EFFECT OF SPEED LIMIT INCREASE ON CRASH RATE ON RURAL TWO-LANE HIGHWAYS IN LOUISIANA

A Thesis

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Dedicated to my dearest parents

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ABSTRACT

Though the rural two-lane roads are the low volume-less traveled roads, the majority of the crashes occur on these roads and the high speed of motor vehicles on these roads is suspected to be one of the main causes for this. This study focused on the development of a methodology to study the impact of a speed limit increase on the crash rate on the rural two-lane roads in Louisiana. The Louisiana crash database obtained from the Louisiana Department of Transportation (LADOTD) was used to carry out the analysis. The analysis consisted of the comparison of crash rates of different severity and crash types before and after a speed limit change on rural road sections with same crash type. The comparison was done statistically using a single-tailed paired t-test on each of the homogeneous data groups established using the SPSS add-in, Answer Tree. Answer Tree Analysis ensured that the homogeneous groups established were controlled for the several factors contributing to high crash rates so that the effect of speed limit change alone could be captured, keeping the other factors unchanged within each homogeneous group. The roadway sections were divided into speed limit change and no speed change sections and the crash trends were observed and tested for significance in the no speed limit change sections. The speed limit change group was divided into before and after speed change sections and the after speed change crash rate values were adjusted for any significant trend in the corresponding cases. These final before and after crash rate values adjusted for the trend were compared statistically to test the null hypothesis that crash rate does not increase with speed limit increase, at 5% level of significance. Based on the results, the null hypothesis was rejected for 6 out of the 39 cases while we failed to reject the null hypothesis for the rest of the cases thus indicating that for these cases, we do not have sufficient evidence to say that the crash rate increased with a speed limit increase.

1. INTRODUCTION

1.1 Background

Safety is the primary reason for setting speed limits. Often, attempts are made to strike an appropriate societal balance between travel time and risk for a road class or specific highway section while setting appropriate speed limits. The posted speed limits thus inform motorists of the maximum legal driving speeds considered reasonable and safe for a road class under favorable conditions of good weather, free-flowing traffic and good visibility. Drivers are expected to reduce speeds as these conditions deteriorate. But often, motorists take advantage of the favorable conditions and tend to exceed the legal posted speed limits. This is very prevalent on the nation's less traveled rural two-lane highways. Rural roads make up around 77 percent i.e., about 3.1 million miles out of the more than 3.9 million miles, of roadway in the United States. While more than half of the nation's traffic fatalities from 1990 to 2003 occurred on rural, non-Interstate routes, only 28 percent of the nation's total vehicle travel occurred on these routes during this period.

The United States Congress, in 1995, repealed the National Maximum Speed Limit of 55 mph which was in effect since 1974 when it was started as a fuel-saving measure, and returned to the states the authority to set their own speed limits on major highways. Following this, Louisiana set the maximum speed limit on rural and urban limited access interstates to 70 mph and on other roads to 55-60 mph, effective from August 15th, 1997 [IIHS, 2005]. However, the speed limit on the rural highways did not experience any change.

There has been a request from the Senate of the state of Louisiana to increase the speed limit on the two-lane rural highways from the existing 55 mph speed limit. In response, Louisiana State University has been approached to conduct a study to determine the advisability of increasing the maximum speed limit on the rural two-lane highways by determining its effects on crash rate, crash severity and several other factors taking into consideration the road conditions, safety factors and the overall feasibility. This will be achieved by, conducting a thorough literature review of the national and international speed limit practices, an inventory of current practices in Louisiana and a review of all the studies conducted to date on this issue. Secondly, a database of crash records on two-lane highways will be established and analysis will be performed on it to identify the impact of speed limit increases on safety on those roads where speed limits have been increased in the past.

1.2 Problem Statement

Highway safety is an enormous problem in Louisiana. Approximately 160,000 crashes occur in the state each year, over 90,000 of which are on the state-maintained highway system. On an average, more than 900 people are killed and about 80,000 injured in automobile crashes in Louisiana each year. As of 2003, the state of Louisiana controlled 60,937 miles of public road serving about 102,585 vehicle miles a day, and consisting of 46,987 miles of rural roads and 13,950 miles of urban roads. This includes 904 miles of freeway, 1345 miles of divided multilane highway and the rest of over 59000 miles of undivided predominantly two-lane roads [FHWA, 2003]. Only about 15% of the fatal crashes occur on the interstates and other limited access highways, while 48% of fatal crashes and 35 % of injury crashes occur on the remaining state-controlled highways [LHSC, 2003]. As the majority of these crashes occur on two-lane rural roads, increasing the speed limit on these roads can potentially pose a threat to overall highway safety.

2. LITERATURE REVIEW

An overview of the current speed limit laws, the various speed limit setting practices in Louisiana, other states and internationally, trends in the rural road conditions and crashes, relation between speed and speed limits and a review of the various studies on speed limit increase and its impact on safety are presented below.

2.1 Federal and State Speed Limit Law Changes

The United States of America in 1974 set a National Maximum Speed Limit (NMSL) of 55 miles per hour (mph) regulating the speed limits on the nation's public highways. Previously, states were given the authority to set their own speed limits and limits of 65 mph and 70 mph were posted on most of the United States' highways. Due to the newly adopted 55 mph speed limit, traffic slowed on all major highways and the total amount of travel declined. These changes in speed and travel were accompanied by a decrease in the total number of traffic fatalities.

The NMSL was started as an effort to conserve oil, as a result of the Arab oil embargo but despite the decrease in oil prices afterwards, the NMSL remained in effect for 13 years. In the mid 1980s, the average highway travel speeds were increasing and the 55 mph speed limit was increasingly being ignored by many drivers. Thus as a result of police agencies and public officials urging for higher speed limits to decrease the long distance travel time, the Congress in 1987 voted to allow speed limits to be increased to 65 mph on rural interstate highways in specified experimental states [NHTSA, 1998].

On November 28, 1995, the National Highway System (NHS) Designation Act was signed into law eliminating the Federal mandate for the NMSL, thus giving states complete discretion over setting their speed limits. Within a year of the repeal, 23 states had raised their rural interstate speed limits to 70 or 75 mph with Montana removing daytime speed limits on its rural interstates altogether and Texas allowing speeds up to 70 mph on almost half of its two-lane "farm to market" highways. In response to the repeal of NMSL, Louisiana's posted maximum limits were raised to 70 mph on rural and urban limited access interstates. However, the speed limit on 2-lane rural highways was retained at 55 mph and 65 mph on divided multilane highways effective from August 15th, 1997 [IIHS, 2005].

2.2 Speed Limit Setting Practices

The relationship among speed limits, driver speed choice, and safety on a given road is complex. Setting appropriate speed limits and related enforcement strategies is the first step in a chain of events that may affect crash probability and crash severity. The decision makers thus attempt to strike an appropriate societal balance between travel time and risk for a road class or specific highway section while setting speed limits. Thus, the posted legal limit informs motorists of maximum driving speeds considered reasonable and safe for a road class under favorable conditions.

A study undertaken by the Transportation Research Board (TRB) in 1998 under the request and funding of the National Highway Traffic Safety Administration (NHTSA), the Federal Highway Administration (FHWA), and the Centers for Disease Control and Prevention, reviewed the current practices for setting and enforcing speed limits on all types of road as described below. According to the study, speed limits are one of the oldest strategies for controlling driving speeds. With two exceptions - during World War II and with the NMSL of 55 mph (89 km/h) in 1974, setting speed limits in the United States has been the responsibility of state and local governments [TRB, 1998].

The review finds that the current framework for speed regulation was developed in the 1920s and 1930s and each state has a basic statute that requires drivers to operate vehicles at a speed reasonable and prudent for existing conditions. Speed limits are legislated by road class and geographic area and generally, statutory limits apply to all roads of a particular class throughout a political jurisdiction. However, state and most local governments have the authority to change the limits by establishing speed zones for highway sections where statutory limits do not fit specific road or traffic conditions, and to determine alternative maximum speed limits in these zones.

Legislated speed limits are established by state legislatures, city councils, or Congress on the basis of judgments about appropriate trade-offs between public safety, community concerns, and travel efficiency. They are established for favorable conditions like good weather, free-flowing traffic, and good visibility. Drivers are expected to reduce speeds as these conditions deteriorate.

Speed limits in speed zones are determined administratively based on an engineering study, taking into consideration factors such as operating speeds of free-flowing vehicles, crash experience, roadside development, roadway geometry, and parking and pedestrian levels, to make a judgment about the speed at which the limit should be set. In many speed zones, speed limit is established near the 85th percentile speed, the speed at or below which 85 percent of drivers travel in free-flow conditions at representative locations on the highway or roadway section. This approach assumes that most drivers are capable of judging the speed at which they can safely travel. Drivers are expected to reduce speeds under deteriorated conditions such as poor visibility, adverse weather, congestion, warning signs, or presence of bicyclists and pedestrians, and most state statutes reflect this requirement. Speed control regulations—both legislated and administratively established maximum speed limits—provide the legal basis for adjudication and sanctions for violations of the law. State and local officials also post advisory speed signs, which do not have the force of law but warn motorists of suggested safe speeds for specific conditions at a particular location [ITE, 1992].

2.3 Speed Limit Statutes in Louisiana

The Louisiana State statutes related to speed are summarized here [NHTSA, 2001].

The Basic Speed Rule states that:

> No person shall drive a vehicle at a speed greater than is reasonable and prudent under the conditions and potential hazards then existing, having due regard for the traffic on, and the surface and width of, the highway, and the condition of the weather. 32:64(A)

Statutory maximum speed limit:

I. 70 MPH on interstate or controlled access highways 32:61(B) & 32:62(A),

II. 65 MPH on other multi-lane divided highways which have partial or no control of access 32:61(B) & 32:62(A), and

III. 55 MPH on other highways 32:61(A) & 32:62(A) is being followed on Louisiana roads.

Posted (Maximum) Speed Limit:

I. Based on engineering and traffic investigations, the State may increase or decrease the above speed limits.32:63(A)

II. The State can promulgate regulations regulating speed on Louisiana expressways. 48:1272

III. Local governments are authorized to establish speed limits or speed zones. However, no speed limit shall be established in excess of the above maximum limits. 32:41(A)(9), 32:42 & 40:403

Minimum Speed Limit:

I. No person shall operate a motor vehicle at such slow a speed as to impede the normal and reasonable movement of traffic. 32:64(B)

2.4 Practices in Other States

The current speed limits for each state and the date of implementing the most recent rural freeway limit change are given in Table 2-1 below:

Table 2-1: Speed Limit Practices in Other States (Insurance Institute of Highway Safety, 2005)

State	**Date**	**New limit (mph)**			
		Rural Freeway	**/Divided Highway**	**UnDivided Highway**	**Urban Freeway**
Alabama	9 May 96	70	65	55	65
Alaska	15 Jan 88	65	55	55	55
Arizona	8 Dec 95	75	55	55	55
Arkansas	19 Aug 96	70 65	55 55	55 55	55 55 (trucks)
California	7 Jan 96	70 55	65 55	65 55	65 55 (trucks)
Colorado	24 Jun 96	75	65	65	55
Connecticut	1 Oct 98	65	55	50	55
Delaware	Jan 96	65	55	50	55
Dist. Of Columbia	n/a		n/a		
Florida	8 Apr 96	70	65	55	55
Georgia	1 Jul 96	70	65	55	65
Hawaii	N/A	55	55	45	55
Idaho	1 May 96	75 65	65	65	55 (trucks)
Illinois	27 Apr 87	65 55	65 55	55 55	65 55 (trucks)
Indiana	1 Jun 87	65 60	55	55	55 (trucks)
Iowa	12 May 87	65	55	55	65
Kansas	7 Mar 96	70	70	65	55
Kentucky	8 Jun 87	65	55	55	55
Louisiana	**15 Aug 97**	**70**	**65**	**55**	**60**
Maine	12 Jun 87	65	55	55	55
Maryland	1 Jul 95	65	55	55	60
Massachusetts	5 Jan 92	65	65	55	65
Michigan	1 Aug 96	70 55	55 55	55 55	65 55 (trucks)
Minnesota	1 Jul 97	70	65	55	65
Mississippi	29 Feb 96	70	55	55	60
Missouri	13 Mar 96	70	70	60	60
Montana	28 May 99	75 65 (trucks)	55	55	55
Nebraska	1 Jun 96	75	65	60	55

(Table 2-1 Continued.)

State	Date	New limit (mph)			
		Rural Freeway	/ Divided Highway	Undivided Highway	Urban Freeway
Nevada	8 Dec 95	75	70	70	65
New Hampshire	16 Apr 87	65	55	55	55
New Jersey	19 Jan 98	65	55	50	55
New Mexico	15 May 96	75	70	65	55
New York	1 Aug 95	65	55	55	65
North Carolina	5 Aug 96	70	55	55	65
North Dakota	10 Jun 96	70 70	65 55	65 55	55 55 (trucks)
Ohio	15 Jul 87	65 55	65 55	55 55	65 55 (trucks)
Oklahoma	29 Aug 96	75 75 60 55 65	70 65 60 55 50	65 55 55 55	60 (day) 60 (night) 60 (trucks) 55(night, trucks) (school bus)
Oregon	27 Jun 87	65 55	55	55	55 (trucks)
Pennsylvania	13 Jul 95	65	55	55	55
Rhode Island	12 May 96	65	55	50	55
South Carolina	30 Apr 99	70	55	55	55
South Dakota	1 Apr 96	75 65	65 55	65 55	55 55 (trucks)
Tennessee	25 Mar 98	70	65	55	65
Texas	8 Dec 95	70 65 60 55 50	70 65 60 55 50	70 65 60 55 50	70 (day) 55 (night) 55 (trucks) 55(night, trucks) 50 (school b)
Utah	1 May 96	75	65	55	65
Vermont	21 Apr 87	65	55	50	55
Virginia	1 Jul 88	65	55	55	55
Washington	15 Mar 96	70 60	70 60	65 60	60 60 (trucks)
West Virginia	25 Aug 97	70	65	55	60
Wisconsin	17 Jun 87	65	55	55	55
Wyoming	Dec 95	75	65	65	60

2.5 International Speed Limit Practices

The existing speed limits in some of the foreign countries are shown in Table 2-2. The crash rates in foreign countries are generally higher than those in the U.S. One reason for this is because, proportionately more travel occurs on freeways in the U.S, which are safer than other types of roads.

Table 2-2: International Speed Limit Practices (in kph)
(Parker, Sung and Dereniewski, 2003)

COUNTRY	Vehicle/Weather Condition	Builtup Areas	2-lane Rural	Motorways	Multilane Divided
		Speed in Kilometers per Hour (kph)			
Australia		50-60	100	110	100-110
Austria		50	100	130	100
Belgium		50-60	90	120	90-120
Czech Republic		60	90	110	
Denmark		50	80	110-100	90
Finland		50	80	120	100
France		50-60	90	130	110
	Wet weather		80	110	
Germany		50	100	130*	
Great Britain		48	96	112	112
Greece		50	80	120-100	100
Hungary		60	80	100	
Ireland		48	88		96
Italy	Engine size				
	up to 599 cm^3	50	80	90	
	600-900 cm^3	50	90	100	
	901-1300 cm^3	50	100	130	
	over 1300 cm^3	50	110	140	
Luxembourg		50-60	90	120	
Netherlands		50	80	120	100
Norway		50	80	90	
Poland		60	90	110	
Portugal		50-60	90	120	100
Rumania	Engine size				
	up to 1100 cm^3	60	70	70	
	from 1100 cm^3	60	80	80	
Sweden		50	70-90	110	90-110
Switzerland		50	70	120	
Spain		50-60	90	120	120
Turkey		50	90	90	
United States		40-60	90	120	105

2.6 Speed and Speed Limits

2.6.1 Relationship between Design Speed, Operating Speed and Maximum Speed

Speed limits are the maximum legal travel speeds under favorable situations of good weather, free-flowing traffic and good visibility. Posting appropriate speed limits are necessary to ensure a reasonable level of safe and efficient travel on highways and streets. An unrealistic posted speed limit generally reduces the drivers' compliance rate, and in turn increases the number of accidents, related injuries and fatality rates [Najjar et al, 2000]. The practice of speed control was founded on the assumption that controlling speeds reduces the number and the severity of crashes. However, a compromise is reached between the desires to maximize efficiency of travel and to exercise control over travel speeds. Thus for setting the speed limits, a proper distinction between the various kinds of speed such as design speed, operating speed and the 85th percentile speed and the importance of each in setting speed limit was defined.

Design consistency on two-lane rural highways has been assumed to be provided through the selection and application of a design speed [FHWA, 2000]. AASHTO defines the design speed as “the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern”. One weakness of the design-speed concept is that it uses the design speed of the most restrictive geometric element within the section, usually a horizontal or vertical curve, as the design speed of the road and does not explicitly consider the speeds that motorists travel on tangents or less restrictive curves [FHWA, 2000].

The AASHTO definition for operating speed is “the highest overall speed at which a driver can travel on a given highway under favorable weather conditions and under prevailing traffic conditions without at any time exceeding the safe speed as determined by the design speed on a section-by-section basis”. A maximum speed limit is posted or set by statute on a highway to inform motorists of the highest speed considered to be safe and reasonable under favorable road, traffic, and weather conditions. The maximum limit should seem high to the majority of drivers, or it is not a maximum limit. When less than ideal conditions exist, the driver must adjust their vehicle speed that is appropriate for conditions. The posted speed limit usually sets the maximum speed limit for a roadway such that the operating speed may be above the design speed for a particular location of the roadway.

2.6.2 Setting of Speed Limit With Respect To 85th Percentile Speeds

The 85th-percentile speed is commonly used by highway agencies for describing actual operating speeds and establishing speed limits. This is the speed at or below which 85 percent of the traffic is traveling and which according to traffic engineers reflects the safe speed for given road conditions. The 85th-percentile speed is in the speed range where the accident involvement rate is lowest, since a study revealed that vehicles traveling one standard deviation above the average speed under free-flow conditions have the lowest involvement rate and average speed plus one standard deviation is approximately the 85th-percentile speed [Agent, Pigman, and Weber, 1998]. Vehicles traveling two standard deviations above the average speed have been found to have significantly higher crash rates. The 85^{th} percentile speed is found to accommodate the safe and prudent driver and lowering or increasing the posted speed limit has little effect on the 85^{th} percentile speed and raising the speed limit to this level causes no increase in crashes. Speed limits determined by the 85th percentile are favored as they are the most realistic and in turn decrease compliance problems and speed variation and lead to better traffic flow [Thornton and Lyles, 1999].

2.7 Review of Studies on Speed Limits and Safety

2.7.1 Speed and the Probability of Crash Involvement

The literature review here attempts to examine the evidence that speeding is linked to the probability of being involved in a crash.

Theoretical Approach: Three theoretical approaches link speed with crash involvement:

(a) The **information processing approach**, which views the driver as an information processor with limited capacity to process information. At higher speeds there is less time for the driver to process information, decide, and act between the time the information is presented to the driver and the time when action must be taken to avoid a crash. A crash is likely to occur when the information processing demands exceed the information processing capabilities of the driver [Shinar, 1978]. Unexpected events dramatically increase information processing requirements and hence the probability of a crash. This approach leads to the conclusion that “speed kills”; as more drivers increase their speed, the probability of information overload increases along with the potential for crashes.

(b) The **traffic conflict approach** assumes that the probability of an individual driver being involved in a multiple-vehicle crash increases as a function of the deviation of that individual driver’s speed from the speeds of other drivers. Drivers with speeds much higher or much lower than the median traffic speed are likely to encounter more conflicts [Hauer, 1971]. This relationship leads to the conclusion that “speed deviation kills” and the prediction that on roads with equivalent average traffic speeds, crash rates will be higher on roads with wider ranges of speed. The theory relates only to two-lane rural roads.

(c) The **risk-homeostasis motivational approach** looks at speed and crash involvement from the perspective of driver perception of risk. From this point of view, drivers adjust their speed according to the risks they perceive to maintain a subjectively acceptable level of risk. The issue is not the link between speed and crash probability but between actual and perceived risk. Thus, driving at high speeds per se is not dangerous but the danger comes from driving at a speed inappropriate for conditions, stemming from a misperception of the situational demands or the vehicle’s handling capabilities or the driver’s skills.

Correlational Studies: Several studies attempted to determine whether there is a link between speed and crash probability. In the benchmark study conducted by Solomon (1964), travel speeds of crash-involved vehicles obtained from police reports were compared with the average speed of free-flowing traffic on six hundred miles of main rural highway of which three quarters were two-lane highways, with the remainder being four-lane divided highways. Solomon found that crash-involved vehicles were overrepresented in the high- and low-speed areas of the traffic speed distribution [Solomon, 1964]. He found that the daytime involvement rates took the form of a U-shaped curve, being greatest for vehicles with speeds of 22 mph or less (43,238 per 100 million vehicle miles (mvm), decreasing to a low at about 65 mph (84 per 100 mvm), then increasing somewhat for speeds of at least 73 mph (reaching 139 per 100 mvm). The night-time rates took the same form especially for speeds in excess of 60 mph but they were higher for the lowest speed category [Kloeden, Ponte, and McLean, 2001].

Solomon's well-known U-shaped curve showed that crash involvement rates are lowest at speeds slightly above average traffic speeds. The greater the deviation between a motorist's speed and the average speed of traffic—both above and below the average speed—the greater the chance of involvement in a crash. The correlation between crash involvement rates and deviations from average traffic speed gave rise to the often-cited hypothesis that it is speed deviation, not speed per se, that increases the probability of driver involvement in a crash. Hauer (1971), in his subsequent theory of traffic conflict provided a theoretical basis for Solomon's findings. Solomon's results are reproduced in Figure 2-1 below.

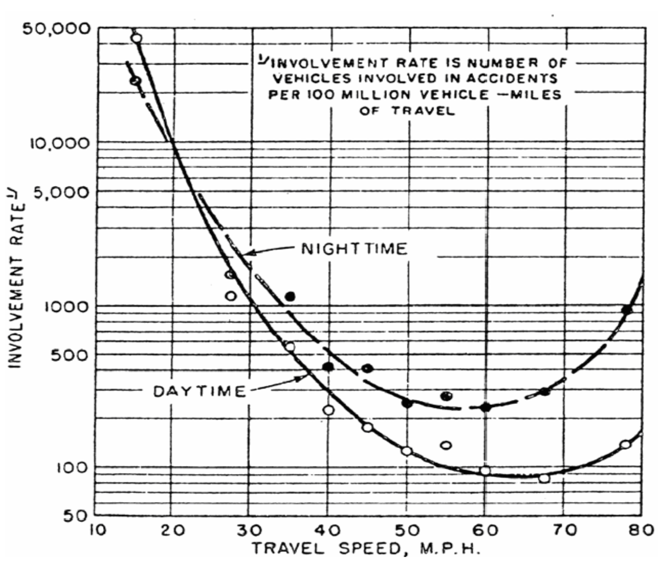

Figure 2-1: Results of Solomon's Study (Solomon, 1964)

Solomon's U-shaped relationship was replicated by Munden (1967) using a different analytic method on main rural roads in the United Kingdom, by Cirillo (1968) on U.S. Interstate highways and more recently by Harkey et al. (1990) on rural and urban roads posted at speeds ranging from 25 to 55 mph (40 to 89 km/h) in two U.S. states. All of the U.S. studies, but most particularly Solomon's, have been criticized for their dependence on crash reports for the pre-crash speeds of the crash-involved vehicles, which could bias the results [White and Nelson, 1970]. Solomon's study has also been criticized for unrepresentative comparative traffic speed data, lack of consistency between the crash and speed data, and mixing of crashes of free-flowing with slowing vehicles, which could explain high crash involvement rates at low speeds. When Solomon's data are disaggregated by crash type, the U-shaped relationship is only fully replicated for one crash type—night-time head-on collisions [Cowley 1987]

The Research Triangle Institute (RTI) together with Indiana University addressed several of these issues by using speed data based, in part, on traffic speeds recorded at the time of the crash. They examined crashes on highways and county roads with speed limits of 40 mph (64 km/h) and above and found a similar but less pronounced U-shaped relationship between crash involvement and speed. Thus, the RTI study appears to confirm the critical role of deviation from average traffic speeds for crash-involved vehicles.

Several studies have provided alternative explanations for the high crash involvement rates found by Solomon at the low end of the speed distribution, whereas others have simply not found the association. West and Dunn (1971) investigated the relationship between speed and crash involvement, replicating Solomon's U-shaped relationship. However, when crashes involving turning vehicles were removed from the sample, the U-shaped relationship was considerably weakened—the curve became flatter—and the elevated crash involvement rates that Solomon had found at the low end of the speed distribution disappeared; crash involvement rates were more symmetric above and below mean traffic speeds (Figure 2-3). West and Dunn's analysis supports the conclusion that the characteristics of the road are as responsible for creating the potential for vehicle conflicts and crashes as the motorist's driving too slowly for conditions.

A recent Australian study, which examined crash involvement rates as a function of speed on urban arterials as well as on two-lane rural roads, found no evidence of the U-shaped relationship. Crash involvement rates rose linearly as a function of speed. Crash involvements were lowest at speeds below average traffic speeds and highest at speeds above the average with no advantage at the average (Fildes et al. 1991) (Figure 2-2). Furthermore, the researchers did not find evidence of very low-speed driving that had been apparent in both the Solomon and Cirillo data. The results are based on small sample sizes and self-reported crash involvement. The findings point to a linear and positive association between crash probability and the speed of crash involved vehicles.

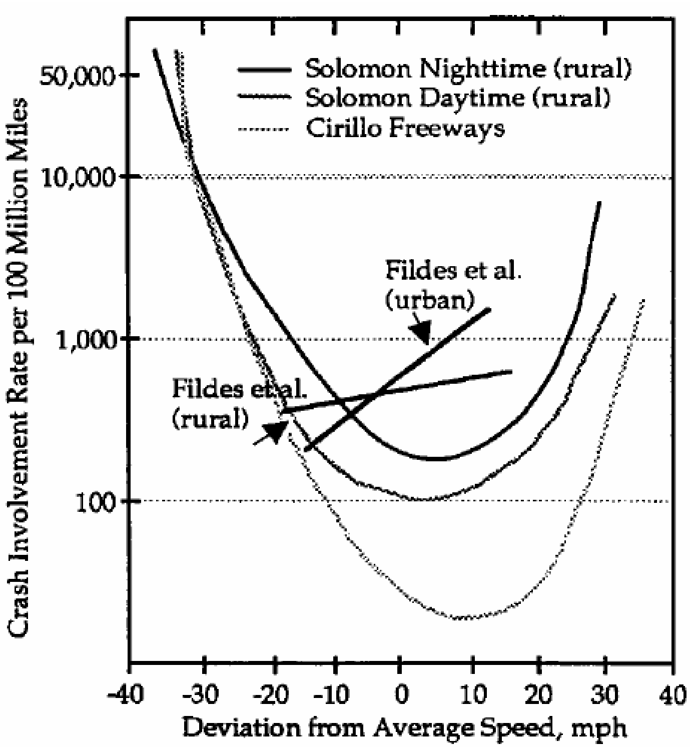

Figure 2-2: Vehicle Crash Involvement Rates As a Function of Deviation from Average Traffic Speeds (Solomon 1964; Cirillo 1968; Fildes et al. 1991)

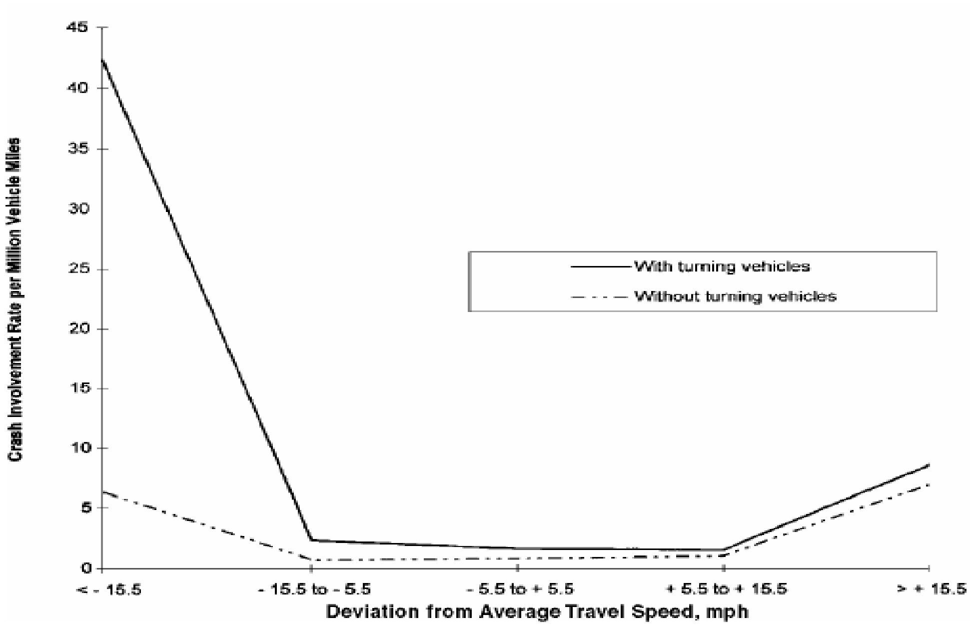

Figure 2-3: Vehicle Crash Involvement Rates Including and Excluding Turning Vehicles (West And Dunn, 1971)

A more recent Australian study (Kloeden et al. 1997) that examined the relationship between speed and the probability of involvement in a casualty crash supports some of the results reported earlier by Fildes et al. (1991), at least for speeds above the average speed of traffic. Using a case control approach, the speeds of cars involved in casualty crashes (the case vehicles) were compared with the free-flowing speeds of cars not involved in crashes but traveling in the same direction at the same location, time of day, day of week, and time of year (the control vehicles). Data collection was focused on weekday, daylight crashes—to exclude most alcohol-related crashes—in speed zones with a 37-mph (60-km/h) speed limit. Pre-crash speeds were determined using crash reconstruction techniques. The data showed a steady and statistically significant increase in the probability of involvement of the case vehicles in a casualty crash with increasing speed above, but not below, the 37-mph speed limit, which roughly approximated the average traffic speed. The risk approximately doubled with each 3-mph (5-km/h) increase in speed above the limit. The probability of casualty crash involvement at speeds below 37 mph was not statistically different from the probability at the speed limit. The absence of a significant association between speed and crash involvement at speeds below the average traffic speed may be the result of the study design.

Several studies have attempted to analyze the relationship between crash involvement and measures of the distribution of speeds in a traffic stream, thereby avoiding the problem of estimating the pre-crash speeds of individual vehicles. On the basis of data from 48 states, Lave (1985) developed models for a range of road classes (e.g., Interstates, arterials, collectors) to investigate the relationship between average traffic speed, speed dispersion, and fatality rates, attempting to hold constant some of the other factors that affect highway fatality rates using standard statistical techniques. He found that speed dispersion was significantly related to fatality rates for rural Interstates and rural and urban arterials. After controlling for speed dispersion, average traffic speed was not found to be significantly related to fatality rates for any road type.

A related study by Garber and Gadiraju (1988) found, as Lave had, that average traffic speeds are not significantly related to fatality rates. They examined the relationship between crash rates, speed dispersion, average traffic speed, and other measures that influence speed—design speed and posted speed limits—on several different classes of roads in Virginia. They found that crash rates declined with an increase in average traffic speeds when data for all road classes were combined [Garber and Gadiraju, 1988]. The correlation disappeared when the data were disaggregated by road class, suggesting that the aggregated analysis simply reflected the effects of the different design characteristics of the roads being studied (e.g., lower crash rates on high-speed Interstates). When crash rates were modeled as a function of speed dispersion for each road class, however, crash rates increased with increasing speed dispersion. The minimum speed dispersion occurred when the difference between the design speed of the highway, which reflects its function and geometric characteristics, and the posted speed limit was small.

The studies just reviewed suggest that the type of road may play an important role in determining driver travel speeds and crash probability. Thus, speed and crash probability on rural non-limited access highways was also examined.

2.7.2 Studies on Non-limited-Access Rural Highways

The potential for vehicle conflicts is considerably greater on undivided highways, particularly high-speed non-limited-access highways. Vehicles entering and exiting the highway at intersections and driveways, and passing maneuvers on two-lane undivided highways, increase the occurrence of conflicts between vehicles with large speed differences and hence increase crash probability. Solomon's study (1964) provides strong evidence for these effects on two- and four-lane rural non-limited-access highways. High crash involvement rates are associated with vehicles traveling well above or below the average traffic speed; at low speeds, the most common crash types are rear-end and angle collisions, typical of conflicts at intersections and driveways.

West and Dunn's analysis (1971) pinpointed the important contribution of turning vehicles to crash probability on these highways. When turning vehicles were excluded from the analysis, crash involvement rates at low speeds were not as high as those found by Solomon (Figure 2-2); they were more symmetric with crash involvement rates at high speeds (Figure 2-3). The study by Fildes et al. (1991) showed a gradual increase in crash probability for vehicles traveling above, but not below, average traffic speeds on two-lane rural roads (Figure 2-2). The previously cited studies by Garber and Gadiraju (1988) and Lave (1985) provide additional support for the contribution of speed dispersion to traffic conflicts and crash involvements on rural non-limited-access highways. Garber and Gadiraju (1988) found a high correlation between increasing speed dispersion and crash rates on rural arterial roads, but the model included only these two variables. Lave's rural arterial model, which attempted to control for more variables, found a weak but statistically significant relationship between traffic speed dispersion and fatality rates for only 1 year of data (Lave 1985). Neither study found any significant relationships between average traffic speeds and crash or fatality rates for this road class. Solomon’s study provides some support for the role of speed per se in crash involvement on high-speed, non-limited-access rural highways. He found that the percentage of single-vehicle crashes, which are more common on high-speed roads generally, increased sharply as a function of the speed of the crash involved vehicles (Solomon 1964). Together, these studies suggest that speed dispersion, created in part by the characteristics of rural non-limited-access highways, contributes significantly to increased crash probability for this road class. The level of speed also appears to affect crash probability for certain crash types, such as single-vehicle crashes.

2.7.3 Speed as a Contributing Factor to Crashes

According to a study conducted by the GAO on rural highway safety, one or more of the four following factors have been identified to contribute to rural road fatalities—human behavior, roadway environment, vehicles, and the degree of care for victims after a crash [GAO, 2004]. Victim care includes the quality of the emergency response and the hospitals that provide medical treatment for those involved in a crash.

Excessive speed is reported to be an important contributory factor in many crashes. Analyses of a number of large databases in the United States indicated that speeding contributed to around 12 per cent of all crashes reported to the police and to about one third of fatal crashes [Kloeden, Ponte, and McLean, 2001]. As rural roads have fewer intersections than urban roads and are more likely to provide travel between urban areas, they often have higher speed limits than many urban routes. From 2000 through 2002, about 62 percent of the nation’s speeding related fatalities were on rural roads, amounting to about 24,000 of the 39,000 fatalities where speed was a contributing factor, according to NHTSA data. According to Insurance Institute for

Highway Safety officials, speed influences crashes by increasing the distance traveled from when a driver detects an emergency until the driver reacts thus increasing the distance needed to stop and ultimately increasing the severity of an accident and reducing the ability of the vehicles, restraint systems, and roadside hardware, such as guardrails and barriers, to protect occupants [GAO, 2004].

Rural roads are more likely than urban roads to have poor roadway design, including narrow lanes, limited shoulders, sharp curves, exposed hazards, pavement drop-offs, steep slopes and limited clear zones along roadsides. Many rural routes have been constructed over a period of years and as a result often have inconsistent design features for such things as lane widths, curves, shoulders and clearance zones along roadsides. Because rural traffic accidents often occur in more remote locations than urban accidents, emergency medical care following a serious accident is often slower, contributing to a higher traffic fatality rate on rural roads. In about 30 percent of fatal rural traffic accidents in 2002, victims who died did not reach a hospital within an hour of the crash, whereas only eight percent of people injured in fatal, urban traffic accidents did not reach a hospital within an hour. [TRIP, 2005].

Drivers' speed choices impose risks that affect both the probability and severity of crashes. Speed is directly related to injury severity in a crash. The probability of severe injury increases sharply with the impact speed of a vehicle in a collision, reflecting the laws of physics. Although injury to vehicle occupants in a crash can be mitigated by safety belt use and airbags, the strength of the relationship between speed and crash severity alone is very evident.

Crash involvement on Interstate highways and non-limited-access rural roads has been associated with the deviation of the speed of crash-involved vehicles from the average speed of traffic. Crash involvement has also been associated with the speed of travel, at least on certain road types. For example, single-vehicle crash involvement rates on non-limited-access rural roads have been shown to rise with travel speed. Speed limits enhance safety in mainly two ways. By establishing an upper bound on speed, they have a limiting function to reduce both the probability and the severity of crashes. Speed limits also have a coordinating function of reducing speed dispersion and thus reducing the potential for vehicle conflicts. A related function of speed limits is to provide the basis for enforcement and sanctions for those who drive at speeds excessive for conditions and endanger others.

2.8 Influences of Speed Limits on Safety

A summary of several speed-related studies and their contribution to highway safety are given below. Table 2-3 presents the increase in speed recorded by a number of researchers when speed limits on U.S. highways were increased from 55 mph to 65 mph. Tables 2-4 and 2-5 lists a number of studies that focused on the relationship between speed limit changes and highway safety. Taken together, these studies show that speeds do increase with an increase in speed limit and that highway safety has generally increased when speed limits are decreased, while speed limit increases have had the opposite effect. However, there is not consistent evidence that a change in speed limits leads to a change in safety.

Table 2-3: Summary of Studies Showing Increased Driver Speeds Resulting from 10 MPH Increase in Speed Limit (Dougherty, 2000)

Authors	Speed Increase (55 → 65 mph)
Brown, Maghsoodloo, and Ardle (1990)	2.4 mph
Freedman and Esterlitz (1990)	2.8 mph
Mace and Heckard (1991)	3.5 mph
Pfefer, Stenzel, and Lee (1991)	4–5 mph
Parker (1997)	0.2–2.3 mph

Table 2-4: Summary of Studies on Effect of Speed Limit Decreases (Dougherty, 2000)

Authors	Country	Speed Limit Decreases	Results
Peltola (1991)	United Kingdom	62–50 mph	Speeds declined by 4 km/h.
Sliogeris (1992)	Australia	68–62 mph	Injury crashes declined by 19 percent.
Authors	**Country**	**Amount of Speed Limit Decrease**	**Results**
Newstead and Mullan (1996)	Australia	3–12 mph	No significant change. (4 percent increase relative to sites not changed.)
Parker (1997)	United States	5–20 mph	No significant changes.

Table 2-5: Summary of Studies on Effect of Speed Limit Increases (Dougherty, 2000)

Authors	Country	Speed Limit Increases	Results
McKnight and Klein (1990)	United States	55–65 mph	Fatal crashes increased by 22 percent. Speeding increased by 48 percent.
Garber and Graham (1990)	United States (40 States)	55–65 mph	Fatalities increased by 15 percent. Decrease or no effect in 12 states.
Lave and Elias (1994)	United States (40 states)	55–65 mph	Statewide fatality rates decreased by 3-5 percent. (Significant in 14 of 40 states.)
Newstead and Mullan (1996)	Australia (Victoria)	3–12 mph	Crashes increased overall by 8 percent, but 35 percent declined in zones raised from 60–80 mph.
Rock (1995)	United States (Illinois)	55–65 mph	Crashes increased by 33 percent. Fatalities increased by 40 percent. Injuries increased by 19 percent.
Parker (1997)	United States (22 states)	5–15 mph	No significant changes.

2.9 Cost and Benefit of Speed Limit Increase

In 2003, speeding was a contributing factor in 31 percent of all fatal crashes, and 13,380 lives were lost in speeding-related crashes compared to 12,480 lives in 1994. The economic cost to society of speed-related crashes, estimated by NHTSA for the year 1994 was more than $23 billion per year while the 2000 costs of speeding-related crashes were estimated to be $40.4 billion per year. The table below shows the estimated annual economic costs of speed-related crashes for the year 1994 (1990 Dollars per Year).

Table 2-6: Estimated Annual Economic Costs of Speed-Related Crashes (1990 Dollars), (NHTSA, 1995)

Crash Type	Cost
Fatal	$9.8 billion
Injury (Non-Fatal)	$9.1 billion
Property-Damage-Only	$4.3 billion
Total	**$23.2 billion**

According to the National Safety Council (2005), the economic cost of motor-vehicle crashes in the year 2004 has been estimated as:

- $ 1,130,000 per Fatality crash,
- $49,700 per Injury crash and
- $7,400 per PDO crash

There have been several studies attempting to quantify the benefits and costs of speed limit changes on highways. The results of these studies uniformly conclude that raising speed limits have higher costs than benefits [Reed, 2001]. In a study of potential benefits and costs of speed changes on rural roads, Professor Max Cameron of the Monash University Accident Research Centre (MUARC), looked at the economic costs and benefits of increasing the speed limit to 130 km/h on rural roads. Impacts were examined for rural freeways, rural divided roads and rural two-way undivided roads. The costs tested were vehicle operating costs, time costs, crash costs and air pollution costs, the aggregate of these impacts representing the total social cost. Two different methodologies were used, ‘human capital’ and ‘willingness to pay’.

With regard to rural undivided roads the report found that there was no economic justification for increasing the speed limit on two-lane undivided rural roads, even on those safer roads with sealed shoulders. On undivided roads through terrain requiring slowing for sharp bends and occasional stops in towns, the increased fuel consumption and air pollution emissions associated with deceleration from and acceleration to high cruise speeds added very substantially to the total social costs. Using ‘human capital’ costs to value road trauma, the optimum speed for cars was about the current speed limit (100 km/h) on straight sections of these roads, but 10–15 km/h less on the curvy roads with intersections and towns. The optimum speed for trucks was substantially below the current speed limit, and even lower on the curvy roads. The optimum speeds would have been even lower if ‘willingness to pay’ valuations of crash costs were used.

3. OBJECTIVES

The objective of this study is to determine the impact on safety of increasing the speed limit on rural two-lane highways in Louisiana from the current 55 mph speed limit to an unspecified higher speed limit. This will be achieved by analyzing the safety record of two-lane road sections in Louisiana before and after they experienced an increase in speed limits. Since road safety is affected by multiple factors, the analysis will be constructed to reduce the impact of extraneous factors as much as possible, leaving the impact of speed limit increase to be measured in the analysis.

4. METHODOLOGY

4.1 Introduction

The main objective of this study was to determine the impact on safety of an indeterminate amount of speed limit increase (the amount of increase ranging between 5mph and 20 mph) on rural two-lane highways. The term safety was defined in terms of the crash rate, defined in this study as the number of persons killed or injured per hundred million vehicle miles of travel. Solomon's study defined crash rate in terms of crash involvement rate, defined as the number of vehicles involved in a crash per 100 million vehicle miles of travel. Though some studies showed that the crash rate increased with increase in speed limit, some other studies argued that the crash rate did not change or sometimes decreased with an increase in speed limit. Most of the studies revealed a definite relation between speed limit and crash rate with the exception of a few cases shown in Table 2.4 and 2.5. The major part of this study involved the development of a methodology to study the effect of speed limit change on crash rate in Louisiana.

The study involved observation of crash rate trends at different speed limits on rural roads over a certain number of years, and the observation of the crash rates on various rural road segments all over Louisiana before and after a speed limit change at that section. The analysis was directed through the use of hypotheses formulated in advance of the analysis. External factors influencing the analysis were controlled for, using classification procedures, so that their influences did not compromise the results of the analysis. This classification was done using classification software SPSS Answer Tree 1.0. Applicable statistical tests were conducted to identify the relative significance of crash involvement with speed limit change in Louisiana and thus to prove the null or alternate hypothesis.

4.2 Hypothesis

The crash rate, defined as the number of crashes per100 million vehicle miles of travel has increased with a speed limit increase on the rural two-lane highways in Louisiana.

4.3 Data

The database used for the analysis consisted of crash and roadway databases for Louisiana for the years 1999 to 2004 obtained from the Louisiana Department of Transportation and Development.

4.3.1 Crash Database

The database consisted of data from the crash and roadway section databases. The crash data was contained in a table called 'DOTD_CRASH_TB' which contains data on police crash reports on all the crashes that occurred in Louisiana from 1999 to 2004. The table contains information on all the different highway classes namely: Rural Two-Lane, Rural Four-Lane, Rural Four-Lane Divided, Rural Interstate, Urban Two-Lane, Urban Four-Lane, Urban Four-Lane Divided, and Urban Interstate. The table contains information on 100 data items for 962,284 crash records for the years 1999 to 2004. It contains details of each crash such as crash year, crash date, crash hour, crash severity, location of crash, control section number, time and day of crash, manner of collision, crash type; details of vehicles involved in crash such as vehicle type, vehicle condition; roadway characteristics at crash site such as posted speed limit, road alignment, surface type and condition, lighting and weather conditions, pavement and median width and driver characteristics such as driver age, sex, driver conditions and other details.

From the crash table the highway class, rural two-lane highway was filtered out to get 104,798 records. This table was named the 'rural two-lane crashes table'. Each record in the table represented a crash that occurred on the two-lane rural highway. Queries were used to filter out the two-lane rural roads (Appendix A).

4.3.2 Creation of New Data Item

The 'rural two-lane crash table' contained all the data items pertaining to the crash, such as crash details, roadway details and vehicle details. As the study pertained to the effect of a speed limit change on crash rate, first the sections which experienced a speed limit change over the period of 1999 - 2004 needed to be identified according to the year of speed limit change. Thus a data item was needed to identify the sections where crashes occurred before and after a speed limit change in each of the year 1999 to 2004. Thus the entire data table was sorted in ascending order of year, control section number 'CSECT', log mile from 'LOGMI_FROM' and log mile to 'LOGMI_TO' as these were the three fields which identified each subsection of each of the two-lane rural highway section. The posted speed limit field, 'POSTED_SPEED', on each of these subsections was observed to determine if there was a speed limit change over the years and the year of speed limit change if there was any.

Then a new field called 'before/after' was created and the year of speed limit change and the letter "B" or "A" was specified for 'before' or 'after' respectively in this column. If the speed limit change for a particular section was found to have occurred sometime in year 2000 then all the crashes that occurred in that particular section in 1999 were identified in the new field 'before/after' as '99B' and all the crashes that occurred from 2000 to 2004 were identified as '99A', implying that the crash occurred on a road section where the speed limit changed after 1999. If no speed limit change was found in a particular section over the entire period then it was entered as 'S' in this field, indicating that the speed limit remained same over the years. Similarly if the speed limit change in a particular section occurred in the year 2000 then all crashes that occurred in 1999 and 2000 were marked with '00B' and all crashes from 2001 – 2004 were marked as '00A'. This was done for each subsection by observing the posted speed limit field and each one was marked as either '99B' or '99A' for speed limit change after 1999, ‘00B’ or ‘00A’ for speed limit change after 2000, ‘01B’ or ‘01A’ for speed limit change after 2001, ‘02B’ or ‘02A’ for speed limit change after 2002, ‘03B’ or ‘03A’ for a speed limit change after 2003 and ‘S’ for no speed limit change over the entire period.

4.3.3 Division into Crash Severity Types

The speed at which a vehicle travels greatly affects the severity of the crash caused. The rural two-lane crash table contains details on all the crashes of different severity levels that occurred at different speed limits over the entire period. As speed is suspected to affect the crash rates among different severity levels differently, the crash table was further divided according to the severity levels so that the effect of speed limit change on each severity level could be studied individually. The rural two-lane crash table contains a field called ‘ACC_CLASS’ which specifies the severity of the crash which may be one of the following:

- Fatality Crash
- Injury Crash
- Property Damage Only (PDO) Crash.

They are coded in the crash table as ‘1’ for Fatality, ‘2’ for Injury and ‘3’ for PDO crashes. The two-lane rural crash table was queried using the Structured Query Language (SQL) querying capabilities of MS Access to get three different tables named as ‘severity type_fatality’, ‘severity type_injury’ and ‘severity type_PDO’ for Fatality, Injury and PDO crashes respectively. These tables contained 1946 fatality crashes, 42,674 injury crashes and 60,178 PDO crash cases.

4.3.4 Crash Rate Calculation

Though the fatality, injury and the PDO crash table contained all the required details on crash, roadway and vehicle characteristics, the crash rate on each section was not present. Thus the field ‘crash rate’ was created separately for the fatality, injury and the PDO crashes. As the rural two-lane roads are the less traveled, low-volume roads, it is appropriate to consider crash rate in terms of the number of crashes per hundred million vehicle miles traveled (VMT) rather than the total number of crashes. Crashes per hundred million VMT also account for the traffic volume in terms of ADT, which is an important factor in speed compliance. VMT is calculated as 100 million VMT in terms of Average Daily Traffic (ADT) and length of a section (SEC_LENGTH) as:

$$VMT = ADT * SEC\_LENGTH * 365/100000000$$

In order to consider the crash rate according to crash severity, the crash rate for each severity group was calculated as shown below. The crash rate for the fatality group was calculated as:

$$Crash\ Rate = Number\ Of\ People\ Killed/\ 100\ Million\ VMT.$$

The number of people killed was determined using the field ‘NUM_TOT_KIL’ which is the sum of the number of drivers, occupants and pedestrians killed in a crash in that section during a particular year. The crash rate for the injury group was calculated as:

$$Crash\ Rate = Number\ Of\ People\ Injured/\ 100\ Million\ VMT.$$

The field ‘NUM_TOT_INJ’ indicated the total number of people injured which is the sum of the number of drivers, occupants and pedestrians injured on that section in a particular year. The crash rate for the PDO group is calculated as the count of PDO crashes in that section divided by 100 million VMT.

4.4 Categorization of Crash Types Using Cross-Classification

The crash type is expected to be dependent, to an extent, on the speed of the vehicles involved in the crash. Thus each of the severity type tables namely, severity type_fatality, severity type_injury and severity type_PDO were subdivided into different crash types to clearly distinguish the influence of speed limit change on each of the crash type for each crash severity type. Speed limit change affects each of the crash type for each severity type differently and thus each of the severity type tables were subdivided based on the crash types most frequent for each severity types. Some of the common crash types may be run-off road, head-on collisions, rear-end collisions, sideswipe, collision with pedestrian, collision with parked vehicle, collision with animal, collision with a fixed object and many other types of crashes, but all these crash types fall under the category of two fields in the crash table, namely, manner of collision, with field name 'MAN_COLL_CD' and type of accident, with field name 'TYPE_ACC'. The field, 'MAN_COLL_CD' contains the sub-categories shown in Table 4-1.

Table 4-1: Description of Manner of Collision Field Categories

COLUMN	CODE	DESCRIPTION
man_coll_cd	A	non collision with motor vehicle
man_coll_cd	B	rear end
man_coll_cd	C	head on
man_coll_cd	D	right angle
man_coll_cd	E	left turn angle
man_coll_cd	F	left turn opposite direction
man_coll_cd	G	left turn same direction
man_coll_cd	H	right turn angle
man_coll_cd	I	right turn opposite direction
man_coll_cd	J	Side swipe same direction
man_coll_cd	K	Side swipe opposite direction
man_coll_cd	L	other

The field 'TYPE_ACC' consists of the following sub-categories:

Table 4-2: Description of Type of Accident Field Categories

COLUMN	CODE	DESCRIPTION
type_acc	A	Running off roadway
type_acc	B	Overturning on roadway
type_acc	C	Collision with pedestrian
type_acc	D	Collision with other motor vehicle in traffic
type_acc	E	Collision with parked vehicle
type_acc	F	Collision with train
type_acc	G	Collision with bicyclist
type_acc	H	Collision with animal
type_acc	I	Collision with fixed object
type_acc	J	Collision with other object
type_acc	K	Other non-collision on road

In order to consider all of the above different categories of manner of collisions and types of accidents and hence to decide on the crash types most influential on each severity types, a cross-classification analysis was performed on these two fields on each of the severity types, fatality, injury and PDO crashes using the pivot table feature in Microsoft Excel, so that some of the categories could be combined together to create a new category and some omitted depending on the number of crashes falling under each category.

The details of the cross-classification conducted on each severity group and the results are reported in the next chapter. The dominant crash types were thus identified for each of the severity types and based on the above obtained crash types for each severity group, queries were built to create new tables for each of them by grouping the categories according to the grouping arrived at through the cross-classification above (Appendix A).

4.5 Dependent and Independent Variables

4.5.1 Dependent Variables

In this study the dependent variables are the crash rate at different severity levels (Fatality, Injury and PDO) for different crash types.

Thus, incorporating the influence of speed limit on crash severity, three dependent variables were defined:

- Number of fatalities/ 100 million VMT
- Number of injury crashes/100 million VMT
- Number of PDO crashes/100 million VMT

The type of crash may be influenced by the speed at which vehicles travel. Thus the fourth dependent variable is the crash type such as run off road, head on collision etc. resulting from the cross-classification.

4.5.2 Independent Variables

Independent variables are those variables that are expected to influence the value of the dependent variables. Many variables have individual as well as combined influence on crash occurrence, but we are particularly interested in the influence of increased speed limits on safety. To eliminate or severely reduce, the impact that other variables have on observed crash occurrence, we have subdivided the data into groups in which the observed crash rates are as homogeneous as possible on these other variables. That is, we have effectively controlled for the influence of these other variables by creating groups in which they are homogenous, leaving only speed limit change as variable within each group.

4.6 Classification Procedure Using Answer Tree 1.0

There are many factors which contribute towards the incidence and severity of crashes and speed is suspected to be only one of these.

It is estimated that speeding alone contributes to about one third of all fatal crashes but often it is speeding combined with other factors, such as road conditions or environmental conditions, which cause a much higher number of crashes.

To isolate the effect of speed from the effect of other factors, the other factors need to be identified and controlled. Identification was achieved by observing which variables were most influential in changing the crash rate of each crash type within each severity type. For this a classification procedure was employed that seek out the division of data so that the resulting groups were as homogeneous with respect to crash rate as possible. This classification procedure was repeated on each of the crash type table obtained for each severity type resulting in thirteen runs of the Classification and Regression Tree (CART) process in Answer Tree, one for each of the group. The variables describing each of the groups were then the variables most influential in describing crash rates.

4.6.1 Answer Tree 1.0

Answer Tree is a computer learning system that creates classification systems displayed in decision trees. It is used to generate the classification rules from existing data. Answer Tree exhaustively examines all the fields of the database with respect to the criterion variable by building a tree from the entire database by splitting and subdividing the data into homogeneous groups until the tree growth is stopped. It seeks out the prime factors by performing all the possible permutations and combinations of the variables.

It provides four algorithms for performing classification and segmentation analysis (Answer Tree 1.0 User's Guide, 1998). They are:

- **CHAID -** Chi-squared Automatic Interaction Detector, a method that uses chi-squared statistics to identify optimal splits.
- **Exhaustive CHAID -** A modification of CHAID that does a more thorough job of examining all possible splits for each predictor but takes longer to compute.
- **C&RT -** Classification and Regression Trees, methods that are based on minimization of impurity measures.
- **QUEST -** Quick, Unbiased, Efficient Statistical Tree, a method that is quick to compute and avoids other methods' biases in favor of predictors with many categories

The CART algorithm was used for performing classification in this analysis.

CART is an exploratory data analysis method that is used to study the relationships between a dependent measure and a number of possible predictor variables which may interact between themselves. The CART tree is constructed by splitting subsets of the data set using all predictor variables to create two child nodes repeatedly, beginning with the entire data set. The best predictor is chosen using a variety of measures to reduce impurity or diversity. The performance of the classifier is measured using risk estimate values. Thus each end node of a fully grown tree can be traced back to the parent node to indicate a homogeneous group of variables affecting the crash rate. The results are displayed graphically and statistically. The classification procedure in this research was required to identify those variables that can effectively distinguish the homogeneous set of factors affecting the crash rate for each severity and crash type group.

4.6.2 Data Items Used in CART Classification Procedure

The CART classification is performed on each crash type group for each of the severity types, (Fatality, Injury and PDO crashes) and the data items used for each of the group may vary. But some of the important data items used commonly in all the groups are described below.

Each data item or variable can be characterized by the kind of values it can take and what those values measure. This general characteristic is referred to as the measurement level of the variable.

A variable has one of three measurement levels:

Nominal - This measurement level includes categorical variables with discrete values, where there is no particular ordering of values.

Ordinal - This measurement level includes variables with discrete values, where there is a meaningful ordering of values. Ordinal variables generally don’t have equal intervals, however, so the difference between the first category and the second may not be the same as, for example, the difference between the fourth and fifth categories.

Continuous - This measurement level includes variables that are not restricted to a list of values but can essentially take any value (although the values may be bounded above or below or both).

Thus the variables or data items described below maybe nominal, ordinal or continuous as described below.

4.6.2.1 Crash Hour

It is the hour in the day at which the crash occurred. The value of this data item varies from 0 to 23 where 0 represents midnight to just before 1.00 am and 23 represents 11 pm to just before midnight. Thus crash hour is a continuous variable.

4.6.2.2 Alcohol

This data item shows whether alcohol was involved in the crash or not. This field takes the value 0 or 1 representing alcohol involvement or no alcohol involvement, respectively.

4.6.2.3 Alignment Condition

This field describes the vertical and horizontal alignment of the roadway at which the crash occurred. This field can take the following values: straight-level (coded as A), straight-level-elevated (B), curve-level (C), curve-level-elevated (D), on grade straight (E), on grade curve (F), hillcrest straight (G), hillcrest curve (H), dip/hump straight (I), dip/hump curve (J), unknown (K) and other (L).

4.6.2.4 Day of Week

This describes the day of the week of the crash. It can take a value ranging from 1 to 7 where 1 represents a Monday and 7 represents a Sunday.

4.6.2.5 Lighting Condition

This field describes the illumination at the time of the crash. It can take the following values: daylight (A), dark-no street light (B), dark-continuous street lights (C), dark-street lights-intersect only (D), dusk (E), dawn (F) and unknown (G).

4.6.2.6 Location Type

This field describes the surrounding environment of the crash and can take value ranging from A to H described as manufacturing or industrial (A), business continuous (B), business, mixed residential (C), residential district (D), residential scattered (E), school or playground (F), open country (G) and other (H).

4.6.2.7 Road Condition

This field describes the condition of the roadway at the time of the crash. It takes the following values: no defects (A), defective shoulders (B), holes (C), deep ruts (D), bumps (E), loose surface material (F), construction, repair (G), overhead clearance limited (H), construction – no warning (I), previous crash (J), flooding (K), animal in the roadway (L), object in the roadway (M), and other defects (N).

4.6.2.8 Surface Condition

This data item describes the moisture condition on the road surface and can take values from A to G as explained. Dry (A), wet (B), snow or slush (C), ice (D), contaminant (sand, mud, dirt, oil, etc) (E), unknown (F) and other (G).

4.6.2.9 Driver Age

This field describes the age of the driver at the time of crash and can take any value ranging from 0 to 99. Drivers aged 99 or above are represented as 99.

4.6.2.10 Driver Sex

This field describes the sex of the driver and is coded as either M or F representing male and female, respectively.

4.6.2.11 Traffic Control Condition

This field describes the presence of traffic control at the location of crash. it can take values ranging from A to X as follows. Stop sign (A), yield sign (B), red signal on (C), yellow signal on (D), green signal on (E) , green turn arrow on (F), right turn arrow on red (G), light phase unknown (H), flashing yellow (I), flashing red (J), officer, watchman (K), RR crossing, sign (L), RR crossing, signal (M), RR crossing, no control (N), warning sign (school, etc) (O), school flashing speed sign (P), yellow no passing line (Q), white dashed line (R), yellow dashed line (S), bike lane (T), cross walk (U), no control (V), unknown (W) and other (X).

4.6.2.12 Vehicle Type

This field describes the type of the vehicle and is coded as following. Passenger car (A), light truck or pickup (B), van (C), A, B or C with trailer (D), motor cycle (E), pedal cycle (F), off road vehicle (G), emergency vehicle (H), school bus (I), other bus (J), motor home (K), single unit truck (L), truck with trailer (M), farm equipment (N) and other (O)

4.6.2.13 Prior Movement

This field describes the movement of the vehicle prior to the crash and takes a value ranging from A to Z as follows. Stopped (A), proceeding straight ahead (B), traveling wrong way (C), backing (D), crossed median into opposing lane (E), crossed center line into opposing lane (F), ran off road (not while making turn at intersection) (G), changing lanes on multilane roads (H), making left turn (I), making right turn (J), stopped preparing to, or making, U-turn (K), making turn, direction unknown (L), stopped, preparing to turn left (M), stopped , preparing to turn right (N), slowing to make left turn (O), slowing to make right turn (P), slowing to stop (Q), properly parked ®, parking maneuver (S), entering traffic from shoulder (T), entering traffic from median (U), entering traffic from parking lane (V), entering traffic from private lane (W), entering freeway from on-ramp (X), leaving freeway via off-ramp (Y), and others (Z).

4.6.2.14 Violations

This field describes the vehicle violations at the time of crash and can take a value ranging from A to V as follows. Exceeding stated speed limit (A), exceeding safe speed limit (B), failure to yield (C), driving too closely (D), driving left of center (E), cutting in improper passing (F), failure to signal (G), made wide right turn (H), cut corner on left turn (I), turned from wrong lane (J), other improper turning (K), disregarded traffic control (L), improper starting (M), improper parking (N), failed to set out flags or flares (O), failed to dim headlights (P), vehicle condition (Q), driver's condition (R) careless operation (S), unknown violation (T), no violation (U) and other (V).

4.6.2.15 Pavement Width

This field describes the width of the pavement where the crash occurred. It can take values ranging from 12 feet to 70 feet in the case of rural two-lane roads.

4.6.2.16 Weather Condition

This describes the weather at the time of the crash. It can take a value ranging from A to J as follows. Clear (A), cloudy (B), rain (C), fog or smoke (D), sleet or hail (E), snow (F), severe cross wind (G), blowing sand, soil, dirt, snow (H), unknown (I) and other (J).

The rest of the data items included in the CART classification system varies according to the type of crash for which the analysis is being performed. For example the data items, vehicle type 1 and vehicle type 2, driver age 1 and driver age 2, driver sex 1 and driver sex 2, violation 1 and violation 2, prior movement 1 and prior movement 2 may be included in a head on collision crash type as two vehicles are involved in such a crash but may not be included in a run-off road crash as a run off road crash usually involves only 1 vehicle. Similarly, an intersection crash may be included in turning angle and sideswipe crashes but may not be included in a run-off road crash.

By considering all of the above variables, with the exception of change in speed limit, in the classification procedure with crash rate as the criterion variable, the resulting groups will be 'controlled' for the influence of these variables within each group (depending on the level of homogeneity achieved). That is, since the influential variables are as uniform as possible within each group (at least with respect to their influence on the crash rate), their influence on the crash rate, within the group, is limited. By comparing, within each group, the crash rate between road sections that have experienced a change in speed limit with those that have not isolates the influence of change in speed limit on crash rate from the influence of other variables as much as possible.

4.6.3 Growing the Tree

To grow a classification tree in SPSS Answer Tree 1.0, the model must first be defined by selecting the target and predictor variables, and the classification procedure. In this case the target variable was the Crash Rate for each crash type and severity level (defined as continuous) and the predictor variables were Crash Hour (continuous), Alcohol (nominal), Alignment Condition (nominal), Day of Week (nominal), Lighting Condition (nominal), Location Type (nominal), Road Condition (nominal), Surface Condition (nominal), Driver Age (continuous), Driver Sex (nominal), Traffic Control Condition (nominal), Vehicle Type (nominal), Prior Movement (nominal), Violations (nominal), and Pavement Width (continuous). The classification procedure chosen was the CART method. After defining the model, the *Growing Criteria* for the tree must be specified.

To generate a tree structure, the program must be able to determine when to stop splitting nodes. The criteria for determining this are called stopping rules and the following stopping rules settings can be controlled:

Maximum Tree Depth: This setting allows controlling the depth (number of levels below the root node) of the generated tree.

Minimum Number of Cases: This setting allows specifying the minimum numbers of cases for nodes. Nodes that do not satisfy these criteria will not be split.

Parent Node Total: The minimum number of cases in a parent node. A parent node is the node in a tree structure that links to one or more child nodes. Thus parent nodes with fewer cases will not be split.

Child Node: The minimum number of cases in child nodes. A child node is a node in the tree structure that is linked to by a parent node and the child node results from the parent node. If splitting a node would result in a child node with number of cases less than this value, the node will not be split.

The stopping rule for CART depends on the minimum change in impurity. If splitting a node results in a change in impurity less than the minimum, the node is not split. The minimum change in impurity was specified as 0.0001. The CART process was run on all of the 13 crash type groups, changing the predictor variables for each of the group according to the crash type, and giving appropriate stopping rules, resulting in thirteen fully grown trees with different number of terminal nodes for each tree. An overview of the classification tree can be seen in the Tree Map shown in Figure 4-1. The nodes display the mean, standard deviation, and the number of data records it could split and the improvement i.e., the measure of decrease in impurity for each predictor in each node with the use of each variable as shown in Figure 4-2. The risk and gain summaries are also displayed for each fully grown tree. The gain charts give the node statistics relative to the mean of the target variable. The risk estimate is the within-node variance about each node's mean, averaged over all the nodes. The automatically grown tree was then analyzed by examining the standard deviation values of the end nodes and finding the proportion of variance captured by the classification procedure. Also the number of data records in the end node is observed and the cases where the end node had less than 30 records were neglected. The other end nodes were traced back to the parent node and each of these were defined as a homogeneous group. The details of the analysis on the 13 crash type are given in detail in the next chapter. After conducting the thirteen consecutive runs of the CART process, the variable splits were examined to identify the homogeneous group of variables that consistently played an important role in distinguishing factors affecting crash rate. The groups with very few cases were neglected and finally forty seven homogeneous groups were identified in all and the crash type tables were queried to establish new tables with the homogeneous groups obtained (Appendix A).

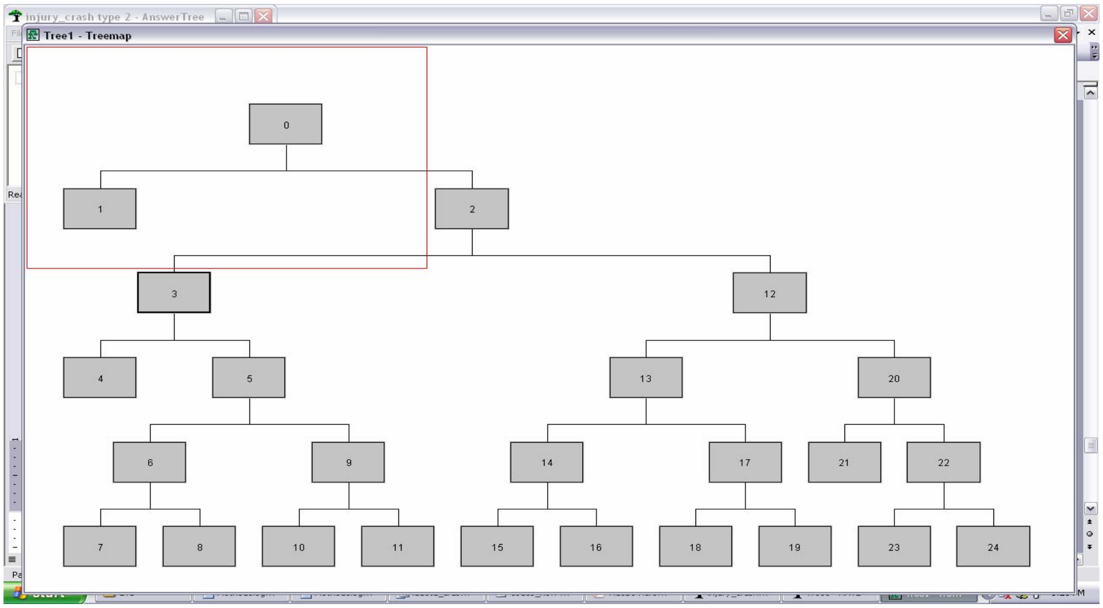

Figure 4-1: Tree Map

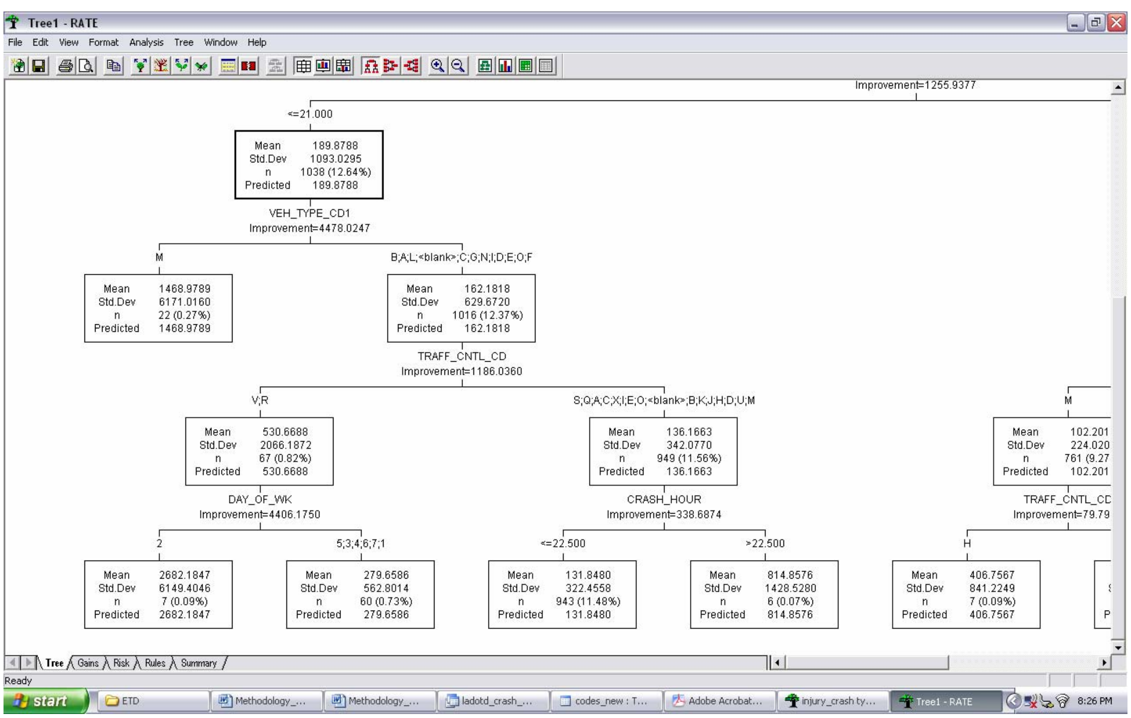

Figure 4-2: Classification Tree Showing the Nodes

4.7 Division into 'No Speed Change' and 'Speed Change' Group

The forty seven homogenous group tables consist of fields which meet the criteria specified by each homogeneous group established in Answer Tree and also the rest of the fields which identify a particular road way section such as control section number, log mile, and other speed details such as posted speed limit and the created new field 'Before/After' which identifies a section as a section which underwent a speed limit change or no speed limit change. As the next step in the analysis the speed limit change sections were separated from the no speed limit change group.

4.7.1 'No Speed Change Group'

The no speed change group was identified by the value 'S' in the newly created field 'before/after' and this was used to filter out the no speed change group from each of the homogeneous group table using queries (Appendix A). Forty seven tables were created in all.

4.7.2 'Speed Change Group'

The speed change group was distinguished by the value '99B' or '99A' or '00B' or '00A' and so on in the 'before/after' field, depending on the year in which the speed limit change was observed. It is noted that any amount of speed limit change, be it 5 mph or 20 mph, was recorded as a speed limit increase irrespective of the amount of increase. This data was tabulated using SQL queries such that the groups with a speed limit change in each of the year 1999 to 2004 were established in separate tables for each of the forty seven groups established through Answer Tree. Thus five separate tables were obtained, one for each year of speed limit change, for each homogeneous group. These tables were named as: 'FAT_CT1_HG_1_99' which indicated a crash group of severity level – fatality, of crash type - 1 and of homogeneous group - 1 in which a speed limit change occurred in 1999. Similarly the other tables were named as 'FAT_CT1_HG_1_00', 'INJ_CT_2_HG_3_00' and so on.

4.8 Plotting of Trends

The no speed limit change group tables for each of the forty seven cases were observed for any trend in crash rate increase so that any crash rate increase in the speed limit change group could be adjusted for the trend. As the first step, the years were ordered in ascending order and the average crash rate was calculated for each year for each of the tables. Each of the years 1999 to 2004 were represented by numbers 0 to 5 respectively for ease of plotting. Then the average crash rate values and the years 0 to 5 were entered in Minitab and regression analysis was performed to obtain the regression equation. Analysis of variance was also conducted on the data set to test the significance of the trend line for 95 % confidence interval. The cases in which the P-value was less than 0.05 were established as significant groups, implying that for the particular group, there was a natural trend for the crash rate to increase.

4.9 Calculation of Average 'Before and After Speed Limit Change' Crash Rate and Adjustment for Trend from Derived Equation

Each of the speed limit change group tables were observed and the average crash rate was calculated according to year of speed limit change and the average of years before and after speed limit change was calculated. For example for a case with a speed limit change in 2001, the average of all the before speed limit change years, i.e., 1999, 2000 and 2001 were calculated and also the average crash rate of these three years were calculated. The average crash rate value was then plotted at the average before speed limit change year, which is 2000 in the above case. Similarly all the after speed limit change years were averaged and the crash rate of all the after years, i.e., 2002, 2003 and 2004 were averaged and plotted against the year 2003. This was done for each of the forty seven tables for speed limit change in each of the years 1999 to 2004. The plot of average crash rate against average year of a case where speed limit change occurred in

2001 is shown in Figure 4-3. In the figure, the years are marked as 0, 1, 2, to 5 corresponding to 1999 to 2004.

After plotting the average crash rates before and after a speed limit change the after speed change crash rate values needed to be adjusted for the cases which were found to have significant crash trends in the no speed limit change group. This adjustment was done so that the effect of natural trends on ‘after’ speed change crash rate were reduced and the new ‘adjusted’ after speed limit change crash rate value was solely attributed to the speed limit change and no other external influences or natural trends.

This adjustment was done by multiplying the slope of the trend line of the particular case with the difference in years between the average before and after speed limit change years and subtracting this product from the original ‘after’ speed limit change crash rate. This can be expressed by the following equation:

$$CR_{(Adj)} = CR_{(Orig)} - S * (Y_{(Avg\ Aft)} - Y_{(Avg\ Bfore)})$$

Where,

$CR_{(Adj)}$ = Adjusted Average after speed limit change Crash Rate

$CR_{(Orig)}$ = Original Average after speed limit change Crash Rate

S = Slope of Trend line

$Y_{(Avg\ Aft)}$ = Average of After speed limit change Years

$Y_{(Avg\ Bfore)}$ = Average of Before speed limit change Years

Thus for all the cases where the crash trend was found to be significant in the no speed limit change group, the corresponding cases in the speed limit change group were adjusted for the crash rate value ‘after’ speed limit change using the above explained equation to get the adjusted crash rate value. An example of original and adjusted before and after crash rate values is shown in Figure 4-4.

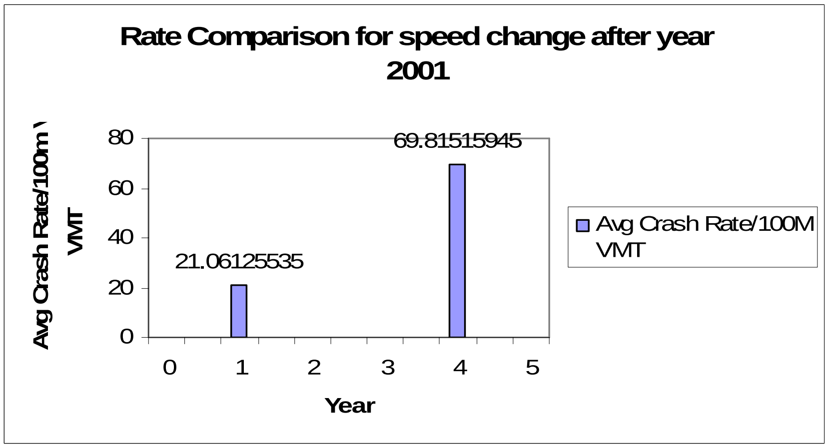

Figure 4-3: Average Crash Rate Before and After Speed Limit Change for Speed Change in 2001

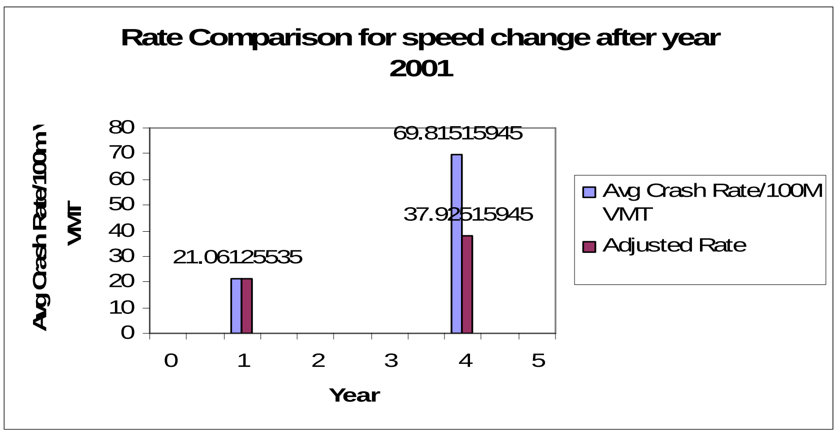

Figure 4-4: Average Crash Rate Values for Speed Change in 2001 Showing Original and Adjusted Crash Rates

Thus for each case we get pairs of values before and after the speed limit change in which the after value has been adjusted for trend. These pairs need to be tested for any statistical similarity and thus to arrive at some statistical conclusion.

4.10 Paired T-test Comparison.

A single tailed paired sample t-test was conducted to test the statistical difference between the before and after speed limit change crash rates. The crash rate of 'after' speed limit change group adjusted for the trend over time was compared with the crash rate of 'before' group for each year of speed change to obtain pairs of values in each of the homogeneous groups. Thus several pairs of values were obtained for each of the classification analysis performed on each of the crash type and crash severity. These pairs were compared and analyzed using the single tailed paired comparison t–test to prove the null or alternate hypothesis.

A paired sample t-test compares the means of two variables. It computes the difference between the two variables for each case and tests to see if the average difference is significantly different from zero. Here a single tailed paired sample t-test was used because we are considering the case of the effect of a speed limit increase on crash rate. The crash rate will always increase or remain same with a speed limit increase but not decrease with a speed limit increase. Since our alternate hypothesis takes the form of a 'greater than' comparison, the upper tailed t-test is considered for the analysis. The upper tailed paired sample t-test is used to test the null hypothesis that the crash rate has not increased with a speed limit increase (crash rate after speed limit change is not greater than crash rate before the change), against the alternative hypothesis that the crash rate has increased with an increase in speed limit ('after' crash rate value is greater than 'before' value). The null hypothesis is rejected if the calculated P-value is less than 0.05, concluding that the 'after' value was greater than the 'before' value.

The upper tailed paired sample t-test was done using MINITAB Statistical Software. It displays the summary statistics of the two samples followed by the mean of the differences between the paired observations, and the standard deviation of these differences, followed by the standard error of the mean of the differences. It also displays the 95% lower confidence bound for the mean, the test statistic (T-value) and the probability, P-value.

5. ANALYSIS AND RESULTS

This section describes the analysis of Louisiana crash data and the results that were obtained from that analysis. The details of the analysis and the results are presented below.

5.1 Cross-Classification Analysis

As discussed in Section 4.4, crash types are described in the data by the variables Manner of Collision (Table 4-1) and Type of Accident (Table 4-2). To establish a common set of crash types a cross classification analysis was conducted on both these variables for all the three severity types.

The results of the classification are shown below for each severity type. Color coding is used to show the different crash types ultimately established.

5.1.1 Cross-Classification Analysis on Fatality Group

Table 5-1 shows the distribution of crashes in each category and the four crash types established for the fatality group by cross-classification. The four crash types most common in the fatality group were obtained as:

- Run-off road crashes,
- Head-on and right angle crashes,
- Turning angle and sideswipe crashes and
- Non-motor vehicle crashes.

The category run-off road crash consisting of 890 crash cases, was established by combining the manner of collision types ‘non-motor vehicle collision’ crashes (A) and the ‘other’ crashes (L) with the type of accident category ‘run-off road’ (A). Table 5-1 clearly suggests that only these two categories of manner of collision had a high contribution to type of accident category run-off road.

The ‘head-on and right angle crashes’ category, consisting of 481 cases, was obtained by combining the manner of collision types, ‘head on’ (C) and ‘right angle’ (D) crashes with the type of crash type category ‘collision with other motor vehicle in traffic’ (D) and ‘collision with parked vehicle’ (E).

Turning angle and side swipe crashes consisting of 137 cases, was obtained by combining the manner of collision categories ‘left turn angle’ (E), ‘left turn opposite direction’ (F), ‘left turn same direction’ (G), ‘right turn angle’ (H), ‘right turn opposite direction’ (I), ‘sideswipe same direction’ (J), and ‘sideswipe opposite direction’ (K) with type of accident category, ‘collision with other motor vehicle in traffic’ (D) and ‘collision with parked vehicle’ (R). In this case only collision with other motor vehicles was considered because all the other type of crashes had very few cases of side swipe or turning angle crashes (Table 5-1).

The collision with a parked vehicle was also included in this category as a lot of side swipe crashes are usually attributed to crash with a parked car, though in this case there were no crash cases falling in this category.

The crash type, non-motor vehicle crashes was created by combining all the crashes which did not involve two motor vehicles but instead involved a motor vehicle and a pedestrian or fixed object or animal etc.

In the fatality group, about 190 crash cases were observed by combining the manner of collision categories, ‘non-motor vehicle crashes’ (A) and ‘other’ crashes (L) with the type of crash categories, ‘Collision with pedestrian’ (C), ‘Collision with train’ (F), ‘Collision with bicyclist’ (G), ‘Collision with animal’ (H), ‘Collision with fixed object’ (I), ‘Collision with other object’ (J), and ‘Other non-collision on road’ (K).

Structured Query Language queries were built to create tables for each crash type from the main fatality table (Appendix A).

Table 5-1: Results of Cross-Classification Analysis on Fatality Group

Count of CRASH_NUM	MAN_COLL_CD													
TYPE_ACC		A	B	C	D	E	F	G	H	I	J	K	L	**Grand Total**
A	8	780	8	6	4						1	1	110	**918**
B	1	12		2								1	2	**18**
C	2	67			1								30	**100**
D	5	20	53	314	166	23	41	1	2	4	11	55	66	**761**
E	2	1	3	1									1	**8**
F		1			6									**7**
G			3					1			1	1	1	**7**
H		2		3									2	**7**
I	4	56		7	4		1						15	**87**
J	1	3	1	2		1								**8**
K		9		5	4	1					2		4	**25**
Grand Total	**23**	**951**	**68**	**340**	**185**	**25**	**42**	**2**	**2**	**4**	**15**	**58**	**231**	**1946**

- Run-off road (890 cases)
- Head-on and Right angle (481 cases)
- Turning angle and Sideswipe (137 cases)
- Non-motorvehicle collisions (190 cases)

5.1.2 Cross-Classification Analysis on Injury Group

Table 5-2 shows the distribution of crashes in each category and the five crash types arrived at for the injury group by cross-classification. The five crash types obtained were:

- Run-off road and Overturning,
- Rear-end crashes,
- Head-on and Right angle crashes,
- Turning angle and side swipe crashes and
- Non-motor vehicle crashes.

The run-off road and overturning crashes contributed to 13,958 crashes and it was obtained by combining the 'Running off roadway' (A) and 'Overturning on roadway' (B) from the type of crash category with all the manner of collision categories except the 'head on' (C) and 'right angle' (D) as they contributed to a considerable number of crashes to be accounted for as a separate group. Similarly the rear end crash category consisting of 8212 crash cases was formed by grouping the ‘rear end crash’ category (B) with the ‘collision with other motor vehicle’ (D) and ‘collision with parked vehicle’ category (E) as these are the most common types of rear end collision cases. The head on and right angle crashes group consisted of 5362 crash cases and was created by combining the manner of collision types, ‘head on’ (C) and ‘right angle’ (D) with type of accident categories, ‘Collision with other motor vehicle in traffic’ (D) and ‘Collision with parked vehicle’ (E). The turning angle and sideswipe crashes were found to be another important crash type for the injury group as it contributed to around 4944 crashes and it was obtained by combining all the turning angle crashes and side swipe crashes with, ‘collision with other motor vehicle’ and ‘collision with parked vehicle’ crashes similar to the grouping of the same crash type for fatality group. The non motor vehicle crash type consisting of 5846 crash cases was formed by combining all the manner of collision types with the type of accident categories, ‘collision with pedestrian’ (C), with ‘bicyclist’ (G), ‘animal’ (H), ‘fixed object’ (I), ‘other object’ (J) and ‘other non collision on road’ (K).

Table 5-2: Results of Cross Classification Analysis on Injury Group

Count of CRASH _NUM	**MAN_ COLL _CD**													
TYPE_ ACC		A	B	C	D	E	F	G	H	I	J	K	L	**Grand Total**
A	226	11368	75	81	67	9	4	2	5	4	49	30	1892	**13812**
B	12	387	9	1	5	2			2			1	119	**538**
C	8	125	1		9						2	2	75	**222**
D	364	940	8144	1086	4383	1324	1437	380	172	115	526	979	2255	**22105**
E	4	3	68	4	5	1	1				6	3	15	**110**
F	1	8	1	2	23	1						1	8	**45**
G	6	12	17		14	4	3	2	1	1	14	3	15	**92**
H	13	459	2	3	9				1	1	3	2	110	**603**
I	104	2175	351	65	139	45	41	21	15	10	41	41	973	**4021**
J	41	94	105	13	36	9	22	5	5	1	9	6	139	**485**
K	46	337	28	18	16	4	7	1		1	7	13	163	**641**
Total	**825**	**15908**	**8801**	**1273**	**4706**	**1399**	**1515**	**411**	**201**	**133**	**657**	**1081**	**5764**	**42674**

- Run-off road and Overturning (13958 cases)
- Rearend crashes (8212 cases)
- Head-on and Right angle (5632 cases)
- Turning angle and Sideswipe (4944 cases)
- Non-motorvehicle collisions (5846 cases)

The injury table was divided into the above obtained five crash types by building queries for each. (Appendix A).

5.1.3 Cross-Classification Analysis on PDO Group

Table 5-3 shows the distribution of crashes in each category and the four crash types established for the injury group by cross-classification. The four crash types obtained were:

- Run-off road & Overturning
- Rear end Crashes
- Right angle and Sideswipe
- Non-motor vehicle collisions

The run-off road and overturning crash category consisted of 13,252 crash cases and was obtained by combining all the manner of collision categories with the type of accident categories 'Running off roadway' (A) and 'Overturning on roadway' (B). The second crash type, rear end crashes consisting of 12541 cases was formed by combining the 'rear end crash' category (B) with the type of accident categories, 'collision with other motor vehicle' (D) and 'collision with parked vehicle' category (E) similar to the rear end crash case for the injury group. The right angle and side swipe crashes consisted of 7686 cases and it took into account only the type of accident categories, 'collision with other motor vehicle' (D) and 'collision with a parked vehicle' (E) and the manner of collision categories ' right angle' (D), 'sideswipe same direction' (J), and 'sideswipe opposite direction' (K). The non-motor vehicle crash type for the PDO group was obtained by combining all the manner of collision types with the type of accident categories, 'collision with pedestrian' (C), with 'bicyclist' (G), 'animal' (H), 'fixed object' (I), 'other object' (J) and 'other non collision on road' (K) and resulted in 12,915 crash cases of this type. Queries were built to create the four crash type tables the details of which are explained in Appendix A.

Table 5-3: Results of Cross Classification Analysis on PDO Group

Count of CRASH_NUM	**MAN_COLL_CD**													
TYPE_ACC		A	B	C	D	E	F	G	H	I	J	K	L	**Grand Total**
A	300	10692	74	53	60	9	3	1	16	12	109	38	1752	**13119**
B	28	325	2	2	1	3				2	2		96	**461**
C	11	122	4	1	3						2		59	**202**
D	1059	1954	12450	303	4287	1868	1261	957	451	329	1899	1428	4140	**32386**
E	11	13	91	3	18	3		2	1		38	16	134	**330**
F	3	36	1	1	18		1						19	**79**
G	10	37	55		11	6	4	5	5	4	13	6	54	**210**
H	128	2751	3	25	71			1	1	1	3	6	780	**3770**
I	276	3637	601	56	160	90	58	66	36	24	106	87	1695	**6892**
J	167	341	205	10	55	19	14	19	6	7	29	31	327	**1230**
K	96	863	74	5	26	8	8	11	3	3	14	19	369	**1499**
Grand Total	**2089**	**20771**	**13560**	**459**	**4710**	**2006**	**1349**	**1062**	**519**	**382**	**2215**	**1631**	**9425**	**60178**

- Run-off road & Overturning (13252 cases)
- Rear end Crashes (12541 cases)
- Right angle and Sideswipe (7686 cases)
- Non-motorvehicle collisions (12915 cases)

5.2 Answer Tree Analysis

Classification procedures were employed to seek out the division of data so that the resulting groups were as homogeneous with respect to crash rate as possible. The classification analysis was carried out using the CART process in Answer Tree software. Thirteen runs were performed in all, one on each of the crash type category obtained for each of the severity types to obtain the variables that effectively distinguished the homogeneous set of factors affecting the crash rate.

Some of the important data items used commonly in all the groups were described in the previous chapter. But the data items used for each of the group varied according to the crash type or severity type. The detailed analysis on each crash type is given below.

5.2.1 Classification Analysis on Fatality Crashes

5.2.1.1 Classification Analysis on Run-off Road Crash Type

For growing the classification tree the crash rate was selected as the target variable and the predictor variables included crash hour, alcohol involvement, alignment, lighting condition, day of the week, location type, road condition, road related condition, surface condition, driver age 1, driver sex 1, traffic control condition, vehicle type 1, violations and pavement width. Figure 5-1 shows the classification tree obtained. The maximum tree depth was specified as five and the minimum number of cases was specified as 20 for the parent node and 1 for the child node as the total number of cases were 890 in all.

This analysis resulted in 16 end nodes with different number of crash cases. Each end node when traced back to the parent node created a homogeneous group. The groups in which the end node had less than 30 cases were neglected, resulting in three final homogeneous groups each having 225, 281 and 270 cases respectively. They were named as 'HG-1', 'HG-2' and 'HG-3'.

The gain charts displaying the statistics associated with the terminal nodes relative to the mean of the target variable are presented in Table 5-4.

The rows of the table represent statistics for individual nodes and the following information is displayed for each node:

- **Node:** identifies the node associated with the row
- **Node: n:** Number of cases in the terminal node
- **Node: %:** The percentage of the total sample cases falling into the particular group
- **Gain:** Gain value of the group computed as the average value for the node for a continuous target variable.
- **Index (%):** Ratio of the group's gain score to the gain score for the entire sample.

Table 5-5 displays the risk summary of the classification analysis. Risk is calculated as the within-node variance about the mean of the node. The risk estimate and the standard error of risk estimate indicate how well the classifier is performing.

Table 5-4: Gain Summary of Classification Analysis on Run-off Road Fatality Crash

Target Variable: RATE				
	Statistics			
Node	Node: n	Node: %	Gain	Index (%)
5	3	0.34	10.67	1467.16
25	2	0.22	9.56	1315.16
2	1	0.11	6.86	943.30
23	1	0.11	5.97	820.79
22	1	0.11	2.71	372.39
27	8	0.90	2.44	335.76
30	5	0.56	1.83	251.05
10	14	1.57	1.82	250.02
7	7	0.79	1.29	177.65
18	21	2.36	1.28	175.76
13	18	2.02	1.26	173.43
12	225	25.28	0.83	113.75
19	281	31.57	0.58	79.11
8	16	1.80	0.51	70.55
21	270	30.34	0.40	54.36
29	17	1.91	0.30	41.36

Table 5-5: Risk Summary

	Resubstitution
Risk Estimate	2.0254
SE of Risk Estimate	0.505277

Within node (error) variance = 2.0254

Total variance = 2.72607 (risk estimate for the tree with only one node)

Proportion of variance due to error = 2.0254/2.72697 =0.74297

Proportion of variance explained by the model = 1- 0.74297 = 0.257

= 25.7%

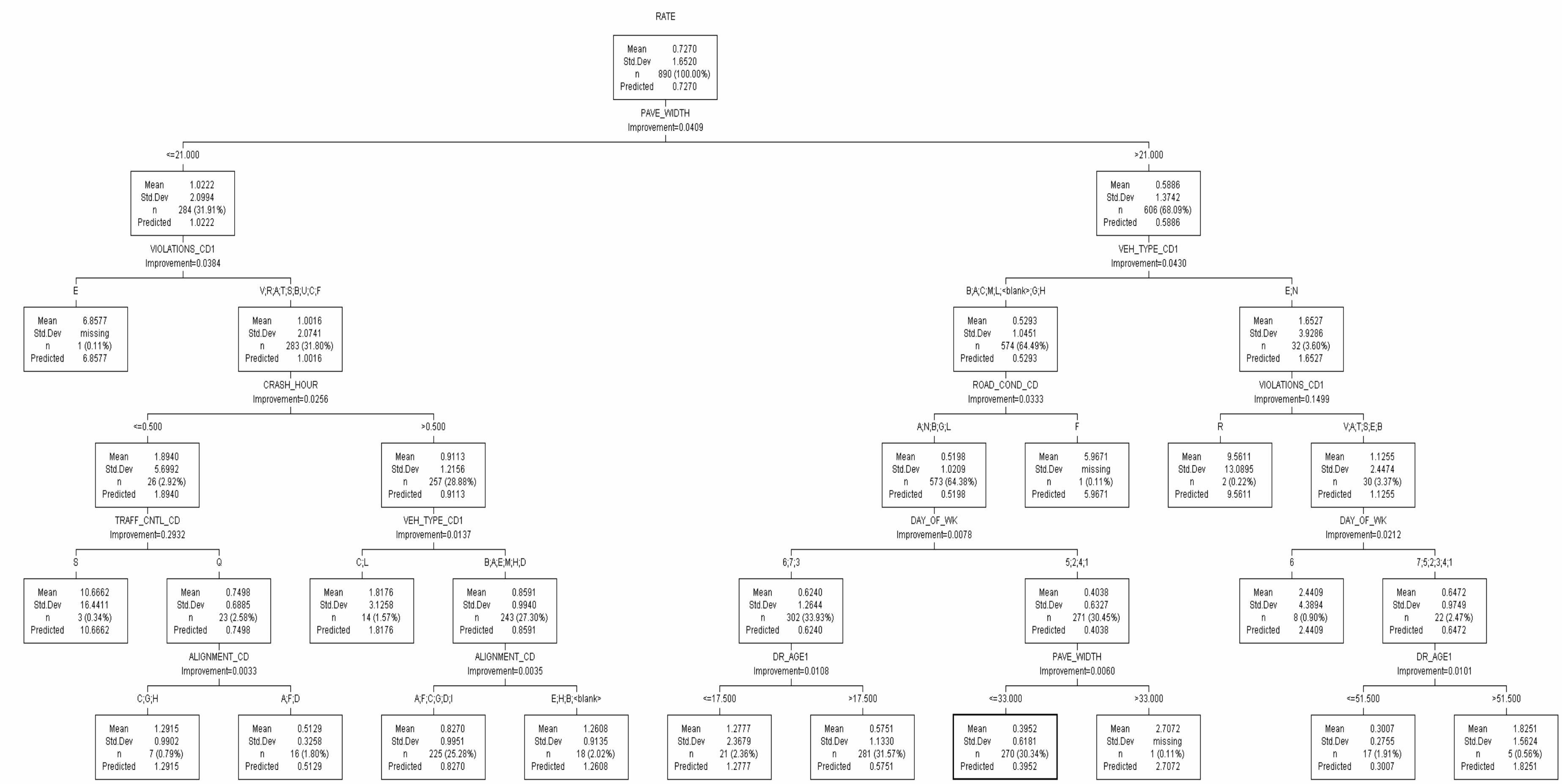

Figure 5-1: Classification Analysis Model for Run-off Road Crashes for Fatality Group

5.2.1.2 Classification Analysis on Head on and Right Angle Crash Type

The tree was grown by selecting the target variable, crash rate and the predictor variables: alcohol involvement, alignment, lighting condition, day of the week, location type, surface condition, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, vehicle type 1, vehicle type 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 10 for the parent node and 1 for the child node as the total number of cases were 481. The analysis resulted in 15 end nodes each with different number of cases thus resulting in 15 homogeneous groups. The groups with less than 30 cases in the end nodes were neglected, resulting in four final homogeneous groups 'HG-1', 'HG-2', 'HG-3' and 'HG-4' each having 144, 130, 79 and 30 crash cases respectively. The tree map and the gain and risk summary tables are given in Appendix B.

5.2.1.3 Classification Analysis on Turning Angle and Sideswipe Crash Type

The classification tree was grown on the 137 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, vehicle type 1, vehicle type 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 10 for the parent node and 1 for the child node. The analysis resulted in 12 homogeneous groups and the groups with less than 20 cases in the end node were neglected, resulting in three final homogeneous groups 'HG-1', 'HG-2', and 'HG-3' each having 20, 54,and 32 cases respectively.

5.2.1.4 Classification Analysis on Non Motor Vehicle Crash Type

The classification tree was grown by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, driver age 1, driver sex 1, traffic control condition, vehicle type 1, pedestrian and pavement width. The maximum tree depth was specified as four in this case as the total number of cases was 190 and the minimum number of cases was specified as 10 for the parent node and 1 for the child node. The analysis resulted in 7 homogeneous groups with different number of cases. The groups with less than 30 cases in the end node were neglected, resulting in two final homogeneous groups 'HG-1', and 'HG-2' each having 31 and 131 cases respectively.

5.2.2 Classification Analysis for Injury Crashes

5.2.2.1 Classification Analysis on Run-off Road Crash Type

The classification tree was grown on the 13958 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, lighting condition, day of the week, location type, surface condition, driver age 1, driver sex 1, vehicle type 1, first harmful event, most harmful event and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 100 for the parent node and 1 for the child node. The analysis resulted in 11 homogeneous groups with different number of cases. The groups with less than 30 cases in the end node were neglected, resulting in five final homogeneous groups 'HG-1', 'HG-2', 'HG-3', 'HG-4' and 'HG-5' each having 1077, 3322, 3343, 2249, and 3805 cases respectively. The details of the analysis are given in Appendix B.

5.2.2.2 Classification Analysis on Rear End Collision Type

The classification tree was grown by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, road condition, surface condition, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, vehicle type 1, vehicle type 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 10 for the parent node and 1 for the child node. The analysis resulted in 13 homogeneous groups with different number of cases. The groups with less than 30 cases in the end node were neglected, resulting in six final homogeneous groups ‘HG-1’, ‘HG-2’, ‘HG-3’, ‘HG4’, ‘HG5’ and ‘HG6’ each having 943, 754, 432, 594, 1489 and 3844 cases respectively. Appendix B gives the detailed description of each of the homogeneous groups through tree maps and gain and risk summaries.

5.2.2.3 Classification Analysis on Right Angle and Head on Crash Type

The classification tree was grown on the 5632 crash cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, surface condition, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, vehicle type 1, vehicle type 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 10 for the parent node and 1 for the child node. The analysis resulted in 15 end nodes with different number of cases and two final homogeneous groups ‘HG-1’, and ‘HG-2’ having 1064 and 4434 cases respectively were formed, the details of which are in Appendix B.

5.2.2.4 Classification Analysis on Turning Angle and Sideswipe Crash Type

The classification tree was grown on the 4944 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, road condition, surface condition, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, vehicle type 1, vehicle type 2, violations 1, violations 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 10 for the parent node and 1 for the child node. The analysis resulted in 10 homogeneous groups with different number of cases and two final homogeneous groups having 165 and 4698 cases respectively were selected depending on the end node values (Appendix B).

5.2.2.5 Classification Analysis on Non Motor Vehicle Crash Type

The classification tree was grown on the 5846 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, road condition, road related factors, surface condition, surface type, driver age 1, driver sex 1, traffic control condition, vehicle type 1, and pavement width. The predictor variables such as driver age 2, vehicle type 2 etc were not considered in this case as it deals with a non motor vehicle crash, i.e., the crash between a motor vehicle and a non motor vehicle, which can be a crash with a fixed object or an animal or any other kind of crash. The maximum tree depth was specified as five and the minimum number of cases was specified as 300 for the parent node and 30 for the child node. The analysis resulted in 7 end nodes with different number of cases. The nodes with less number of cases compared to original number of cases were neglected, resulting in 5 homogeneous groups having 1264, 213, 1739, 1156, and 1342 cases respectively.

5.2.3 Classification Analysis for PDO Crashes

5.2.3.1 Classification Analysis on Run off Road and Overturning Crash Type

The classification tree was grown on the 13252 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, lighting condition, day of the week, location type, road condition, road related factors, surface condition, driver age 1, driver sex 1, traffic control condition, vehicle type 1, and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 100 for the parent node and 10 for the child node. The analysis resulted in 9 terminal nodes. The groups with less number of cases in the end nodes compared to the original number of cases were neglected, resulting in five final homogeneous groups each having 4012, 2704, 672, 960, and 3821 cases respectively.

5.2.3.2 Classification Analysis on Rear End Crash Type

The classification tree was grown on the 12,541 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, road condition, road related factors, surface condition, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, vehicle type 1, vehicle type 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 100 for the parent node and 10 for the child node. The analysis resulted in 8 terminal nodes and four homogeneous groups having 2334, 6047, 760, and 2986 cases in each were selected from it depending on the number of cases and other values of the terminal node.

5.2.3.3 Classification Analysis on Right Angle and Sideswipe Crash Type

The classification tree was grown on the 7686 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, intersection, lighting condition, day of the week, location type, , road condition, road related factors, surface condition, driver age 1, driver age 2, driver sex 1, driver sex 2, traffic control condition, prior movement 1, prior movement 2, vehicle type 1, vehicle type 2 and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 100 for the parent node and 10 for the child node. The analysis resulted in 7 terminal nodes and three final homogeneous groups ‘HG-1’, ‘HG-2’, and ‘HG-3’ each having 3435, 1259, and 2867 cases were established.

5.2.3.4 Classification Analysis on Non Motor Vehicle Crash Type

The classification tree was grown on the 12914 cases by selecting the predictor variables: crash hour, alcohol involvement, alignment, lighting condition, day of the week, location type, , road condition, road related factors, surface condition, driver age 1, driver sex 1,traffic control condition, vehicle type 1, and pavement width. The maximum tree depth was specified as five and the minimum number of cases was specified as 100 for the parent node and 10 for the child node. The analysis resulted in 7 terminal nodes. The groups with less number of cases in the end node compared to the original number of cases were neglected, resulting in three final homogeneous groups ‘HG-1’, ‘HG-2’, and ‘HG-3’ each having 8978, 2040, and 1690 cases respectively.

Forty seven homogeneous groups were obtained in all and tables were created for each of these groups using the querying techniques in MS Access (Appendix A). Table 5-6 explains how well each of the thirteen trees has performed in achieving the required classification. It presents the summary of the risk estimates and the proportion of variance explained by each of the classification tree models described above. The risk estimate is the within node variance and it indicates how well the classifier is performing. Total variance is the sum of the within node (error) variance and the between node (explained) variance. The total variance is the risk estimate for the tree with only one node.

Table 5-6: Summary of Model Performances

Crash Case	**Within Node Variance**	**Total Variance**	**Proportion of Variance due to Error**	**Proportion of Variance Explained by Model**	**Proportion of Explained Variance (%)**
FATALITY					
Run-off Road	2.02	2.72	0.74	0.26	25.7%
Head-on & Right Angle	6065.18	7803.84	0.78	0.22	22.2%
Turning Angle & Sideswipe	719.13	4698.23	0.15	0.85	84.7%
Non Motor Vehicle	14397.7	40633.7	0.35	0.65	64.6%
INJURY					
Run-off Road	186430	192688	0.97	0.03	3.2%
Rear End	241089	256503	0.94	0.06	6.0%
Right Angle & Head-on	190484	276401	0.69	0.31	31.1%
Turning Angle & Sideswipe	140292	322716	0.44	0.56	56.5%
Non Motor Vehicle	141445	145875	0.97	0.03	3.0%
PDO					
Run-off Road & Overturning	135903	137997	0.99	0.01	1.5%
Rear End	97855.5	107196	0.91	0.08	8.7%
Right Angle & Sideswipe	85898.6	89072.5	0.96	0.03	3.6%
Non Motor Vehicle	306440	316560	0.96	0.03	3.20%

5.3 Trend Analysis on No Speed Change Group

On each of the no speed limit change data group, the average crash rate was plotted by year, and trend lines fitted to these plotted values using regression analysis. The significance of the slope of the trend line was tested by considering the significance of the slope coefficient in the regression equation.

5.3.1 Results of Trend Analysis

The crash trend was plotted for all the no speed change crash cases and significance tested for each case. It was found that for the fatality group, none of the crash trends were found to be significant while in the injury crash group, rear end injury crash case of homogeneous group 5, non motor vehicle injury crash of homogeneous group 2 and non motor vehicle injury crash of homogeneous group 3 were found to be significantly different to zero at the 5% level of significance. For the PDO crash group, rear end PDO crash of homogeneous group 3 was found to have a significant crash rate. The details of trend plot and regression analysis for each case is shown in Appendix C. Table 5-7 presents the results of the trend analysis on each homogeneous group of each crash type and each severity level. The standard error value 'S', the R-squared value, the adjusted R-squared value, the F value and P value are shown. The cases which had a P value less than 0.05 were considered to have a significant crash trend and those cases have been highlighted in the table. The regression equation of each case is also given in the figure in terms of year and average crash rate as: *Average crash rate = Intercept + Slope * Year*

Table 5-7: Results of Trend Analysis

CRASH CASE	S	R^2	$R^2_{(Adj)}$	F	P	REGRESSION EQUATION
FATALITY GROUP						
RUN OFF ROAD CRASH TYPE						
HG1	23.44	0.21	0.02	1.12	0.35	Crash $Rate_{(Avg)}$ = 62.78 + 5.920 Year
HG2	11.40	0.62	0.53	6.71	0.061	Crash $Rate_{(Avg)}$= 76.03 - 7.061 Year
HG3	8.08	0.22	0.03	1.18	0.339	Crash $Rate_{(Avg)}$= 33.58 + 2.095 Year

(Table 5-7 Continued.)

CRASH CASE	S	R^2	$R^2_{(Adj)}$	F	P	REGRESSION EQUATION
HEAD ON AND RIGHT ANGLE CRASH TYPE						
HG1	15.21	0.33	0.17	2.01	0.229	Crash Rate$_{(Avg)}$= 63.21 - 5.159 Year
HG2	11.98	0.32	0.15	1.91	0.239	Crash Rate$_{(Avg)}$= 20.06 + 3.962 Year
HG3	3.61	0.16	0.00	0.77	0.43	Crash Rate$_{(Avg)}$= 12.59 + 0.758 Year
HG4	17.18	0.34	0.17	2.09	0.222	Crash Rate$_{(Avg)}$=15.78 + 5.941 Year
SIDESWIPE AND TURNING ANGLE CRASH TYPE						
HG1	39.83	0.07	0.00	0.24	0.656	Crash Rate$_{(Avg)}$=54.32 - 6.21 Year
HG2	5.91	0.55	0.43	4.89	0.092	Crash Rate$_{(Avg)}$=29.42 + 3.128 Year
HG3	4.07	0.01	0.00	0.04	0.85	Crash Rate$_{(Avg)}$=11.67 - 0.1960 Year
NON MOTOR VEHICLE CRASH TYPE						
HG1	25.44	0.10	0.00	0.46	0.537	Crash Rate$_{(Avg)}$=94.00 - 4.104 Year
HG2	11.16	0.26	0.07	1.42	0.299	Crash Rate$_{(Avg)}$=25.59 + 3.181 Year
INJURY GROUP						
RUN OFF ROAD CRASH TYPE						
HG1	70.00	0.00	0.00	0	0.996	Crash Rate$_{(Avg)}$=182.7 - 0.10 Year
HG2	15.93	0.00	0.00	0	0.994	Crash Rate$_{(Avg)}$=110.8 + 0.028 Year
HG3	11.78	0.05	0.00	0.21	0.669	Crash Rate$_{(Avg)}$=64.41 + 1.296 Year
HG4	11.64	0.10	0.00	0.45	0.54	Crash Rate$_{(Avg)}$=68.09 - 1.860 Year
HG5	6.82	0.25	0.06	1.37	0.307	Crash Rate$_{(Avg)}$=43.85 + 1.908 Year
REAR END CRASH TYPE						
HG1	15.08	0.46	0.33	3.52	0.134	Crash Rate$_{(Avg)}$=97.57 + 6.762 Year
HG2	25.80	0.18	0.00	0.91	0.395	Crash Rate$_{(Avg)}$=76.96 + 5.870 Year
HG3	63.83	0.50	0.37	4.05	0.114	Crash Rate$_{(Avg)}$=91.24 + 30.72 Year
HG4	84.13	0.18	0.00	0.89	0.4	Crash Rate$_{(Avg)}$=198.3 - 18.94 Year
HG5	**14.65**	**0.69**	**0.62**	**9.21**	**0.039**	**Crash Rate$_{(Avg)}$=43.46 + 10.63 Year**
HG6	5.10	0.62	0.52	6.54	0.063	Crash Rate$_{(Avg)}$=45.07 + 3.121 Year
RIGHT ANGLE AND HEAD ON CRASH TYPE						
HG1	18.38	0.40	0.25	2.7	0.17	Crash Rate$_{(Avg)}$=113.9 + 7.223 Year
HG2	14.27	0.17	0.00	0.82	0.41	Crash Rate$_{(Avg)}$=80.17 + 3.095 Year
TURNING ANGLE AND SIDESWIPE CRASH TYPE						
HG1	97.80	0.01	0.00	0.06	0.82	Crash Rate$_{(Avg)}$=106.4 + 5.67 Year
HG2	8.09	0.62	0.52	6.61	0.06	Crash Rate$_{(Avg)}$=78.90 + 4.974 Year
NON MOTOR VEHICLE CRASH TYPE						
HG1	19.3861	0.02	0.00	0.08	0.787	Crash Rate$_{(Avg)}$=113.4 + 1.337 Year
HG2	**10.08**	**0.79**	**0.74**	**15.82**	**0.016**	**Crash Rate$_{(Avg)}$=61.68 + 9.592 Year**
HG3	**9.039**	**0.71**	**0.63**	**9.83**	**0.035**	**Crash Rate$_{(Avg)}$=60.83 + 6.776 Year**
HG4	5.30	0.23	0.047	1.25	0.327	Crash Rate$_{(Avg)}$=53.62 - 1.416 Year
HG5	24.965	0.051	0.00	0.22	0.666	Crash Rate$_{(Avg)}$=123.9 + 2.775 Year
PDO GROUP						
RUN OFF ROAD AND OVERTURNING CRASH TYPE						
HG1	35.02	0.01	0.00	0.05	0.829	Crash Rate$_{(Avg)}$=160.3 + 1.926 Year
HG2	21.93	0.11	0.00	0.54	0.503	Crash Rate$_{(Avg)}$=120.0 + 3.853 Year

(Table 5-7 Continued.)

CRASH CASE	S	R^2	$R^2_{(Adj)}$	F	P	REGRESSION EQUATION
HG3	16.85	0.63	0.54	7.02	0.057	Crash $Rate_{(Avg)}$=69.41 + 10.68 Year
HG4	6.44	0.35	0.19	2.24	0.209	Crash $Rate_{(Avg)}$=71.96 + 2.305 Year
HG5	21.44	0.08	0.00	0.36	0.58	Crash $Rate_{(Avg)}$=86.68 - 3.079 Year
REAR END CRASH TYPE						
HG1	56.81	0.61	0.51	6.31	0.066	Crash $Rate_{(Avg)}$=176.4 + 34.12 Year
HG2	10.34	0.16	0.00	0.81	0.419	Crash $Rate_{(Avg)}$=96.98 + 2.229 Year
HG3	**28.26**	**0.69**	**0.62**	**9.15**	**0.039**	**Crash $Rate_{(Avg)}$=201.7 + 20.43 Year**
HG4	14.21	0.28	0.10	1.56	0.28	Crash $Rate_{(Avg)}$=141.9 + 4.239 Year
RIGHT ANGLE AND SIDESWIPE CRASH TYPE						
HG1	12.48	0.03	0.00	0.16	0.709	Crash $Rate_{(Avg)}$=81.36 - 1.195 Year
HG2	47.90	0.08	0.00	0.36	0.58	Crash $Rate_{(Avg)}$=156.0 + 6.89 Year
HG3	13.06	0.59	0.49	5.92	0.072	Crash $Rate_{(Avg)}$=89.29 + 7.600 Year
NON MOTOR VEHICLE CRASH TYPE						
HG1	17.53	0.44	0.30	3.14	0.151	Crash $Rate_{(Avg)}$=83.32 + 7.430 Year
HG2	104.17	0.47	0.34	3.64	0.129	Crash $Rate_{(Avg)}$=35.03 + 47.48 Year
HG3	48.56	0.37	0.219	2.4	0.196	Crash $Rate_{(Avg)}$=120.3 + 18.00 Year

5.4 Results of Adjustment of 'After' Group for Trend over Time

In the speed limit change group, the before speed limit change crash rate and after speed limit change crash rates were averaged for each year of speed limit change and a pair of 'before' and 'after' crash rate values were obtained for each year for each homogeneous group. The average 'after' value calculated in this case was then adjusted for the trend over time for those cases that were identified as having significant trend from the trend plot on the no speed limit change group described in the previous section. The adjustment for the 'after' group was carried out using the following equation which was derived in the previous chapter.

$$CR_{(Adj)} = CR_{(Orig)} - S * (Y_{(Avg\ Aft)} - Y_{(Avg\ Bfore)})$$

Where,

$CR_{(Adj)}$ = Adjusted Average after speed limit change Crash Rate

$CR_{(Orig)}$ = Original Average after speed limit change Crash Rate

S = Slope of Trend line

$Y_{(Avg\ Aft)}$ = Average of After Speed Limit Change Years

$Y_{(Avg\ Bfore)}$ = Average of Before Speed Limit Change Years

Table 5-8, Table 5-9. and Table 5-10 show the 'before' speed limit change crash rate values (CR_{BEFORE}), original 'after' speed limit change crash rate values ($CR_{AFT\ (Orig)}$) and the 'adjusted' after speed limit change crash rate values ($CR_{AFT(Adj)}$) along with the slope of the trend line of the corresponding case used to calculate the adjusted crash rate value. The difference between the 'before' years average ($Y_{AVG(Bef)}$) and the 'after' years average ($Y_{AVG(Aft)}$) takes a constant value of 3 in all the cases. The tables show only the cases in which the trends were significant. Details of the analysis of all 47 homogeneous crash groups are presented in Appendix D.

Table 5-8 shows the crash rate adjustment for the homogeneous group 5 of crash type 2 of the injury crash group. Table 5-9 shows the crash rate adjustment for homogeneous groups 2 and 3 of crash type 5 of the injury crash group. Table 5-10 shows the crash rate adjustment for the homogeneous group 3 of crash type 2 of the PDO crash group.

Table 5-8: Results of Crash Rate Adjustment for Trend for Rear End Injury Crash of Homogeneous Group 5

INJURY GROUP - CRASH TYPE 2 -REAR END COLLISION						
CRASH CASE	**Year of Speed Limit Change**	**CR_{BEFORE}**	**$CR_{AFT\ (Orig)}$**	**Slope of Trend Line**	**$Y_{AVG(Aft)} - Y_{AVG(Bef)}$**	**$CR_{AFT\ (Adj)}$**
HG - 5	1999	71.1	37.6	10.6	3	5.7
	2000	108.6	99.2	10.6	3	67.3
	2001	21.1	69.8	10.6	3	37.9
	2002	75.7	383.1	10.6	3	351.2
	2003	110.3	47.9	10.6	3	16.0

Table 5-9: Results of Crash Rate Adjustment for Trend for Non Motor Vehicle Injury Crash of Homogeneous Group 2 and 3

INJURY GROUP						
CRASH TYPE 5-NON MOTOR VEHICLE CRASHES						
CRASH CASE	Year of Speed Limit Change	CR BEFORE	CR_{AFT} (Orig)	Slope of Trend Line	$Y_{AVG(Aft)} - Y_{AVG(Bef)}$	$CR_{AFT(Adj)}$
HG - 2	1999	22.1	126.3	9.5	3	97.6
	2000	50.7	17.04	9.5	3	-11.7
	2001	46.2	81.5	9.5	3	52.8
	2002	67.0	579.8	9.5	3	551.0
	2003	61.4	51.8	9.5	3	23.1
HG - 3	1999	86.9	58.4	6.7	3	38.1
	2000	103.3	64.0	6.7	3	43.6
	2001	58.1	71.3	6.7	3	51.0
	2002	69.1	92.1	6.7	3	71.7
	2003	67.6	74.1	6.7	3	53.7

Table 5-10: Results of Crash Rate Adjustment for Trend for Rear End PDO Crash of Homogeneous Group 3

PDO GROUP						
CRASH TYPE 2-REAR END COLLISION						
CRASH CASE	Year of Speed Limit Change	CR BEFORE	CR_{AFT} (Orig)	Slope of Trend Line	$Y_{AVG(Aft)} - Y_{AVG(Bef)}$	$CR_{AFT(Adj)}$
HG - 3	1999	59.6	222.2	20.4	3	160.9
	2000	378.7	278.5	20.4	3	217.2
	2001	82.36	167.6	20.4	3	106.3
	2002	155.	110.4	20.4	3	49.1
	2003	61.2	122.5	20.4	3	61.2

5.5 Results of Paired T-Test Comparison

Upper-tailed paired sample t-tests were performed on all pairs of values obtained after adjustment of 'after' crash rate values for each crash type and severity. Table 5-11 presents the results of the single tailed paired sample t-test conducted on each homogeneous group of each crash type and each severity type. The details of the paired t-test are provided in Appendix E. The paired sample t-test was conducted only on those crash types which had sufficient pairs of values in the fatality group (i.e., 4 of the 12 shown in Table 5-7).

Table 5-11 shows that in the four fatality crash cases listed, no significant increase in crash rate was found after a speed limit change in any of the years.

In the injury crash group, for the run-off road crash case of homogeneous group 5, rear end crash case of homogeneous group 2, and non motor vehicle crash case of homogeneous group 4, a significant increase in crash rate was observed after a speed limit increase while in all the other injury crash cases no significant increase in crash rate was found.

In the PDO group, the run off road and overturning PDO crash case for homogeneous group 1 and homogeneous group 5 and rear end crash case of homogeneous group 2 were found to have a significant increase in crash rate with speed limit increase. However, in all other PDO cases, no significant change in crash rate with an increase in speed limit was observed.

Thus, of the 39 homogeneous crash types tested using the paired sample t-test, 6 cases demonstrated a significant increase in crash rate following an increase in speed limit. From this observation we can say that in general, with an indeterminate amount of speed limit increase, there is a significant increase in the crash rate for the run-off road and overturning crashes, the rear end crashes and the non-motor vehicle crashes in the injury and PDO level of severity. This trend may not have appeared significant in the fatality group because of insufficient pairs of observations in this group.

Table 5-11: Results of Paired T-Test Comparison

CRASH	MEAN			STD DEV			SE MEAN			95% Lower	T	P	TEST
TYPE	BEF	AFT	DIFF	BEF	AFT	DIFF	BEF	AFT	DIFF	Bound			RESULT
FATALITY GROUP													
CRASH TYPE 1 - RUN OFF ROAD													
CT1_HG2	11.6	34.9	23.3	5.1	22.7	26.6	2.5	11.3	13.3	-8.0	1.75	0.089	Not Significant
CT1_HG3	127.2	18.7	-108.4	139.4	13.5	152.9	80.5	7.8	88.3	-366.3	-1.23	0.828	Not Significant
CRASH TYPE 2 - HEAD ON AND RIGHT ANGLE													
CT2_HG1	63.1	75.3	12.2	63.4	53.5	9.9	44.8	37.8	7.0	-31.99	1.74	0.166	Not Significant
CT2_HG2	50.0	12.2	-37.7	11.6	1.8	13.5	8.2	1.2	9.5	-97.96	-3.96	0.921	Not Significant
INJURY GROUP													
CRASH TYPE 1 - RUN OFF ROAD													
CT1_HG1	216.2	169.7	-46.6	319.8	146.9	362.7	143.0	65.7	162.2	-392.34	-0.29	0.606	Not Significant
CT1_HG2	98.6	204.1	105.4	37.8	138.9	111.2	16.9	62.2	49.7	-0.56	2.12	0.051	Not Significant
CT1_HG3	123.4	103.5	-19.9	67.1	34.6	54.8	30.4	15.4	24.5	-72.22	-0.81	0.769	Not Significant
CT1_HG4	105.3	47.5	-57.8	60.2	20.2	66.5	30.1	10.1	33.2	-136.02	-1.74	0.91	Not Significant
CT1_HG5	48.5	133.3	84.87	21.7	80.5	76.5	9.7	36.0	34.2	11.91	2.48	0.034	Significant
CRASH TYPE 2 - REAR END													
CT2_HG1	147.0	115.9	-31.0	132.1	28.2	110.6	66.1	14.1	55.2	-161.21	-0.56	0.693	Not Significant
CT2_HG2	37.9	130.1	92.1	19.5	51.7	58.3	8.7	23.1	26.1	36.61	3.54	0.012	Significant
CT2_HG3	69.5	160.79	91.291	46.749	86.1	113.9	23.4	43.1	56.9	-42.83	1.6	0.104	Not Significant
CT2_HG4	85.0	149.9	64.8	108.4	124.8	203.6	54.2	62.4	101.8	-174.79	0.64	0.285	Not Significant
CT2_HG5	77.3	95.7	18.3	36.3	144.8	149.4	16.2	64.7	66.8	-124.18	0.27	0.399	Not Significant
CT2_HG6	47.7	61.3	13.9	4.9	19.9	20.4	2.1	8.8	9.1	-5.86	1.49	0.105	Not Significant
CRASH TYPE 3 - RIGHT ANGLE AND HEAD ON													
CT3_HG1	197.5	141.8	-55.6	151.8	94.3	141.9	67.9	42.1	63.5	-190.91	-0.88	0.785	Not Significant
CT3_HG2	109.948	154.842	44.895	68.325	205.62	246.46	30.556	91.9	110.2	-190.00	0.41	0.352	Not Significant
CRASH TYPE 4 - TURNING ANGLE AND SIDESWIPE													
CT4_HG1	24.0	25.8	1.8	4.0	12.3	15.4	2.0	6.1	7.7	-16.34	0.24	0.411	Not Significant
CT4_HG2	85.0	97.2	12.1	27.0	15.5	39.8	12.1	6.9	17.8	-25.72	0.68	0.266	Not Significant

(Table 5-11 Continued.)

CRASH	MEAN			STD DEV			SE MEAN			95% Lower Bound	T	P	TEST
TYPE	BEF	AFT	DIFF	BEF	AFT	DIFF	BEF	AFT	DIFF				RESULT
CRASH TYPE 5 - NON MOTOR VEHICLE CRASH													
CT5_HG1	191.5	161.2	-30.3	187.2	95.5	156.9	83.7	42.7	70.2	-180.00	-0.43	0.656	Not Significant
CT5_HG2	49.5	142.6	93.1	17.4	231.8	224.7	7.7	103.6	100.5	-121.15	0.93	0.203	Not Significant
CT5_HG3	77.00	51.6	-25.3	18.0	12.7	27.2	8.0	5.7	12.2	-51.39	-2.08	0.947	Not Significant
CT5_HG4	24.5	63.5	38.9	13.3	29.2	36.4	5.9	13.0	16.3	4.15	2.39	0.038	Significant
CT5_HG5	117.1	199.5	82.4	71.4	157.9	174.4	31.9	70.64	78.01	-83.89	1.06	0.175	Not Significant
PDO GROUP													
CRASH TYPE 1 - RUN OFF ROAD AND OVERTURNING													
CT1_HG1	117.3	256.9	139.6	44.5	135.2	108.5	19.9	60.5	48.5	36.14	2.88	0.023	Significant
CT1_HG2	88.5	402.6	314.1	30.9	667.7	665.5	13.8	298.6	297.6	-320.42	1.06	0.175	Not Significant
CT1_HG3	62.9	103.5	40.5	30.0	41.6	67.6	13.4	18.6	30.2	-23.96	1.34	0.126	Not Significant
CT1_HG4	84.3	135.1	50.7	40.7	80.9	83.7	18.2	36.2	37.4	-29.08	1.36	0.123	Not Significant
CT1_HG5	42.1	64.1	22.0	8.1	16.5	22.5	3.6	7.4	10.1	0.48	2.18	0.047	Significant
CRASH TYPE 2 - REAR END													
CT2_HG1	161.0	158.9	-2.0	69.5	100.0	100.4	31.2	44.7	44.9	-97.80	-0.05	0.517	Not Significant
CT2_HG2	97.4	148.0	50.6	41.0	71.6	46.4	18.3	32.0	20.7	6.38	2.44	0.036	Significant
CT2_HG3	147.5	118.9	-28.5	135.1	70.4	105.1	60.4	31.5	47.0	-128.74	-0.61	0.712	Not Significant
CT2_HG4	94.2	221.0	126.8	36.2	216.7	197.6	16.1	96.93	88.38	-61.62	1.43	0.112	Not Significant
CRASH TYPE 3 - RIGHT ANGLE AND SIDESWIPE													
CT3_HG1	82.5	79.9	-2.7	38.7	24.1	46.9	17.3	10.7	21.0	-47.43	-0.13	0.548	Not Significant
CT3_HG2	112.9	119.4	6.4	64.3	43.6	83.2	28.7	19.5	37.2	-72.93	0.17	0.436	Not Significant
CT3_HG3	106.3	118.2	11.9	59.9	33.8	49.3	26.7	15.1	22.1	-35.12	0.54	0.309	Not Significant
CRASH TYPE 4 - NON MOTOR VEHICLE CRASH													
CT4_HG1	121.5	168.8	47.3	37.5	97.5	97.8	16.7	43.6	43.7	-45.99	1.08	0.170	Not Significant
CT4_HG2	84.4	137.8	53.4	17.7	51.6	61.2	7.9	23.1	27.4	-4.99	1.95	0.061	Not Significant
CT4_HG3	177.2	302.1	124.8	95.1	329.1	322.4	42.5	147.2	144.2	-182.62	0.87	0.218	Not Significant

6. CONCLUSIONS AND FURTHER RECOMMENDATIONS

6.1 Study Summary

The study presented a methodology to identify the effect of a speed limit change on crash rate on rural two-lane highways in Louisiana, using the six year crash data (1999-2004), obtained from the LaDOTD. The crash data contained details of all the roadway sections and the speed limits of each section for all the years. The crash rate values were calculated for all the sections for all the years and the sections which underwent a speed limit change were separated according to the year of speed change from the sections which did not undergo a speed limit change over the entire period.

The approach focused on grouping the crashes according to the severity types and using cross-classification analysis to obtain the crash types and then using the CART classification procedure to identify homogeneous groups of factors affecting the crash rate within each crash type and severity type. The homogeneous groups identified were such that within each group all other factors affecting crash rate except speed limit, remain relatively constant and thus the sole effect of speed limit change on crash rate was identified. The no speed limit change sections, separated out from each homogeneous group, were observed for their natural trend and any significant trend of increased crash rate for a particular crash case was accounted for and the after speed limit change crash rate for the same crash case in the speed limit change group was adjusted for this trend using a derived formula.

To test the significance of a speed limit increase on the crash rate, a single tailed paired sample t-test was conducted on the before and after speed limit change crash rate pairs obtained for 39 of the 47 homogeneous groups of each crash type and severity type. This was done to compare the crash rates of a particular crash type and severity level before a speed limit change with the crash rate of the sections falling under the same homogeneous category after a speed limit change. Based on the results of the single tailed paired sample t-test the null hypothesis was rejected for 6 out of the 39 cases while we were unable to reject the null hypothesis for the rest of the cases due to lack of evidence to reject it thus indicating that we do not have sufficient evidence to say that the crash rate increased with a speed limit increase.

6.2 Conclusions

Based on the analyses and results reported in the previous chapter, the following conclusions were drawn from the present study:

- Based on the results of the statistical comparison of the pairs of crash rate values before and after speed limit change, we reject the null hypothesis that the crash rate after speed limit change is not greater than the crash rate before speed limit change, at 5% level of significance in 6 of the 39 cases.
- Of the remaining cases, in some cases, the pairs were observed to have undergone a decrease in crash rate value with speed limit increase in some years and some cases had very low degrees of freedom. Also, the proportion of variance explained by the classification of each of the model by Answer Tree was as low as less than 10% for most of the cases as can be seen from Table 5-6, implying that the models were able to capture less than 10% of all the factors affecting the crash rates. The above stated factors must have lead to all of these crash cases not showing a significant increase in crash rate with speed limit increase. Thus we fail to reject the null hypothesis in these 33 cases as we do not have sufficient evidence to reject it. We cannot say that the crash rate did not increase with speed limit increase but only that we do not have enough evidence to say that the crash rate increased with speed limit increase in these cases.
- The classification procedures employed were found to be effective in grouping the contributing factors only in a few of the crash categories as can be seen from the

percentage values of the variance captured in Table 5-6. This maybe because some crucial factor might have been overlooked in the analysis or there might have been loss of information due to binary splitting of continuous predictor variables such as driver age, pavement width etc. Hence we have been able to capture the most important variables only in a few cases as listed below:

  - Turning angle and side swipe crash type for Fatality Group which captured 84.7% of the variance of the model and,
  - Non motor vehicle crash type for Fatality Group which captured 64.6% of the variance.
  - Turning angle and side swipe crash type for injury group which captured 56.5% of the variance.

- From the results of the Answer Tree analysis of the three groups identified previously as being effective in grouping, we can conclude that,
  - For the turning angle and sideswipe fatality crashes, the alignment condition was the most important determining factor for the crash rate value of this group.
  - For the non motor vehicle fatality crash, the pavement width was the most determinate factor.
  - For the turning angle and sideswipe injury crashes, the pavement width and violations were the most determinate factor.
- Based on the results of the trend plot for the no speed limit change group (Table 5-7) the following crash types were found to have a significant increase in crash trend over the period 1999-2004 even without a speed limit increase:
  - Rear end injury crashes of homogeneous group 5
  - Non motor vehicle injury crashes of homogeneous group 2 and 3

    - Rear end PDO crashes of homogeneous group 3

- The 6 cases which were found to have a significant increase in crash rate were as follows:
    - Run-off Road and Overturning Crashes
        - Injury for homogeneous group 5 which accounted for 8.72% of all injury crashes.
        - Property Damage Only for homogeneous group 1 which accounted for 6.67% of all PDO crashes.
        - PDO for homogeneous group 5 accounting for 6.27% of all PDO crashes
    - Rear-end Crashes
        - Injury for homogeneous group 2 (1.77% of all Injury crashes)
        - PDO for homogeneous group 2 (10% of all PDO crashes)
    - Non Motor Vehicle Crashes
        - Injury for homogeneous group 4 (2.63% of all Injury crashes)

From the above observation it is clear that a speed limit increase results in an increase in the run-off road and rear end crashes resulting in mostly Injury and Property Damage Only severity levels. The non motor vehicle crashes resulting in injury was also found to increase with speed limit increase. These observations can be related to the commonly observed trend for run off road, rear end and non motor vehicle crashes, such as collision with a pedestrian, collision with a fixed object etc., to increase at high driving speeds.

It is also observed that none of the fatality crash groups have been found to be significant and this may be because only 4 out of the 12 fatality groups were considered for the paired t-test as the rest of the cases did not have sufficient amount of observations and also due to the low degrees of freedom for the 4 tested groups. Also the total number of fatality crashes in the crash database was very low compared to the injury and PDO group.

- According to the National Safety Council, the economic costs of motor-vehicle crashes in the year 2004 has been estimated as - $ 1,130,000 per Fatality crash, $49,700 per Injury crash and $7,400 per PDO crash. Equating these values to the number of crashes before and after a speed limit change in each of the 6 significant categories, the amount of speed limit increase being an indeterminate value between 5mph and 20 mph, the following conclusions were drawn regarding the economic impact of a speed limit increase on the safety of two-lane highways:
  - For the run-off road injury crashes of homogeneous group 5, with an indeterminate amount of speed limit increase over the years 1999 to 2004, the average number of crashes increased from 102 to 224 resulting in a cost increase from $5.0694 million to $ 11.1328 million. Hence there was 119.6% increase in cost of run off road injury crashes.
  - For the run-off road and overturning PDO crash of homogeneous group 1, the average number of crashes increased from 79 to 157 resulting in an increase in cost from $0.5846 million to $1.1618 million, which was a percentage increase in cost of 98.7%.
  - For the run-off road and overturning PDO crash of homogeneous group 5, the average number of crashes increased from 113 to 216 resulting in an increase in cost from $0.8362 million to $1.5984 million, which was a percentage increase in cost of 91.15%.
  - For the rear-end injury crashes of homogeneous group 2, with an indeterminate amount of speed limit increase, the average number of crashes increased from 51

to 55 resulting in a cost increase from $2.5347 million to $ 2.7335 million, a percentage increase of 7.84%.

  - For the rear-end PDO crashes of homogeneous group 2, the average number of crashes increased from 258 to 308 resulting in a cost increase from $1.9092 million to $ 2.2792 million, a percentage increase of 19.38%.
  - For the non-motor vehicle injury crashes of homogeneous group 4, the average number of crashes increased from 27 to 58 leading to a cost increase from 1.3419 million to 2.8826 million, a percentage increase in crash cost of 114.81%.

6.3 Further Recommendations

- The study was limited to the data for the years 1999 to 2004 only. Use of data over more number of years would have resulted in more observations and thus more pairs of values for statistical testing and this would have enhanced the results of the analysis.
- The available crash data contains a category ‘driving over posted speed limit’ under the violations data item but it does not contain sufficient information as the data may not have been reported properly. This information, if available, may improve the accuracy of the results.

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APPENDIX A

SQL QUERIES

Query for Selection of Rural Two-lane highways from the Louisiana Crash Database

```
SELECT *
FROM DOTD_CRASH_TB
WHERE (((DOTD_CRASH_TB.HWY_CLASS) ="1"))
ORDER BY DOTD_CRASH_TB.CSECT, DOTD_CRASH_TB.LOGMI_FROM,
DOTD_CRASH_TB.LOGMI_TO;
```

Query for the fatality group:

```
SELECT *
FROM [rural two-lane road_crash table]
WHERE ((([rural two-lane road_crash table].ACC_CLASS) ="1"));
```

Query for the injury group:

```
SELECT *
FROM [rural two-lane road_crash table]
WHERE ((([rural two-lane road_crash table].ACC_CLASS) ="2"));
```

Query for the PDO group:

```
SELECT *
FROM [rural two-lane road_crash table]
WHERE ((([rural two-lane road_crash table].ACC_CLASS) ="3"));
```

Query build for the rate calculation for fatality group:

```
SELECT ADT*SEC_LENGTH*365/100000000 AS VMT, NUM_TOT_KIL/VMT AS
RATE,
FROM [rural two-lane road_crash table]
WHERE ((([rural two-lane road_crash table].ACC_CLASS) ="1"));
```

Query build for the rate calculation of injury group:

```
SELECT ADT*SEC_LENGTH*365/100000000 AS VMT, NUM_TOT_INJ/VMT AS
RATE,
FROM [rural two-lane road_crash table]
WHERE ((([rural two-lane road_crash table].ACC_CLASS) ="2"));
```

Query to create a new table called FATALITY_crash type 1_run-off road' for the run-off road crash type.

```
SELECT *
FROM [severity type_fatality]
WHERE ((([severity type_fatality].TYPE_ACC) ="A" AND (([severity
type_fatality].MAN_COLL_CD) ="A" Or ([severity type_fatality].MAN_COLL_CD)
="L")) ;
```

Query to create the table ‘FATALITY_crash type 2-head-on & rt angle’ for the head on and right angle crashes:

```
SELECT *
FROM [severity type_fatality]
WHERE ((([severity type_fatality].TYPE_ACC) ="D" Or ([severity
type_fatality].TYPE_ACC) ="E") AND (([severity type_fatality].MAN_COLL_CD)
="C" Or ([severity type_fatality].MAN_COLL_CD) ="D"));
```

The table ‘FATALITY_crash type 3-turning angle & sideswipe’ was created using the following query:

```
SELECT *
FROM [severity type_fatality]
```

WHERE ((([severity type_fatality].TYPE_ACC)="D") Or ([severity type_fatality].TYPE_ACC)="E") AND (([severity type_fatality].MAN_COLL_CD)="E" Or ([severity type_fatality].MAN_COLL_CD)="F" Or ([severity type_fatality].MAN_COLL_CD)="G" Or ([severity type_fatality].MAN_COLL_CD)="H" Or ([severity type_fatality].MAN_COLL_CD)="I" Or ([severity type_fatality].MAN_COLL_CD)="J" Or ([severity type_fatality].MAN_COLL_CD)="K"));

The table 'FATALITY_crash type 4- non-mv collisions' was created usinghte following query:

```
SELECT *
FROM [severity type_fatality]
WHERE ((([severity type_fatality].TYPE_ACC)="C" Or ([severity type_fatality].TYPE_ACC)="F" Or ([severity type_fatality].TYPE_ACC)="G" Or ([severity type_fatality].TYPE_ACC)="H" Or ([severity type_fatality].TYPE_ACC)="I" Or ([severity type_fatality].TYPE_ACC)="J" Or ([severity type_fatality].TYPE_ACC)="K") AND (([severity type_fatality].MAN_COLL_CD)="A" Or ([severity type_fatality].MAN_COLL_CD)="L"));
```

Query built for the run off road and overturning crash type, named 'INJURY_crash type 1-run off road' is as follows:

```
SELECT *
FROM [severity type_injury]
WHERE ((([severity type_injury].TYPE_ACC)="A" Or ([severity
type_injury].TYPE_ACC)="B") AND (([severity type _ injury].MAN_COLL_CD)="A"
Or ([severity type _ injury].MAN_COLL_CD)="B" Or ([severity type _injury]
.MAN_COLL_CD)="E" Or ([severity type_ injury] .MAN_COLL_CD)="F" Or
([severity type_ injury] .MAN_COLL_CD)="G" Or ([severity type_ injury]
.MAN_COLL_CD)="H" Or ([severity type_ injury] .MAN_COLL_CD)="I" Or
([severity type_ injury] .MAN_COLL_CD)="J" Or ([severity type_ injury]
.MAN_COLL_CD)="K" Or ([severity type_ injury] .MAN_COLL_CD)="L"));
```

Query built for the 'INJURY_crash type 1-run off road' is as follows:

```
SELECT *
FROM [severity type_injury]
WHERE ((([severity type_injury].TYPE_ACC)="A" Or ([severity
type_injury].TYPE_ACC)="B") AND (([severity type_injury].MAN_COLL_CD)="A"
Or ([severity type_injury].MAN_COLL_CD)="B" Or ([severity
type_injury].MAN_COLL_CD)="E" Or ([severity type_injury].MAN_COLL_CD)="F"
Or ([severity type_injury].MAN_COLL_CD)="G" Or ([severity
type_injury].MAN_COLL_CD)="H" Or ([severity type_injury].MAN_COLL_CD)="I"
Or ([severity type_injury].MAN_COLL_CD)="J" Or ([severity
type_injury].MAN_COLL_CD)="K" Or ([severity
type_injury].MAN_COLL_CD)="L"));
```

Query built for the 'INJURY_crash type 2-rear end' table is as follows:

```
SELECT *
FROM [severity type_injury]
WHERE ((([severity type_injury].TYPE_ACC)="D" Or ([severity
type_injury].TYPE_ACC)="E") AND (([severity type_injury].MAN_COLL_CD)="B"));
```

Query built for the 'INJURY_crash type 3-rt angle & headon' table is as follows:

```
SELECT *
```

```
FROM [severity type_injury]
WHERE ((([severity type_injury].TYPE_ACC)="D" Or ([severity
type_injury].TYPE_ACC)="E" Or ([severity type_injury].TYPE_ACC)="A" Or
([severity type_injury].TYPE_ACC)="B") AND (([severity
type_injury].MAN_COLL_CD)="C" Or ([severity
type_injury].MAN_COLL_CD)="D"));
```

Query built for the ‘INJURY_crash type 4-turning angle & sideswipe’ table is as follows:

```
SELECT *
FROM [severity type_injury]
WHERE ((([severity type_injury].TYPE_ACC)="D" Or ([severity
type_injury].TYPE_ACC)="E") AND (([severity type_injury].MAN_COLL_CD)="E"
Or ([severity type_injury].MAN_COLL_CD)="F" Or ([severity
type_injury].MAN_COLL_CD)="G" Or ([severity type_injury].MAN_COLL_CD)="H"
Or ([severity type_injury].MAN_COLL_CD)="I" Or ([severity
type_injury].MAN_COLL_CD)="J" Or ([severity
type_injury].MAN_COLL_CD)="K"));
```

Query built for the ‘INJURY_crash type 5-non motor vehicle crashes’ table is as follows:

```
SELECT *
FROM [severity type_injury]
WHERE ((([severity type_injury].TYPE_ACC)="C" Or ([severity
type_injury].TYPE_ACC)="G" Or ([severity type_injury].TYPE_ACC)="H" Or
([severity type_injury].TYPE_ACC)="I" Or ([severity type_injury].TYPE_ACC)="J" Or
([severity type_injury].TYPE_ACC)="K") AND (([severity
type_injury].MAN_COLL_CD)="A" Or ([severity type_injury].MAN_COLL_CD)="B"
Or ([severity type_injury].MAN_COLL_CD)="C" Or ([severity
type_injury].MAN_COLL_CD)="D" Or ([severity type_injury].MAN_COLL_CD)="E"
Or ([severity type_injury].MAN_COLL_CD)="F" Or ([severity
type_injury].MAN_COLL_CD)="G" Or ([severity type_injury].MAN_COLL_CD)="H"
Or ([severity type_injury].MAN_COLL_CD)="I" Or ([severity
type_injury].MAN_COLL_CD)="J" Or ([severity type_injury].MAN_COLL_CD)="K"
Or ([severity type_injury].MAN_COLL_CD)="L"));
```

Query built for the ‘PDO_crash type 1-run off road & overturning’ table:

```
SELECT *
FROM [severity type_PDO]
WHERE ((([severity type_PDO].TYPE_ACC)="A" Or ([severity
type_PDO].TYPE_ACC)="B") AND (([severity type_PDO].MAN_COLL_CD)="A" Or
([severity type_PDO].MAN_COLL_CD)="B" Or ([severity
type_PDO].MAN_COLL_CD)="C" Or ([severity type_PDO].MAN_COLL_CD)="D"
Or ([severity type_PDO].MAN_COLL_CD)="E" Or ([severity
type_PDO].MAN_COLL_CD)="F" Or ([severity type_PDO].MAN_COLL_CD)="G" Or
([severity type_PDO].MAN_COLL_CD)="H" Or ([severity
type_PDO].MAN_COLL_CD)="I" Or ([severity type_PDO].MAN_COLL_CD)="J" Or
([severity type_PDO].MAN_COLL_CD)="K" Or ([severity
type_PDO].MAN_COLL_CD)="L"))
ORDER BY [severity type_PDO].CRASH_YEAR, [severity type_PDO].CSECT,
[severity type_PDO].LOGMI_FROM, [severity type_PDO].LOGMI_TO;
```

Query built for the ‘PDO_crash type 1-rear_end’ table:

```
SELECT *
FROM [severity type_PDO]
WHERE ((([severity type_PDO].TYPE_ACC)="D" Or ([severity
type_PDO].TYPE_ACC)="E") AND (([severity type_PDO].MAN_COLL_CD)="B"));
```

Query built for the 'PDO_crash type 3-rt angle and sideswipe' table:

```
SELECT *
FROM [severity type_PDO]
WHERE ((([severity type_PDO].TYPE_ACC)="D" Or ([severity
type_PDO].TYPE_ACC)="E") AND (([severity type_PDO].MAN_COLL_CD)="D" Or
([severity type_PDO].MAN_COLL_CD)="J" Or ([severity
type_PDO].MAN_COLL_CD)="K"))
ORDER BY [severity type_PDO].CRASH_YEAR, [severity type_PDO].CSECT,
[severity type_PDO].LOGMI_FROM, [severity type_PDO].LOGMI_TO;
```

Query built for the 'PDO_crash type 4 - non-mv crashes' table:

```
SELECT *
FROM [severity type_PDO]
WHERE ((([severity type_PDO].TYPE_ACC)="C" Or ([severity
type_PDO].TYPE_ACC)="H" Or ([severity type_PDO].TYPE_ACC)="I" Or ([severity
type_PDO].TYPE_ACC)="J" Or ([severity type_PDO].TYPE_ACC)="K") AND
(([severity type_PDO].MAN_COLL_CD)="A" Or ([severity
type_PDO].MAN_COLL_CD)="B" Or ([severity type_PDO].MAN_COLL_CD)="C" Or
([severity type_PDO].MAN_COLL_CD)="D" Or ([severity
type_PDO].MAN_COLL_CD)="E" Or ([severity type_PDO].MAN_COLL_CD)="F" Or
([severity type_PDO].MAN_COLL_CD)="G" Or ([severity
type_PDO].MAN_COLL_CD)="H" Or ([severity type_PDO].MAN_COLL_CD)="I" Or
([severity type_PDO].MAN_COLL_CD)="J" Or ([severity
type_PDO].MAN_COLL_CD)="K" Or ([severity type_PDO].MAN_COLL_CD)="L"))
ORDER BY [severity type_PDO].CRASH_YEAR, [severity type_PDO].CSECT,
[severity type_PDO].LOGMI_FROM, [severity type_PDO].LOGMI_TO;
```

CRASH TYPE 1_FATALITY_HOMOGROUP_1 query:

```
SELECT *
FROM [FATALITY_crash type 1-run-off road query], [FINAL BEF_AFTR
TABLE_NOV29TH]
WHERE ((([FATALITY_crash type 1-run-off road query].ALIGNMENT_CD)="A" Or
([FATALITY_crash type 1-run-off road query].ALIGNMENT_CD)="F" Or
([FATALITY_crash type 1-run-off road query].ALIGNMENT_CD)="C" Or
([FATALITY_crash type 1-run-off road query].ALIGNMENT_CD)="G" Or
([FATALITY_crash type 1-run-off road query].ALIGNMENT_CD)="D" Or
([FATALITY_crash type 1-run-off road query].ALIGNMENT_CD)="I") AND
(([FATALITY_crash type 1-run-off road query].VEH_TYPE_CD1)="B" Or
([FATALITY_crash type 1-run-off road query].VEH_TYPE_CD1)="A" Or
([FATALITY_crash type 1-run-off road query].VEH_TYPE_CD1)="E" Or
([FATALITY_crash type 1-run-off road query].VEH_TYPE_CD1)="M" Or
([FATALITY_crash type 1-run-off road query].VEH_TYPE_CD1)="H" Or
([FATALITY_crash type 1-run-off road query].VEH_TYPE_CD1)="D") AND
(([FATALITY_crash type 1-run-off road query].CRASH_HOUR)>0.5) AND
(([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="V" Or
```

([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="R" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="A" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="T" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="S" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="B" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="U" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="C" Or
([FATALITY_crash type 1-run-off road query].VIOLATIONS_CD1)="F") AND
(([FATALITY_crash type 1-run-off road query].PAVE_WIDTH)<=21) AND
(([FATALITY_crash type 1-run-off road]![CRASH_NUM])=[FINAL BEF_AFTR TABLE_NOV29TH]![CRASH_NUM]))
ORDER BY [FATALITY_crash type 1-run-off road query].CSECT, [FATALITY_crash type 1-run-off road query].LOGMI_FROM;

Query for no speed limit change group for CRASH TYPE 1_FATALITY _ HOMOGROUP_1:

SELECT *
FROM [CRASH TYPE 1_FATALITY_HOMOGROUP_1]
WHERE ([CRASH TYPE 1_FATALITY_HOMOGROUP_1]. BEFORE/ AFTER) = ‘S’;

Query for the CRASH TYPE 1_FATALITY_HOMOGROUP_1 to obtain the speed change group with speed change in 1999:

SELECT *
FROM [CRASH TYPE 1_FATALITY_HOMOGROUP_1]
WHERE ([CRASH TYPE 1_FATALITY_HOMOGROUP_1]. BEFORE/ AFTER) = ‘99B’ Or ([CRASH TYPE 1_FATALITY_HOMOGROUP_1] .BEFORE/ AFTER) = ‘99A’;

Query for the CRASH TYPE 1_FATALITY_HOMOGROUP_1 to obtain the speed change group with speed change in 2000:

SELECT *
FROM [CRASH TYPE 1_FATALITY_HOMOGROUP_1]
WHERE ([CRASH TYPE 1_FATALITY_HOMOGROUP_1]. BEFORE/ AFTER) = ‘00B’ Or ([CRASH TYPE 1_FATALITY_HOMOGROUP_1] .BEFORE/ AFTER) = ‘00A’;

Query for the CRASH TYPE 1_FATALITY_HOMOGROUP_1 to obtain the speed change group with speed change in 2001:

SELECT *
FROM [CRASH TYPE 1_FATALITY_HOMOGROUP_1]
WHERE ([CRASH TYPE 1_FATALITY_HOMOGROUP_1]. BEFORE/ AFTER) = ‘01B’ Or ([CRASH TYPE 1_FATALITY_HOMOGROUP_1] .BEFORE/ AFTER) = ‘01A’;

Query for the CRASH TYPE 1_FATALITY_HOMOGROUP_1 to obtain the speed change group with speed change in 2002:

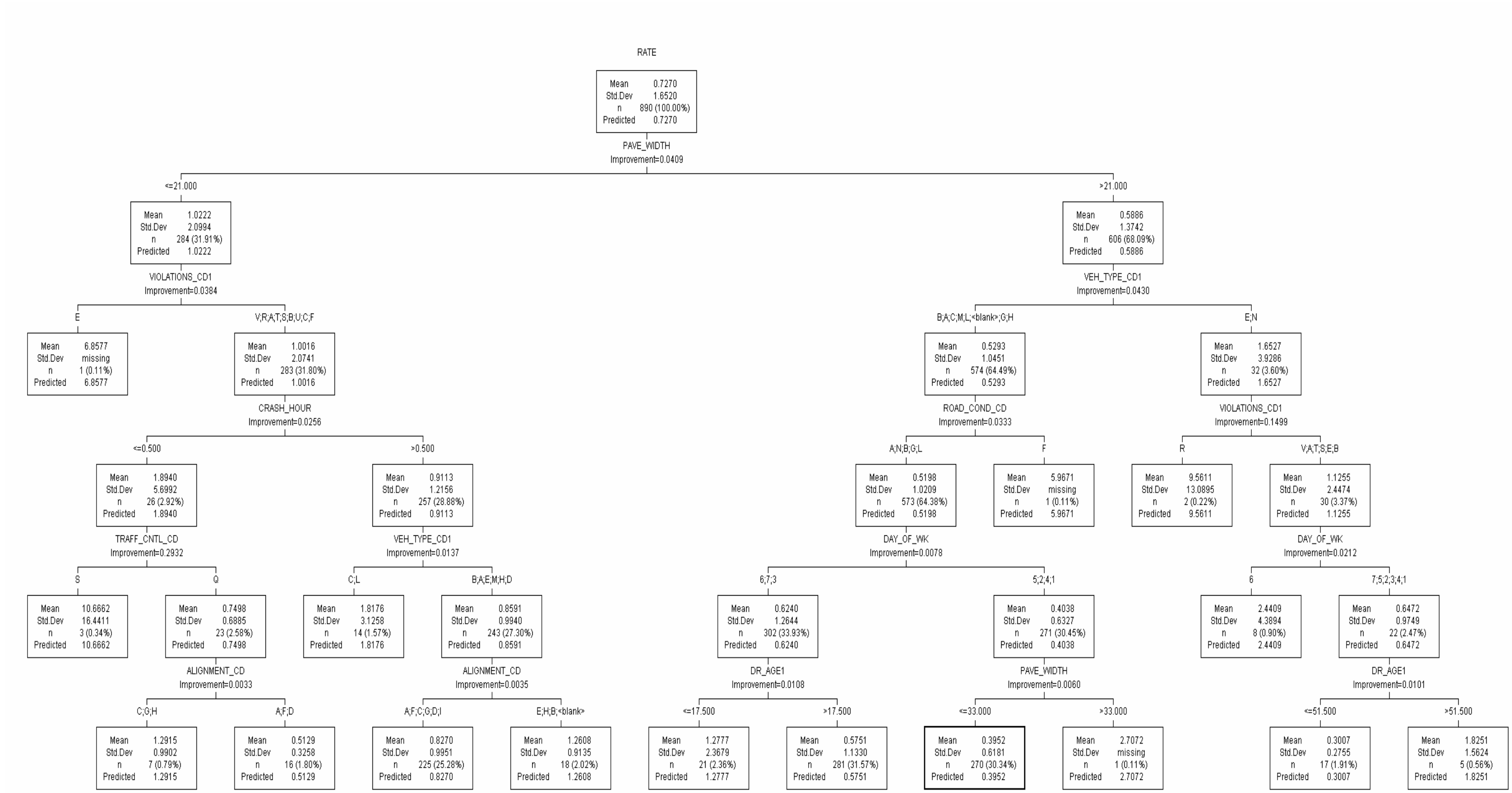
SELECT *
FROM [CRASH TYPE 1_FATALITY_HOMOGROUP_1]
WHERE ([CRASH TYPE 1_FATALITY_HOMOGROUP_1]. BEFORE/ AFTER) = ‘01B’ Or ([CRASH TYPE 1_FATALITY_HOMOGROUP_1] .BEFORE/ AFTER) = ‘01A’;

Query for the CRASH TYPE 1_FATALITY_HOMOGROUP_1 to obtain the speed change group with speed change in 2003:

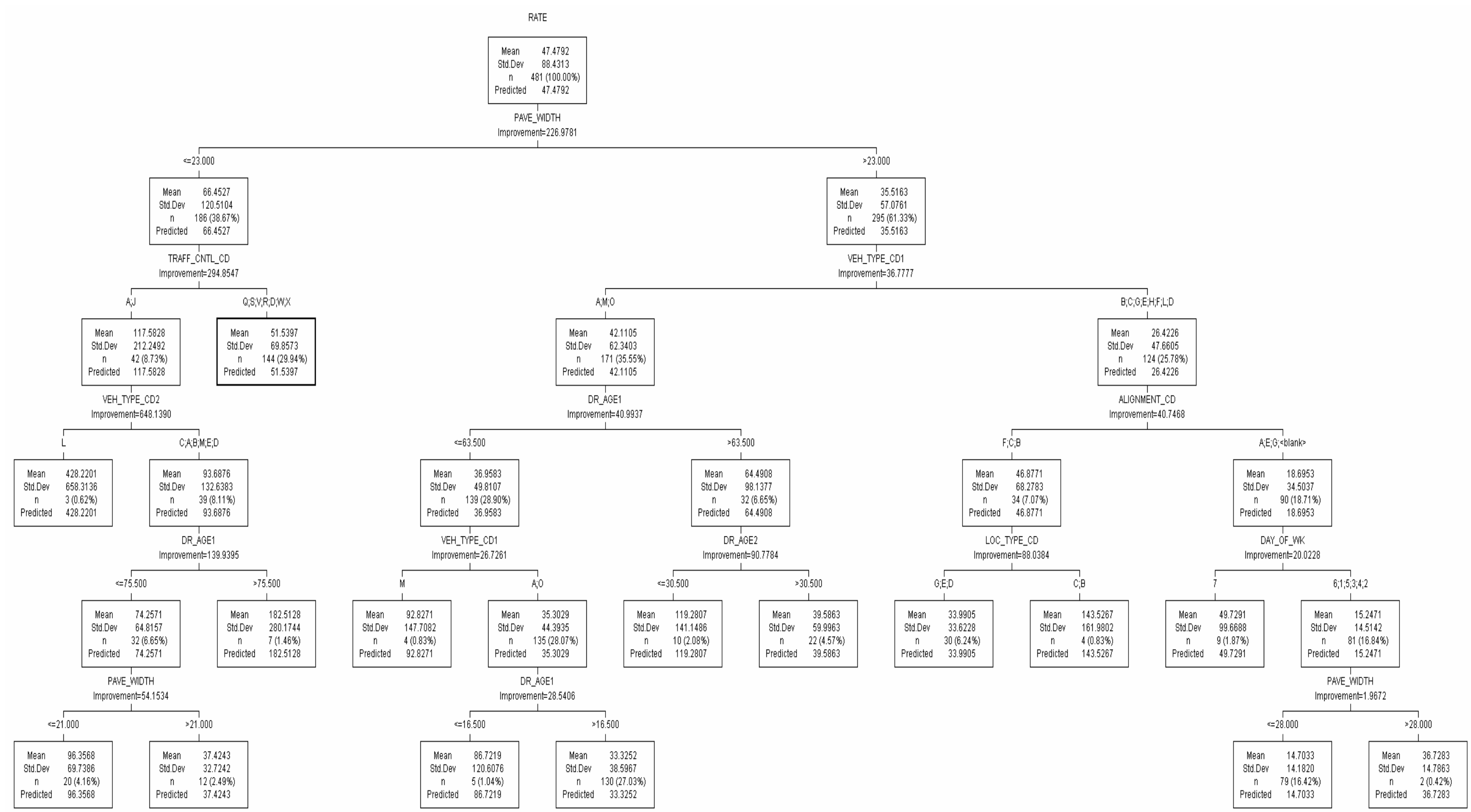
```
SELECT *
FROM [CRASH TYPE 1_FATALITY_HOMOGROUP_1]
WHERE ([CRASH TYPE 1_FATALITY_HOMOGROUP_1]. BEFORE/ AFTER) =
‘03B’ Or ([CRASH TYPE 1_FATALITY_HOMOGROUP_1] .BEFORE/ AFTER) =
‘03A’;
```

APPENDIX B

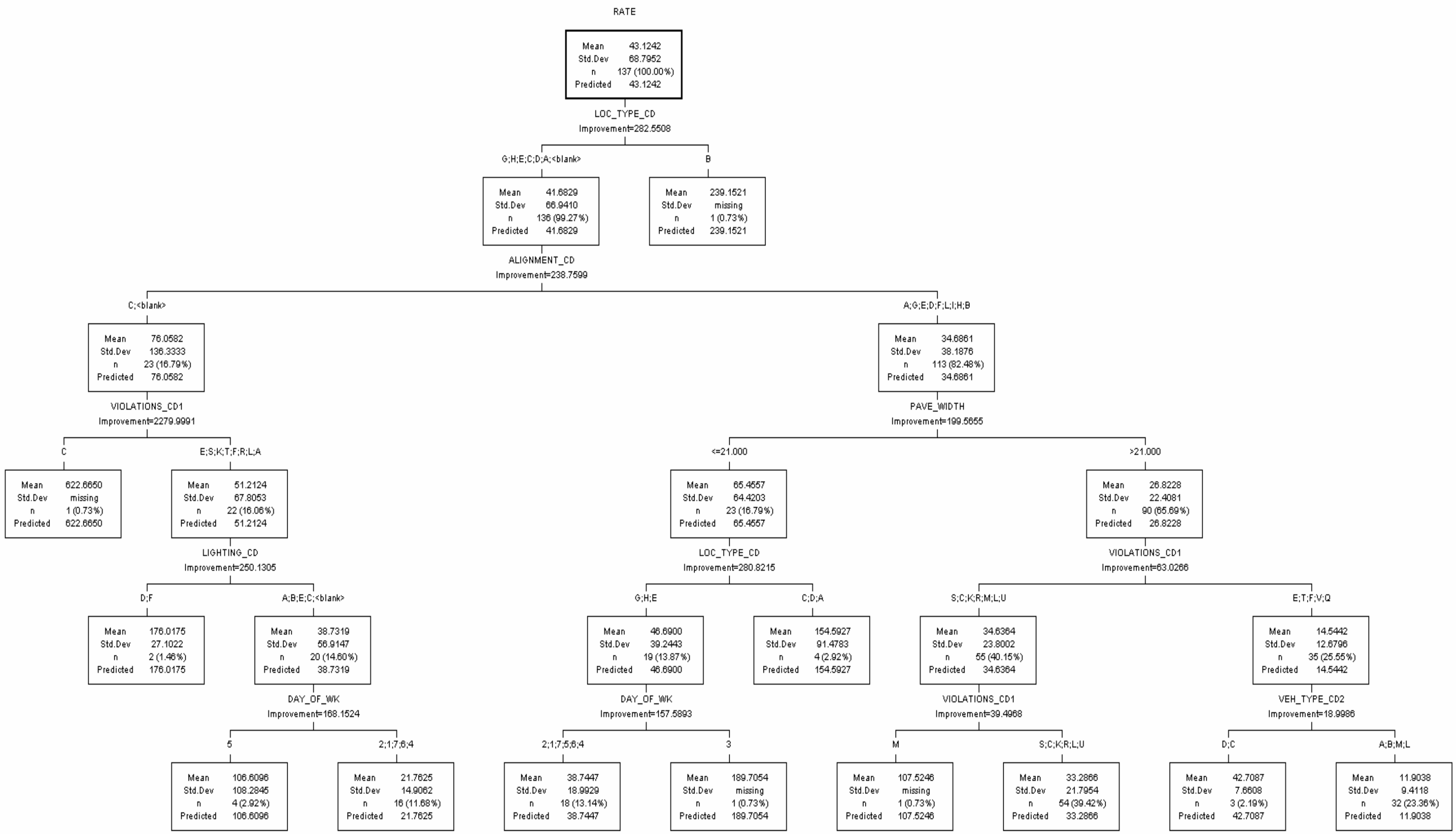
ANSWER TREE ANALYSIS



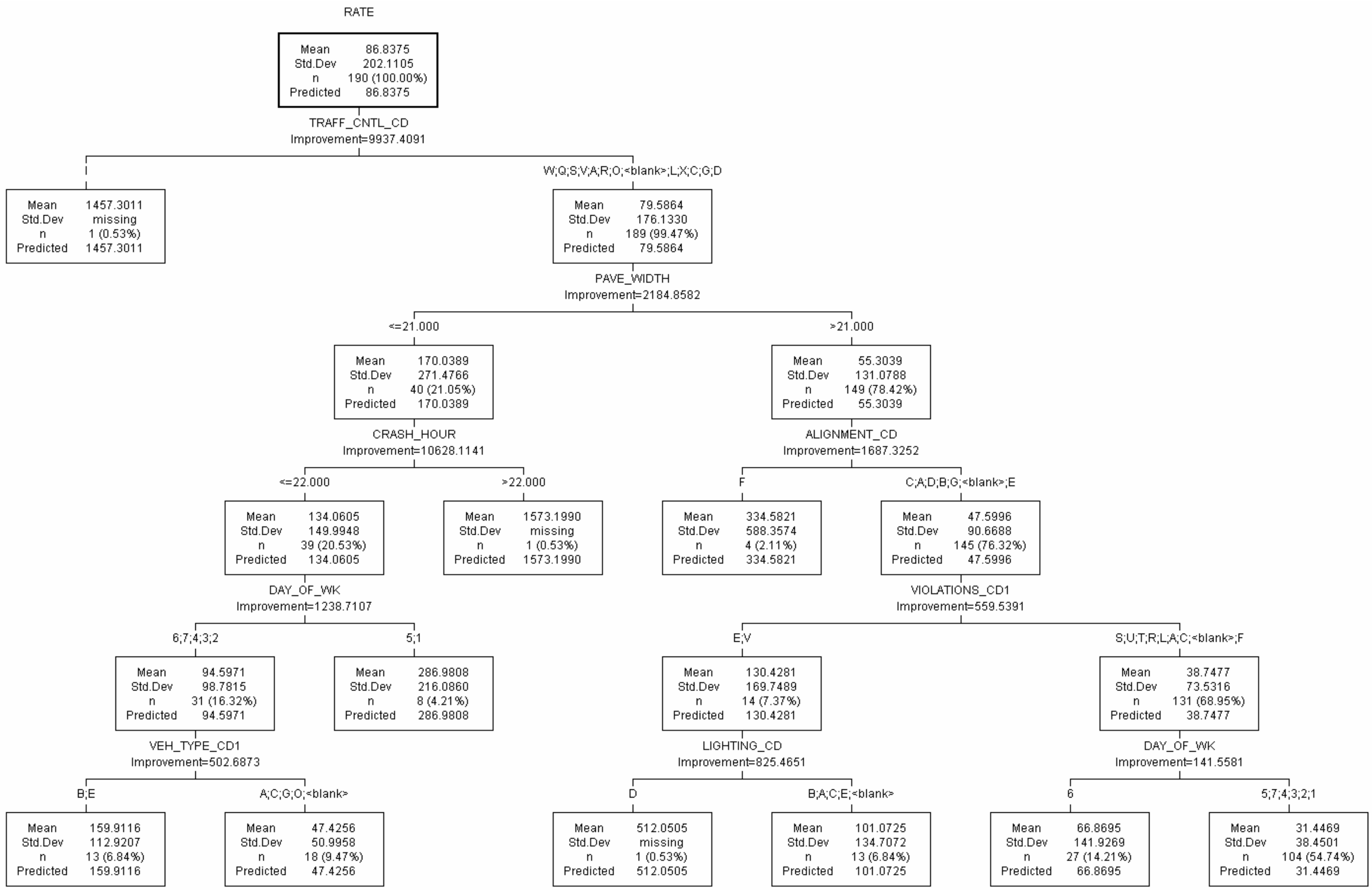
Tree Map for Run-off Road Crash Type in Fatality Group



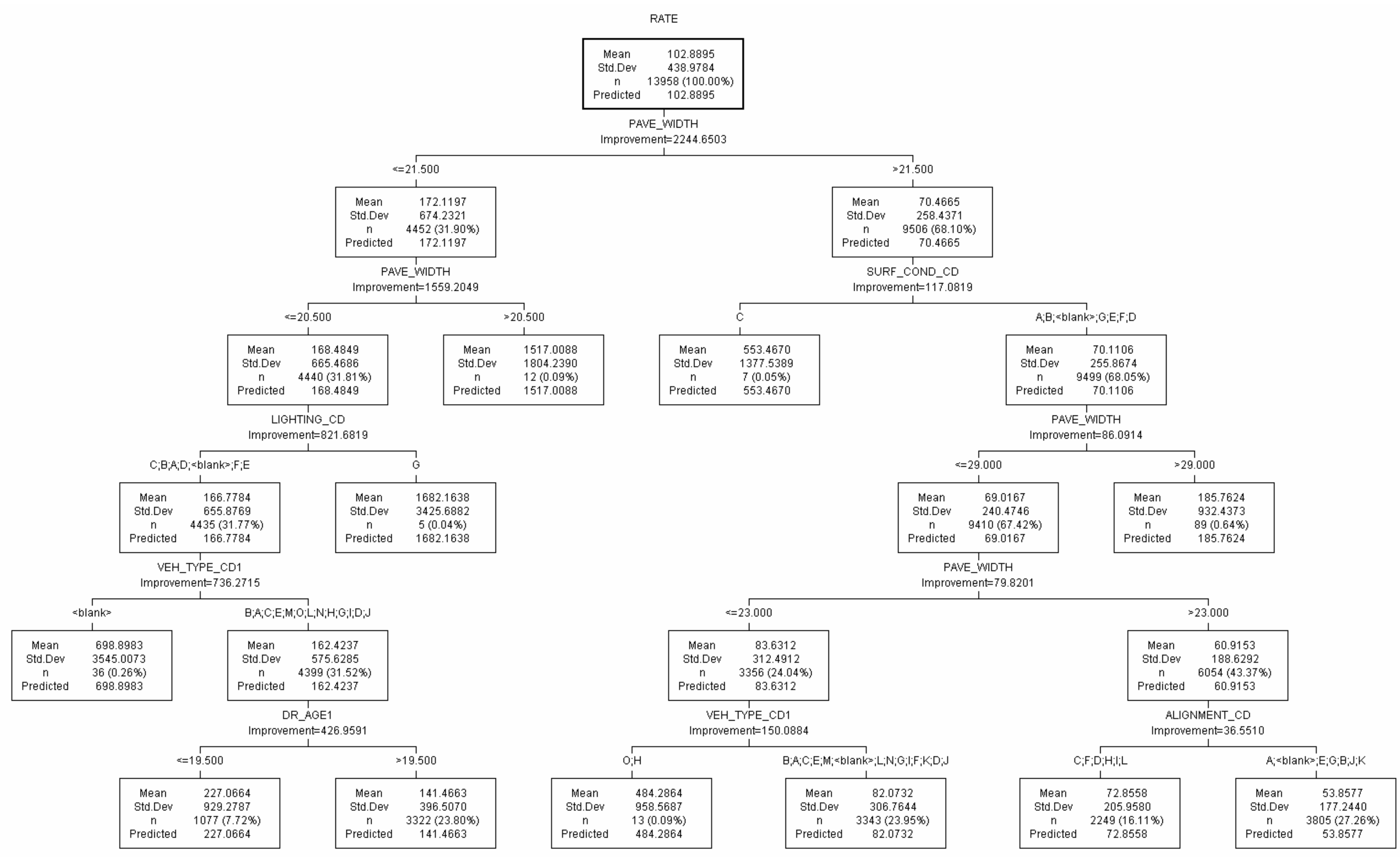
Tree Map for Head on and Right Angle Crash Type in Fatality Group



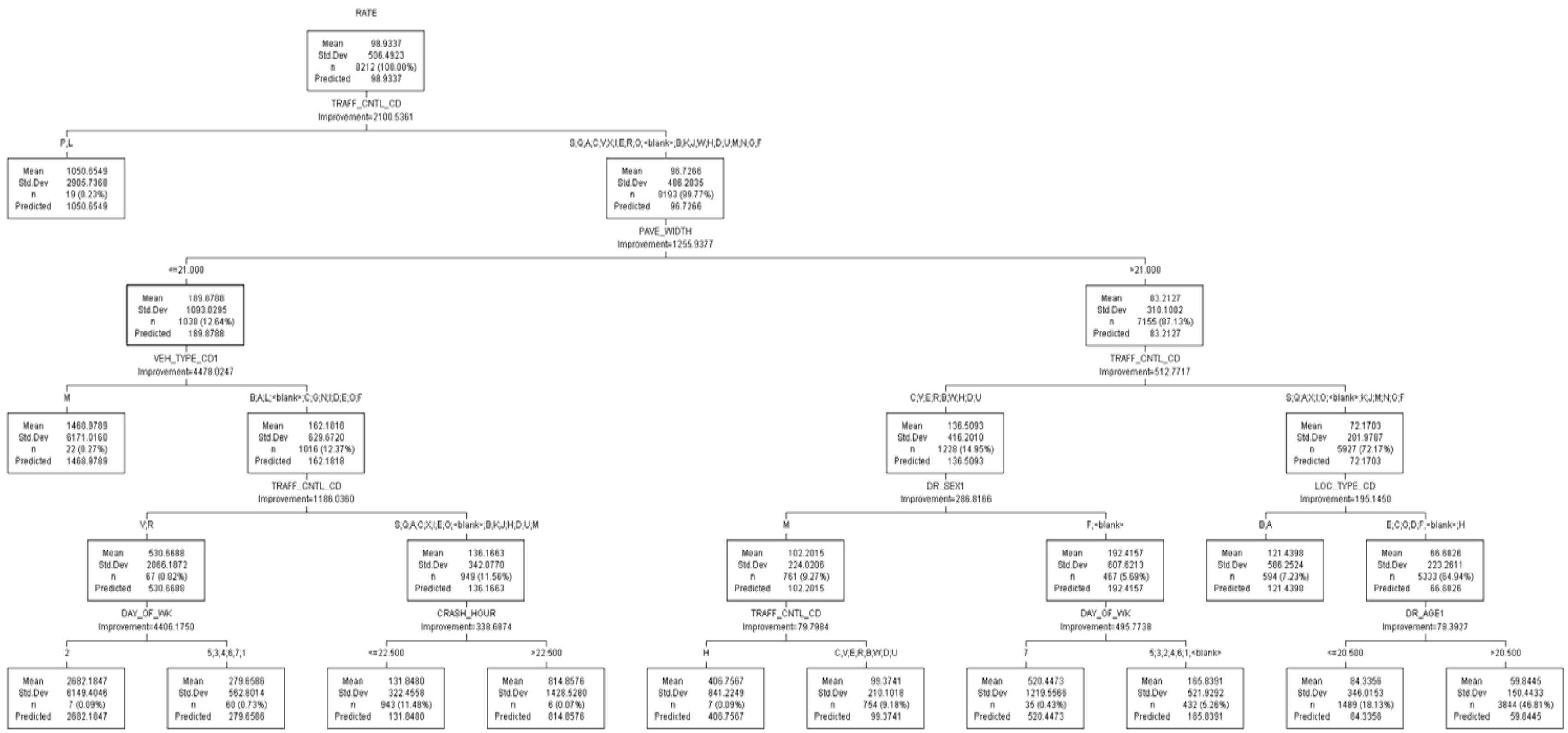
Tree Map for Turning Angle and Sideswipe Crash Type in Fatality Group



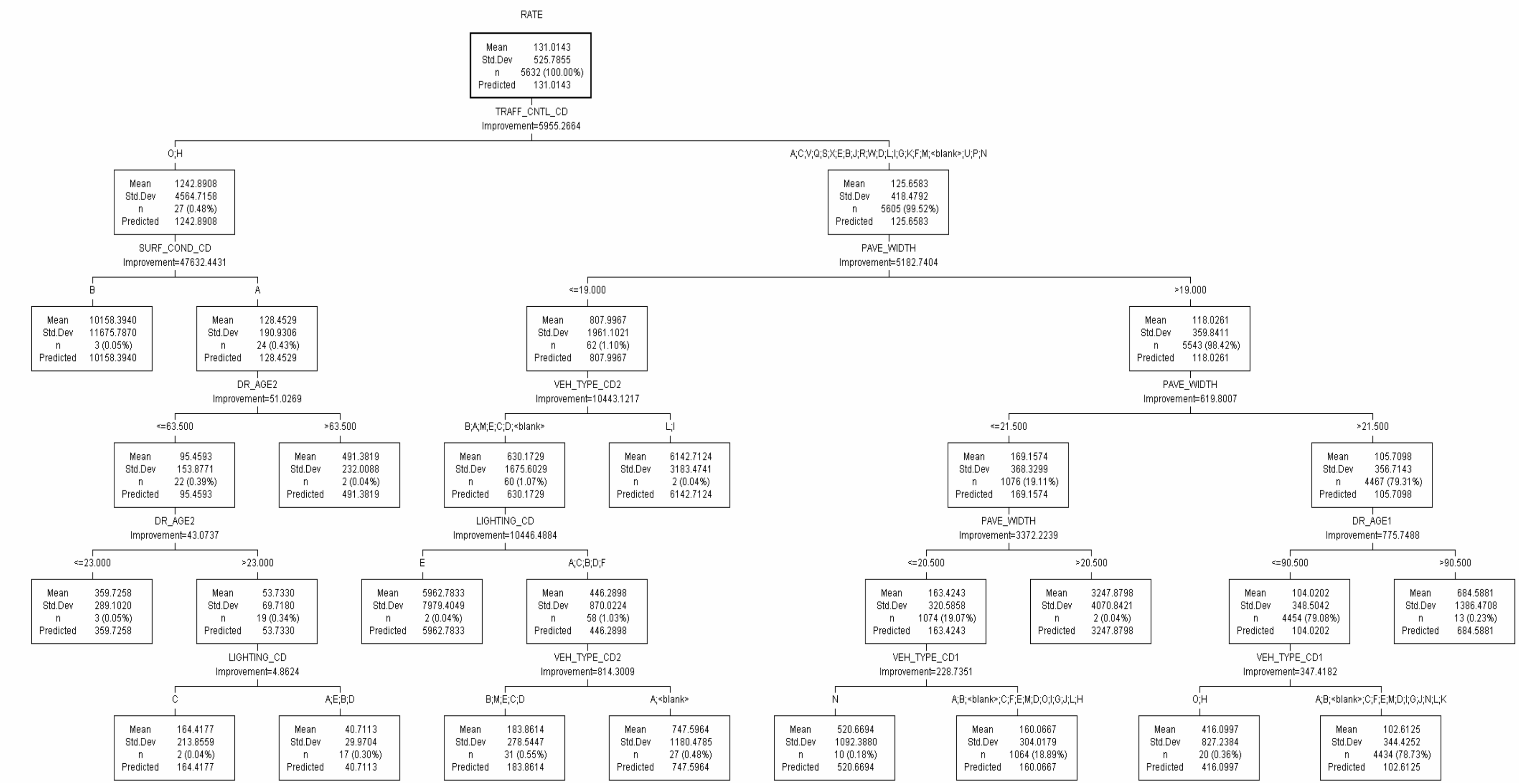
Tree Map for Non Motor Vehicle Crash Type in Fatality Group



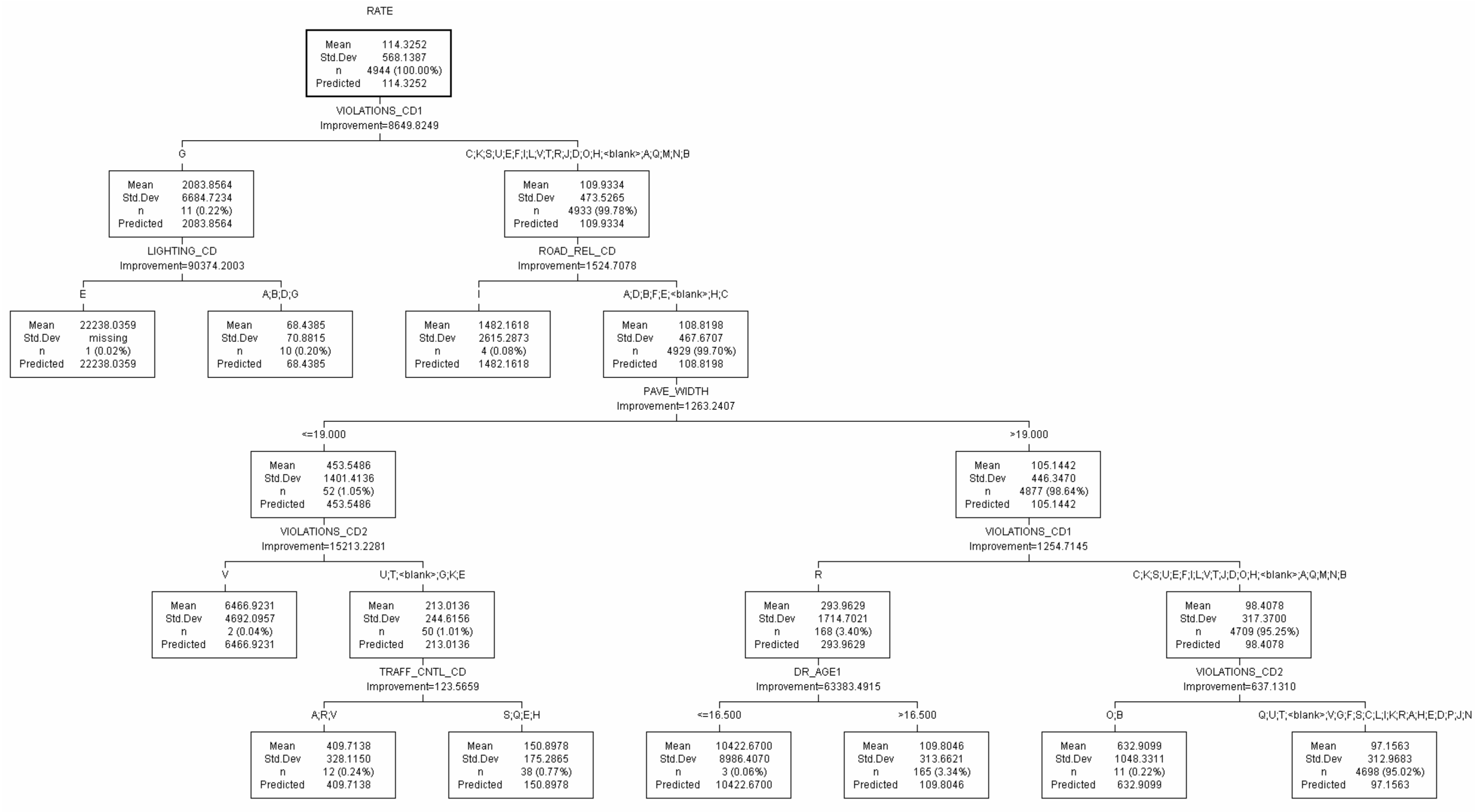
Tree Map for Run-off Road Crash Type in Injury Group



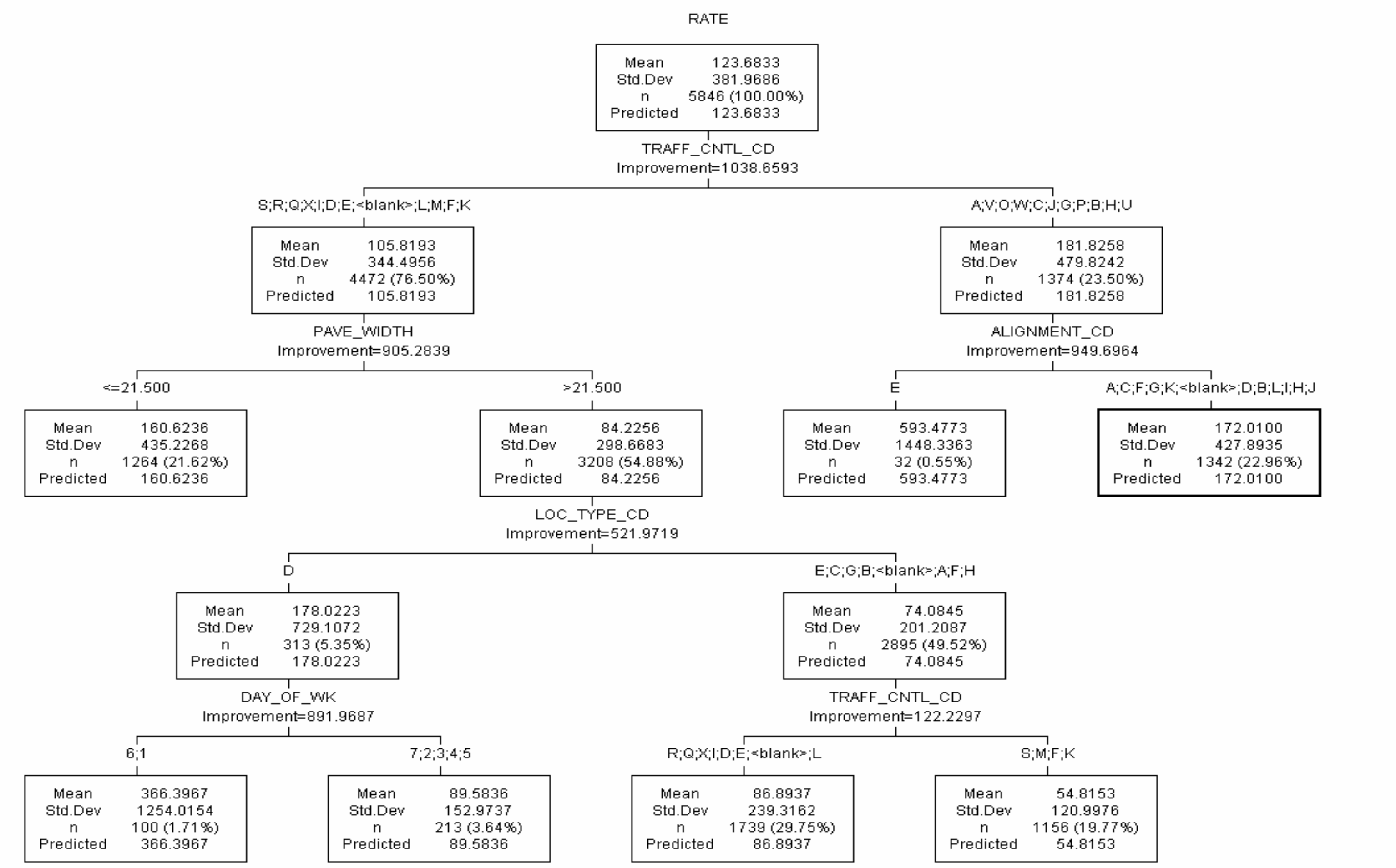
Tree Map for Rear-End Collision Crash Type in Injury Group



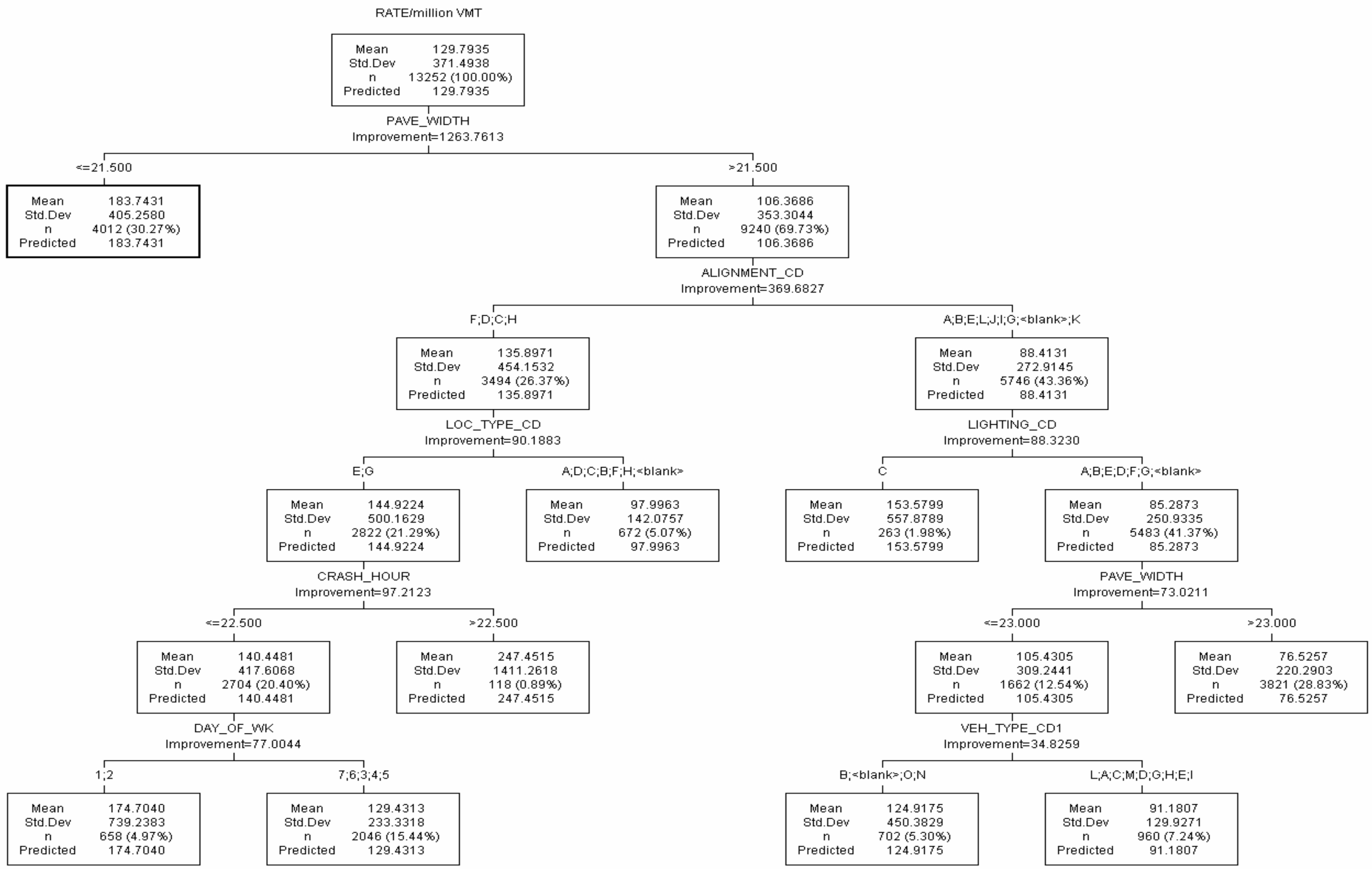
Tree Map for Right Angle and Head on Crash Type in Injury Group



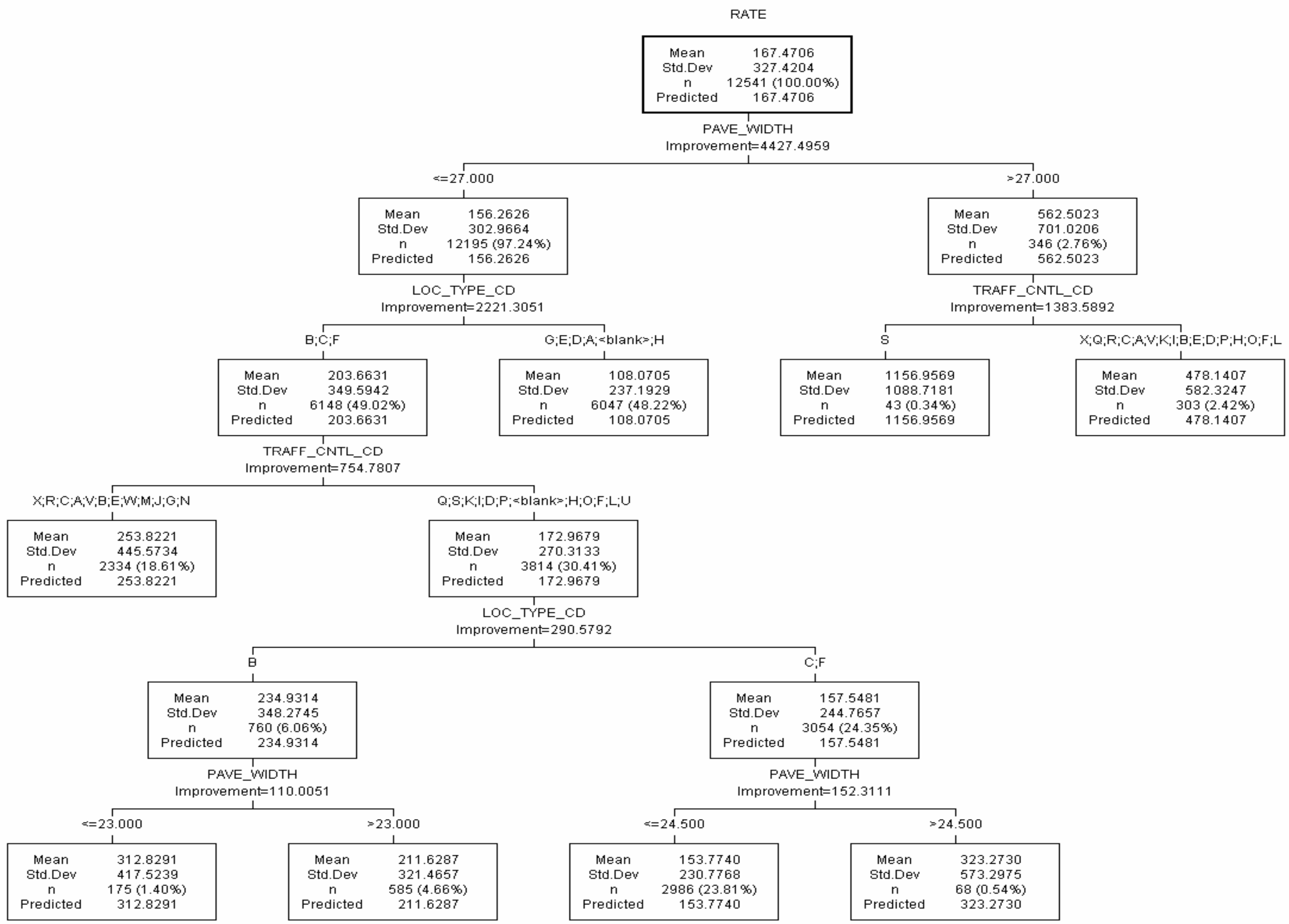
Tree Map for Turning Angle and Sideswipe Crash Type in Injury Group



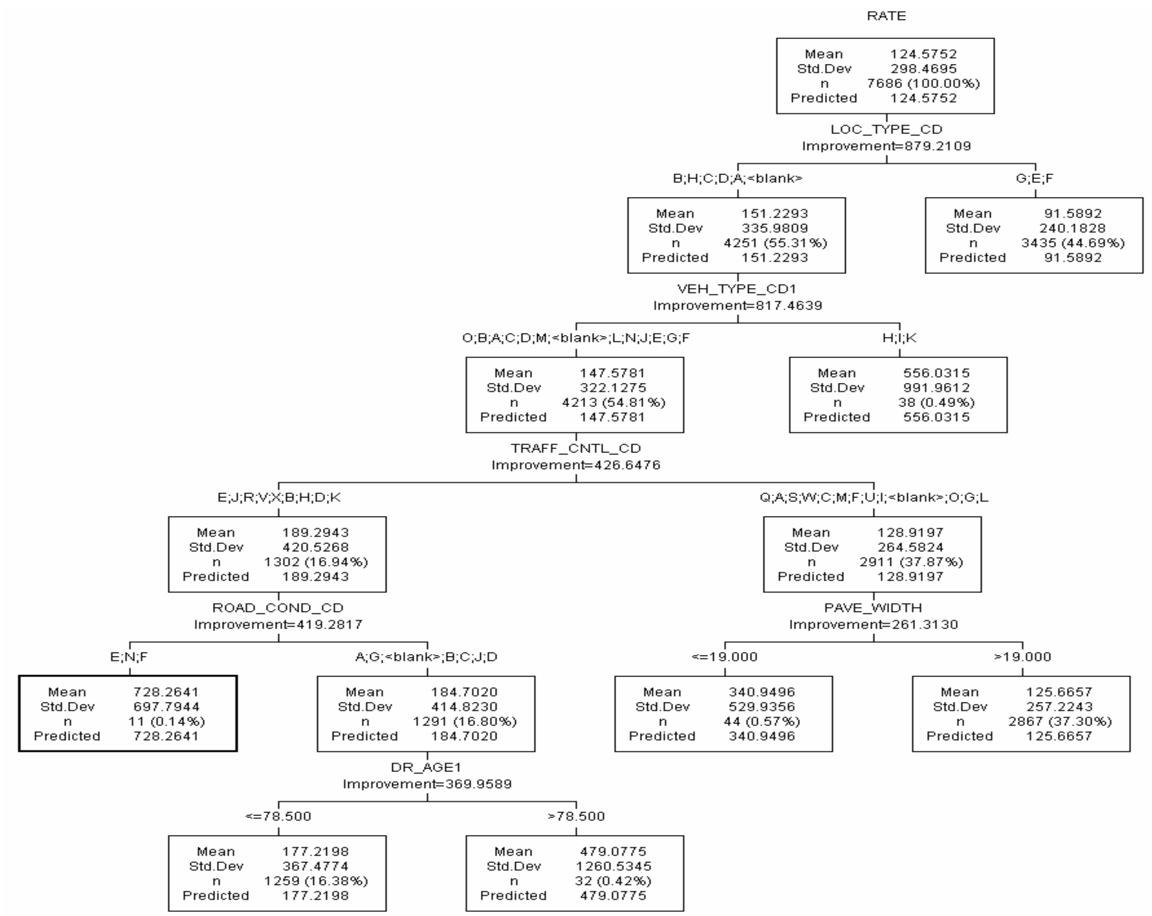
Tree Map for Non Motor Vehicle Crash Type in Injury Group



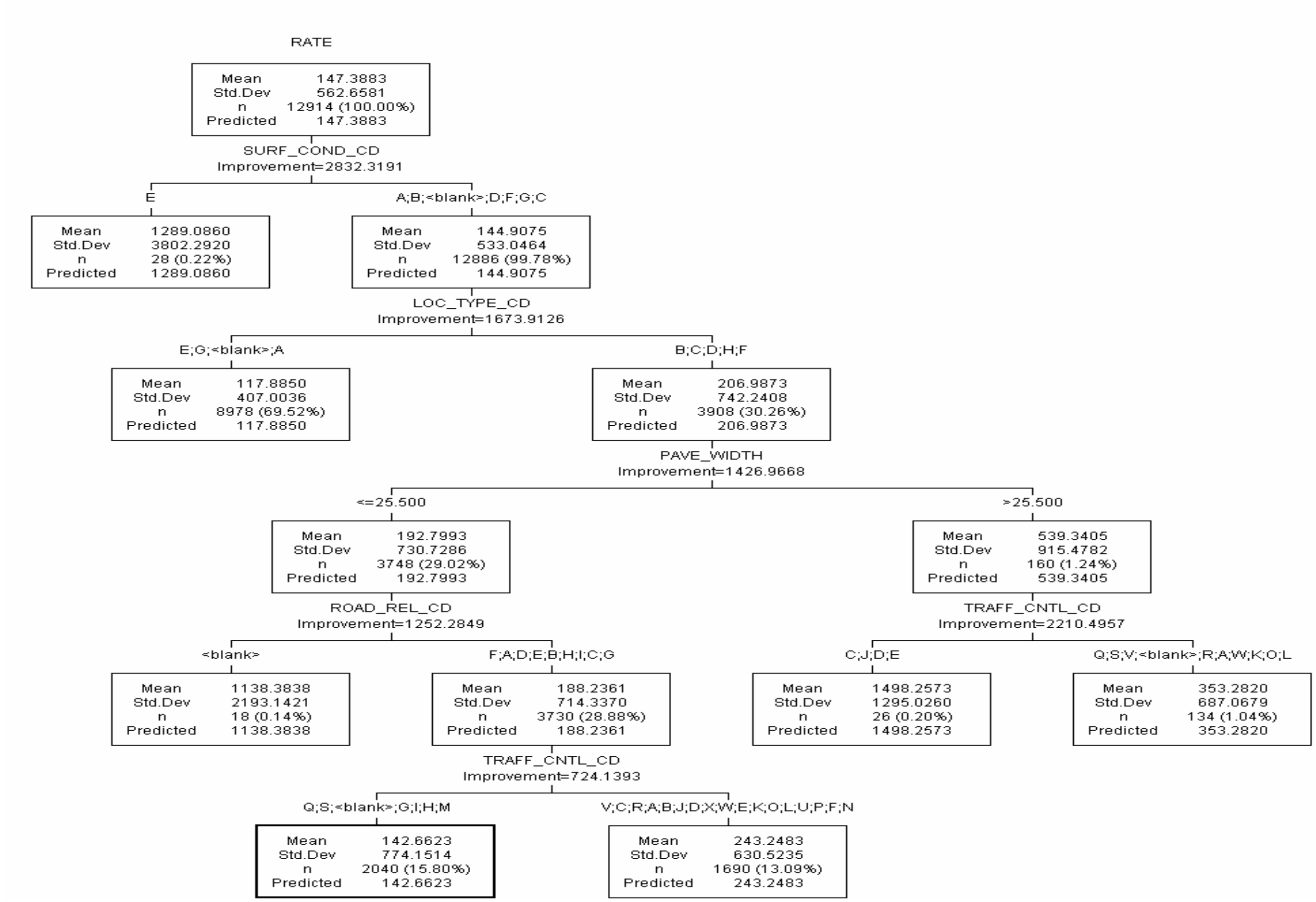
Tree Map for Run-off Road Crash Type in PDO Group



Tree Map for Rear End Crash Type in PDO Group



Tree Map for Right Angle & Sideswipe Crash Type in PDO Group



Tree Map for Non Motor Vehicle Crash Type in PDO Group

Run-off Road Crash Type for Fatality Group

	Resubstitution
Risk Estimate	2.0254
SE of Risk Estimate	0.505277

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
5	3	0.34	10.67	1467.16
25	2	0.22	9.56	1315.16
2	1	0.11	6.86	943.30
23	1	0.11	5.97	820.79
22	1	0.11	2.71	372.39
27	8	0.90	2.44	335.76
30	5	0.56	1.83	251.05
10	14	1.57	1.82	250.02
7	7	0.79	1.29	177.65
18	21	2.36	1.28	175.76
13	18	2.02	1.26	173.43
12	225	25.28	0.83	113.75
19	281	31.57	0.58	79.11
8	16	1.80	0.51	70.55
21	270	30.34	0.40	54.36
29	17	1.91	0.30	41.36

Head on and Right Angle Crash Type for Fatality Group

	Resubstitution
Risk Estimate	6065.18
SE of Risk Estimate	1608.46

Gain Summary

Statistics				
Node	Node: n	Node: %	Gain	Index (%)
3	3	0.62	428.22	901.91
8	7	1.46	182.51	384.41
23	4	0.83	143.53	302.29
18	10	2.08	119.28	251.23
6	20	4.16	96.36	202.95
13	4	0.83	92.83	195.51
15	5	1.04	86.72	182.65
9	144	29.94	51.54	108.55
25	9	1.87	49.73	104.74
19	22	4.57	39.59	83.38
7	12	2.49	37.42	78.82
28	2	0.42	36.73	77.36
22	30	6.24	33.99	71.59
16	130	27.03	33.33	70.19
27	79	16.42	14.70	30.97

Turning Angle and Sideswipe Crash Type for Fatality Group

	Resubstitution
Risk Estimate	719.137
SE of Risk Estimate	186.029

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
3	1	0.73	622.67	1443.89
22	1	0.73	239.15	554.57
13	1	0.73	189.71	439.90
5	2	1.46	176.02	408.16
14	4	2.92	154.59	358.48
17	1	0.73	107.52	249.34
7	4	2.92	106.61	247.21
20	3	2.19	42.71	99.04
12	18	13.14	38.74	89.84
18	54	39.42	33.29	77.19
8	16	11.68	21.76	50.46
21	32	23.36	11.90	27.60

Non Motor Vehicle Crash Type for Fatality Group

	Resubstitution
Risk Estimate	14397.7
SE of Risk Estimate	5096.92

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
9	1	0.53	1573.20	1811.66
1	1	0.53	1457.30	1678.19
11	4	2.11	334.58	385.30
8	8	4.21	286.98	330.48
13	14	7.37	130.43	150.20
5	31	16.32	94.60	108.94
16	131	68.95	38.75	44.62

Run-off Road Crash Type for Injury Group

	Resubstitution
Risk Estimate	186430
SE of Risk Estimate	47721.8

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
8	5	0.04	1682.16	1634.92
9	12	0.09	1517.01	1474.41
4	36	0.26	698.90	679.27
11	7	0.05	553.47	537.92
15	13	0.09	484.29	470.69
6	1077	7.72	227.07	220.69
20	89	0.64	185.76	180.55
7	3322	23.80	141.47	137.49
16	3343	23.95	82.07	79.77
18	2249	16.11	72.86	70.81
19	3805	27.26	53.86	52.35

Rear End Crash Type for Injury Group

	Resubstitution
Risk Estimate	241089
SE of Risk Estimate	99462.3

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
7	7	0.09	2682.18	2711.09
4	22	0.27	1468.98	1484.81
1	19	0.23	1050.65	1061.98
11	6	0.07	814.86	823.64
18	35	0.43	520.45	526.06
15	7	0.09	406.76	411.14
8	60	0.73	279.66	282.67
19	432	5.26	165.84	167.63
10	943	11.48	131.85	133.27
21	594	7.23	121.44	122.75
16	754	9.18	99.37	100.45
23	1489	18.13	84.34	85.24
24	3844	46.81	59.84	60.49

Right Angle and Head on Crash Type for Injury Group

	Resubstitution
Risk Estimate	190484
SE of Risk Estimate	50023.5

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
2	3	0.05	10158.39	7753.65
17	2	0.04	6142.71	4688.58
13	2	0.04	5962.78	4551.24
23	2	0.04	3247.88	2479.03
16	27	0.48	747.60	570.62
28	13	0.23	684.59	522.53
21	10	0.18	520.67	397.41
9	2	0.04	491.38	375.06
26	20	0.36	416.10	317.60
5	3	0.05	359.73	274.57
15	31	0.55	183.86	140.34
7	2	0.04	164.42	125.50
22	1064	18.89	160.07	122.17
27	4434	78.73	102.61	78.32
8	17	0.30	40.71	31.07

Turning Angle and Sideswipe Crash Type for Injury Group

	Resubstitution
Risk Estimate	140292
SE of Risk Estimate	44765.4

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
2	1	0.02	22238.04	19451.56
14	3	0.06	10422.67	9116.69
8	2	0.04	6466.92	5656.60
5	4	0.08	1482.16	1296.44
17	11	0.22	632.91	553.60
10	12	0.24	409.71	358.38
11	38	0.77	150.90	131.99
15	165	3.34	109.80	96.05
18	4698	95.02	97.16	84.98
3	10	0.20	68.44	59.86

Non Motor Vehicle Crash Type for Injury Group

	Resubstitution
Risk Estimate	141445
SE of Risk Estimate	27272.5

Gain Summary				
Target Variable: RATE				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
11	32	0.55	593.48	479.84
5	100	1.71	366.40	296.24
12	1342	22.96	172.01	139.07
2	1264	21.62	160.62	129.87
6	213	3.64	89.58	72.43
8	1739	29.75	86.89	70.26
9	1156	19.77	54.82	44.32

Run off Road and Overturning Crash Type for PDO Group

	Resubstitution
Risk Estimate	135903
SE of Risk Estimate	28294.4

Gain Summary				
Target Variable: RATE/million VMT				
Statistics				
Node	Node: n	Node: %	Gain	Index (%)
8	118	0.89	247.45	190.65
1	4012	30.27	183.74	141.57
6	658	4.97	174.70	134.60
11	263	1.98	153.58	118.33
7	2046	15.44	129.43	99.72
14	702	5.30	124.92	96.24
9	672	5.07	98.00	75.50
15	960	7.24	91.18	70.25
16	3821	28.83	76.53	58.96

Rear End Crash Type for PDO Group

	Resubstitution			
Risk Estimate	97855.5			
SE of Risk Estimate	8048.75			
		Gain Summary		
		Target Variable: RATE		
		Statistics		
Node	Node: n	Node: %	Gain	Index (%)
13	43	0.34	1156.96	690.84
14	303	2.42	478.14	285.51
10	68	0.54	323.27	193.03
5	760	6.06	234.93	140.28
3	2334	18.61	253.82	151.56
9	2986	23.81	153.77	91.82
11	6047	48.22	108.07	64.53

Right Angle and Sideswipe Crash Type for PDO Group

	Resubstitution			
Risk Estimate	85898.6			
SE of Risk Estimate	11404.1			
		Gain Summary		
		Target Variable: RATE		
		Statistics		
Node	Node: n	Node: %	Gain	Index (%)
4	11	0.14	728.26	584.60
11	38	0.49	556.03	446.34
7	32	0.42	479.08	384.57
9	44	0.57	340.95	273.69
6	1259	16.38	177.22	142.26
10	2867	37.30	125.67	100.88
12	3435	44.69	91.59	73.52

Non Motor Vehicle Crash Type for PDO Group

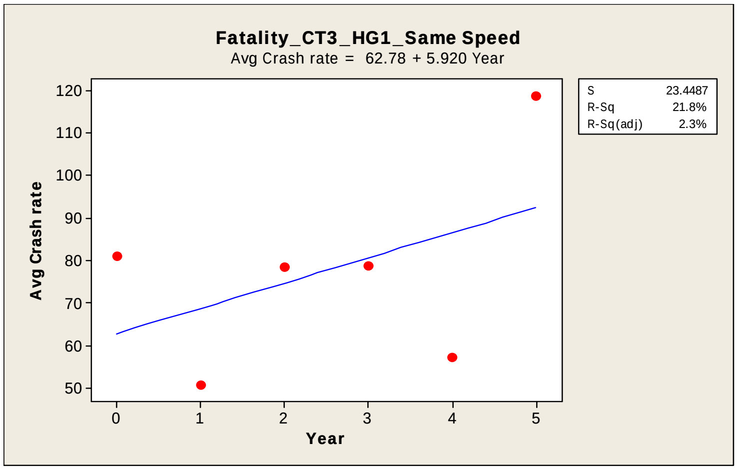
	Resubstitution
Risk Estimate	306440
SE of Risk Estimate	71443.8

		Gain Summary		
		Target Variable: RATE		
		Statistics		
Node	Node: n	Node: %	Gain	Index (%)
11	26	0.20	1498.26	1016.54
1	28	0.22	1289.09	874.62
6	18	0.14	1138.38	772.37
12	134	1.04	353.28	239.69
9	1690	13.09	243.25	165.04
8	2040	15.80	142.66	96.79
3	8978	69.52	117.88	79.98

APPENDIX C

TREND ANALYSIS

FATALITY-RUN-OFF ROAD-HG1



Regression Analysis: Avg Crash rate versus Year

The regression equation is

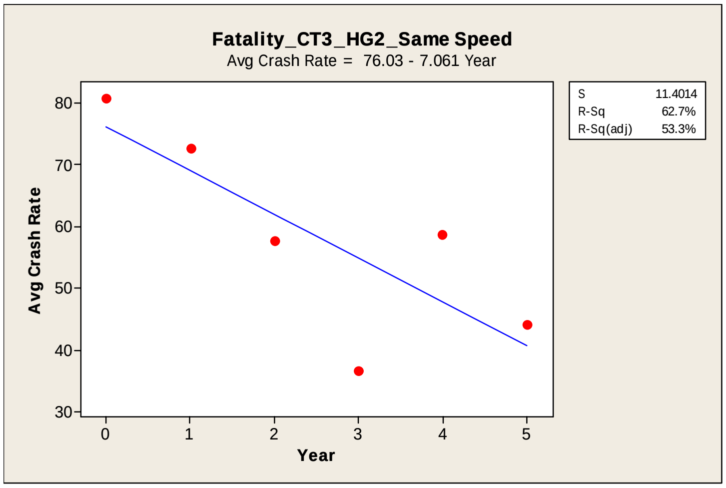
Avg Crash rate = 62.78 + 5.920 Year

S = 23.4487 R-Sq = 21.8% R-Sq(adj) = 2.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	613.29	613.291	1.12	0.350
Error	4	2199.36	549.840		
Total	5	2812.65			

FATALITY-RUN-OFF ROAD-HG2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

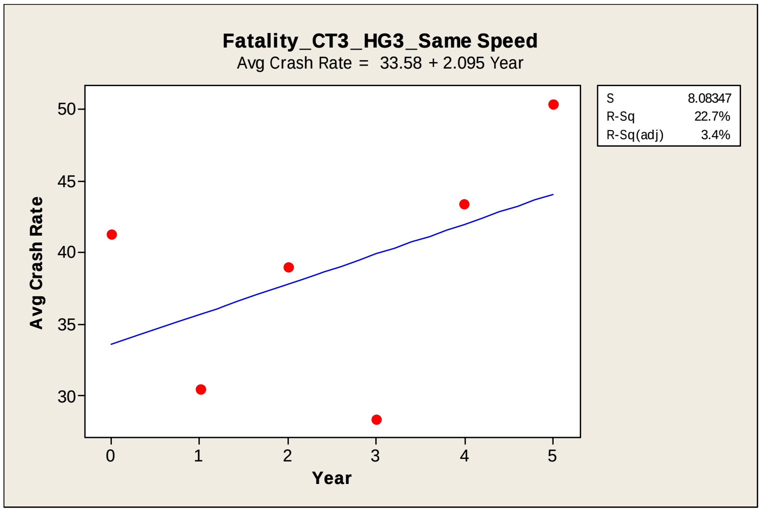
Avg Crash Rate = 76.03 - 7.061 Year

S = 11.4014 R-Sq = 62.7% R-Sq(adj) = 53.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	872.47	872.468	6.71	0.061
Error	4	519.97	129.993		
Total	5	1392.44			

FATALITY-RUN-OFF ROAD-HG3



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

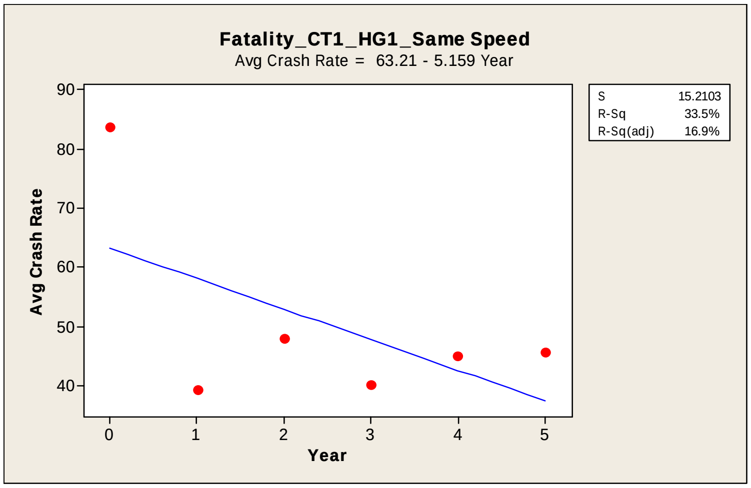
Avg Crash Rate = 33.58 + 2.095 Year

S = 8.08347   R-Sq = 22.7%   R-Sq(adj) = 3.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	76.791	76.7912	1.18	0.339
Error	4	261.370	65.3425		
Total	5	338.161			

FATALITY-HEAD ON AND RIGHT ANGLE-HG1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 63.21 - 5.159 Year

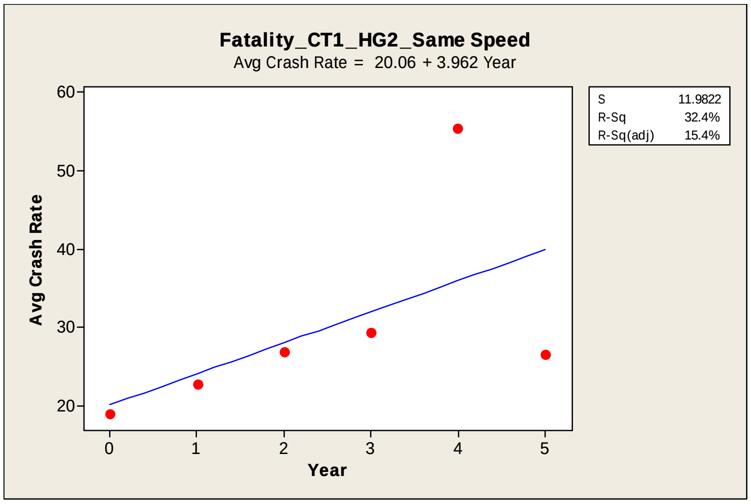
S = 15.2103   R-Sq = 33.5%   R-Sq(adj) = 16.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	465.85	465.848	2.01	0.229
Error	4	925.41	231.352		

Total	5	1391.25

FATALITY-HEAD ON AND RIGHT ANGLE-HG2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

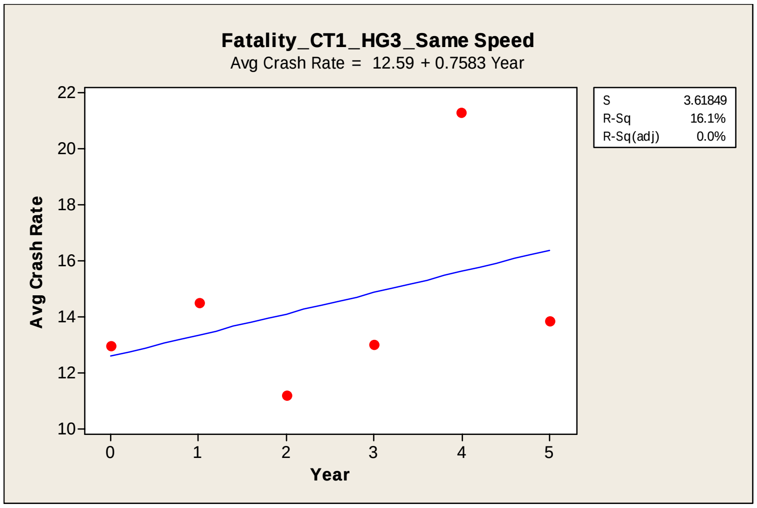
Avg Crash Rate = 20.06 + 3.962 Year

S = 11.9822 R-Sq = 32.4% R-Sq(adj) = 15.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	274.675	274.675	1.91	0.239
Error	4	574.295	143.574		
Total	5	848.970			

FATALITY-HEAD ON AND RIGHT ANGLE-HG3



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 12.59 + 0.7583 Year

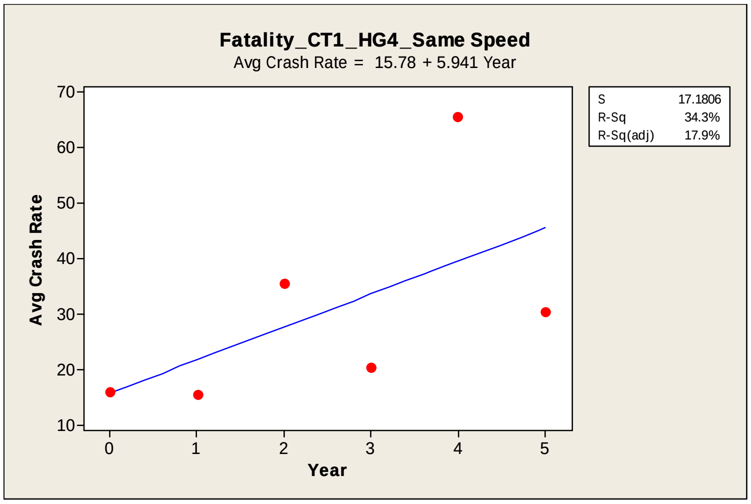
S = 3.61849 R-Sq = 16.1% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	10.0637	10.0637	0.77	0.430
Error	4	52.3738	13.0934		

Total	5	62.4375

FATALITY-HEAD ON AND RIGHT ANGLE-HG4



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

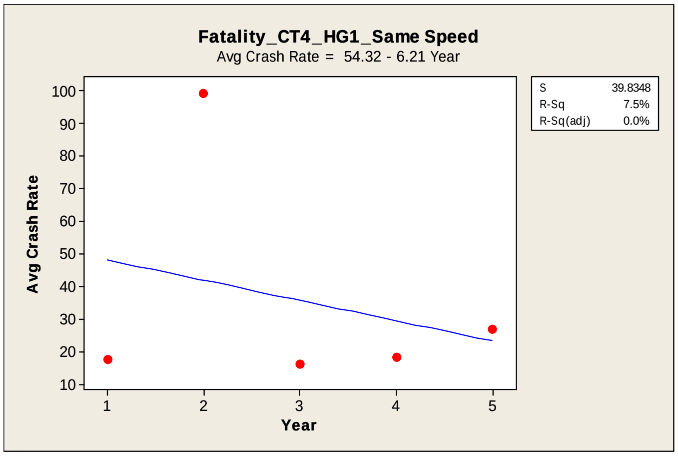
Avg Crash Rate = 15.78 + 5.941 Year

S = 17.1806 R-Sq = 34.3% R-Sq(adj) = 17.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	617.63	617.628	2.09	0.222
Error	4	1180.70	295.174		
Total	5	1798.33			

FATALITY-SIDESWIPE AND TURNING ANGLE-HG1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

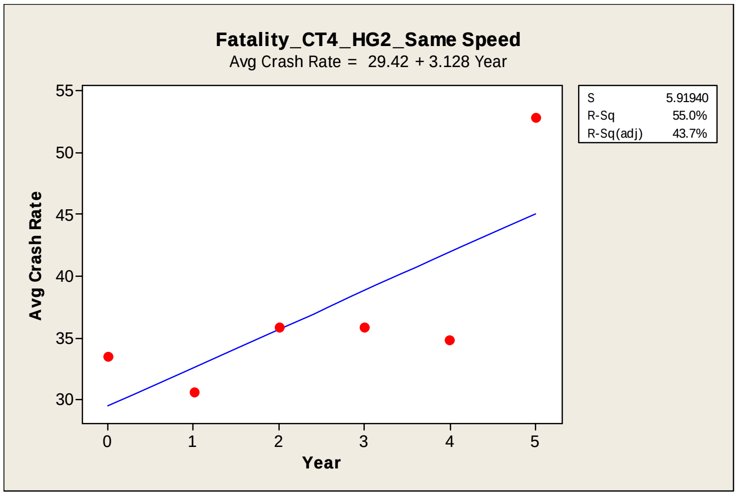
Avg Crash Rate = 54.32 - 6.21 Year

S = 39.8348 R-Sq = 7.5% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	386.26	386.26	0.24	0.656
Error	3	4760.44	1586.81		
Total	4	5146.70			

FATALITY-SIDESWIPE AND TURNING ANGLE-HG2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

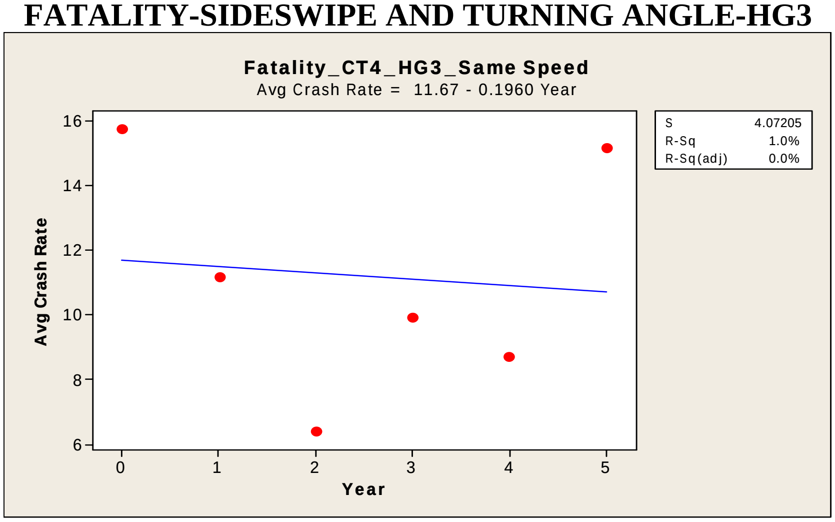
Avg Crash Rate = 29.42 + 3.128 Year

S = 5.91940   R-Sq = 55.0%   R-Sq(adj) = 43.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	171.277	171.277	4.89	0.092
Error	4	140.157	35.039		
Total	5	311.434			

FATALITY-SIDESWIPE AND TURNING ANGLE-HG3



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 11.67 - 0.1960 Year

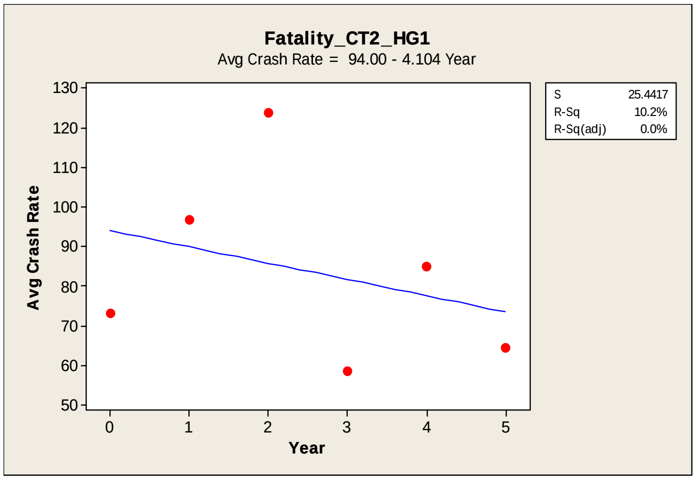
S = 4.07205   R-Sq = 1.0%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.6724	0.6724	0.04	0.850
Error	4	66.3262	16.5816		

Total	5	66.9986

FATALITY-NON MOTOR VEHICLE-HG1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

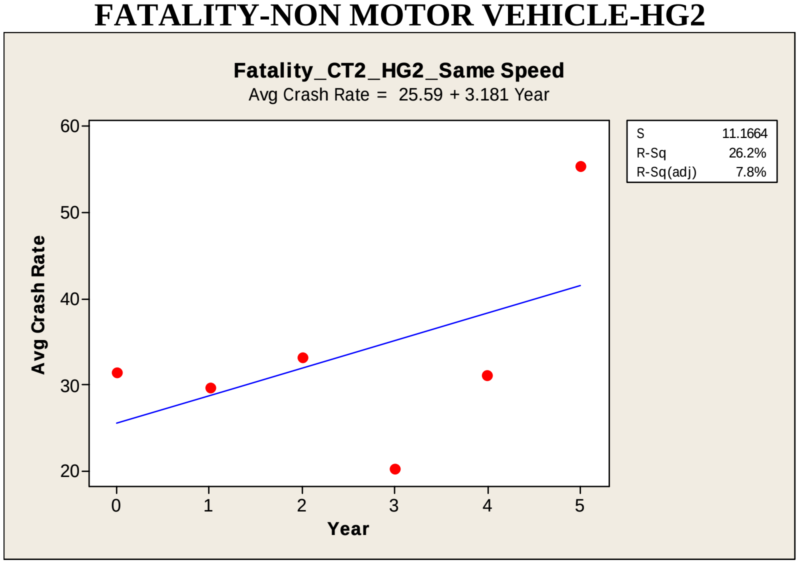
Avg Crash Rate = 94.00 - 4.104 Year

S = 25.4417   R-Sq = 10.2%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	294.80	294.799	0.46	0.537
Error	4	2589.12	647.280		
Total	5	2883.92			

FATALITY-NON MOTOR VEHICLE-HG2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 25.59 + 3.181 Year

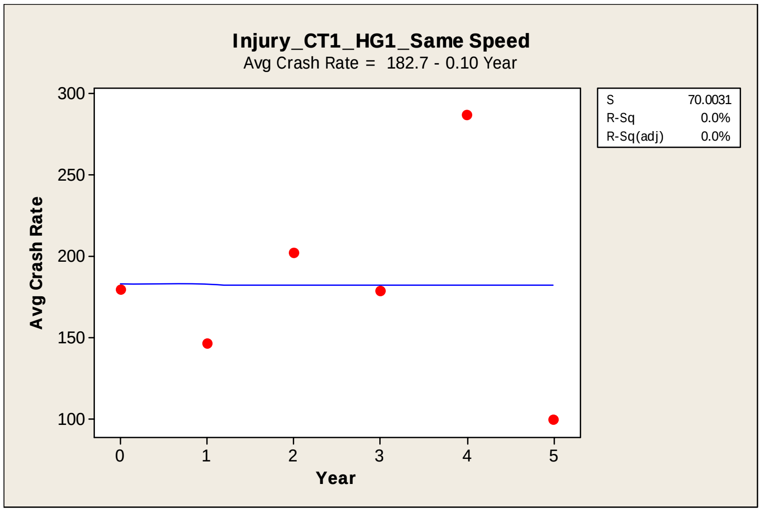
S = 11.1664   R-Sq = 26.2%   R-Sq(adj) = 7.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	177.121	177.121	1.42	0.299
Error	4	498.752	124.688		

Total	5	675.873

INJURY RUN OFF ROAD HG-1



Regression Analysis: Avg Crash Rate versus Year I_CT1_HG1

The regression equation is

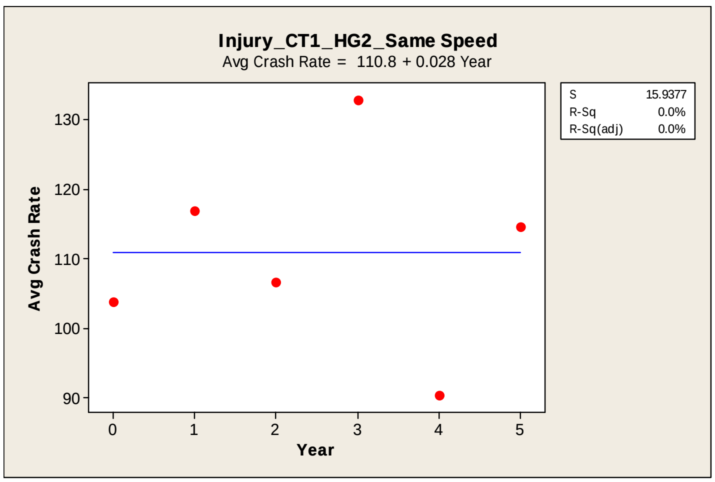
Avg Crash Rate = 182.7 - 0.10 Year

S = 70.0031   R-Sq = 0.0%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.2	0.17	0.00	0.996
Error	4	19601.7	4900.44		
Total	5	19601.9			

INJURY RUN OFF ROAD HG-2



Regression Analysis: Avg Crash Rate versus Year I_CT1_HG2

The regression equation is

Avg Crash Rate = 110.8 + 0.028 Year

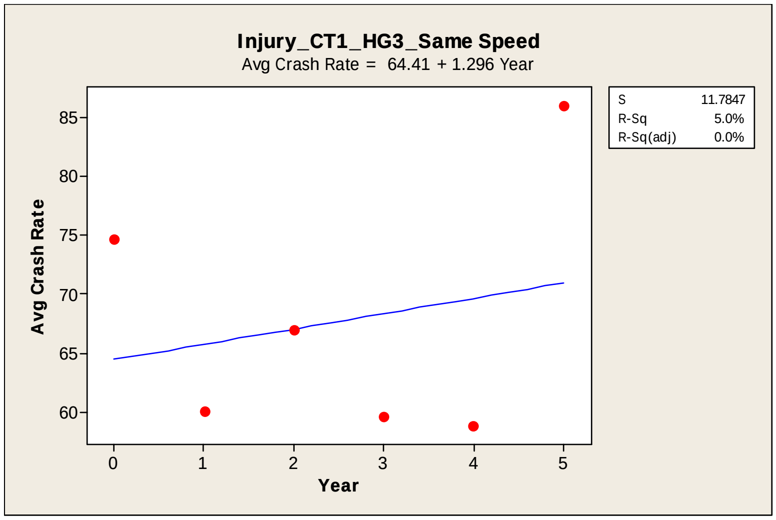
S = 15.9377   R-Sq = 0.0%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.01	0.014	0.00	0.994
Error	4	1016.05	254.011		

Total	5	1016.06

INJURY RUN OFF ROAD HG-3



Regression Analysis: Avg Crash Rate versus Year I_CT1_Hg3

The regression equation is

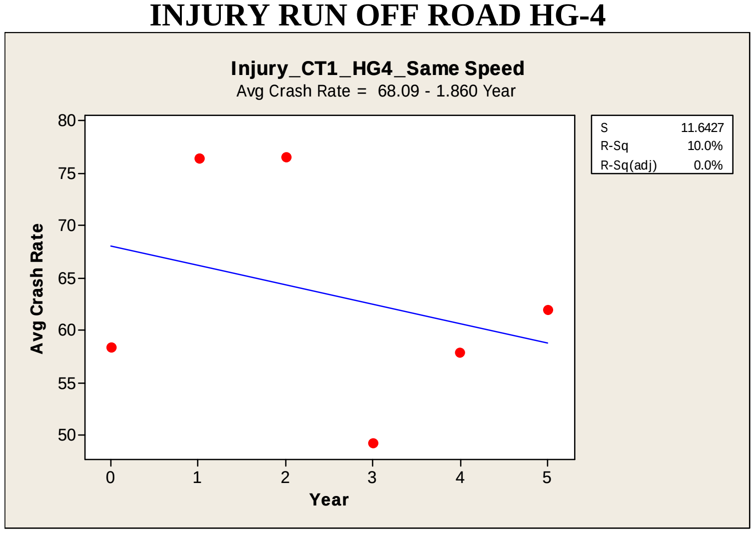
Avg Crash Rate = 64.41 + 1.296 Year

S = 11.7847 R-Sq = 5.0% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	29.405	29.405	0.21	0.669
Error	4	555.512	138.878		
Total	5	584.917			

INJURY RUN OFF ROAD HG-4



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 68.09 - 1.860 Year

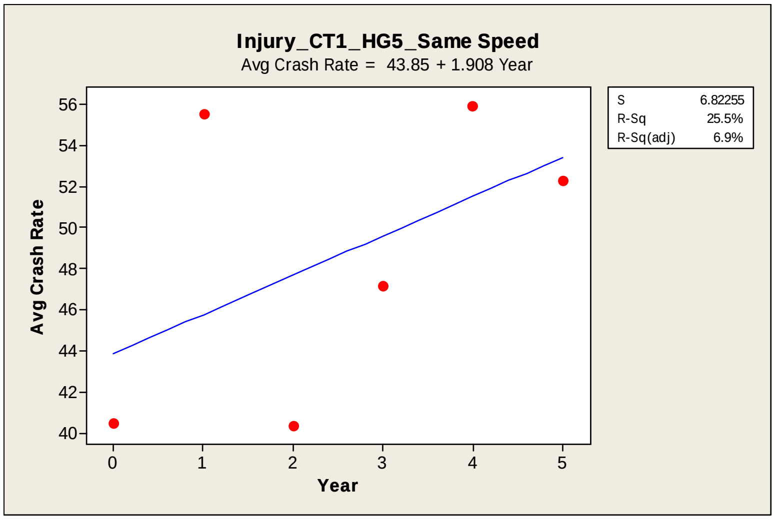
S = 11.6427 R-Sq = 10.0% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	60.567	60.567	0.45	0.540

Error	4	542.209	135.552
Total	5	602.776	

INJURY RUN OFF ROAD HG-5



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

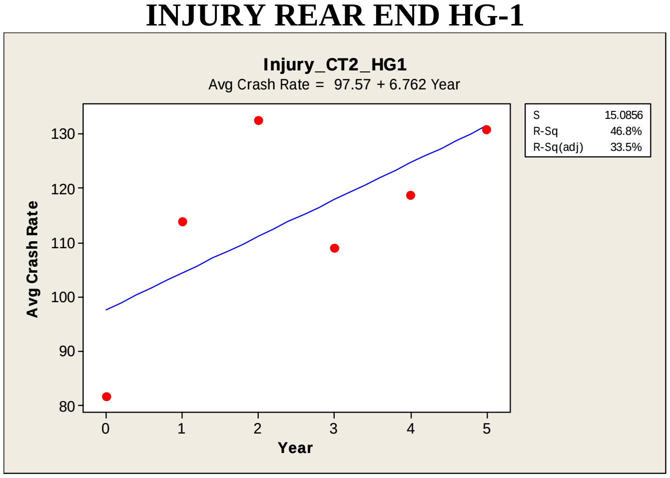
Avg Crash Rate = 43.85 + 1.908 Year

S = 6.82255 R-Sq = 25.5% R-Sq(adj) = 6.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	63.703	63.7029	1.37	0.307
Error	4	186.189	46.5472		
Total	5	249.892			

INJURY REAR END HG-1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 97.57 + 6.762 Year

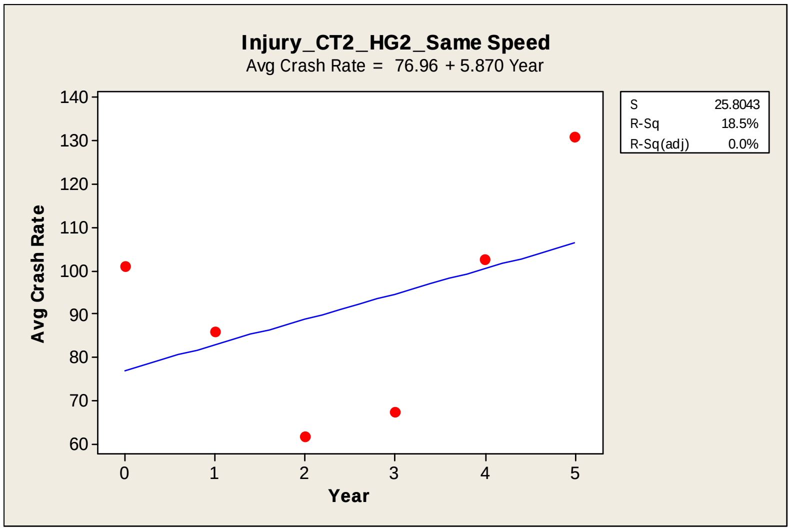
S = 15.0856 R-Sq = 46.8% R-Sq(adj) = 33.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	800.17	800.172	3.52	0.134
Error	4	910.30	227.574		

Total	5	1710.47

INJURY REAR END HG-2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

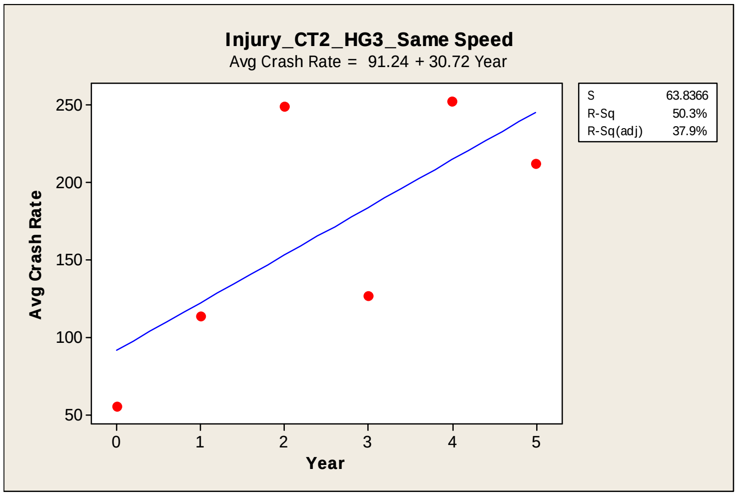
Avg Crash Rate = 76.96 + 5.870 Year

S = 25.8043 R-Sq = 18.5% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	602.94	602.942	0.91	0.395
Error	4	2663.45	665.863		
Total	5	3266.40			

INJURY REAR END HG-3



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 91.24 + 30.72 Year

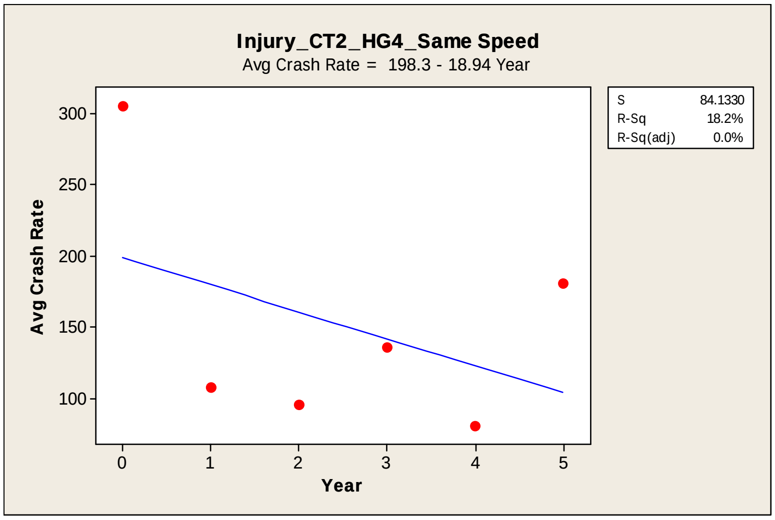
S = 63.8366 R-Sq = 50.3% R-Sq(adj) = 37.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	16518.7	16518.7	4.05	0.114

Error	4	16300.5	4075.1
Total	5	32819.2	

INJURY REAR END HG-4



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

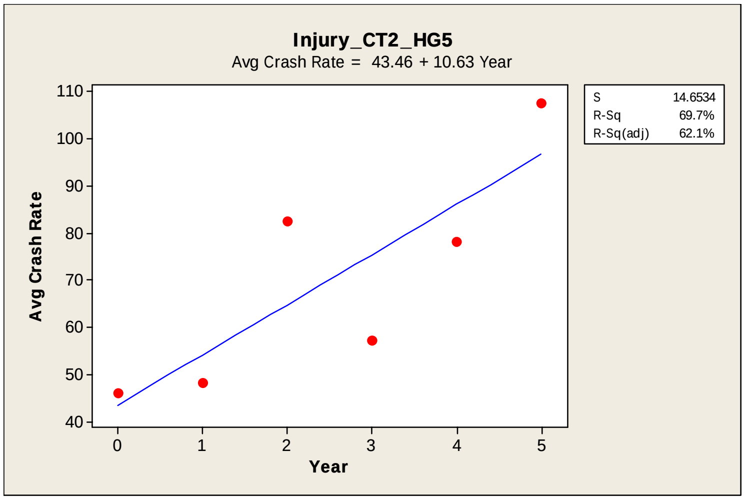
Avg Crash Rate = 198.3 - 18.94 Year

S = 84.1330 R-Sq = 18.2% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	6278.8	6278.84	0.89	0.400
Error	4	28313.5	7078.37		
Total	5	34592.3			

INJURY REAR END HG-5



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 43.46 + 10.63 Year

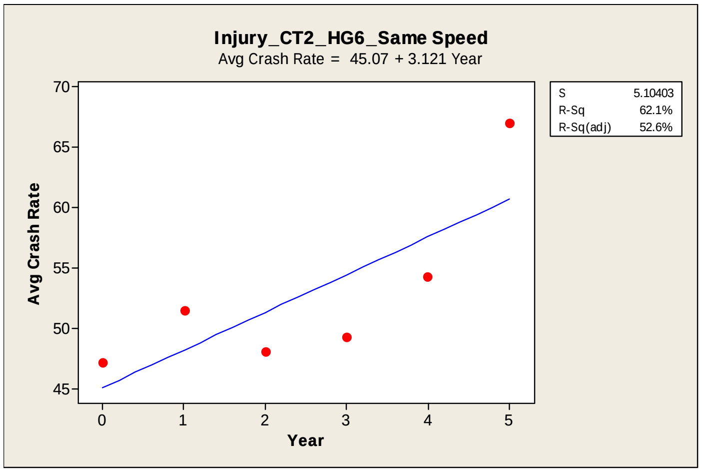
S = 14.6534 R-Sq = 69.7% R-Sq(adj) = 62.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1976.64	1976.64	9.21	0.039

Error	4	858.89	214.72
Total	5	2835.53	

INJURY REAR END HG-6



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

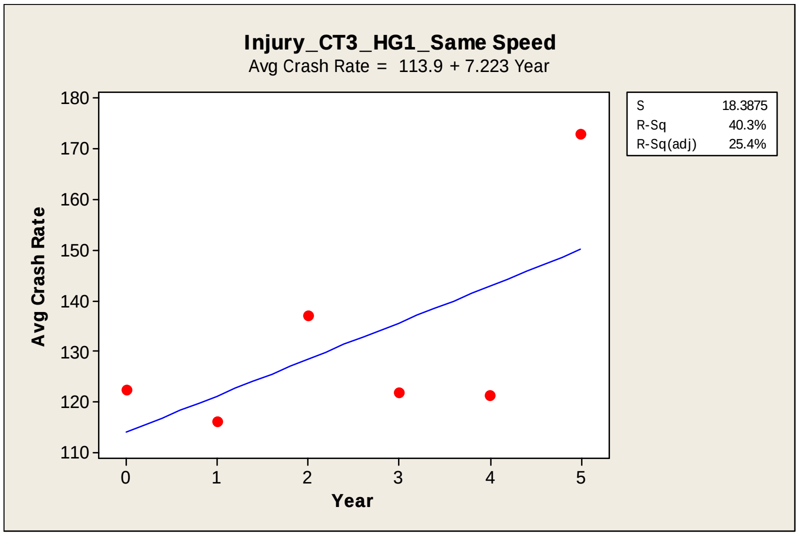
Avg Crash Rate = 45.07 + 3.121 Year

S = 5.10403 R-Sq = 62.1% R-Sq(adj) = 52.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	170.455	170.455	6.54	0.063
Error	4	104.205	26.051		
Total	5	274.659			

INJURY-RIGHT ANGLE & HEADON-HG1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 113.9 + 7.223 Year

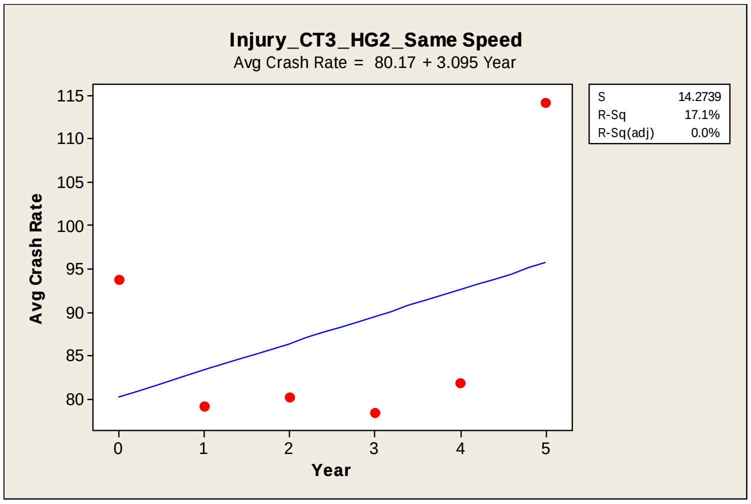
S = 18.3875 R-Sq = 40.3% R-Sq(adj) = 25.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	912.91	912.912	2.70	0.176

Error	4	1352.40	338.100		
Total	5	2265.31			

INJURY-RIGHT ANGLE & HEADON-HG2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

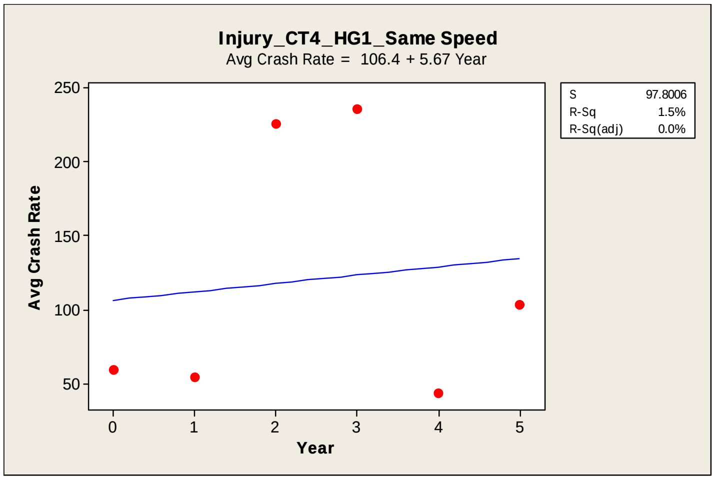
Avg Crash Rate = 80.17 + 3.095 Year

S = 14.2739   R-Sq = 17.1%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	167.605	167.605	0.82	0.416
Error	4	814.976	203.744		
Total	5	982.580			

INJURY- TURNING ANGLE & SIDE SWIPE- HG-1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 106.4 + 5.67 Year

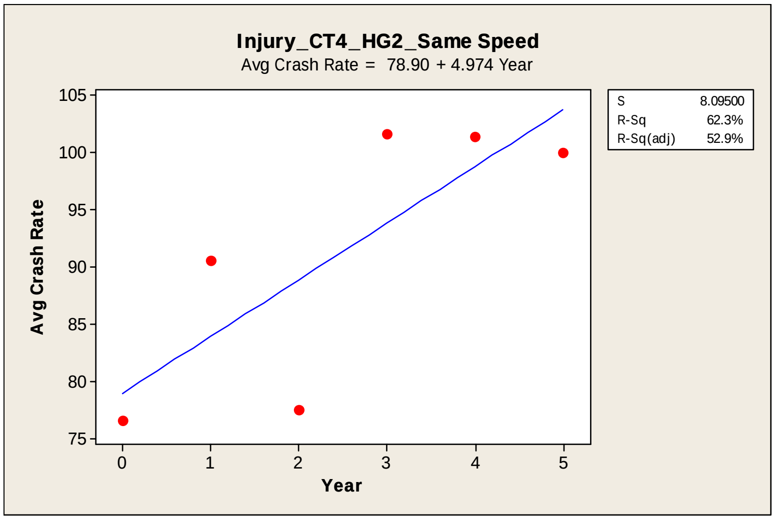
S = 97.8006   R-Sq = 1.5%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	563.4	563.44	0.06	0.820

Error	4	38259.8	9564.95
Total	5	38823.2	

INJURY- TURNING ANGLE & SIDE SWIPE- HG-2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

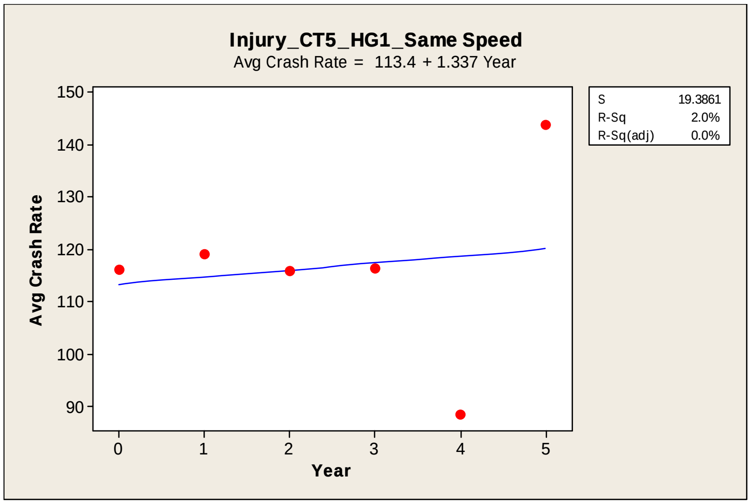
Avg Crash Rate = 78.90 + 4.974 Year

S = 8.09500   R-Sq = 62.3%   R-Sq(adj) = 52.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	432.986	432.986	6.61	0.062
Error	4	262.116	65.529		
Total	5	695.102			

INJURY-NON MOTOR VEHICLE-HG1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 113.4 + 1.337 Year

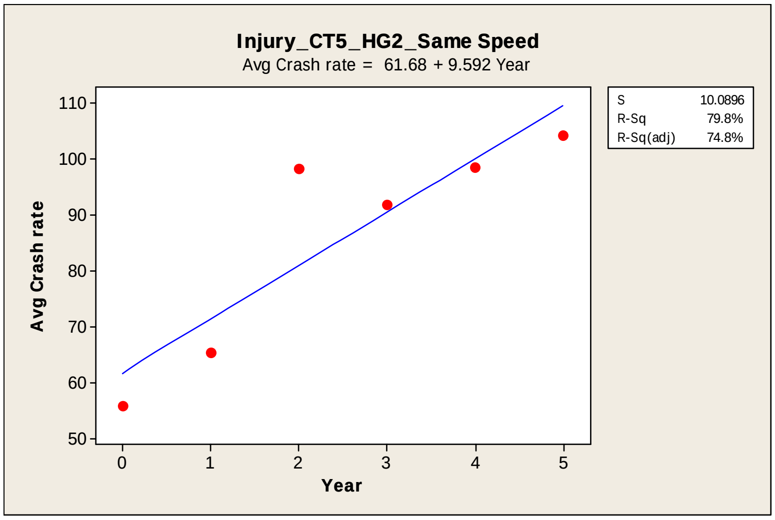
S = 19.3861   R-Sq = 2.0%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	31.29	31.286	0.08	0.787

Error	4	1503.28	375.819
Total	5	1534.56	

INJURY-NON MOTOR VEHICLE-HG2



Regression Analysis: Avg Crash rate versus Year

The regression equation is

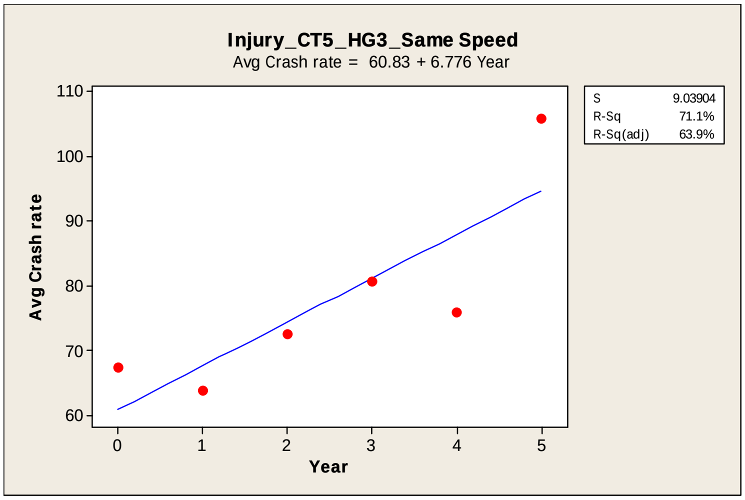
Avg Crash rate = 61.68 + 9.592 Year

S = 10.0896 R-Sq = 79.8% R-Sq(adj) = 74.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1610.10	1610.10	15.82	0.016
Error	4	407.20	101.80		
Total	5	2017.29			

INJURY-NON MOTOR VEHICLE-HG3



Regression Analysis: Avg Crash rate versus Year

The regression equation is

Avg Crash rate = 60.83 + 6.776 Year

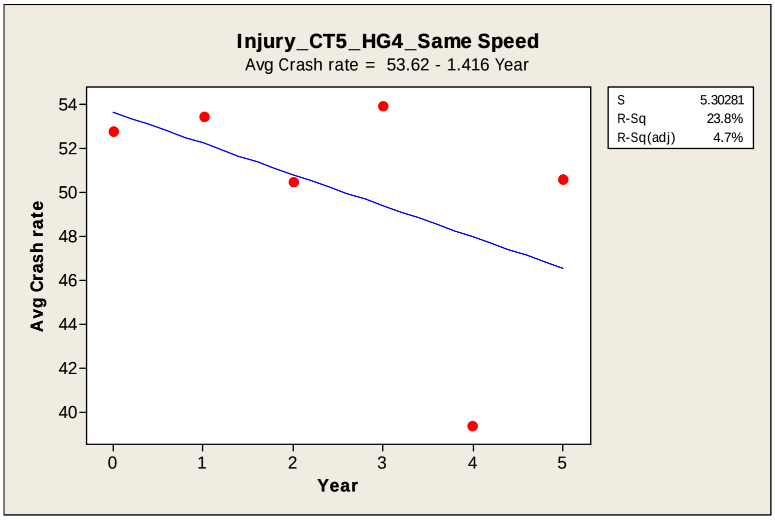
S = 9.03904 R-Sq = 71.1% R-Sq(adj) = 63.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	803.52	803.521	9.83	0.035

Error	4	326.82	81.704
Total	5	1130.34	

INJURY-NON MOTOR VEHICLE-HG4



Regression Analysis: Avg Crash rate versus Year

The regression equation is

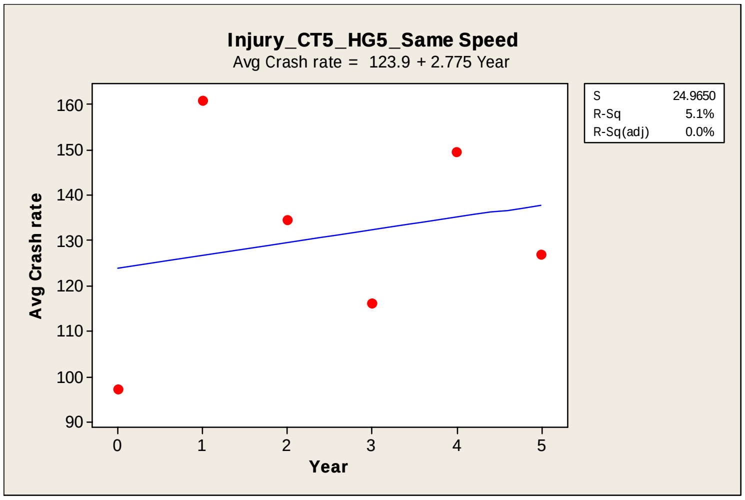
Avg Crash rate = 53.62 - 1.416 Year

S = 5.30281 R-Sq = 23.8% R-Sq(adj) = 4.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	35.072	35.0725	1.25	0.327
Error	4	112.479	28.1197		
Total	5	147.551			

INJURY-NON MOTOR VEHICLE-HG5



Regression Analysis: Avg Crash rate versus Year

The regression equation is

Avg Crash rate = 123.9 + 2.775 Year

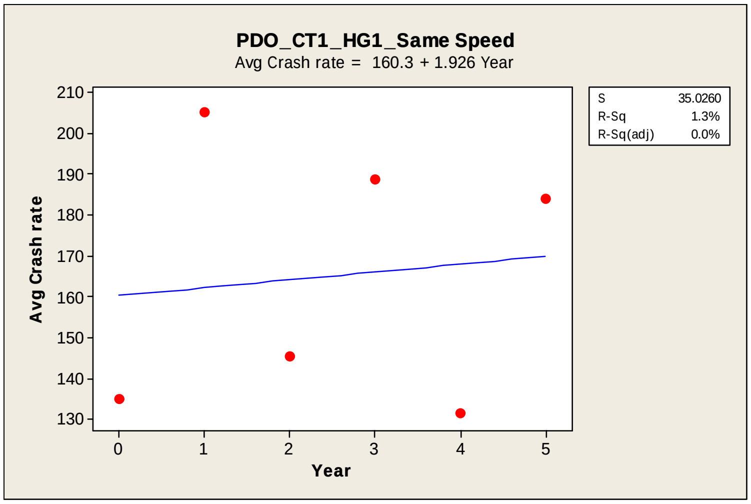
S = 24.9650 R-Sq = 5.1% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	134.77	134.771	0.22	0.666

Error	4	2493.00	623.250		
Total	5	2627.77			

PDO RUN OFF ROAD AND OVER TURNING HG-1



Regression Analysis: Avg Crash rate versus Year

The regression equation is

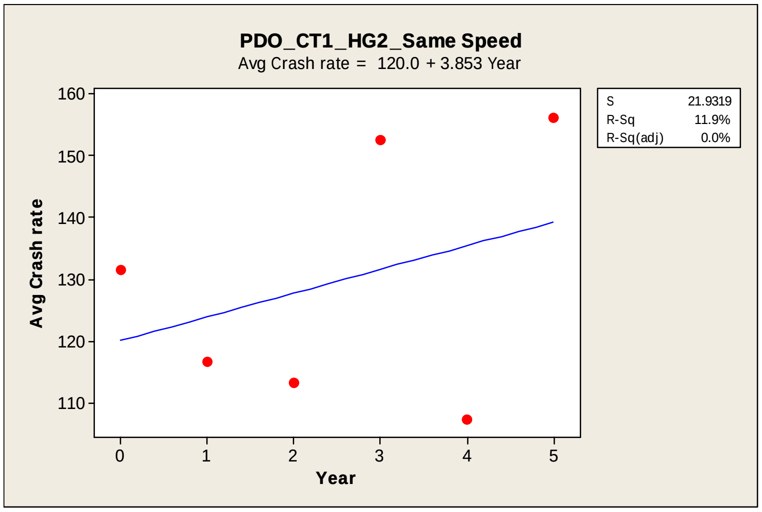
Avg Crash rate = 160.3 + 1.926 Year

S = 35.0260 R-Sq = 1.3% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	64.89	64.89	0.05	0.829
Error	4	4907.28	1226.82		
Total	5	4972.17			

PDO RUN OFF ROAD AND OVER TURNING HG-2



Regression Analysis: Avg Crash rate versus Year

The regression equation is

Avg Crash rate = 120.0 + 3.853 Year

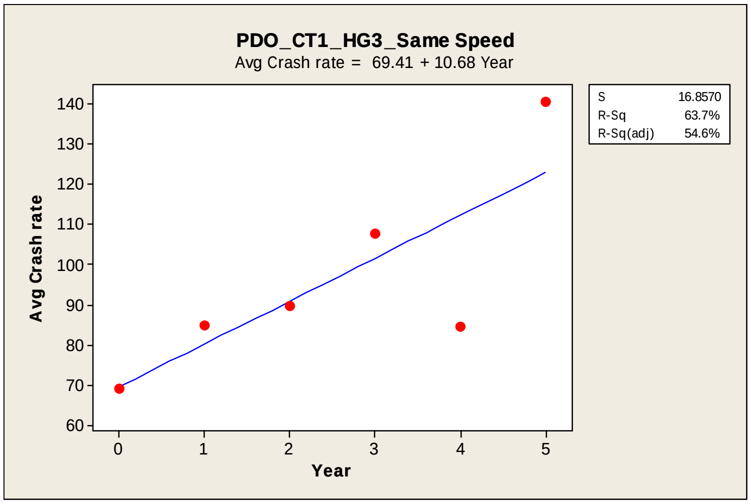
S = 21.9319 R-Sq = 11.9% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	259.73	259.733	0.54	0.503

Error	4	1924.02	481.006
Total	5	2183.76	

PDO RUN OFF ROAD AND OVER TURNING HG-3



Regression Analysis: Avg Crash rate versus Year

The regression equation is

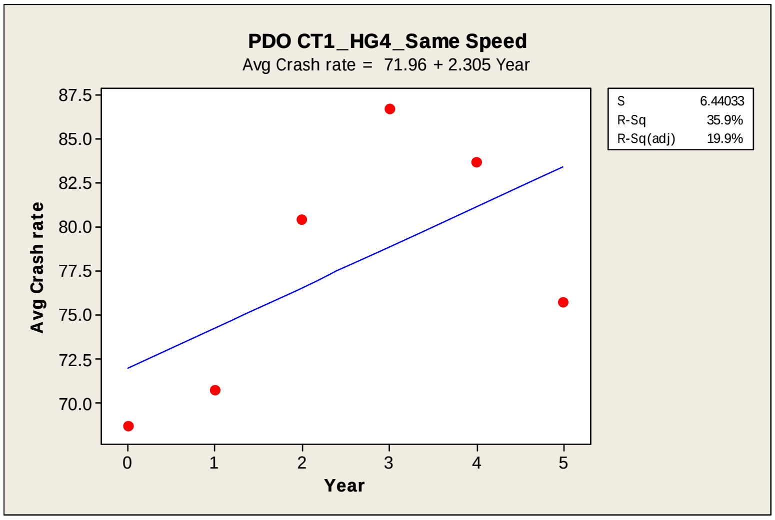
Avg Crash rate = 69.41 + 10.68 Year

S = 16.8570   R-Sq = 63.7%   R-Sq(adj) = 54.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1994.73	1994.73	7.02	0.057
Error	4	1136.64	284.16		
Total	5	3131.37			

PDO RUN OFF ROAD AND OVER TURNING HG-4



Regression Analysis: Avg Crash rate versus Year

The regression equation is

Avg Crash rate = 71.96 + 2.305 Year

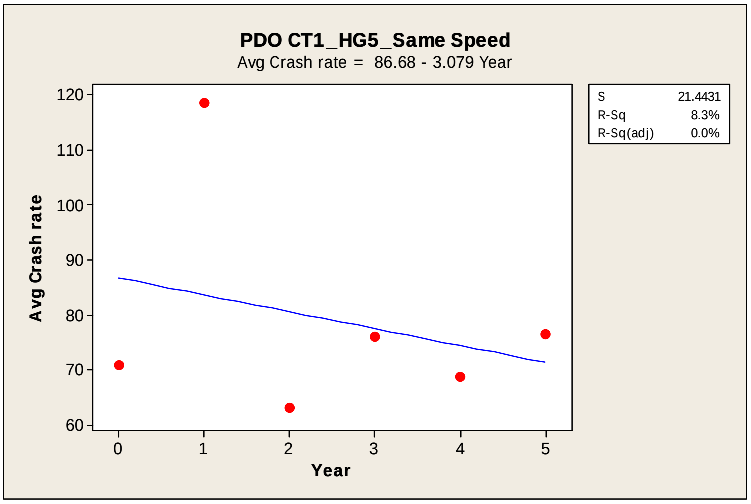
S = 6.44033   R-Sq = 35.9%   R-Sq(adj) = 19.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	92.962	92.9621	2.24	0.209

Error	4	165.912	41.4779		
Total	5	258.874			

PDO RUN OFF ROAD AND OVER TURNING HG-5



Regression Analysis: Avg Crash rate versus Year

The regression equation is

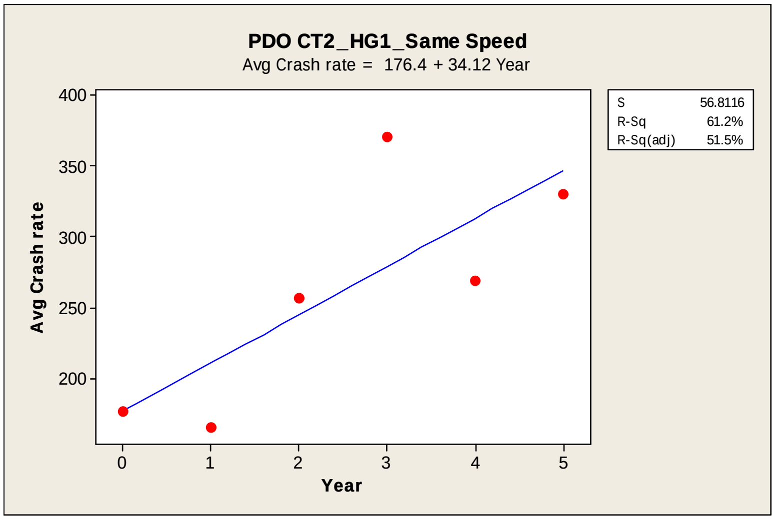
Avg Crash rate = 86.68 - 3.079 Year

S = 21.4431 R-Sq = 8.3% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	165.93	165.926	0.36	0.580
Error	4	1839.23	459.808		
Total	5	2005.16			

PDO REAR END HG-1



Regression Analysis: Avg Crash rate versus Year

The regression equation is

Avg Crash rate = 176.4 + 34.12 Year

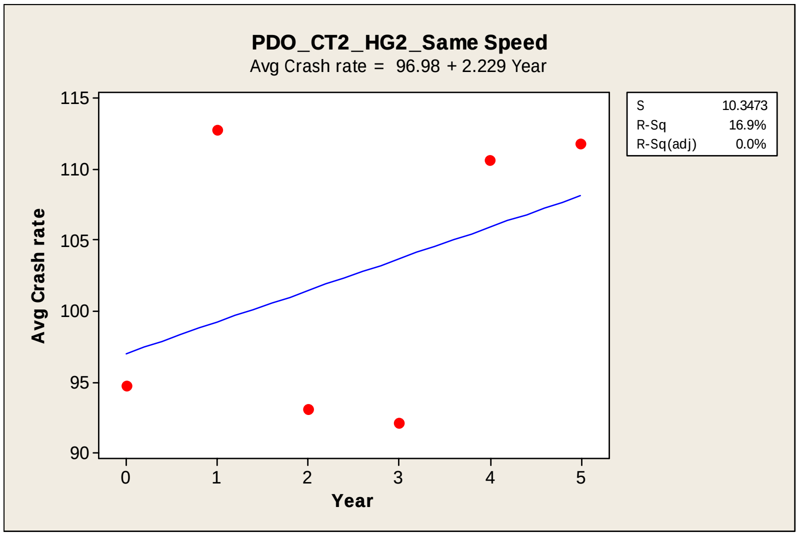
S = 56.8116 R-Sq = 61.2% R-Sq(adj) = 51.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	20376.6	20376.6	6.31	0.066

Error	4	12910.2	3227.6
Total	5	33286.9	

PDO REAR END HG-2



Regression Analysis: Avg Crash rate versus Year

The regression equation is

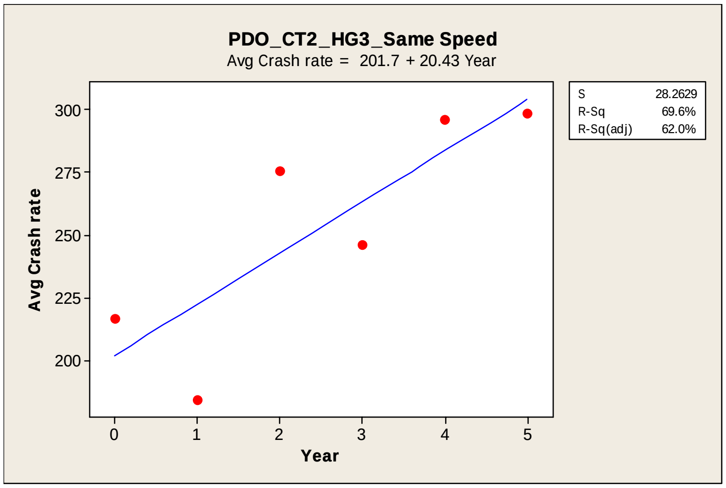
Avg Crash rate = 96.98 + 2.229 Year

S = 10.3473   R-Sq = 16.9%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	86.926	86.926	0.81	0.419
Error	4	428.268	107.067		
Total	5	515.194			

PDO REAR END HG-3



Regression Analysis: Avg Crash rate versus Year

The regression equation is

Avg Crash rate = 201.7 + 20.43 Year

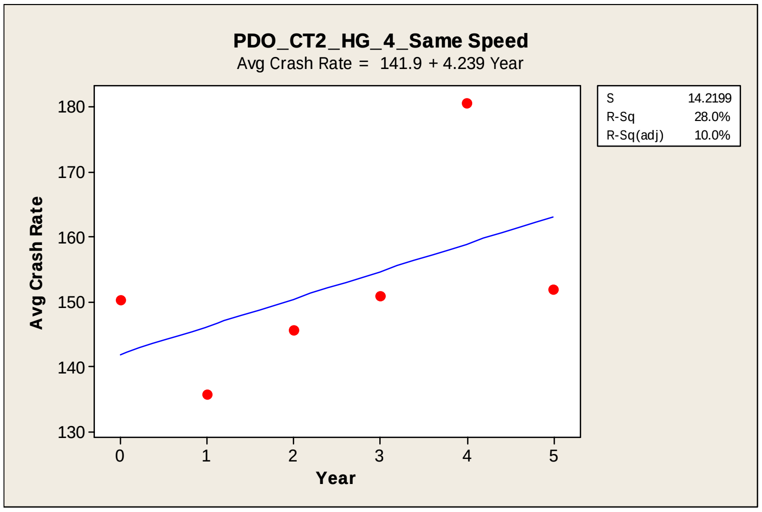
S = 28.2629   R-Sq = 69.6%   R-Sq(adj) = 62.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7307.5	7307.50	9.15	0.039

Error	4	3195.2	798.79
Total	5	10502.7	

PDO REAR END HG-4



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

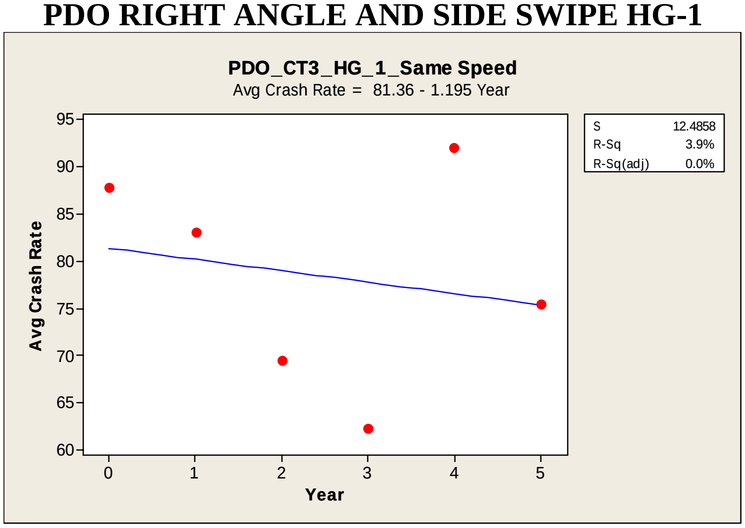
Avg Crash Rate = 141.9 + 4.239 Year

S = 14.2199 R-Sq = 28.0% R-Sq(adj) = 10.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	314.47	314.474	1.56	0.280
Error	4	808.82	202.205		
Total	5	1123.30			

PDO RIGHT ANGLE AND SIDE SWIPE HG-1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 81.36 - 1.195 Year

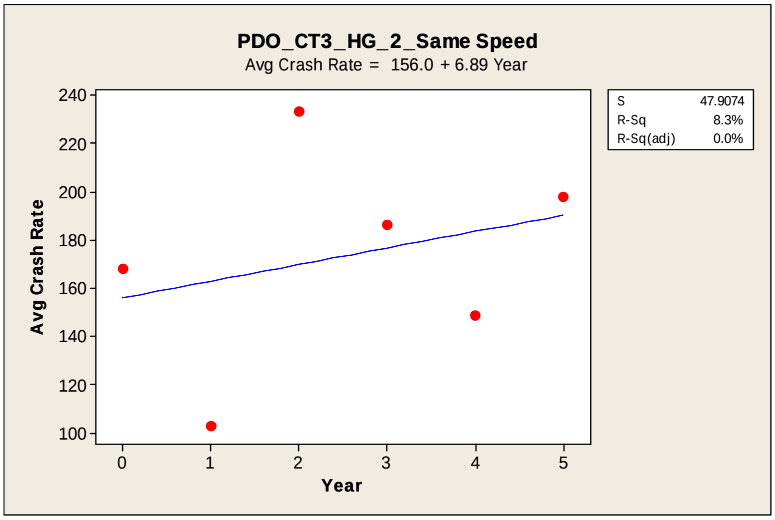
S = 12.4858 R-Sq = 3.9% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	24.986	24.986	0.16	0.709

Error	4	623.578	155.894
Total	5	648.564	

PDO RIGHT ANGLE AND SIDE SWIPE HG-2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

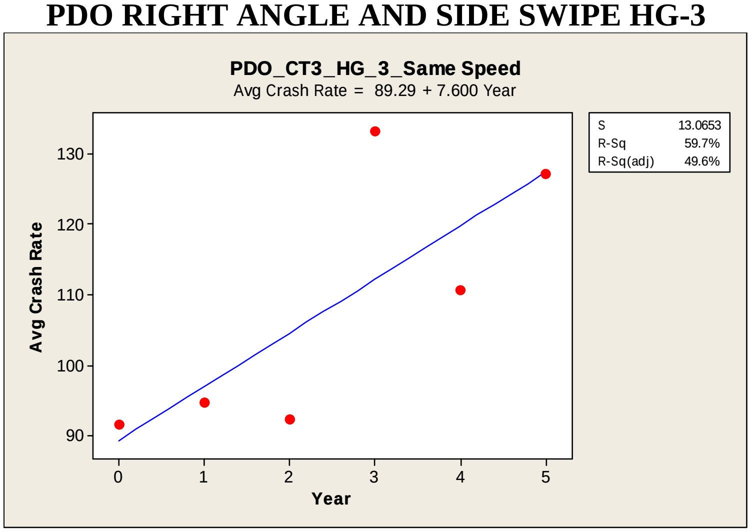
Avg Crash Rate = 156.0 + 6.89 Year

S = 47.9074   R-Sq = 8.3%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	830.3	830.28	0.36	0.580
Error	4	9180.5	2295.12		
Total	5	10010.8			

PDO RIGHT ANGLE AND SIDE SWIPE HG-3



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 89.29 + 7.600 Year

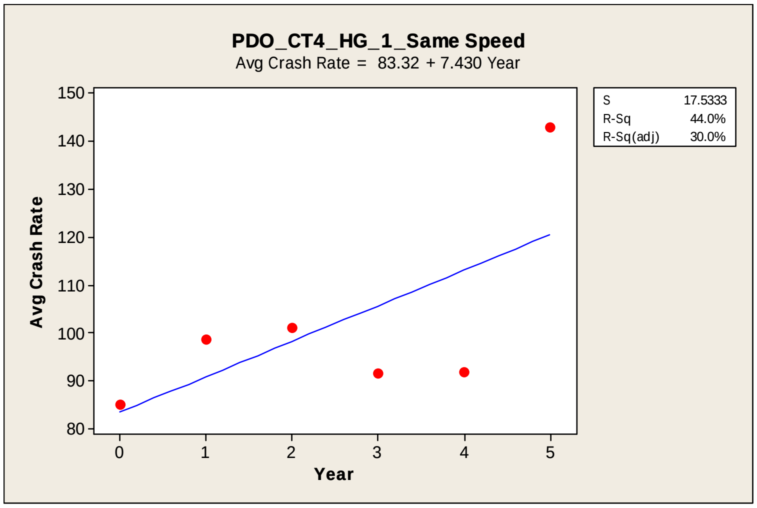
S = 13.0653   R-Sq = 59.7%   R-Sq(adj) = 49.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1010.81	1010.81	5.92	0.072

Error	4	682.81	170.70
Total	5	1693.62	

PDO NON MOTOR VEHICLE HG-1



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

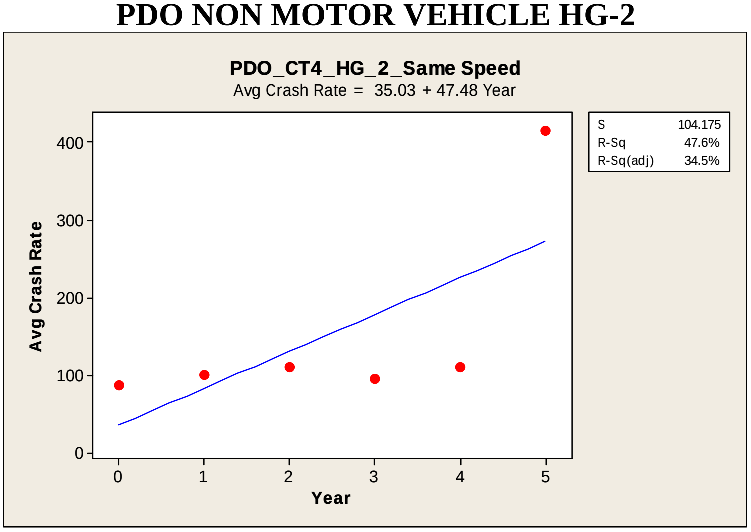
Avg Crash Rate = 83.32 + 7.430 Year

S = 17.5333 R-Sq = 44.0% R-Sq(adj) = 30.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	966.11	966.106	3.14	0.151
Error	4	1229.66	307.415		
Total	5	2195.77			

PDO NON MOTOR VEHICLE HG-2



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 35.03 + 47.48 Year

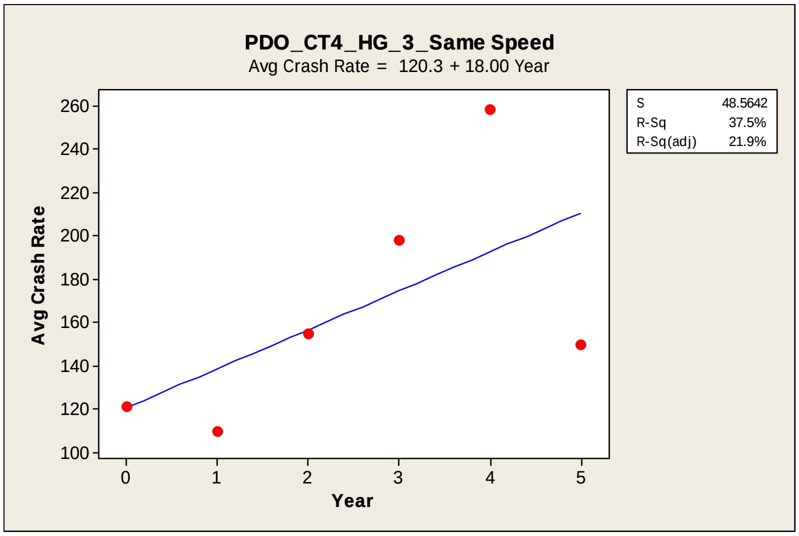
S = 104.175 R-Sq = 47.6% R-Sq(adj) = 34.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	39450.9	39450.9	3.64	0.129

Error	4	43409.3	10852.3
Total	5	82860.2	

PDO NON MOTOR VEHICLE HG-3



Regression Analysis: Avg Crash Rate versus Year

The regression equation is

Avg Crash Rate = 120.3 + 18.00 Year

S = 48.5642 R-Sq = 37.5% R-Sq(adj) = 21.9%

Analysis of Variance

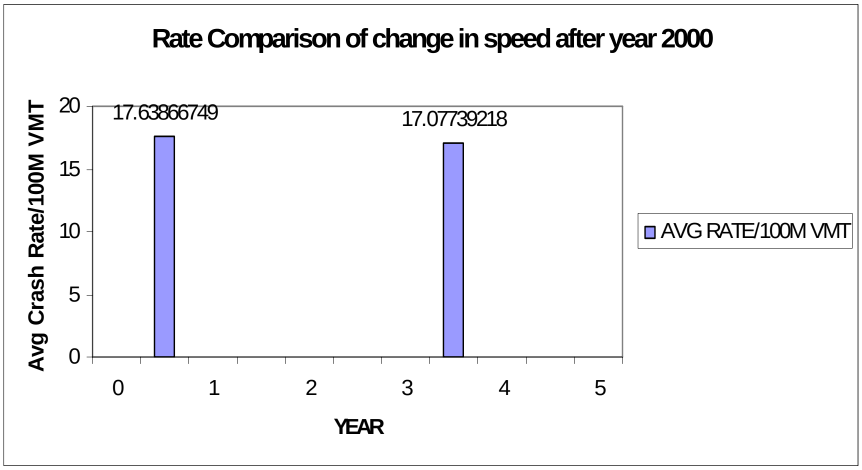
Source	DF	SS	MS	F	P
Regression	1	5667.9	5667.89	2.40	0.196
Error	4	9433.9	2358.48		
Total	5	15101.8			

APPENDIX D

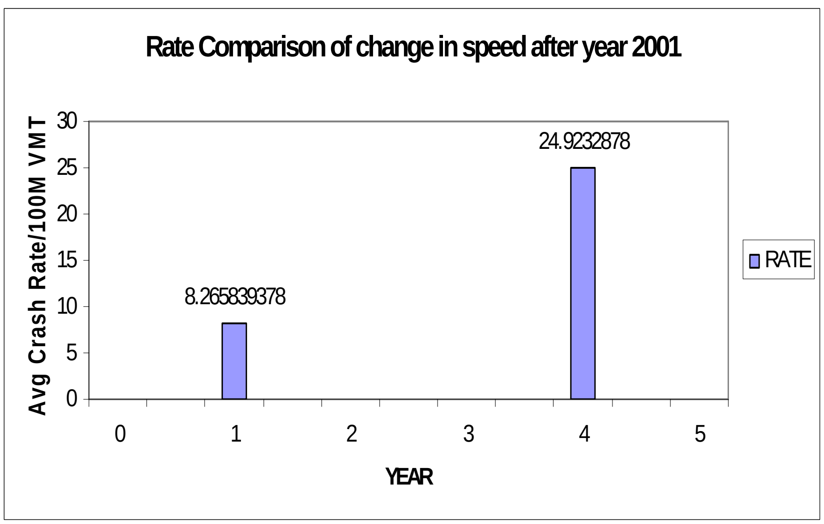
RATE ADJUSTMENT FOR AFTER SPEED CHANGE GROUP

FATALITY

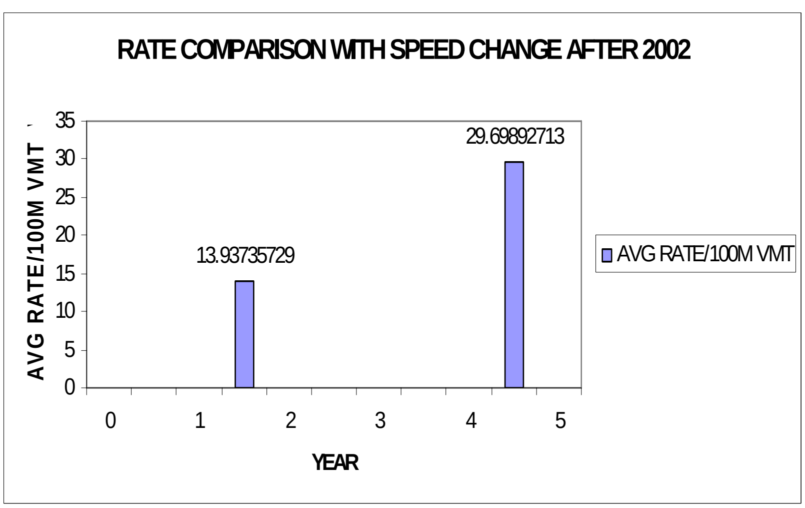
FATALITY_CRASH TYPE1_RUNOFF ROAD_HG1



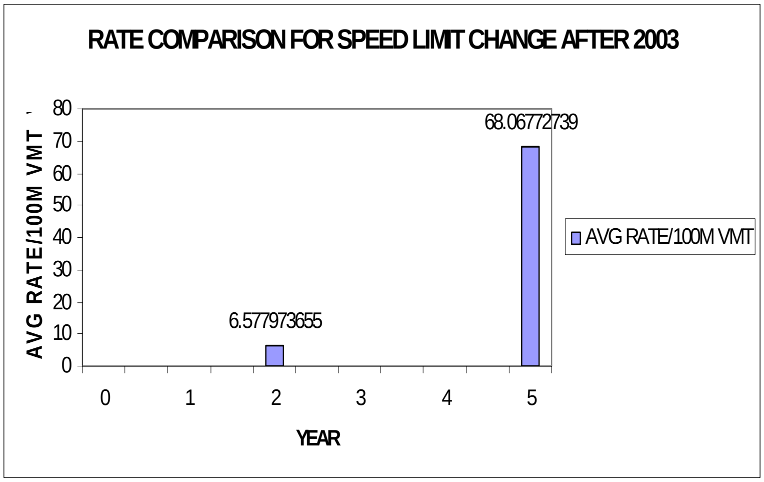
YEAR	RATE
0	
	17.63867
1	
2	
3	
	17.07739
4	
5	



YEAR	AVG RATE/100M VMT
0	
1	8.265839
2	
3	
4	24.92329
5	



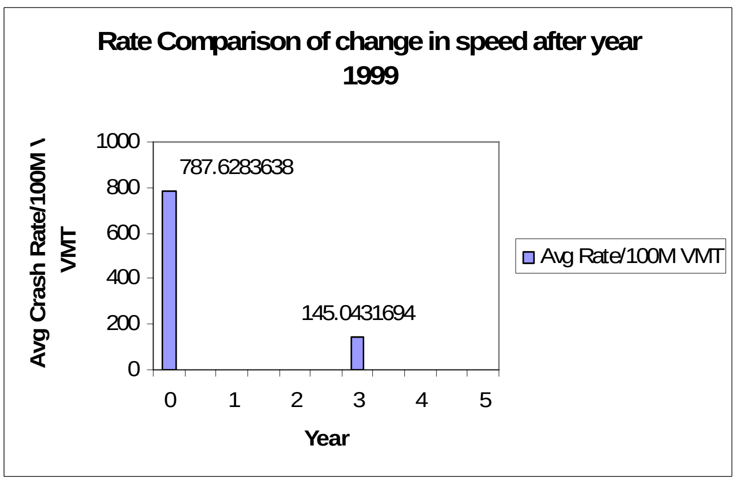
YEAR	AVG RATE/100M VMT
0	
1	
	13.93736
2	
3	
4	
	29.69893
5	



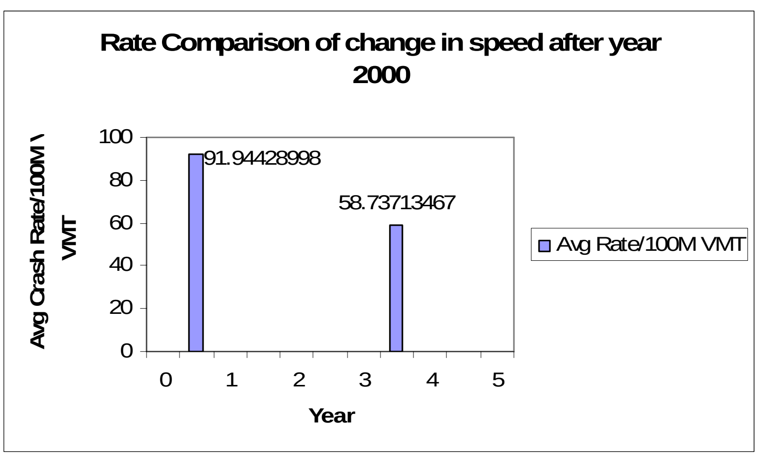
YEAR	AVG RATE/100M VMT
0	
1	
2	6.577974
3	
4	
5	68.06773

INJURY

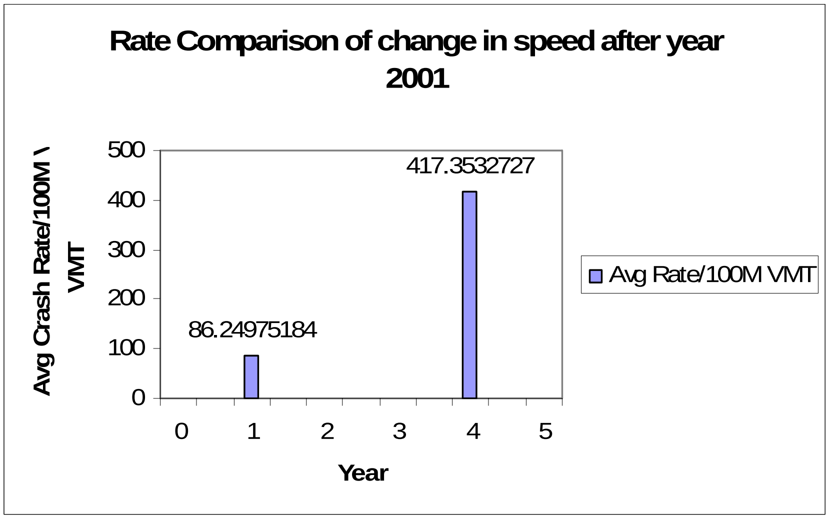
INJURY_CRASH TYPE 1_RUNOFF ROAD_HG1



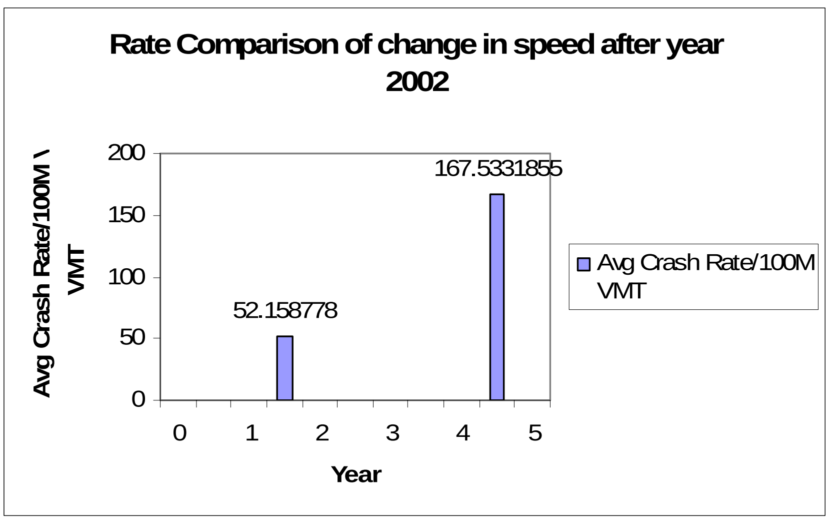
Year	Avg Rate/100M VMT
0	787.6284
1	
2	
3	145.0432
4	
5	



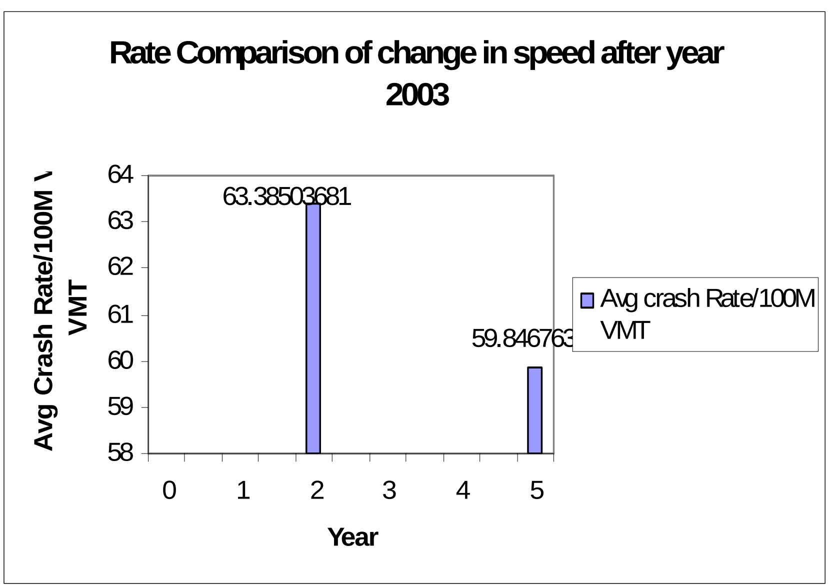
Year	Avg Crash Rate/100M VMT
0	
	91.94429
1	
2	
3	
	58.73713
4	
5	



Year	Avg Rate/100M VMT
0	
1	86.24975
2	
3	
4	417.3533
5	



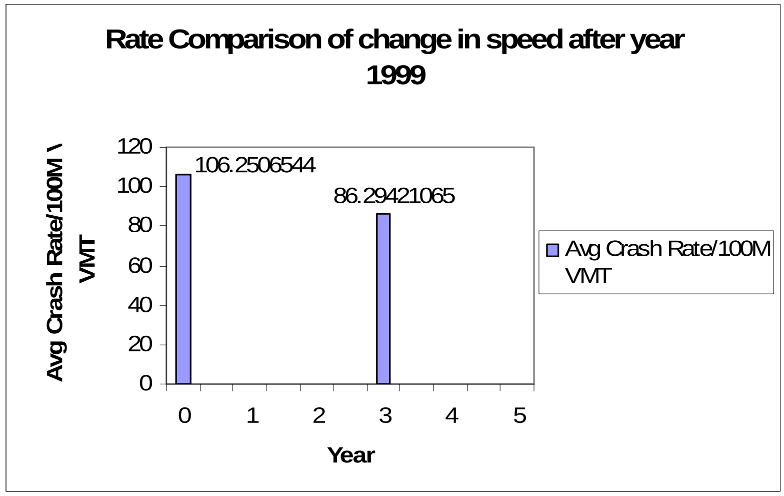
Year	Avg Crash Rate/100M VMT
0	
1	
	52.15878
2	
3	
4	
	167.5332
5	



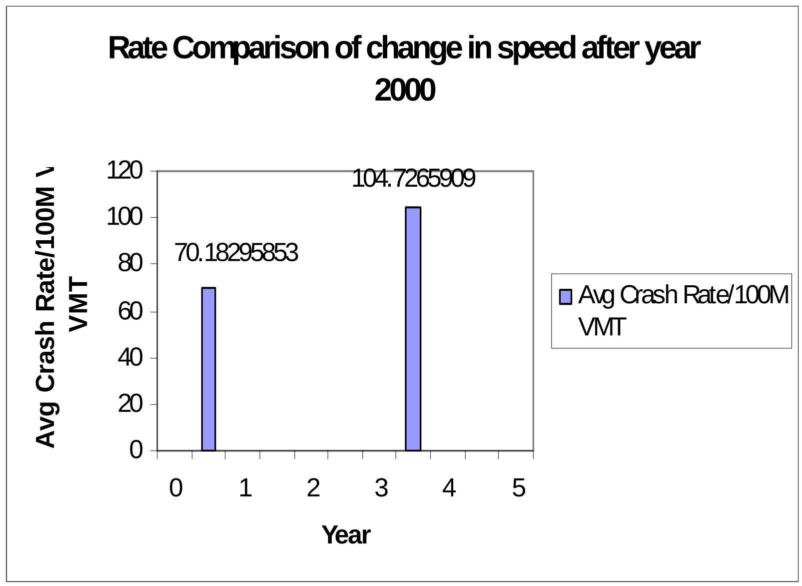
Year	Avg crash Rate/100M VMT
0	
1	
2	63.38504
3	
4	
5	59.84676

INJURY_CRASH TYPE 2_REAR END_HG1

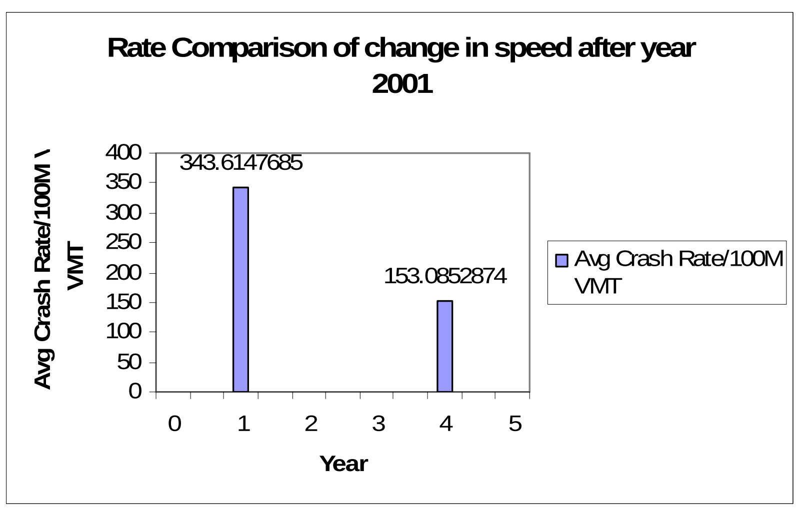
Year	Avg Crash Rate/100M VMT
0	106.2507
1	
2	
3	86.29421
4	
5	



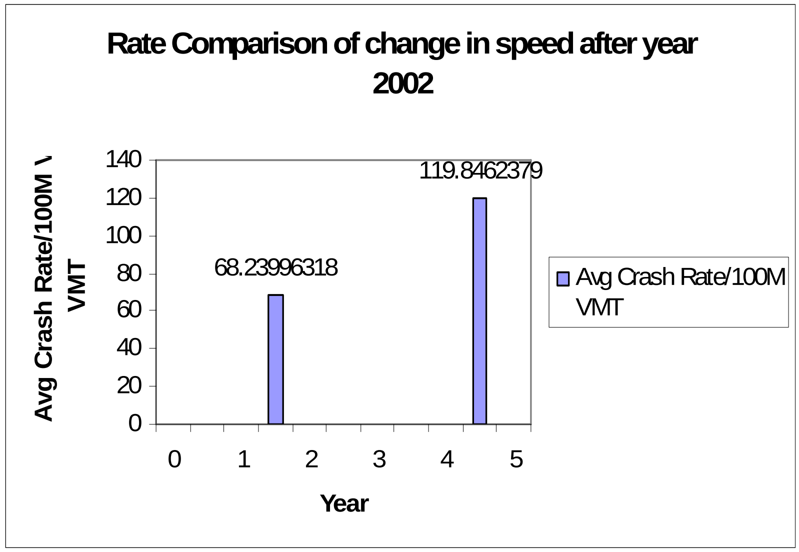
Year	Avg Crash Rate/100M VMT
0	
	70.18296
1	
2	
3	
	104.7266
4	
5	



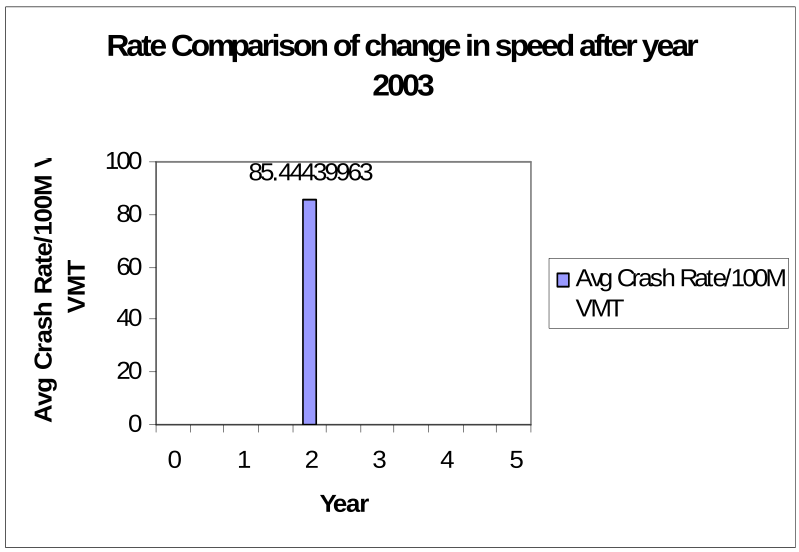
Year	Avg Crash Rate/100M VMT
0	
1	343.6148
2	
3	
4	153.0853
5	



Year	Avg Crash Rate/100M VMT
0	
1	
	68.23996
2	
3	
4	
	119.8462
5	

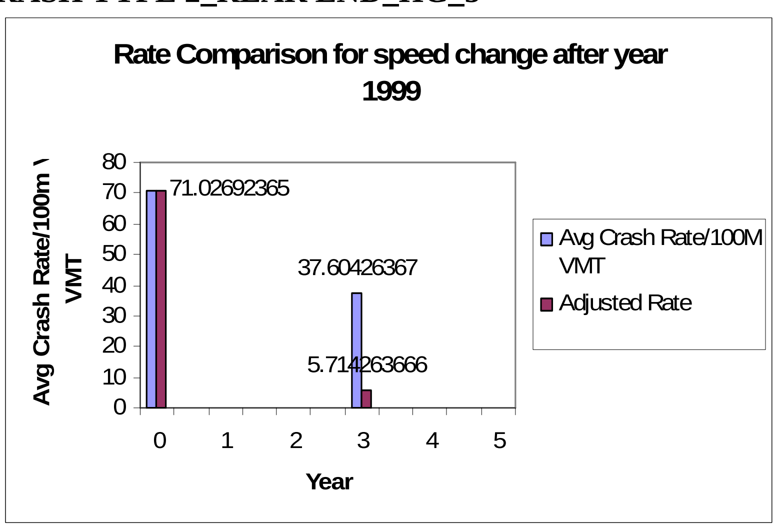


Year	Avg Crash Rate/100M VMT
0	
1	
2	85.4444
3	
4	
5	

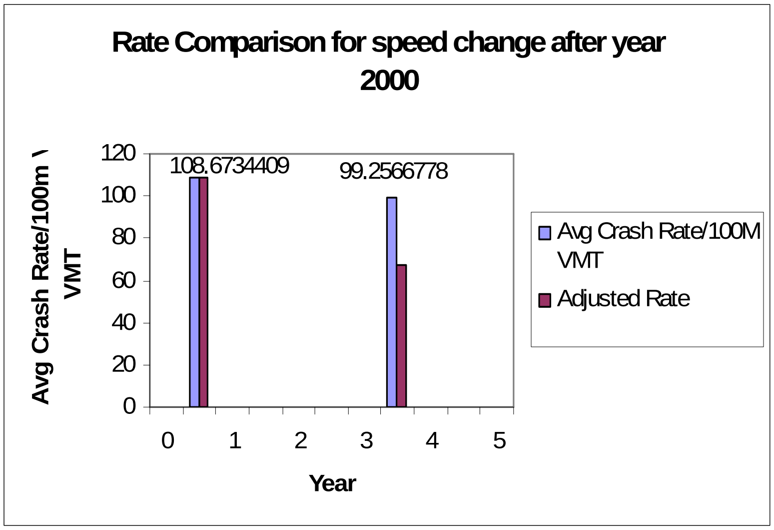


INJURY_CRASH TYPE 2_REAR END_HG_5

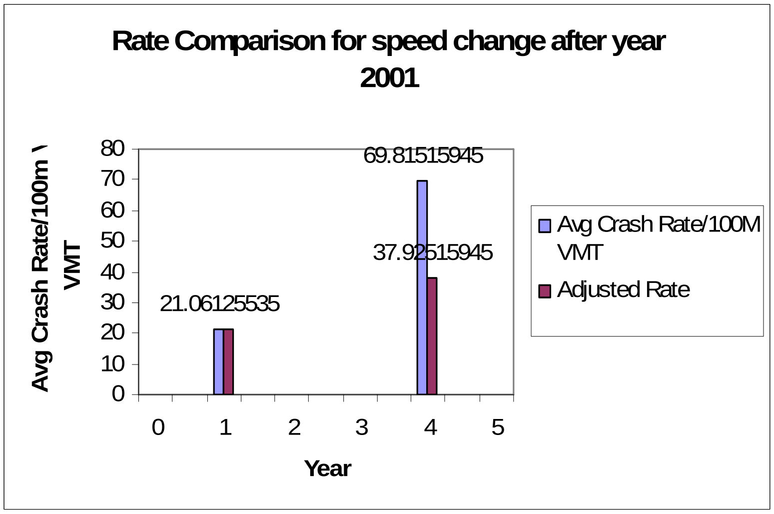
Year	Avg Crash Rate/100M VMT	Adjusted Rate
0	71.02692	71.02692
1		
2		
3	37.60426	5.714264
4		
5		



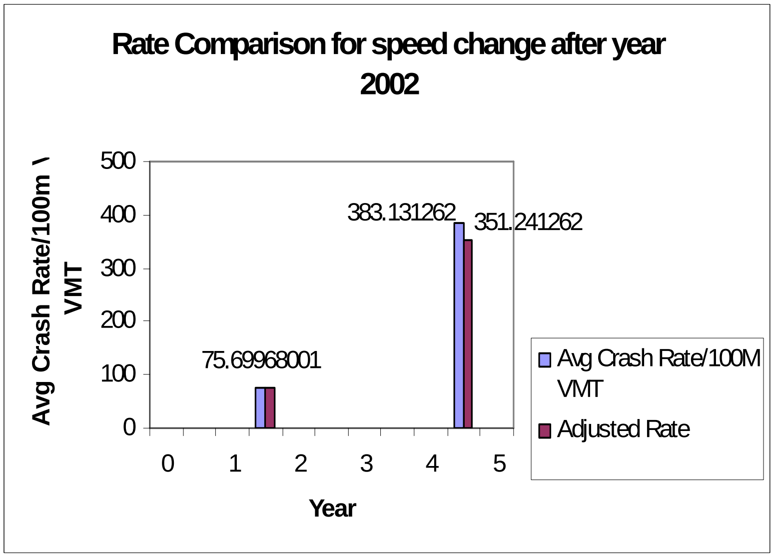
Year	Avg Crash Rate/100M VMT	Adjusted Rate
0		
	108.6734	108.6734
1		
2		
3		
	99.25668	67.36668
4		
5		



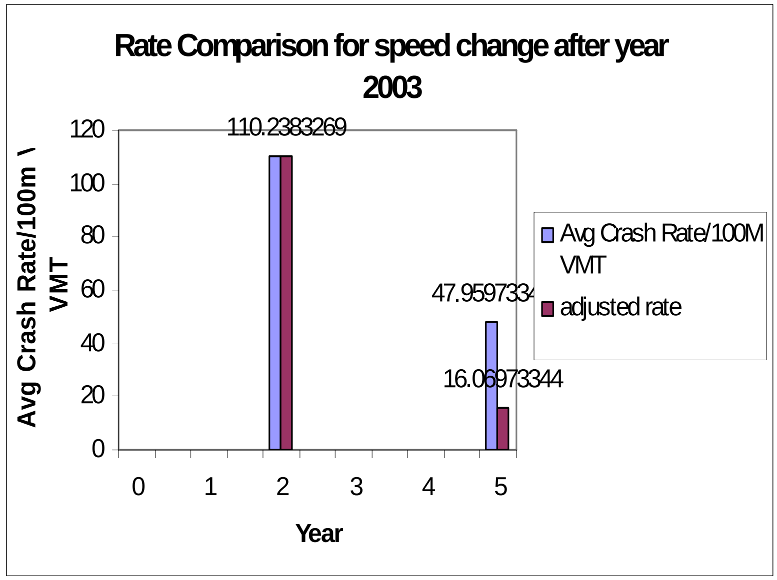
Year	Avg Crash Rate/100M VMT	Adjusted Rate
0		
1	21.06126	21.06126
2		
3		
4	69.81516	37.92516
5		



Year	Avg Crash Rate/100M VMT	Adjusted Rate
0		
1		
	75.69968	75.69968
2		
3		
4		
	383.1313	351.2413
5		

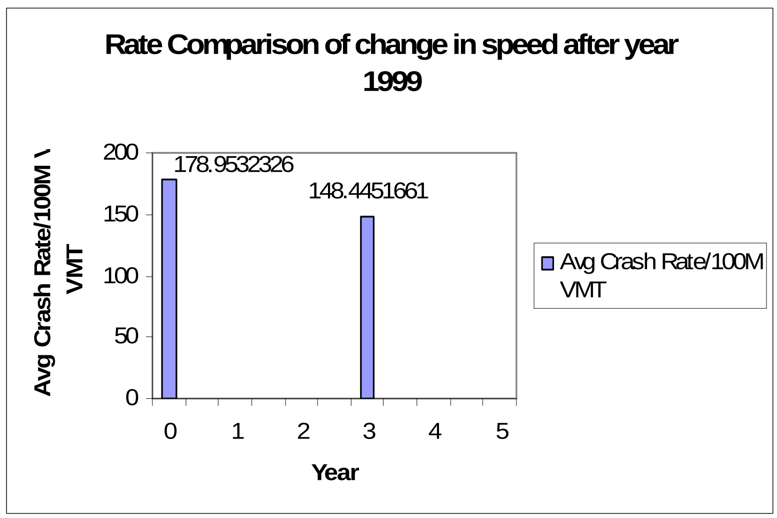


Year	Avg Crash Rate/100M VMT	adjusted rate
0		
1		
2	110.2383	110.2383
3		
4		
5	47.95973	16.06973

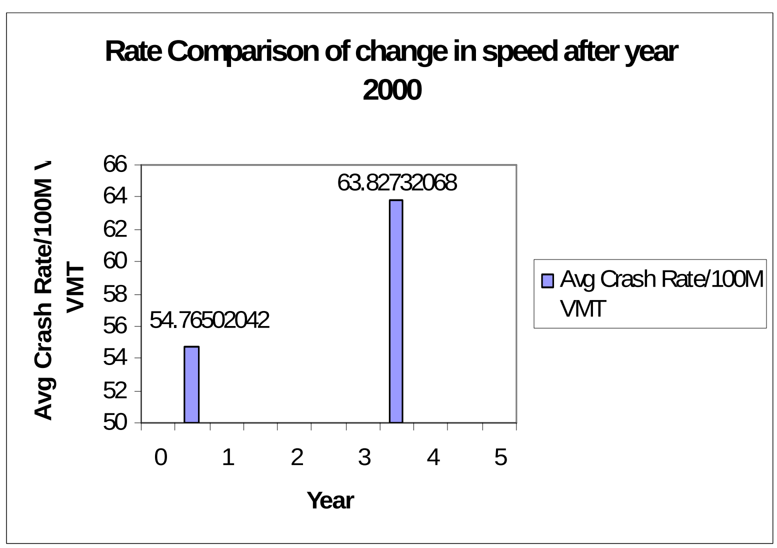


INJURY_CRASH TYPE 3_RIGHT ANGLE AND HEAD ON_HG_1

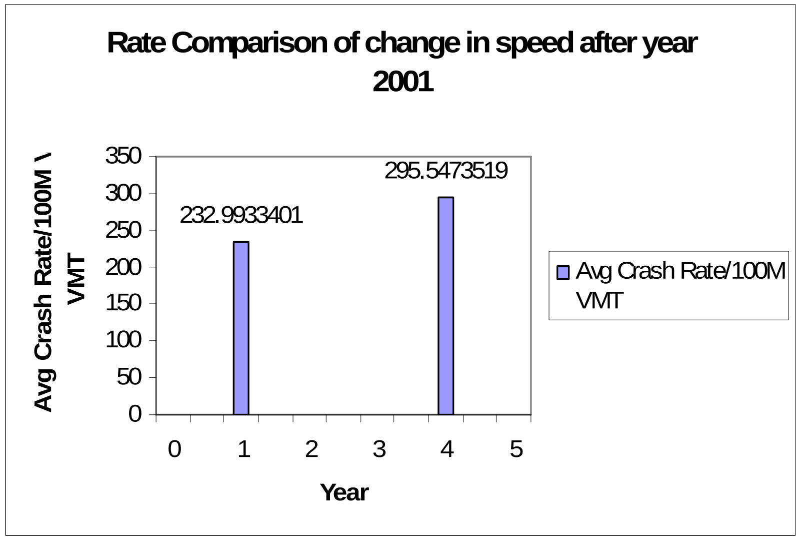
Year	Avg Crash Rate/100M VMT
0	178.9532
1	
2	
3	148.4452
4	
5	



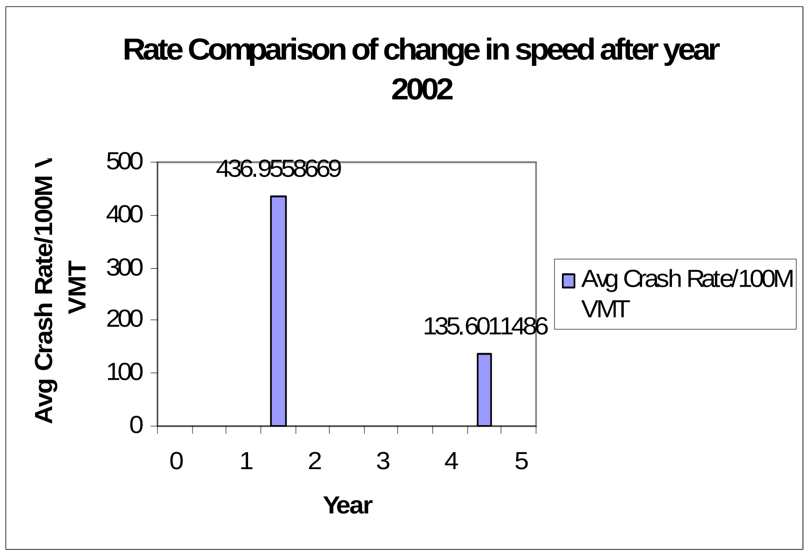
Year	Avg Crash Rate/100M VMT
0	
	54.76502
1	
2	
3	
	63.82732
4	
5	



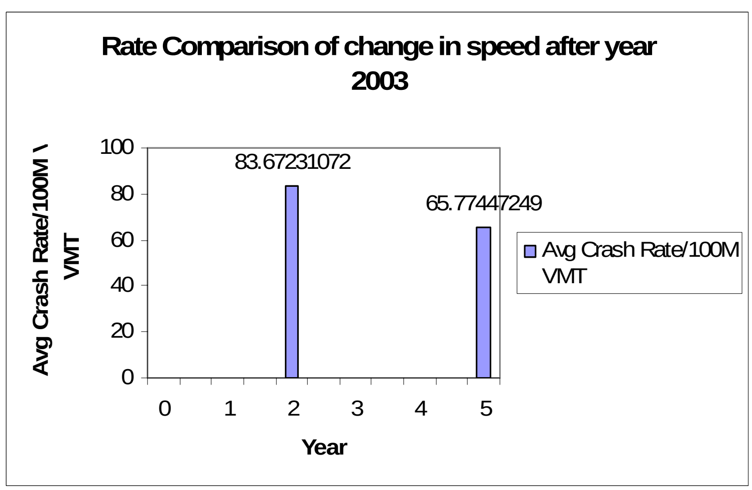
Year	Avg Crash Rate/100M VMT
0	
1	232.9933
2	
3	
4	295.5474
5	



Year	Avg Crash Rate/100M VMT
0	
1	
	436.9559
2	
3	
4	
	135.6011
5	

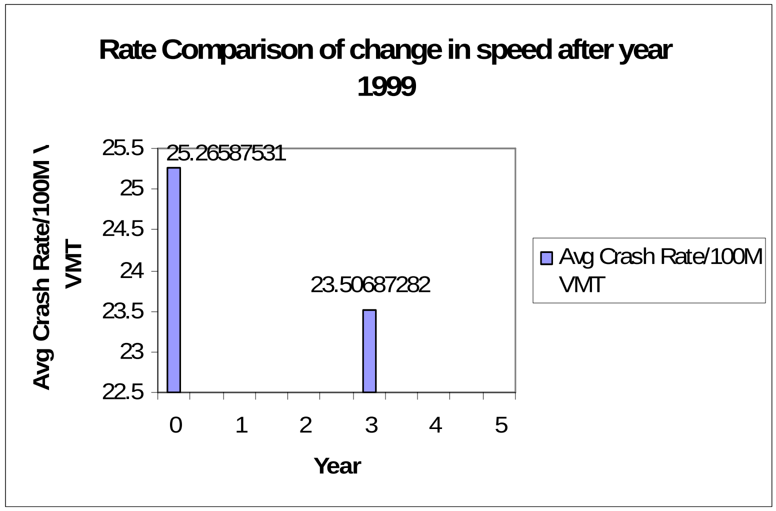


Year	Avg Crash Rate/100M VMT
0	
1	
2	83.67231
3	
4	
5	65.77447

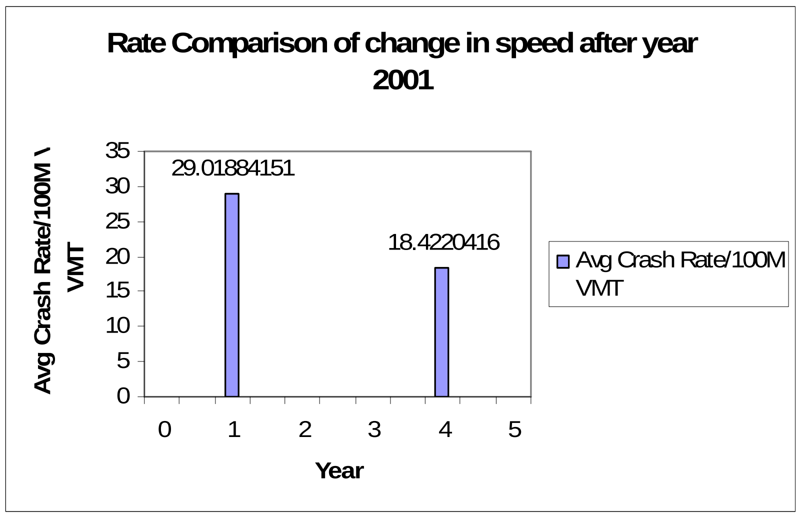


INJURY_CRASH TYPE 4_TURNING ANGLE AND SIDE SWIPE_HG_1

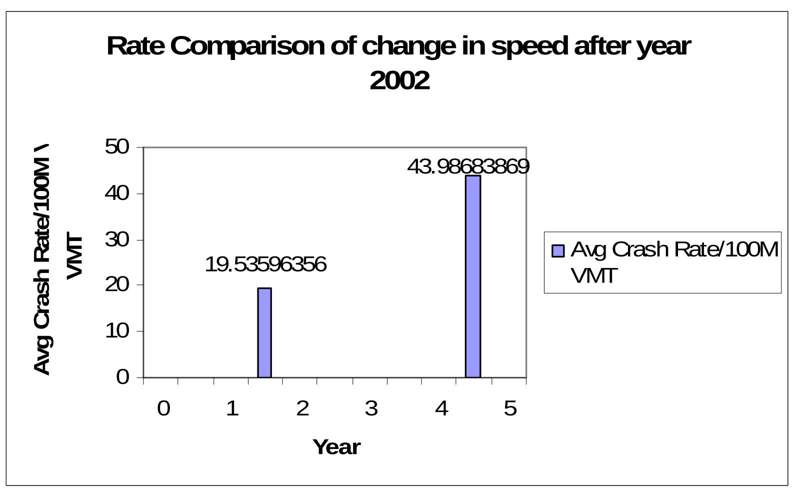
Year	Avg Crash Rate/100M VMT
0	25.26588
1	
2	
3	23.50687
4	
5	



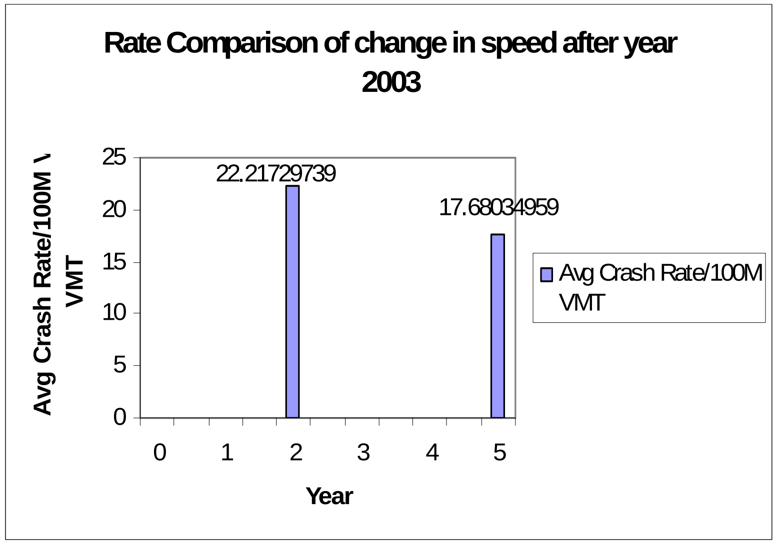
Year	Avg Crash Rate/100M VMT
0	
1	29.01884
2	
3	
4	18.42204
5	



Year	Avg Crash Rate/100M VMT
1	
	19.53596
2	
3	
4	
	43.98684
5	

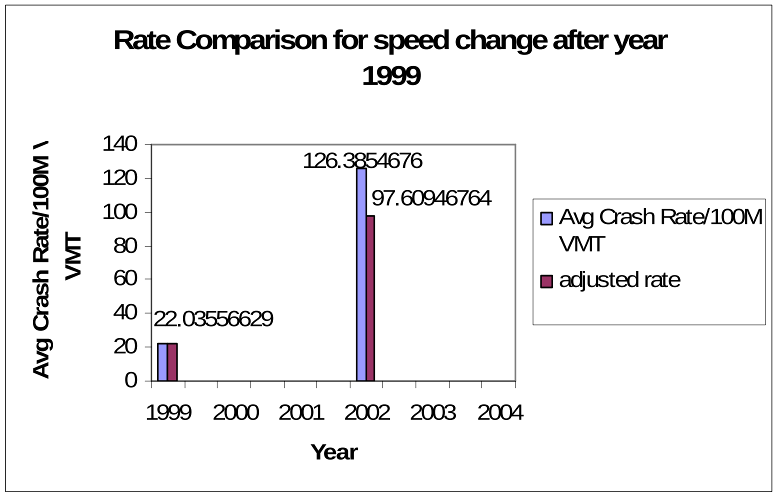


Year	Avg Crash Rate/100M VMT
0	
1	
2	22.2173
3	
4	
5	17.68035

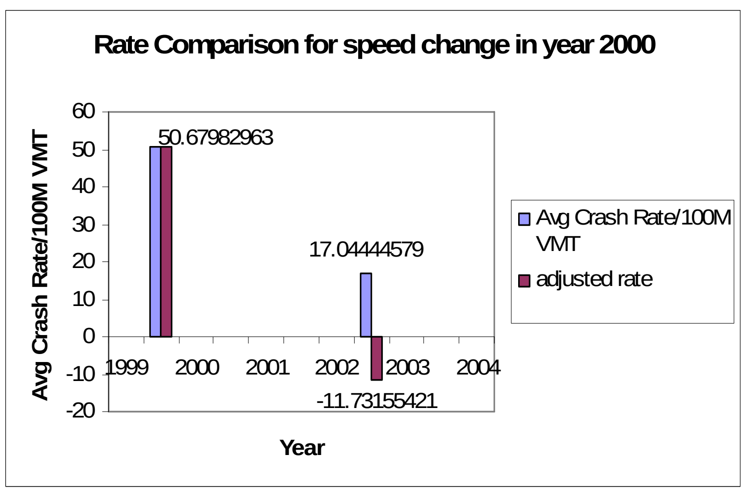


INJURY_CRASH TYPE 5_NONMOTOR VEHICLE CRASH_HG_2

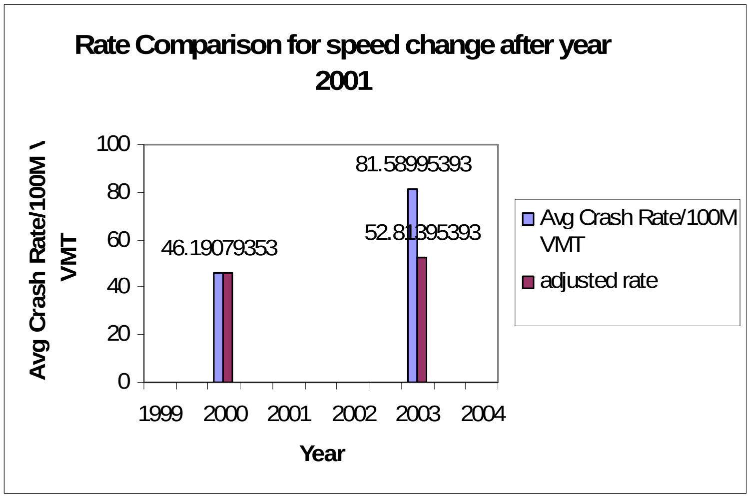
Year	Avg Crash Rate/100M VMT	adjusted rate
1999	22.03557	22.03557
2000		
2001		
2002	126.3855	97.60947
2003		
2004		



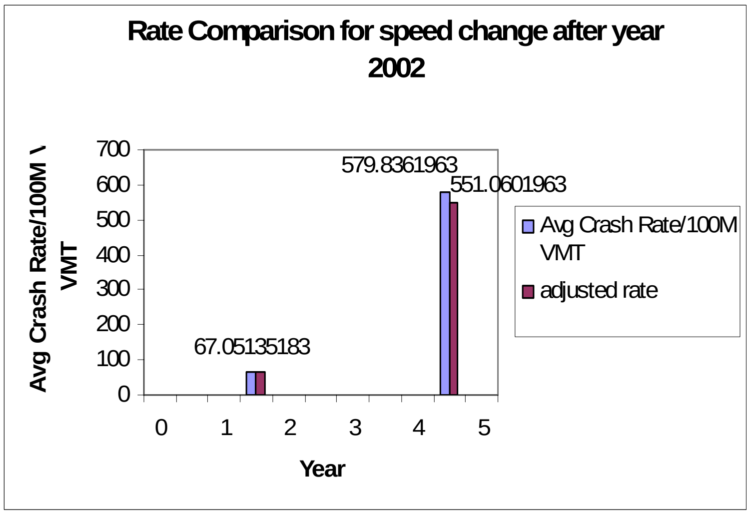
Year	Avg Crash Rate/100M VMT	adjusted rate
1999		
	50.67983	50.67983
2000		
2001		
2002		
	17.04445	-11.7316
2003		
2004		



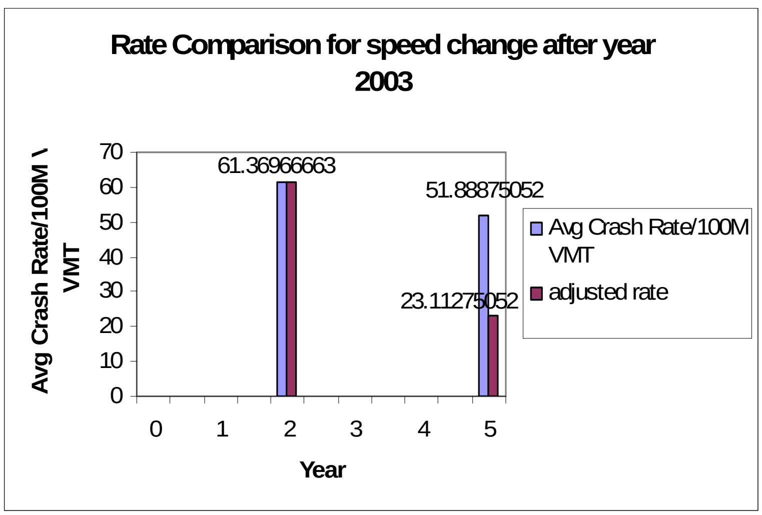
Year	Avg Crash Rate/100M VMT	adjusted rate
1999		
2000	46.19079	46.19079
2001		
2002		
2003	81.58995	52.81395
2004		



Year	Avg Crash Rate/100M VMT	adjusted rate
0		
1		
	67.05135	67.05135
2		
3		
4		
	579.8362	551.0602
5		

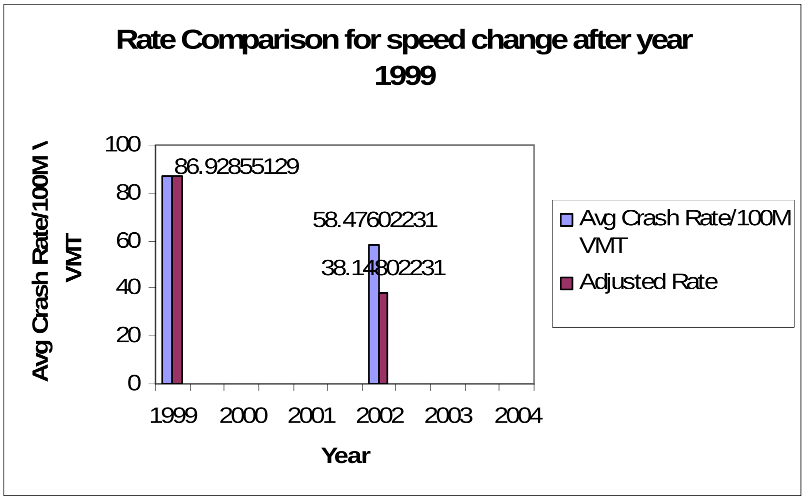


Year	Avg Crash Rate/100M VMT	adjusted rate
0		
1		
2	61.36967	61.36967
3		
4		
5	51.88875	23.11275

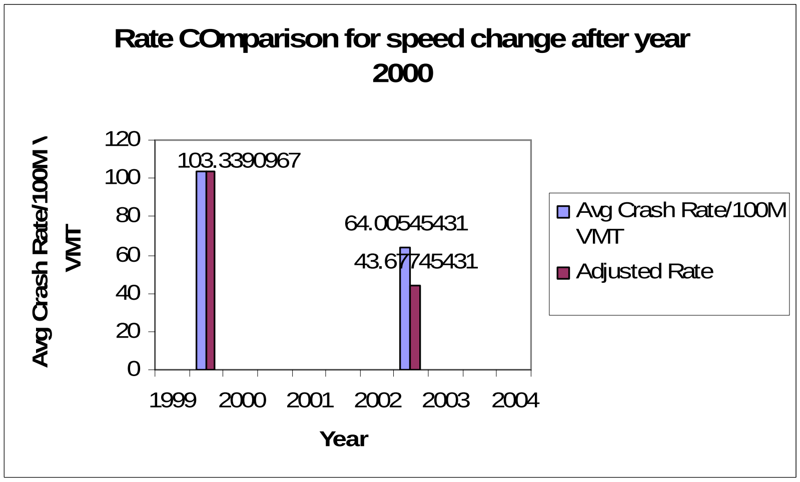


INJURY_CRASH TYPE 5_NONMOTOR VEHICLE CRASH_HG_3

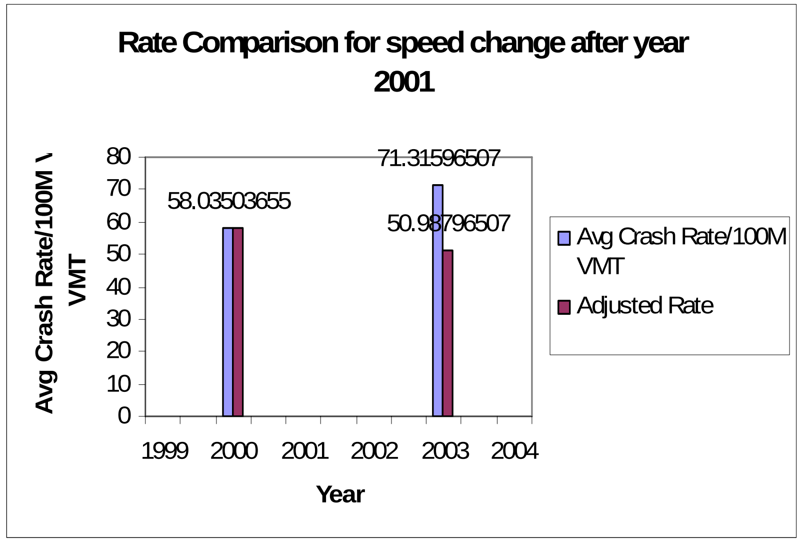
Year	Avg Crash Rate/100M VMT	Adjusted Rate
1999	86.92855	86.92855
2000		
2001		
2002	58.47602	38.14802
2003		
2004		



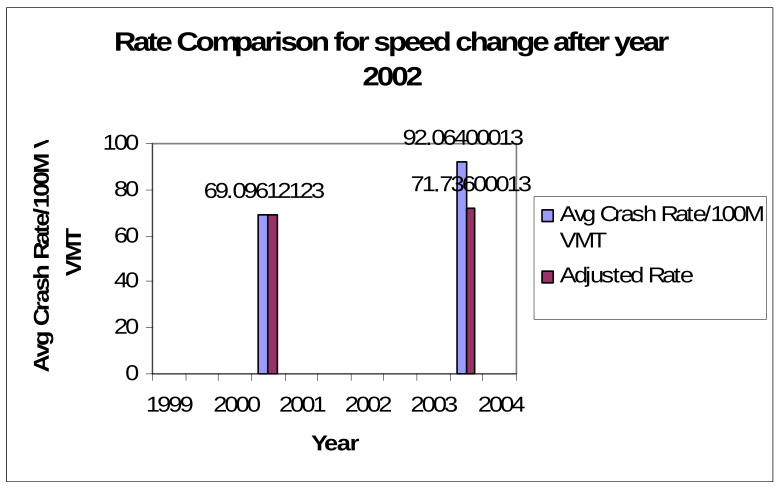
Year	Avg Crash Rate/100M VMT	Adjusted Rate
1999		
	103.3391	103.3391
2000		
2001		
2002		
	64.00545	43.67745
2003		
2004		



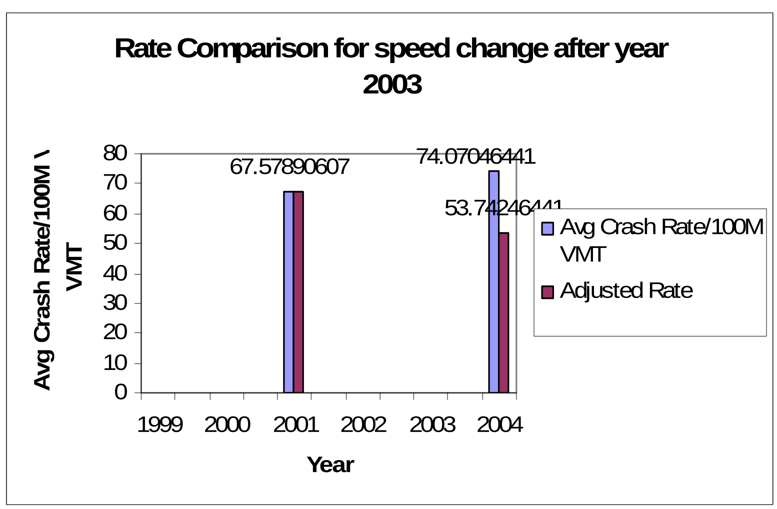
Year	Avg Crash Rate/100M VMT	Adjusted Rate
1999		
2000	58.03504	58.03504
2001		
2002		
2003	71.31597	50.98797
2004		



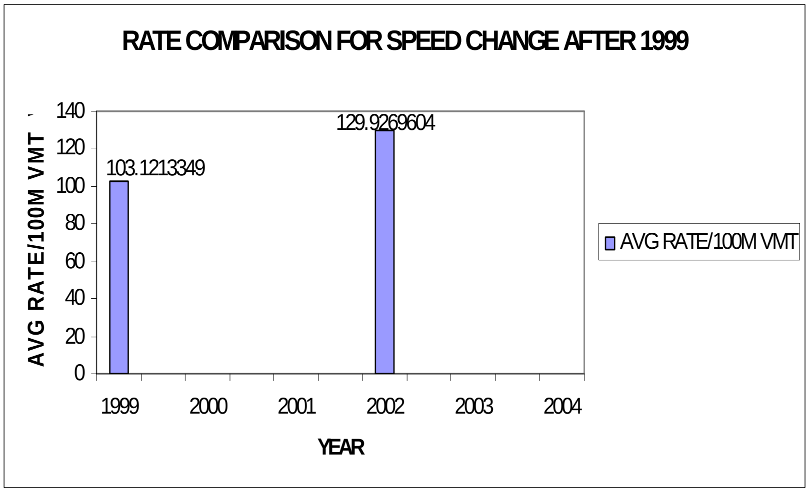
Year	Avg Crash Rate/100M VMT	Adjusted Rate
1999		
2000		
	69.09612	69.09612
2001		
2002		
2003		
	92.064	71.736
2004		



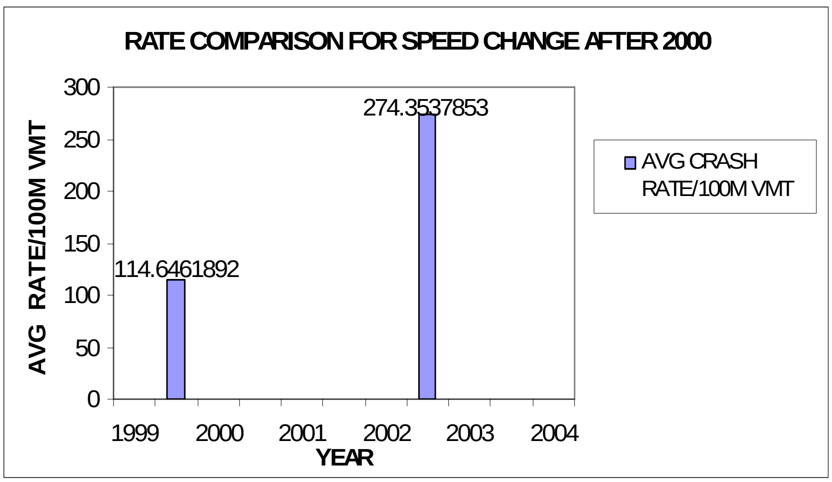
Year	Avg Crash Rate/100M VMT	Adjusted Rate
1999		
2000		
2001	67.57891	67.57891
2002		
2003		
2004	74.07046	53.74246



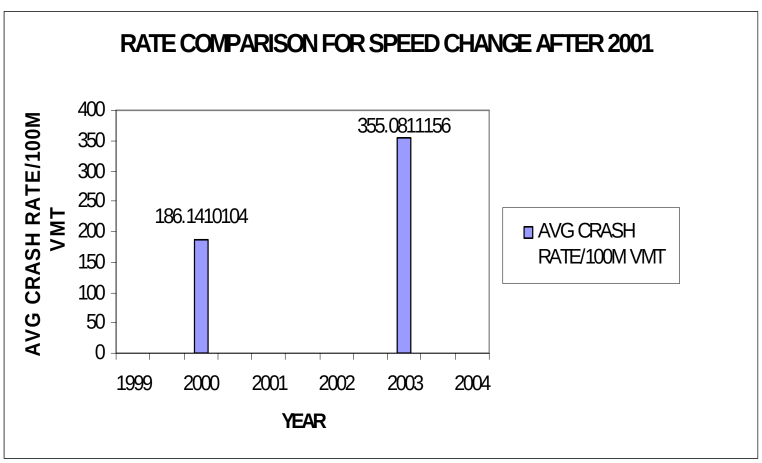
PDO_CRASH TYPE 1_RUN-OFF ROAD & OVERTURNING FOR HOMOGENEOUS GROUP 1



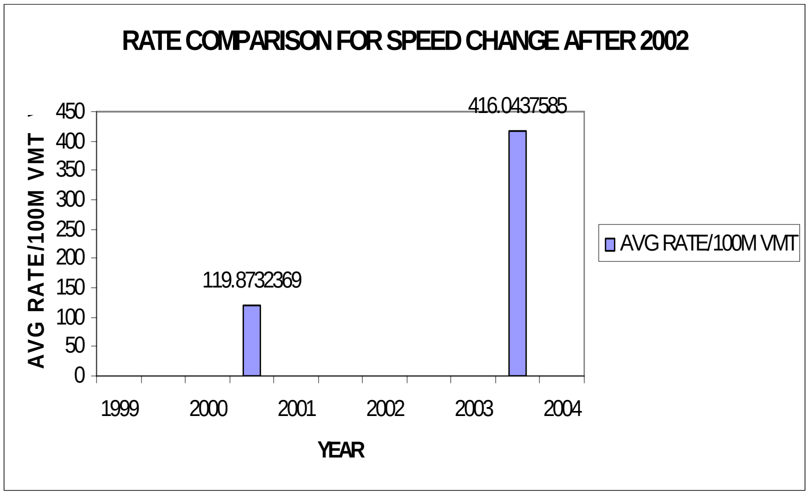
YEAR	AVG RATE/100M VMT
1999	103.1213
2000	
2001	
2002	129.927
2003	
2004	



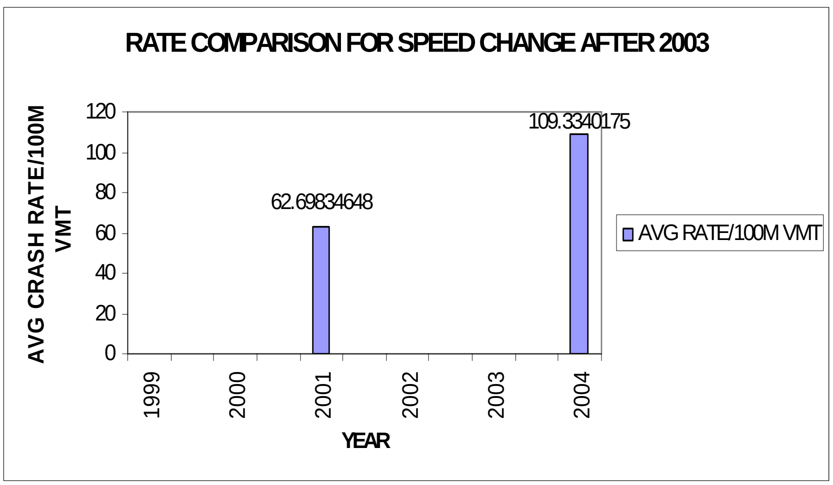
YEAR	AVG CRASH RATE/100M VMT
1999	
	114.6462
2000	
2001	
2002	
	274.3538
2003	
2004	



YEAR	AVG RATE/100M VMT
1999	
2000	186.141
2001	
2002	
2003	355.0811
2004	

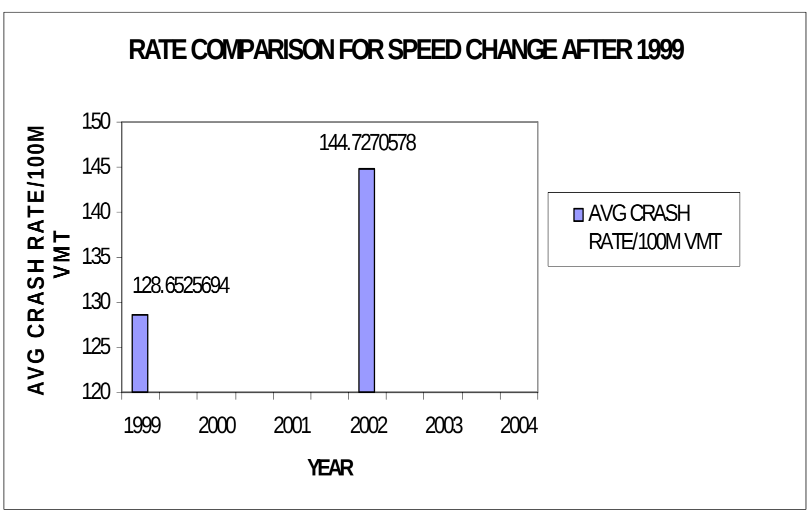


YEAR	AVG RATE/100M VMT
1999	
2000	
	119.8732
2001	
2002	
2003	
	416.0438
2004	

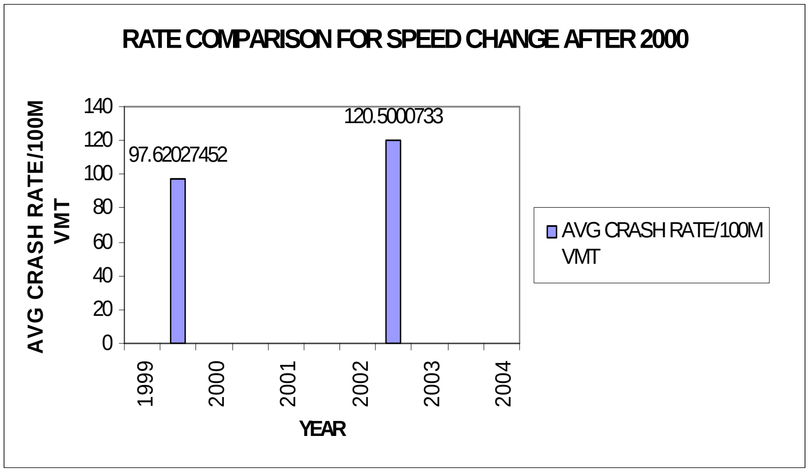


YEAR	AVG RATE/100M VMT
1999	
2000	
2001	62.69835
2002	
2003	
2004	109.334

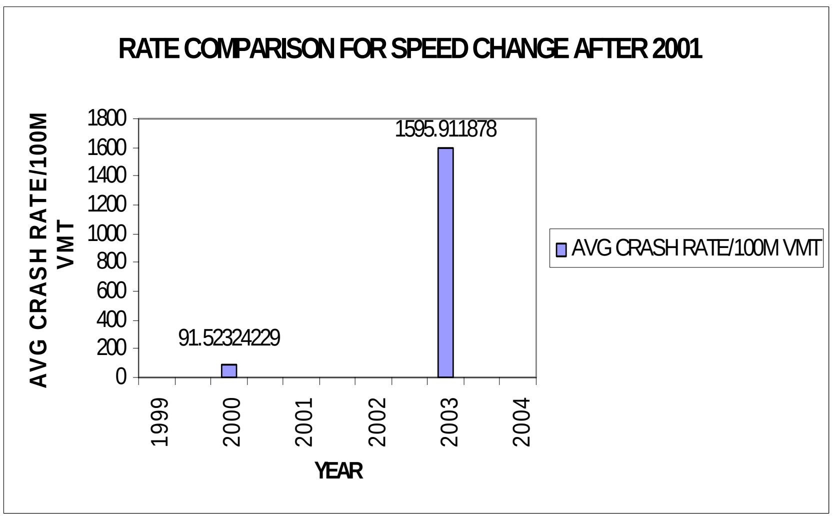
PDO_CRASH TYPE 1_RUN-OFF ROAD & OVERTURNING FOR HOMOGENEOUS GROUP 2



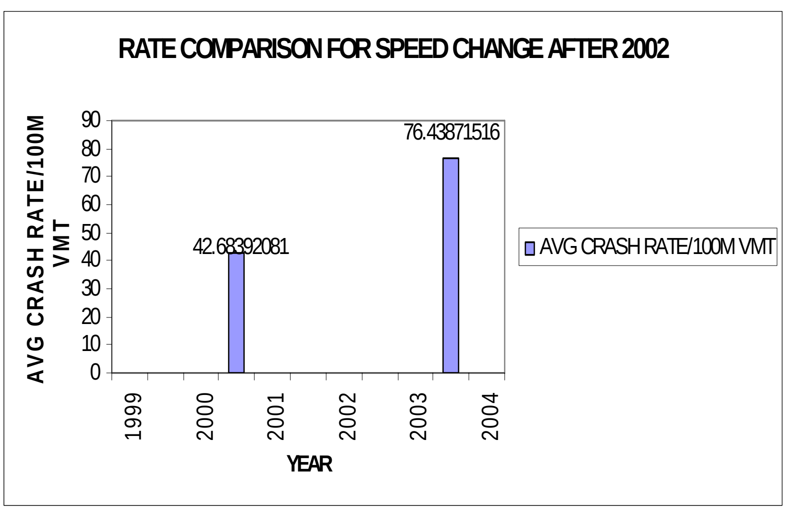
YEAR	AVG CRASH RATE/100M VMT
1999	128.6526
2000	
2001	
2002	144.7271
2003	
2004	



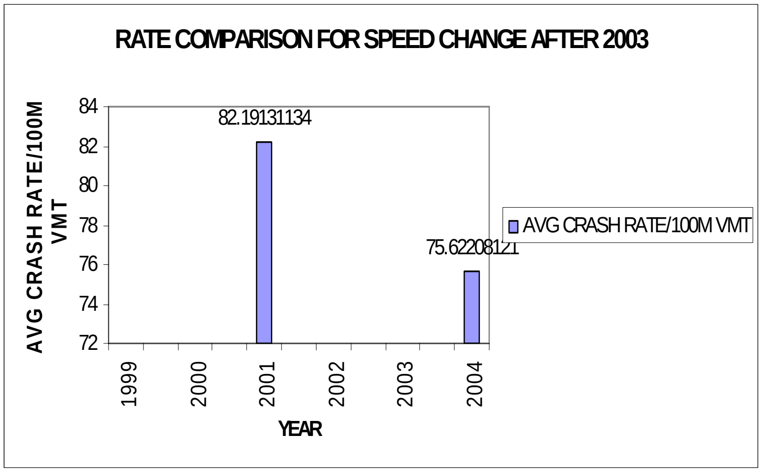
YEAR	AVG CRASH RATE/100M VMT
1999	
	97.62027
2000	
2001	
2002	
	120.5001
2003	
2004	



YEAR	AVG CRASH RATE/100M VMT
1999	
2000	91.52324
2001	
2002	
2003	1595.912
2004	



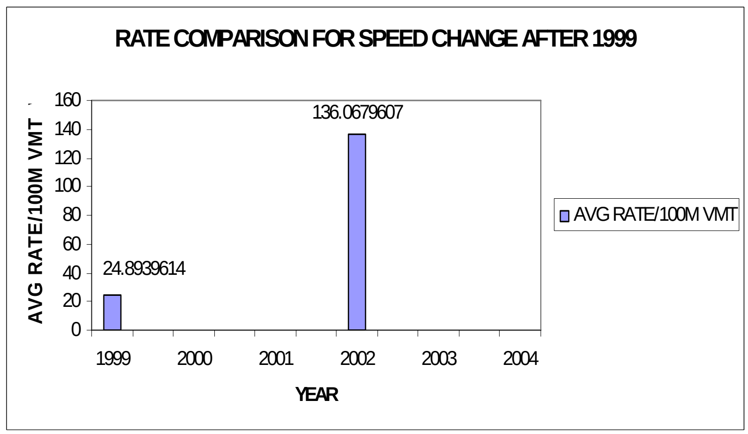
YEAR	AVG CRASH RATE/100M VMT
1999	
2000	
	42.68392
2001	
2002	
2003	
	76.43872
2004	



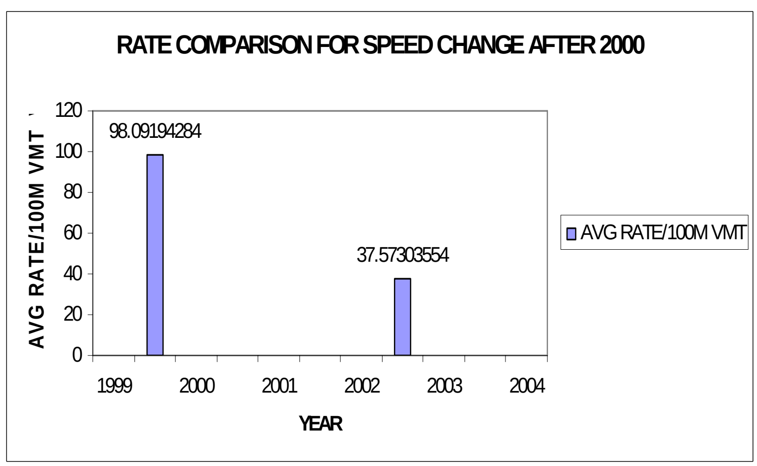
YEAR	AVG CRASH RATE/100M VMT
1999	
2000	
2001	82.19131
2002	
2003	
2004	75.62208

PDO_CRASH TYPE 1_RUN-OFF ROAD & OVERTURNING FOR HOMOGENEOUS GROUP 3

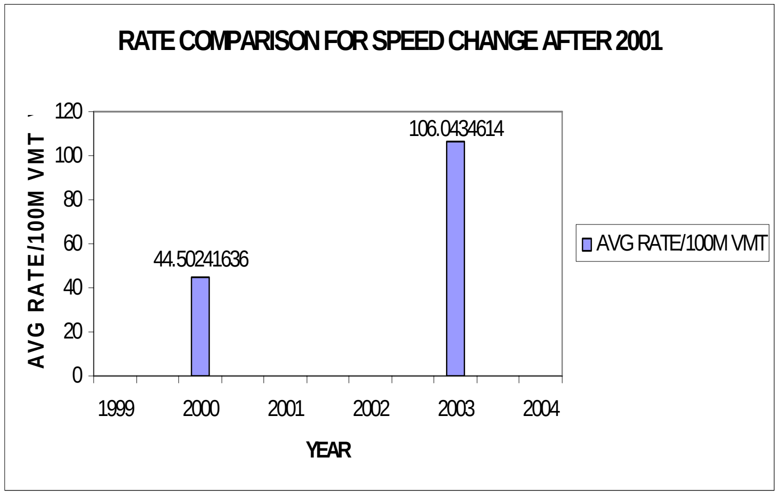
YEAR	AVG RATE/100M VMT
1999	24.89396
2000	
2001	
2002	136.068
2003	
2004	



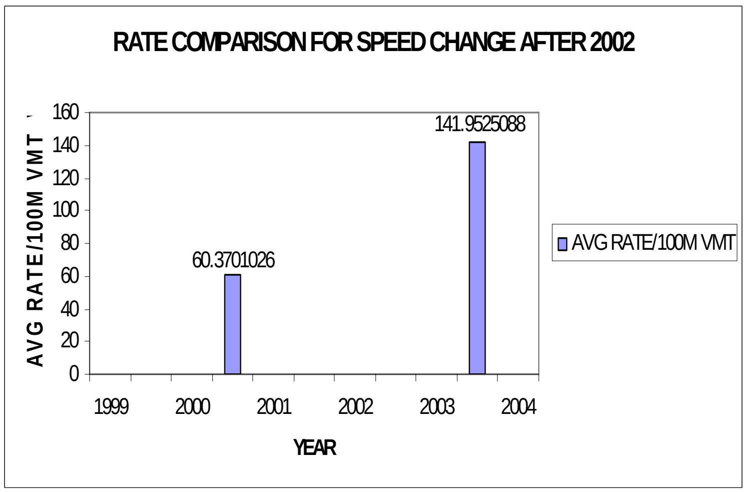
YEAR	AVG RATE/100M VMT
1999	
	98.09194
2000	
2001	
2002	
	37.57304
2003	
2004	



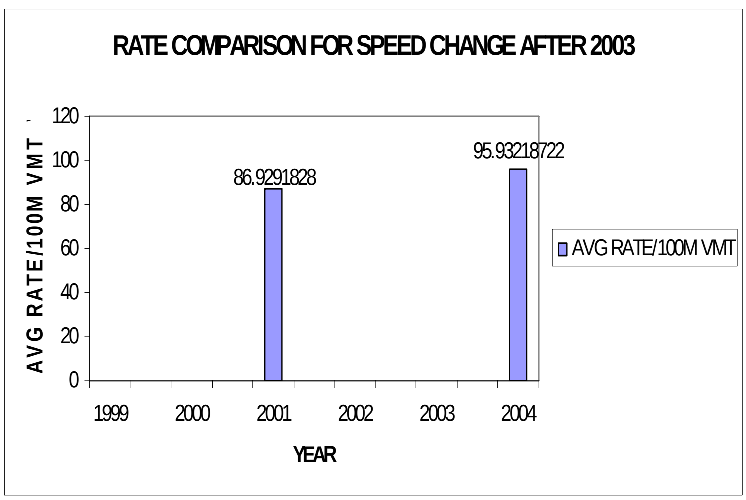
YEAR	AVG RATE/100M VMT
1999	
2000	44.50242
2001	
2002	
2003	106.0435
2004	



YEAR	AVG RATE/100M VMT
1999	
2000	
	60.3701
2001	
2002	
2003	
	141.9525
2004	

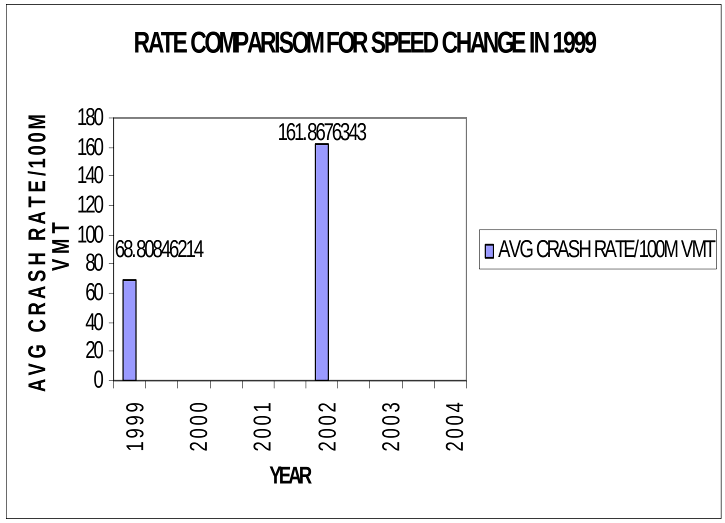


YEAR	AVG RATE/100M VMT
1999	
2000	
2001	86.92918
2002	
2003	
2004	95.93219

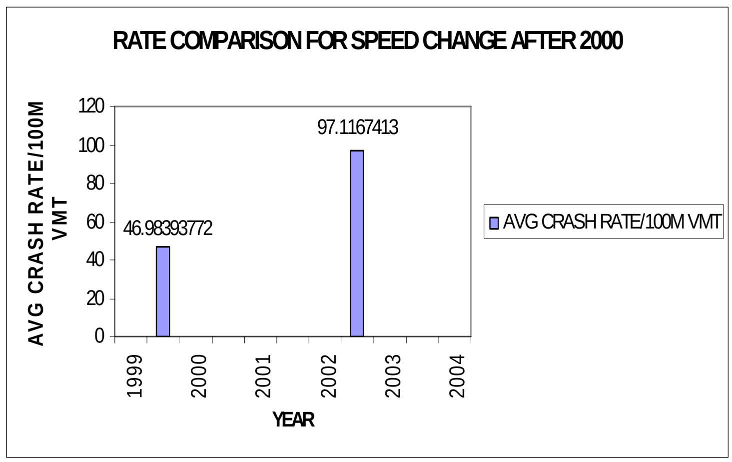


PDO_CRASH TYPE 1_RUN-OFF ROAD & OVERTURNING FOR HOMOGENEOUS GROUP 4

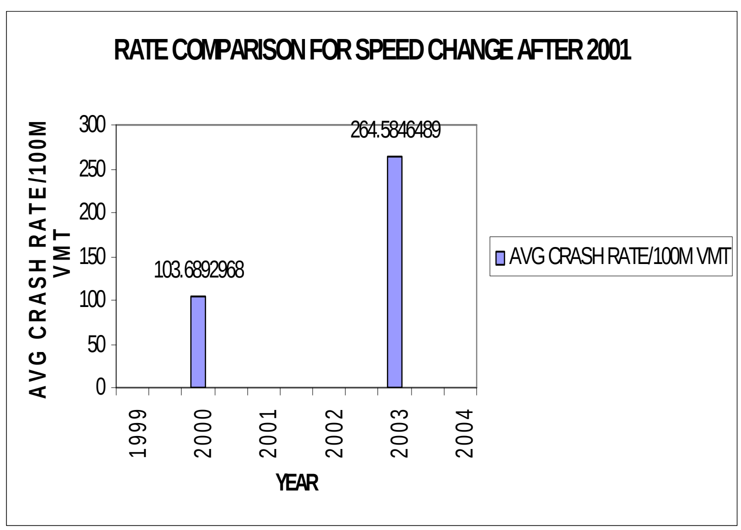
YEAR	AVG CRASH RATE/100M VMT
1999	68.80846
2000	
2001	
2002	161.8676
2003	
2004	



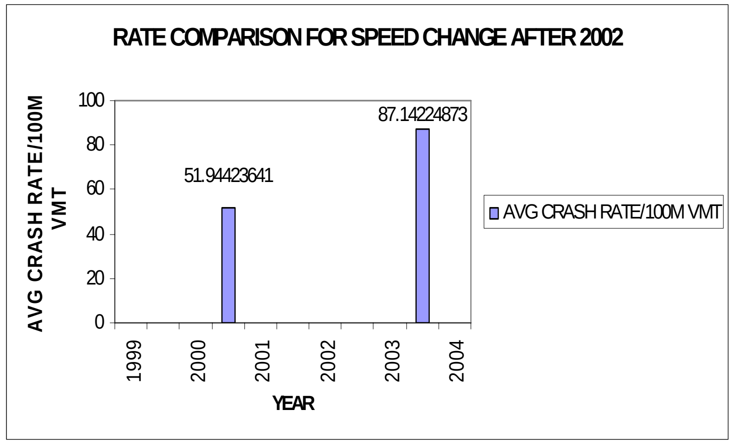
YEAR	AVG CRASH RATE/100M VMT
1999	
	46.98394
2000	
2001	
2002	
	97.11674
2003	
2004	



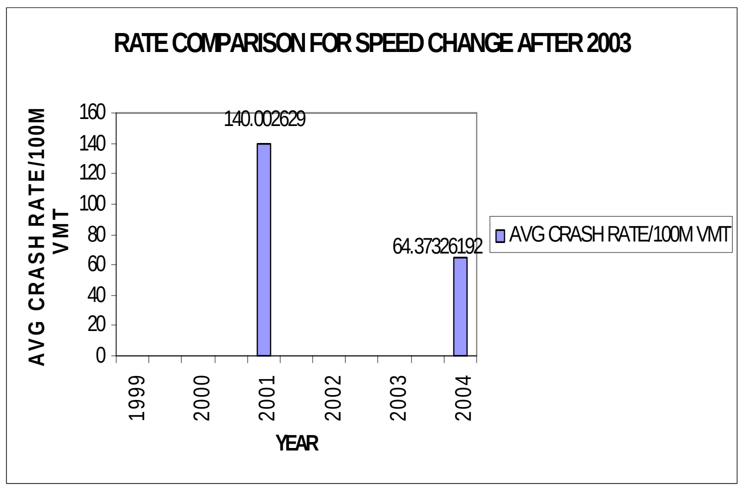
YEAR	AVG CRASH RATE/100M VMT
1999	
2000	103.6893
2001	
2002	
2003	264.5846
2004	



YEAR	AVG CRASH RATE/100M VMT
1999	
2000	
	51.94424
2001	
2002	
2003	
	87.14225
2004	

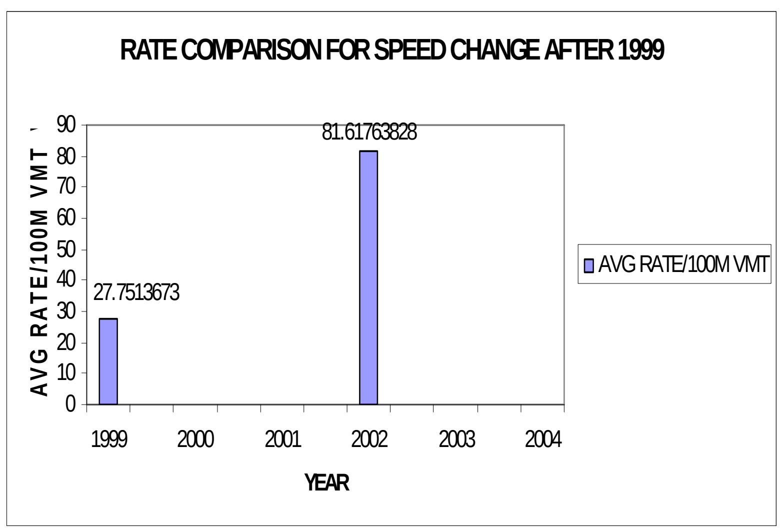


YEAR	AVG CRASH RATE/100M VMT
1999	
2000	
2001	140.0026
2002	
2003	
2004	64.37326

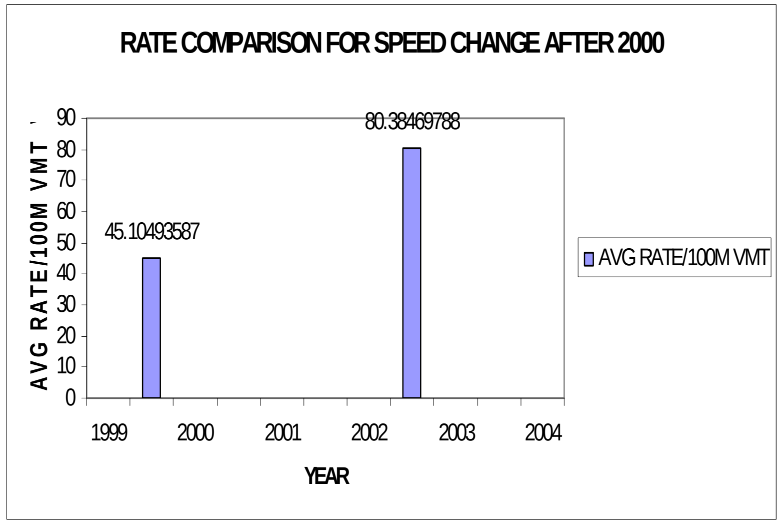


PDO_CRASH TYPE 1_RUN-OFF ROAD & OVERTURNING FOR HOMOGENEOUS GROUP 5

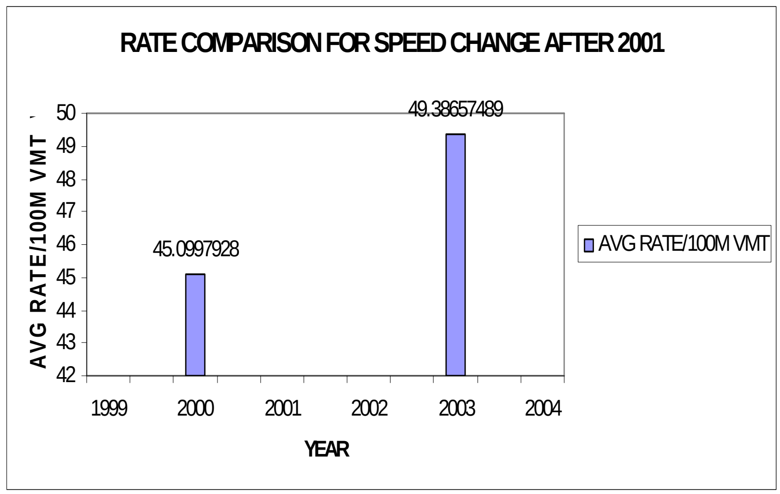
YEAR	AVG RATE/100M VMT
1999	27.75137
2000	
2001	
2002	81.61764
2003	
2004	



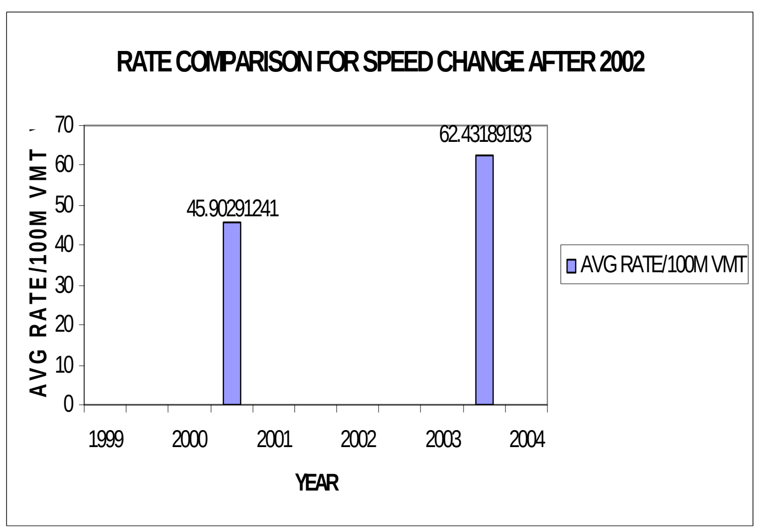
YEAR	AVG RATE/100M VMT
1999	
	45.10494
2000	
2001	
2002	
	80.3847
2003	
2004	



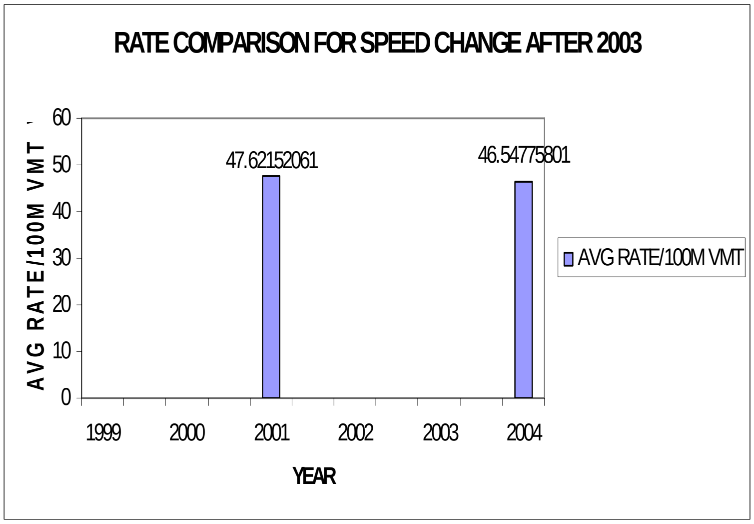
YEAR	AVG RATE/100M VMT
1999	
2000	45.09979
2001	
2002	
2003	49.38657
2004	



YEAR	AVG RATE/100M VMT
1999	
2000	
	45.90291
2001	
2002	
2003	
	62.43189
2004	

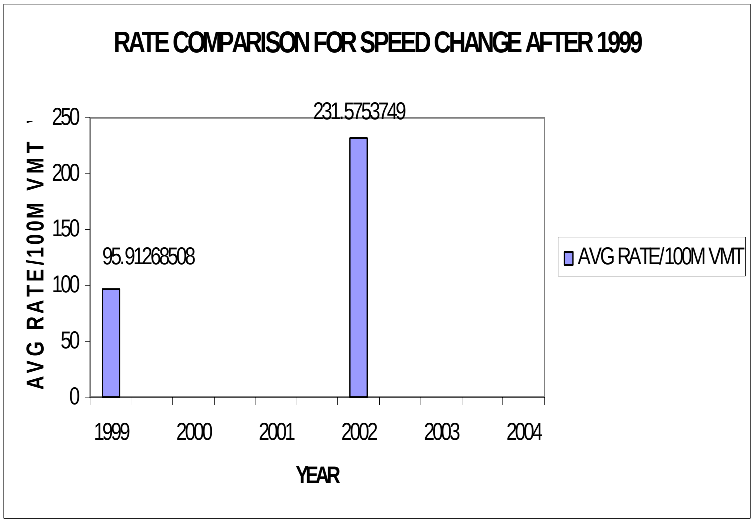


YEAR	AVG RATE/100M VMT
1999	
2000	
2001	47.62152
2002	
2003	
2004	46.54776

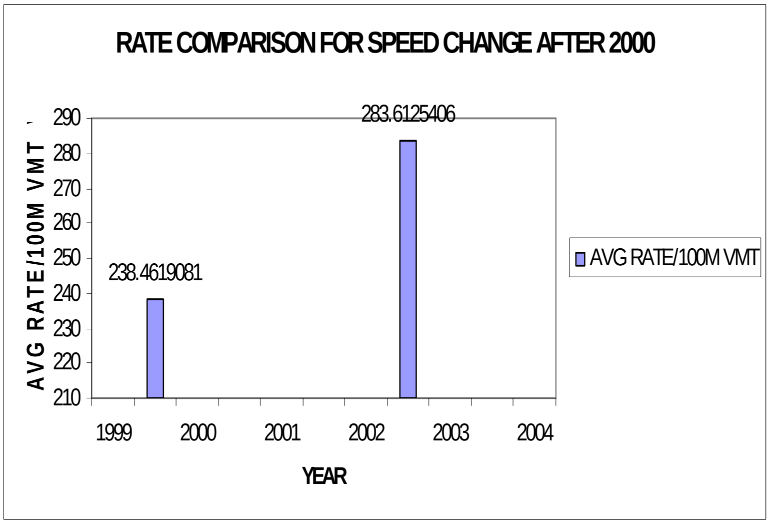


PDO_CRASH TYPE 2_REAR-END FOR HOMOGENEOUS GROUP 1

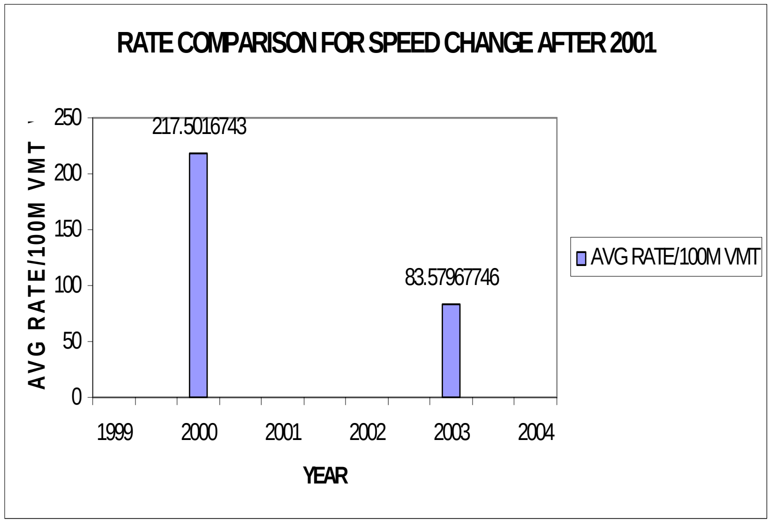
YEAR	AVG RATE/100M VMT
1999	95.91269
2000	
2001	
2002	231.5754
2003	
2004	



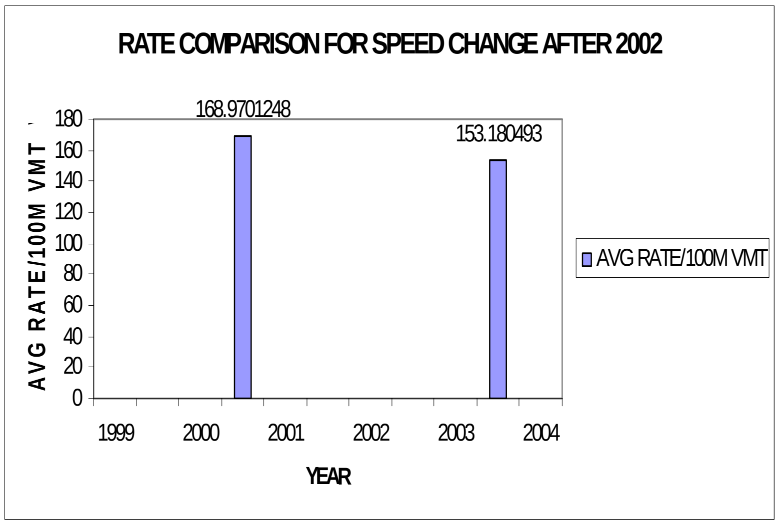
YEAR	AVG RATE/100M VMT
1999	
	238.4619
2000	
2001	
2002	
	283.6125
2003	
2004	



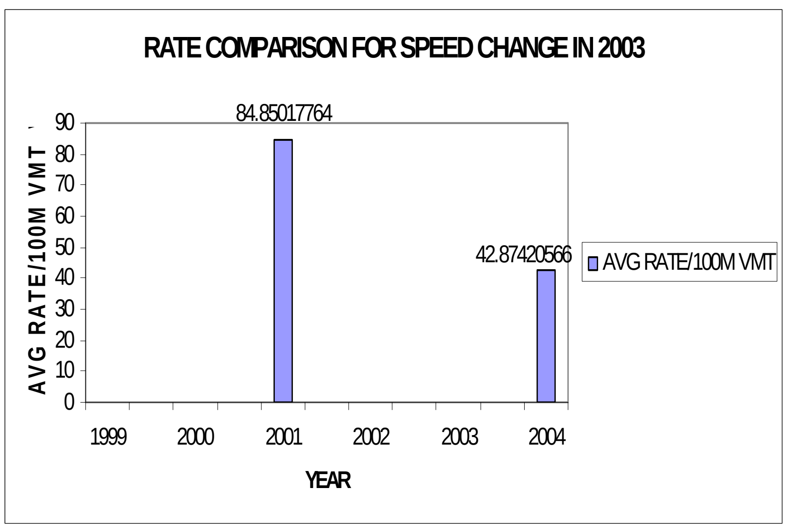
YEAR	AVG RATE/100M VMT
1999	
2000	217.5017
2001	
2002	
2003	83.57968
2004	



YEAR	AVG RATE/100M VMT
1999	
2000	
	168.9701
2001	
2002	
2003	
	153.1805
2004	

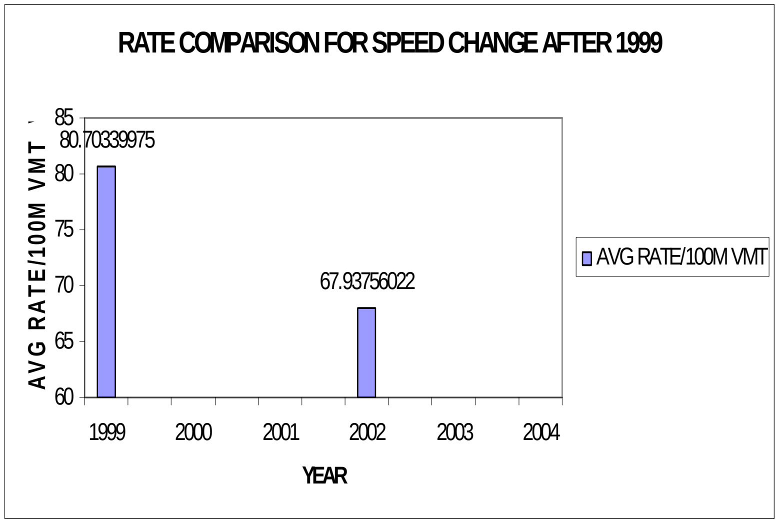


YEAR	AVG RATE/100M VMT
1999	
2000	
2001	84.85018
2002	
2003	
2004	42.87421

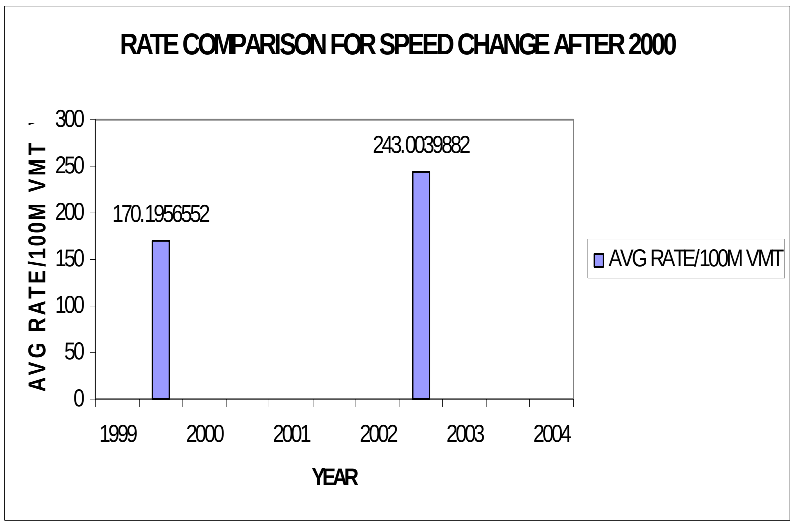


PDO_CRASH TYPE 2_REAR-END FOR HOMOGENEOUS GROUP 2

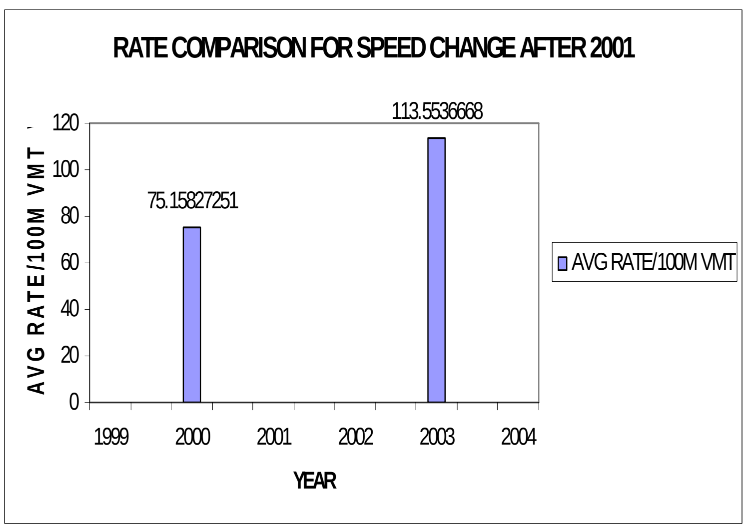
YEAR	AVG RATE/100M VMT
1999	80.7034
2000	
2001	
2002	67.93756
2003	
2004	



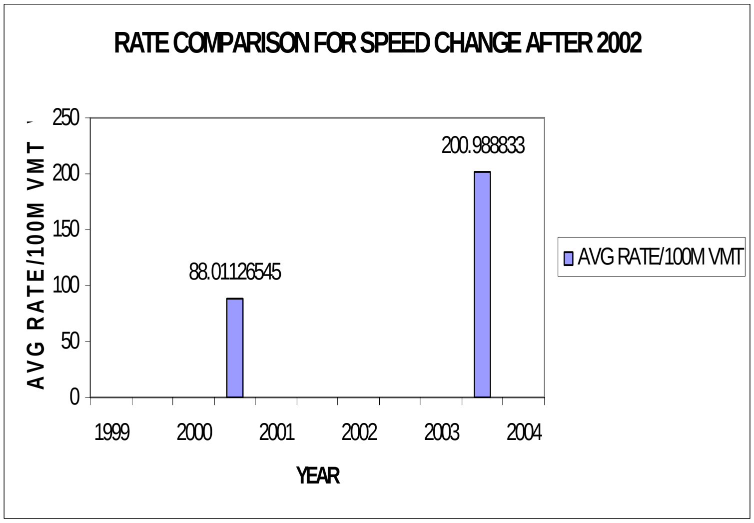
YEAR	AVG RATE/100M VMT
1999	
	170.1957
2000	
2001	
2002	
	243.004
2003	
2004	



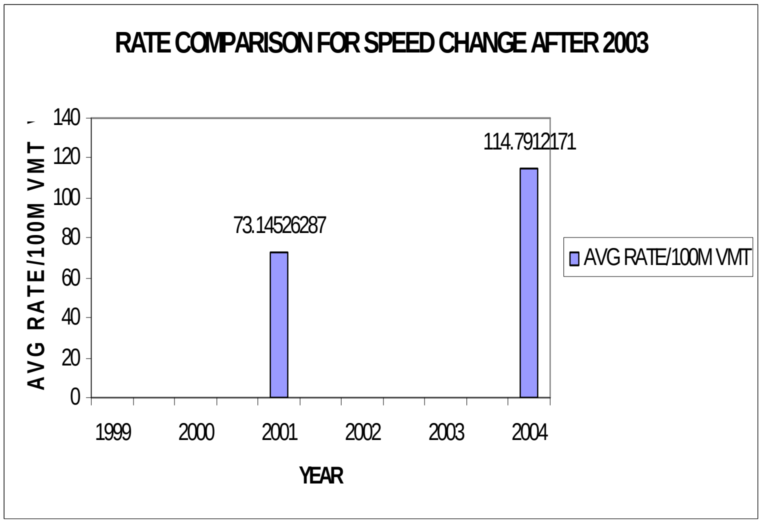
YEAR	AVG RATE/100M VMT
1999	
2000	75.15827
2001	
2002	
2003	113.5537
2004	



YEAR	AVG RATE/100M VMT
1999	
2000	
	88.01127
2001	
2002	
2003	
	200.9888
2004	

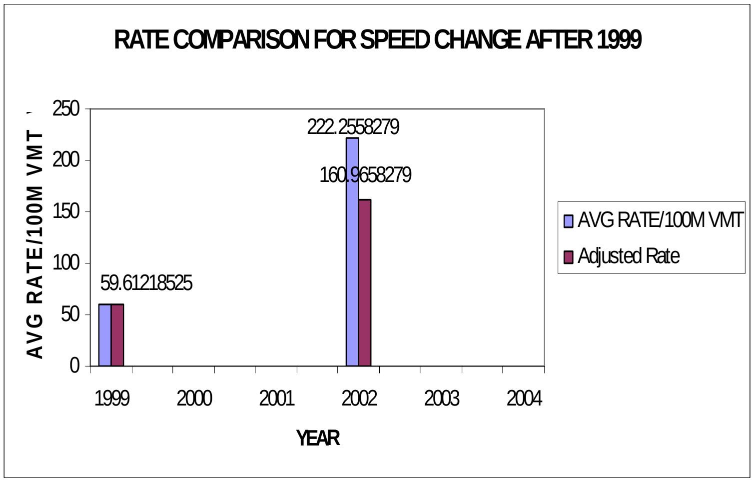


YEAR	AVG RATE/100M VMT
1999	
2000	
2001	73.14526
2002	
2003	
2004	114.7912

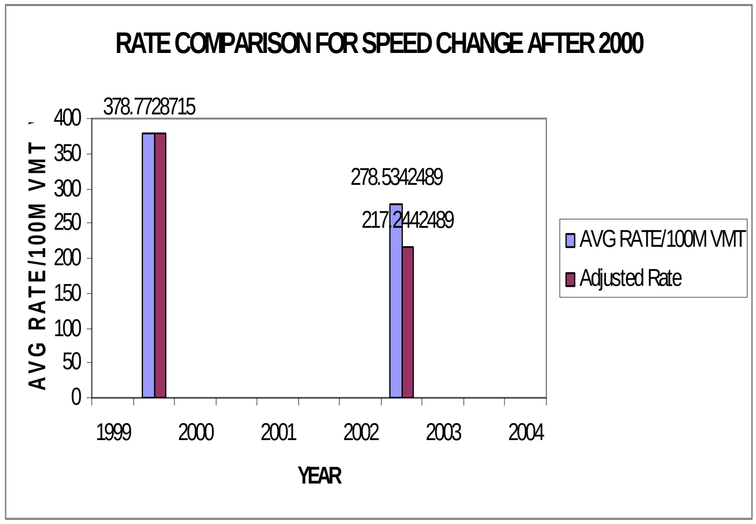


PDO_CRASH TYPE 2_REAR-END FOR HOMOGENEOUS GROUP 3

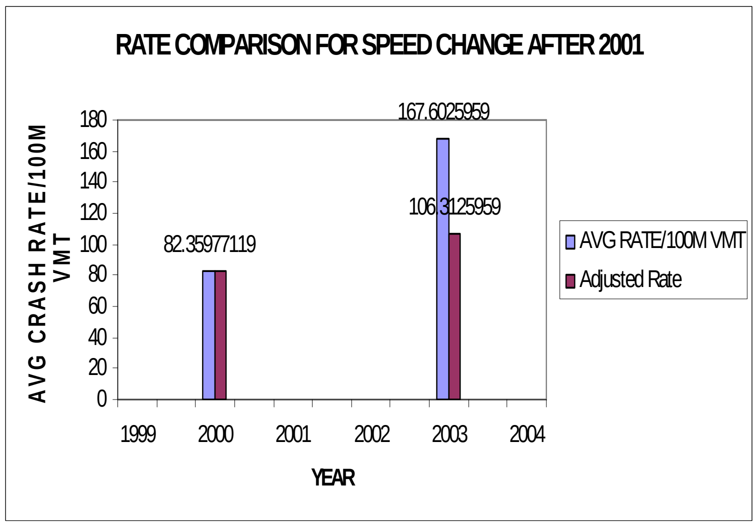
YEAR	AVG RATE/100M VMT	Adjusted Rate
1999	59.61219	59.61219
2000		
2001		
2002	222.2558	160.9658
2003		
2004		



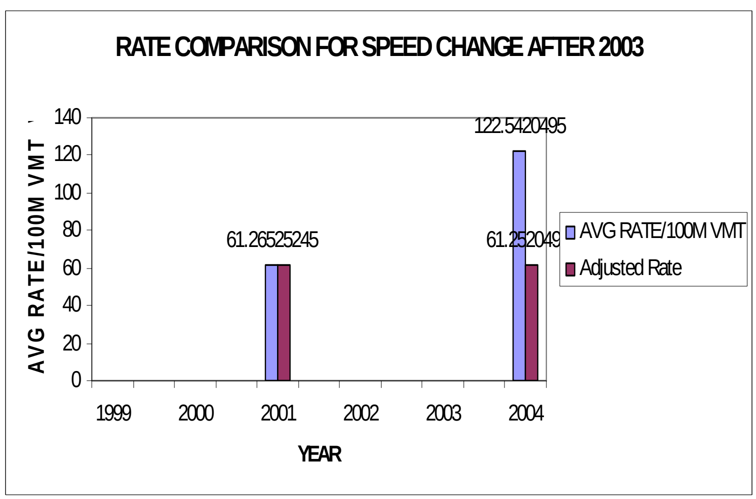
YEAR	AVG RATE/100M VMT	Adjusted Rate
1999		
	378.7729	378.7729
2000		
2001		
2002		
	278.5342	217.2442
2003		
2004		



YEAR	AVG RATE/100M VMT	Adjusted Rate
1999		
2000	82.35977	82.35977
2001		
2002		
2003	167.6026	106.3126
2004		



YEAR	AVG RATE/100M VMT	Adjusted Rate
1999		
2000		
2001	61.26525	61.26525
2002		
2003		
2004	122.542	61.25205



APPENDIX E

SINGLE TAILED PAIRED SAMPLE T-TEST

FATALITY_CRASH TYPE 1_RUN-OFF ROAD_HOMOGENEOUS GROUP_2

BEFORE	AFTER
17.6387	17.0774
8.2658	24.9233
13.9374	29.6989
6.5780	68.0677

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	4	34.9418	22.6886	11.3443
C1	4	11.6050	5.1077	2.5539
Difference	4	23.3369	26.6381	13.3190

95% lower bound for mean difference: -8.0077

T-Test of mean difference = 0 (vs > 0): T-Value = 1.75 P-Value = 0.089

FATALITY_CRASH TYPE 1_RUN-OFF ROAD_HOMOGENEOUS GROUP_3

Before	After
34.964	28.6327
59.033	24.3019
287.635	3.2890

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	3	18.741	13.556	7.827
C1	3	127.211	139.452	80.513
Difference	3	-108.469	152.974	88.320

95% lower bound for mean difference: -366.361

T-Test of mean difference = 0 (vs > 0): T-Value = -1.23 P-Value = 0.828

FATALITY_CRASH TYPE 2_HEAD-ON & RT ANGLE_HOMOGENEOUS GROUP_1

Before	After
18.285	37.488
108.009	113.212

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	2	75.3500	53.5450	37.8620
C1	2	63.1470	63.4444	44.8620
Difference	2	12.2030	9.8995	7.0000

95% lower bound for mean difference: -31.9933

T-Test of mean difference = 0 (vs > 0): T-Value = 1.74 P-Value = 0.166

FATALITY_CRASH TYPE 2_HEAD-ON & RT ANGLE_HOMOGENEOUS GROUP_2

Before	After
41.7526	13.5295
58.2493	10.9551

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	2	12.2423	1.8204	1.2872
C1	2	50.0010	11.6649	8.2483
Difference	2	-37.7587	13.4853	9.5355

95% lower bound for mean difference: -97.9637

T-Test of mean difference = 0 (vs > 0): T-Value = -3.96 P-Value = 0.921

INJ _CT1_RUNOFF ROAD_HG1

Before	After
787.625	145.043
91.944	58.737
86.250	417.353
52.159	167.533
63.385	59.847

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	169.703	146.906	65.698
C1	5	216.273	319.810	143.024
Difference	5	-46.5698	362.6718	162.1918

95% lower bound for mean difference: -392.3378

T-Test of mean difference = 0 (vs > 0): T-Value = -0.29 P-Value = 0.606

INJ _CT1_RUNOFF ROAD_HG2

Before	After
96.583	93.779
71.209	203.891
80.752	219.001
164.332	425.576
80.585	78.261

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	204.101	138.996	62.161
C1	5	98.692	37.809	16.909
Difference	5	105.409	111.157	49.711

95% lower bound for mean difference: -0.567

T-Test of mean difference = 0 (vs > 0): T-Value = 2.12 P-Value = 0.051

INJ _CT1_RUNOFF ROAD_HG3

Before	After
152.481	76.313
67.475	64.428
211.763	138.341
45.924	98.928
139.741	139.592

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	103.520	34.652	15.497
C1	5	123.477	67.176	30.042
Difference	5	-19.9565	54.8168	24.5148

95% lower bound for mean difference: -72.2183

T-Test of mean difference = 0 (vs > 0): T-Value = -0.81 P-Value = 0.769

INJ _CT1_RUNOFF ROAD_HG 4(Failed)

	Before	**After**
	186.697	43.8432
	114.739	48.8428
	56.075	73.2682
	63.784	24.0663

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	4	47.505	20.235	10.117
C1	4	105.324	60.170	30.085
Difference	4	-57.8185	66.4594	33.2297

95% lower bound for mean difference: -136.0200

T-Test of mean difference = 0 (vs > 0): T-Value = -1.74 P-Value = 0.910

INJ _CT1_RUNOFF ROAD_HG 5(Failed)

	Before	After
	24.2374	50.924
	45.2680	56.872
	34.3315	239.735
	58.6568	142.328
	79.8613	176.857

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	133.343	80.520	36.010
C1	5	48.471	21.717	9.712
Difference	5	84.8722	76.5343	34.2272

95% lower bound for mean difference: 11.9051

T-Test of mean difference = 0 (vs > 0): T-Value = 2.48 P-Value = 0.034

INJ _CT2_REAR END _HG1(Failed)

	Before	**After**
	106.251	86.294
	70.183	104.727
	343.615	153.085
	68.240	119.846

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	4	115.988	28.282	14.141
C1	4	147.072	132.189	66.095
Difference	4	-31.0843	110.5916	55.2958

95% lower bound for mean difference: -161.2154

T-Test of mean difference = 0 (vs > 0): T-Value = -0.56 P-Value = 0.693

INJ _CT2_REAR END _HG 2

	Before	**After**
	26.6163	91.683
	22.9162	212.789
	40.9824	81.933
	70.6714	137.551

		28.6395	126.552	

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	130.102	51.724	23.132
C1	5	37.965	19.500	8.721
Difference	5	92.1364	58.2590	26.0542

95% lower bound for mean difference: 36.5929

T-Test of mean difference = 0 (vs > 0): T-Value = 3.54 P-Value = 0.012

INJ _CT2_REAR END _HG 3

Before	After
18.190	142.264
129.760	98.923
76.257	114.764
53.792	287.211

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	4	160.791	86.161	43.081
C1	4	69.500	46.749	23.374
Difference	4	91.2908	113.9832	56.9916

95% lower bound for mean difference: -42.8312

T-Test of mean difference = 0 (vs > 0): T-Value = 1.60 P-Value = 0.104

INJ _CT2_REAR END _HG4

Before	After
247.642	54.407
29.457	279.127
29.888	233.928
33.116	32.165

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	4	149.907	124.821	62.410
C1	4	85.026	108.423	54.212
Difference	4	64.8810	203.6909	101.8454

95% lower bound for mean difference: -174.7983

T-Test of mean difference = 0 (vs > 0): T-Value = 0.64 P-Value = 0.285

INJ _CT2_REAR END _HG 5

Before	After
71.027	5.714
108.673	67.367
21.061	37.925
75.700	351.241
110.238	16.070

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	95.6634	144.8105	64.7612
C1	5	77.3398	36.3108	16.2387
Difference	5	18.3236	149.4724	66.8461

95% lower bound for mean difference: -124.1821

T-Test of mean difference = 0 (vs > 0): T-Value = 0.27 P-Value = 0.399

INJ _CT2_REAR END _HG 6

Before	After
52.7115	40.6636
51.9123	69.9504
41.4156	62.1400
48.3148	89.4039
44.0418	44.1888

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	61.2693	19.8998	8.8995
C1	5	47.6792	4.9018	2.1922
Difference	5	13.5901	20.4016	9.1239

95% lower bound for mean difference: -5.8606

T-Test of mean difference = 0 (vs > 0): T-Value = 1.49 P-Value = 0.105

INJ _CT3_RIGHT ANGLE AND HEAD ON _HG1

Before	After
178.953	148.445
54.765	63.827
232.993	295.547
436.956	135.601
83.672	65.775

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	141.839	94.314	42.178
C1	5	197.468	151.882	67.924
Difference	5	-55.6288	141.9403	63.4776

95% lower bound for mean difference: -190.9534

T-Test of mean difference = 0 (vs > 0): T-Value = -0.88 P-Value = 0.785

INJ _CT3_RIGHT ANGLE AND HEAD ON _HG2

Before	After
220.401	59.484
126.207	66.824
90.925	53.104
61.011	72.373
51.194	522.427

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	154.842	205.615	91.954
C1	5	109.948	68.325	30.556
Difference	5	44.8948	246.4564	110.2186

95% lower bound for mean difference: -190.0745

T-Test of mean difference = 0 (vs > 0): T-Value = 0.41 P-Value = 0.352

INJ _CT4_TURNING ANGLE AND SIDESWIPE _HG1

Before	After
25.2659	23.5069
29.0188	18.4220
19.5360	43.9868
22.2173	17.6804

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	4	25.8990	12.3334	6.1667
C1	4	24.0095	4.0782	2.0391
Difference	4	1.88953	15.48688	7.74344

95% lower bound for mean difference: -16.33360

T-Test of mean difference = 0 (vs > 0): T-Value = 0.24 P-Value = 0.411

INJ _CT4_TURNING ANGLE AND SIDESWIPE _HG2

Before	After
73.312	114.612
77.629	109.127
132.438	74.973
64.549	92.257
77.254	95.169

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	97.2276	15.5566	6.9571
C1	5	85.0364	27.0164	12.0821
Difference	5	12.1912	39.8296	17.8123

95% lower bound for mean difference: -25.7820

T-Test of mean difference = 0 (vs > 0): T-Value = 0.68 P-Value = 0.266

INJ_CT5_NON MOTOR VEHICLE CRASH_HG1

Before	After
97.792	97.770
61.574	127.697
189.548	296.026
515.537	221.360
93.437	63.288

	N	Mean	StDev	SE Mean
C2	5	161.228	95.564	42.737
C1	5	191.578	187.271	83.750
Difference	5	-30.3494	156.9661	70.1974

95% lower bound for mean difference: -179.9995

T-Test of mean difference = 0 (vs > 0): T-Value = -0.43 P-Value = 0.656

INJ_CT5_NON MOTOR VEHICLE CRASH_HG2

Before	After
22.0356	97.610
50.6798	-11.732
46.1908	52.814
67.0514	551.060

			61.3697	23.113

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	142.573	231.852	103.687
C1	5	49.465	17.433	7.796
Difference	5	93.1075	224.7406	100.5071

95% lower bound for mean difference: -121.1581

T-Test of mean difference = 0 (vs > 0): T-Value = 0.93 P-Value = 0.203

INJ_CT5_NON MOTOR VEHICLE CRASH_HG3

Before	After
86.929	38.1480
103.339	43.6775
58.035	50.9880
69.096	71.7360
67.579	53.7425

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	51.6584	12.7880	5.7190
C1	5	76.9956	18.0501	8.0723
Difference	5	-25.3372	27.2823	12.2010

95% lower bound for mean difference: -51.3479

T-Test of mean difference = 0 (vs > 0): T-Value = -2.08 P-Value = 0.947

INJ_CT5_NON MOTOR VEHICLE CRASH_HG4

Before	After
13.5192	34.084
32.1828	53.185
31.7932	50.583
38.0211	68.758
7.1960	110.884

	N	Mean	StDev	SE Mean
C2	5	63.4988	29.2038	13.0603
C1	5	24.5425	13.3701	5.9793
Difference	5	38.9563	36.4864	16.3172

95% lower bound for mean difference: 4.1705

T-Test of mean difference = 0 (vs > 0): T-Value = 2.39 P-Value = 0.038

INJ_CT5_NON MOTOR VEHICLE CRASH_HG 5

Before	After
49.101	54.034
84.047	91.988
220.796	144.269
159.911	262.557
71.477	444.601

	N	Mean	StDev	SE Mean
C2	5	199.490	157.972	70.647
C1	5	117.066	71.385	31.924
Difference	5	82.4234	174.4516	78.0171

95% lower bound for mean difference: -83.8971

T-Test of mean difference = 0 (vs > 0): T-Value = 1.06 P-Value = 0.175

PDO Crash type 1_run off road and overturning for homogenous group 1

Before	After
103.121	129.927
114.646	274.354
186.141	355.081
119.873	416.044
62.698	109.334

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	256.948	135.249	60.485
C1	5	117.296	44.540	19.919
Difference	5	139.652	108.564	48.551

95% lower bound for mean difference: 36.148

T-Test of mean difference = 0 (vs > 0): T-Value = 2.88 P-Value = 0.023

PDO Crash type 1_run off road and overturning for homogenous group 2

Before	After
128.653	144.73
97.620	120.50
91.523	1595.91
42.684	76.44
82.191	75.62

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	402.640	667.713	298.610
C1	5	88.534	30.998	13.863
Difference	5	314.106	665.551	297.643

95% lower bound for mean difference: -320.424

T-Test of mean difference = 0 (vs > 0): T-Value = 1.06 P-Value = 0.175

PDO Crash type 1_run off road and overturning for homogenous group 3

Before	After
24.8940	136.068
98.0919	37.573
44.5024	106.044
60.3701	141.953
86.9292	95.932

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	103.514	41.682	18.641
C1	5	62.958	30.022	13.426
Difference	5	40.5565	67.6798	30.2673

95% lower bound for mean difference: -23.9689

T-Test of mean difference = 0 (vs > 0): T-Value = 1.34 P-Value = 0.126

PDO Crash type 1_run off road and overturning for homogenous group 4

Before	After
68.808	161.868
46.984	97.117
113.689	264.585
51.944	87.142
140.003	64.373

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	135.017	80.975	36.213
C1	5	84.286	40.761	18.229
Difference	5	50.7314	83.7160	37.4390

95% lower bound for mean difference: -29.0827

T-Test of mean difference = 0 (vs > 0): T-Value = 1.36 P-Value = 0.123

PDO Crash type 1_run off road and overturning for homogenous group 5

Before	After
27.7514	81.6176
45.1049	80.3847
44.0998	49.3866
45.9029	62.4319
47.6215	46.5478

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	64.0737	16.5786	7.4142
C1	5	42.0961	8.1219	3.6322
Difference	5	21.9776	22.5470	10.0833

95% lower bound for mean difference: 0.4815

T-Test of mean difference = 0 (vs > 0): T-Value = 2.18 P-Value = 0.047

PDO Crash type 2_rear end homogenous group 1

Before	After
95.913	231.575
238.462	283.613
217.502	83.580
168.970	153.181
84.350	42.874

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	158.965	100.004	44.723
C1	5	161.039	69.584	31.119
Difference	5	-2.07480	100.40657	44.90318

95% lower bound for mean difference: -97.80151

T-Test of mean difference = 0 (vs > 0): T-Value = -0.05 P-Value = 0.517

PDO Crash type 2_rear end homogenous group 2

Before	After
80.703	67.938
170.196	243.004
75.158	113.554
88.011	200.988
73.145	114.791

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	148.055	71.646	32.041
C1	5	97.443	41.077	18.370
Difference	5	50.6124	46.4444	20.7706

95% lower bound for mean difference: 6.3328

T-Test of mean difference = 0 (vs > 0): T-Value = 2.44 P-Value = 0.036

PDO Crash type 2_rear end homogenous group 3

Before	After
59.612	160.966
378.773	217.244
82.360	106.313
155.575	49.139
61.265	61.252

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	118.983	70.337	31.456
C1	5	147.517	135.052	60.397
Difference	5	-28.5342	105.1138	47.0083

95% lower bound for mean difference: -128.7487

T-Test of mean difference = 0 (vs > 0): T-Value = -0.61 P-Value = 0.712

PDO Crash type 2_rear end homogenous group 4

Before	After
79.407	148.134
137.104	244.366
98.664	90.936
114.453	583.872
41.677	38.041

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	221.070	216.750	96.934
C1	5	94.261	36.223	16.199
Difference	5	126.809	197.644	88.389

95% lower bound for mean difference: -61.624

T-Test of mean difference = 0 (vs > 0): T-Value = 1.43 P-Value = 0.112

PDO Crash type 3_right angle and side swipe homogenous group 1

Before	After
44.396	53.751
78.822	70.148
107.702	72.888
134.229	84.352
47.720	118.381

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	79.9040	24.1280	10.7904
C1	5	82.5738	38.6849	17.3004
Difference	5	-2.66980	46.95695	20.99979

95% lower bound for mean difference: -47.43813

T-Test of mean difference = 0 (vs > 0): T-Value = -0.13 P-Value = 0.548

PDO Crash type 3_right angle and side swipe homogenous group 2

Before	After
67.540	144.113
77.769	171.250
108.287	113.308
224.840	114.201
86.474	54.207

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	119.416	43.627	19.511
C1	5	112.982	64.308	28.759
Difference	5	6.43380	83.22036	37.21727

95% lower bound for mean difference: -72.90773

T-Test of mean difference = 0 (vs > 0): T-Value = 0.17 P-Value = 0.436

PDO Crash type 3_right angle and side swipe homogenous group 3

Before	After
66.936	136.091
112.819	142.990
88.442	73.486
206.406	148.054
57.046	90.585

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	118.241	33.867	15.146
C1	5	106.330	59.913	26.794
Difference	5	11.9114	49.3376	22.0644

95% lower bound for mean difference: -35.1266

T-Test of mean difference = 0 (vs > 0): T-Value = 0.54 P-Value = 0.309

PDO Crash type 4_non motor vehicle crash homogenous group 1

Before	After
67.204	77.043
142.774	99.547

Before	After
119.892	325.455
167.418	159.583
110.526	182.667

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	168.859	97.511	43.608
C1	5	121.563	37.524	16.781
Difference	5	47.2962	97.8552	43.7622

95% lower bound for mean difference: -45.9981

T-Test of mean difference = 0 (vs > 0): T-Value = 1.08 P-Value = 0.170

PDO Crash type 4_non motor vehicle crash homogenous group 2

Before	After
105.776	102.845
68.236	106.055
101.065	129.732
77.033	122.654
70.032	227.962

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	137.850	51.607	23.079
C1	5	84.428	17.725	7.927
Difference	5	53.4212	61.2672	27.3995

95% lower bound for mean difference: -4.9904

T-Test of mean difference = 0 (vs > 0): T-Value = 1.95 P-Value = 0.061

PDO Crash type 4_non motor vehicle crash homogenous group 3

Before	After
140.408	157.454
86.804	92.922
162.752	858.676
338.678	338.816
157.805	62.512

Paired T for C2 - C1

	N	Mean	StDev	SE Mean
C2	5	302.076	329.092	147.174
C1	5	177.289	95.112	42.535
Difference	5	124.787	322.436	144.198

95% lower bound for mean difference: -182.621

T-Test of mean difference = 0 (vs > 0): T-Value = 0.87 P-Value = 0.218

VITA

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