat belt usage.

The impact of holidays on seat belt usage was found to be significant for the left-back seat belt usage and the middle-back seat belt usage models. For the left-back seat occupant, the impact of whether it was a holiday was negligible on the occupant's seat belt usage. For the middle-back seat occupant, the probability that the occupant is belted when riding in a vehicle on a holiday was significantly higher than if it is not a holiday.

The impact of light condition on seat belt usage was found to be significant for the left-back seat belt usage model only. The results showed that for left-back seat occupants, they are more likely to be belted during lighted conditions than when there are dark conditions.

5.1.2 Summary Results Injury Severity Models

The objective of the injury severity models was to determine the factors that influence the injury severity of belted driver and belted front-seat occupant with and without rear-seat occupants. Furthermore, the impact of seat belt usage by rear-seat occupants on the injury severity of front-seat occupants was studied. Ordinal logistic regression models were developed to determine these factors.

The impact of atmospheric condition at the time of crash on the injury severity of belted driver and belted right-front seat occupant was found to be significant for the driver with left-back seat occupant model. This variable was also found to be significant for the right-front seat occupant with left, middle and back seat occupants. For a belted driver with a left-back seat occupant, the impact of whether it was adverse atmospheric condition during the crash was significant on the driver’s injury severity. For the right-front seat occupant the probability that the occupant would sustain more severe injuries in crashes that occurred during adverse atmospheric conditions was significantly higher than in crashes that occurred in no adverse atmospheric conditions.

Light condition significantly impacts injury severity for driver with left-back seat occupant model. Light condition also significantly impacts the injury severity for the right-front seat occupant with left-back seat occupant, right-back seat occupant, and middle-back seat occupant. In all models where light condition is significant, it is more likely that a driver or a right-front seat occupant will sustain more severe injuries when a crash occurs in dark conditions than when it occurs in lighted conditions.

Four collision types were evaluated to determine their impact on the injury severity of driver and right-front seat occupant. The collision type was a significant variable for both the driver and right-front seat occupant models. The probability of a driver sustaining more severe injury severities increases with an increase in the number of occupants in the back seat and this probability is higher in front-to-rear including rear-end collisions and front-to-side right-angle collisions than in front-to front head-on collisions. For the right-front seat occupant the probability for the occupant having more severe injuries considering the different types of collision is the same with increase in the number of occupants in the back seat of the vehicle. The situation is different for a driver who is alone in the vehicle during a crash. The probability of a driver being more severely injured is higher in front-to-front head-on collision and front-side right-angle collision than in front-to-rear including rear-ends collision and single vehicle crashes.

Four roadway types were also evaluated to determine their impact on the injury severity of the driver and the right-front seat occupant. This variable was significant for the driver and right-front seat occupant models except for the driver with left-back seat occupant model and right-front seat occupant with no back-seat occupant model. Drivers and right-front seat occupants on urban principal arterials sustained more severe injuries than those on other roadway types. Drivers and right-front seat occupants on rural roadways, urban minor arterials, and rural principal arterials were found to sustain less severe injuries than those on other roadway types.

The posted speed limit was significant in the driver with left-back seat occupant model and the driver alone model. This variable was also significant for the right-front greater impact of the posted speed limit on the driver or right-front seat occupant injury severity when there is at least one occupant in the back seat than when there is no occupant in the back seat.

Gender was found to be a significant variable for drivers with left-back and right-back seat, and drivers with right-front seat occupant. The model results indicate that in general female drivers are more likely to be more severely injured than male drivers. This could be due to the fact that women are generally physically weaker than men. The driver with only right-front seat occupant model indicates that there is a higher probability for a female right-front seat occupant to sustain more severe injuries than a male right-front seat occupant.

The age of the driver was found to significantly influence the injury severity of the driver in the driver only model, and driver with left-back seat, middle-back seat and right-back seat occupant model. The results of the driver alone model indicate that there is a higher probability for a driver who is between the ages of 29 and 65 to sustain more severe injuries than a driver who is older than 65 years. For the driver with three back-seat occupant model the results indicates that a driver with three occupants in the back seat who is between the age of 20 and 30 has a higher probability of sustaining more severe injuries than a driver with three occupants in the back seat who is 65 years or older. The reason may be because older drivers are less aggressive and most of them drive at lower speeds. Driver's age was also found to be significant in influencing the injury severity of right-front seat occupants. The probability of the right-front seat occupant sustaining more severe injuries is higher in vehicles with younger drivers than in vehicles with older drivers. This is obvious due to the fact that younger drivers are more aggressive and drive at higher speed than older ones.

The seat belt usage by back-seat occupants was found to significantly impact injury severity of driver with three back seat occupants' model, and the right-front seat occupant with three back seat occupants' model. Apart from the right-front seat with left-back and right back seat occupant model, the results indicate that the probability of sustaining more severe injuries by a driver or right-front seat occupant is higher when a left-back seat, or middle-back seat, or right-back seat occupant is unbelted. This result was true for vehicles that had three occupants or a right-back seat occupant in the row directly behind the front-seat occupants.

5.2 Conclusion and Future Work

5.2.1 Conclusion

The research shows there are differences in the factors that influence the seat belt usage of front-seat occupants and back-seat occupants in passenger vehicles. These differences should be accounted for in the development of programs aimed at increasing seat belt usage for all occupants in passenger vehicles. Further research is needed to better understand why some of the differences exist and to include additional factors not traditionally used in seat belt usage models that may influence the seat belt usage for back-seat occupants. This research also indicated that the impact of back seat occupant seat belt usage on the injury severity of front-seat occupant was significant. However the impact was greater with an increase in the number of back seat occupants in the vehicle In particular the impact is highly significance if there are three occupants in the back seat.

The implication of the results obtained in this research is that seat belt laws should be required from every state in the United States. More importantly these laws should be applied to every vehicle occupant regardless of their age and seating position on the vehicle. In particular it would be of great safety benefit to all vehicle occupants in the state of New Jersey if the present rear-seat belt law is upgraded to a primary seat belt law.

Traffic enforcement and seat belt usage campaign programs like Click It or Ticket (CIOT) among others should include signs and advertisement on roadways that are focused not only on front-seat passengers but on rear-seat passengers as well.

5.2.2 Future Work

Several aspects of future work can be addressed from this work. These include data, the general applicability of the developed models, and model development.

Data

Data that was used for this study was restricted to fatal-crash data. This data might not be a good representative of traffic in the country. Non-fatal crash data could also be included in the data used for the development of the models. But most non-fatal crash data do not have enough factors that could be used to determine the seat belt usage of vehicle occupants. Added to this vehicle occupants involved in non-fatal crash might not always say the truth about their seat belt usage when questioned by a police at the scene of the crash for fear that he or she could be given a summon. Observational data could also be used for the model development. To get good observational data cameras could be stationed at observational locations, so that there will be no guessing, or redesigning like how and where to gather or capture data.

General Applicability of Model

The models developed in this research have shown their usefulness in the prediction of the probability of using a seat belt and the probability of sustaining a certain injury severity during a crash by a vehicle occupant. New York state FARS data was used to validate the data. This is because the perception was that drivers in New Jersey and New York have similar characteristics, similar seat belt usage laws, and other factors like weather and time are similar in both states. Can these models be applied to other states in other regions of the country with different characteristics? It would be of great importance if this is done.

Model Development

In order to develop seat belt usage models and injury severity model, more independent variables like the occupants' race, height and weight should be considered in future studies to better reflect the impact of these variables on seat belt usage and injury severity.

REFERENCES

.

1. Abdel-Aty M. Analysis of Driver Injury Severity Levels at Multiple Locations Using Ordered Probit Models. Journal of Safety Research, vol. 34, pp.597-603.

2. Adams, J. G. U. Seat Belt Legislation: The Evidence Revisited. Safety Science, Vol. 18, No. 2, 1994, pp. 135-152.

3. Agresti, A. Analysis of Ordinal Categorical Data. Wiley, New York. 1984

4. Al-Ghamdi, A.S. Using Logistic Regression to Estimate the Influence of Accident Factors on Accident Severity. Accident Analysis and Prevention, vol. 34, No.6, 2001, pp.729-741.

5. Altman, D.G, and P.Royston. What do We Mean by Validating a Prognostic Model? Statistics in Medicine, vol. 19, 200, pp. 453-473.

6. Asch, P., D. T. Levy, d. Shea, and H. Bodenhorn. Risk Compensation and Effectiveness of Safety Belt Use Laws: A Case Study of New Jersey. Policy Sciences, 24 No. 2, 1991, pp. 181-197

7. Awadzi, K .D., S. Classen, A. Hall, R. P. Duncan, and C. W. Garvan. Predictors of Injury among Younger and Older Adults in Fatal Motor Vehicle Crashes. Accident Analysis and Prevention, vol. 40, No. 6, 2008, pp. 1804-1810.

8. Bleeker,S.E., Moll, H.A., Steyerberg,E.W., Donders, A.R.T., Derksen-Lubsun,G., Grobbee,D.E, and K.G.M. Moons. External Validation is Necessary in Prediction Research: A Clinical Example. Journal of Clinical Epidemiology, vol. 55, No. 9, 2003, pp826-832.

9. Boontob, N., Tanaboriboon, Y., Kanitpong, K, and Suriyawongpaisal, P. Effects of Seatbelt Use on Road Accidents in Thailand. Transportation Research Record, Issue 2038, 2007, pp. 84-92.

10. Braver, E. R. Race, Hispanic Origin, and Socioeconomic Status in Relation to Motor Vehicle Occupant Death Rates and Risks Factors among Adults. Accident Analysis and Prevention, vol. 35. No. 3, 2003, pp. 295-309.

11. Briggs, N. C., D.G. Schlundt, R.S. Levine, I.A. Goldweig, N. Stinson Jr., and R.C. Warren. Seat Belt Law Enforcement and Racial Disparities in Seat Belt Use. American Journal of Preventive Medicine, vol. 31, No. 2, 2006, pp. 135-141.

12. Briggs, N. C., D.G. Schlundt, R.S. Levine, I.A. Goldweig, N. Stinson Jr., and R.C. Warren. Seat Belt Use among Hispanic Ethnic Subgroups of National Origin. Injury Prevention, vol. 12, No. 6, 2006, pp. 421-426.

13. Broughton, J., and L. K. Walter. Trends in Fatal Car Accidents-Analysis of CCIS. DFT Road Safety Research Report PPR 172, 2007.

14. Campbell, B. J. The Association between Enforcement and Seat Belt Use. Journal of Safety Research, No. 19, 1998, pp. 159-163.

15. Campbell, B., J. R. Stewart, and F. A. Campbell. Early Results of Seat Belt Legislation in the United States of America. University of North Carolina Highway Safety Research Center Working Paper, No. A-123, 1986, Chapel Hill NC.

16. Cohen, A., and L. Einav. The Effects of Mandatory Seat Belts Laws on Driving Behavior and Traffic Fatalities. Review of Economic and Statistics, vol. 85, No. 4, 2003, pp. 828-843.

17. Colon, I. Race, Belief in Destiny, and Seat Belt Usage: A Pilot Study. American Journal of Public Health, vol. 82, No. 6, 1992, pp. 875-877.

18. Cummings, P., and F. P. Rivara. Car Occupant Death According to the Restraint Use of Other Occupants. Journal of American Medical Association, vol. 291, No.3, 2004, pp. 343-349.

19. Curtis, K. M., S. W. Rodi, and M. G. Sepulveda. The Lack of an Adult Seat Belt Law in New Hampshire: Live Free and Die? Accident Analysis and Prevention. vol. 39, No. 2, 2007, pp. 380-383.

20. Daniels, F., W. Moore, L.C. Norville Perez, B.M. Gaines, R.G. Hood, I. J. Swain, R. William, and C. T. Burgess. The Role of the African- American Physician in Reducing Traffic Related Death among African- Americans: Consensus Report of the National Medical Association. Journal of the National Medical Association, vol. 94, No. 2, 2002, pp. 108-118.

21. Dee, T. S. Reconsidering the Effect of Seat Belt Laws and their Renforcement Status. Accident Analysis and Prevention, vol. 30, No. 1, 1998, pp. 1-10.

22. Delen, D., R. Sharda, and M. Bessonov. B. Identifying Significant Predictors of Injury Severity in Traffic Accidents Using a Series of Artificial Neural Networks. Accident Analysis and Prevention, vol. 38, No.3, 2006, pp. 434-444.

23. Derrig, R.A., M. Segui-Gomez, A. Abtahi, and L. L. Lieu. The Effect of Population Safety Belt Usage Rates on Vehicle- Related Fatalities. Accident Analysis and Prevention, vol. 34, No. 1. 2002, pp. 101-110.

24. Dinh-Zarr, T. B., D. A. Sleet, R. A. Shults, S. Zaza, R. W. Elder, J. L. Nichols, R. S. Thompson, and D. M. Sosin. Review of Evidence Regarding Interventions to Increase the Use of Safety Belts. American Journal of Preventive Medicine, 21 (4SUPPL. 1), 2001, pp. 48-65.

25. DOE Road Safety, U.K. Department of Transportation, New Seat Belt Regulation, 2007. http://www.roadsafetyni.gov.uk/newseatbeltregulations/seatbelts.htm, Access, February 2010.

26. DOT State of Hawaii, Seat Belt Usage Literature Review, 2003. http://www.state.hi.us/dot/publiaffairs/safecommunities/report/seatbelt/seatbelt-litreview.pdf. Accessed October 2008.

27. Ellis, H. M., B. Nelson, O. Cosby, L. Morgan, W. Haliburton, and P. Dew. Achieving a Credible Health and Safety Approach to Increasing Seat Belt Use among African Americans. Journal of Health Care for the Poor and the Underserved, vol. 11, No. 2, 2000, pp. 144-150.

28. Evans, Leonard. Belted and Unbelted Driver Accident Involvement Rates Compared. Journal of Safety Research, vol. 18, No. 2, 1987, pp. 57-64.

29. Evans, Leonard. Effectiveness of Safety Belts in Preventing Fatalities. Accident Analysis and Prevention, vol. 18, No. 3, 1996, pp. 229-241.

30. Falcon Jr, R. A., A. L. Brenley, C.D, Ricketts, S.E. Allen, and V. F. Garcia. Development, Implementation and Evaluation of a Unique African- American Faith-Based Approach to Increase Automobile Restraint Use. Journal of the National Medical Association, vol. 98, No. 8, 2006, pp. 1335-1341.

31. Frank, E.H, Jr. Regression Modeling Strategies with Application to Linear Models, Logistic Regression and Survival Analysis. Springer-Verlag New York, Inc, 2001.

32. Garbacz, C. Estimating Seat Belt Effectiveness with Seat Belt Usage Data from the Centers for Disease Control. Economic Letters, vol. 34, No. 1, 1990, pp. 83-88.

33. Garrison, H. G., and C. E. Crump. Commentary: Race, Ethnicity and Motor Vehicle Crashes. Annals of Emergency Medicine, vol. 49, No. 2, 2007, pp. 219-220.

34. GHSA, The States Voice on Highway, Click it or Ticket, 2007 Mobilization, 2008. http://www.ghsa.org/html/projects/op/ciot/07.html. Accessed November 2008.

35. Harper, H. J. Buckle-up and Smile for Life: Uncommon Partners find Common Ground to Collaborate and Eliminate Disparities. Part 1. Dental Assistant (Chicago, Ill: 1994), vol. 72, No. 3, 2003, pp. 8-12.

36. Harper, J. S., W. M. Marine, C. T. Garrett, D. Lezotte, and S.R. Lowenstein. Motor Vehicle Crash Comparism of Hispanics and Non- Hispanics Motorists in Colorado. Annals of Emergency Medicine, vol. 36, No. 6, 2000, pp. 589-596.

37. Hitosugi, M., and A. Takatsu. Injury Severity in Motor Vehicle Occupants. Legal Medicine, 2, No. 3, 2000, pp. 166-170.

38. Hosmer, D. W., and S. Lemeshow. Applied Logistic Regression. Second Edition. John Wiley& Sons Inc., 2000.

39. Houston, D. J., and L. E. Richardson Jr. Getting Americans to Buckle-up: the Efficacy of State Seat Belt Laws. Accident Analysis and Prevention, vol. 37, No. 6, 2005, pp. 1114-1120.

40. Houston, D. J., and L. E. Richardson Jr. Reducing Traffic Fatalities in the American States by Upgrading Seat Belt Laws to Primary Enforcement. Journal of Policy Analysis and Management, vol. 25, No. 3, 2006, pp. 645-659.

41. Houston, D. J., and L. E. Richardson Jr. Safety Belts Use and the Switch to Primary Enforcement, 1991-2003. American Journal of Public Health, vol. 96, No. 11, 2006, pp. 1949-1954.

42. Houston, D. J., and L. E. Richardson Jr. Traffic Safety and the Switch to a Primary Seat Belt Law: The California Experience. Accident Analysis and Prevention, vol. 34, No. 6, 2002, pp. 743-751.

43. Houston, D. J., and L. E. Richardson Jr., and G. W. Neely. Mandatory Seat Belt Laws in the States: A Study of Fatal and Severe Occupant Injuries. Evaluation Review, vol. 20, No. 2, 1996, pp. 146-159.

44. Hunter, W. W., J. C. Stutts, J. R. Stewart, and E. A. Rodgman. Characteristics of Seat Belt Users and Non-users in the State with a Mandatory Belt Use Law. Health Education Research, vol. 5, No. 2, 1990, pp. 161-173.

45. Ichikawa, M., S. Nakahara, and S. Wakai. Mortality of Front-Seat Occupants Attributed to Unbelted Rear-Seat Passengers in Car Crashes. The Lancet, vol. 359, No. 9300 2002, pp. 43-44.

46. Jonah, B.A., N.E. Dawson, and G.A. Smith. Effects of a Selective Traffic Enforcement Program on Seat Belt Usage. Journal of Applied Psychology, vol. 67, No. 1, 1982, pp.89-96.

47. Kim, K., L. Nitz, J. Richardson, and L. Li. Personal and Behavioral Predictors of Automobile crash and Injury Severity. Accident Analysis and prevention, vol. 27, No. 4, 1995, pp. 469-481.

48. Konig, R., Malley, J.D., Weimar, C., Diener, H.C, and A. Ziegler. Practical Experiences on the Necessity of External Validation. Statistics in Medicine, vol. 26, 2007, pp5499-5511.

49. Kuzuaki, S., O. Jiro, S. Hironori, K. Yoshibumi, and M. Akinori. A Clinical Survey of Motor Vehicle Crashes. The Severity in High-energy Traumas. Proceedings Society of Automotive Engineers of Japan (JSAE) Annual Congress, vol. 41, No. 4, 2004, pp. 1-4.

50. Lerner, E. B., D.V. K. Jehle, AJ. Billittier IV, R.M. Moscati, C. M. Connery, and G. Stiler. The Influence of Demographic Factors on Seat Belt Use by Adults Injured in Motor Vehicle Crashes. Accident Analysis and Prevention, vol. 33, No. 5, 2001, pp. 659-662.

51. Levine , R. S., N. C. Briggs, D. G. Schundt, n. Stinson Jr., R. C. warren, and I. A. Goldzweig. Seat Belt Law Enforcement and Motor Vehicle Crash Fatalities among Blacks and Whites in Louisiana and Mississippi. Southern Medical Journal, vol. 99, No. 2, 2006, pp. 143-148.

52. Lund, A. K., P. Zador, and J. Pollner. Motor Vehicle Occupant Fatalities in Four States with Seat Belt Use Laws. SAE special Publication, 1987, pp. 43-51.

53. Lund, Adrian K. Voluntary Seat Belt Use among U.S Drivers: Geographic, Socioeconomic and Demographic Variation. Accident Analysis and Prevention, vol. 18. No.1, 1986, pp. 43-50.

54. Maguire, B., W. R. Faulhner, and R. A. Mathers. Seat Belt Laws and Traffic Fatalities; A Research Update. Social Science Journal, vol. 33, No. 3, 1996, pp. 321-333.

55. March, J.A., M. A. Evans, B. Ward, and K.L. Brewer. Motor Vehicle Crash Fatalities among Hispanics in the Rural North Carolina. Academic Emergency Medicine, vol. 10, No. 11, 2003, pp. 1249-1252.

56. Martin, M., M. Leonard, s. Allen, N. Botchwey and M .Carney. Commentary: Using Culturally Competent Strategies to Improve Traffic Safety in the Black Community. Annals of Emergency Medicine, vol. 44, No. 4, 2004, pp. 414-418.

57. Mayrose, J., A. Blatt, D.P. Roberts, M.J.Kilgallon, R.A. Galganski. The Effect of Unrestrained Rear-seat Passenger on Driver Mortality. The Journal of TRAUMA Injury, Infection, and Critical Care, vol. 61, No. 5, 2006, pp.1249-1254.

58. Mayrose, J., and D. V. K. Jehle. An Analysis of Race and Demographic Factors among Motor Vehicle Fatalities. Journal of Trauma- Injury, Infection and Critical Care, vol. 52, No. 4, 2002, pp. 752-755.

59. Mayrose, J., D. Jehle, M. Hayes, D. Tinnesz, G. Piazza, and G. E. Wilding. Influence of the Unbelted Rear-seat Passenger on Driver Mortality: "The Backseat Bullet." Academic Emergency Medicine, vol. 12, No. 2, 2005, pp. 130-134.

60. Morgan, J. N. Who Uses Seat Belts? Journal of Behavioral Science, vol. 12, No. 6, 1967, pp. 463-465

61. Nelson, D. E., J. Bolen, and M. J. Kresnow. Trends in Safety Belt Use by Demographics and by Type of State Safety Belt Law, 1987 through 1993. American Journal of Public Health, vol. 88. No. 2, 1998, pp. 245-249.

62. NHTSA, U.S .Department of Transportation, Traffic Safety Facts, Crash Statistics, 2008. http://www-nrd.nhtsa.dot.gov/pubs/811049.pdf. Accessed on November 2009.

63. NHTSA, U.S .Department of Transportation, Traffic Safety Facts, Crash Statistics, 2009a. http://www.trafficsafetymarketing.gov/ciot/planner10/peak/lives-saved-2008.pdf. Accessed on November 2009.

64. NHTSA, U.S .Department of Transportation, Traffic Safety Facts, Research Note, 2009b. http://ww-nrd.nhtsa.dot.gov/pubs/811100.pdf. Accessed November 2009

65. NHTSA, U.S .Department of Transportation, The Facts to Buckle Up America, Safety Belt and Teens Report, 2003a. http://www.nhtsa.gov/people/injury/airbags/buasbteen.pdf. Accessed November 2009

66. NHTSA, U.S .Department of Transportation, Traffic Safety Digest, 2003b. http://www.nhtsa.gov/people/outreach/safedige/spring2003/spr03_w15_NC.htm. Accessed November 2009.

67. NHTSA, U.S .Department of Transportation Traffic Safety Digest, 2000. http://www.nhtsa.gov/people/outreach/safedige/fall2000/fal00-6.html. Accessed November 2009.

68. NHTSA: The Facts to Buckle Up America, 2003c. Report. http://www.buckleuptexas.com/clickit/documents/2003AABeltfacts.pdf. Accessed November 2009.

69. NJ Department of Law and Public Safety, Division of Highway Traffic and Safety. http://www.njpublicsafety.com. Access March 2010.

70. Norusis, M. SPSS 15.0 Advanced Statistical Procedures companion. Prentice Hall Inc., 2007.

71. Orsay, M. E., T. L. Turnball, M. Ounne, J. a. Barrett, P. Langenber, and C. P. Orsay. Prospective Study of the Effect of Safety Belts on Morbidity and Health Care Costs in Motor-vehicle Accidents. Journal of the American Medical Association, vol. 260, No. 24, 1988, pp. 3598-3603.

72. Romano, E., S. Tippetts, K. Blackman, and R. Voas. Acculturation, Income, Education, Safety Belt Use, and Fatal Motor Vehicle Crashes in California. Prevention Science, vol. 6, No. 2, 2005, pp. 139-148.

73. Shin, D., L. Hong, and I. Waldron. Possible Causes of Socioeconomic and Ethnic Differences in Seat Belt Use among High School Students. Accident Analysis and Prevention, vol. 31, No.5, 1999, pp.485-496.

74. Shinar, D. Demographic and Socioeconomic Correlates of Safety Belt Use. Accident Analysis and Prevention, vol. 25, No. 6, 1993, pp. 745-755.

75. Shults, R. A., R. W. Elder, D. A. Sleet, R. S. Thompson, and J. L. Nichols. Primary Enforcement Seat Belt Laws are Effective Even in the Face of Rising Seat Belt Use Rates. Accident Analysis and Prevention, vol. 36, No. 3, 2004, pp. 491-493.

76. Solomon, M.G. Evaluation of NHTSA's Region IV Click it or Ticket Campaign. Report No. HS809404, U.S. Department of Transportation, Washington DC, May 2001.

77. Solomon, M.G. Occupant Protection Special Traffic Enforcement Program Evaluation. Report No. HS808 884, NHTSA, U.S. Department of Transportation, Washington, DC, 1999.

78. Solomon, M.G, R.P. Compton, and D.F. Preusser. Taking the Click It or Ticket Model Nationwide. Journal of Safety Research, vol 35, No. 21, 2004, pp197-201.

79. USDOT, Fiscal Year 2010 Budget Highlights, 2009. http://www..dot.gov/budget/2010/bib2010.htm. Accessed October 2009

80. Vivoda, J.M., D. W. Eby, and L. P. Kostyniuk. Differences in Safety Belt Use by Race. Accident Analysis and Prevention, vol. 36, No. 6, 2004, pp. 1105-1109.

81. Vyrostek, S. B., J. L. Annest, and G. W. Ryan. Surveillance for Fatal and Non-fatal Injuries- United States, 2001. MMWR. Surveillance Summaries: Morbidity

and Mortality Weekly Report. Surveillance Summaries / CDC, vol. 53, No. 7, 2004, pp. 1-57

82. Wells, J.K., A.F. Williams, and C. M. Farmer. Seat Belt Use among African Americans, Hispanics, and Whites. Accident Analysis and Prevention, vol. 34, No. 4, 2002, pp. 523-529.

83. Westlake-Kenny., B. The Benefits of Buckling up: Seat belt Save Lives. UAB Magazine, vol. 18, No. 2, 1998.

84. Williams, A.F., J.K. Wells, A.T. McCatt, and D.F. Preusser. “BuckleUp Now!” An Enforcement Program to Achieve High Seat Belt Use. Journal of Safety Research, Vol. 31,No. 4, 2000, pp. 195-201

85. Yamamoto, T., J. Hashiji, and V.N. Shankar. Underreporting in Traffic Accident Data, Bias in Parameters and the Structure of Injury Severity Models. Accident Analysis and Prevention, vol. 40, No. 4, 2008, pp1320-1329.

86. Zhu, M., S.B. Hardman, and L.J. Cook. Backseat Safety Belt Use and Crash Outcome. Journal of Safety Research, vol. 36, No.5, 2005, pp. 505-507