An Evaluation of Airbags

by

Tremika Finney

(Under the direction of Dr. Mary Meyer)

Abstract

Since the emergence of airbags, they have been surrounded by controversy. Do airbags protect the occupants from death and/or injury? Do they perform better under certain vehicle or occupant characteristics (seatbelt use, impact speed, impact direction, vehicle body type, role, age, gender, height, or weight)? A logistic regression was conducted using the Crashworthiness Data System (CDS), provided by the National Highway Transportation Safety Administration (NHTSA). Analysis revealed that airbag presence alone reduced death and/or injury outcomes, especially for seniors without seatbelts. Airbag deployment, however, was found to increase rates of death and/or injury. For frontal impacts, however, airbag deployment was found to reduce fatality rates.

Index words: Airbag presence, Airbag deployment, Supplemental Restrain System (SRS), Crashworthiness Data System (CDS), National Highway Transportation Safety Administration (NHTSA), Injury, Fatality, Motor Vehicle Collisions (MVC's), logistic regression, Delta-v

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Chapter 1

Introduction

Currently airbags are considered one of the most important and controversial topics when it comes to automobile safety. But what many do not know is the history behind them. When were airbags created? How did they end up as the mandated safety devices that they have now become? How does the airbag system work? Should airbags and seatbelts both be used? And why is there still controversy surrounding the use of airbags today?

Technology surrounding airbags has been growing and developing over the last few decades. The first known instance of airbay use dates back to 1911. This was when British Royal Navy Office Lieutenant Aurthur Longmore "flew an aircraft to the world's first water landing using pontoon shaped airbags" ("Naval Aviation History ...", 2001). Airbag technology continued toa dvance and during WWII the US patented airbags to be used as inflatable safety devices to aid in the advent of an airplane's crash landing ("The History of Cars", 2004). The development of the airbag soon grew beyond the technology and field of aviation. The emergence of airbag technology in automobiles started with John W. Hetrick back in 1952. One day, Hetrick was out for a Sunday drive with his wife and daughter. Apparently they were cruising along when a deer jumped out in front of them in an attempt to cross the road. Hetrick slammed on the brakes and veered to the side of the road and the car ended up in a ditch. Hetrick recalled that moment when he applied the brakes, when both he and his wife threw their hands up to try to prevent their daughter from flinging forward and hitting the dashboard. Luckily, they were all unharmed, but Hetrick just could not let the incident go. He thought to himself, why could there not be some type of device that would stop you from hitting the inside of the car? Hetrick thought about this for awhile and then recalled some of his US Navy experience. Hetrick specifically recalled an instance where he was working on a canvas covering for a torpedo. He remembered that when the compressed air was released the covering had ballooned up to the ceiling. He developed his airbag design based upon this and then patented it on August 5, 1952. Soon after this event, companies such as General Motors and Ford Motor Company started to experiment with this new technology. Upon testing this device both companies realized that was one major problem that needed to be solved- and that problem was in relation to the deployment rate of the airbag. Until the deployment rate could be as speedy as it needed to be to protect the vehicle occupants, airbags were put on the back burner. In 1966, however, the US Army discovered a new detonator. With this new device if a sensor was triggered, the detonator would release gas into a bag. These releases were described as "explosions" and were said to have the power of a .22-caliber rifle shell ("Airbags", 2002). Even with this advance, the technology still needed to be improved upon.

Approximately five years later in 1971, Ford Motor Company became the first to manufacture commercial passenger vehicles with driver-side airbags. That year they had 831 Mercury models produced. But this was merely the first step. The next big step occurred between 1974 and 1976. It was during this period that General Motors started selling airbag technology as an extra (or optional equipment) on approximately 10,000 of their luxury models (Thompson, 1999). It must be noted, however, that this escalation of airbag installation, as the newest automotive safety advice, came with warnings. As early as the 1970s, "Ford Motor Company [has] recommended a warning placard be affixed to the crash pad directly in front of the right front passenger to warn of hazards associated with the airbags[including]out of position occupants and warnings against right front seat occupancy by those of small stature, the aged or the infirm" (Smock & Nichols, 2004).

So, what fueled the development of airbag technology for the automobile industry? Well, some thought that airbags were a moneymaking scheme for the automotive industry. This is usually emphasized because of the cost to have the airbag system installed in the vehicle- the low threshold/deployment rate and the cost of installing another bag. In 1998, a study, entitled "Airbags in Low Speed Crashes: Costing Lives and Money", was conducted by Ralph Hoar. This study determined that approximately 74% of airbag deployments happened in cases with speeds less than 15.5 mph, which concerned many since it has been noted that almost all deaths caused by airbags occurred at low speeds. It was also estimated that approximately 2.25 million driver airbags deployed between the 1980s and 1998, while approximately 344,000 passenger airbags deployed. Conducting a sample, they found that airbag installment costs ranged from $1,269 to $8,735. Doing the math, they found:

2,250,000	driver airbag deployment
x 74%	crashes below 15.5mph delta-v
=1,665,000	airbag protection probably unnecessary
x $644	(low estimate) cost of replacement airbag parts
=$1,072,260,000	cost of parts for probably unnecessary driver airbag deployments
344,000	passenger side deployment
x 74%	crashes below 15.5mph delta-v
=254,560	airbag protection probably unnecessary
x $625	(low estimate) cost of replacement airbag parts
=$159,100,000	cost of parts for probably unnecessary passenger airbag deployments
$1,231,360,000	Total part sales from probably unnecessary airbag deployments.

These numbers, support the whole automotive conspiracy, but the truth, however, is that airbag technology was actually not pushed by the automotive industry, but it was brought on by politicians. This push was primarily brought on by Ralph Nader.

So who is Ralph Nader? Ralph Nader has been described as a 'public citizen'. He has placed himself at the forefront of several progressive campaigns over the last couple of decades, especially with reference to airbags ("Ralph Nader..."). He is also known for various reports and books on public safety, which have been read by many politicians as well as the general public ("Automotive Air Bags"). Nader teamed up with Joan Claybrook, who was the Administrator of the National Highway Transportation Safety Administration in the late 70's ("Safe Airbags or No Airbags", 2000). Together they emphasized to the government, the small percentage of seatbelt use throughout the nation (approx. 14% use rate in 1983) and offered airbags as the next big safety device. They pushed for airbags because they "were looking for something that worked without involvement from the occupants" (Healy and O' Donnel, 1996). So, airbags seemed like a great alternative for those automobile users who refused to use their seatbelts, which would have helped in the prevention of injuries and fatalities for vehicle occupants.

The push for airbags continued over the next couple of years, but before mandating of airbags there was a push by the government and the automobile industry for more seatbelt use by occupants. Elizabeth Dole, President Reagan's Transportation Secretary issued "a rule in 1984 requiring auto belts or airbags in all cars by 1990, [however] she included an escape route: if states representing 2/3 of the US population enact mandatory-use seatbelt laws before April 1989, the passive-restraint regulation would not take effect" (Healy and O' Donnel, 1996). For many states, the "support for mandatory use was lukewarm, sometimes nonexistent" (Healy and O' Donnel, 1996). Not enough states enacted this seatbelt law and because of this, in 1991, President Bush signed an act requiring that all cars manufactured after 1996 to have airbags as standard equipment ("Automotive Air Bags"). And in 1999, frontal airbags for both driver and passenger became required by law ("Things You Should Know...").

Even with the increase in the number of airbags on the road, many still are ignorant of the steps and procedures of the supplemental restraint system (SRS). The airbag system consists of three main components. These components are the airbag module, crash sensor(s), and a diagnostic unit. The first component, the airbag module, is made up of two parts. One is the indicator unit and the other is the actual airbag. For the driver, the airbag module is located in the steering wheel hub. When this airbag inflates fully it is approximately the size of a large beach ball. For the passenger, the airbag module is located in the instrument panel. When this airbag inflates it can be up to two to three times larger than the driver's. This is because the space between the instrument panel and the passenger is larger than the space between the steering wheel and the driver. The second component is the crash sensor. The sensors are primarily located in either the front of the vehicle or in the passenger compartment. Vehicles are equipped with at least one crash senor, but they may have more. The third and final component is the diagnostic unit. The diagnostic unit is used to check on the readiness of the airbag system. Some of these units contain a device that maintains enough electrical energy to deploy the airbag even if the vehicle's motor had been destroyed previously in the crash sequence (Thompson, 1999).

Airbags are designed to deploy when there is a moderate or severe frontal impact collision. When the crash sensor detects the impact, it sends a signal to the inflator unit, which is inside the airbag module. When this happens, the air bag deployment process begins. "Once the electrical circuit has been turned on by the sensor, a pellet of sodium azide (NaN3) is ignited. A rapid reaction occurs, generating nitrogen gas (N_2). This gas fills a nylon or polyamide bag ("Chemistry Behind Airbags", 2005). This reaction causes the airbag to deploy through the module cover (Thompson, 1999). What many do not know about airbags is that the module cover is purposely weakened during the manufacturing process. This along with the speed of inflation, which averages between 144 and 214 mph, allows for the airbag's speedy deployment (Smock, 2004). After deployment, the airbag starts to deflate almost as rapidly as it had inflated. The gas escapes through the fabric of the airbag and through vents. This immediate deflation is used as a sort of cushioning effect that helps to maintain a constant pressure as the occupant comes in contact with the airbag. This deflation is also designed so that in case the vehicle is still in motion it can still be steered so that an occupant can not be trapped inside the vehicle ("Effectiveness of Occupant...", 1996). Even knowing these facts, some still do not understand that an airbag is not like some soft pillow that you can just fall into. The airbag has been said to deploy "faster than the blink of an eye", and this is certainly true. It has been noted that "the bag inflates within about 1/20th of a second after impact. The inflated bag creates a protective cushion between the occupant and the vehicle's interior (i.e. the steering wheel, dashboard, and windshield). At 4/20th of a second following impact, the airbag begins to deflate" ("Effectiveness of Occupant...", 1996).

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Now knowing the process, the question can now be addressed as to why both the seatbelt and airbag should be used. Even though airbags were mandated because of low seatbelt use rates, what should be noted is that the automotive industry has developed airbags as a supplemental restraint system. In case of an accident or sudden stop, seatbelts are used to restrain occupants from propelling forward and hitting their head on the dashboard or steering wheel, but seatbelts cannot be relied upon solely, since they are subject to malfunctions and/or defects. Using an airbag alone does not necessarily work because without a seatbelt since the occupant could end up impacting the bag before it has had time to fully deploy. Therefore, the perfect combination seems to involve using both safety devices. This combination starts with the seatbelt helping to "restrain a passenger from being thrown forward into a deploying bag" ("Airbags - More than...") and then the airbag acting to spread the impact/force of the crash across a wide area of the body ("Air Bag Safety Facts...") all the while helping to guard "against injuries to the upper torso, head and face" (Kneuper, Robert, Yandle & Bruce, 1994).

But even with evidence (see Literature Review) that the seatbelt and airbag combination reduces both injury and fatality rates, there is still controversy surrounding the use of airbags. With the reduction of injury, due to the protection that the airbag provides, what must be kept in mind is that "there are hazards and risks associated with airbag deployment" (Smock, 2004). According to Dr. William Smock, who has worked with the Department of Emergency Medicine at the University of Louisville and the Kentucky Medical Examiner's Office and has over 10 years of clinical experience and study, occupants who are too close to a deploying airbag, can sustain injuries that vary all the way from slight (cuts and bruises) to extreme (death). He has seen injuries from the amputation of fingers, hands, and forearms to compound fractures of the forearms and upper arms (Smock, 2004).

Sadly, though, the question of whether or not an airbag is truly an effective safety device for preventing injuries and fatalities is not as simple as looking at the injury/fatality outcomes and airbag availability/presence. A true evaluation of their effectiveness would have to look at several other characteristics. The first and probably most important characteristic to examine is the relationship between an airbag and seatbelt use. This is because it has been said that the "airbag's effectiveness depends on whether or not the occupant is wearing a seatbelt" (Thompson, Segui-Gomez & Graham, 1999). This is supported by several studies that have determined that there is a relationship between the airbag and the seatbelt. With regard to injury, the National Highway Transportation Administration (NHTSA), using Crashworthiness Data System (CDS), found that airbags alone provided the lowest effectiveness rate (approximately 29%); followed by the seatbelt alone (approximately 60%) and then the combination of an airbag and seatbelt provided the highest estimated effectiveness rate of approximately 73% ("Effectiveness of Occupant...", 2002). The second most important aspect is that of vehicle impact speed (a.k.a. delta-v). On its own "delta-v [the impact velocity minus separation velocity] has been shown to be a significant factor in determining injury severity, with higher levels of delta-v indicating a greater likelihood of more serious injuries" ("Effectiveness of Occupant...", 1996). But interacting with the airbag, it has been shown that "[in] low-speed crashes, the injuries induced by the deploying airbag may be more serious than injuries that would otherwise have occurred, whereas in higher-speed crashes, airbag deployment may actually prevent the driver from sustaining more severe injuries" (Segui-Gomez, 2000). This is definitely a concern since "virtually all of the 115 deaths that the NHTSA attributes to airbags occurred in crashes with delta-v's at or below 15 mph, which is considered a low speed" (Hoar, 1998). Another factor is that of impact direction. It was noted that approximately 60% of vehicle fatalities occurred in vehicles with frontal damage (Traffic Safety Facts, 1998). Since airbags were developed to help protect occupants from frontal impacts, this factor definitely needs to be examined. Another factor is vehicle body type. Since airbags were first developed for cars, a difference in protection levels from cars to trucks to utility vehicles needs to be investigated. This factor is also considered because of its relationship to and possible confounding with both gender and age. Other characteristics examined deal with the occupants. Occupant role is also used to determine seat position. It should be investigated to determine if there is a difference between the driver and the passenger since although their airbags work in the same manner, they are designed differently. Role is considered because of its possible confounding relationship with gender. In general, especially in the past, males have tended to dominate the driver role. Occupant age is also investigated since it has been reported that "drivers under the age of 25 had the highest rate of involvement in fatal crashes of any age group" (Traffic Safety Facts, 2003) and since a study by Mackay and Hassan proved that the "55 year old age groups are shown to be especially vulnerable" (2000). Occupant gender must also be looked at since originally "airbag systems were developed for the 5 ft 8 inch 180 lb male" (Segui-Gomez, 2000). Some research has "suggested that [these] airbag injuries are more likely in female drivers" (Segui-Gomez, 2000). Gender is also investigated for its relationship to occupant role, height and weight, since women, in general, tend to be shorter and lighter then men. Height is also considered since shorter drivers are listed as a "high risk group" in terms of injury and death (Smock, 2004). Height and weight are looked at because of their relationship with occupant gender and seating position, with shorter and heavier occupants sitting closer to the airbag than their counterparts.

The data used for analysis in this project was obtained from the (NHTSA's) National Accident Sampling System's (NASS's) Crashworthiness Data System (CDS), "which collects additional detailed information on a sample of police reported traffic crashes" ("National Automotive Sampling System...", 2002). This data set has been said to be "the most comprehensive, representative crash investigation system available and has the most accurate safety belt use reporting of any file available to the NHTSA" ("Effectiveness of Occupant...", 1996). "The crashes investigated in NASS CDS are a probability sample of all police reported crashes in the U.S. A NASS CDS crash must fulfill the following requirements: must be police reported, must involve a harmful event (property damage and/or personal injury) resulting from a crash and must involve at least one towed passenger car or light truck or van in transport on a trafficway. Every crash, which meets these conditions, has a chance of being selected. This type of sample design makes it possible to compute estimates, which are representative of the entire country.

The selection of sample crashes in NASS is accomplished in three stages: (1) selection of PSU's, (2) selection of police jurisdictions and (3) selection of crashes.

Stage 1 - Select PSU's

For the first stage of selection, the country was divided into 1195 geographic areas called Primary Sampling Units (PSU's). Each PSU consisted of either a central city, a county surrounding a central city, an entire county or a group of contiguous counties. The PSU's were defined so that their minimum population was approximately

50,000. The 1195 PSU's were grouped into 12 strata based on geographic region and type, e.g., central cities, suburban counties, and other PSU's. The 27 PSU's to be sampled were allocated to each stratum roughly proportional to the number of crashes in each stratum. At least two PSU's were selected from each stratum.

Stage 2 - Select Police Jurisdictions

If every crash in each PSU were investigated, a national estimate could be obtained by weighting each crash by the inverse of the probability of selecting the PSU. Because it is uneconomical and impractical to investigate every crash in each sample PSU, a second and third stage of sampling are performed. Each PSU contains a number of police jurisdictions which process reports of crashes that occur within the PSU's boundaries. These police jurisdictions form the frame of the second stage of sampling. Each jurisdiction is assigned a measure of size based on the number, severity and type of its crashes. A sample of jurisdictions is selected which over-samples those having a larger measure of size.

Stage 3 - Select Crashes

The final stage of sampling is the selection of crashes within the sampled jurisdictions. Each week, the police jurisdictions are contacted and all crashes that qualify for the NASS CDS for which a police crash report has been filed since the last date that jurisdiction was contacted are listed. While being listed, each crash is classified into a stratum based on type of vehicle; most severe police reported injury, disposition of the injured, tow status of the vehicles and model year of the vehicles. All qualifying crashes are listed, except in a few of the largest police jurisdictions. In these jurisdictions only crashes with either an even or an odd police crash report number are listed.

To select crashes, each team is assigned a fixed number of crashes to investigate each week. The number of crashes a team selects for investigation is governed by the number of researchers on a team. Sampling weights for the strata are assigned so that a larger percentage of the higher severity crashes are selected than of the lower severity crashes. Also, crashes in the same stratum have the same probability of being selected, regardless of the PSU" ("National Automotive Sampling System...", 2002).

It must be noted here that all results from this data set will results in over-estimates for all injury and fatality outcomes. This is primarily because of the sampling system, which admits to sample higher amounts of the more severe crash impacts. The other reason is that these estimates have to be put into perspective. They are good only for crashes that result with a car qualifying for the data set, meaning that one vehicle had to have been towed away from the scene.

Chapter 2

Literature Review

The emergence of airbags has left the driving population with various feelings. Some believe that airbags are the answer to reducing injury and fatality rates in vehicle crashes. Others believe that airbags cause more harm than good. Learning more about airbags and their relationships to other vehicle and occupant characteristics will help in answering the question of whether or not airbags are truly an effective safety device.

Airbags began being installed in automobiles during the 1970s. Up until "1993, fewer than 500,000 new passenger cars a year were equipped with dual airbags, but by 1995, 15 million passenger vehicles had been sold with both driver and passenger airbags" (Ferguson, Reinfurt & Williams, 1997). But why was there such an explosion of their growth?

Before the mandating of airbags into automobiles during the mid 90's, airbags were sold to the public as a safety device that although it does not prevent accidents, they do provide added protection, for an occupant, against injury or death in the event of a collision (Boulding, William & Purohit, 1996). So far, this marketing ploy has worked. In 1997, "a survey of over 200 drivers who were involved in crashes in which the airbag deployed found that 89% of them felt that the airbag protected them from injury, and almost all of the drivers would want an airbag in their next car" (Ferguson, Reinfurt & Williams, 1997). On the other end of the spectrum lies the view/theory that airbags are death devices. At one point there was once an engineer who applied for a patent for a device that would use airbags as a "quicker more humane way to kill convicts than hanging or the electric chair" (Healey & O'Donnel, 1996).

In a 1994 study by the Insurance Institute for Highway Safety (IIHS), it was found that 42% of airbag deployments resulted in injuries from contact with airbags or airbag generated gas. Of that 42%, 96% of the injuries were deemed as minor [scrapes and scratches], 3% of the injuries are deemed as moderate [contusions], and a mere 1% of the injuries were deemed as serious or worse [fractures, dismemberment, death] ("The Truth About Airbags...", 1997). In 2003, it was estimated that there were approximately 250 million frontal airbags in the United States (Evans, 2003). It was also estimated that approximately 1.7 million of these airbags had deployed. Using the percentages above, in 2003, there should have been approximately 714,000 injuries caused by contact with an airbag or airbag-generated gas. Out of the 714,000 injuries, 685,440 drivers (approx. 96%) should have sustained minor injuries, 21,420 drivers (approx. 3%) should have sustained moderate injuries, and approximately 7,140 drivers (1%) should have sustained serious or worse injuries. With a growing number of airbags into vehicles and the number of deployments, injuries and fatalities will keep increasing, which is why this is an important investigation.

The most common source for data on motor vehicle collisions is provided by the NHTSA (National Highway Traffic Safety Administration). The NHTSA supports the National Center for Statistics and Analysis (NCSA). The NCSA maintains several data sets. The two most commonly used are FARS (Fatality Analysis Reporting System), used to report fatality statistics, and the NASS's (National Accident Sampling System) CDS (Crashworthiness Data System), used to report injury statistics. "FARS is a census of all fatal traffic crashes that occur in the U.S., on roads customarily open to the public, where at least one person dies from crash related causes within 30 days of the crash" ("Effectiveness of Occupant", 1996). The CDS "is a crash data collision system which is based on a nationally representative sample of crashes selected from police reported crashes involving at least one passenger motor vehicle which had to be towed from the scene due to damage from the crash" ("Effectiveness of Occupant", 1996).

The NHTSA reports to congress every couple of years about the "Effectiveness of Occupant Protection Systems and Their Use". Here they calculate the airbag's effectiveness rates for reducing fatalities, using the FARS dataset, with two different methods of analysis. The first analysis compares the "ratio of driver fatalities (with the air bag) to right-front passenger fatalities (without the air bag) is calculated, and it is compared to the corresponding ratio in earlier cars of the same makes and models, equipped only with 3-point belts at both seating positions. The fatality-reducing effectiveness of air bags is estimated by the relative difference in the two ratios. This analysis includes all drivers and right-front passengers of the cars, both belted and unbelted." ("Effectiveness of Occupant", 1996). The second analysis compares the "ratio of frontal to nonfrontal driver fatalities in cars equipped with driver air bags is compared to the corresponding ratio in earlier cars of the same makes and models, equipped only with 3-point belts. The fatality-reducing effectiveness of air bags in frontal crashes is estimated by the relative difference in the two ratios" ("Effectiveness of Occupant", 1996), without taking into account occupant seatbelt use, and again the relative difference is calculated to show fatality reducing effectiveness. The results are as follows:

Fatality-Reducing Effectiveness of Driver Air Bags

Estimated for 1996 (and 2001) Reportings	Comparison Group				Final	
	Right-Front Passengers		Nonfrontal Crashes		(Average) Effectiveness	
All frontal crashes	***18%***	***(19%)***	***19%***	***(20%)***	***19%***	***(20%)***
All crashes (frontals plus nonfrontals)	***10%***	***(11%)***	***12%)***	***(13%)***	***11%***	***(12%)***

Note: ***Bold italics*** indicates that the estimate is statistically significantly different from zero.

("Effectiveness of Occupants", 1996 & 2001).

Another method used by the NHTSA is to "group drivers by their belt use. Belted drivers in cars equipped with air bags experienced a statistically significant 21 percent fatality reduction in purely frontal crashes, relative to belted drivers in comparable cars without air bags. Unbelted drivers with air bags experienced a statistically significant 36 percent fatality reduction in purely frontal crashes, relative to unbelted drivers without air bags. In other words, air bags have significant life saving benefits in purely frontal crashes for belted and unbelted drivers; however, the benefit appears to be somewhat larger, relatively speaking, for the unbelted driver.

The two preceding estimates need to be carefully interpreted. The 21 percent reduction for the belted driver with an air bag is measured relative to the belted driver without an air bag; it does not include the very substantial effect of belts, but represents the increment of air bags plus belts over belts alone. Both estimates are for purely frontal crashes; the fatality reduction in all types of crashes is substantially less than the reduction in purely frontal crashes – viz., about 11 percent for the belted driver (relative to a belted driver without air bags) and 14 percent for the unbelted driver. NHTSA estimates that safety belts alone reduce fatality risk by 45 percent. Thus, if an unrestrained driver has a fatality risk of 100, a driver protected by both a safety belt and an air bag will have a risk of: $100 \times (1 - .45) \times (1 - .11) = 49$" ("Effectiveness of Occupant", 2001). The results were as follows:

Estimated Effectiveness of Occupant Protection Systems in Reducing Fatality Risk for Passenger Car Drivers

System Used	***Fatality Reduction***
Air bag plus lap-shoulder belt	***51%***
Air bag alone	***14%***
Manual lap-shoulder belt	***45%***

Exhibit 6

Note: The ***bold italics*** font means that the estimate is statistically significantly different from zero.

Interpreting this means that "if 100 drivers not using seat belts driving cars not equipped with air bags were killed in crashes, 51 of them would have been saved if they had been wearing a lap-shoulder belt and their cars had been equipped with a driver air bag (49 would still have been killed, analogous to the risk of 49 in the example above Exhibit 6). Had these same 100 drivers been unbelted in a vehicle with air bags, 14 of them would have been saved" ("Effectiveness of Occupant", 2001).

Calculations have also been done to calculate effectiveness in preventing injuries. The NHTSA has reported several findings. One is

Estimated Effectiveness of Occupant Protection Systems in Reducing the Likelihood of Moderate Injury (MAIS 2+)

(2001 reporting)

System Used	***All Damage Areas***		***Front Damage***	
Air bag plus lap-shoulder belt	***60%***	**(73%)**	***61%***	**(76%)**
Air bag alone	*18%*	*(29%)*	*6%*	*(**35%**)*
Manual lap-shoulder belt	***49%***	**(60%)**	***56%***	**(62%)**

Note: ***Bold italics*** means statistically significant difference from the risk of unrestrained occupants.

("Effective of Occupant", 1996 & 2001). Injuries were also looked at over other characteristics. Results were as follows. "The estimates presented in Exhibit 13 represent the percentage reduction in the likelihood of a moderate injury for male and female drivers. For example, the 64 percent estimated effectiveness of the air bag plus lap-shoulder belt for male drivers means that males protected by this system experienced a 64 percent reduction in the chance of a moderate injury, compared to an unrestrained male driver.

Exhibit 13

Estimated Effectiveness of Occupant Protection Systems in Reducing the Likelihood of Moderate and Greater Injury for Male and Female Drivers

System Used	**Male Drivers**	**Female Drivers**
Air bag plus lap-shoulder belt	***64%***	***59%***
Air bag alone	12%	25%
Manual lap-shoulder belt	***38%***	***59%***

Note: ***Bold italics*** means statistically significant difference from the risk of unrestrained occupants.

Estimated Effectiveness of Occupant Protection Systems in Reducing the Likelihood of Moderate and Greater Injury for Two Driver Age Groups

System Used	**Drivers Age 15-49**	**Drivers Age 50+**
Air bag plus lap-shoulder belt	***62%***	***57%***
Air bag alone	12%	9%
Manual lap-shoulder belt	***46%***	***54%***

Note: ***Bold italics*** means statistically significant difference from the risk of unrestrained occupants.

Estimated Effectiveness of Occupant Protection Systems in Reducing the Likelihood of Moderate and Greater Injury for Three Driver Height Groups

System Used	**Drivers < 65 Inches**	**Drivers 65-70 Inches**	**Drivers > 70 Inches**
Air bag plus lap-shoulder belt	***48%***	***60%***	36%
Air bag alone	31%	15%	10%
Manual lap-shoulder belt	***55%***	24%	***46%***

Note: ***Bold italics*** means statistically significant difference from the risk of unrestrained occupants.

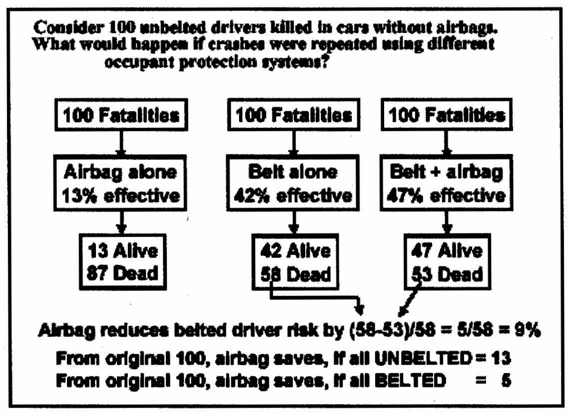
Estimated Effectiveness of Occupant Protection Systems in Reducing the Likelihood of Moderate and Greater Injury for Three Driver Weight Groups

System Used	**Drivers** < **135 lbs.**	**Drivers 135-179 lbs.**	**Drivers** > **179 lbs.**
Air bag plus lap-shoulder belt	***55%***	39%	***64%***
Air bag alone	-36%	37%	36%
Manual lap-shoulder belt	***42%***	***44%***	***43%***

Note: ***Bold italics*** means statistically significant difference from the risk of unrestrained occupants.

("Effectiveness of Occupant", 1996). What should be noted from these tables is that in all of the airbag alone groups they are not significantly different from the occupant group using neither safety device. This indicates that an airbag alone is not effective in preventing injuries.

In an article entitled Transportation Safety, from the Handbook of Transportation Science, they demonstrate a different method for calculating driver risk. Using the following figure:



(Evans, 2004)

The NHTSA also publishes Traffic Safety Facts each year. In 2003, they found that "speeding is one of the most prevalent factors contributing to traffic crashes". They also noted in both 1998 and 2003 that young males were most likely to be speeding- indicating a possible confounder. For both 1998 and 2003, "the fatal crash involvement per 100,000 population was almost 3 times as high for male drivers than for females". It was also found for both years that females were almost 12% more likely to be wearing their seatbelts.

In 2000, Dr. Maria Segui-Gomez, conducted a study entitled "Driver Air Bag Effectiveness by Severity of the Crash". "The goal of this analysis is to provide net effectiveness estimates of the driver-side air bag in preventing fatal and nonfatal injuries in frontal and near frontal crashes by severity of the crash, while controlling for characteristics known to influence the frequency and severity of injuries, such as age and sex of the driver, vehicle size and mass, and safety belt use". For this analysis, the data used was from the CDS years 1993-1996. Injuries/fatalities were measured using the Abbreviated Injury Scale (AIS), the Injury Severity Score (ISS), and the Functional Capacity Index (FCI). A multivariate logistic regression was conducted. Analysis originally pertained to airbag deployment, but was also run with regard to airbag presence and in both cases results were the same. "Independent variables for inclusion in the multivariate regression were those that had significant or quasi-significant coefficients ($P < .25$) in the univariate regressions (i.e., driver's sex, age, and height; seat belt use; vehicles' wheelbase; and crash severity) and a dummy variable indicating whether the air bag deployed. For each dependent variable, models were built systematically and included 2, 3, or more independent variables and the interaction terms between air bag deployment and each of the covariates (e.g., air bag deployment and crash severity). In the final models, we also included the 2 terms reflecting the interaction between air bag deployment and driver's sex and air bag deployment and Delta V when these terms achieved statistical significance ($P < .1$).The logistic multivariate regression confirmed that air bag deployment was associated with a statistically significant decrease in the probability of fatal injuries. This protective effect did not differ by sex of the driver".

In 2002, Peter Cummings, Barbara McKnight, Frederick Rivara and David Grossman conducted a matched pair cohort study to evaluate the relation of driver airbags and their fatality rates. They used the FARS dataset for the years 1990-2000. Records included those with a driver and only one front-seat passenger and to help control for confounding by age, records selected were where both occupants were at least sixteen years of age. "The relative risk of death for drivers with an air bag compared with those without, using conditional Poisson regression [including] seat position, age, sex, seatbelt use, airbag presence and their interaction terms." "[There] was little difference in the distribution of driver's age by air bag status (table 1), but those with an air bag were more often men (as men were more often drivers), somewhat more likely to be belted, and more likely to survive." They also found that airbags interacted with sex, with women having a 12% decrease in risk where there was only a 6% decrease in risk for the men. There was also an effect found between airbag and direction with a decrease in risk of death for frontal impacts. No significant relationships were found between airbags and vehicle speed or vehicle type.

Dr. John Sutyak, Vikas Passi, and Dr. Jeffrey Hammond conducted a study on airbags alone versus the combination of airbags with seatbelts. The data used here came from "drivers involved in an MVC in which their air bag deployed and who were admitted to a state-designated, American College of Surgeons verified, level I trauma center between January 1, 1991, and December 31, 1994". For this study they made sure that the drivers selected were similar in age, sex, alcohol use and impact direction for both groups, thus controlling for those variables. They found that drivers with the airbag alone groups versus the airbag and seatbelt group had significantly higher injury severity scores and longer hospital stays.

Chapter 3

Analysis

3.1 Data Description

Since 1985, the National Automotive Sampling System (NASS), operated by the National Highway Transportation Safety Administration (NHTSA), has collected vehicular crash data as part of the Crashworthiness Data System (CDS) (”What is NASS?”, 2004). The data collected is about various aspects of the crash ranging from the steps before the accident, the accident itself, and the aftermath. Each incident used in the collecting period has 11 records filed. These records that can be downloaded from: ftp://ftp.nhtsa.dot.gov/nass/. These records include: the Accident Description Record (which contains a text summary about the accident), the Accident Record (which contains the month, time, and manner of the collision), the Event Record (which contains the vehicle type, and general damage areas), the General Vehicle Record (which contains information about the airbag, speed, and road conditions), the Occupant Assessment Record (which contains the occupant's age, gender, airbag/seatbelt use, and injury/death status), the Occupant Injury Record (which contains the number of injuries and source of injury for each occupant), the Person Profile Record (which contains a text summary about the occupant), the Type Accident Record (which contains a text summary about the type of accident), the Vehicle Exterior Record (which contains the direction of impact and objects contacted), the Vehicle Profile Record (which contains a text summary about the vehicle), and the Vehicle Interior Record (which contains information about the windows, odometer and the steering wheel). For this analysis, only the Occupant Assessment (OA), the General Vehicle (GV) and the Vehicle Exterior (VE) records for 1995-2003 were used. The data set merged these three records. The data set was reduced by eliminating all vehicle occupants who were not in the driver seat or in the right-front passenger seat, since those are the two positions that frontal airbags were designed to protect. Occupants younger than age sixteen were also eliminated to ensure the focus on licensed drivers (sixteen is minimum age required to be licensed) and to get rid of children, since it is a well-known fact, provided by the warning labels back in the 70s, that children do not belong in the front seat. The data set is further decreased by eliminating missing observation for response and predictor variables.

3.2 Variable Descriptions

3.2.1 Response Variables

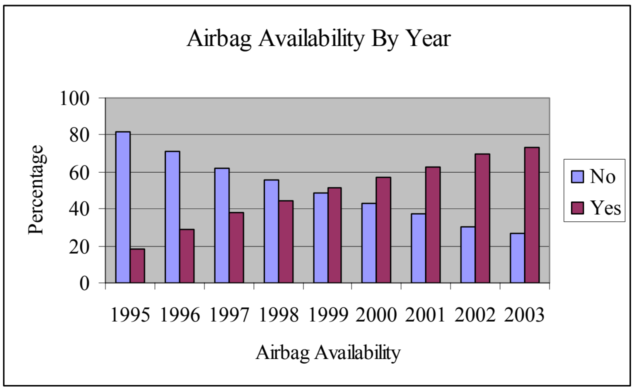
This analysis will involve two response (dependent) variables. The first response variable is death. There were several variables in the data set that could be used to indicate an occupant's death. The variables that indicated this type of outcome were labeled treatment and death. The treatment variable indicated whether or not the occupant received treatment, was transported, hospitalized or dead. The death variable measured the occupant's time to death - indicating the number of hours/days until their passing. Unknown and/or missing variables in death group were replaced by treatment measures and vice versa. Those occupants who were deemed dead make up the fatalities in this analysis. Overall, there were 3,567 fatalities out of the 65,207 occupants. Approximately 5% of the occupants were killed.

The second response variable is injury. Here again, there are several measures indicating injury. For this investigation, however, the variable chosen to measure injury was the occupant's hospital stay. If the occupant spent more than one day in the hospital then that occupant was deemed as injured. If an occupant was deemed as a fatality then they were also characterized as being injured. Therefore, during this analysis, the term injured will indicated serious injuries requiring hospital stays or even death. Overall, there were 17,149 injured occupants out of the 65,207 occupants. Approximately 26% of the occupants were injured.

3.2.2 Predictor Variables

Airbag availability is the first variable investigated. It has two categories: yes (indicating that an airbag was available) and no (indicating that an airbag was not available). Looking at the airbag presence in vehicles over time, an increasing trend appears.

Figure 3.1: Airbag Availability Over Time



Overall, it was found that 31,933 out of 65,207 of the occupants (approximately 49%) had airbags available to them. Looking further, there were 1,376 of the occupants (approximately 4%) killed with an airbag available and 2,191 of the occupants (approximately 7%) without airbags were killed. The same trend appeared with injuries. For injuries, it was found that 6,939 of the occupants with airbags available (approximately 22%) sustained injuries and that 10,210 of the occupants without airbags available (approximately 31%) sustained injuries. This indicates that occupant's without airbags available will tend to be killed or injured more than those occupant's without an airbag available.

Using these numbers, a calculation can be done to estimate the number of fatalities or injuries that could have been prevented. To do so, one would take the number of occupants without airbags available and multiply that by the fatality/injury rate for those occupants with airbags available. Doing that estimates the number of occupants that would have been injured or killed had they had an airbag been available to them. If one subtracts the estimated amount from number of actual injuries, one will find the approximate amount of occupant fatalities or injuries that could have been prevented because of airbags.

Table 3.1: Estimating the Number of Preventable Fatalities for Airbag Availability

Fatality		
With Airbag	Without Airbag	No. of Fatalities that could have been prevented
$1376/31933 \approx$ 0.0431	$2191/33274 \approx$ 0.0658	$2191 - (0.0431 * 33274) \approx 757$ 0.0227 (34.50% $\downarrow$)

Table 3.2: Estimating the Number of Preventable Injuries for Airbag Availability

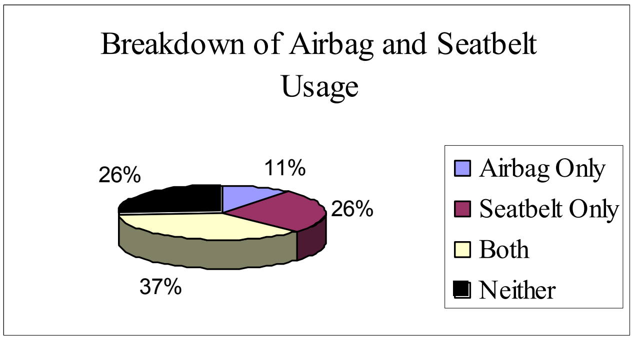
Injury		
With Airbag	Without Airbag	No. of Injuries that could have been prevented
$6939/31933 \approx$ 0.2173	$10210/33274 \approx$ 0.3068	$10210 - (0.2173 * 33274) \approx 2980$ 0.0895 (29.19% $\downarrow$)

Looking at the tables above, more can be said that 757 lives could have been saved and that 2,980 injuries could have been prevented. The second number listed under the number of lives/injuries that could have been prevented can be described using two different methods. The first method is that it is the relative difference of the ratio of fatality/injury without an airbag available to the ratio of fatality/injury with an airbag available. Using fatality, for example, one would take 0.0658 (fatality rate without airbag availability) and subtract that from 0.0431 (the fatality rate with airbag availability) = 0.0227. The second method is by solving a proportion-the proportion of number of lives saved if an airbag had been available over the number of occupants without an airbag. Using the same example, one could take 757 (the number of estimated lives saved) and divide that by 33,274 (the number of occupants without an airbag available) = 0.0227. This number is important. It is needed to find the last number which shows the percentage change that could have occurred. By dividing the relative frequency/proportion of lives saved by the proportion of fatalities/injuries, one can calculate the increasing or decreasing effect that an airbag can have. Continuing with the same example, one would take the relative difference (0.0227) and divide that by the proportion killed without an airbag available (0.0658) and find that the fatality rates for occupants without an airbag would have been reduced by approximately 35% if those occupants had had an airbag available to them. The same follows for injury, indicating that for occupants without airbags approximately 29% of them could have avoided injury if they had had an airbag available to them. An alternate method to calculate these percentages would be to subtract the proportion of occupants with and airbag available to the proportion of occupant without an airbag available from one. Doing this one gets $1 - (0.0431/0.0658) = 1 - 0.6550 = 0.3450$, which is approximately 35% and $1 - (0.2173/0.3068) = 1 - 0.7083 = 0.2917$, which is approximately 27%.

Seatbelt use was the next variable investigated. Seatbelt use consisted of two categories either yes, indicating correct/proper seatbelt use, or no, indicating either incorrect/improper seatbelt use or no use of the seatbelt. Proper seatbelt use was deemed as using both the lap and shoulder belt (the 3-point system). Looking at the seatbelt usage in vehicles over time, an increasing trend also appears, although not as steep of an increase as airbag availability. Overall, it was found that 31,350 out of 50,222 occupants (approximately 62%) had and used their seatbelts properly. It must be noted, however, that the seatbelt usage rates may be slightly inflated. "Repeated analyses have demonstrated that self-reported safety belt [seatbelt] use, such as that contained in most police reports, overstates the level of safety belt use in these crashes" ("Effectiveness of Occupant", 1996). These overages are speculated to be because of insurance purposes and fear of ticketing from police. It must also be noted that "[unlike] other post crash surveys, the NASS CDS investigator does not rely primarily on the self-reporting of safety belt use by the person involved in the crash, which is generally the source for the information cited on police reports. It is for this reason that the NASS CDS is believed to provide the most reliable indication of the use of safety belts by crash-involved parties" ("Effectiveness of Occupant", 1996).

What needs to be investigated next is the relationship between airbag availability and proper seatbelt use. By grouping the different airbag and seatbelt outcomes, it was found that:

Figure 3.2: Occupant Airbag and Seatbelt Usage Rates



For the no airbag or seatbelt group, the data showed that 1,302 of the 13,116 occupants were killed (approximately 10%) while 5,750 of the occupants were injured (approximately 44%). The airbag only group showed that 586 of the 5,756 occupants were killed (approximately 10%) while 2,346 were injured (approximately 41%). The seatbelt only group showed that 419 of the 13,101 occupants were killed (approximately 3%) while 2,616 were injured (approximately 20%). For the airbag and seatbelt group 403 of the 18,249 occupants were killed (approximately 2%) while 2,922 were injured (approximately 16%). So, what was shown here was that the lowest fatality and injury rates occur when the occupant has both an airbag available and correct use of their seatbelt. This is followed by seatbelt use only, airbag use only, and then no airbag or seatbelt. To illustrate what a dramatic change a seat belt or both an airbag and seatbelt can make over an airbag alone, or neither safety device, some estimations can be calculated. Using the same formulas as above it was found that:

Table 3.3: Estimating the Number of Preventable Fatalities for Airbag Availability by Seatbelt Usage

With Seatbelt			Without Seatbelt		
With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without	No. of Fatalities that could have been prevented
403/18249 ≈ 0.0221	419/13101 ≈ 0.0320	129 0.0099 (30.94%↓)	586/5756 ≈ 0.1018	1302/13116 ≈ 0.0993	-33 -0.0025 (2.53%↑)

Table 3.4: Estimating the Number of Preventable Injuries for Airbag Availability by Seatbelt Usage

With Seatbelt			Without Seatbelt		
With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without	No. of Injuries that could have been prevented
2922/18249 ≈ 0.1601	2616/13101 ≈ 0.1997	519 0.0396 (19.83%↓)	2346/5756 ≈ 0.4076	5750/13116 ≈ 0.4384	404 0.0308 (7.03%↓)

Now, after looking at airbag effectiveness by seatbelt use, it was found that looking at the airbag effectiveness rates found earlier could be misleading. For fatality, the airbag is only effective with a seatbelt, indicating that an occupant without a seatbelt with an airbag present is more likely to die than an occupant who has neither safety device. For injury, the airbag is more effective with a seatbelt, although, not much more. These results seem to contradict the airbag effect found previously. To see what is going on, the focus is now put onto seatbelts.

Table 3.5: Estimating the Number of Preventable Fatalities for Proper Seatbelt Use

Fatality		
With Seatbelt	Without Seatbelt	No. of Fatalities that could have been prevented
$822/31350 \approx 0.0266$	$1888/18872 \approx 0.1000$	$1888 - (0.0266 * 18872) \approx 1386$ 0.0734 (73.40% ↓)

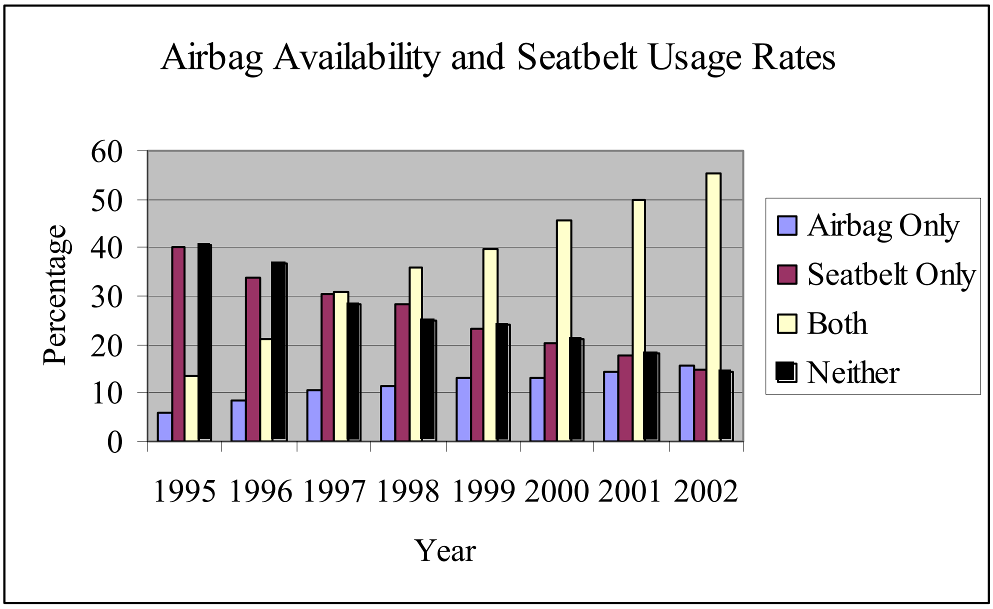
Table 3.6: Estimating the Number of Preventable Injuries for Proper Seatbelt Use

Injury		
With Seatbelt	Without Seatbelt	No. of Injuries that could have been prevented
$5538/31350 \approx 0.1767$	$8096/18872 \approx 0.4290$	$8096 - (0.1767 * 18872) \approx 4761$ 0.2523 (58.81% ↓)

Looking at the tables above, it becomes clear that proper seatbelt use is much more effective than an airbag. By looking solely at airbag use, a researcher would find much higher results of effectiveness than if they had looked at the airbag's effectiveness with the seatbelt. This is known as a confounding variable.

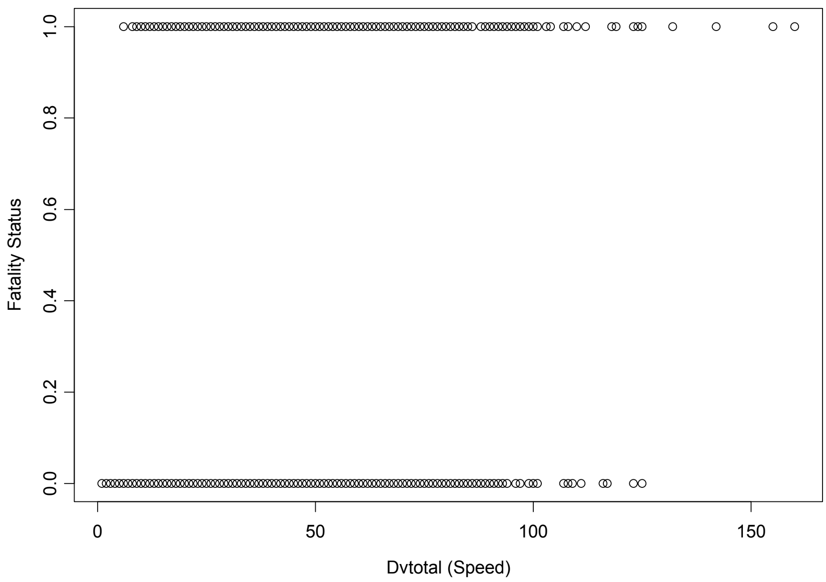
Looking at the trends of airbag availability and seatbelt use several things can be noted. There is a slow increase in the airbag availability group. There is also a strong decrease in seatbelt only group. There is a sharp rise in the use of both safety device group and a decreasing effect for occupants with using/having neither safety devices. The decrease in the neither and seatbelt only groups is due to the mandating of airbags into automobiles. This now moves those occupants who did not wear their seatbelt to the airbag only group and those who did wear their seatbelt properly to the both safety device group. Looking strictly at the difference (the loss) of the seatbelt only group and the difference (the increase) of the both category, it serves to illustrate that many of the occupants in the both category were more likely to have worn their seatbelt all along. Indicating that they are probably more safety conscious and probably had airbags installed into their vehicles before the mandating.

Figure 3.3: Airbag Availability and Seatbelt Usage Rates Over Time



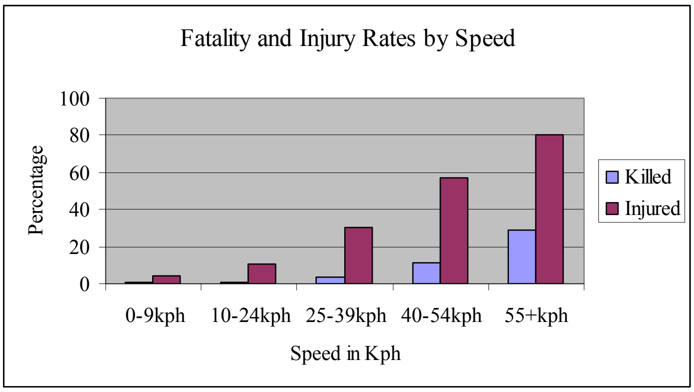
The next variable investigated was impact speed. The speed (a.k.a. dvtotal) is calculated by using a formula that subtracts the separation velocity from the impact velocity of a collision ("National Automotive Sampling System", 2002). Overall, the speeds ranged from 1 kph to 160 kph (approximately 1 to 99 mph). For cases where the speed was not known it was replaced by an estimated value. The variable dvest was used. These estimated values were listed categorically. The estimated speed categories ranged from: 0-9 kph (approximately 0-5 mph), 10-24 kph (approximately 6-15 mph), 25-39 kph (approximately 16-24 mph), 40-54 kph (approximately 25-34 mph), and 55+ kph (approximately 35+ or greater mph). First speed was looked at in a continuous manner.

Figure 3.4: Fatality Outcomes for Continuous Impact Speed



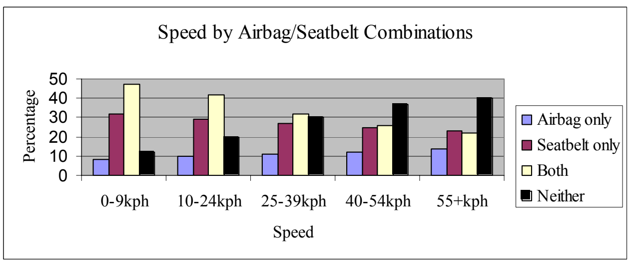
In the figure above, the zero represents an occupant not being killed and the one represents an occupant who was killed. A picture approximately the same was derived for injury. Seeing these observations occur simultaneously, indicating no injury/fatality as well as observations indicating injury/fatality. Not much can be derived, by looking at speed in a continuous manner. A logistic regression could be run to fit these points, but a logistic regression yields and S-shaped curve, and this curve would not be a good fit for this data. Because of this lack of fit, speed was looked at categorically. The continuous dvtotal was then categorized into the estimate groups, as previously listed. Doing this, the following was found:

Figure 3.5: Injury and Fatality Rates by Impact Speed



This reinforces what many would expect- a positive relationship between speed and injury and/or fatality levels, indicating that more fatalities and/or injuries are likely to occur as the vehicle traveled at higher speeds. By looking at the steep increasing rate, one could probably conclude that speed is a very significant indicator of fatality and injury outcomes. Another thing to look at would be the relationship between speed and the safety device usage.

Figure 3.6: Impact Sped by Airbag and Seatbelt Combinations



This is an interesting aspect to note. It seems as though the faster the impact speed the less likely an occupant is to have use of both or one safety device. But now the real question is- how does the impact speed relate with airbag availability?

Table 3.7: Estimating the Number of Preventable Fatalities for Airbag Availability by Seatbelt Usage and Speed

	With Seatbelt			Without Seatbelt		
Speed	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
0-9	0/461 ≈ 0	0/312 ≈ 0	0 0 (no change)	3/75 ≈ 0.04	1/120 ≈ 0.083	-4 -0.0317 (381.92%↑)
10-24	21/6498 ≈ 0.0032	17/4467 ≈ 0.0038	3 0.0006 (15.79%↓)	37/1521 ≈ 0.0243	61/3146 ≈ 0.0194	-15 -0.0049 (25.26%↑)
25-39	60/3094 ≈ 0.0194	64/2630 ≈ 0.0243	13 0.0049 (19.75%↓)	62/1072 ≈ 0.0578	172/2968 ≈ 0.0580	0 0 (no change)
40-54	54/831 ≈ 0.0650	64/790 ≈ 0.0810	13 0.0160 (20.37%↓)	60/387 ≈ 0.1550	174/1158 ≈ 0.1503	-5 -0.0047 (3.13%↑)
55+	63/322 ≈ 0.1957	79/334 ≈ 0.2365	14 0.0408 (17.25%↓)	73/205 ≈ 0.3561	203/582 ≈ 0.3488	-4 -0.0073 (2.09%↑)

Table 3.8: Estimating the Number of Preventable Injuries for Airbag Availability by Seatbelt Usage and Speed

	With Seatbelt			Without Seatbelt		
Speed	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
0-9	10/461 ≈ 0.0217	10/312 ≈ 0.0323	3 0.0106 (31.46%↓)	9/75 ≈ 0.12	13/120 ≈ 0.1083	-1 -0.0117 (10.80%↑)
10-24	489/6498 ≈ 0.0753	340/4467 ≈ 0.0761	4 0.0008 (1.05%↓)	262/1521 ≈ 0.1723	611/3146 ≈ 0.1942	69 0.0219 (11.28%↓)
25-39	629/3094 ≈ 0.2033	627/2630 ≈ 0.2384	92 0.0351 (14.72%↓)	414/1072 ≈ 0.3862	1266/2968 ≈ 0.4265	120 0.0403 (9.45%↓)
40-54	368/831 ≈ 0.4428	388/790 ≈ 0.4911	38 0.0483 (9.83%↓)	255/387 ≈ 0.6589	803/1158 ≈ 0.6934	40 0.0345 (4.98%↓)
55+	210/322 ≈ 0.6522	259/334 ≈ 0.7754	41 0.1232 (15.89%↓)	178/205 ≈ 0.8683	511/582 ≈ 0.8780	6 0.0097 (1.10%↓)

Looking at the tables above, two things should be noted. First, it should be noted that airbag availability was only effective with proper seatbelt use. Without proper seatbelt use airbags have negative effects indicating that occupants tend to be killed and/or injured more often. Second, it should be noted, that contrary to the hypothesis stated earlier, that airbag effectiveness increased as the vehicle's speed increased, the airbag's effectiveness increased for the lower speed categories (0-9, 10-24, and possibly 25-39), but then had a decreasing effect for the higher speed categories (40-54,and 55+).

Next, direction was investigated. This direction variable indicates where the greatest impact force/damage was located. Since this analysis is investigating the importance of a frontal airbag, direction was classified into two groups: frontal impacts and non-frontal (side or rear) impacts. It was found that 18,681 out of 29,394 (approximately 64%) of the occupants were involved in frontal impacts. Overall, for frontal crashes, it was found that 643 out of 18,681 occupants (approximately 3%) were injured and 4,692 out of (approximately 25%) were killed. For the non-frontal impacts, there were 607 out of 10,713 occupants (approximately 6%) killed and 2,760 (approximately 26%) injured. But, how does the direction of impact interact with airbag availability?

Table 3.9: Estimating the Number of Preventable Fatalities for Airbag Availability by Seatbelt Usage and Direction

	With Seatbelt			Without Seatbelt		
Direction	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Front	65/6512 ≈ 0.0100	103/5023 ≈ 0.0205	98 0.0105 (51.22%↓)	110/1939 ≈ 0.0567	365/5207 ≈ 0.0701	70 0.0134 (19.12%↓)
Non-Front	132/4154 ≈ 0.0318	116/2976 ≈ 0.0390	21 0.0072 (18.46%↓)	123/1195 ≈ 0.1029	236/2388 ≈ 0.0988	-10 -0.0041 (4.15%↑)

Table 3.10: Estimating the Number of Preventable Injuries for Airbag Availability by Seatbelt Usage and Direction

	With Seatbelt			Without Seatbelt		
Direction	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Front	922/6512 ≈ 0.1412	977/5023 ≈ 0.1945	268 0.0533 (27.40%↓)	632/1939 ≈ 0.3259	2161/5207 ≈ 0.4150	464 0.0891 (21.50%↓)
Non-Front	754/4154 ≈ 0.1815	591/2976 ≈ 0.1986	51 0.0171 (8.61%↓)	468/1195 ≈ 0.3916	947/2388 ≈ 0.3966	12 0.0050 (1.26%↓)

Here it can be seen that airbags seem to be effective in frontal impacts and in non-frontal impacts, but only for those occupants with proper seatbelt use. To take an even deeper look into direction, injury and fatality rates were plotted for direction by speed for the various airbag and seatbelt combinations to look for possible interactions.

Figure 3.7: Fatality Rates by Impact Direction

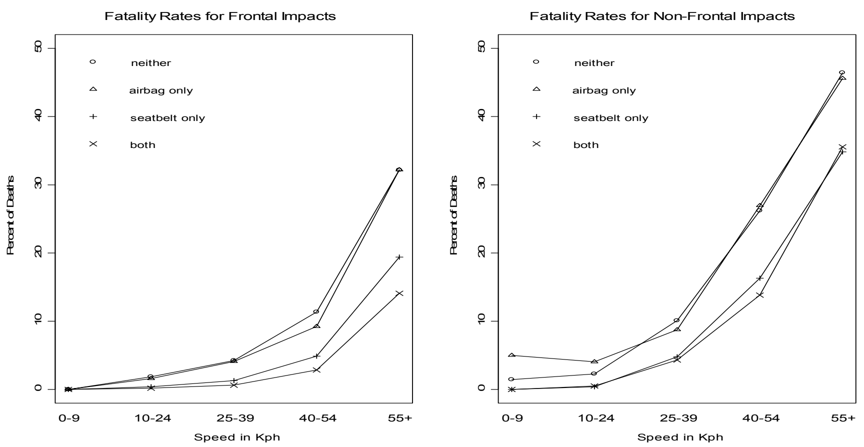
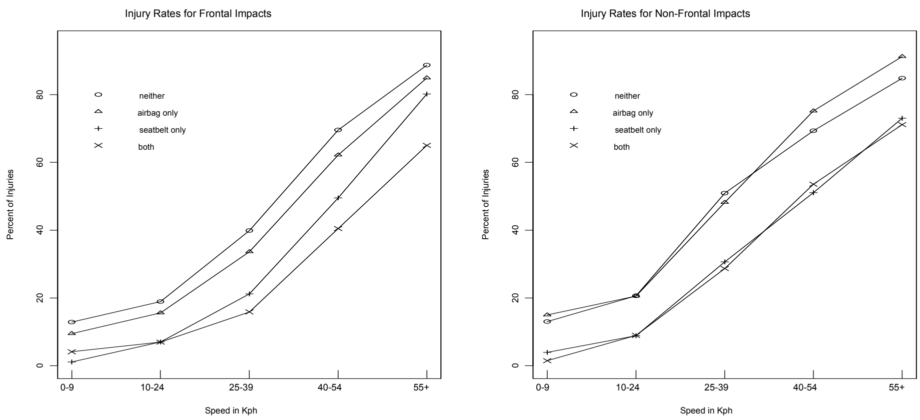


Figure 3.8: Injury Rates by Impact Direction



Looking at the figures above, it can be suggested that there is an interaction between the airbag and direction. For frontal impacts, both the fatality and injury rates for the airbag alone are strictly below the rates of neither safety device, while in non-frontal impacts, the two go back and forth in being the leading case of injury and fatality. A relationship between speed and direction can also been seen for fatalities. The fatality rates are consistently higher for non-frontal impacts in each speed category. A slight seatbelt effect can also be seen in non-frontal impacts, since at the higher speeds for both fatality and injury the seatbelt only groups had lower rates than both an airbag and seatbelt.

Next, the vehicle's body type was investigated. The vehicle's body type was categorized into the following groups: car, utility vehicle, or truck. The car group included: convertibles, 2dr sedans, 3dr sedans, 4dr sedans, 5dr sedans, station wagons, etc. The utility vehicle group included all models of SUVs. And the truck group included: minivans, van-based vehicles, and pick-ups. All of these groups were determined by using the General Vehicle Form provided by the NHTSA (http://www.fmcsa.dot.gov/Pdfs/General_Vehicle_form.pdf). Overall, for vehicle body type it was found that 74% of the occupants were in cars, 18% were in trucks, and 8% were in utility vehicles. For cars, it was found that 1,030 of the 21,688 occupants were killed (approximately 5%) while 5,789 were injured (approximately 27%). In trucks, it was found that 167 of the 5,289 occupants were killed (approximately 3%) while 1,194 were injured (approximately 23%). In utility vehicles, it was found that 53 of the 2,447 occupants were killed (approximately 2%) while 469 were injured (approximately 19%). Since the percentages for injury and fatality seem to decrease in the larger vehicle sizes (trucks and utility vehicle), this suggests that the vehicle's body type could be a predictor of injury and fatality outcomes. So, how do vehicle body type and airbag availability interact?

Table 3.11: small Estimating the Number of Fatalities that Could Have Prevented for Airbag Availability by Seatbelt Usage and Vehicle Body Type

	With Seatbelt			Without Seatbelt		
Vehicle Body Type	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Car	170/7857 ≈ 0.0216	182/5323 ≈ 0.0342	67 0.0126 (36.84%↓)	19/2496 ≈ 0.0757	489/6012 ≈ 0.0813	34 0.0056 (6.89%↓)
Truck	20/1728 ≈ 0.0116	26/1882 ≈ 0.0138	4 0.0022 (15.94%↓)	29/477 ≈ 0.0649	92/1202 ≈ 0.0765	14 0.0116 (15.16%↓)
Utility	7/1081 ≈ 0.0065	11/794 ≈ 0.0139	6 0.0074 (53.24%↓)	15/191 ≈ 0.0785	20/381 ≈ 0.0525	-10 -0.0260 (49.52%↑)

Table 3.12: Estimating the Number of Injuries that Could Have Prevented for Airbag Availability by Seatbelt Usage and Vehicle Body Type

	With Seatbelt			Without Seatbelt		
Vehicle Body Type	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Car	1355/7857 ≈ 0.1725	1150/5323 ≈ 0.2160	232 0.0435 (20.14%↓)	866/2496 ≈ 0.3470	2418/6012 ≈ 0.4022	332 0.0552 (13.72%↓)
Truck	208/1728 ≈ 0.1204	301/1882 ≈ 0.1599	74 0.0395 (24.70%↓)	153/477 ≈ 0.3423	532/1202 ≈ 0.4426	121 0.1003 (22.66%↓)
Utility	113/1081 ≈ 0.1045	117/794 ≈ 0.1474	34 0.0429 (29.10%↓)	81/191 ≈ 0.4241	158/381 ≈ 0.4147	-4 -0.0094 (2.27%↑)

For both fatality and injury, airbag availability with the seatbelt seems to be better for larger vehicles. Airbag availability without proper seatbelt use seems to be ineffective especially for occupants in utility vehicles. To get a better look at possible relationships, the percent of fatalities/injuries were plotted by speed for the various airbag and seatbelt combinations, for all three body types.

Figure 3.9: Fatality Rates by Vehicle Body Type

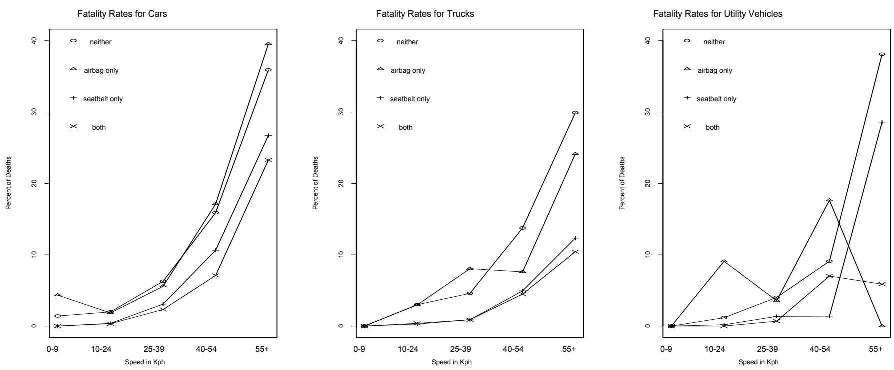
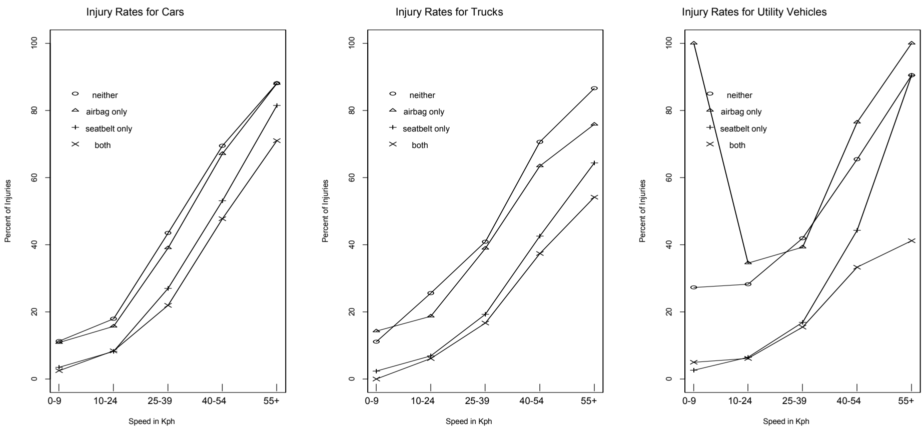


Figure 3.10: Injury Rates by Vehicle Body Type



Looking at the graphs above, several relationships are noticed. Not much can be said here except that there seems to be an interaction between airbag availability and vehicle body type. An airbag alone seems to increase fatality rates. For injuries, however, an airbag alone prevents injuries in cars and trucks rather than in utility vehicles.

The next variable investigated was occupant role. Role refers to the position of the occupant in the vehicle, whether they were the driver or the passenger. Overall, it was found that about 79% of the occupants were drivers. For drivers, it was found that 954 out of 23,107 drivers were killed (approximately 4%) and 5,847 injured (approximately 25%). For passengers, it was found that 296 of the 6,287 passengers were killed (approximately 5%) and 1,605 injured (approximately 26%). So, now the question is, does the occupant's role have an impact on airbag effectiveness?

Table 3.13: Estimating the Number of Fatalities that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Role

	With Seatbelt			Without Seatbelt		
Role	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Driver	147/8822 ≈ 0.0167	160/6170 ≈ 0.0259	57 0.0092 (35.52%↓)	188/2521 ≈ 0.0746	459/5594 ≈ 0.0821	42 0.0075 (9.14%↓)
Passenger	50/1844 ≈ 0.0271	59/1829 ≈ 0.0323	9 0.0052 (16.10%↓)	45/613 ≈ 0.0734	142/2001 ≈ 0.0710	-5 -0.0024 (3.38%↑)

Table 3.14: Estimating the Number of Injuries that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Role

	With Seatbelt			Without Seatbelt		
Role	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Driver	1380/8822 ≈ 0.1564	1213/6170 ≈ 0.1966	248 0.0402 (20.45%↓)	903/2521 ≈ 0.3582	2351/5594 ≈ 0.4203	347 0.0620 (14.75%↓)
Passenger	296/1844 ≈ 0.1605	355/1829 ≈ 0.1941	61 0.0334 (17.31%↓)	197/613 ≈ 0.3214	757/2001 ≈ 0.3783	114 0.0570 (15.07%↓)

For fatalities, airbag effectiveness with proper seatbelt use is almost twice as much for the driver than the passengers. Without proper seatbelt use, the airbag is about three times as likely to cause an injury for the passenger. For injury, there was only a slight difference in effectiveness rates. With a seatbelt, passengers were more likely than drivers to be injured, but without a seatbelt the driver was more likely to be injured. To get a further look at the relationships, fatality and injury rates were plotted by occupant role over speed.

Figure 3.11: Fatality Rates by Occupant Roles

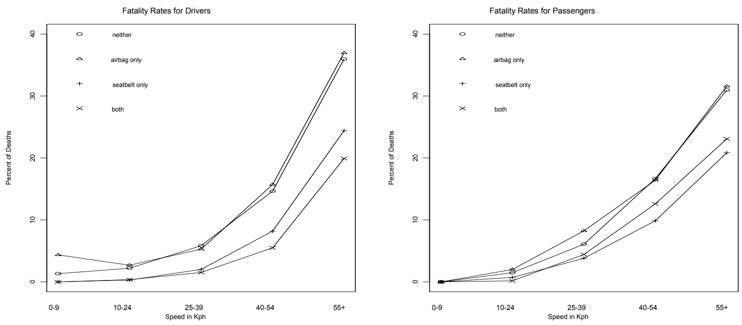
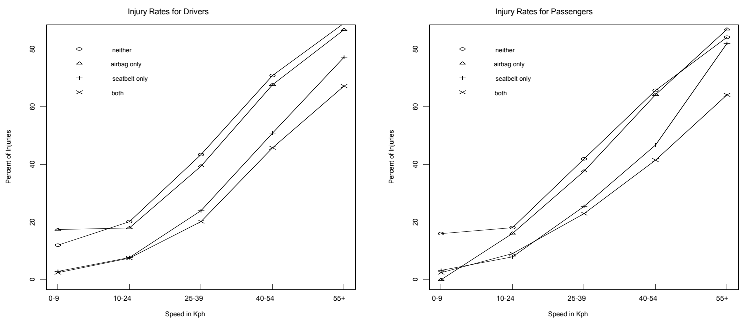


Figure 3.12: Injury Rates by Occupant Roles



Looking at the tables above, one finds several relationships can be noted with regard to injury. Having an airbag alone leads to more fatalities for both drivers and passengers at the higher speeds, while seeming to be more effective in preventing injuries.

The next variable being looked at is that of occupant age. The ages in this data set age ranged from 16 to 97 years of age. Ages less than sixteen were omitted, since sixteen is the legal age for most individuals to drive. Age was then divided into three groups: young adults (16-29 years), adults (30-54 years), and seniors (55 years and older). Overall, 44% of the occupants fell in the young adult category. For young adults, it was found that 385 out of 12,809 were injured (approximately 3%) while 2,749 were killed (approximately 21%). Adults comprised up about 40% of the occupants. For adults, it was found that 438 out of 11,568 were injured (approximately 4%) while 2,857 were killed (approximately 25%). Seniors made up the remaining 17%. There were 427 out of 5,017 seniors injured (approximately 9%) and 1,846 killed (approximately 37%). Because the proportions differ, age will probably be a good indicator of injury and fatality outcomes.

Table 3.15: Estimating the Number of Fatalities that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Age

	With Seatbelt			Without Seatbelt		
Occupant Age	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Young Adult	$45/4120 \approx 0.0109$	$63/3414 \approx 0.0185$	26 0.0076 (41.08%↓)	$96/1483 \approx 0.0647$	$181/3792 \approx 0.0477$	-64 -0.0170 (35.65%↑)
Adult	$61/4534 \approx 0.0135$	$65/3142 \approx 0.0207$	23 0.0072 (35.78%↓)	$76/1132 \approx 0.0671$	$236/2760 \approx 0.0855$	51 0.0184 (21.52%↓)
Senior	$91/1485 \approx 0.0452$	$91/1443 \approx 0.0631$	26 0.0179 (28.37%↓)	$61/519 \approx 0.1175$	$184/1043 \approx 0.1764$	61 0.0589 (33.39%↓)

Table 3.16: Estimating the Number of Injuries that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Age

	With Seatbelt			Without Seatbelt		
Occupant Age	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Young Adult	$502/4120 \approx 0.1218$	$527/3414 \approx 0.1544$	111 0.0326 (21.11%↓)	$436/1483 \approx 0.3122$	$1257/3792 \approx 0.3315$	73 0.0193 (5.82%↓)
Adult	$647/4534 \approx 0.1427$	$575/3142 \approx 0.1830$	127 0.0403 (22.02%↓)	$400/1132 \approx 0.3534$	$1235/2760 \approx 0.4475$	260 0.0942 (21.05%↓)
Senior	$527/1485 \approx 0.2619$	$466/1443 \approx 0.3229$	88 0.0610 (18.89%↓)	$237/519 \approx 0.4566$	$616/1043 \approx 0.5906$	140 0.1342 (22.72%↓)

For fatalities, airbag effectiveness with proper seatbelt use seems to decrease as the occupant age increases. Without a seatbelt, airbag effectiveness seems to be better for seniors and adults. For both fatality and injury, the effectiveness of an airbag without proper seatbelt use decreases dramatically for young adults putting them at a huge disadvantage. For a closer look at these relationships, fatality and injury rates for age was also plotted over speed by different airbag and seatbelt combinations.

Figure 3.13: Fatality Rates by Occupant Age

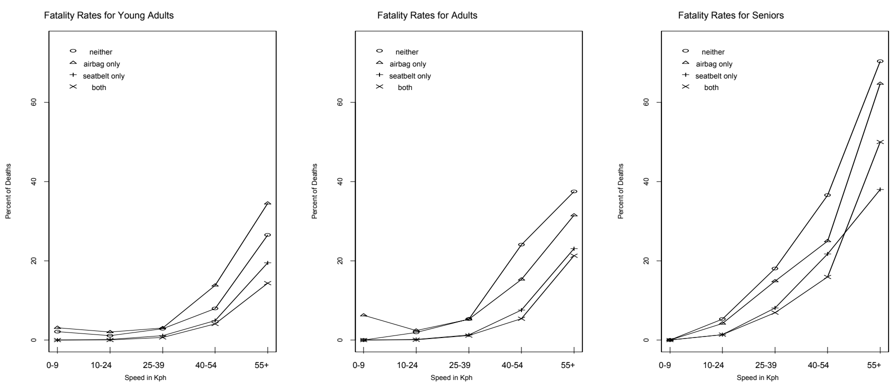
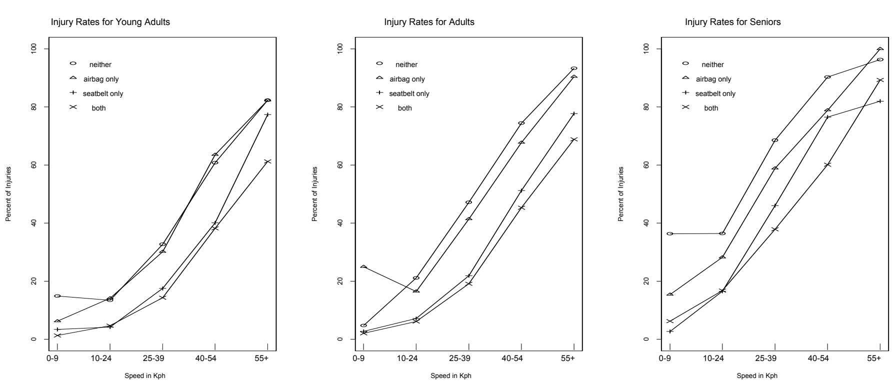


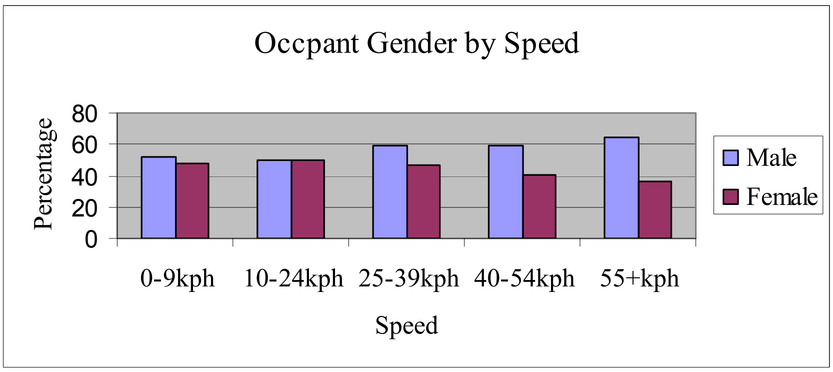
Figure 3.14: Injury Rates by Occupant Age



Overall, it can be seen that seniors have the highest rates of fatality and injury. For fatality, it is clear that an airbag alone leads to higher rates of death for young adults. For adults and seniors, airbags seem to have a preventive effect for both fatalities and injuries, supporting the estimates from the tables above.

The next variable to be investigated was sex. Sex referred to the occupants' gender (male/female). Overall it was found that, 53% of the occupants were male and 47% female. For males, it was found that 752 of 15,536 males were killed (approximately 3%) while 3,939 injured (approximately 25%). For females, it was found that 498 of the 13,841 females were killed (approximately 4%) while 3,510 were injured (approximately 25%). There is only a slight difference between the gender types. Another aspect to be looked at here involving gender was brought up previously in the Literature Review. How does occupant gender relate to speed?

Figure 3.15: Occupant Gender by Impact Speed



This reinforces the statement provided by the NHTSA's Traffic Safety Facts, that male do tend to drive faster than females. But now, the question is whether or not airbags seem to be more effective for males than females?

Table 3.17: Estimating the Number of Fatalities that Could Have Prevented for Airbag Availa Availability by Seatbelt Usage and Occupant Gender

	With Seatbelt			Without Seatbelt		
Gender	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Male	103/5003 ≈ 0.0206	118/4383 ≈ 0.0269	28 0.0063 (23.42%↓)	146/1703 ≈ 0.0857	385/4447 ≈ 0.0866	4 0.0009 (1.04%↓)
Female	94/2324 ≈ 0.0166	101/3609 ≈ 0.0280	41 0.0114 (40.71%↓)	87/1431 ≈ 0.0608	216/3144 ≈ 0.0687	25 0.0079 (11.50%↓)

Table 3.18: Estimating the Number of Injuries that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Gender

	With Seatbelt			Without Seatbelt		
Gender	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Male	724/5003 ≈ 0.1447	767/4383 ≈ 0.1750	133 0.0303 (17.31%↓)	603/1703 ≈ 0.3541	1845/4447 ≈ 0.4149	270 0.0608 (14.65%↓)
Female	951/2324 ≈ 0.1681	801/3609 ≈ 0.2219	194 0.0538 (24.25%↓)	497/1431 ≈ 0.3473	1261/3144 ≈ 0.4011	169 0.0538 (13.41%↓)

For fatality, a clear difference can be seen indicating that females, regardless of their seatbelt use status, seem to have better protection with airbag availability. Males, however, seem to need the seatbelt for the airbag to be effective. For injury, it can be seen that airbags seem to be consistent in their protection level for females regardless of their seatbelt status, although without a seatbelt, their effectiveness is slightly less than their male counterparts. Fatality/injury rates were plotted by sex against speed to get a closer look at the relationship between it and various airbag and seatbelt combinations.

Figure 3.16: Fatality Rates by Occupant Gender

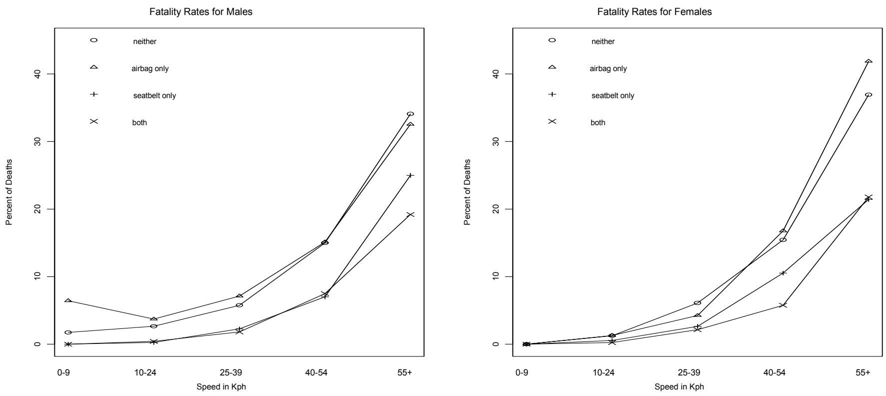
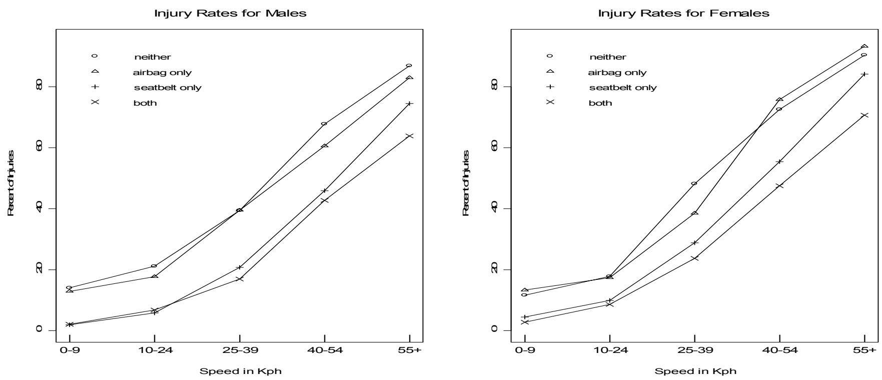


Figure 3.17: Injury Rates by Occupant Gender



Here it has been noted that at the higher speeds females tend to be killed or injured more often than males. It should also be noted that at the higher speeds, the airbag is less effective in preventing death and/or injury than no safety device, while it works in the opposite manner for males. This seems to contradict the effectiveness rating from the tables above.

The next variable investigated was occupant height. Height ranged from 119 cm to 211 cm (approximately 47 to 83 inches). Height was turned into a categorical variable with three categories. The short category comprised of the lower quartile range. These heights ranged from 119cm to 164cm, which translates to occupants with heights less than 5'4". The average category comprised of the middle range. These heights ranged from 165-177cm, which translates to occupants between 5'5" and 5'9". The tall category was comprised of the upper quartile range. These heights ranged from 178-211cm, which translates to 5'10" and taller. For the shorter occupants, it was found that 274 out of 4,852 were injured (approximately 4%) while 1,700 were killed (approximately 26%). For the average height occupants, it was found that 510 out 10,663 of were killed (approximately 5%) while 2,688 were injured (approximately 25%). For the tall occupants, it was found that 345 out of 8,028 were killed (approximately 4%) while 1,966 were injured (approximately 24%). The question now is- does airbag effectiveness differ by occupant height?

Table 3.19: Estimating the Number of Fatalities that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Height

	With Seatbelt			Without Seatbelt		
Occupant Height	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Shorter	47/2650 ≈ 0.0177	62/1764 ≈ 0.0351	31 0.0174 (49.57%↓)	55/663 ≈ 0.0830	550/1475 ≈ 0.3729	428 0.2899 (77.74%↓)
Medium	82/4007 ≈ 0.0205	91/2894 ≈ 0.0314	32 0.0109 (34.71%↓)	68/1092 ≈ 0.0623	269/2670 ≈ 0.1007	103 0.0384 (38.13%↓)
Tall	50/2747 ≈ 0.0182	46/2279 ≈ 0.0202	5 0.0020 (9.90%↓)	85/908 ≈ 0.0936	164/2094 ≈ .0783	-32 -0.0153 (19.54%↑)

Table 3.20: Estimating the Number of Injuries that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Height

	With Seatbelt			Without Seatbelt		
Occupant Height	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Shorter	447/2650 ≈ 0.1687	417/1764 ≈ 0.2364	119 0.0677 (28.64%↓)	237/663 ≈ 0.3575	599/1475 ≈ 0.4061	72 0.0486 (11.97%↓)
Medium	638/4007 ≈ 0.1592	546/2894 ≈ 0.1887	85 0.0295 (15.63%↓)	384/1092 ≈ 0.3516	1120/2670 ≈ 0.4195	181 0.0678 (16.06%↓)
Tall	395/2747 ≈ 0.1438	387/2279 ≈ 0.1698	590 0.0260 (15.31%↓)	318/908 ≈ 0.3502	966/2094 ≈ 0.4136	132 0.0634 (15.34%↓)

For fatality, airbags, regardless of seatbelt use, seem to be more effective the shorter the occupants is. For injury, airbag effectiveness is approximately the same for medium to tall occupants, but for shorter occupants, airbags seem to offer more airbag protection with proper seatbelt use. Fatality and injury rates were plotted over speed by the various airbag and seatbelt combinations for the different occupant height groups to look for possible interactions.

Figure 3.18: Fatality Rates by Occupant Height

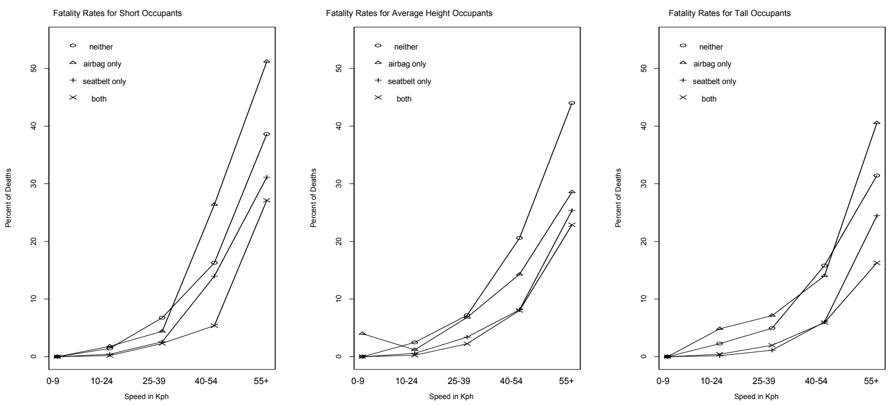
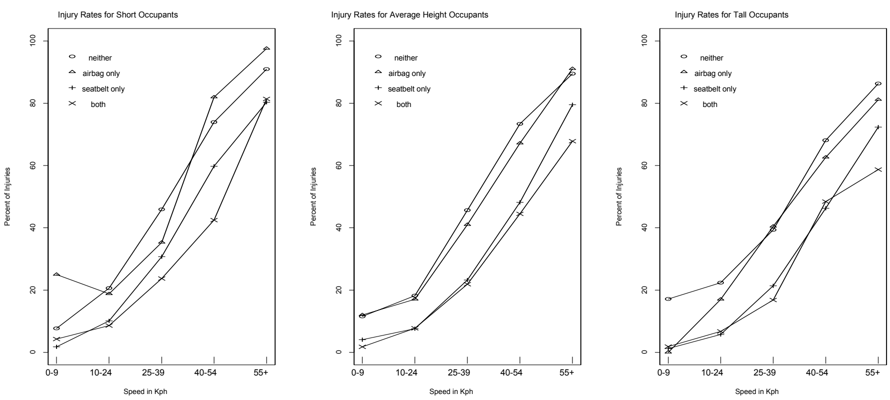


Figure 3.19: Injury Rates by Occupant Height



For both fatality and injury, there seems to be a height effect, indicating that the taller the occupant is the less chance they have for death or injury. For fatality, the airbag seems to be more effective for the medium height individuals. For the shorter and taller occupants the airbag seems to indicate a higher rate of death. For injury, the airbag seems to be more effective for the medium and tall occupants. These results are expected, since airbags were originally designed for the 5'8" (173cm) male, which is within the medium height occupants.

The last variable being investigated is occupant weight. Weight ranged from 31 kg to 150 kg (approximately 68 to 330 pounds). The lighter category referred to occupants who weighed in the lower quartile range. These weights were less than 63kg, which translates into approximately 138lbs. The average category comprised of the middle range. These weights ranged from 63-86kg, which translates to between 139 and 191lbs. The heavier category was comprised of the upper quartile range. These weights ranged from 87-150kg, which translates from approximately 192 to 330lbs. Vehicle body type was plotted over speed for the various airbag and seatbelt combinations to look for possible interactions. For the lighter occupants it was found that 210 out of 6,354 occupants were killed (approximately 3%) while 1,530 were injured (approximately 24%). For the average weight occupants it was found that 593 out of 13,294 were injured (approximately 4%) while 3,292 were killed (approximately 25%). For the heavier weight occupants, it was found that 326 out of 5,595 were killed (approximately 6%) while 1,532 were injured (approximately 27%). There is a slight difference in injury rates suggesting that weight could be a predictor of injury and fatality outcomes.

Table 3.21: Estimating the Number of Fatalities that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Weight

	With Seatbelt			Without Seatbelt		
Occupant Weight	With Airbag	Without Airbag	No. of Fatalities that could have been prevented	With Airbag	Without Airbag	No. of Fatalities that could have been prevented
Lighter	34/2520 ≈ 0.0135	56/1774 ≈ 0.0316	32 0.0181 (57.28%↓)	37/595 ≈ 0.0622	83/1465 ≈ 0.0567	-8 -0.0055 (9.70%↑)
Average	95/4865 ≈ 0.0195	100/3695 ≈ 0.0271	28 0.0076 (28.04%↓)	103/1379 ≈ 0.0747	295/3355 ≈ 0.0879	44 0.0132 (15.02%↓)
Heavier	50/2019 ≈ 0.0248	43/1468 ≈ 0.0293	6 0.0045 (15.36%↓)	68/689 ≈ 0.0987	165/1419 ≈ 0.1183	25 0.0196 (16.57%↓)

Table 3.22: Estimating the Number of Injuries that Could Have Prevented for Airbag Availability by Seatbelt Usage and Occupant Weight

	With Seatbelt			Without Seatbelt		
Occupant Weight	With Airbag	Without Airbag	No. of Injuries that could have been prevented	With Airbag	Without Airbag	No. of Injuries that could have been prevented
Lighter	382/2520 ≈ 0.1516	389/1774 ≈ 0.2193	120 0.0677 (30.87%↓)	209/595 ≈ 0.3513	550/1465 ≈ 0.3754	35 0.0241 (6.42%↓)
Average	755/4865 ≈ 0.1552	680/3695 ≈ 0.1840	107 0.0288 (15.65%↓)	473/1379 ≈ 0.3430	1364/3355 ≈ 0.4125	233 0.0695 (16.85%↓)
Heavier	343/2019 ≈ 0.1699	281/1468 ≈ 0.1914	32 0.0215 (11.23%↓)	257/689 ≈ 0.3730	651/1419 ≈ 0.4588	122 0.0858 (18.70%↓)

Using the tables above, one can clearly see that the airbag with the seatbelt tends to be more effective for the lighter the occupant is. Without a seatbelt the trend is reversed with the greatest effectiveness for the heavier the occupant is. To better see these interactions, weight was plotted over speed for the various airbag and seatbelt combinations to look for possible interactions.

Figure 3.20: Fatality Rates by Occupant Weight

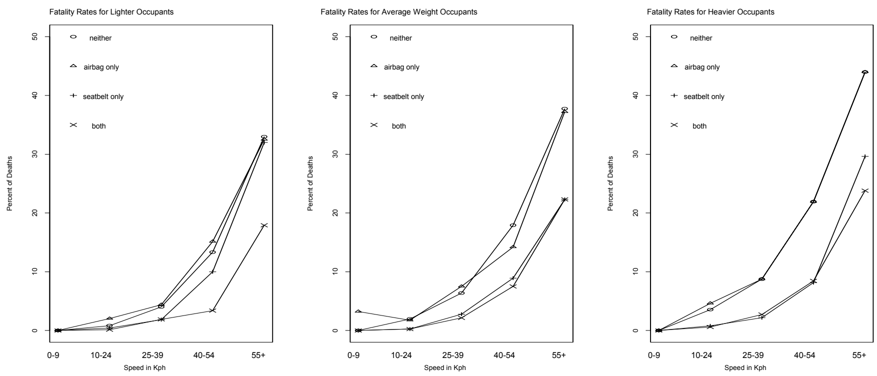
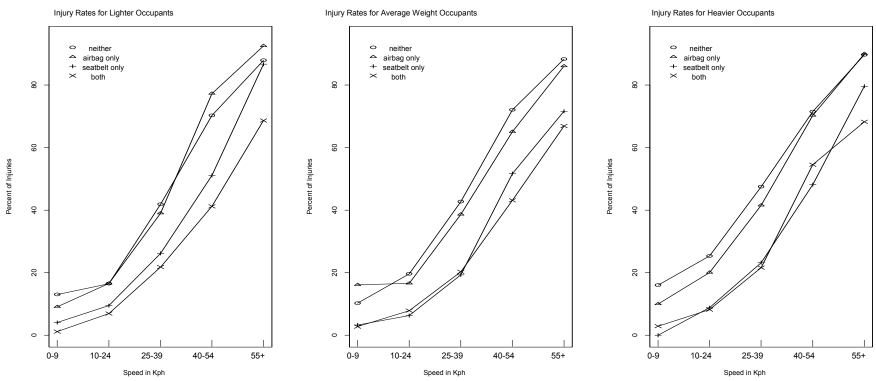


Figure 3.21: Injury Rates by Occupant Weight

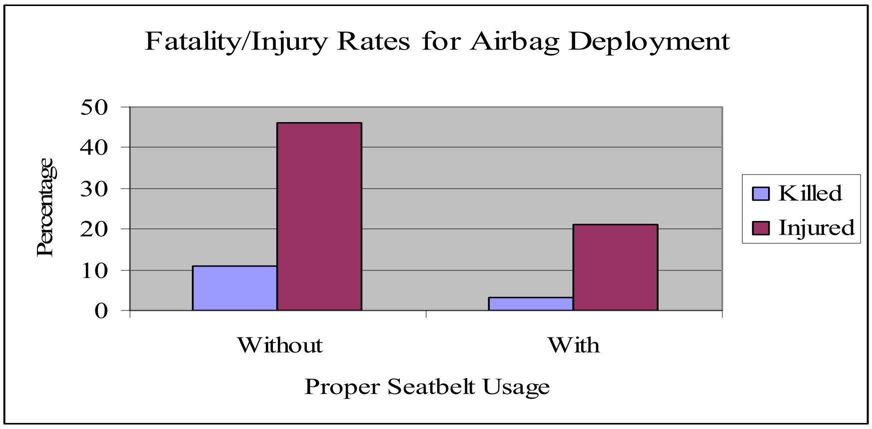


Looking at fatality rates, average weight occupants seem to be the only groups that an airbag seems to help. For injury, it was found that the higher speeds airbags were less effective for the lighter weight occupants than for the average and heavier weight occupants. This again is expected since airbags were designed for the 5'8" 180 lb (82 kg) male, which is covered in the average weight group.

This is not the end, however. Airbag presence is not the only step in evaluating airbags. Once an occupant has an airbag, the issue of airbag deployment comes into play. Therefore, airbag deployment rates must also be investigated. In all, there were

30,476 occupants who had airbags available to them. 16,164 of these occupants had their airbags deploy (approximately 53%). Of the 16,164 occupants 853 were killed (approximately 5%) and 4,565 were injured (approximate 28%). Airbag deployment was looked at along with proper seatbelt use. It showed that:

Figure 3.22: Fatality/Injury Rates for Airbag Deployment



Fatality and injury rates seem to drop dramatically with proper seatbelt use. But how does airbag deployment rates compare to airbag without deployment rates?

Table 3.23: Estimating the Number of Preventable Fatalities with Airbag Deployment by Seatbelt Usage

With Seatbelt			Without Seatbelt		
Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
260/9321 ≈ 0.0279	140/8713 ≈ 0.0161	-16 -0.0118 (73.29%↑)	381/3463 ≈ 0.1100	188/2189 ≈ 0.0859	-53 -0.0241 (28.06%↑)

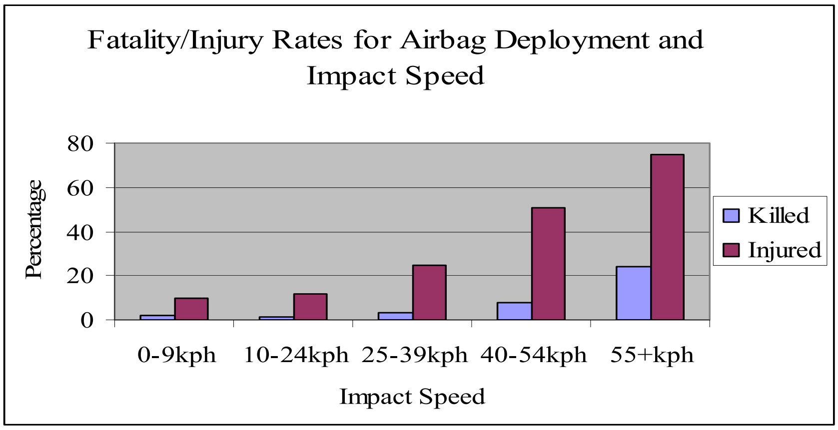
Table 3.24: Estimating the Number of Preventable Injuries with Airbag Deployment by Seatbelt Usage

With Seatbelt			Without Seatbelt		
Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
2003/9321 ≈ 0.2149	881/8713 ≈ 0.1011	-991 -0.1138 (112.56%↑)	1580/3463 ≈ 0.4563	725/2189 ≈ 0.3312	-273 -0.1251 (37.77%↑)

Looking at the calculations above, it seems to contradict the previous figure. Here, it seems as though airbag deployment causes less death and injury without proper seatbelt use that with.

Airbag deployment rates were then looked at with regard to impact speed. These results were very similar results with regard to airbag presence and speed.

Figure 3.23: Fatality/Injury Rates for Airbag Deployment and Impact Speed



Here one can also see that the higher the speed the more likely an occupant is to be killed or injured. But are these consistent with the estimates?

Table 3.25: Estimating the Number of Preventable Fatalities with Airbag Deployment by Seatbelt Usage and Impact Speed

	With Seatbelt			Without Seatbelt		
Speed	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
0-9	0/88 ≈ 0	0/370 ≈ 0	0 0 (no change)	2/17 ≈ 0.1176	1/56 ≈ 0.0179	-6 -0.0997 (556.98%↑)
10-24	40/3379 ≈ 0.0118	11/3088 0.0036 ≈	-25 -0.0082 (227.78%↑)	49/831 ≈ 0.0590	18/683 ≈ 0.0264	-22 -0.0326 (123.48%↑)
25-39	36/2221 ≈ 0.0162	20/854 ≈ 0.0234	6 0.0072 (30.77%↓)	45/801 ≈ 0.0562	13/269 ≈ 0.0483	-2 -0.0079 (16.36%↑)
40-54	45/675 ≈ 0.0667	18/152 ≈ 0.1184	8 0.0517 (43.67%↓)	66/318 ≈ 0.2075	15/67 ≈ 0.2239	1 0.0164 (7.32%↓)
55+	9/270 ≈ 0.0333	17/48 ≈ 0.3542	15 0.3209 (90.60%↓)	19/184 ≈ 0 0.1083	7/20 ≈ 0.3500	5 0.2467 (69.06%↓)

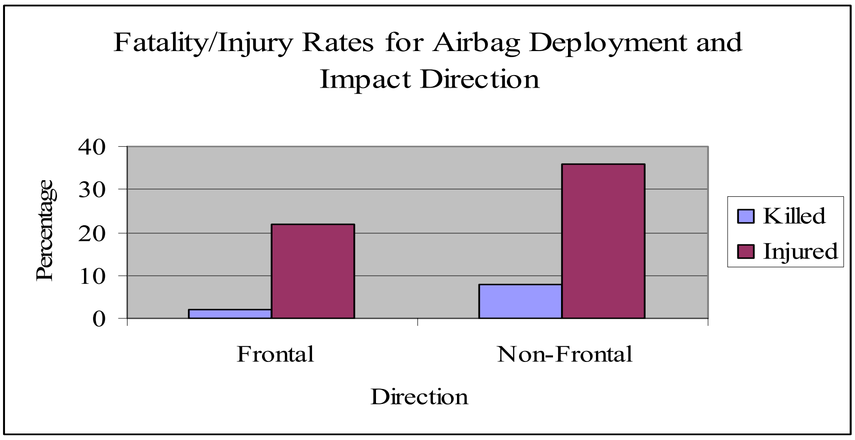
Table 3.26: Estimating the Number of Preventable Injuries with Airbag Deployment by Seatbelt Usage and Impact Speed

	With Seatbelt			Without Seatbelt		
Speed	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
0-9	6/88 ≈ 0.0682	4/370 ≈ 0.0108	-21 -0.0674 (531.48%↑)	4/17 ≈ 0.2353	5/56 ≈ 0.0118	-8 -0.2235 (18.94%↑)
10-24	328/3379 ≈ 0.0971	157/3088 ≈ 0.0508	-143 -0.0463 (91.14%↑)	158/831 ≈ 0.1901	102/683 ≈ 0.1493	-28 -0.0408 (27.33%↑)
25-39	451/2221 ≈ 0.2031	174/854 ≈ 0.2037	1 0.0006 (0.29%↓)	311/801 ≈ 0.3883	102/269 ≈ 0.3792	-2 -0.0091 (2.40%↑)
40-54	298/675 ≈ 0.4415	69/152 ≈ 0.4539	2 0.0124 (2.73%↓)	212/318 ≈ 0.6667	42/67 ≈ 0.6269	-3 -0.0398 (6.35%↑)
55+	178/270 ≈ 0.6593	31/48 ≈ 0.6458	-1 -0.0135 (2.09%↑)	160/184 ≈ 0.8696	17/20 ≈ 0.8500	0 -0.0196 (2.30%↑)

Looking at the tables above, one can see that with proper seatbelt use airbag deployment helps to decrease both fatality and injury rates; while without proper seatbelt use, airbag deployments seems to not have a protective effect.

Airbag deployment rates then looked at with impact direction. It was found that 6,772 out of 8,425 occupants had their airbag deploy in frontal impacts (approximately 80%), while only 1,728 out of 5,346 occupants had their airbag deploy in non-frontal impacts (approximately 32%). Looking at their fatality and injury rates, the following was found:

Figure 3.24: Fatality/Injury Rates for Airbag Deployment and Impact Direction



Here one can see that there is quite a strong relationship with deployment and direction. Frontal impacts seem to have significantly reduced fatality and injury rates. But are these consistent with the estimates?

Table 3.27: Estimating the Number of Preventable Fatalities with Airbag Deployment by Seatbelt Usage and Impact Direction

	With Seatbelt			Without Seatbelt		
Direction	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Front	60/5128 ≈ 0.0117	4/1359 ≈ 0.0029	-12 -0.0088 (303.45%↑)	104/1644 ≈ 0.0633	6/294 ≈ 0.0204	-13 -0.0429 (210.29%↑)
Non-Front	70/268 ≈ 0.0552	62/2883 ≈ 0.0215	-98 -0.0337 (156.74%↑)	76/460 ≈ 0.1652	47/735 ≈ 0.0639	-75 -0.1613 (158.83%↑)

Table 3.28: Estimating the Number of Preventable Injuries with Airbag Deployment by Seatbelt Usage and Impact Direction

	With Seatbelt			Without Seatbelt		
Direction	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Front	866/5128 ≈ 0.1689	51/1359 ≈ 0.0375	-179 -0.1314 (350.40%↑)	587/1644 ≈ 0.3571	45/294 ≈ 0.1531	-60 -0.2040 (133.25%↑)
Non-Front	379/1268 ≈ 0.2989	375/2883 ≈ 0.1301	-487 -0.1688 (129.75%↑)	249/460 ≈ 0.5413	219/735 ≈ 0.2980	-179 -0.2433 (81.64%↑)

Here again, contrary results were found between the tables and figure above. Here it seems as though airbag deployment in frontal impacts lead to higher fatality and injury rates, but it should also be remembered that most of the impacts were frontal- hence the higher rates. To get a further look at these relationships, fatality and injury rates were plotted by impact direction and speed.

Figure 3.25: Airbag Deployment Fatality Rates by Impact Direction

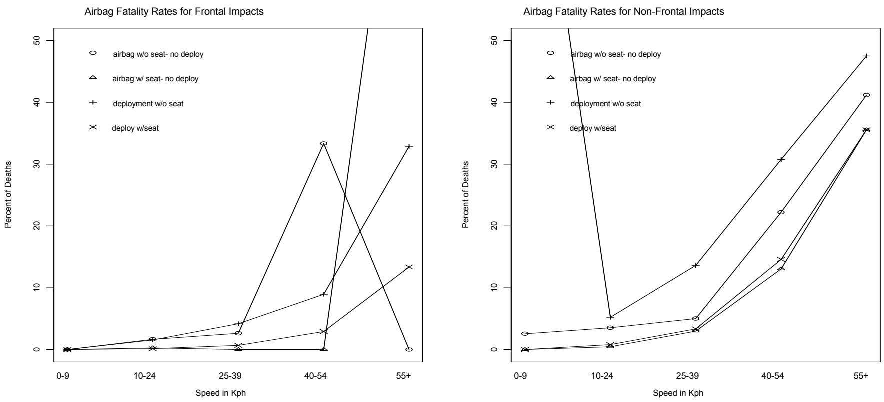
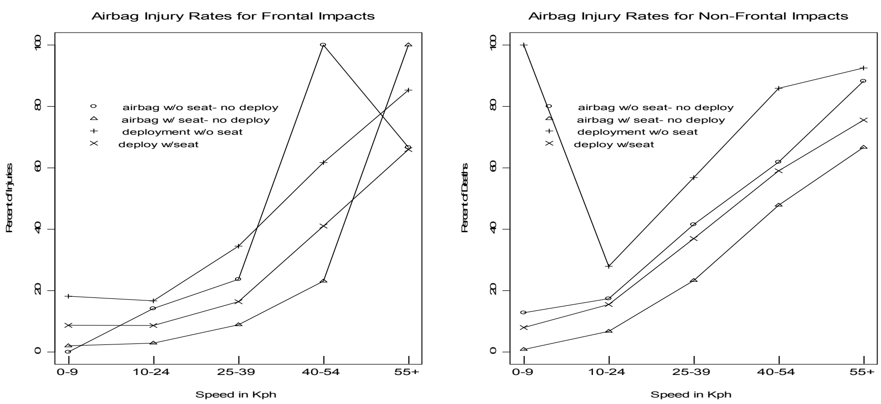


Figure 3.26: Airbag Deployment Injury Rates by Impact Direction



Looking at these figures, it can clearly be seen airbag deployments rates are lower for frontal impacts than for non-frontal impacts. For injury, airbag deployments rates with and without proper seatbelt use seem to be slightly higher for non-frontal impacts, although, they are very similar.

Next, airbag deployment was looked at with regard to vehicle body type. It was found that 6,571 out 10,332 car occupants had their airbags deploy (approximately 64%), while 1,247 out of 2,172 truck occupants had their airbags deploy (approximately 57%) and 682 out of 1,267 utility vehicle occupants had their airbags deploy (approximately 54%). Of these deployments, it was found that for cars, 4% were killed and 25% were injured, trucks, 3% were killed and 21% injured, and utility vehicles, 2% were killed and 21% injured. But how does that translate to number of fatalities and injuries?

Table 3.29: Estimating the Number of Fatalities that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Vehicle Body Type

	With Seatbelt			Without Seatbelt		
Vehicle Body Type	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Car	109/4875 ≈ 0.0224	60/2962 ≈ 0.0203	-6 -0.0021 (10.34%↑)	150/1696 ≈ 0.0884	39/799 ≈ 0.0488	-32 -0.0396 (81.15%↑)
Truck	15/961 ≈ 0.0156	5/764 ≈ 0.0065	-7 -0.0091 (140.00%↑)	22/286 ≈ 0.0769	7/161 ≈ 0.0435	-5 -0.0334 (76.78%↑)
Utility	6/560 ≈ 0.0107	1/516 ≈ 0.0019	-5 -0.0088 (463.16%↑)	8/122 ≈ 0.0656	7/69 ≈ 0.1014	2 0.0358 (35.31%↓)

Table 3.30: Estimating the Number of Injuries that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Vehicle Body Type

	With Seatbelt			Without Seatbelt		
Vehicle Body Type	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Car	1008/4875 ≈ 0.2068	343/2962 ≈ 0.1158	-270 -0.0910 (78.58%↑)	665/1696 ≈ 0.3921	201/799 ≈ 0.2516	-112 -0.1405 (55.84%↑)
Truck	149/961 ≈ 0.1550	59/764 ≈ 0.0772	-59 -0.0778 (100.78%↑)	119/286 ≈ 0.4161	34/161 ≈ 0.2112	-33 -=0.2049 (97.02%↑)
Utility	88/560 ≈ 0.1571	24/516 ≈ 0.0465	-57 -0.1106 (237.85%↑)	52/122 ≈ 0.4263	29/69 ≈ 0.4203	0 -0.0660 (1.43%↑)

It was found that for both fatality and injury the highest effective rate for airbag deployment was for car provided that they had proper seatbelt use. Without proper seatbelt use, cars became the least effective group for airbag deployment fatality, while trucks and cars became the least effective group for injury. To get a further look at these relationships, fatality and injury rates were plotted by vehicle body type.

Figure 3.27: Airbag Deployment Fatality Rates by Vehicle Body Type

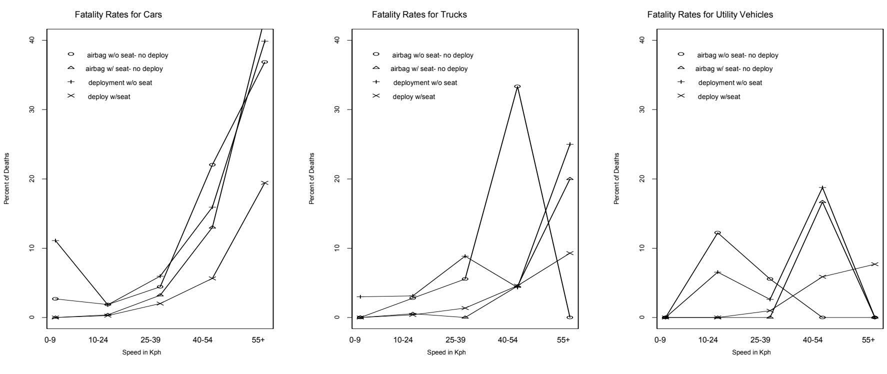
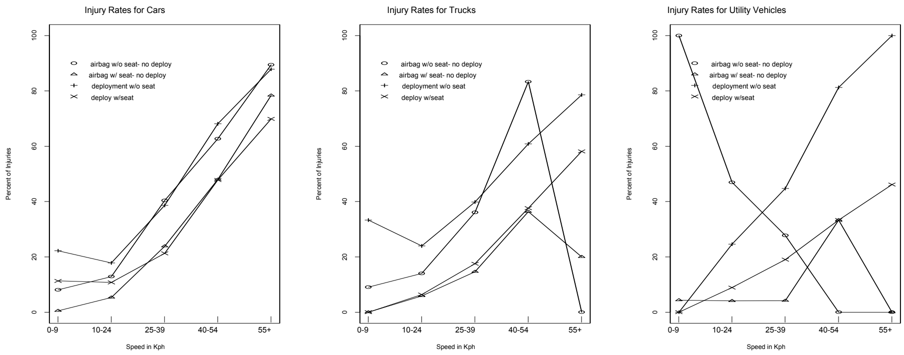


Figure 3.28: Airbag Deployment Injury Rates by Vehicle Body Type



These graphs show interactions between airbag deployment and airbag without deployment regardless of seatbelt use alternating as the highest rates for injury.

Airbag deployment was next investigated by occupant role. It was found that 7,138 out of 11,319 drivers had their airbag deploy (approximate 84%) while only 1,362 out of 2,452 passenger had their airbag deploy (approximately 16%). For airbag deployments, it was also found that for drivers 3% were killed and 24% injured, and for passengers 5% were killed and 26% were injured. Does this mean that deploying airbags work better for drivers than passengers?

Table 3.31: Estimating the Number of Fatalities that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Role

	With Seatbelt			Without Seatbelt		
Role	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Driver	98/5397 ≈ 0.0182	48/3402 ≈ 0.0141	-14 -0.0041 (29.08%↑)	150/1742 ≈ 0.0862	38/779 ≈ 0.0488	-29 -0.0374 (76.64%↑)
Passenger	32/999 ≈ 0.0320	18/840 ≈ 0.0214	-9 -0.0106 (49.53%↑)	30/363 ≈ 0.0826	15/250 ≈ 0.0600	-6 -0.0226 (37.67%↑)

Table 3.32: Estimating the Number of Injuries that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Role

	With Seatbelt			Without Seatbelt		
Role	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Driver	1038/5397 $\approx$ 0.1923	338/3402 $\approx$ 0.0994	-316 -0.0924 (93.46%$\uparrow$)	694/1742 $\approx$ 0.3986	209/779 $\approx$ 0.2683	-101 -0.1303 (48.57%$\uparrow$)
Passenger	207/999 $\approx$ 0.2070	88/840 $\approx$ 0.1048	-86 -0.1024 (97.71%$\uparrow$)	142/363 $\approx$ 0.3912	55/250 $\approx$ 0.2200	-43 -0.1712 (77.82%$\uparrow$)

For fatality, it was found that airbag deployment is more effective for drivers with proper seatbelt use and for passengers without proper seatbelt use. For injury, airbag deployment was lower for the driver regardless of seatbelt use- indicating that passengers at more at risk when it comes to airbag deployment. To further investigate these relationships, fatality and injury rates were plotted by occupant role over speed.

Figure 3.29: Airbag Deployment Fatality Rates by Occupant Role

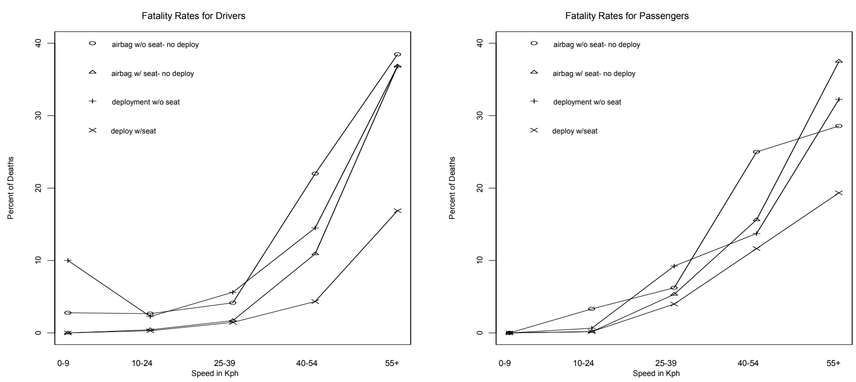
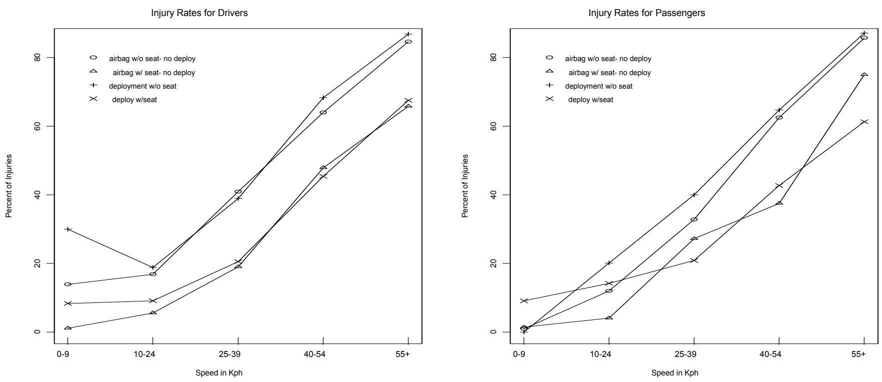


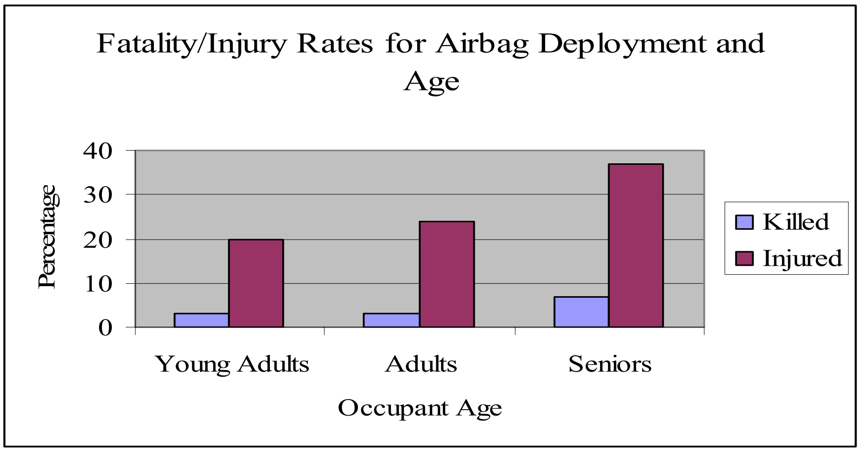
Figure 3.30: Airbag Deployment Injury Rates by Occupant Role



These plots show that for fatality, airbag deployment with proper seatbelt use is highly effective for both drivers and passenger, but more so for drivers. For injury, there is interaction between airbags deployed and airbags not deployed, not really giving a clear picture.

Occupant age also showed a relationship with airbag deployment rates. It was found that 3,655 out of 5,589 young adults had their airbags deploy (approximately 43%), while 3,368 out of 5,5657 adults had their airbags deploy (approximately 40%), but only 1,477 out of 2,525 senior occupants had their airbags deploy (approximately 17%). By looking at their injury and fatality rates it showed that:

Figure 3.31: Fatality/Injury Rates for Airbag Deployment and Occupant Age



Seniors are much more likely to be injured and perhaps killed than young adults and adults.

Table 3.33: Estimating the Number of Fatalities that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Age

	With Seatbelt			Without Seatbelt		
Occupant Age	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Young Adult	28/2616 ≈ 0.0107	16/1490 ≈ 0.0107	0 0 (no change)	73/4169 ≈ 0.0703	23/444 ≈ 0.0518	-8 -0.0185 (35.71%↑)
Adult	47/2610 ≈ 0.0180	14/1915 ≈ 0.0073	-20 -0.0107 (146.58%↑)	61/758 ≈ 0.0805	15/374 ≈ 0.0401	-15 -0.0404 (100.75%↑)
Senior	55/1170 ≈ 0.0470	36/837 ≈ 0.0430	-3 -0.0040 (9.30%↑)	46/307 ≈ 0.1498	15/211 ≈ 0.0711	-17 -0.0787 (110.69%↑)

Table 3.34: Estimating the Number of Injuries that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Age

	With Seatbelt			Without Seatbelt		
Occupant Age	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Young Adult	381/2616 ≈ 0.1456	119/1490 ≈ 0.0797	-98 -0.065 (82.69%↑)	358/4169 ≈ 0.3446	105/444 ≈ 0.2365	-48 -0.1081 (45.71%↑)
Adult	489/2610 ≈ 0.1874	157/1915 ≈ 0.0828	-202 -0.1046 (126.33%↑)	310/758 ≈ 0.4090	90/374 ≈ 0.2406	-63 -0.1684 (69.99%↑)
Senior	375/1170 ≈ 0.3205	150/837 ≈ 0.1792	-118 -0.1413 (78.85%↑)	168/307 ≈ 0.5472	69/211 ≈ 0.3270	-46 -0.2202 (67.34%↑)

Looking at these estimates, they indicate that for both fatality and injury adults are more likely to be killed/injured with airbag deployment with proper seatbelt use and without proper seatbelt both adults and seniors are the most likely to be killed/injured. To get a further look at the relationships, fatality and injury rates were plotted by occupant age over speed.

Figure 3.32: Airbag Deployment Fatality Rates by Occupant Age

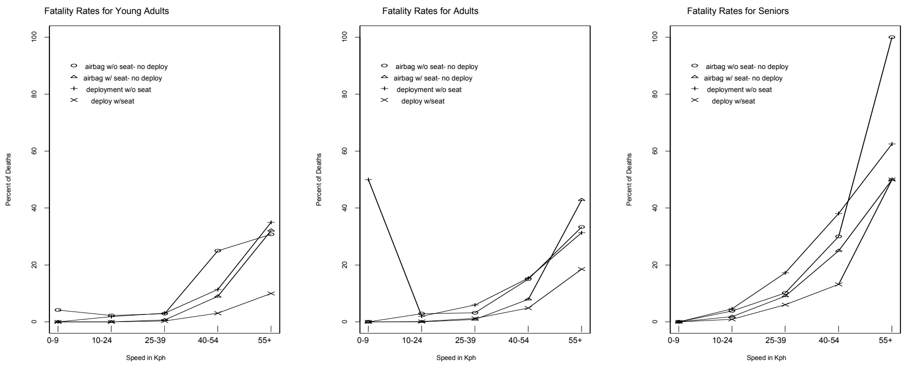
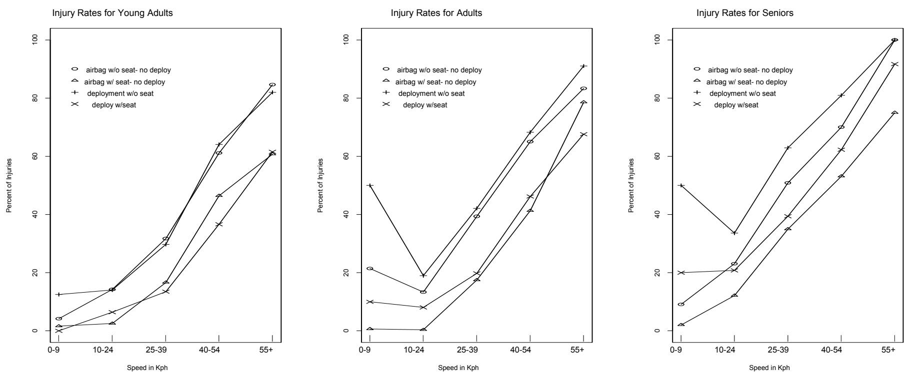


Figure 3.33: Airbag Deployment Injury Rates by Occupant Age



By looking at the plots above, it can clearly be seen that seniors have higher risk rates for both fatality and injury. For fatality, it can be seen that airbag deployment with seatbelt is the best course for reducing death rates; while, for injury, being belted without a deploying airbag is better, especially for adults and seniors.

Airbag deployment was also looked at along with occupant gender. It was found that 4,246 out of 6,690 male occupants had their airbags deploy (approximately 63%) and 4,249 out of 7,075 female occupants had their airbag deploy (approximately 60%). For airbag deployments, it was also found that for males 4% were killed and 24% injured while for females 3% were killed and 25% were injured. To try to determine if airbag deployment was better for one gender than the other estimates were calculated.

Table 3.35: Estimating the Number of Fatalities that Could Have Prevented with an Airbag Deployment by Seatbelt Usage and Occupant Gender

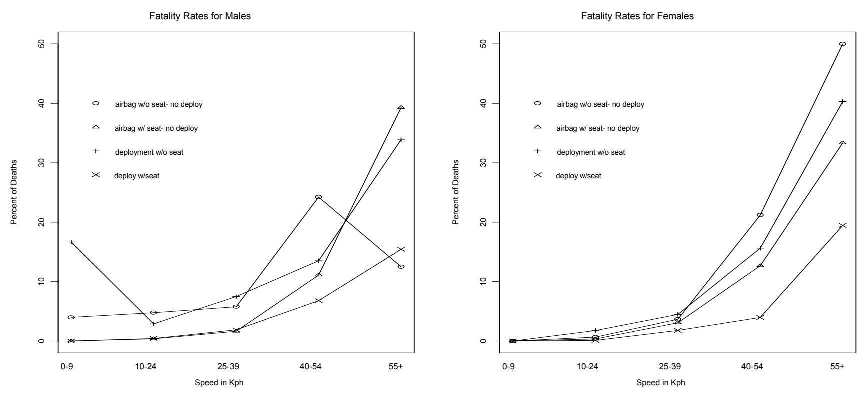
	With Seatbelt			Without Seatbelt		
Gender	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Male	73/3064 ≈ 0.0238	30/1922 ≈ 0.0156	-16 -0.0082 (52.56%↑)	113/1180 ≈ 0.0958	33/522 ≈ 0.0632	-17 -0.0326 (51.58%↑)
Female	57/3325 ≈ 0.0171	36/2319 ≈ 0.0155	-4 -0.0016 (10.32%↑)	67/924 ≈ 0.0725	20/507 ≈ 0.0394	-17 -0.0331 (84.01%↑)

Table 3.36: Estimating the Number of Injuries that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Gender

	With Seatbelt			Without Seatbelt		
Gender	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Male	545/3064 ≈ 0.1778	178/1922 ≈ 0.0926	-164 -0.0852 (92.01%↑)	459/1180 ≈ 0.3890	144/522 ≈ 0.2759	-59 -0.1131 (40.99%↑)
Female	699/3325 ≈ 0.2102	248/2319 ≈ 0.1069	-229 -0.1033 (96.63%↑)	377/924 ≈ 0.4080	120/507 ≈ 0.2367	-87 -0.1713 (72.37%↑)

For fatality, it seems that airbag deployment is most effective for females with proper seatbelt use and most effective for males without proper seatbelt use. For injury, the highest effectiveness rates for were males regardless of seatbelt use. To get a further look at the relationships, fatality and injury rates were plotted by occupant gender over speed.

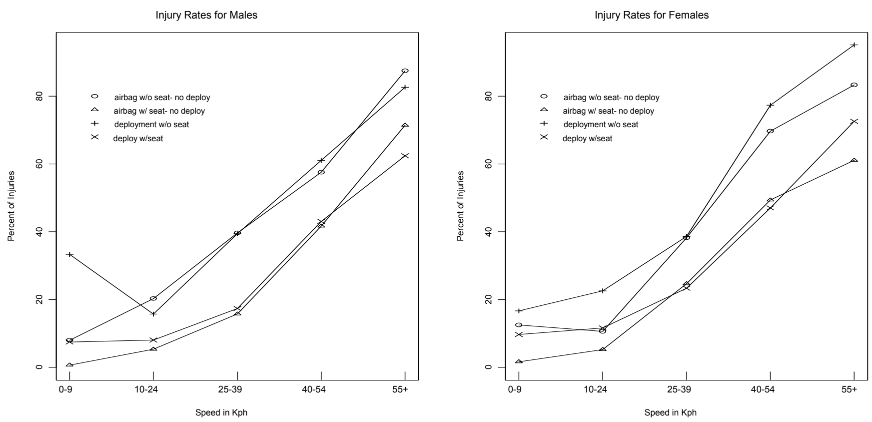
Figure 3.34: Airbag Deployment Fatality Rates by Occupant Gender



Looking at these plots, again it is seen that airbag deployments are oscillating with airbag without deployment regardless of seatbelt use- not giving a clear picture.

Airbag deployment was also looked at with occupant height. It was found that 1,999 out of 3,311 short occupant had their airbag deploy (approximately 60%),

Figure 3.35: Airbag Deployment Injury Rates by Occupant Gender



3,080 out of 5,087 of the medium height occupant had their airbag deploy (approximately 61%) and that 2,280 out of 3,649 tall occupants had their airbag deploy (approximately 62%). Of these deployments, it was found that approximately 4% of the shorter occupants were killed and 26% were injured. Approximately 3% of the medium height occupants were killed 26% were injured. And approximately 4% of the tall occupants were killed and 23% were injured. But how does this translate to airbag deployment effectiveness?

Table 3.37: Estimating the Number of Fatalities that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Height

	With Seatbelt			Without Seatbelt		
Occupant Height	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Shorter	34/1569 ≈ 0.0217	13/1079 ≈ 0.0120	-10 -0.0092 (80.83%↑)	48/430 ≈ 0.1116	7/233 ≈ 0.0300	-19 -0.0816 (272.00%↑)
Medium	53/2369 ≈ 0.0224	28/1626 ≈ 0.0172	-8 -0.0052 (30.23%↑)	49/711 ≈ 0.0689	19/381 ≈ 0.0499	-7 -0.0190 (38.08%↑)
Tall	32/720 ≈ 0.0444	18/1082 ≈ 0.0166	-30 -0.0278 (167.47%↑)	65/621 ≈ 0.1047	20/287 ≈ 0.0697	-10 -0.0350 (50.22%↑)

Looking at these estimates, it can be seen that for both fatality and injury, airbag deployment with proper seatbelt use if more effective for medium height occupants, while without proper seatbelt use it is more effective for medium to tall occupants. To get a further look at the relationships, fatality and injury rates were plotted by occupant height and impact speed.

Figure 3.36: Airbag Deployment Fatality Rates by Occupant Height

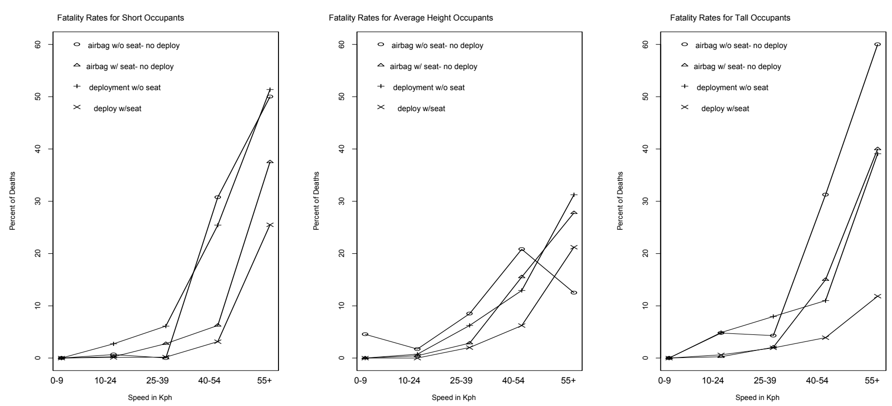


Table 3.38: Estimating the Number of Injuries that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Height

	With Seatbelt			Without Seatbelt		
Occupant Height	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Shorter	332/1569 ≈ 0.2116	115/1079 ≈ 0.1068	-113 -0.1050 (98.13%↑)	185/430 ≈ 0.4302	52/233 ≈ 0.2232	-48 -0.2070 (92.74%↑)
Medium	463/2369 ≈ 0.1954	172/1626 ≈ 0.1058	-146 -0.0896 (84.69%↑)	284/711 ≈ 0.3994	100/381 ≈ 0.2625	-52 -0.1369 (52.15%↑)
Tall	293/720 ≈ 0.4069	102/1082 ≈ 0.0943	-338 -0.3126 (331.50%↑)	241/621 ≈ 0.3881	77/287 ≈ 0.2683	-34 -0.1198 (44.65%↑)

Looking at the plots above, however, it can be seen that airbag deployment with proper seatbelt use leads to lower fatality and injury rates for tall occupants.

Airbag deployment was also looked at along with occupant weight. Out of 3,111 of the lighter weight occupants 1,906 of them had their airbag deploy (approximately 61%). For average weight occupants 3,801 out of 6,230 had their airbag deploy (approximately 61%). And for heavier weight occupants 1,652 out of 2,706 (approximately 61%) had their airbag deploy. Of these deployments it was found that 3% of the light, 4% of the average and 5% of the heavier occupants were killed; while 23 of the light, 24% of the average and 28% of the heavier occupants were injured. But how do these relate to airbag deployment effectiveness?

Figure 3.37: Airbag Deployment Injury Rates by Occupant Height

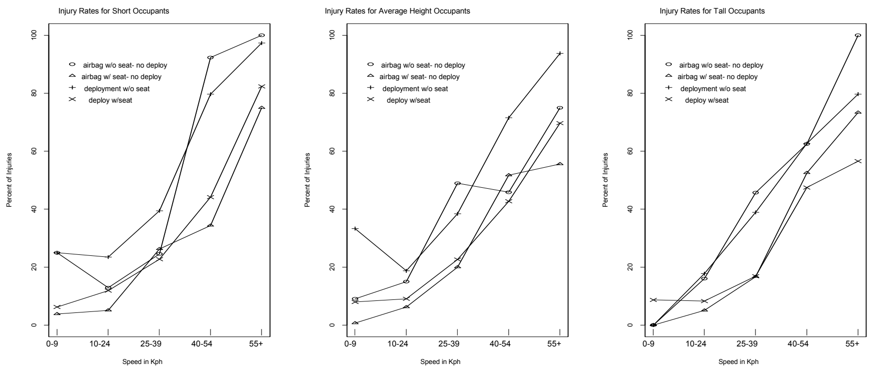


Table 3.39: Estimating the Number of Fatalities that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Weight

	With Seatbelt			Without Seatbelt		
Occupant Weight	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Fatalities that could have been prevented
Lighter	24/1592 ≈ 0.0152	9/1000 ≈ 0.0900	-6 -0.0061 (83.11%↑)	26/390 ≈ 0.0667	11/205 ≈ 0.0537	-3 -0.130 (24.21%↑)
Average	60/2879 ≈ 0.0208	35/1972 ≈ 0.0177	-6 -0.0031 (17.51%↑)	81/922 ≈ 0.0879	22/445 ≈ 0.0481	-17 -0.0398 (82.74%↑)
Heavier	35/1202 ≈ 0.0291	15/815 ≈ 0.0184	-8 -0.0107 (58.15%↑)	55/450 ≈ 0.1222	13/239 ≈ 0.0544	-16 -0.0678 (124.63%↑)

Table 3.40: Estimating the Number of Injuries that Could Have Prevented with Airbag Deployment by Seatbelt Usage and Occupant Weight

	With Seatbelt			Without Seatbelt		
Occupant Weight	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented	Airbag Deployment	Airbag Available, No Deploy	No. of Injuries that could have been prevented
Lighter	353/1592 ≈ 0.2217	103/1000 ≈ 0.1030	-119 -0.1187 (115.24%↑)	158/390 ≈ 0.4051	51/205 ≈ 0.2448	-32 -0.1563 (65.48%↑)
Average	550/;2879 ≈ 0.1910	204/1972 ≈ 0.1034	-173 -0.0876 (84.72%↑)	353/3829 ≈ 0.3829	120/445 ≈ 0.2626	-50 -0.1203 (45.81%↑)
Heavier	261/1202 ≈ 0.2171	82/815 ≈ 0.1006	-95 -0.1165 (115.81%↑)	199/450 ≈ 0.4422	58/239 ≈ 0.2427	-48 -0.1995 (82.20%↑)

Looking at the estimates above, one can see that for with proper seatbelt use, fatalities are best prevented for average and heavier weight occupants, while without proper seatbelt use, fatalities are best for lighter weight occupants. For injury, again with proper seatbelt use airbag deployment was more effective for average weight occupants, while without proper seatbelt use it is more effective for the lighter to average weight occupants. To get a further look at the relationships, fatality and injury rates were plotted by occupant weight with speed.

Here again, it is noted that airbag deployment alternates with airbag without deployment giving an unclear picture as to whether or not an occupant is better of with airbag deployment.

For further information regarding the variables and how they were determined from the data please refer to Appendix A.

Figure 3.38: Airbag Deployment Fatality Rates by Occupant Weight

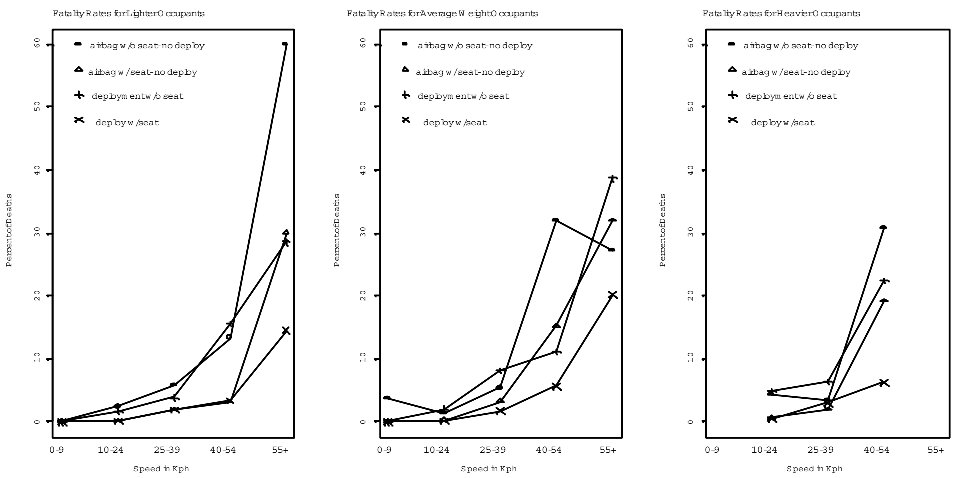
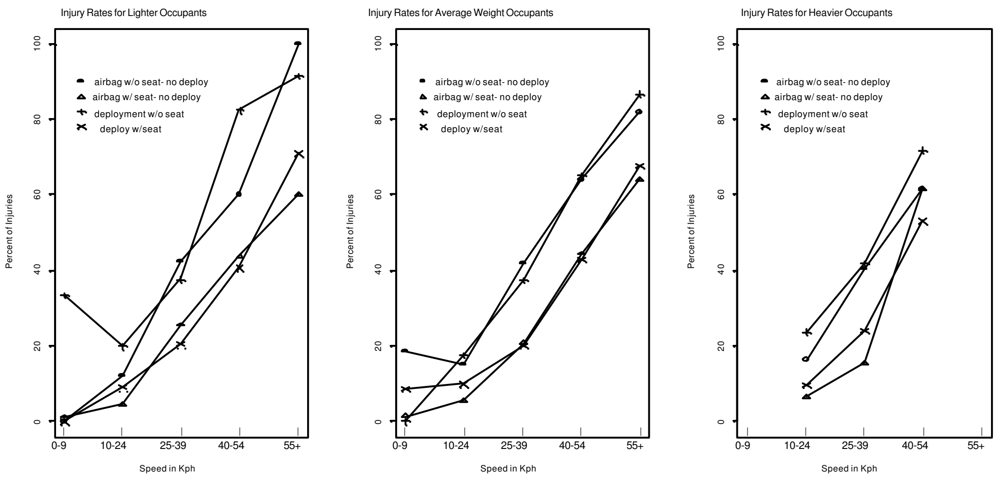


Figure 3.39: Airbag Deployment Injury Rates by Occupant Weight



Chapter 4

Model Building Process

Before starting the process of building a model, one must have a plan before conducting the analysis. The first part of the plan consists of looking at the data. This helps to determine the type of analysis that needs to be conducted. In this case, since the response variables are categorical, either injured/not injured or fatal/not fatal, a logistic regression analysis is called for. This analysis has eleven variables: airbag availability, airbag deployment, seatbelt usage, vehicle impact speed, the direction of impact, vehicle body type, the occupant's role, age, gender, height and weight. This analysis, however, must also look at the interactions between these variables. Taking into account all of these interactions, there are over a thousand different combinations of variables that could belong to a model (complete variable list listed in Appendix B). Because of this, there are a several different models that could be used to predict injury and/or fatality outcomes. So, the second part of the plan consists of how one builds the model(s). Here there are several different routes that can be taken.

For this analysis, it was decided to use the main effects, all of the two-way interactions, some of the three-way interactions, as suggested by the plots and/or research. The method decided to be used for building the model was a backwards process conducting using SAS. The process of this method starts off with an initial model containing all of the variables. The model is then reduced one variable at a time to eliminate all insignificant variables. So, before analysis can be conducted, a level of significance must be decided upon. The level of significance chosen for the process was alpha equal to 0.01. This is to make sure that all results found are truly relevant in predicting injury and fatality outcomes. So, one by one variables are eliminated that do not meet the significance level. This continues until the model contains only variables that are deemed significant.

Using this process, a model was built to predict fatality outcomes. The results were as follows:

Table 4.1: Fatality Model

Parameter	Estimate	Pr > ChiSq
Intercept	-3.9524	<0.0001
Airbag (yes)	-0.2041	0.0010
Deploy (yes)	0.2588	0.0004
Speed (0-9kph)	-5.9248	<0.0001
Speed (25-39kph)	0.8110	0.0002
Speed (40-54kph)	2.1938	<0.0001
Speed (55+kph)	3.6305	<0.0001
Sex (female)	-0.1004	0.0144
Age (adult)	-0.2734	0.0002
Age (senior)	1.0039	<0.0001
Role (passenger)	0.1265	0.0028
Weight (lighter)	-0.1882	0.0037
Weight (heavier)	0.2787	<0.0001
Deploy*direction (yes front)	-0.1078	0.0088
Seatbelt*speed (yes 0-9kph)	2.2571	<0.0001
Seatbelt*speed (yes 25-39kph)	-0.5530	<0.0001
Seatbelt*speed (yes 40-54kph)	-0.4951	<0.0001
Seatbelt*speed (yes 55+kph)	-0.2753	0.0003
Seatbelt*direction (yes front)	-0.1182	0.0022
Speed*direction (0-9kph front)	2.2751	<0.0001
Speed*direction (25-39kph front)	-0.6745	<0.0001
Speed*direction (40-54kph front)	-0.7258	<0.0001
Speed*direction (55+kph front)	-0.4320	<0.0001
Direction*age (front senior)	0.1803	0.0006
Sex*height (female short)	-0.2639	<0.0001
Sex*height (female tall)	0.3435	<0.0001
Role*age (passenger senior)	0.2538	<0.0001
Deploy*seatbelt*role (yes yes driver)	-0.2340	0.0043
Airbag*seatbelt*age* (yes no senior)	-0.1867	0.0062

Writing this out, one gets: Log odds (death) = -3.9524 - 0.2041 airbag (yes) + 0.2588 deploy (yes)-2.9248 speed (0-9) + 0.8110 speed (25-39) + 2.1938 speed (40-54) + 3.6305 speed (55 +) - 0.1004 sex (female) - 0.2734 age(adult) + 1.0039 age (senior) + 0.1265 role (passenger) - 0.1882 weight (lighter) + 0.2787 weight (heavier) - 0.1078 deploy*direction (yes front) + 2.2571 seatbelt*speed (yes 0-9) - 0.5530 seatbelt*speed (yes 25-39) - 0.4951 seatbelt*speed (yes 40-54) - 0.2753 seatbelt*speed (yes 55 +) - 0.1182 seatbelt*direction (yes front) + 2.2751 speed*direction (0-9 front) - 0.6745 speed*direction (25-39 front) - 0.7258 speed*direction (40-54 front) - 0.4320 speed*direction (55+ front) + 0.1803 direction*age (front adult) - 0.2639 direction*age (front senior) - 0.2639 sex*height (female short) + 0.3435 sex*height (female tall) + 0.2538 role*age (passenger senior) - 0.2340 deploy*seatbelt*role (yes yes driver) - 0.1867 airbag*seatbelt*age (yes no senior).

To interpret this model, in general, one can look at the coefficients/estimates. If the estimate is positive it indicates an increase for the occupant's chance for death. If the estimate is negative is indicates a decrease for the occupant's chance for death. But to actually get a true interpretation of these results, some calculations need to be done. The first step is to calculation the probability of death. The formula used to do this is: $P\ (\text{death}) = \frac{e^{(\text{intercept + airbag + deploy + ...})}}{1+e^{(\text{intercept + airbag + deploy + ...})}}$. And after calculating these probabilities, the same type of reductions performed previously in the descriptive analysis can be done.

To begin, impact speed will be looked at. Looking at the coefficients for speed, one can see that in general the higher the speed the higher the occupant's chance for death will be. It must also be noted that there is an interaction between impact speed and seatbelt use. With proper seatbelt use, it can be seen that for all speed greater than 25kph, an occupant's chance for death decreases slightly. An interaction can also be seen between seatbelt use and frontal impacts. This has a negative estimate, so, this indicates that an occupant in a frontal impact with a seatbelt has an even lesser chance for death than a non-frontal impact.

Next, the impact speed will be controlled to illustrate how an airbag interacts with impact direction and seatbelt use. Picking a scenario will help to show how the interaction works between the two variables. So now, the scenario is a young adult male driver with medium height average weight traveling between 10 and 24kph.

Table 4.2: Young Adult Driver Occupant in Frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0154	18%	0.0154	18%
Deployed	0.0142	24%	0.0170	10%
None	0.0188		0.0188	

Table 4.3: Young Adult Driver Occupant in Non-Frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0154	18%	0.0154	18%
Deployed	0.0158	16%	0.0200	-6%
None	0.0188		0.0188	

Looking at the tables above is should be noted that the lowest fatality rate for a frontal impact was when the occupant was belted with a deployed airbag. In a non-frontal impacts, the lowest rate of fatality occurred when an occupant was also not belted with a deployed airbag. This shows a slight interaction between proper seatbelt use and airbag deployment. Looking at the percent reduction it becomes clear that a deploying airbag is much effective for frontal than for non-frontal impacts. By comparing the reduction rates, for airbags available but not deployed, one can also see that is no difference it and impact direction and seatbelt usage. This, however, does not really make sense, because how can an airbag prevent fatality if it is just there and does not do anything (deploy)? Well, this is a sign that airbag availability without deployment is measuring something else. This indicates that there is at least one confounding variables that should be controlled for in this analysis. For example, one could use the model year of the vehicle. This could be because before the mandating of airbags into automobiles, an occupant who had on would have been more safety conscious. There are several other possibilities, but they will be discussed later.

Another important aspect to look at is occupant age. So now the scenario will remain the same, as above, except now the driver is a senior instead of a young adult.

Table 4.4: Senior Occupant Driver in Frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0487	18%	0.0407	31%
Deployed	0.0450	24%	0.0562	5%
None	0.0591		0.0591	

Table 4.5: Senior Occupant Driver in Non-frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0410	18%	0.0342	31%
Deployed	0.0420	16%	0.0525	-5%
None	0.0498		0.0498	

Looking here, it should be noted first and foremost that all fatality rates for seniors are higher than the fatality rates for young adults- indicating that seniors are more likely to die than younger aged occupants. It should also be noted that even thought the airbag deployment effectiveness rates are higher in frontal impacts- it must also be noted that all fatality rates are higher for seniors regardless of direction and or airbag/seatbelt use. This indicates an overall increased likelihood for death effect for seniors. It should also be noted that airbag availability, without deployment, has higher effectiveness rates for a seniors without proper seatbelt use.

Passenger interactions were also hard to interpret. To do so, the same scenario used above was used except for now the occupants are passengers instead of drivers.

Table 4.6: Young Adult Passengers in Frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0175	18%	0.0175	18%
Deployed	0.0203	5%	0.0203	5%
None	0.0213		0.0213	

Table 4.7: Young Adult Passengers in Non-frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0175	18%	0.0175	18%
Deployed	0.0225	-6%	0.0225	-6%
None	0.0213		0.0213	

By comparing the same age groups to different roles, it was found that overall passenger fatality rates were higher than for drivers - indicating that passengers if the vehicle are more likely to die than drivers. By comparing airbag deployment effectiveness rates, it was seen that deployment rates for drivers with a seatbelt dropped dramatically for passengers. This illustrates the interaction between a driver with proper seatbelt use and a deploying airbag. A check can also be done to see if there is any interaction between age and role. By comparing percent reduction in separate categories for both age groups, it was noted that the rates were much larger for senior passengers than for young adult passengers. It should also be noted that the airbag available, without deployment, fatality rate increased for seniors without proper seatbelt usage. And this relationship will be investigated for possible confounders. Looking at non-frontal impacts, it can be seen that fatality effectiveness is dramatically less for seniors with airbags available without deployment, but increased for seniors with deployed airbags as opposed to the young adults.

Table 4.8: Senior Passengers in Frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0670	20%	0.0585	30%
Deployed	0.0801	5%	0.0801	5%
None	0.0841		0.0841	

Table 4.9: Senior Passengers in Non-frontal Impact

Airbag Status	Probability of Fatality w/seatbelt	% reduction	Probability of Fatality w/o seatbelt	% reduction
Available, Not Deployed	0.0697	2%	0.0493	31%
Deployed	0.0666	6%	0.0749	-5%
None	0.0712		0.0712	

Other relationships that should be fairly obvious to detect straight from the model are the interaction between occupant gender with height, and the effects of age and weight. The interaction between an occupant's gender and height showed that shorter stature females were less at risk for fatality than male occupants. Medium height females are more likely to be injured than males, but the groups especially at risk are the tall females. Occupant age, illustrated earlier in the tables demonstrated that seniors are more likely to be killed. The negative estimate for adults, however, indicates that they are less likely to die than the other occupants. Weight was also shown to be a significant factor. It showed that lighter weight occupants are less at risk for fatality than average weight occupants, who in turn are less likely than heavier weight occupants to die.

The same process was used to build a model to predict injury outcomes. The results were as follows:

Table 4.10: Injury Model

Parameter	Estimate	Pr > ChiSq
Intercept	-0.3172	<0.0001
Airbag (yes)	-0.3173	<0.0001
Deploy (yes)	0.4254	>0.0001
Seatbelt (yes)	-0.5357	<0.0001
Speed (0-9kph)	-1.8748	<0.0001
Speed (40-54kph)	1.0897	<0.0001
Speed (55+kph)	2.2429	<0.0001
Direction (front)	-0.1762	0.0002
Age (adult)	-0.1627	<0.0001
Age (senior)	0.7300	<0.0001
Sex (female)	0.1043	<0.0001
Weight (heavier)	0.1033	0.0005
Airbag*direction (yes front)	-0.1668	<0.0001
Seatbelt*sex (yes female)	0.0797	<0.0001
Speed*direction (25-39kph front)	-0.1477	0.0034
Direction*age (front senior)	0.1100	0.0001
Direction*sex (front female)	0.1107	<0.0001

Writing this out, one gets: Log odds (injury) = - 0.3172 - 0.3173 airbag (yes) + 0.4254 deploy (yes) - 0.5357 seatbelt (yes) - 1.8748 speed (0-9) + 1.0897 speed (40-54) + 2.2429 speed (55 +) - 0.1762 direction (front) - 0.1627 age(adult) + 0.7300 age (senior) + 0.1043 sex (female) + 0.1033 weight (heavier) - 0.1668 airbag*direction (yes front) +0.0797 seatbelt*sex (yes female) -0.1477 speed*direction (25-39 front) + 0.1100 direction*age (front senior) + 0.1107 direction*sex.

Since this model has some of the same interactions as the fatality model, it should be easier to see the interactions here. Overall, there is a decreasing effect for seatbelt use. This is unless the occupant is a female. Then the seatbelt becomes slightly less effective. Frontal impacts decrease an occupant's chance for injury. The frontal impact is not nearly as effective, though for senior or female occupants. Adults again have a decreased chance for injury than the other occupants. Females are more likely to be injured. This rate of injury is increased especially with proper seatbelt use and in frontal impacts. And heavier weight occupants were also found to be at a higher risk of injury than lighter or average weight occupants.

Airbag rates were calculated and found to be:

Table 4.11: Young Adult Occupant in Frontal Impact

Airbag Status	Probability of Injury w/seatbelt	% reduction	Probability of Injury w/o seatbelt	% reduction
Available, Not Deployed	0.1805	31%	0.2734	28%
Deployed	0.2520	4%	0.3654	4%
None	0.2633		0.3791	

Table 4.12: Young Adult Occupant in Non-Frontal Impact

Airbag Status	Probability of Injury w/seatbelt	% reduction	Probability of Injury w/o seatbelt	% reduction
Available, Not Deployed	0.2368	21%	0.3465	18%
Deployed	0.3223	-8%	0.4479	-6%
None	0.2988		0.4214	

Comparing fatality rates, one can see that all injury rates in frontal impacts are lower than the injury rates for non-frontal impacts- this illustrates the interaction between airbag availability, without deployment, and direction. Looking at the tables above, one can see that an approximate 10% difference between injury rates. Even though airbag deployment did not have a direct interaction with direction, one can see that the same trend exists. And even though there no significant interaction between airbag and seatbelt use, one can see that an airbag's effectiveness is slightly higher with proper use of a seatbelt.

Chapter 5

Conclusion

The main purpose of this analysis was to evaluate whether or not an airbag plays a significant role in predicting fatality and injury outcomes. As part of this evaluation, it was also important to study the relationships between an airbag along with other variables pertaining to certain vehicle and/or personal occupant characteristics to control for possible confounders. Looking at both, the fatality and injury, models several important relationships can be found.

With regard to fatality, several claims were made. The NHTSA has reported that airbag presence reduced fatality rates for driver, even more so for occupants in frontal impacts. The study by Cummings, McKnight, Rivara, and Grossman also found an effect "between airbag presence and direction with a decrease in death for frontal impacts" (2002). In this analysis, it was found that airbag presence, without deployment, did decrease an occupant's chance for death, although it did not have an interaction with impact direction. Looking at the model example of a young adult male driver in frontal and non-frontal impacts, it was found that there was no difference in airbag availability, without deployment, fatality effectiveness rates and impact direction.

Dr. Maria Segui-Gomez' study, which sampled drivers involved in frontal impacts only, claimed that "airbag deployment was associated with statistically significant decrease in the probability of fatal injuries" (2000). This analysis also found the same result. Airbag deployment for drivers had a significant reduction in fatality rates of approximately 8%, using the model example. However, Segui- Gomez' sample consisted of only frontal impacts, showing her only part of the picture. By looking at the scenarios conducted earlier, it is clear that without proper seatbelt use airbag deployment can be more harmful to a driver than not having an airbag available. Results also indicated that airbag deployment effectiveness was not as great for passengers as it was for drivers.

A study by Thompson, Segui-Gomez, and Graham, conducted an analysis studying the airbag's life-saving effectiveness. In, their research, it was found that "early [airbag] estimates were applied uniformly to all occupants regardless of age, gender, physical stature or health status" (1999). They found that this statement was untrue. Evidence has now been found that "suggests that some members of the population (e.g. the elderly) are particularly at risk". The Mackay and Hassan study also emphasized the fact that "age is crucial and the over 55-year old age groups are shown to be especially vulnerable" (2000). This analysis too showed a relationship between airbags and age. However, it was found that having an airbag available, without deployment, and without proper seatbelt use was found to be a significant factor in decreasing a senior's chance for death. Using the model example, it was found to increase the risk of fatality by approximately 13%.

Several claims were made with regard to injury as well. The NHTSA has reported that airbag presence alone was significantly effective in reducing injury rates for frontal impacts. They also tried interactions between occupant sex, age, height and weight, but no significant effects were found. This analysis found the same results. Airbag presence did decrease injury rates, especially in frontal impacts. Using the model example, it was found that airbag availability was about 10% more effective in frontal than in non-frontal impacts.

With regard to airbag deployment, a study by Dr. John Sutyak, Vikas Passi, and Dr. Jeffrey Hammond found that drivers with an airbag alone versus airbag deployment with seatbelt use had significant higher rates for injury. This analysis did not show these results. The injury rates for occupants with deployed airbags were higher (all around) than injury rates for occupants with airbag available only.

In summary, airbags were found to be more effective in frontal impacts for both fatality and injury. Airbags also tend to be more effective with the use of a seatbelt. Airbags do tend to be harmful to the elderly, as posted on airbag warning labels with regard to fatality. The airbag does not however show any other effects with regard to impact speed, vehicle body type, sex, height, or weight for either outcome.

Chapter 6

Discussion

So, why do the results of this analysis not compare to the other studies? Well, one reason is because of some confounding variables that were not accounted for. One example, as mentioned earlier, is vehicle model year. Before the mandating of airbags, airbags were sold as an extra option- therefore increasing the vehicle's prices. For those occupants who took the options- their reasons could be that they were more safety conscious, which would tie back into proper seatbelt use. It could also be due to their socio-economic status, meaning that they could afford the extra option. But then the socio-economic status could also tie into the occupant's health level- indicating that a poorer person might have less health care, which could indicate that they are walking around with illnesses not taken care of thus making them more susceptible to death or injury.

Also, in conducting some post-analysis on the data using vehicle model year and the original variables, it was found that for cars modeled 95 and older adults and females were found to have the highest rates. This could partially explain the age and gender trends. Looking at the trend of safety device use it was also found that for cars 1990 and up, the highest trend of safety device was the having use of both safety devices, while the 1980-1990 years had the highest trend of proper seatbelt use only, and cars older than 1980 the trend was for no safety device use. Besides, there is also the issue of the variables themselves and how they are related. Examples of what this would be: that men driver more daily than women, women are often shorter and lighter, men tend to dominate the driving role, gender, height and weight play a role in vehicle type (distance of gas and brake pedals), etc.And this can continue even further.

Also some of the differences in the findings stem from the data set. Most studies conducted with regard to fatalities are conducted using the FARS dataset. The FARS dataset consists of data taken from vehicle collisions in which at least one occupant was killed. This limits the scope of inferences that can be made. The results here are only useful in cases where a person dies in a vehicle crash- which is a pretty rare occurrence in regular day-to-day life. The CDS dataset on the other hand uses data where at least one car has been towed away from the scene. This is a slightly more common occurrence, and is much more applicable for making inferences. Because of the differences in these situations, there are going to be different findings. The question now becomes which one is more useful- the chances of an occupant being killed if there is another fatality in the car or the chances of an occupant where the crash led to a vehicle being towed away? There are two other issues that are important in answering the question about airbags. They are, however, pretty much incalculable. The first one is the occupant's hand position. People have been taught since the introduction of cars to have their hands at 10 and 2 o'clock on the steering wheel. With the introduction of airbags, those positions have been lowered to 9 and 3 o'clock to help prevent the occupant from hand injuries. The second one is the ten inch rule, which states that there should be at least 10 inches between the driver's chest and the steering wheel, since this would allow room for the airbag to deploy without causing too much injury.

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Appendix A

How Variables Were Created

ORIGINAL VARIABLE	VARIABLE USED
VALUE AGE 00 = 'LESS THAN ONE YR' 97 = '97 YEARS + OVER' .U = 'UNKNOWN';	VALUE AGE1 < 16 = deleted; 16-29 = 'young adult' 30-54 = 'adult' 55+ = 'senior' .U = deleted;
VALUE BAGAVAIL 0 = 'NOT EQUIP/AVAIL' 1 = 'AIRBAG' 2 = 'BAG DISCONNECTED' 3 = 'BAG NOT REINSTAL' .U = 'UNKNOWN';	VALUE AIRBAG 0 = 'no' 1 = 'yes' 2 = 'no' 3 = 'no' .U = deleted;
VALUE BAGDEPLY **0** = 'NOT EQUIP/AVAIL' **1** = 'BAG DEPLOYED' **2** = 'BAG DEPLY INADV' **3** = 'BAG DEPLOY UNDET' **4** = 'BAG DEPLOY-NOCOL' **5** = 'UNK IF DEPLOYED' **7** = 'NONDEPLOYED' **.U** = 'UNKNOWN';	VALUE DEPLOY not deployed deployed deployed deleted deployed deleted not deployed deleted
VALUE BODYTYPE 01 = 'CONVERTIBLE' 02 = '2DR SEDAN/HT/CPE' 03 = '3DR/2DR HATCHBAK' 04 = '4-DR SEDAN/HDTOP' 05 = '5DR/4DR HATCHBAK' 06 = 'STATION WAGON' 07 = 'HATCHBACK DR UNK' 08 = 'OTHER AUTOMOBILE' 09 = 'UNK AUTO TYPE' 10 = 'AUTO BASE PICKUP' 11 = 'AUTO BASED PANEL' 12 = 'LARGE LIMOUSINE' 13 = 'THREE-WHEEL AUTO' 14 = 'COMPACT UTILITY' 15 = 'LARGE UTILITY'	VALUE BODTYPE car car car car car car car car car car car car car utility utility

16 = 'UTILITY STAWAGON'	utility
19 = 'UTILITY UNK BODY'	utility
20 = 'MINIVAN'	truck
21 = 'LARGE VAN'	truck
22 = 'STEP VAN <10K LB'	truck
23 = 'VAN BASE MTRHOME'	truck
24 = 'VAN BASED SCHBUS'	truck
25 = 'VAN BASED OTHBUS'	truck
28 = 'OTHER VAN TYPE'	truck
29 = 'UNKNOWN VAN TYPE'	truck
30 = 'COMPACT PICKUP'	truck
31 = 'LARGE PICKUP'	truck
32 = 'PICKUP/CAMPER'	truck
33 = 'CONVERT PICKUP'	truck
39 = 'UNK PICKUP TRUCK'	truck
40 = 'CAB CHASSIS'	truck
41 = 'TRUCK BASE PANEL'	truck
42 = 'LT TRK MOTORHOME'	truck
45 = 'OTH LIGHT TRUCK'	truck
48 = 'UNK LIGHT TRUCK'	truck
49 = 'UNK LIGHT VEH'	truck
50 = 'SCHOOL BUS'	
58 = 'OTHER BUS'	the rest of these vehicle types were not included in the analysis
59 = 'UNKNOWN BUS'	
60 = 'STEP VAN >10K LB'	
61 = 'SU TRUCK 10-19.5'	
62 = 'SU TRUCK 19.5-26'	
63 = 'SU TRUCK >26K LB'	
64 = 'SU TRUCK GVW UNK'	
65 = 'MH TRK MOTORHOME'	
67 = 'BOBTAIL TRACTOR'	
68 = 'TRK-TRAC 1 TRAIL'	
69 = 'TRK-TRAC 2 TRAIL'	
70 = 'TRK-TR UNK TRAIL'	
78 = 'UNK MED/HVY TRK'	
79 = 'UNKNOWN TRUCK'	
80 = 'MOTORCYCLE'	
81 = 'MOPED'	
82 = '3 WHEEL MC/MOPED'	
88 = 'OTH MOTORED CYCL'	
89 = 'UNK MOTORED CYCL'	
90 = 'ATV AND ATC'	
91 = 'SNOWMOBILE'	
92 = 'FARM EQUIPMENT'	
93 = 'CONSTRUCT EQUIP'	
97 = 'OTHER VEHICLE TYPE'	

98 = 'NOT APPLICABLE' .N = 'NOT COLLECTED' .U = 'UNKNOWN BODY TYPE';	
VALUE DVTOTAL . = 'NON CDS VEHICLE' 000 = 'LESS THAN 0.5KPH' 160 = '159.5 KPH + OVER' .U = 'UNKNOWN'; VALUE DVEST 0 = 'DELTA V CODED' 1 = 'LESS THAN 10KMPH' 2 = '>9 AND <25 KMPH' 3 = '>24 AND <40 KMPH' 4 = '>39 AND <55 KMPH' 5 = '>54 KMPH' 6 = 'MINOR' 7 = 'MODERATE' 8 = 'SEVERE' .U = 'UNKNOWN';	VALUE SPEED 0= 0-9kph 1= 10-24kph 2= 25-39kph 3= 40-54kph 4= 55+kph categorized as above 0= 0-9kph 1= 10-24kph 2= 25-39kph 3= 40-54kph 4= 55+kph deleted deleted deleted deleted
VALUE GAD1 'F' = 'FRONT' 'R' = 'RIGHT SIDE' 'L' = 'LEFT SIDE' 'B' = 'BACK/TRK BACK' 'T' = 'TOP' 'V' = 'FR OF CARGO AREA' 'D' = 'BACK OF TRACTOR' 'C' = 'REAR OF CAB' 'U' = 'UNDERCARRIAGE' '9' = 'UNKNOWN' 'N' = 'NONCOLLISION' '0' = 'NOT A MOTOR VEH';	VALUE DIRECTION front other other other deleted deleted deleted deleted deleted deleted deleted deleted;
VALUE HEIGHT 220 = '219.5 CM + OVER' .U = 'UNKNOWN';	VALUE HEIGHT1 <164 = short 164 - 177 = 'medium' 177+ ='tall' .U = deleted;

VALUE HOSPSTAY 00 = 'NOT HOSPITALIZED' 61 = '61 DAYS OR MORE' .U = 'UNKNOWN';	VALUE INJURED 0 = not injured < 0 = injured deleted;
VALUE MANPROPR 0 = 'NONE USED/AVAIL' 1 = 'USED PROPERLY' 2 = 'USE OK W/CH SEAT' 3 = 'SHBELT UNDER ARM' 4 = 'SHBELT BEHIND ST' 5 = 'AROUND >1 PERSON' 6 = 'BELT ON ABDOMEN' 7 = 'IMPROP W/CH SEAT' 8 = 'OTH IMPROPER USE' .U = 'UNKNOWN';	VALUE SEATBELT no yes yes no no no no no no deleted;
VALUE ROLE 1 = 'DRIVER' 2 = 'PASSENGER' .U = 'UNKNOWN';	VALUE ROLE driver passenger deleted
VALUE SEX 1 = 'MALE' 2 = 'FEMALE-NOT PREG' 3 = 'FEM-PREG 1ST TRI' 4 = 'FEM-PREG 2ND TRI' 5 = 'FEM-PREG 3RD TRI' 6 = 'FEM-PREG UNKTERM' .U = 'UNKNOWN';	VALUE GENDER male female female female female female deleted
VALUE TREATMNT 0 = 'NO TREATMENT' 1 = 'FATAL' 2 = 'FATAL-RL DISEASE' 3 = 'HOSPITALIZED' 4 = 'TRANS/RELEASED' 5 = 'TREAT-SCNE-NTRANS' 6 = 'TREATMENT-LATER' 7 = 'TREATMENT-OTHER' 8 = 'TRANS-UNK TREAT' .N = 'NOT COLLECTED'	VALUE DEAD not dead dead dead not dead not dead not dead not dead not dead not dead .N = deleted

.U = 'UNKNOWN'; VALUE DEATH **0** = 'NOT FATAL' **1 - 6** = '1 TO 6 HOURS' **7 - 12** = '7 TO 12 HOURS' **13 - 18** = '13 TO 18 HOURS' **19 - 24** = '19 TO 24 HOURS' **31 - 36** = '2 TO 6 DAYS' **37 - 42** = '7 TO 12 DAYS' **43 - 48** = '13 TO 18 DAYS' **49 - 54** = '19 TO 24 DAYS' **55 - 60** = '25 TO 30 DAYS' **96** = 'FATAL-RL DISEASE' **.U** = 'UNKNOWN';	.U = see death value not dead dead dead dead dead dead dead dead dead dead dead .U = see treatmnt value
VALUE WEIGHT 150 = '149.5KG AND OVER' .U = 'UNKNOWN';	VALUE WEIGHT1 <63 = short 63 - 86 = 'medium' 87+ ='tall' .U = deleted;

Appendix B

Variables Entered In Models

VARIABLES ENTERED IN MODELS

Airbag
Deploy
Seatbelt
Speed
Direction
Body type
Role
Age
Sex
Height
Weight
Airbag*seatbelt
Airbag*speed
Airbag*direction
Airbag*body type
Airbag*role
Airbag*age
Airbag*sex
Airbag*height
Airbag*weight
Deploy*seatbelt
Deploy *speed
Deploy *direction
Deploy *body type
Deploy *role
Deploy *age
Deploy *sex
Deploy *height
Deploy *weight
Seatbelt*speed
Seatbelt*direction
Seatbelt*body type
Seatbelt*role
Seatbelt*age
Seatbelt*sex
Seatbelt*height
Seatbelt*weight
Speed*direction
Speed*body type

Speed*role
Speed*age
Speed*sex
Speed*height
Speed*weight
Direction*body type
Direction*role
Direction*age
Direction*sex
Direction*height
Direction*weight
Body type*role
Body type*age
Body type*sex
Body type*height
Body type*weight
Role*age
Role*sex
Role*height
Role*weight
Age*sex
Age*height
Age*weight
Sex*height
Sex*weight
Height*weight
Airbag*speed*role
Airbag*age*sex
Airbag*direction*body type
Airbag*seatbelt*direction
Airbag*seatbelt*role
Airbag*seatbelt*sex
Airbag*seatbelt*height
Airbag*seatbelt*weight
Airbag*seatbelt*driver
Airbag*sex*speed
Airbag*no belt*low speed (0-24kph)
Airbag*no belt*sex
Deploy*speed*role

Airbag*sex*speed
Airbag*no belt*low speed (0-24kph)
Airbag*no belt*sex
Deploy*speed*role
Deploy *age*sex
Deploy *direction*body type
Deploy *seatbelt*direction
Deploy *seatbelt*role
Deploy *seatbelt*sex
Deploy *seatbelt*height
Deploy *seatbelt*weight
Deploy *seatbelt*driver
Deploy *sex*speed
Deploy *no belt*low speed (0-24kph)
Deploy *no belt*sex