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16. Abstract

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Statewide Traffic Safety Study Phase II: Identification of Major Traffic Safety Problem Areas in Louisiana

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IMPLEMENTATION STATEMENT

Eight major problem areas were identified as needing special attention in Louisiana in this study. As the first step in addressing these concerns, countermeasures have been suggested that legislators and administrators can implement such as implementing a point system for drivers and extending the existing Graduated Driver Licensing law to include more stringent requirements. To assist in identifying those countermeasures that are the most cost-effective, a prioritization process was developed that identifies countermeasures that provide the greatest benefit relative to the cost of their implementation. Certain actions are recommended for implementation.

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INTRODUCTION

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 average, more than 900 people are killed and about 50,000 injured in automobile crashes in Louisiana each year. In the last decade, Louisiana has consistently been featured among the states with the highest fatality rate in the nation, and in 2001 it tied with Montana and South Carolina for the highest rate. In that year, Louisiana’s fatality rate was 2.3 per 100 million miles traveled, while the national average was 1.5.

Louisiana’s high crash rate has significant economic and social costs. Property damage, lost productivity, medical expenses, and inflated motor vehicle insurance rates imposed an estimated $5.3 billion burden on the state in 2002 (HRSG, 2004). These costs are not distributed equally; fatality rates among 16- to 20-year olds in Louisiana are double that of other ages (HSRG, 2005). While improvement of road safety is a national objective, the conditions in Louisiana are sufficiently dire to justify an independent study into the cause of these conditions and what can be done about it. That is the purpose of this study.

In Phase I of the Statewide Traffic Safety Study from which this study grew, effort was focused on conducting a review of state-of-the-art road safety in Louisiana, in the nation, and to a limited extent, internationally. The review included studies on factors influencing road safety, identification of available data, safety legislation, safety initiatives and programs, and safety related funding (Wilmot, et al., 2005). This study (Phase II) identifies the traffic safety problem areas in the state and conducts detailed analysis on these areas to better understand their underlying causes. After identifying the major causes for Louisiana high crash rates, countermeasures are introduced and evaluated according to their effectiveness in combating Louisiana traffic safety problems. Finally, strategies to improve Louisiana traffic safety are recommended.

OBJECTIVE

The objective of this study was to identify and quantify the factors leading to the high crash rate in the state of Louisiana. A secondary objective was to develop countermeasures to address the identified factors and prioritize their application based on cost effectiveness.

SCOPE

The research in this study was restricted to traffic safety in Louisiana, and its main emphasis is on identifying factors that distinguish Louisiana from other states in regard to traffic safety. Because human factors are generally accepted as being the major cause of crashes (Dewar and Olson, 2002), the study was directed to include as many human factors in the analysis as possible. However, the scope did include consideration of roadway and vehicle factors as well although they were not emphasized. The analysis included a tentative consideration of countermeasures.

The study was aimed at identifying current conditions in Louisiana and comparing them with peer states (Alabama, Arkansas, Colorado, Kentucky, Mississippi, Oklahoma, and Tennessee) and the nation. To get a representative picture of current conditions, the most recent six years of data available at the start of this study (1994-2004) was used, although some aspects of the study used local data up to 2006 (e.g., investigation of the impact of legislation on road safety).

METHODOLOGY

Introduction

The basic approach adopted in this study was to use data of past crashes to identify the characteristics of crashes where Louisiana has unusually high values when compared to other states. When possible, Louisiana is compared to peer states; otherwise, comparisons are drawn to national averages. The data used in the analysis, and the method used to conduct the analysis to draw comparisons, develop countermeasures, and prioritize their application are explained below.

Data

Data used in this study included the FARS, GES, the Highway Safety Research Group crash database, the DOTD crash database, and the DOTD segment data for the period 1999 - 2004. These data sources were reviewed and are described in the Phase I report of the project (Wilmot et al., 2005). The LSU Highway Safety Research Group Web site, which is maintained by Louisiana State University, was also used to obtain additional information, such as demographics of driver and population. Traffic Safety Fact documentation from the National Highway Traffic Safety Administration (NHTSA) was also accessed.

The FARS database consists of an annual record of all fatal crashes in the U.S. by state and was used to compare Louisiana's fatal crash record with peer states. FARS contains data on approximately 40,000 fatal crashes per year. The GES database contains an annual, national sample of police-reported traffic crashes of all severity levels. It was used to compare Louisiana's crash record with the nation as a whole. The GES data set contains information on approximately 50,000 crashes per year.

The Louisiana Crash Database, which is a relational database, has several tables including a crash table, vehicle table, occupancy table, pedestrian table, and two tables related to train-related crashes. The train-related crash tables were not used in this analysis. For the period of six years from 1999 to 2004, the crash table has 962,210 records; the vehicle table has more than 1,828,325 records; the pedestrian table has 9,864 records, and the occupancy table has 494,163 records.

The DOTD crash database is an aggregated version of the Louisiana crash database, with additional roadway information such as average daily traffic and road geometric data added to it. This additional information was available only for state and national highways; parish and city roads were excluded. All the data were stored in one crash table that has 962,284 records.

In general, crash databases have information on the crashes, vehicles, and persons involved. Crash information includes general crash characteristics and the environmental and roadway conditions at the time of each crash; vehicle information describes the vehicles involved in each crash; and person information describes the characteristics of the people involved in the crashes: drivers, passengers, pedestrians, and pedal cyclists.

The combined databases were reviewed for integrity and quality. A thorough understanding of the variables and their relationships were obtained. The query functions in Microsoft Access were used as the main tool for data query. The queries were often presented in the form of pivot tables to facilitate data retrieval.

The Louisiana crash databases record crash severities in five categories: fatal, incapacitating/severe, non-incapacitating/moderate, possible/complaint, and no injury. These five crash severities were converted into fatal, injury, and property damage only (PDO) crashes in the analysis conducted in this study. Fatal crashes correspond to severity 1; injury crashes include severities 2 through 4, and PDO are equivalent to 5 on the original five-category scale.

The data provides two ways of determining alcohol-related crashes. The first involves reported driver Blood Alcohol Content (BAC) level (> 0), driver alcohol presence (yes), and driver condition (drinking). If any of those variables are positive, the crash is considered alcohol-related. However, BAC levels or other alcohol-identifying properties of the driver are not always reported, resulting in underreporting of alcohol-related crashes if only reported alcohol-involvement is relied upon (Pollock et al., 1987; Williams and Wells, 1993; McCarthy et al., 2009). The NHTSA routinely imputes alcohol involvement in the FARS database for cases where direct evidence of alcohol involvement is not available (Rubin, Schafer, and Subramanian, 1998; NHTSA, 2002a). A similar process has been applied to the Louisiana crash database by the Highway Safety Research Group (HSRG) in the Department of Information Systems and Decision Sciences (ISDS) at LSU to add imputed estimates of alcohol-involvement in the Louisiana data set (Schneider, 2005). In this procedure, 11 variables from the crash record are used to infer alcohol use including reported alcohol use, hour of the day, day of the week, crash severity, driver restraint system use, driver age, driver gender, vehicle body type, number of vehicles involved, most harmful event, and violations charged. The Louisiana crash database includes this variable of estimated alcohol-related crashes. A cross tabulation of reported and estimated alcohol-related crashes from the Louisiana crash database are shown in Table 1. Within each crash severity category, the percentages show the percentage satisfying both conditions simultaneously. For example, among fatal crashes, both methods agree on 54.0 percent of the cases as being not related to alcohol and 30.4 percent of the cases as being alcohol-related. However, the estimation method identifies a further 15.1 percent as involving alcohol that were not designated as such in the reported method. The percentages in each severity category add up to 100 percent.

Table 1
Comparing estimated alcohol and reported alcohol involvement

Estimated alcohol involvement	Reported alcohol involvement (%)					
	Fatal		Injury		PDO	
	no alcohol	alcohol	no alcohol	alcohol	no alcohol	alcohol
no alcohol	54.0	0.5	89.5	0.1	94.7	0.0
alcohol	15.1	30.4	2.3	8.1	1.8	3.5

As expected, the results indicate that more alcohol-related crashes are identified using the estimated method than the reported method, because many alcohol-related cases go unreported. The more severe the crash, the greater the proportion of alcohol-related crashes.

Identification of Traffic Safety Problems in Louisiana

DOTD identified seven states as peers for transportation comparison purposes. The states were selected using a wide array of measures, including population, congestion, safety, and budget. The official peer states of Louisiana are Alabama, Arkansas, Colorado, Kentucky, Mississippi, Oklahoma, and Tennessee. Texas and Florida were also included in the analysis even though they are not peer states.

FARS contains fatal crash data by state and thus allows comparison of the fatal crash characteristics between Louisiana and peer states. The GES database, on the other hand, has data on crash severity (fatal, injury, and PDO) but does not have data at the state level. GES is based on a random sample of police jurisdictions in the country and, therefore, provides an estimate of national conditions. This enabled researchers to draw comparisons between Louisiana (using Louisiana safety databases) and the rest of the nation with respect to crashes of different severities.

During the comparison, FARS, GES, and the Louisiana crash database were employed. Effort was made to compare every relevant variable available for comparison. Examples of the variables that were used in the analysis are: roadway functional class, roadway alignment, roadway profile, roadway surface conditions, traffic control devices, traffic flow, age of the driver and occupants, injury severity, alcohol and drug involvement, restraint systems use, vehicle maneuver, most harmful event, licensing state, rollover, vehicle speed, body type, commercial vehicles, violations charged, previous driving while intoxicated (DWI) convictions, temporal and atmospheric conditions, most harmful event, light condition, and manner of collision. Statistics such as the crash rate per 100 million vehicle miles traveled, per 1,000 licensed drivers, or by functional class of roadway, were also compared to assess Louisiana's traffic safety status in the nation and among peer states.

It is typical in safety analysis to account for exposure when reporting crash statistics so as to account for the opportunity for crashes to occur by the presence of more or less traffic. Thus, rather than report the total number of crashes occurring on a facility per year, it is generally more meaningful to express crash incidence in terms of the number of crashes per 100 million vehicle miles traveled on the facility. Other rates may also be used, such as crashes per million population, per 1000 licensed drivers, per registered vehicle, or per lane mile, but these denominators in the rate calculation are generally not good measures of crash exposure. More bothersome though, is the fact that the value of the denominator in the rate calculation is often not known for subpopulations in which researchers are interested. For example, for subdivisions of the population distinguished by age, gender, or ethnic group, the denominator of vehicle miles traveled (VMT) is not known, and therefore the crash rate accounting for exposure cannot be established. Other subdivisions of the data, such as alcohol-related versus non alcohol-related crashes, or vehicles with different numbers of occupants, create the same problem. In fact, the more data are broken down into subdivisions, the more difficult it becomes to express crashes as a rate in terms of VMT, or other less pertinent denominators such as population, drivers, registered vehicles, or lane miles of highway. Unfortunately, it is essential to break down crashes in Louisiana if the source of the elevated crash statistics is to be identified.

The approach adopted in this study to identify aberrant subgroups was to observe where the proportion of crashes in these subgroups in Louisiana were different to those in peer states, or in the nation. For example, the proportion of alcohol-related crashes in Louisiana were compared to the proportion of alcohol-related crashes in peer states, and the proportion of fatalities in a certain age group were compared between Louisiana and elsewhere. In addition, the rate of change in the proportion of crashes of different types were observed over time. This was done to detect whether conditions were deteriorating or improving over time.

The comparison was conducted by statistically comparing the proportion of crashes by category between Louisiana and those in peer states or the nation. Because the FARS and GES datasets generated approximately 40,000 and 50,000 observations per year, respectively, the number of observations in each category was expected to be large enough to justify a normal approximation to the binomial distribution and use of the following test statistic to test the significance of the difference in proportions between the test and control datasets in each category (Freund, 2004):

$$z = \frac{\frac{x_1}{n_1} - \frac{x_2}{n_2}}{\sqrt{p^*(1-p^*)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \qquad (1)$$

where,

x_1 = crash frequency of the crash category tested in the Louisiana data,
x_2 = crash frequency of the same crash category in the control data (peer state or nation),
n_1 = total crash frequency in the Louisiana data,
n_2 = total crash frequency in the control crash data, and

$$p^* = \frac{x_1 + x_2}{n_1 + n_2}$$

The null hypothesis is that the two proportions are the same. The alternative hypothesis is that the proportion of crashes in Louisiana is higher than in the control crash data (i.e., it is a one-sided test). Subsequently, if the test statistic above is larger than the normal standard deviate at the 95 percent level of significance (1.64), the null hypothesis is rejected, indicating over representation of crash rates in Louisiana relative to the control environment.

To quantify the degree of over representation, an over representation factor (ORF) was developed to indicate by its magnitude the degree to which conditions in Louisiana exceed those elsewhere. The ORF is defined as:

$$ORF = \frac{x_1}{n_1} \bigg/ \frac{x_2}{n_2} \qquad (2)$$

Clearly, if the ORF is less than one, the crash category in Louisiana is under-represented, and, conversely, if larger than one, the classification is over represented. However, an over represented area is not necessarily a problem area of traffic safety; rather, it is a potential problem area only. For example, if rural two-lane road crashes in Louisiana are over-represented, it may indeed mean rural two-lane roads in Louisiana have more traffic safety problems, but it may also mean that Louisiana has proportionately more rural two-lane roads, so a greater proportion of the crashes in the state occur on these types of roads. Thus, further analysis of over-represented areas is often warranted to determine whether they represent safety problems or not. ORFs were calculated for fatal, injury, and PDO crashes separately, as well as for all crashes combined.

It must be noted that the test identifying a significant positive difference in proportion of crashes of a certain category, or an ORF in excess of one does not necessarily indicate that crashes in the category in question are more prevalent in Louisiana than elsewhere. If conditions in the two environments (Louisiana and that of the comparison area) are the same, then the difference in proportions will provide similar results to those that would be obtained with a statistic that was normalized for exposure and other possible differences. However, when the conditions in the two environments are different, the difference in proportions will be biased up or down depending on the nature of the difference in environments. To accommodate this, ORFs were used only as an indicator of a potential problem in this study, and ORFs of a certain magnitude were required before further investigation was conducted. In addition, confirmation of a problem by large ORFs in associated categories was required before the ORF was allowed to motivate further investigation of the crash category.

Categories of crashes with moderate to severe potential safety problems were considered for inclusion in the initial list of problem areas. The criteria used to classify categories as moderate to severe problem areas were based on the ORF and the proportion of cases the category forms of the whole. The former represents how serious the problem area is in Louisiana and the latter how widespread it is. For example, if crashes involving 15-year-old drivers in Louisiana were found to be over represented, the ORF and the proportion of 15-year-old drivers among all drivers in Louisiana were taken into account. Those areas with at least five percent of crash percentage and an ORF of at least 105 percent were first selected. However, if an area had an ORF of at least 200 percent, then the area was selected no matter how small the crash percentage was. Considerable effort was made to include as many human factor areas in the analysis as possible. This first selection was conducted for fatal, injury, and PDO crashes as well as for total crashes.

The list of areas from the first selection was then reviewed and some areas were eliminated. Reasons for elimination included not having enough sample size for the area, items for which reported values were possibly biased or incorrect, data incompatibility between GES and Louisiana Crash Database, or the two databases having disproportionate amounts of missing data. If the sample size was too small, then the confidence of the ORF was compromised; if the definition of a variable was different in the two databases, then the ORF would be meaningless; if the two databases had disproportionate amounts of missing data, then the ORF value would not be reliable.

In the final preparation of the list of problem areas, more detailed analysis was conducted on the Louisiana safety data. The objective was to try to find the root cause of the problems behind the high ORF and crash percentages. Whether the identified categories were the source of the problem, or whether they were merely correlated with other variables that were the cause of the problem, was investigated. For example, if the age of a driver was found to be significant in describing high crash rates, it was explored whether age, or factors associated with age such as inexperience, caused the high crash rates. The product of this process was a final list of the major factors associated with traffic safety problems in Louisiana.

The methodology above employed compared conditions in Louisiana with conditions in peer states or the nation. However, it is sometimes more convenient, or more appropriate, to compare conditions in different categories within the same data set. When this occurs, it is no longer comparing like with like, and the above procedure employing ORFs no longer applies. For example, with the procedure using ORFs to measure the comparison, it is appropriate to compare the proportion of crashes involving 15-17 old drivers in Louisiana with the proportion of crashes of similar aged drivers in other states. However, to compare the proportion of crashes of 15-17 old drivers with the proportion of crashes of another age group in the same data set, the problem of exposure arises. That is, how much do the two groups travel and, therefore, how much are they each being exposed to the possibility of being in a crash. Under these conditions, the ORF is no longer an appropriate measure since the denominators in the proportions are the same, and the ORF therefore becomes the number of crashes in the two age groups. This does not reflect relative crash rate but the ratio of crash incidence (i.e., crash occurrence), and crash incidence is heavily affected by exposure (i.e., presence on the road). For example, if there are more drivers in one age group than another, or if one age group travels more than the other, a large number of crashes in one group may be due to greater exposure rather than a greater tendency to have a crash.

Some researchers have developed measures that incorporate exposure within the formulation of their crash statistic (Thorpe, 1967; Carr, 1970). The most popular of these methods is the so-called Quasi-Induced Exposure Technique. In this method, the number of not at fault drivers in multi-vehicle crashes is taken as a proxy for exposure; the larger the number of not at fault drivers, the greater the assumed exposure. Crash propensity is measured by a statistic called the Relative Crash Involvement Ratio (RCIR), which is defined as the ratio of proportion of drivers at fault in a specific subgroup to the drivers not at fault from the same subgroup. For both single and multi-vehicle crashes, RCIR is calculated using not at fault drivers for multi-vehicle crashes in the denominator. If the RCIR is greater than one, it indicates that the particular subgroup of drivers is more prone to cause crashes. For example, if data being analyzed show that among young drivers (e.g., drivers aged 15-17) there were 16,000 single-vehicle crashes of which 12,000 involved male drivers, and 20,000 multi-vehicle crashes in which 7,500 male drivers and 12,500 female drivers were considered not at fault, then the RCIR for young male and young female drivers in single-vehicle crashes is:

$$\text{RCIR}_{\textit{young male drivers in single-vehicle crashes}} = \frac{12{,}000/16{,}000}{7{,}500/20{,}000} = 2.0$$

$$\text{RCIR}_{\textit{young female drivers in single-vehicle crashes}} = \frac{4{,}000/16{,}000}{12{,}500/20{,}000} = 0.4$$

The quasi induced exposure technique was used in this study to measure the effect passengers have on the safety record of teenage drivers. The effect of age and gender of passengers and driver on road safety were studied using this approach.

Other problem areas studied in greater detail in this study include the effect of graduated driving license laws on safety, the effect of mandatory helmet law on motorcycle crashes (after repeal in 1999 and reenactment in 2004), the effect of blood alcohol content law on both motor vehicle and motorcycle crashes, and, finally, the effect of open container law on alcohol crashes.

To study the effect of legislation on crash rates, 20 percent of the data from the LADOTD crash database was collected from 1995-2006. The data for the 12 years were combined into one dataset. In the analysis, crash rate per month per unit population at each severity level was used as the dependent variable. Four models were developed for each law investigated for both motorcycle and motor vehicle crashes. Analysis of Variance (ANOVA) was used to identify the effects of different independent factors on crash rate for each crash severity type.

Traffic laws were included among the independent variables in the form of dummy variables and the significance of the dummy variable used to determine the significance of the law. Initially, the variables which influenced crash rate were identified using one way ANOVA and then the effect of traffic laws on crash rate in the presence of these variables was studied using two-way ANOVA. If a variable was identified as significant in influencing crash rates in both tests, it was included in identifying the effectiveness of legislation along with other variables for further analysis.

Safety Performance Functions

A safety performance function is an expression describing the relationship between the frequency or severity of crashes and features or characteristics of a road on which the crashes occur. Safety performance functions serve multiple purposes. First, they can be used as a means of identifying contributing factors/problem areas in place of ORFs (over-representation factors) or RCIRs (Relative Crash Involvement Ratios). Second, safety performance functions help identify effective countermeasures by quantifying their safety impact.

In this study, a crash severity prediction model was developed that uses human and roadway characteristics to predict crash severity given a crash has occurred. An ordered mixed logit model was found to estimate these conditions most accurately. Fifteen independent variables were considered as candidate variables: driver's age, driver's seatbelt use, driver's alcohol involvement, vehicle operating speed, driver ejected from the vehicle, airbag deployed, head-on collision, driver distracted, reckless driving, failing to yield, tailgating, obscured vision, driver gender, curved roadway crashes, and rural two-lane highway crashes. The independent variables were evaluated based on the sign and the significance of the coefficients of the factors. Goodness of fit was measured by the likelihood ratio index and by comparing the aggregated shares of each severity level with the observed shares where aggregated shares are the average probability of a crash at each severity level that the model predicted for all the drivers involved in a crash times the total number of drivers.

The model was used to evaluate the impact on severity of a percentage change in alcohol involvement, seatbelt use, and vehicle operating speed. Published crash reduction factors were used to estimate the percentage change in crashes that would result from a particular countermeasure, and then the model was used to estimate the countermeasure's effect on crash severity. The safety impact of countermeasures was assessed using the aggregated share of crashes at each severity level before and after the implementation of a countermeasure.

Development of Countermeasures/Strategies

For each of the major causes of Louisiana traffic safety problems identified, strategies and countermeasures were developed. One of the major sources of potential countermeasures was the National Cooperative Highway Research Program (NCHRP) Report 500, which provides countermeasures and guidance for implementation in the 22 emphasis areas of the American Association of State Highway and Transportation Officials (AASHTO) highway safety plan. Effort was made to estimate the performance of each strategy and countermeasure quantitatively through the assessment of a crash reduction factor (CRF). A CRF is defined as the percentage crash reduction that is expected to follow implementation of a given countermeasure. A related measure, an accident modification factor (AMF), is the factor current crashes can be multiplied by to estimate the number of crashes that will occur after implementation of a countermeasure. An AMF is (1-CRF) of the same countermeasure. For example, a CRF of 10 percent is equivalent to an AMF of 0.9.

One of the countermeasures for which there is little information on CRFs is legislation − either in promulgating new laws or changing existing laws. In order to have a better understanding of the impact of legislation on certain problem areas such as alcohol-related and teenage driver crashes, a special investigation was conducted to determine the impact of past legislation on crashes in Louisiana. As mentioned earlier, Analysis of Variance was used to estimate the effect of legislation on crashes in Louisiana in the presence of other factors.

Prioritization of Countermeasure/Strategies

Countermeasures were evaluated based on a measure that combines the need, performance, and cost of a countermeasure into a single value:

1. Need is the extent to which conditions in Louisiana are inferior to conditions elsewhere. To estimate need, the difference in the number of crashes in Louisiana and the nation at each severity level is multiplied by the standard cost of a crash at that severity level and summed over the severities.
2. Performance is measured by the reduction in crashes that it is estimated would result from implementing the countermeasure, where the reduction is measured in dollars in the same way as need was measured previously.

3. Cost is the estimated cost of implementing the countermeasure.

It is postulated that priority is directly related to need and performance (i.e., priority increases as need increases and the ability of the countermeasure to alleviate that need improves) and inversely related to the cost of the countermeasure. Thus, a priority index is formulated that increases with increased need and performance and decreases with increased cost:

$$Priority\ index = \frac{Need * Performance}{Cost} \qquad (3)$$

The magnitude of the index reflects the priority of the countermeasure; a value of zero indicates no priority (i.e., no motivation for implementation), while increasing positive values of the index signify increasing priority. By multiplying the extent of the problem (as expressed by need) by how much it can be improved (measured by performance), a measure of achievable alleviation is obtained. By dividing this by the cost, a measure of alleviation efficiency is established. Thus, countermeasures that receive the highest priority are those that address serious remediable problems at lowest cost.

It is worthwhile noting that the priority index formulated in equation (3) differs from the benefit/cost (B/C) ratio approach often adopted in selecting among countermeasures in other studies. A B/C ratio is obtained by dividing performance by cost. Benefit/cost ratios measure investment efficiency and therefore prioritize by return on investment. Interestingly, the Sufficiency Rating approach often used to prioritize road improvements uses the opposite approach; it uses the need to establish priority and neglects performance. Using the product of need and performance and dividing by cost, as done in this study, ensures priority is awarded to cases where need alleviation is achieved most efficiently

The cost of implementing certain countermeasures may be difficult to estimate. In these cases, if benefit/cost ratios are available, they can be multiplied by need (as defined above) to estimate a priority index comparable to that established in equation (3).

In this study, a Fuzzy Inference System (FIS) was developed to prioritize countermeasures based on cost, need, and performance (Akbarzadeh, 2009). The system allows an analyst to assign different levels of importance to need, performance, and cost to accommodate situations where the importance of each component is different. For example, in a situation where safety is observed to be particularly deficient in relation to peer states but the economic climate in the state is good, a ranking of need as the most important criterion, followed by performance as less important, and cost as the least important criterion would be appropriate. Conversely, poor economic conditions and moderate safety needs would suggest the reverse of the previous ranking.

The inference system is capable of being run under all six possible permutations of decision criteria. In developing the procedure, input on problem severity was gathered from previous research on safety conditions in Louisiana, and research conducted as part of the development of the Traffic Safety Manual was used to estimate cost and the crash reduction potential of individual countermeasures.

DISCUSSION OF RESULTS

Louisiana's General Traffic Safety Status

To objectively estimate Louisiana traffic safety status, commonly used criteria were used. These criteria included crash rates per 100 million vehicle miles traveled (VMT), per 100,000 population, per 100,000 registered vehicles, and per 100,000 licensed drivers. Data used were mainly from FARS, GES and the Louisiana Crash Database.

As mentioned earlier, in this study Louisiana's crash record was compared to seven peer states, Florida, Texas, and the national average. Figure 1 presents the fatality rates per 100 million VMT from 1999 to 2004. The results indicate that almost all peer states have higher fatality rates than the US average, and for the most recent statistics reported in the analysis, Louisiana is the third worst among the peer states. However, the trend is downward in Louisiana, which is not the case for some peer states.

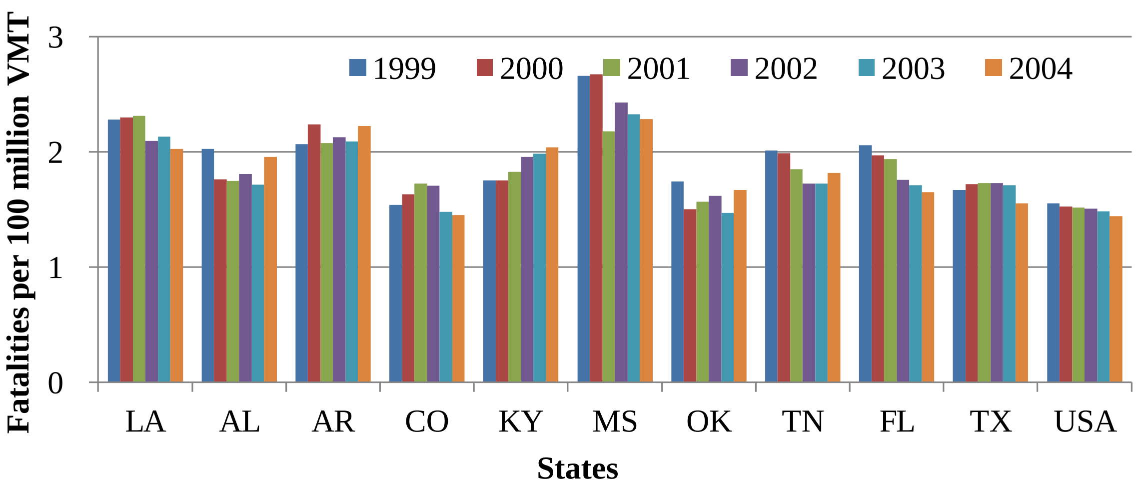


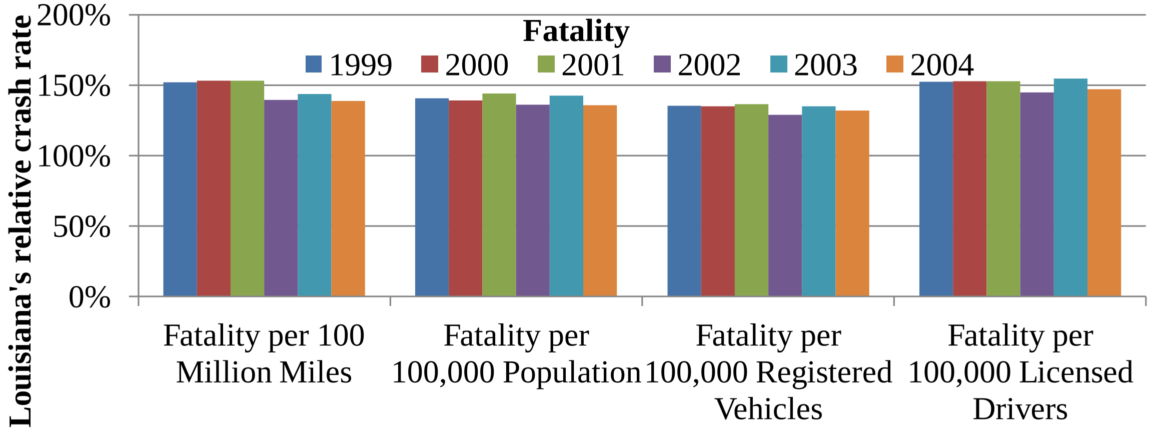
Figure 1
Comparison of fatality rates among states

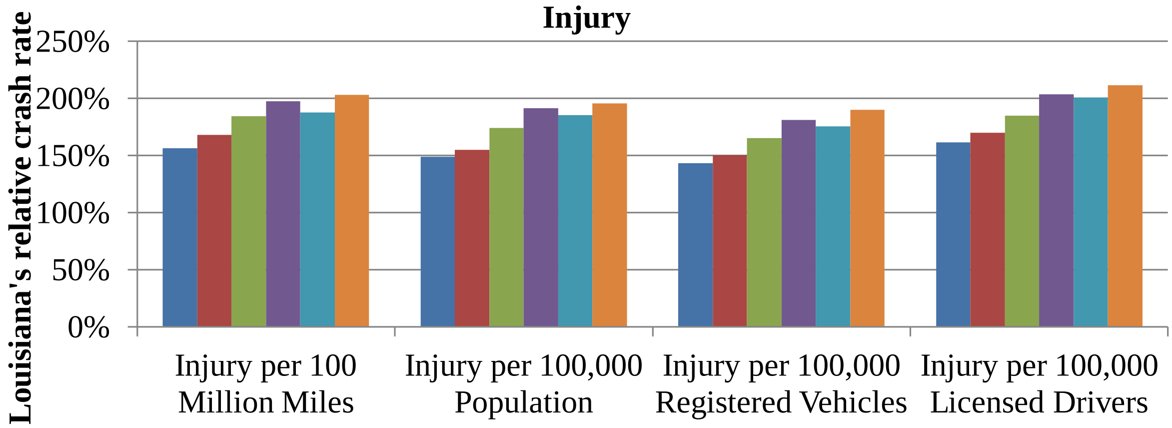
Figure 2 presents the relative crash rates between Louisiana and the US average for fatal, injury, and PDO crashes. The relative crash rates were created by dividing the Louisiana rates by the US rates for fatalities per 100 million VMT, per 100,000 population, per 100,000 registered vehicles, and per 100,000 licensed drivers. Although it is not possible to ensure that the definition of crashes in Louisiana and other states are consistent, according to the statistics, Louisiana is considerably over represented in all four criteria for fatal, injury, and PDO crashes. However, the trends of the past six years show that Louisiana's status is unchanged or somewhat improving for fatal crash, but significantly worsening for injury crash, and marginally worsening for PDO crash. The information on the number of licensed drivers was taken from HSRG data because the definition of the total number of licensed drivers from the Highway Statistics was not consistent from 1999 through 2004.

A review of the information in Figure 2 confirms the poor road safety record in Louisiana in comparison to peer states and to the nation as a whole. Among the eight states in the peer group, Louisiana is second or third worst (depending on what year is being considered) in fatal crash rate, and has a 30-50 percent higher fatality rate, 45-100 percent higher injury rate, and a 0-20 percent higher PDO rate than the rest of the country. In addition, conditions are worsening in injury and PDO crash rates over time.

As explained in the methodology section, after calculating the ORFs, areas with ORF larger than 105 percent and crash percentages of at least five percent were selected. Those areas with ORF larger than 200 percent were also selected irrespective of their crash percentages. The product of the ORF and the crash percentage of an area provides a convenient measure of the importance of the problem because it reflects both the intensity and extent of the deficiency. Thus, an important problem would be one in which an intense deficiency is identified within an extensive portion of all crashes. If either the intensity or extent of the problem is limited, the problem is average, and is minor if either the intensity or extent of the problem is limited.

Table 2 lists the FARS comparison results and Table 3 shows the GES comparison results, together with the importance measures (i.e., the product of ORFs and crash percentage) shown as importance (IMP) in the table.





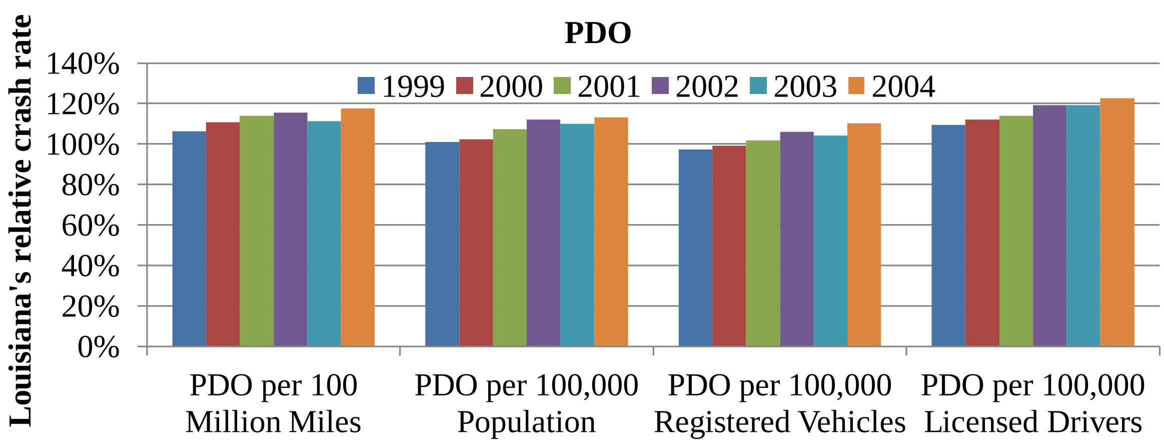


Figure 2
Relative crash rates by severity

Table 2
Problem areas based on FARS comparison

General Area	Specific Area	Crash% (1)	ORF_{peer} (2)	ORF_{USA} (3)	IMP_{peer} (1)*(2)	IMP_{USA} (1)*(3)
Human factor	Alcohol-related fatalities	45.8	1.22	1.17	55.88	53.59
Posted Speed	Under 25 mph 35 mph 50-60 mph 70 mph	2.1 27.6 38.4 23.7	2.62 1.31 1.06 1.24	3.52 1.09 1.21 1.75	5.50 36.16 40.70 29.39	7.39 30.08 46.46 41.48
Driver age	Age 18-20 21-24 25-34 Male 18-20 Male 21-24 Male 25-34 Female 18-20 Female 21-24 Female 25-34	10.3 11.8 21.7 10.2 12.2 22.0 10.5 10.5 20.7	1.07 1.11 1.06 1.09 1.13 1.08 1.03 1.05 1.03	1.07 1.09 1.07 1.07 1.10 1.06 1.08 1.11 1.09	11.02 13.10 23.00 11.12 13.79 23.76 10.82 11.03 21.32	11.02 12.86 23.22 10.91 13.30 23.32 11.34 11.66 22.56
Driver with alcohol	Age 25-34 35-44 Male age 21-24 Male age 25-34	28.6 23.6 17.8 29.1	1.04 1.01 1.08 1.08	1.07 1.07 0.97 1.09	29.74 23.84 19.22 31.43	30.60 25.25 17.27 31.72
Highest BAC	>0.8 <0.8	15.2 3.5	1.15 1.49	1.02 1.19	17.48 5.22	15.50 4.17
Driver Licensure	a) CDL invalid b) Non-CDL license c) Endorsement not complied with d) Not licensed or not valid license	11.7 17.1 0.6 17.2	2.81 1.43 13.75 1.35	2.07 1.52 6.11 1.40	32.88 24.45 8.25 23.22	24.22 25.99 3.67 24.08
Vehicle body type	a) Light truck & Van b) Buses c) Motorcycles	31.6 0.4 5.3	1.09 1.17 1.23	1.21 0.70 0.95	34.44 0.47 6.52	38.24 0.28 5.04
Vehicle Type	Hazardous cargo	0.8	2.18	2.11	1.74	1.69
Vehicle Maneuver	a) slowing/stopping in traffic lane	1.3	1.30	1.07	1.69	1.39

(continued)

	b) Starting in traffic lane c) Stopped in traffic lane d) changing lanes/merging	2.1 3.7 4.6	1.84 1.59 3.99	2.03 1.19 2.59	3.86 5.88 18.35	4.26 4.40 11.91
Violations charged	a) reckless/careless/hit-and-run	5.3	3.32	2.82	17.60	14. 95
	b) equipment	0.6	3.08	3.03	1.85	1.82
	c) impaired offenses	1.6	2.10	1.54	3.36	2.46
	d) non-moving license and registration violations	1.0	1.41	1.41	1.41	1.41
	e) rules of the road-wrong side, passing & following	0.6	3.93	3.00	2.36	1.80
	f) rules of the road-Turning, yielding, signaling	0.6	2.08	1.36	1.25	0.82
Occupants Seatbelt use	a) Overall seatbelt use:					
	Not used	45.6	0.94	1.13	42.86	51.53
	b) By age:					
	Female <5	5.5	1.03	1.17	3\5.67	6.44
	Female 25-34	16.2	1.11	1.12	17.98	18.14
	Male 16-20	13.6	1.09	1.00	14.82	13.60
	Male 25-34	19.7	1.12	1.10	22.06	21.67
	Male 35-44	18.1	1.04	1.06	18.82	19.19
	c) Type:					
	None	45.6	0.94	1.13	42.86	51.53
	Shoulder belt	1.2	2.89	2.11	3.47	2.53
	Child seat used improperly	0.4	4.50	3.59	1.80	1.44
	Lap & shoulder belt	47.7	1.17	0.98	55.81	46.75
	d) By age:					
	16-20	13.9	1.07	1.01	14.87	14.04
	21-24	9.6	1.15	1.08	11.04	10.37
	25-34	18.4	1.12	1.11	20.61	20.42
Pedestrian by age	1<5	3.3	1.26	1.16	4.16	3.83
	5-15	9.8	1.42	1.25	13.92	12.25
	16-20	7.1	1.12	1.10	7.95	7.81
	21-24	7.7	1.39	1.34	10.70	10.32
	25-34	14.7	1.14	1.13	16.76	16.61
Vehicle Body type	a) Light Truck & Van	31.6	1.09	1.21	34.44	38.24
	b) Large Trucks	9.3	1.00	1.08	9.30	10.04
	c) Motorcycles	5.3	1.23	0.95	6.52	5.04
Temporal	a) Hour of the Day:					
	1	8.0	1.08	0.93	8.64	7.44
	2	10.5	1.46	1.16	15.33	12.18

(continued)

	3 23 b) Day of the week: Saturday	6.3 8.7 27.1	1.26 1.13 1.09	1.12 1.13 1.11	7.94 9.83 29.54	7.06 9.83 30.08
Speed Limit	<=35 55	17.6 38.4	1.18 1.06	0.85 1.21	20.77 40.70	14.96 46.46
Relation to Roadway	a) Shoulder b) Off Roadway-Location unknown c) Median d) On roadway	5.6 13.4 2.4 56.3	1.78 1.02 1.06 1.08	0.96 1.60 0.78 0.96	9.97 13.67 2.54 60.80	5.38 21.44 1.87 54.05
Relation to Junction	a) Rail grade crossing b) Driveway, Alley access etc. c) Entrance/exit ramp related d) Intersection	1.5 1.4 1.0 19.6	1.65 1.15 3.00 1.41	2.26 1.01 2.25 1.09	2.48 1.61 3.00 27.64	3.39 1.41 2.25 21.36
Traffic way Flow	a) Not Physically divided(2-way) b) Not Physically divided(2 way with left-turn lane) c) Divided Highway-Median Strip(with traffic barrier)	69.1 27.2 0.9	0.98 1.15 2.93	1.06 1.16 1.03	67.72 31.28 2.64	73.25 31.55 0.93
Number of travel lanes	a) Rural 2 lane: Major collector Principal arterial-interstate b) Urban 2 lane: Other principal arterial Minor arterial Principal arterial-interstate	 33.8 13.7 37.0 25.3 12.6	 1.43 1.15 1.33 1.19 1.07	 1.33 1.42 1.38 1.08 1.74	 48.33 15.76 49.21 30.11 13.48	 44.95 19.45 51.06 27.32 21.92
Roadway Signing	Interstate U.S.Highway State Highway	14.4 17.5 47.3	1.09 0.75 1.54	1.13 1.07 1.69	15.70 13.13 72.84	16.27 18.73 79.94
Functional class	a) Urban: Other principal arterial Minor arterial	 37.2 24.5	 1.21 1.24	 1.23 1.21	 45.01 30.38	 45.76 29.65

(continued)

	Collector	8.7	1.07	1.24	9.31	10.79
	b) Rural:					
	Principal arterial-interstate	14.3	1.21	1.17	17.30	16.73
	Major Collector	33.4	1.45	1.42	48.43	47.43
Traffic control device	a) Railroad-passive devices	71.1	1.49	1.53	105.94	108.78
	b) Highway traffic signal					
	Flashing	15.3	3.91	3.73	59.82	57.07
	Traffic signal on colors	16.2	3.46	3.37	56.05	54.59
	c) Rail grade crossing passive devices (aggregate)	1.1	2.52	3.54	2.77	3.89
	d) Highway traffic signal(aggregate)	5.2	1.07	0.67	5.56	3.48
	e) No control devices:					
	Major collector	24.4	1.45	1.73	35.38	42.21
	Principal arterial-interstate	11.7	1.17	1.33	13.69	15.56
	Minor collector	8.0	0.77	1.71	6.16	13.68
	Minor arterial	7.2	1.54	1.00	11.09	7.20
	Other principal arterial	9.0	1.38	0.92	12.42	8.28
Most Harmful event	a) Collision with fixed object	23.2	0.91	1.09	21.11	25.29
	b) Collision with object not fixed	11.2	1.62	1.07	18.14	11.98
First harmful event aggregated	a) Collision with fixed object	34.4	0.92	1.12	31.65	38.53
	b) Collision with object not fixed	15.7	1.61	1.03	25.28	16.17
	c) Ditch	7.0	1.70	2.73	11.90	19.11
	d) Tree	9.7	0.79	1.12	7.66	10.86
	e) Culvert	3.2	1.01	2.01	3.23	6.43
	f) Railway train	1.5	1.62	2.30	2.43	3.45
	g) Immersion	0.4	4.60	3.26	1.84	1.30
	h) Pedal cycle	2.5	2.95	1.27	7.38	3.18
	i) Pedestrian	11.4	1.54	0.91	17.56	10.37
Manner of collision	a) Front-to-front	7.7	1.49	1.62	11.47	12.47
	b) Front-to-rear	4.7	1.77	1.64	8.32	7.71
	c) Front-to-side/angle direction not specified	1.3	3.87	2.37	5.03	3.08
	d) Rear-to-side/right angle	0.2	2.03	1.23	0.41	0.25

(continued)

Hit and Run	Hit pedestrians	2.7	2.29	1.07	6.18	2.89

ORF_{peer} = Over representation factor with respect to peer states
ORF_{USA} = Over representation factor with respect to all states in the nation
Crash % = Percentage of crashes in the specific area
IMP_{peer} = Importance of the over representation with respect to peer states
IMP_{USA} = Importance of the over representation with respect to all states

Table 3
Problem areas as identified from GES comparison

General Area	Specific Area	ORF_{USA}	Crash(%)	IMP_{USA}
Inadequate driver attention	inattentive/distracted/illness/fatigued/ apparently asleep/blacked out (ALL CRASHES)	1.38	1.44	1.99
	inattentive/distracted/illness/fatigued/ apparently asleep/blacked out (FATAL CRASHES)	2.69	17.72	47.61
	inattentive/distracted/illness/fatigued/ apparently asleep/blacked out (INJURY CRASHES)	1.23	3.41	4.19
	inattentive/distracted/illness/fatigued/ apparently asleep/blacked out (PDO CRASHES)	1.42	0.94	1.33
Driver alcohol involvement	alcohol (FATAL CRASHES)	1.31	38.92	50.99
Driver age	18-20	1.06	11.41	12.09
	21-24	1.11	12.17	13.51
	25-34 (ALL CRASHES)	1.02	21.91	22.35
	18-20	1.39	11.39	15.83
	21-24	1.22	12.05	14.70
	25-34 (FATAL CRASHES)	1.09	20.26	22.08
	18-20	1.06	11.46	12.15
	21-24	1.13	12.78	14.44
	25-34 (INJURY CRASHES)	1.04	22.18	23.07
	18-20	1.05	11.40	11.97
	21-24	1.10	12.01	13.21
	25-34 (PDO CRASHES)	1.02	21.85	22.29

(continued)

Driver ejected	ejected (FATAL CRASHES)	1.51	34.54	52.16
Occupant age	25-34 45-54 (FATAL CRASHES) 25-34 (INJURY CRASHES) 25-34 (PDO CRASHES)	1.09 1.17 1.20 1.08	12.82 8.69 13.15 11.07	13.97 10.17 15.78 11.96
Occupant seating position	first row seat-right side second row seat-right side (FATAL CRASHES)	1.04 1.07	61.56 12.40	64.02 13.27
Number of Occupants	2 3 4-14 (ALL CRASHES) 2 3 4-14 (FATAL CRASHES) 2 3 4-14 (INJURY CRASHES) 2 3 4-14 (PDO CRASHES)	0.97 1.20 2.16 1.17 1.77 2.78 1.30 1.75 2.95 0.78 0.86 1.56	18.74 7.07 8.22 26.71 16.90 21.08 32.74 14.36 17.32 13.89 4.54 5.07	18.18 8.48 17.76 31.25 29.91 58.60 42.56 25.13 51.09 10.83 3.90 7.91
Pedestrian age	0-14 21-24 25-34 35-44 (ALL CRASHES) 0-14 21-24 25-34 35-44 (FATAL CRASHES) 0-14 21-24 25-34 35-44 (INJURY CRASHES) 0-14 18-20 (PDO CRASHES)	1.04 1.23 0.84 1.05 1.46 0.75 1.49 2.15 3.82 0.67 1.13 1.26 4.08 7.30	38.80 6.49 11.12 13.00 12.25 6.71 14.26' 21.31 33.69 7.15 12.15 13.62 60.80 3.60	40.35 7.98 9.34 13.65 17.89 5.03 21.25 45.82 128.70 4.79 13.73 17.16 248.06 26.28
Pedestrian gender	female (FATAL CRASHES) female (PDO CRASHES)	1.35 1.13	42.18 39.67	56.94 44.83

(continued)

Vehicle cargo type	van/enclosed box cargo tank (ALL CRASHES) van/enclosed box cargo tank (FATAL CRASHES) van/enclosed box cargo tank (INJURY CRASHES) van/enclosed box cargo tank (PDO CRASHES)	1.24 2.37 1.36 1.16 1.25 1.76 1.26 2.47	42.18 12.80 41.77 27.85 38.55 12.16 43.29 12.87	52.30 30.34 56.81 32.31 48.19 21.41 54.55 31.79
Vehicle type	light truck/pickup/SUV (ALL CRASHES) light truck/pickup/SUV(FATAL CRASHES) light truck/pickup/SUV (INJURY CRASHES) light truck/pickup/SUV (PDO CRASHES)	1.99 2.82 1.75 2.04	29.40 33.04 25.46 30.38	58.51 93.17 44.56 61.98
Vehicle year	1981-1985 (ALL CRASHES) 1981-1985 (FATAL CRASHES) 1981-1985 (INJURY CRASHES) 1981-1985 (PDO CRASHES)	1.06 1.64 1.00 1.04	4.46 6.76 4.92 4.20	4.73 11.09 4.92 4.37
Temporal effect	day of the week (ALL CRASHES) Saturday Sunday Tuesday time of the day (ALL CRASHES) 0 hr 1 hr 2 hr 3 hr 4 hr 5 hr day of the week (FATAL) Saturday Sunday Tuesday time of the day (FATAL)	 1.31 1.28 1.00 0.99 1.00 1.10 1.06 1.16 1.05 0.88 1.08 1.20 	 17.44 13.34 14.73 1.76 1.52 1.60 1.11 1.04 1.33 15.09 17.22 14.06 	 22.85 17.08 14.73 1.74 1.52 1.76 1.18 1.21 1.40 13.28 18.60 16.87

(continued)

	0 hr	1.32	5.08	6.71
	1 hr	1.15	4.71	5.42
	2 hr	1.28	5.38	6.89
	3 hr	1.40	3.29	4.61
	4 hr	1.43	3.01	4.30
	5 hr	1.17	3.09	3.62
	<u>day of the week</u> (INJURY CRASHES)			
	Saturday	1.02	14.43	14.72
	Sunday	0.99	11.09	10.98
	Tuesday	0.97	14.11	13.69
	<u>time of the day</u> (INJURY CRASHES)			
	0 hr	1.11	2.02	2.24
	1 hr	1.12	1.78	1.99
	2 hr	1.18	1.84	2.17
	3 hr	1.16	1.28	1.48
	4 hr	1.33	1.19	1.58
	5 hr	1.28	1.44	1.84
	<u>day of the week</u> (PDO CRASHES)			
	Saturday	1.02	13.20	13.46
	Sunday	0.96	9.60	9.22
	Tuesday	0.99	14.68	14.53
	<u>time of the day</u> (PDO CRASHES)			
	0 hr	0.93	1.62	1.51
	1 hr	0.95	1.38	1.31
	2 hr	1.06	1.47	1.56
	3 hr	1.01	1.02	1.03
	4 hr	1.08	0.96	1.04
	5 hr	0.95	1.27	1.21
Relation to roadway	off roadway-location	2.55	6.90	17.60
	shoulder (ALL CRASHES)	2.62	2.71	7.1
	off roadway-location	3.38	20.69	69.93
	shoulder (FATAL CRASHES)	1.37	2.80	3.84
	off roadway-location	2.43	8.30	20.17
	shoulder (INJURY CRASHES)	1.75	1.99	3.48
	off roadway-location	2.64	6.19	16.34
	shoulder (PDO CRASHES)	3.10	3.03	9.39
Work zone	(ALL CRASHES)	1.88	3.40	6.39
	(FATAL CRASHES)	2.95	5.66	16.70
	(INJURY CRASHES)	1.75	2.84	4.97

(continued)

	(PDO CRASHES)	1.86	3.50	6.51
Traffic way flow	Not physically divided One way Physically divided (ALL CRASHES) Not physically divided One way Physically divided (FATAL CRASHES) Not physically divided One way Physically divided (INJURY CRASHES) Not physically divided One way Physically divided (PDO CRASHES)	1.04 2.72 1.24 1.10 1.92 0.90 1.03 2.77 1.14 1.05 2.65 1.30	55.56 11.61 29.97 67.60 4.14 26.71 56.58 10.47 30.60 55.03 12.17 29.69	57.78 31.58 37.16 74.36 7.95 24.04 58.28 29.0 34.88 57.78 32.25 38.60
Functional class	interstate (ALL CRASHES) interstate (FATAL CRASHES) interstate (INJURY CRASHES) interstate (PDO CRASHES)	1.30 0.59 1.41 1.26	9.72 7.17 9.94 9.61	12.64 4.23 14.02 12.11
Manner of collision	angle head-on rear end (ALL CRASHES) angle head-on rear end (FATAL CRASHES angle head-on rear end (INJURY CRASHES) angle head-on rear end (PDO CRASHES)	0.84 0.73 1.10 0.87 1.13 0.94 0.89 0.64 1.11 0.81 0.82 1.09	25.43 1.44 32.80 18.68 11.34 6.86 29.71 2.14 33.18 23.57 1.06 32.82	21.36 1.05 36.08 16.25 12.81 6.45 26.44 1.37 36.83 19.09 0.87 35.77
Lighting condition	dark but lighted dark (ALL CRASHES) dark but lighted dark (FATAL CRASHES) dark but lighted dark (INJURY CRASHES)	1.16 0.69 1.25 1.20 1.14 0.95	17.14 7.98 19.91 32.22 17.79 9.98	19.88 5.51 24.89 38.66 20.82 9.48

(continued)

	dark but lighted dark (PDO CRASHES)	1.17 0.58	16.81 6.94	19.67 4.03
Driver restraint System	not used shoulder belt used only (ALLCRASHES) not used shoulder belt used only (FATAL CRASHES) not used shoulder belt used only (INJURY CRASHES) not used shoulder belt used only (PDO CRASHES)	1.16 5.38 1.10 1.58 0.93 3.57 0.87 6.33	5.92 3.83 60.32 1.36 10.52 2.94 3.02 4.34	6.87 20.60 66.35 2.15 9.78 10.50 2.63 27.47
Occupant restraint system	not used child safety seat (ALL CRASHES) not used child safety seat (FATAL CRASHES) not used child safety seat (INJURY CRASHES) not used child safety seat (PDO CRASHES)	0.96 0.81 1.09 2.44 0.77 1.23 0.97 0.80	11.66 6.90 59.96 3.26 14.37 5.47 10.00 7.68	11.19 5.59 65.36 7.95 11.06 6.73 9.7 6.14
Violations charged	running a traffic signal/stop sign speed related failure to yield (ALL CRASHES) running a traffic signal/stop sign speed related failure to yield (INJURY CRASHES) running a traffic signal/stop sign speed related failure to yield (PDO CRASHES)	1.75 8.63 2.13 1.59 7.04 1.79 1.81 9.82 2.21	2.52 0.63 10.12 3.05 1.05 8.88 2.39 0.52 10.43	4.41 5.44 21.56 4.85 7.39 15.90 4.33 5.11 23.05
Vision obscured	trees & bushes (ALL CRASHES) trees & bushes (PDO CRASHES)	3.56 3.61	0.41 0.41	1.46 1.48

(continued)

The investigation of specific features of recorded crashes in Louisiana and their comparison with the same features from data in peer states or the nation, produced the results shown in Tables 2 and 3. Based on this information, the following potential problem areas were identified for further analysis:

Driver Characteristics:

1. Driver age and gender
2. Driver physical and mental condition
3. Driver seatbelt usage
4. Driver violations, including running a traffic signal or stop sign and speeding
5. Driver alcohol
6. Motor cyclist
7. Young drivers
8. Driver licensing

Occupant Characteristics:

9. Number of occupants
10. Restraint system use

Pedestrian Characteristics:

11. Pedestrian age
12. Pedestrian alcohol use

Roadway Characteristics:

13. Highway class
14. Relation to roadway
15. Traffic way flow, including one-way streets and roadways without physical separation
16. Rail grade crossing and highway traffic control
17. Posted speed limit

Crash Characteristics:

18. First harmful event, including ditch, tree, culvert, railway train, and pedestrian
19. Most harmful event, including collision with fixed object, collision with object not fixed for fatal
20. Manner of collision, including head-on (fatal), rear end, and side swipe
21. Day of the week and time of the day
22. Emergency medical services

Vehicle Characteristics:

23. Cargo type

As described in the Methodology, identification of areas in which Louisiana is over represented in crash statistics often requires further analysis to identify the root of the problem. Detailed analysis of the problem areas was conducted as described below.

Detailed Analysis of Problem Areas

Analysis of Driver Characteristics

Driver Age Distribution. The ORF by driver age for different crash severities based on GES and the Louisiana crash database showed that drivers from 18 to 34 were over represented, with fatal crashes being seriously over represented among drivers between 18 and 24 years of age. The problem diminishes as drivers approach 34 years of age but Louisiana's young drivers clearly have inferior crash records to their peers in other states.

The crash rates per 100,000 licensed drivers for fatal and injury crashes by driver gender are presented in Figure 3. Drivers from 15-17 and 18-20 had the highest crash rates for all crash severities. Crash rates decrease as driver ages increase above 21. However, for drivers 75+, fatal crash rates increase again. Drivers under 21 years of age were more than three times more likely to have a fatal crash than those between the ages of 55-64, and more than four times more likely to experience an injury or PDO crash than 65- to 74-year-old drivers. Moreover, there is a huge difference in fatal crash rates between male and female drivers. Male drivers are two to three times more likely to be involved in fatal crashes than female drivers. However, at the injury level, the difference between male and female is marginal.

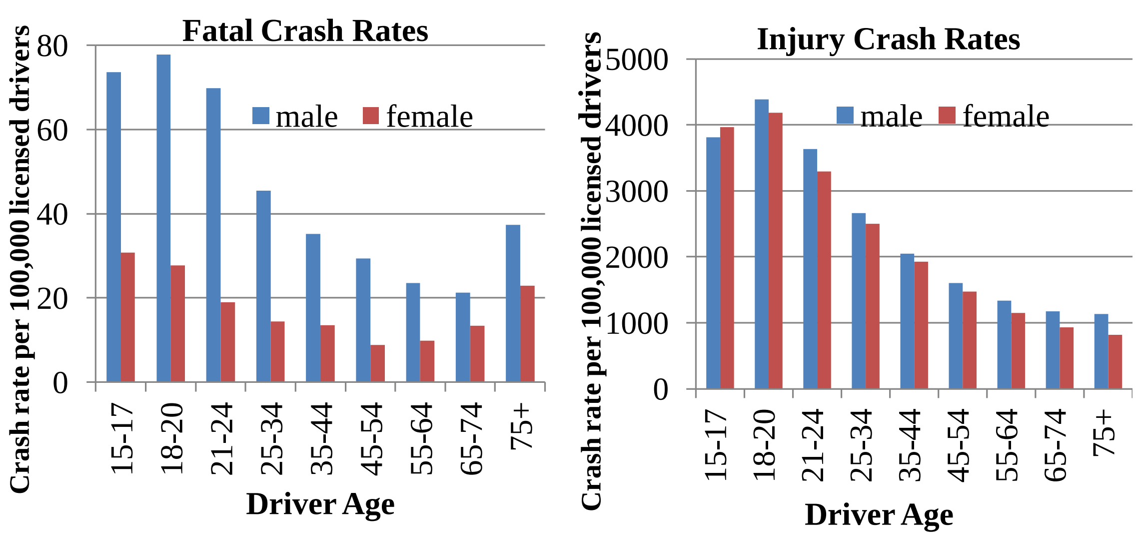


Figure 3
Fatal and injury crash rates per 100,000 licensed drivers by gender

Driver Physical and Mental Condition. Of the crashes reported to be due to various driver physical and mental impairments such as inattention, distraction, illness, fatigue, falling asleep, or blacking out, almost 97 percent were due to inattention or distraction. When analyzed by hour of day, total crashes related to the above impairments were more dominant during daytime when most travel occurs. However, percentages for fatal crashes were higher than injury and PDO crashes late at night and in the early morning.

Figure 4 gives the crash rates per 100,000 licensed drivers by age group for fatal crashes for inattention, distraction, illness, fatigue, falling asleep, and blacking out. The rates for injury and PDO crashes were higher than for fatal crashes but followed a similar pattern and hence are not presented here. Figure 4 shows how crash rates for physical and mental impairments of the driver differ significantly by age group. One of the possible explanations for the high crash rate for young drivers is the impact that occupants can have in distracting a driver. This matter is investigated further later in the report where the impact of occupants on young drivers is found to be significant. The increased rate of crashes among older drivers as they age is probably due to impaired perception, slower cognition, and reduced reaction times.

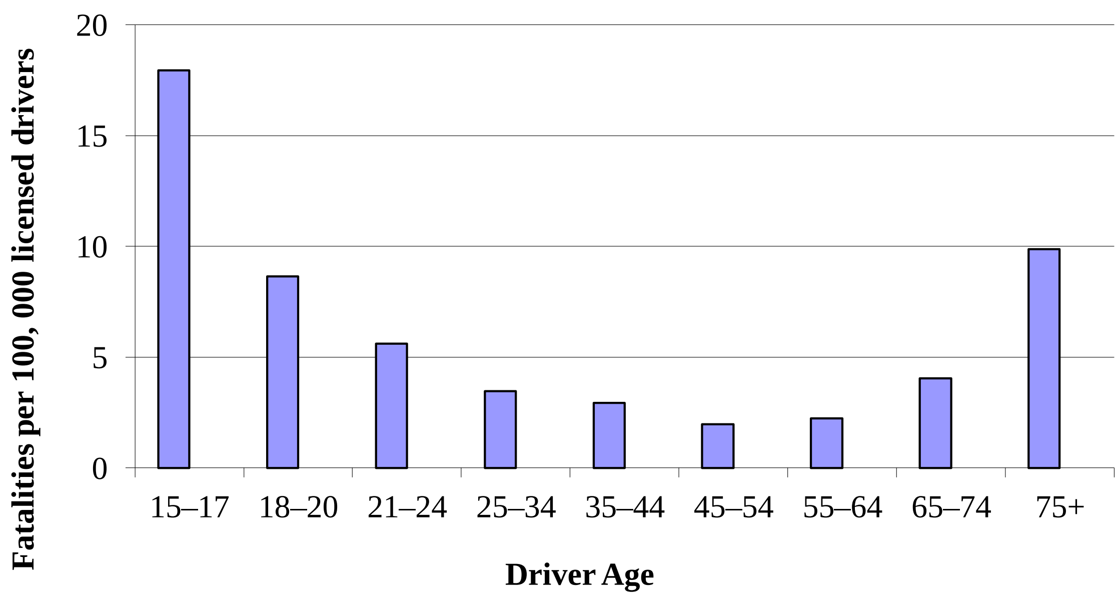


Figure 4
Fatalities due to inattention/distraction/illness/fatigue/sleep/blackout by age

Driver Seatbelt Use. According to a recent study by the National Highway and Traffic Safety Administration (NHTSA, 2008), seatbelt use in Louisiana was 74.8 percent, compared to 81 percent of US average. Compared to the peer states, Louisiana was in the middle tier among peer states with higher seat-belt use rates than Arkansas, Kentucky, and Mississippi. The rates were for overall seatbelt use and were not limited to driver seatbelt use only.

In terms of driver seatbelt use, Louisiana has been trailing the national average. In particular, Louisiana has a higher non-use rate for fatal crashes according to the data from GES and Louisiana crash database from 1999 to 2004, with an ORF of 1.1. Louisiana was also highly over represented for using shoulder belt only for all severities, although the percentage of crashes involving the use of shoulder belt only was relatively small (1.5 percent, 3.0 percent, and 4.3 percent for fatal, injury, and PDO crashes, respectively). Using both shoulder and lap belts obviously provides better protection during crashes, and the incidence of this violation in comparison with the national average was extremely high (ORF of 1.6, 3.5, and 6.3 for fatal, injury, and PDO crashes respectively).

Figure 5 presents the percentages of seatbelt non-use for fatal, injury, and PDO crashes for all drivers and for crashes that were alcohol-related using the Louisiana crash data. It can be seen that non-use increases as crash severity increases. Alcohol-related crashes have much higher seatbelt non-use than all crashes combined.

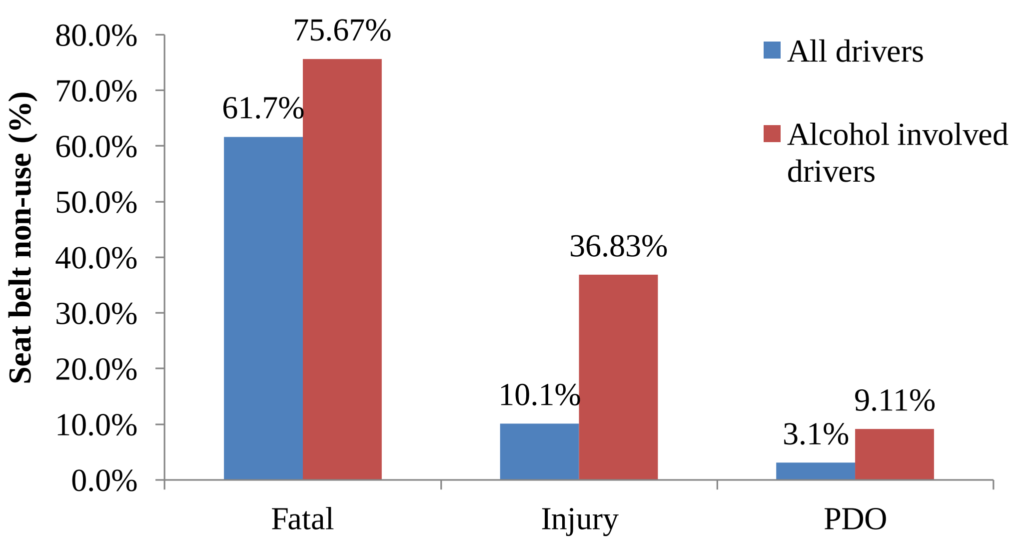


Figure 5
Seatbelt non-use by severity: all drivers vs. alcohol involved drivers

Violations Charged. Speed-related violations and disregarding traffic controls, are violations that are over represented by more than 200 percent in Louisiana but account for only 1.8 percent and 4.7 percent of all violations respectively. Using the DOTD database, crash distributions of these two types of violations were analyzed further.

The DOTD crash database has information on highway type for state and US highways, but such information is not available for parish and city roads. Using crash data on state and US highways from the Louisiana Crash Database, the percentage of crashes involving speed-related violations by highway type is shown in Figure 6. It should be noted that since it is difficult to identify speed being related to the crash after the crash has occurred, reported speed-related violations are not necessarily reliable. However, the inaccuracy in reporting is expected to be similar among different types of roads, and as can be seen in Figure 6, a large portion of speed-related crashes are reported to occur on rural two-lane roads. This is not due to more travel occurring on these roads because Figure 7 shows that only 30 percent of all travel occurs on rural two-lane roads in Louisiana. In Figure 6, rural two-lane highways account for 50.6, 37.9, and 32.9 percent of the fatal, injury, and PDO speed-related crashes in Louisiana, respectively, thus far outstripping the number of crashes expected from the amount of travel on these roads, especially for injury and fatal crashes.

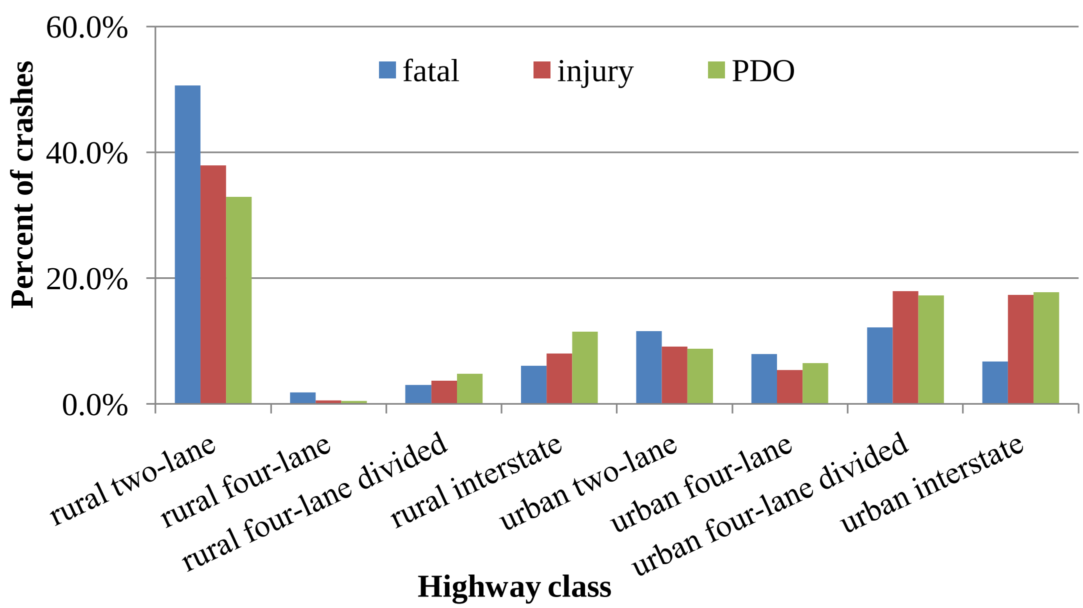


Figure 6
Highway type distribution for speed-related crashes

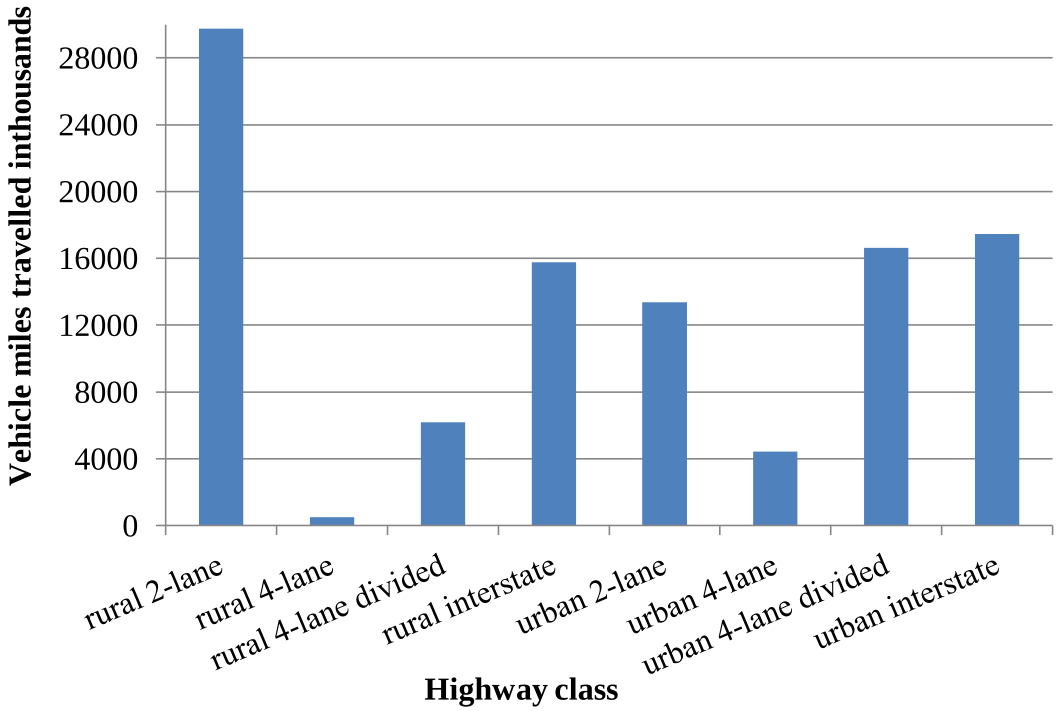


Figure 7
Vehicle miles travelled by highway class

The distribution of crashes resulting from disregarding traffic controls is different to that of speed-related crashes. Injury and PDO crashes resulting from this violation occur more on rural two-lane highways with percentages of 49.5 and 53.4, respectively, whereas fatal crashes are more evenly distributed across highway types with a percentage of 25.6 on rural two-lane highways. Among disregarding traffic controls violations, 36 percent of violations involved disregarding stop signs and 48 percent running red lights. A detailed analysis is provided in the section on Highway Traffic Control.

Drivers aged 18 to 44 constitute the majority of speed-related and disregarding traffic control violations. However, this is because it is the largest group of drivers. Teenagers (15-17 and 18-20) are only 8.3 percent of all licensed drivers, but they contributed 30.0 percent and 20.0 percent of the violations, respectively. To provide a comparison among different age groups of drivers, Figure 8 presents the violations per 100,000 licensed drivers by age of driver for speed-related and disregarding traffic control violations. Crash rates are the lowest for drivers aged 45-64. The rates for 15- to 17-year-old drivers are the highest, followed by 18- to 20-year-old drivers. The highest and lowest crash rates differ by an order of four (for disregarding traffic control) to 14 times (for speed related). Between these two violations, speed-related violations were more serious for teenager drivers when both the percentages and the rates were taken into consideration. Among fatal crashes, 6.1 percent of the crashes were speed-related.

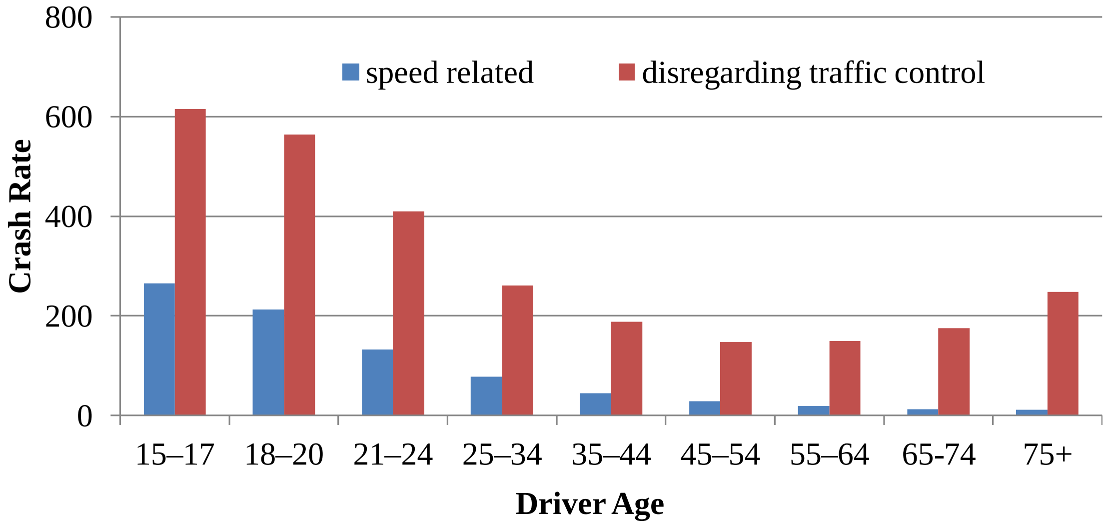


Figure 8
Crash rates per 100,000 licensed drivers by type of violation and driver age

Driver Alcohol. In 2004, 45.5 percent of fatalities were alcohol-related (Schneider, 2005). According to Traffic Safety Facts published by the National Highway Traffic Safety Admininstration (NHTSA, 2005), in terms of percentages of alcohol-related fatalities, Louisiana ties with Texas and is higher than the peer states, Florida, and the US average. Louisiana is 17 percent higher than the national average for alcohol-related fatalities. In terms of the fatality rate per 100,000 licensed vehicles, Louisiana was 8 percent and 56 percent higher than the peer states and the national average, respectively, in 2004 (NHTSA, 2005). These analyses clearly indicate the seriousness of alcohol-related crashes in Louisiana.

An analysis of the ORF of alcohol-related crashes by driver age indicated that drivers from 15 to 44 were over represented for fatal crashes. The problem was especially serious for age group 18-20 with an over representation factor of over 140 percent. Injury crashes were over represented for ages from 25 to 44; PDO crashes were over represented for drivers from 21 to 44.

After subtracting alcohol-related crashes, 15- to 17-year-old drivers were no longer over represented. This suggests that alcohol is the prime factor causing drivers of this age in Louisiana to have more crashes than drivers of the same age elsewhere. On the other hand, when alcohol-related crashes were removed from 18- to 20- and 21- to 24-year-old drivers, they were still over represented. This suggests that for these drivers, alcohol was only one of the reasons for over representation and other reasons also existed. Nonetheless, if we further subtract the crashes for violation-related crashes (including speeding and disregarding traffic controls) and for driver conditions (including inattention/distraction and drinking impaired), which 18- to 20-year-old drivers had much higher rates than most other age groups, the over representation for 18- to 20-year-old drivers almost disappears (the ORF becomes only 104.5 percent). This indicates that alcohol, speeding, disregarding traffic control, and inattention/distraction are a large part of the causes of over representation for 18- to 20-year-old drivers in Louisiana, if not all.

Motorcyclists. In 2004, registered motorcycles were under 1.5 percent of all registered motor vehicles in Louisiana. However, motorcycle related fatalities were 7.2 percent of all traffic fatalities, and 44.8 percent of the motorcycle fatalities were alcohol-related, according to the Louisiana Crash Database from 1999 to 2004.

Further studies revealed that from 1999 to 2004, motorcycle crashes increased by 88.1 percent, 78.9 percent, and 58.5 percent for fatal, injury, and PDO, respectively. During the same period, registered motorcycles increased by only 30.2 percent. Thus, crash rates per registered motorcycle increased by 44.5, 37.5, and 21.7 percent for fatal, injury, and PDO crashes, respectively. A better measure would be crash rate per vehicle mile traveled if it is assumed that travel per vehicle varied between 1999 and 2004, but travel by motorcycle in Louisiana was unknown at the time of the analysis. As shown in Figure 9, motorcycle crash rates are increasing over time in Louisiana.

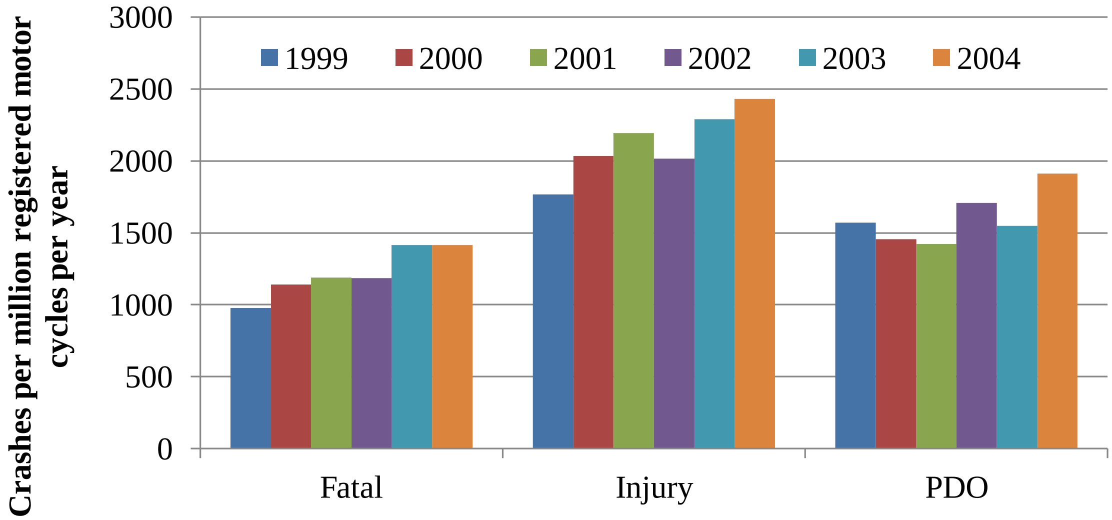


Figure 9
Motorcycle crash rates by year by severity in Louisiana

Unlike motor vehicle crashes, motorcycle crash percentages were found to peak on Saturday and Sundays, especially on Saturday, for all crash severities. The crash percentages were higher for alcohol-related motorcycle crashes compared to alcohol-related motor vehicle crashes.

An analysis of gender indicated that 94.5 percent of all motorcycle crashes and 98.2 percent of fatal crashes were male drivers. In terms of age distribution, most motorcycle crashes (about 70 percent) occurred among drivers aged 25 to 54, a much smaller percentage (less than 10 percent) among young drivers 15-20, and little (less than 3 percent) among older drivers (65+). The results were consistent among fatal, injury, and PDO crashes.

Louisiana enacted a universal helmet law in 1982. This was later amended in August 1999 to require helmet use by motorcycle operators and passengers under the age of 18 and riders 18 and older not holding medical insurance coverage of at least $10,000 (NHTSA, 2003). The universal helmet law was reinstated in August 2004. Therefore, part of 1999 and 2004 and all of 2000 to 2003 covered the period when the amended motorcycle law was in effect. Figure 10 gives the percentage helmet use for motor cyclists in crashes from 1999 to 2004 derived from the Louisiana crash database. It is obvious that helmet use decreased sharply from 1999 to 2003, and the decline was reversed in 2004 when mandatory helmet use was reinstated. Those who were involved in fatal crashes clearly had lower helmet use rates than those involved in injury and PDO crashes. It can be seen in Figure 10 that the helmet use decline from 1999 to 2003 was associated with increased fatal and injury crash rates, which were partially caused by the growth in the number of registered motorcycles.

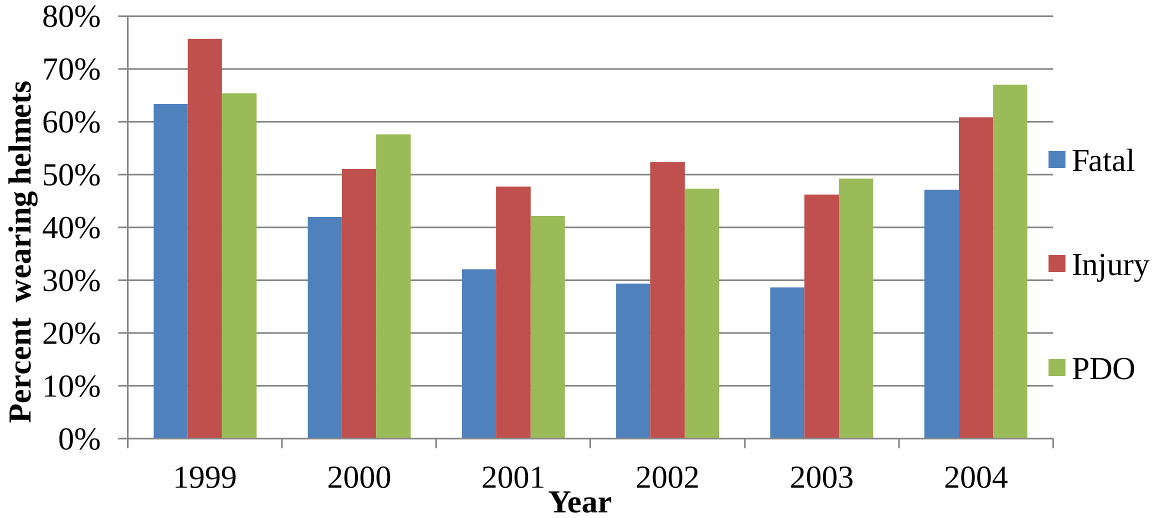


Figure 10
Louisiana motor cyclist percent helmet use from 1999-2004

From 1999 to 2004, alcohol-related motorcycle crash rates per 100,000 registered motorcycles for fatal and injury crash increased by 57.7 percent and 33.7 percent for fatal and injury crashes, respectively. This indicated that alcohol-related motorcycle fatal crash rate in Louisiana had been increasing faster than motorcycle fatal crash rates (57.7 percent vs. 44.5 percent), while the reverse was true for injury and PDO crash rates. This faster increase of motorcycle fatal crash rate coexisted with the low helmet use rate. However, a detailed study of the effectiveness of the helmet laws in Louisiana (Mudumba, 2008) concluded that when the influence of other factors were taken into account (e.g., age and gender of motorcycle drivers and passengers), there was insufficient evidence at the 95 percent level of significance to conclude that the repeal of the mandatory helmet law in 1999 and the reenactment of the mandatory helmet law in 2004 had a significant impact in changing motorcycle crash rates at all severity levels in Louisiana. It should be noted that the analysis did show a change in motorcycle crash rates in response to the change in helmet laws, but the probability that the change was significant was less than 95 percent .

Figure 11 presents the percentage of alcohol-related crashes over all crashes for motor cyclists and for all motor vehicle crashes. Motor cyclists had higher alcohol-related crashes than all motor vehicle drivers for all severities; they were 6.1, 45.7, and 88.3 percent higher for fatal, injury, and PDO crashes than for motor vehicle drivers. Obviously, alcohol is a more serious problem for motorcycle riders than for motor vehicle drivers.

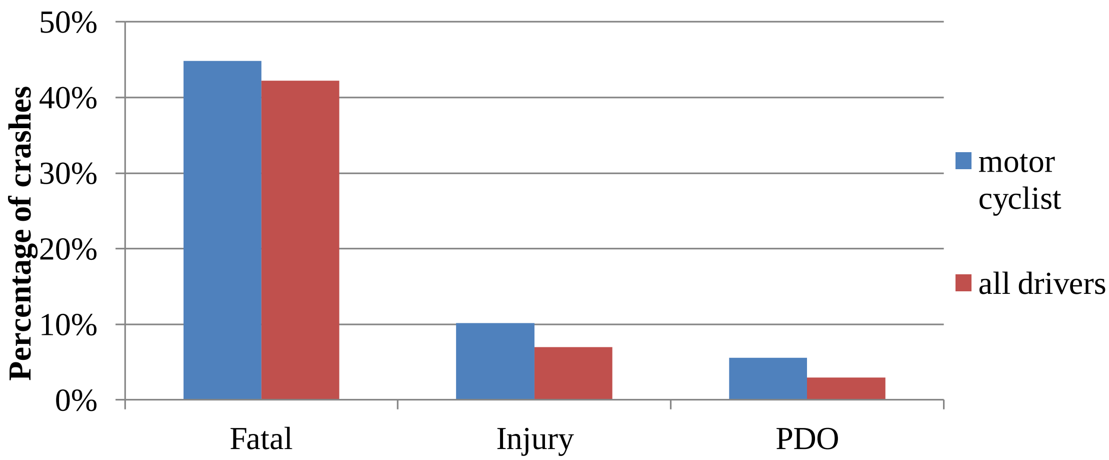


Figure 11
Percent of alcohol-related crashes for motor cyclists and all drivers

Two major types of motorcycle violations were careless operation and speeding. Careless operations were 43.0 percent, 55.4 percent, and 36.1 percent of motorcycle crashes for fatal, injury, and PDO. Speeding (either exceeding the stated speed limit or the safe speed limit) was the second most dominant violation for motor cyclists. They accounted for almost 20 percent of motor cyclist fatalities.

A query to the Louisiana crash database on motor cyclist license compliance indicated that 22 percent of motor cyclists who had a crash did not have a valid license for motorcycles they were operating and 3 percent were not licensed at all.

Young Drivers. As discussed earlier, 18- to 20-year-old drivers were over represented for fatal crashes, and 15- to 20-year-old drivers were over represented for driver alcohol-related fatal crashes. Fatal crash rates due to inattention/distraction were highest for 15- to 17-year-old drivers. The rates for 18- to 20-year-old drivers were also high, next only to 15- to 17- and 75+-year-old groups. Finally, 18- to 20-year-old drivers had the highest alcohol-impaired fatal crash rate.

Young driver crash characteristics are investigated intensively in this section. Two methods were used; one employs crash risk, while the other uses the quasi-induced exposure technique. Crash risk was measured either by crash rate (number of crashes per 100,000 licensed drivers) or relative crash risk (the ratio of the crash rates between the young drivers and the reference group of drivers 21 years or older). The definitions of young drivers and peer passengers also differed slightly between the two methods. For the method using crash risk, young drivers were from 15 to 20 years of age and they were further divided into two age groups: 15-17 and 18-20; passengers were grouped into 15-17, 18-20, and 21+. When using the quasi-induced exposure technique, young drivers were defined as 15-21 years of age and they were further divided into 15, 16-17, and 18-21 age groups; passengers were grouped into solo (no passenger), peer (from 12 to 24), and adult/child (at least one passenger older than 24 or younger than 12). Individual aspects of young driver behavior in the presence of passengers are reported below.

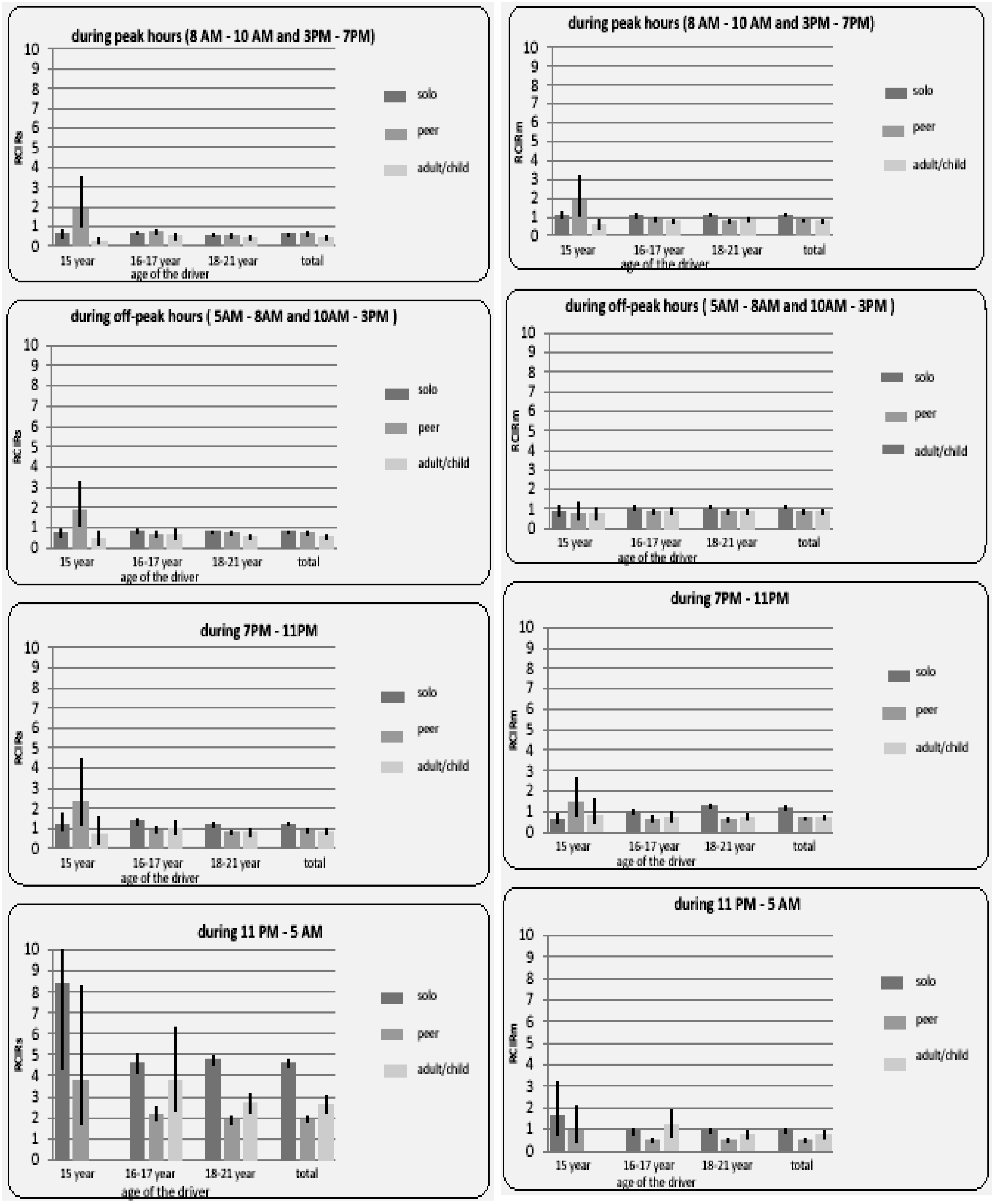
Temporal Distribution. The driving behavior of young drivers during dark and various traffic conditions may vary depending on the presence or absence of passengers in the vehicle. The Graduated Driver's Licensing (GDL) law in Louisiana clearly states that young drivers under the age of 17 are not supposed to drive unsupervised between 11 p.m. and 5 a.m. This prompted the comparison of crash rates during peak hours, off peak hours, and after dark hours among young drivers. The after dark hours were further categorized to find the crash rates during 11 p.m. and 5 a.m. when young drivers were not legally allowed to drive in Louisiana according to the GDL. Figure 12 presents the single-vehicle relative crash involvement ratio (RCIR) by the time of the day. The upper and lower 95 percent confidence limits are presented by black lines.

It can be seen from Figure 12 that the RCIR values for single-vehicle crashes are very high for young drivers below 18 years of age between 11 p.m. and 5 a.m. even with adult supervision. This clearly indicates the poor safety record young drivers generate that time of the night. Young drivers driving alone after dark have higher single-vehicle RCIR values than two-vehicle values, showing that young drivers are more susceptible to the conditions promoting single-vehicle crashes after dark than older drivers.

In Figure 12 the value for the single-vehicle and two-vehicle crashes involving a 15-year-old driver with an adult/child passenger between 11 p.m. and 5 a.m. was not attainable as there was no two-vehicle crashes reported during that time for the period of study (1999-2004) in which the 15-year-old driver involved was not-at-fault for the crash. Hence the denominator in the equation was zero and the crash involvement ratio could not be computed.

In terms of the day of the week, there was not much difference in RCIR values for two-vehicle for all groups of passenger and driver classifications showing that there was not much influence of the day of the week on multi-vehicle crashes. However, RCIR values of single-vehicle crashes were higher over the weekend for solo and peer groups, which could be due to the social activities of young people during the weekends. It should be noted that RCIR values are high for 15-year-old drivers with peer group passengers throughout the week, which infers that 15-year-olds are more likely to be involved in a crash at any time when accompanied by peers.

Seatbelt Use by Gender and by Number of Passengers. In order to investigate the relationship between the number of crashes and young driver risk-taking behavior, crash incidence by use of safety restraint systems was considered. The notion adopted was that drivers who do not use the mandatory safety restraints display greater risk taking behavior, and subsequently can be identified as risk-takers. Single-vehicle crash RCIR ratios for drivers who did not use safety restraints are presented in Figure 13. The results show that the single-vehicle RCIR ratios were very high when no safety restraints were used, suggesting that risk-taking young drivers had considerably higher crash rates of all crashes than those who do not display the risk-taking behavior of not wearing safety restraints.



single-vehicle **two-vehicle**

Figure 12
RCIR values by time of day

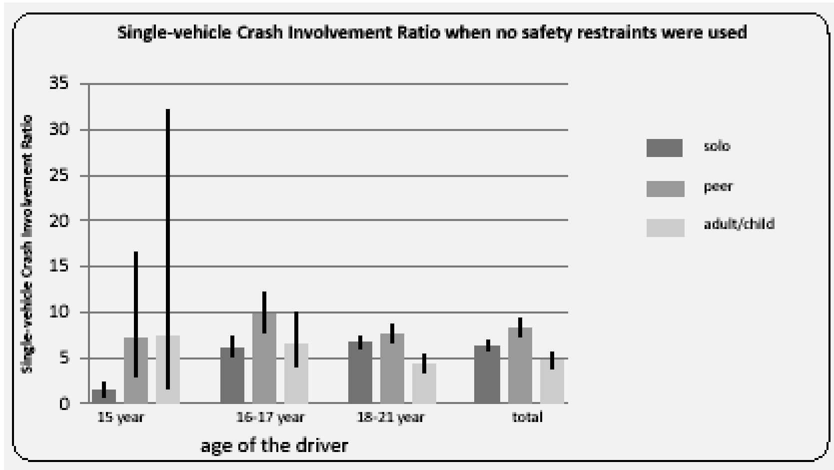
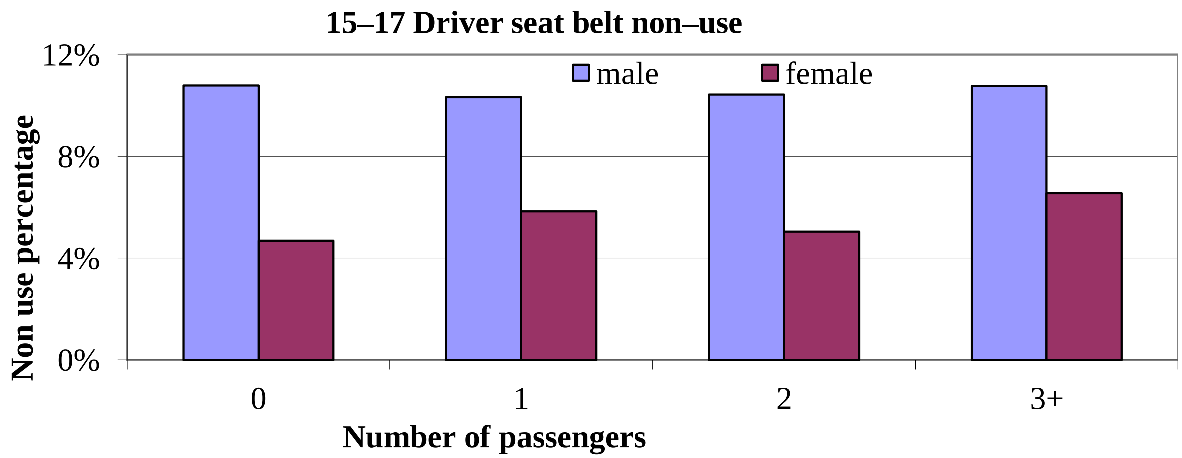


Figure 13
Single-vehicle RCIR when no safety restraints were used

Figure 14 presents the seatbelt non-use percentages for young drivers involved in crashes in Louisiana as reported in the Louisiana crash database. These are likely to be under-reported since the officer investigating the crash must rely on the statement of the driver(s), but they do provide an opportunity to compare behavior among driver age and number of passenger groups. The non-use rate for 15-17 years was slightly higher than that for 18-20 years (10.6 percent vs. 9.5 percent, respectively); the non-use rates changed marginally as the number of passengers changed. Also, there was a huge difference between male and female non-use rates. The male non-use rate was almost twice that of female. This indicates that seatbelt usage among young male drivers is a problem in Louisiana.



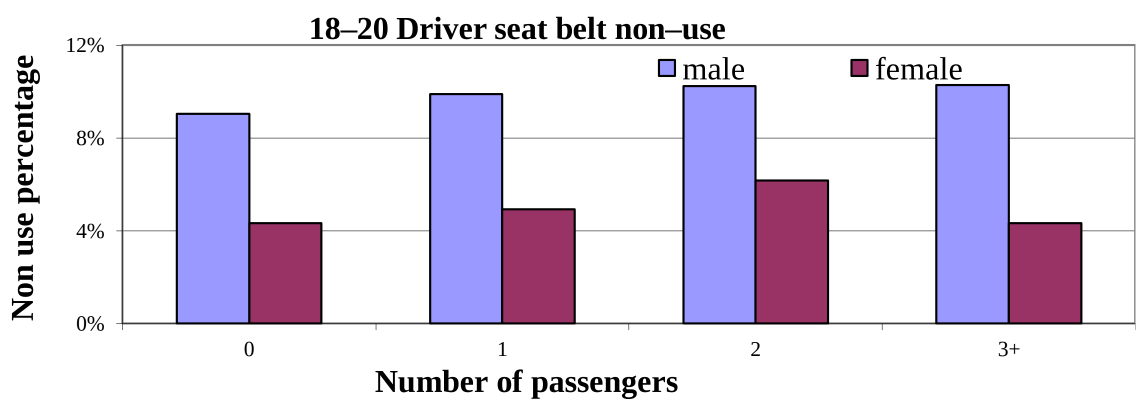
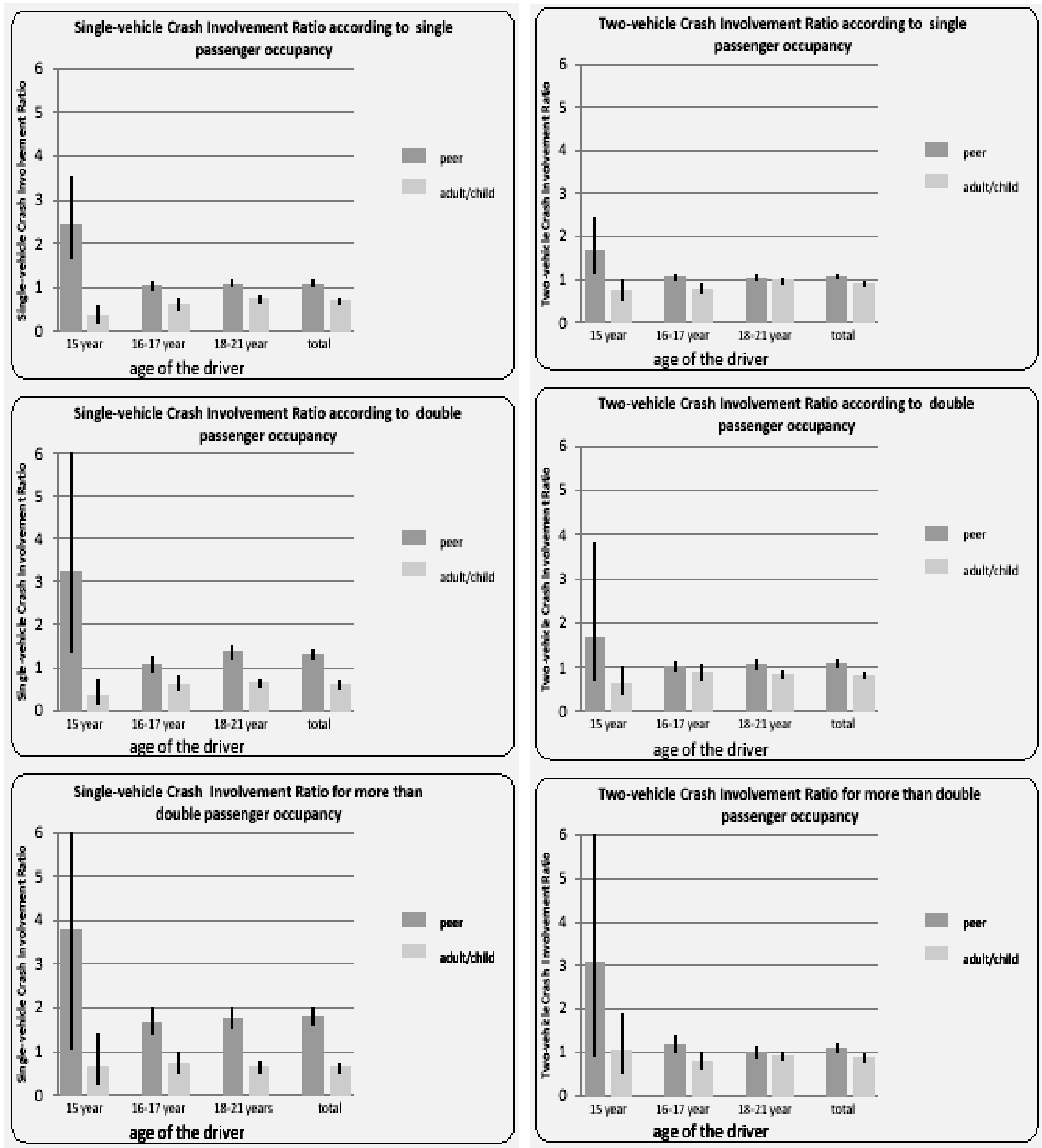


Figure 14
Seatbelt non-use percentage by gender and by number of passengers

Influence of Number of Passengers. Figure 15 presents the RCIR values for one, two, and three and more passengers for young drivers. That is, the ratio of the percentage at-fault crashes among young drivers with different numbers of passengers is divided by the ratio of the percentage not-at-fault multi-vehicle crashes by the same group. The RCIR values for single-vehicle crashes for the peer group demonstrated that the crash propensity increases with an increase in the number of passengers. This increase in crash propensity with the peer category may be indicative of the fact that the driver must deal with increased peer pressure and distractions, thus compromising driving safety. The adult/child



single-vehicle **two-vehicle**

Figure 15
RCIR by passenger occupancy and age

category for both single-vehicle and two-vehicle shows an almost stable trend with the RCIR values decreasing slightly with an increase in the number of passengers. This may possibly be attributed to an increased sense of responsibility with multiple passengers while driving under supervision. The RCIR values for two-vehicle crashes for peer group do increase with increasing occupancy in the same manner as with single-vehicle crashes, but not as rapidly. Learner drivers (drivers less than 16 years of age) were clearly the most influenced by passengers.

The relative crash rates for young drivers by number of passengers were also investigated. Relative crash rate in this analysis was defined as the ratio between crash rates per 100,000 licensed drivers for different crash characteristics. Crash rates per 100,000 licensed drivers were first calculated for drivers aged 15-17, 18-20, and 21+ with different numbers of passengers. Then relative crash rates for 15-17 and 18-20 age groups were calculated as the ratio of the crash rate per 100,000 licensed drivers for the corresponding age groups and the crash rate per 100,000 licensed drivers for the 21+ aged drivers for the same number of passengers. A value greater than one indicated higher risk than the 21+ driver while a value smaller than one indicated lower risk than the 21+ drivers. The larger the value, the greater the relative risk. The results are presented in Figure 16.

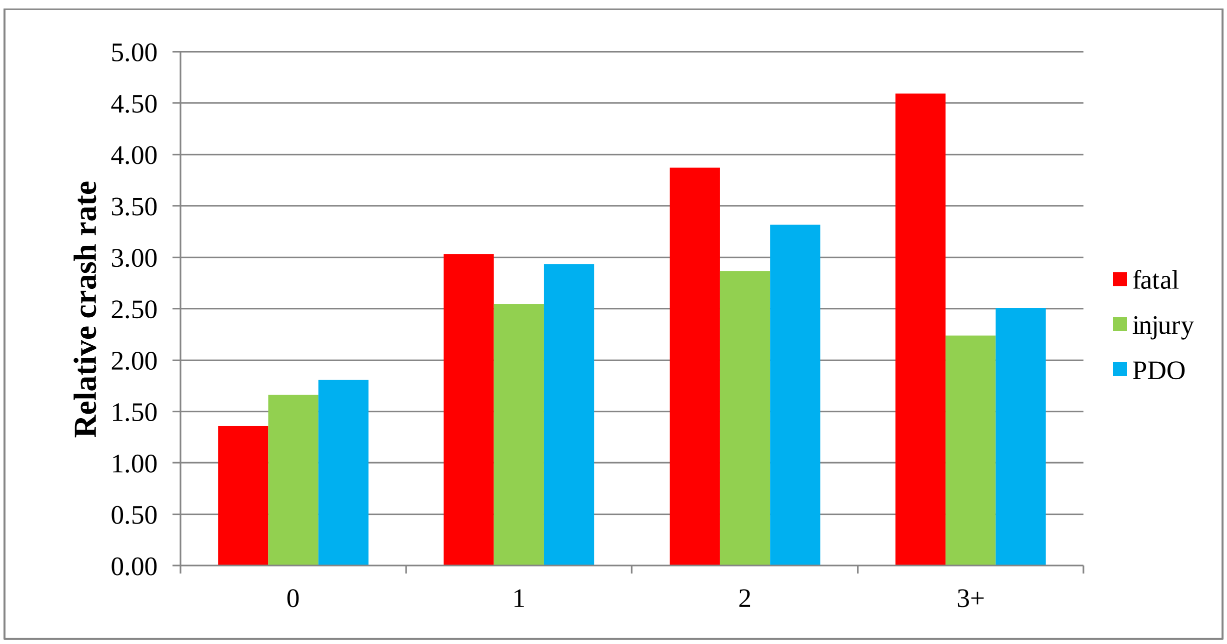
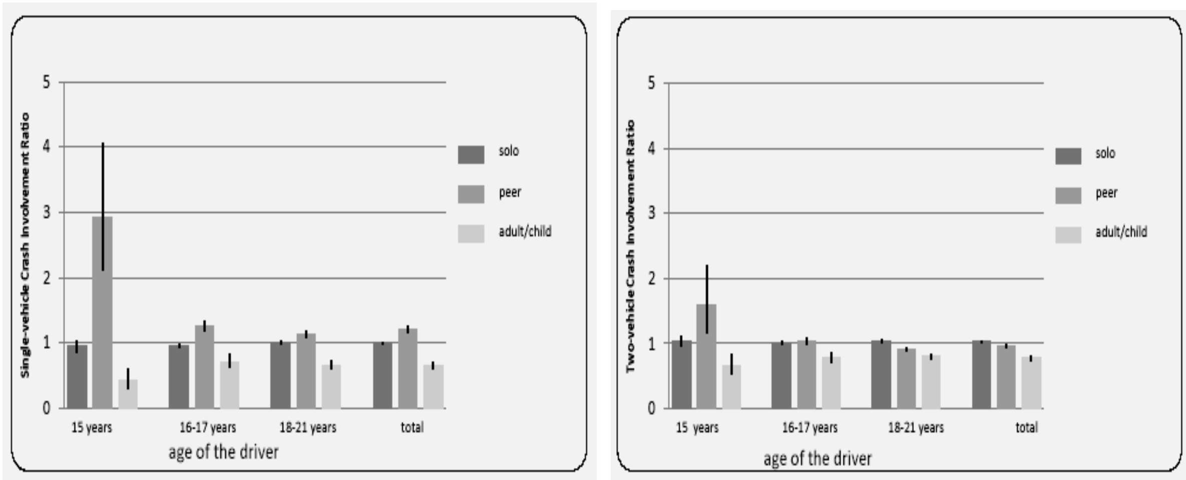


Figure 16
Relative risks for young drivers by number of passengers

The results show that 15- to 17-year-old drivers with passengers had a higher relative crash rate than 18- to 20-year-old drivers. However, without passengers, the 18- to 20-year-old group had higher crash rates than the 15- to 17-year-old group. For 15- to 17-year-old drivers, relative crash rates for fatal crashes increased dramatically as the number of passengers increased; the increase for the 18- to 20-year olds was relatively small and it reached a plateau with two passengers. For 15- to 17-year-old drivers, the ratio between fatal crashes with 1, 2 and 3 passengers over that of zero passengers were 2.06, 2.47, and 3.72. This confirms other research that restrictions on the number of passengers for drivers of this age group is likely to be effective in saving lives.

An analysis of the trend of the number of passengers accompanying teenage drivers from 1994 to 2004 in Louisiana revealed that teenager drivers were increasingly likely to have passengers and to have an increasing number of passengers in their vehicles, which according to the analysis above, would result in more crashes.

The Impact of Passenger Age on Young Drivers. The RCIR values for different passenger groups by age are presented in Figure 17. It is clear that young drivers with learner's licenses (i.e., drivers younger than 16 years) were most likely to be involved in crashes when traveling with their peer group and they were safest when traveling with an adult or a child for both single-vehicle and two-vehicle crashes. This suggested that adult supervision had a strong influence on young drivers to drive safely. When they were traveling with peers, the chance of being involved in a single-vehicle crash was greater than the chance of being in a two-vehicle crash, with an RCIR value of 2.93 versus 1.60 for two-vehicle crashes. It is likely that single-vehicle crashes are mostly caused by distractions during driving and the risk-taking nature of the driver. The higher single-vehicle RCIR values here suggest that there were distractions to the young drivers caused by the peer group or peer pressure contributing to risk taking. Adding to this observation is the fact that the highest RCIR values in each group in the analysis was for the drivers below the age of 16 (i.e., the drivers with learners' permits) involved in single-vehicle crashes with peer group passengers. Moreover, the adult/child category had the lowest RCIR values of the three passenger groups, suggesting that the driver's attitude does indeed change when there is adult supervision or when they have responsibility for a younger child in the vehicle. The RCIR values for drivers traveling alone for all age groups are approximately 1 for both single-vehicle and two-vehicle crashes, suggesting that the young drivers were relatively responsible when alone.



single-vehicle **two-vehicle**

Figure 17
RCIR values by passenger age group

Next, passengers were divided into 0-14, 15-17, 18-20 and 21+ age groups to analyze the interactions among young drivers and young passengers, using crash risk. In this part of the analysis, researchers altered the definition of the relative crash rates slightly to reflect the impact of teenage drivers with different age of passengers. First, crash rates per 100,000 licensed drivers were calculated as the ratio of the number of crashes for each passenger age category by severity to the number of 100,000 licensed drivers in the driver age groups of 15-17, 18-20, and 21+ years of age. However, crash rates can be impacted by degree of exposure. To reduce the impact of exposure in each driver age group, crash rates with passengers of each age group were normalized by taking the ratio of the crash rates with passengers to the crash rate without passengers for each age group. Finally, the normalized crash rates for 15-17 and 18-20 old drivers were divided by the normalized crash rate for drivers 21+ to produce the relative crash risk of each passenger age category as shown in Figure 18.

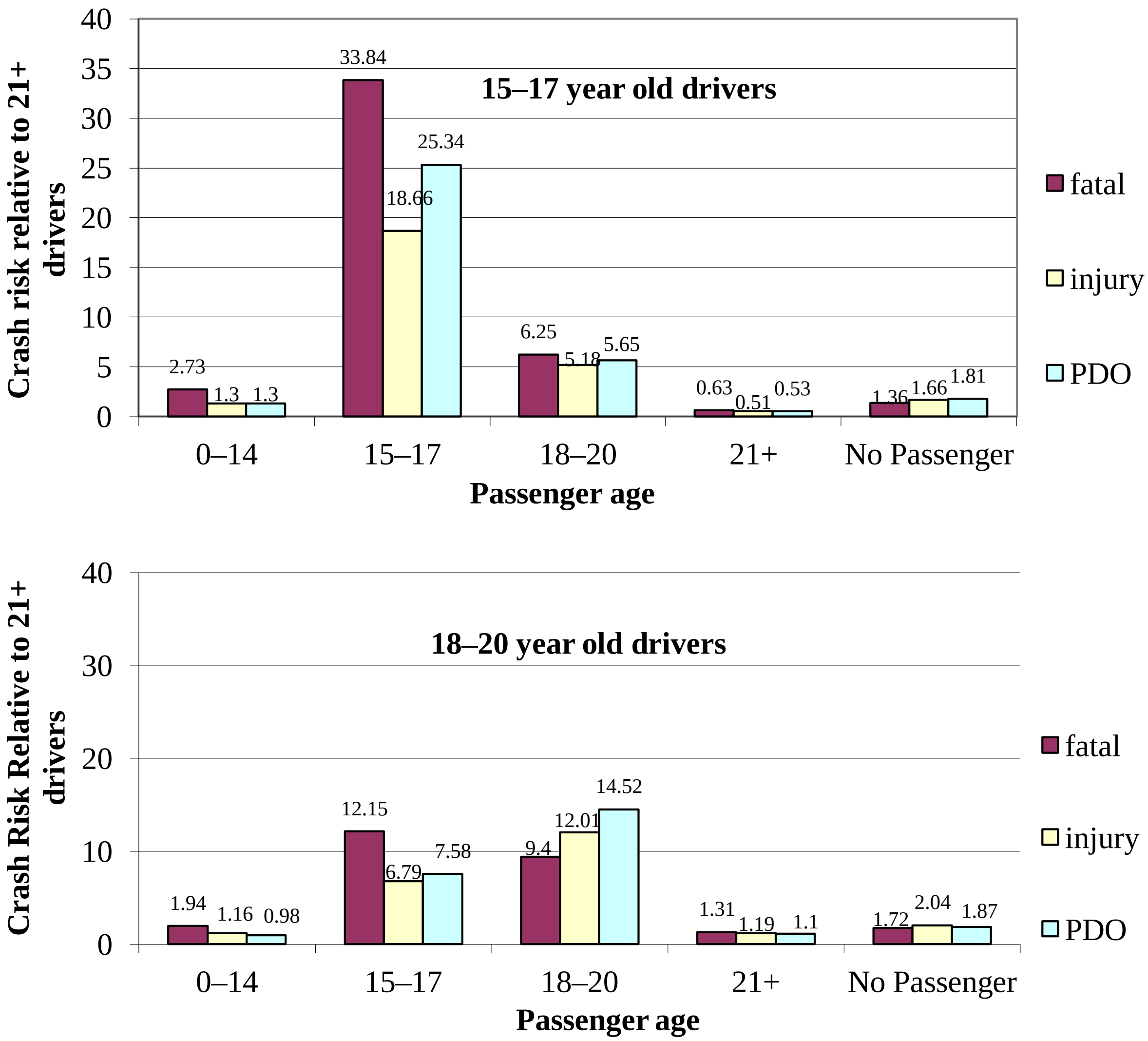


Figure 18
Young driver crash risks by passenger age

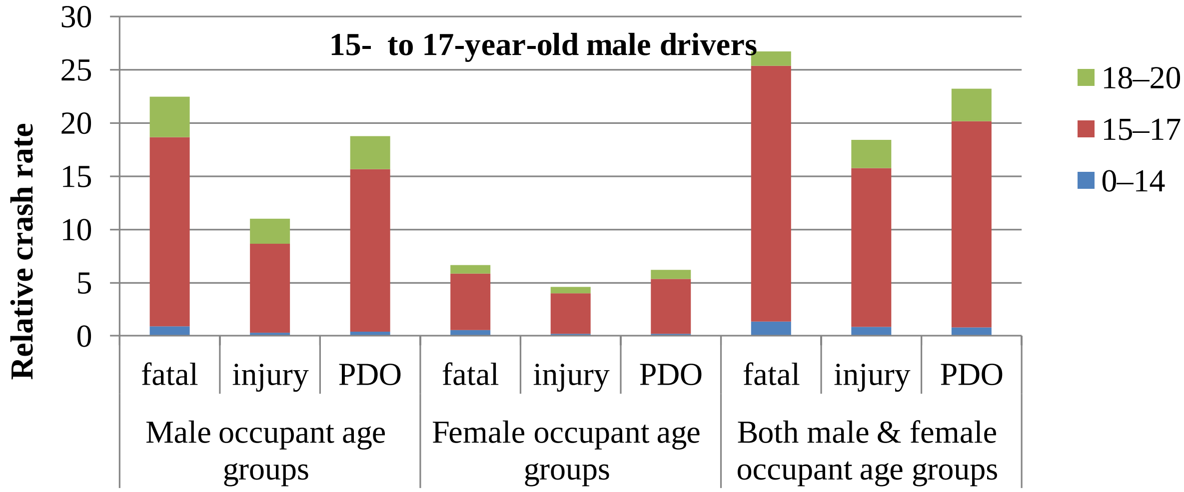
The following observations can be made from these results:

- For both 15- to 17- and 18- to 20-year-old drivers, having passengers from their own peer age group greatly increases the relative risk of a crash.
- The presence of 15- to 17-year-old passengers was associated with the highest relative risk for fatal crash. This was true for both 15- to 17- and 18- to 20-year-old drivers.

- The presence of 21+ passengers was associated with the lowest crash rates for both 15-17 and 18-20 age groups. For the 15-17 age group, when passengers 21+ were present, the relative crash rates for all crash severities were even lower than drivers of 21+.
- Without passengers, both 15- to 17- and 18- to 20-year-old drivers had relative crash rates higher than one, indicating that drivers from these age groups were more likely to be involved in crashes than drivers 21+ when driving alone. Furthermore, the crash rates without passengers were higher than for those with 21+ passengers, indicating the positive effect of adult supervision of teenage driving.
- Exposure also had an impact on the relative crash rates. For example, the low relative crash rates associated with 0- to 14-year-old passengers might have been due to the fact that teenagers were less likely to have 0- to 14-year olds as passengers.
- There was also a differential inter-age group passenger impact on drivers. For example, 15- to 17-year-old passengers had a stronger negative impact on 18- to 20-year-old drivers than 18- to 20-year-old passengers had on 15- to 17-year-old drivers.

The Impact of Gender of Young Passenger on Young Drivers. In this part of the analysis, teenage drivers (15-17 and 18-20) were first divided by gender, and then further stratified by the age and gender of the passengers. The relative crash rates by different combinations of teenager driver and passenger characteristics were analyzed. The denominator of the relative crash rates was still the mixed passenger groups for drivers ages 21+.

Figure 19 gives the relative crash rates for 15- to 17 year-old male and female drivers with different passenger age and gender mixes.



(a)

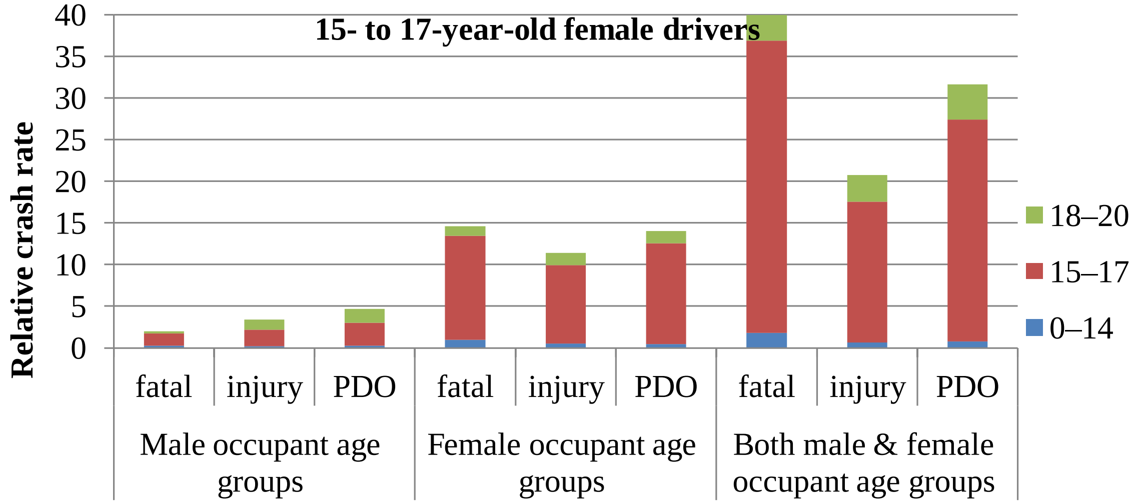


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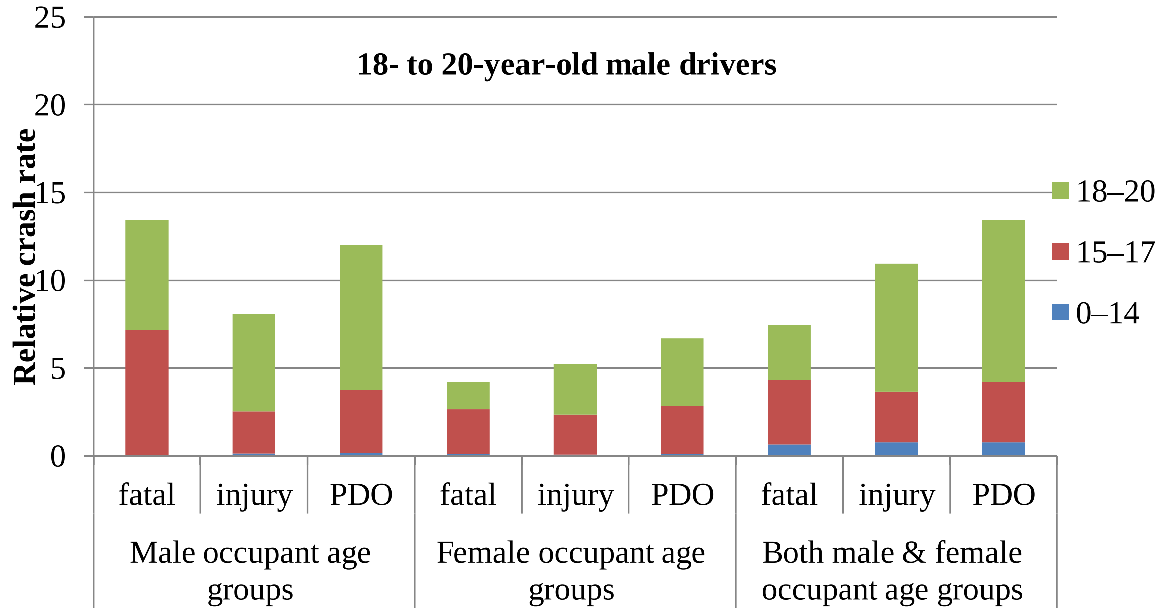
Figure 19
Relative crash rates for 15- to 17-year-old drivers

Based on the figures, the following observations were made about 15- to 17-year-old drivers:

- For all crash severities and for both male and female drivers, accompaniment of mixed gender passengers leads to the highest relative crash risk, whereas accompaniment of passengers of the opposite gender leads to the lowest relative crash risk.

- Passengers in the 15- to 17-year-old age group have a higher relative crash risk than passengers in other age groups.
- For crash severity, fatal crashes were found to be the highest, followed by PDO and then injury crashes except in cases where female drivers were accompanied by male passengers, where the order for crash severity was PDO followed by injury and fatal crashes.
- Compared to male drivers, female drivers have a higher relative crash risk with accompanying passengers except when accompanied by male passengers.
- Again, the issue of exposure might have played a role in the previous figures. For example, the relative rates for 15-17 female drivers with younger or older passenger age groups were much lower than for their own peer age group. This was probably because children from the 0-14 age group were less likely to be passengers of 15-17 male drivers.

Figure 20 gives the relative crash rates for 18- to 20-year-old male and female drivers with different passenger age and gender mixes.



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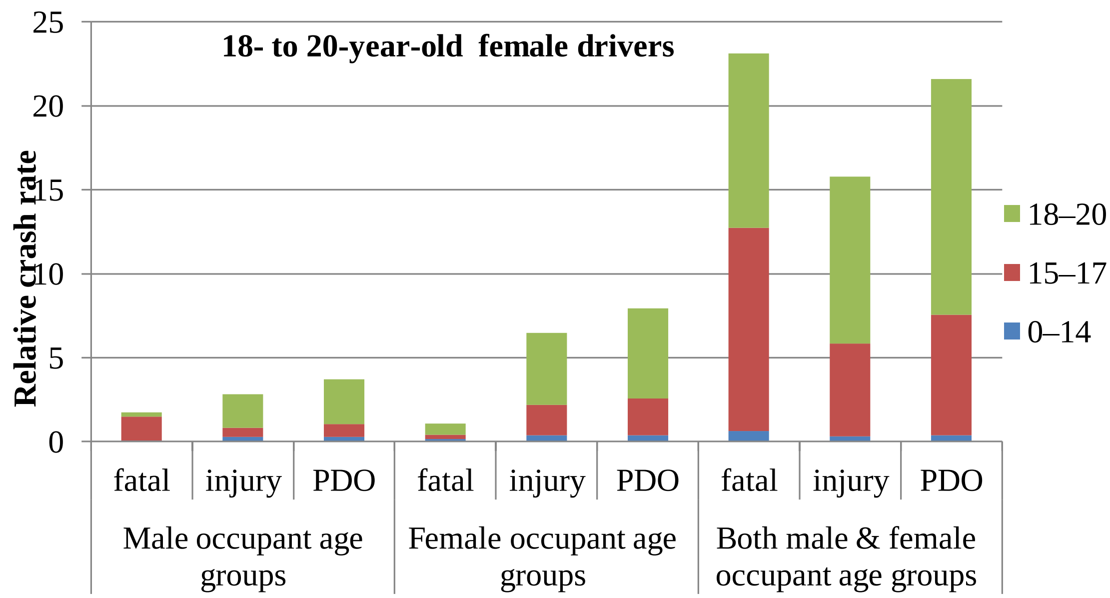

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Figure 20
Relative crash rates for 18- to 20-year-old female drivers

Based on the previous figures, the following observations were made about 18- to -20-year-old drivers:

- For both male and female drivers, an accompaniment of passengers of the opposite gender led to lowest relative crash risk and an accompaniment of mixed gender passengers led to the highest relative crash risk.
- Passengers in the 18- to 20-year-old age group were found to have the highest relative crash rate. The 15- to 17-year-old group passengers were found to have higher impact on the 18- to 20-year-old drivers but not vice versa.
- Generally, the order of severity of crashes was PDO followed by injury and fatal crashes except in cases where female drivers were accompanied by mixed gender passengers or when male drivers were accompanied by male passengers.
- Female drivers with mixed gender passengers had high relative crash risk rates except when they were accompanied by male passengers.
- An important observation is that the relative crash risk rate of 18- to 20-year-old drivers is much smaller than that of 15- to 17-year-old drivers.

Driver Licensing. The analysis of the FARS data revealed that for drivers involved in fatal crashes, Louisiana had a higher percentage of licensing problems than peer states and the national average, as shown in Figure 21. Louisiana drivers had the highest rates of not possessing valid driver's licenses for both commercial driver license (CDL) and non-CDL license. In terms of compliance with license endorsement, license type, and license restrictions, when alcohol-related drivers per 100,000 licensed drivers with previous license suspensions and revocations were considered, the rates were 1.70, 1.24, and 1.08 for Louisiana, peer states, and the US, respectively. Louisiana was 63.9 percent higher than the national average. The analysis of alcohol-related drivers with previous license suspensions and/or revocations also indicated possible licensing problems for repeat DUI recidivism. However, failure to have vehicle insurance in Louisiana results in the registered owner's drivers license being suspended even though that driver is legally able to drive a vehicle with adequate insurance. Other states may have different regulations regarding when to suspend a drivers license resulting in an inequitable comparison. On the other hand, the fact that the rates are as high as they are in Louisiana suggests that further investigation is warranted.

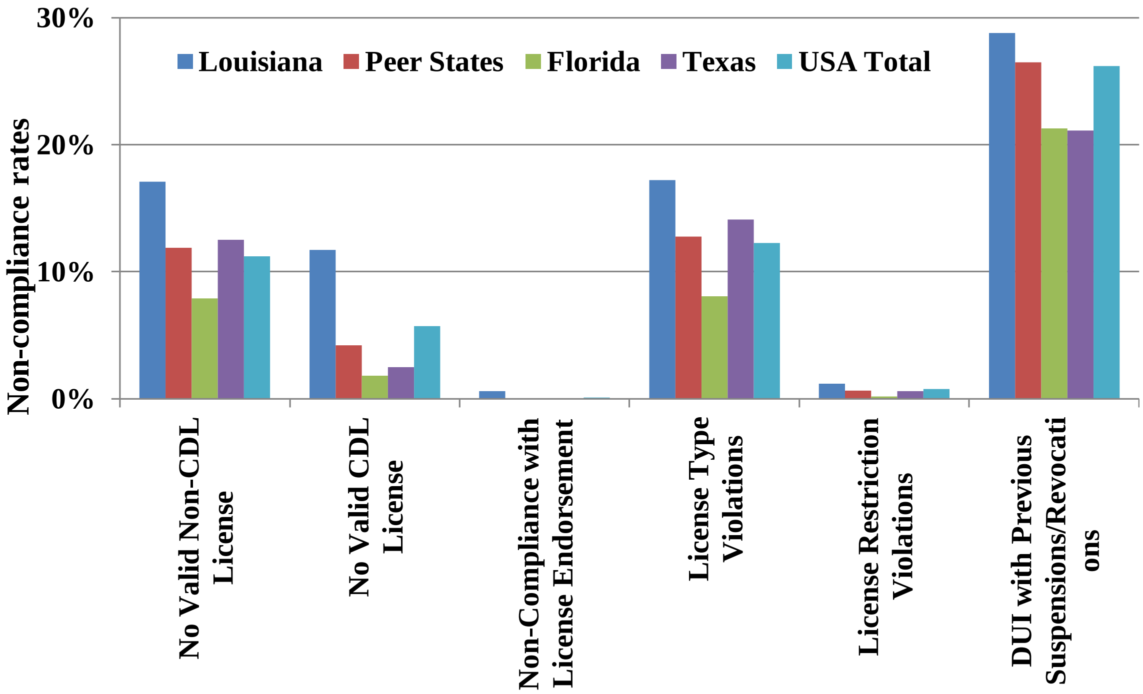


Figure 21
Licensing problems in Louisiana

Analysis of Occupant Characteristics

Restraint System. Louisiana is over represented in seatbelt non-use. According to FARS from 1999 to 2004, the non-use rate for both drivers and passengers in fatal crashes for Louisiana was 45.6 percent, which was lower than the average for the peer states (48.5 percent), but higher than Florida (41.7 percent), Texas (36.0 percent), and the national average (40.4 percent). Note that these seatbelt non-use rates are for fatal crashes only and are not non-use rates in general. According to NHTSA (NHSTA, 2008), the Louisiana seatbelt non-use rate was 25.2 percent in general, compared to the US average of 19.0 percent for 2006. Thus, the non-use rates among fatal crashes are almost twice the rate for non-use in general.

Figure 22 gives the occupant seatbelt non-use rate per 1,000 populations by age and gender from the Louisiana crash database. It is clear that 18- to 20-year-old occupants had the highest rate of not using seatbelts. The rate decreases as age increases except for the 7- to 14-year-old group. In general, males had higher non-use rates than females, although the gap decreases as age progresses. For occupants 55 and over, female non-use rates were higher than male. Among those who used a seatbelt, 4.0 percent and 4.9 percent used only shoulder or lap belts, respectively.

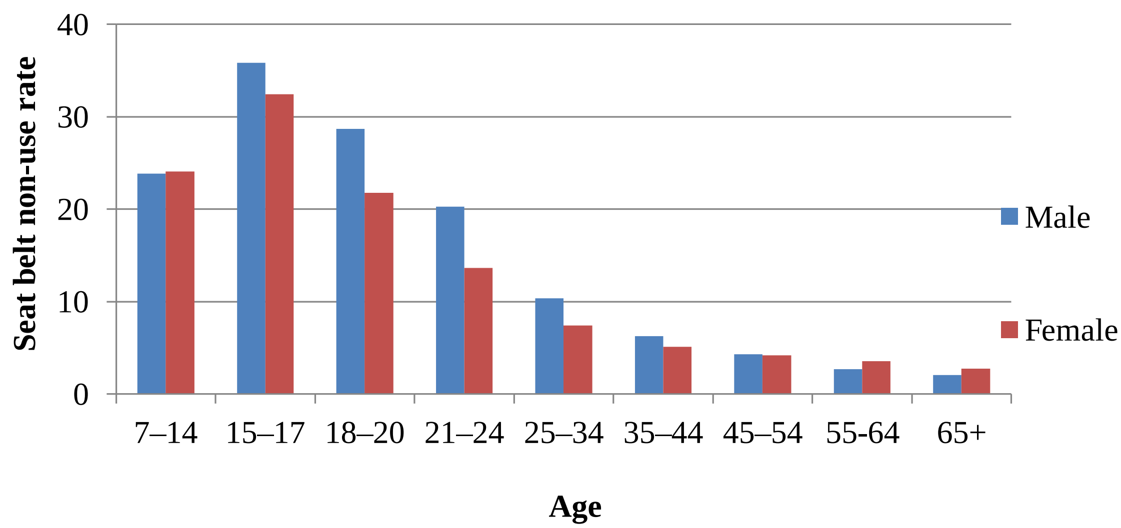


Figure 22
Seatbelt non-use rate per 1,000 population by age and gender

Louisiana law requires the use of proper child safety restraint systems for children under the age of six. The following results were obtained through further analysis of child safety restraint systems for Louisiana:

- Children 6 years and younger were more likely to sit in the second row of seats than the first row of seats.
- Child restraint systems non-use rate for the second row seats was almost twice that for first row seats except for one-year-old children.
- Children in the second row seats were more likely to use shoulder/lap belt instead of child safety restraint systems. This tendency increased markedly when children reached the age of 3 and kept increasing until age 4 and became constant for ages 5 and 6.
- The use of child restraint systems decreased markedly as age progressed, almost by 50 percent every year of increase of age.
- The rate of improper use of child restraint systems was almost constant at approximately 10 percent for those involved in crashes.

Figure 23 presents the seating positions of passengers under 17 years old. Almost 80 percent of passengers under the age of 6 sat in the second row seats. For 7- to 14-year-old passengers, about 41 percent and 54 percent sat in the second and first row of seats, respectively, and fewer than 5 percent in the third row seats. However, 66 percent of 15- to 17-year-old passengers sat in the first row seats and 33 percent in the second row seats. This indicated a trend that, as age progressed, children were more likely to move from second row seats to first row seats.

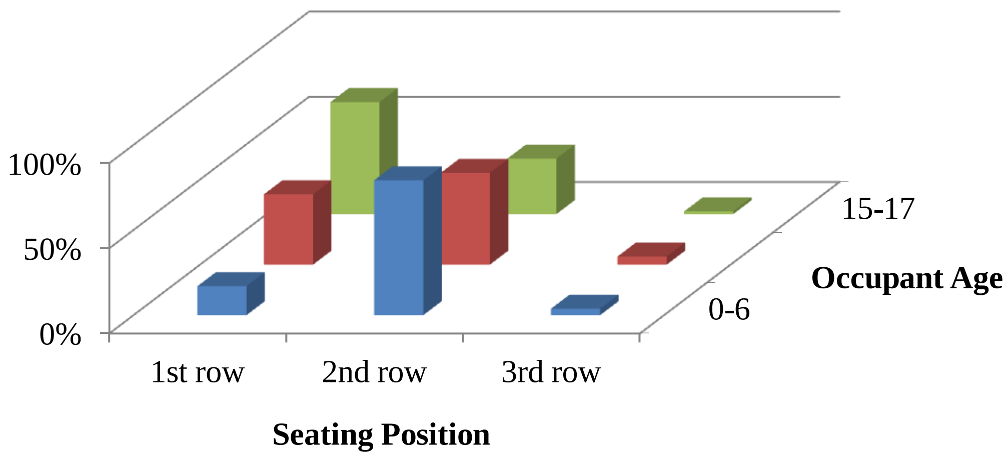


Figure 23
Seating position for occupants 17 years old and under by percentage

For passengers from 7 to 17 years old who sat in the first row, the percentage using both shoulder and lap belts were about the same for age groups 7-14 and 15-17. However, after moving to the second row seats, 15- to 17-year olds who used both shoulder and lap belts decreased markedly to 9 percent, in contrast to the 7-14 age group who retained their level of seatbelt use. From the analysis, it seems that a requirement for passengers in the second row seats to use seatbelts will provide better protection for children less than 14 years of age, especially when considering the fact that child safety restraint systems usage for children under 6 decreased sharply after reaching 3 years of age.

Number of Occupants. Louisiana was over represented with respect to the national average in terms of crashes where there was more than one passenger in the vehicle. The over representation was primarily caused by teenage drivers (15-7 and 18-20), who had much higher crash rates when there were passengers, especially when there were a higher number of passengers. This can be demonstrated by recalculating the ORF after crashes from teenage drivers (15-17 and 18-20) in Louisiana are subtracted. After that, almost all the over representations for occupants over two disappear. The majority of the passengers of young drivers were from their peer age groups (Fu and Wilmot, 2008).

Analysis of Pedestrian Characteristics

Pedestrian fatalities constituted 5.2 percent of all fatalities in Louisiana according to FARS. The top activities associated with pedestrian crashes included crossing/entering roads not at an intersection, crossing/entering roads at an intersection, walking in roads with traffic, and standing in roadways. Crossing/entering road not at an intersection was the most frequent pedestrian activity associated with crashes.

Pedestrian Age and Action. Figure 24 presents the frequency distribution by age and by pedestrian actions for pedestrians under 55 years of age. The grouping of age was based on the similarity of the crash frequencies for each age group. The frequencies were the total number of crashes divided by the age span each age group covers.

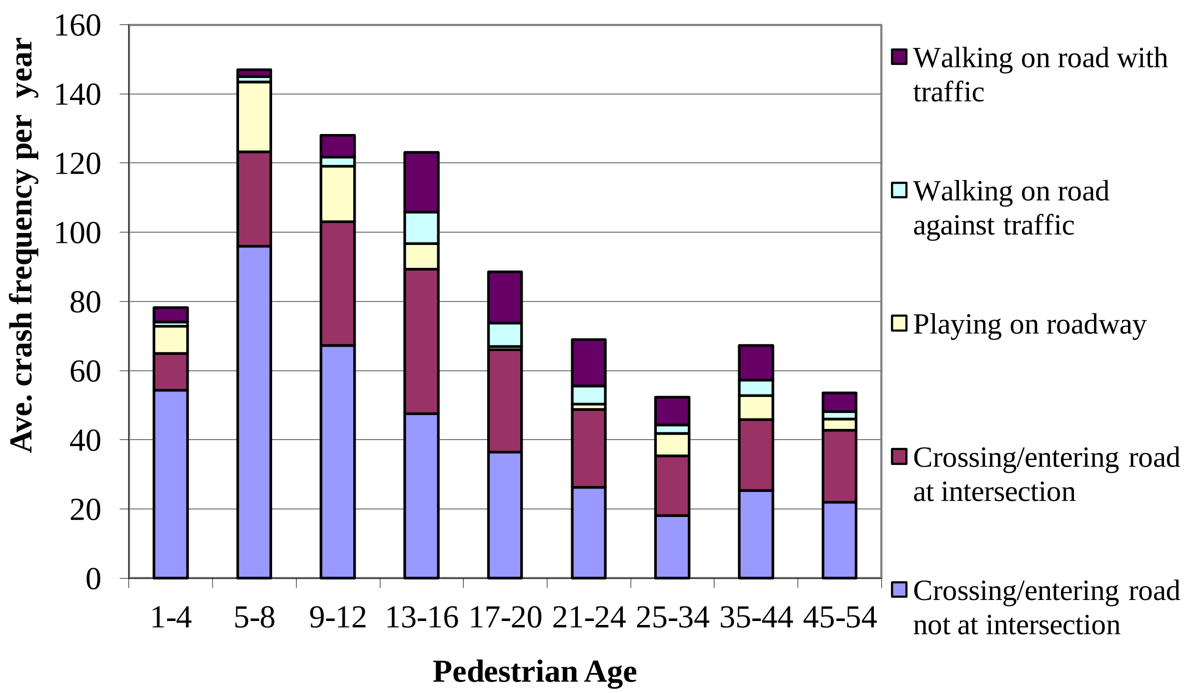


Figure 24

Frequency distribution by pedestrian age and action

For young pedestrians under 13, most crashes were crossing/entering roads not at intersections. This group also had considerable crashes while playing on roadways. It seems that traffic safety education for these children would be an important countermeasure. Age group 13-16 is the age of transition. Starting from about 13 years of age, pedestrians become more involved in crashes involving walking on the road (with or against traffic), and the activity of crossing/entering a road not at an intersection begins to decrease significantly. The frequency of crossing/entering roads at an intersection was fairly consistent across the ages for pedestrians 21 and older.

Pedestrian Alcohol-Related Crashes by Age. A considerable number of pedestrian-related crashes were found to be associated with alcohol or drug involvement of pedestrians. Of the alcohol- and drug-related crashes, over 96 percent were alcohol-related.

Figure 25 presents the percentages of pedestrian alcohol-impaired crashes, relative to total pedestrian crashes by age group for different severities. Overall, 18.5, 7.0, and 4.2 percent of all fatal, injury, and non-injury crashes were due to pedestrian impairment, respectively. Most alcohol-related crashes were for pedestrians from their early 20s through their early 50s for all severities. For pedestrians in the 35-44 age group, over 30 percent pedestrian fatalities were alcohol-related, followed by 28.2 percent for 45-54 and 25 percent for 21-24. Pedestrians from 21-54 accounted for about 85 percent of all alcohol-related fatalities, and 80 percent and 70 percent for injury and non-injuries, respectively.

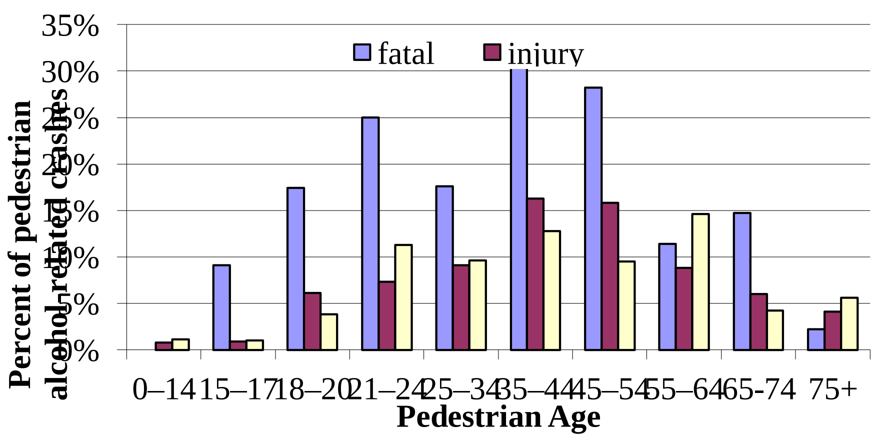


Figure 25
Pedestrian alcohol-related crashes by age and crash severity

Percentage of Pedestrian Alcohol-related Crashes by Age and Severity. Pedestrians in the 35-44 and 45-44 year-old groups had the most pedestrian drinking-impaired crashes and half of them took place when they tried to cross/enter roads not at an intersection. In terms of gender distribution, 38.4 percent pedestrians involved in crashes were female compared to 61.6 percent for male, while only 22.7 percent female were drinking impaired compared to 77.3 percent for male.

Temporal Distribution. In terms of temporal distribution, injury and no injury pedestrian crashes started to increase from 7 a.m. and reached a peak at about 4 or 5 p.m. Fatal pedestrian crashes were the lowest from 7-8 a.m. and did not increase significantly until 2 p.m., and then increased sharply and reached a peak at about 8 p.m. However, most alcohol-related crashes took place at night. For children 17 and younger, most crashes took place in the afternoon hours. The most frequent was from 3-7 p.m. The number one cause for pedestrian crashes involving children 5 years and younger was crossing/entering roadway not at intersections.

Analysis of Roadway Characteristics

Highway Class. The total segment length in miles and VMT for state highways, US highways, and Interstates in Louisiana can be calculated from the 2004 segment table of the DOTD 2004 database. Of these highways, state highways comprise of 80.6 percent of their total center line miles, but carry only 46.3 percent of the VMT. Figure 26 presents the distribution of center lane miles by highway class. Among state highways, US highways, and interstate freeways, 75.9 percent are rural two-lane highways.

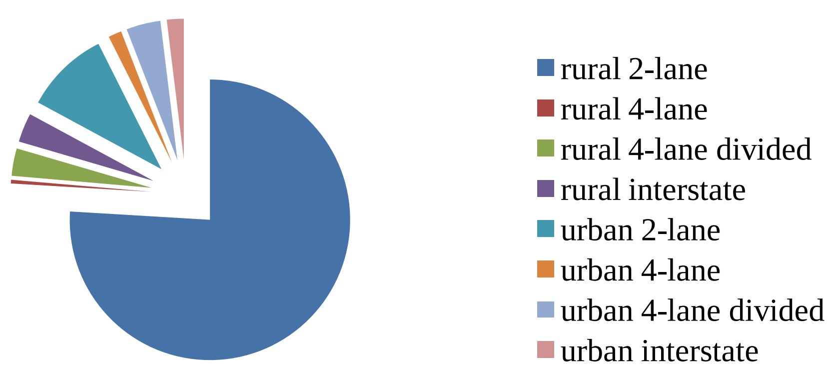


Figure 26
Center lane mile distribution by highway class

Figure 27 presents the crash rates per 1 million VMT by highway class for fatal crashes, and Figure 28 shows crash rates for injury and PDO crashes per 100 million VMT. Fatal crash rates are higher on rural roads than on urban roads; however, injury and PDO crash rates are higher on urban roads than on rural roads. Alcohol-related crash rates follow similar patterns.

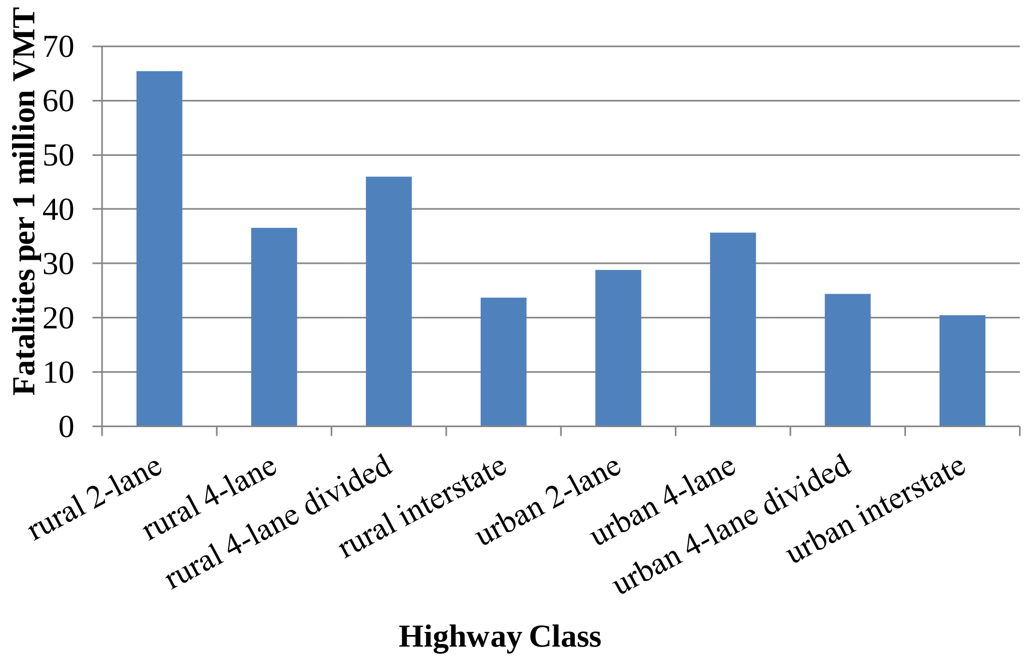


Figure 27
Fatality rates by highway class

The top five parishes with the highest crash percentages on rural two-lane highways in Louisiana were identified. These five parishes are Livingston, LaFourche, Ascension, St. Tammany, and Tangipahoa. They accounted for 22.2 percent of all crashes on rural two-lane highways in Louisiana but accounted for only 10.3 percent of Louisiana's population according to the 2004 census. They are also among the top five parishes for alcohol-related crashes on rural two-lane highways.

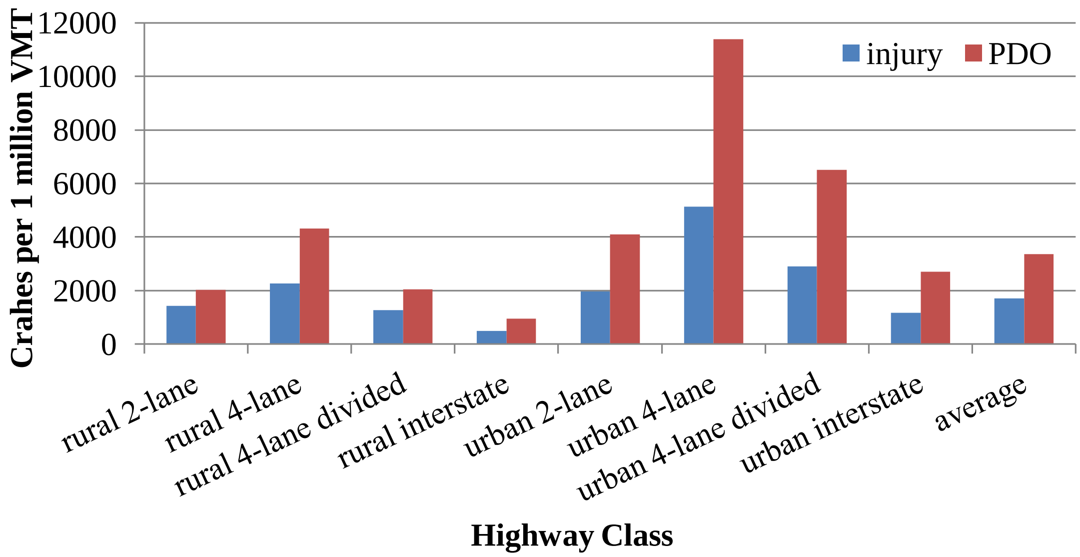
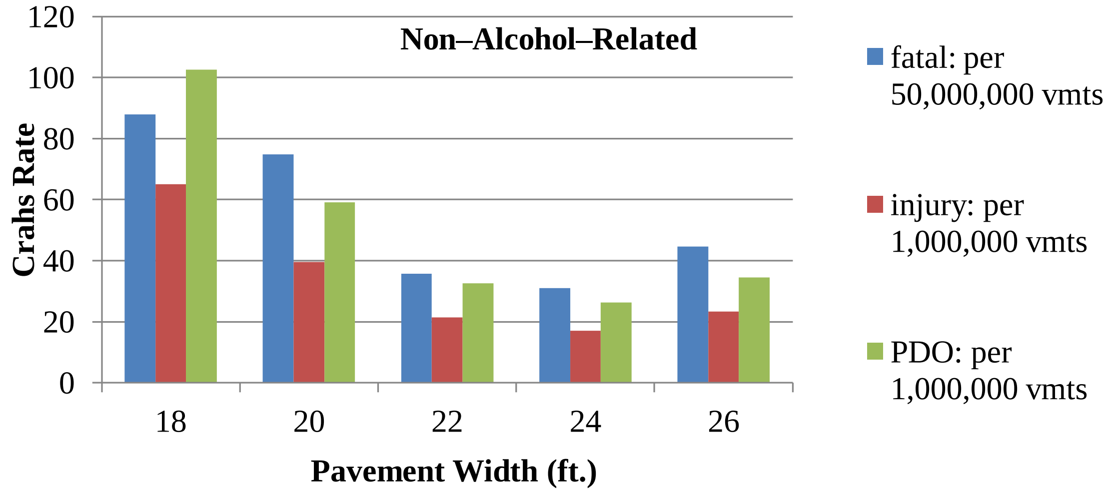


Figure 28
Crash rates by highway class

Rural Two-Lane Highways by Width. An investigation of crash distribution and crash rates on rural two-lane highways by lane width revealed the problems associated with narrow rural two-lane roads. Figure 29 presents the crash rates for both alcohol and non-alcohol-related crashes on rural two-lane highways by crash severity. Crash rates are higher on narrower roads, and particularly on 18-ft. wide roads, and this is exacerbated with alcohol-related crashes where they are more than five times higher than on 24-ft. wide roads.

In terms of crash percentages, only 1.6, 1.6, and 1.7 percent of all fatal, injury, and PDO rural two-lane highway crashes, respectively, occur on narrow rural two-lane highways. From 1999 to 2004, the mileage of two-lane highways less than 24-ft. wide had decreased from 940 miles to 644 miles. However, based on the high crash rates on narrow rural two-lane highways, they remain a matter of concern.



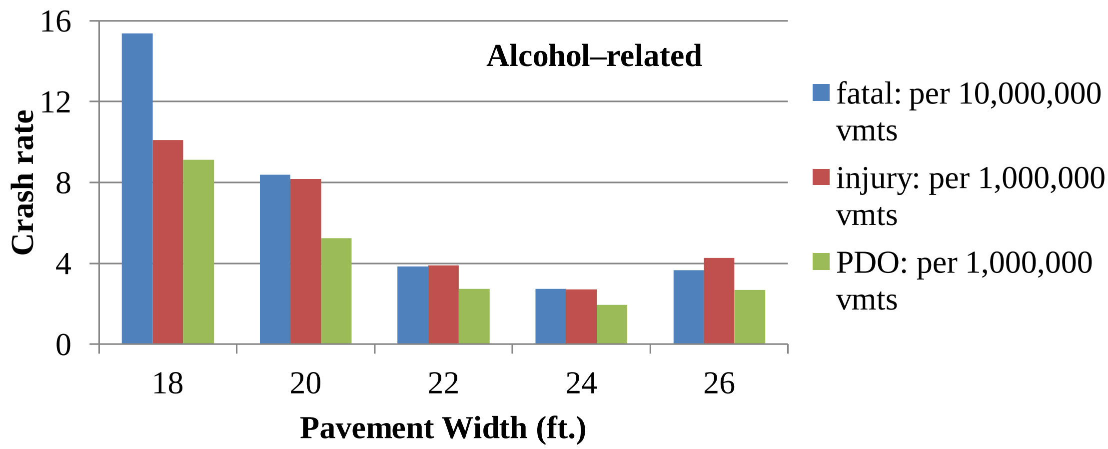


Figure 29

Crash rates on rural two-lane highways by width and by alcohol involvement

Relation to Roadway. On-shoulder and off-roadway crashes are over represented in Louisiana with ORFs of 262 percent and 255 percent, respectively, in reference to the national average. Fatal off-roadway crashes are over represented by 338 percent. Of all fatal crashes in Louisiana, 20.7 percent occurred as off-roadway crashes, while only 2.8 percent are on shoulder crashes. Only 8.3 percent injury and 6.2 percent PDO crashes occurred off-roadway in Louisiana, so the problem appears to be related to fatal off-roadway crashes. Subsequently, they were analyzed in greater depth as reported next.

Most off-roadway fatal crashes took place in open country (34.6 percent) and scattered residential areas (37.1 percent). Figure 30 presents the fatal off-roadway crash percentage distribution by most harmful event. The six items in the figure constitute over 82.3 percent of all most harmful events. Hitting trees has the highest percentage of 36.3 percent, followed by vehicle overturning of 25.7 percent. The percentages for hitting utility poles, culvert, embankment, and ditches were approximately 5 percent each.

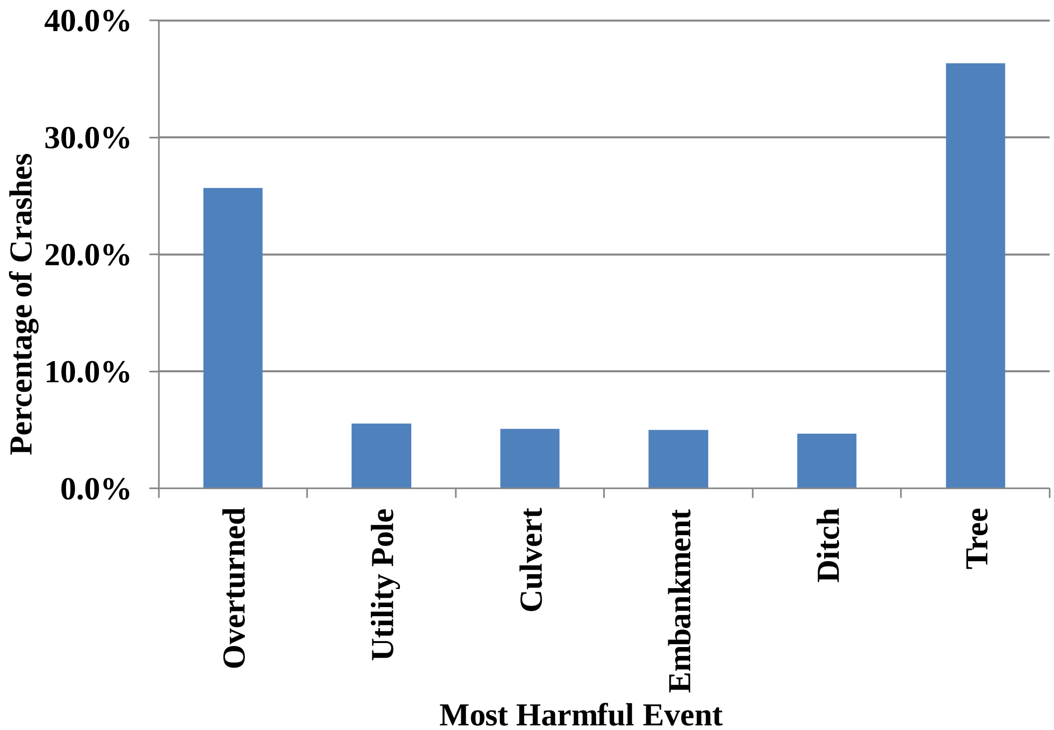


Figure 30

Fatal off-roadway crash distribution by most harmful event

Previous research (Wilmot, 1999) has shown that Louisiana has a higher proportion of embankment material in road construction than other states, supposedly due to the need to build roads up in low-lying areas of the state. Having greater side slopes to the road provide greater opportunity for vehicles to overturn when leaving the road. Also, the ubiquity of trees in the state provided greater opportunity for collision when leaving the road. The consequence of this is that if a driver drives off the road, they are more likely to have a fatal crash in Louisiana than elsewhere because of sloping embankments or the plethora of trees lining roads in Louisiana.

Looking at some of the factors that may contribute to drivers leaving the road, it is found that alcohol-related fatal crashes constitute more than 50 percent of off-roadway fatal crashes in Louisiana. With respect to the type of road, 69.1 percent of off-roadway fatal crashes took place on rural two-lane highways, 46.9 percent of which were alcohol-related. Thus, alcohol seems to be a major contributor to the driver leaving the road, and it is more prevalent on two-lane roads than on higher order roads.

The top 10 parishes for off-roadway fatal crashes on rural two-lane highways and alcohol-related fatal crashes on rural two-lane highways were determined from the data. Seven parishes appear on both lists. They are St. Mary, LaFourche, Vermillion, St. Tammany, Tangipahoa, St. Landry, and Ascension parishes. These parishes are all located in the south and southeast region of the state. Four of them, LaFourche, St. Tammany, Tangipahoa, and Ascension, are also among the five parishes having the highest crash percentages on rural two-lane highways as discussed earlier.

The time of day distribution of fatal off--roadway crashes is presented in Figure 31. Late night and early mornings (from 10 p.m. to 2 a.m.) have the highest crash percentages. This is consistent with times that drivers are likely to have used alcohol, but it also coincides with the time that drivers are most likely to experience fatigue and sleepiness.

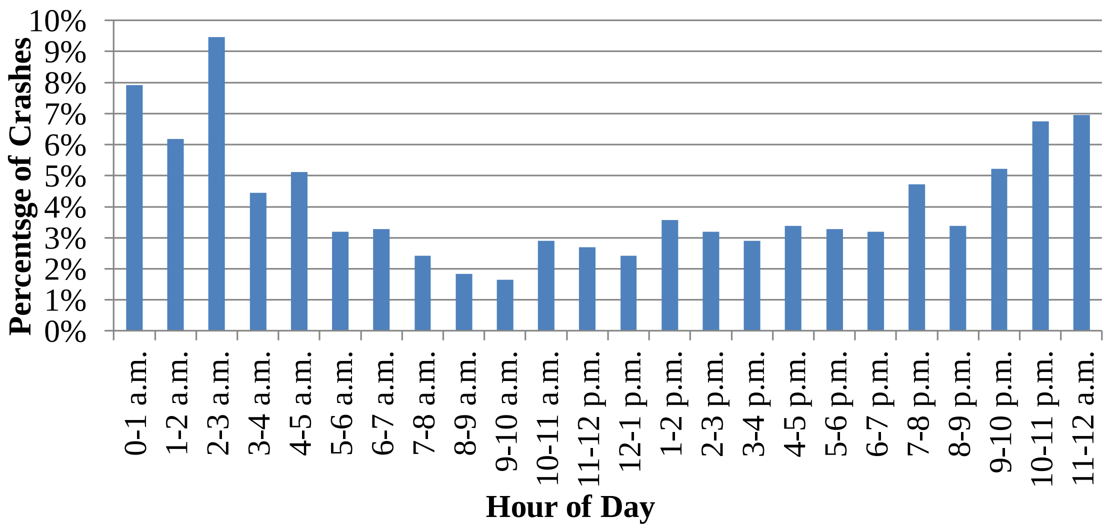


Figure 31
Hour of day distribution of fatal off-roadway crashes

To identify the contribution of alcohol to off-roadway fatal crashes by the hour of the day, alcohol-related crashes as a percentage of all off-roadway fatal crashes are presented in Figure 32. As shown, the share of alcohol involved crashes are high from 6 p.m. to 4 a.m., which indicates that the hours of alcohol impact are longer than the peak period of off-roadway fatal crashes (from 10 p.m. to 2 a.m.). Note also that there appears to be a small peak of alcohol-related crashes at lunch time.

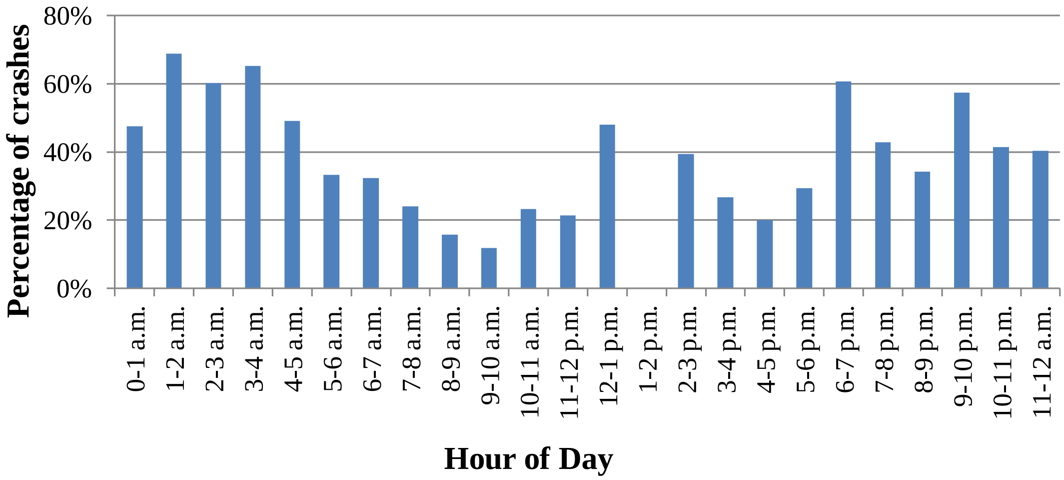


Figure 32
Percentage of alcohol-related fatal off-roadway crashes by hour of day

Posted Speed Limit. To investigate the impact of posted speed limit on crashes, the crash percentages across different posted speed limits in Louisiana were analyzed. The results are shown in Figure 33 where the percentage of crashes at each severity level adds up to 100 percent. Because the diagram is based on frequencies, the graph reflects the prominence of certain speed limits within the road network (e.g., 25, 35, 45, and 55 mph) and the relative scarcity of others (e.g., 20, 30, 40, and 60 mph). However, what the diagram shows quite clearly is the change in the proportion of crash severities as speed limits increase. At low speed limits, fatalities and injury crashes seldom occur and PDO crashes dominate, but as speed limits increase, fatal and injury crashes become more prevalent until fatal crashes dominate with speed limits of 55 mph and higher. While motorists do not necessarily obey speed limits, their speed is influenced by them, so Figure 33 illustrates that speed significantly influences the severity of a crash.

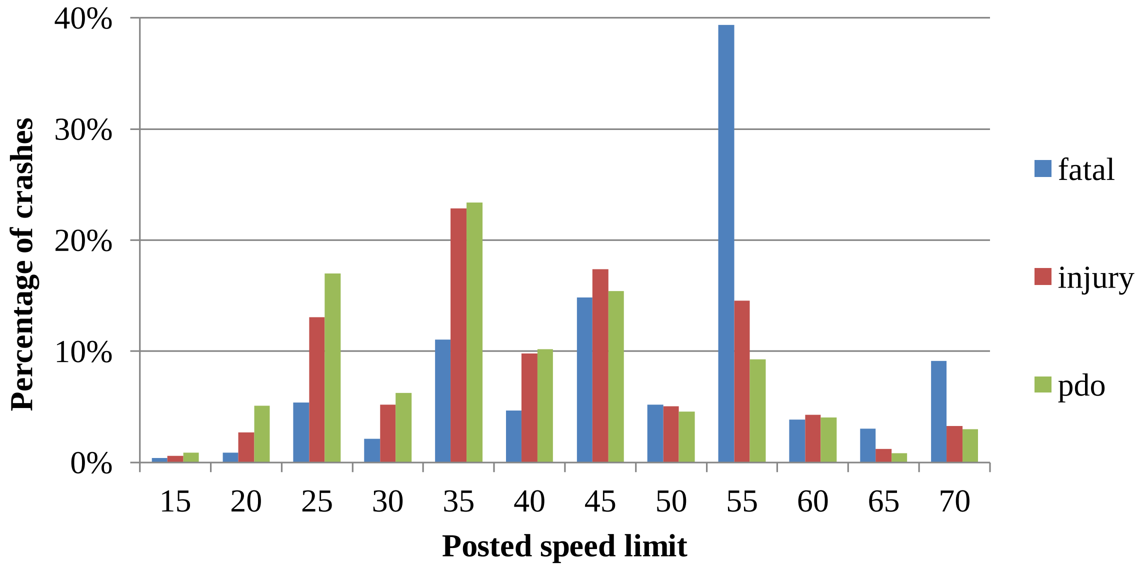


Figure 33
Crash percentages by posted speed limit

Traffic Control. Fatal crashes, in which traffic control featured in the crash, were found to be over represented in Louisiana by more than 300 percent. Figure 34 presents the percentage of these crashes by traffic control type and severity. The results show that a greater proportion of crashes at intersections occur at traffic signals than at stop signs, but when they do occur at a stop sign, they are more likely to be fatal. The diagram also shows the percentage of crashes that occur with at least one vehicle entering the intersection on a red signal (14 percent of fatalities, 30 percent of injuries, and 32 percent of PDO).

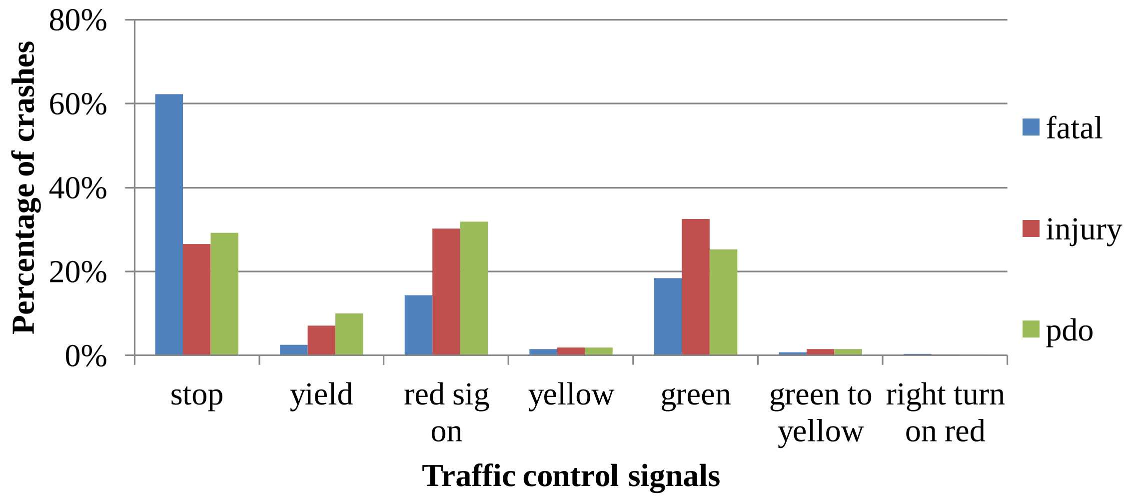


Figure 34
Percent crashes in Louisiana by traffic control signal

Looking into the data in greater detail, it is revealing that regarding the manner of collision, 74 percent of the fatal crashes were at right angles at stop signs, and 76 percent took place when the vehicles were proceeding straight ahead, 19.5 percent were making left turns, and only 3.9 percent were stopped. This suggests that the majority of crashes at stop-controlled intersections are due to failure to stop at the stop sign, or the inability of those at stop signs to adequately assess the critical gap at which they can safely negotiate their movement.

For fatal crashes with traffic signal control, 44 percent were right-angle crashes, and 26 percent were rear-end crashes with the red signal on. Both these statistics suggest red light running and/or failure to follow a clear protocol when the yellow signal appears so that rear-end crashes are minimized. Drivers should be aware that, provided they can enter an intersection on yellow, they are expected to proceed through the intersection. Conversely, entering the intersection on a red signal is a violation.

To observe the role age plays in these types of crashes, an analysis was conducted on the Louisiana crash database to determine the crash percentage distribution by driver age for fatal, injury, and PDO crashes for stop sign and red light signal violations. The results are shown in Figure 35. Of the crashes at stop signs, the majority of crashes involve drivers between the ages of 25 and 45, but fatal crashes are prevalent among older drivers as well. Drivers 65 years of age and older are involved in a high percentage of all fatal crashes (36 percent), with the problem becoming distinctly worse among drivers 75 years of age and older (24 percent). For crashes involving red signal violations, drivers 75 years of age and older also had a high percentage of fatal crashes (26.3 percent). The percentage fatalities for these two types of crashes were much higher among older drivers than among any other age group. An investigation of alcohol-related crashes for the two types of crashes indicated that the high crash percentages for the elderly drivers were not alcohol-related.

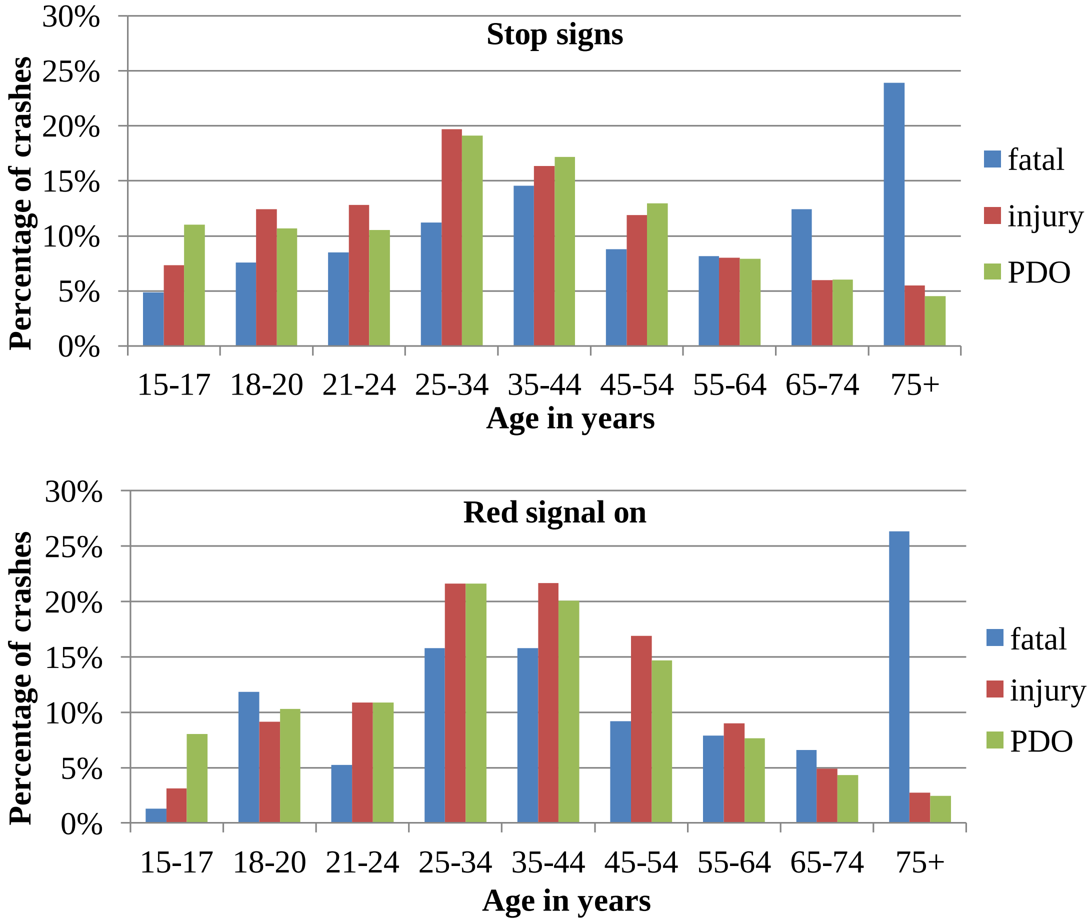


Figure 35

Crash distribution by traffic signal type, severity, and driver age

Analysis of Crash Characteristics

Manner of Collision. Based on the initial analysis from GES and the Louisiana crash database, sideswipe (both in the same direction and opposite direction) was over-represented for all severities (ORFs ranged from 103 percent to 176 percent), so were rear end for injury and PDO (ORFs were 111 percent and 109 percent), and head-on for fatal crashes (ORF was 113 percent). These three types of crashes were further analyzed by highway type and highway class.

Head-On Fatal Crashes. A total of 67.6 percent fatal, 39.3 percent injury, and 20.5 percent PDO head-on crashes took place on rural two-lane highways. Most head-on crashes on rural two-lane highways took place in daytime, especially in the afternoon. Head-on collisions resulted in more injury and fatal crashes than PDO on rural two-lane highways. Further analysis of driver age distribution indicated that the age distribution on rural two-lane highways was not different from that for all roads.

Figure 36 presents the percentage of the alcohol-related head-on crashes on rural two-lane highways over all head-on crashes on rural two-lane highways by severity and time of day. Alcohol-related head-on crashes had similar distributions as all alcohol-related crashes; it constituted a large share of nighttime crashes, especially for injury and fatal crashes.

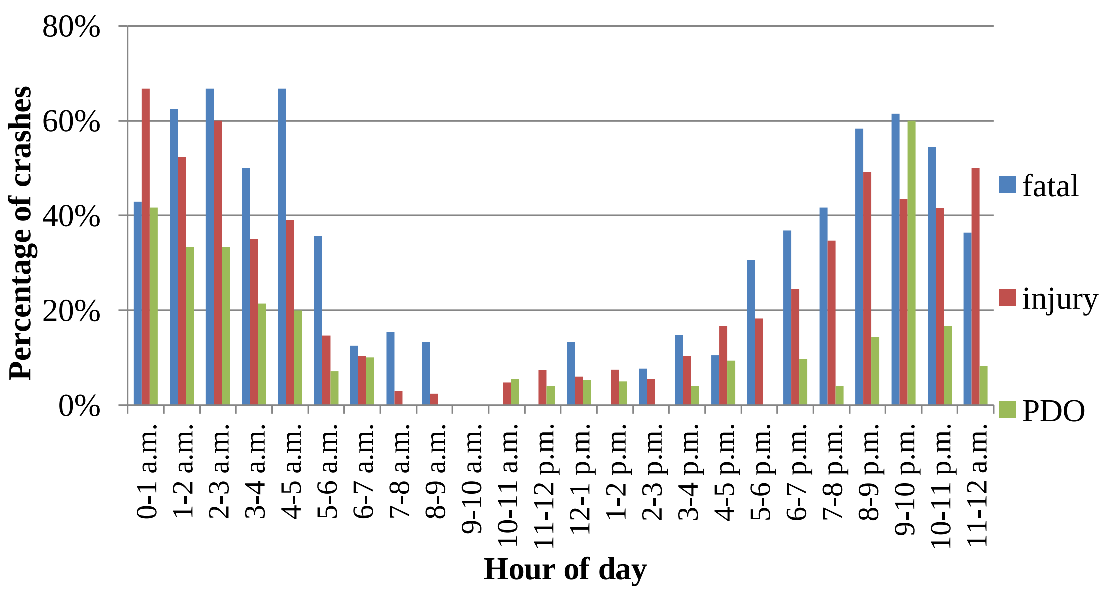


Figure 36
Percent alcohol-related head-on crashes by hour of the day

Rear-End Crashes. Because there were few fatal rear-end crashes, only injury and PDO crashes were analyzed. The majority of rear-end crashes took place on state highways (33-35 percent) and US highways (21-23 percent). The rear-end crashes on these roads could be most conveniently analyzed using the DOTD database. Results showed that approximately

80 percent of injury crashes and PDO crashes took place on urban roads and about one-third took place on urban four-lane divided highways. Thus urban roads were targeted for further investigation.

Figure 37 presents the rear-end crashes on urban roads, which included state and US highways and interstate freeways. The distribution was almost identical to that of urban four-lane highways. Most injury and PDO crashes took place on day time hours.

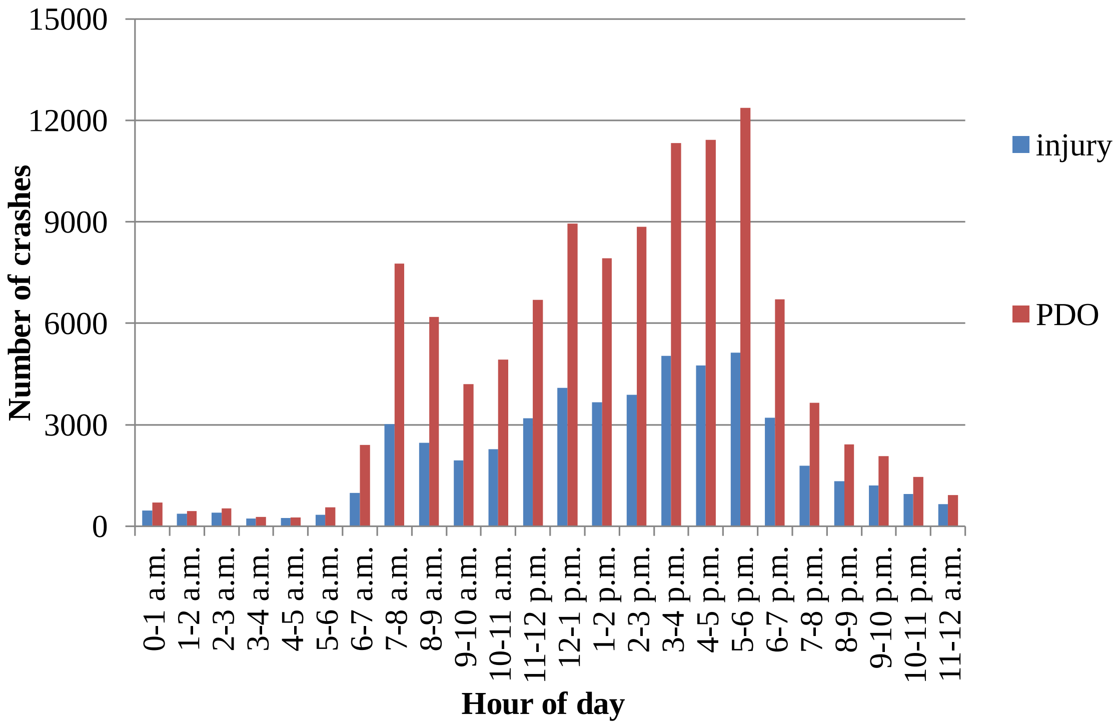
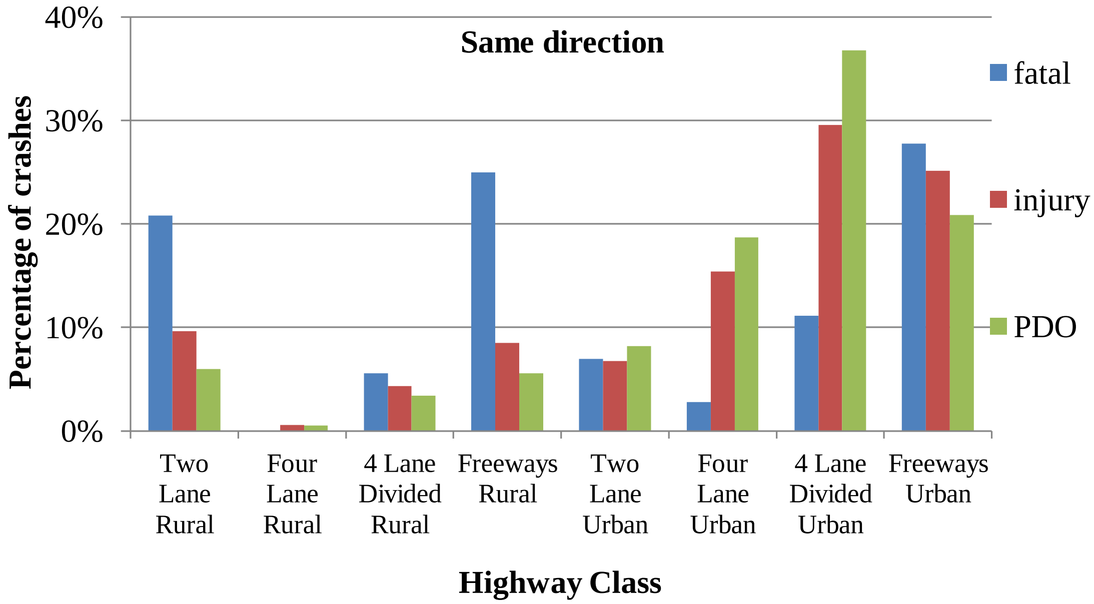


Figure 37
Number of rear-end crashes for urban roads by hour of the day

Sideswipe. Sideswipe crashes were over represented for both the same and opposite directions for all crash severities. Figure 38 presents the percentage distribution by highway class for sideswipe crashes. For same direction sideswipe fatal crashes, freeways (both rural and urban) had the highest crash percentages, followed by rural two-lane highways. Urban four-lane divided highways and urban freeways had the most injury and PDO crashes. However, for opposite direction crashes, rural two-lane highways had the most crashes, with 69.0, 53.7, and 41.1 percents of all crashes for fatal, injury, and PDO crashes, respectively.



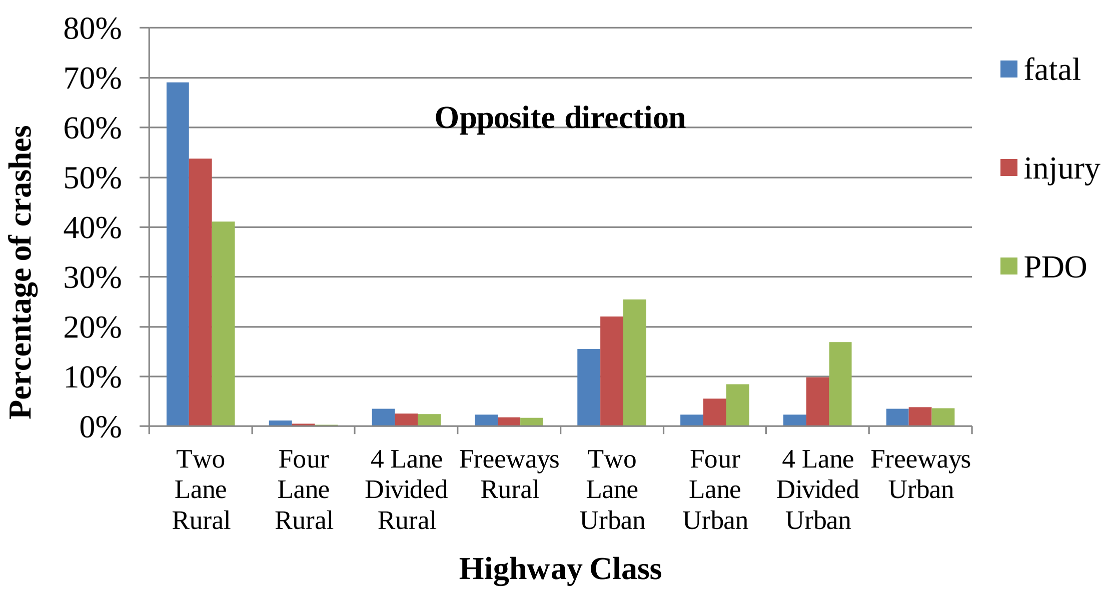
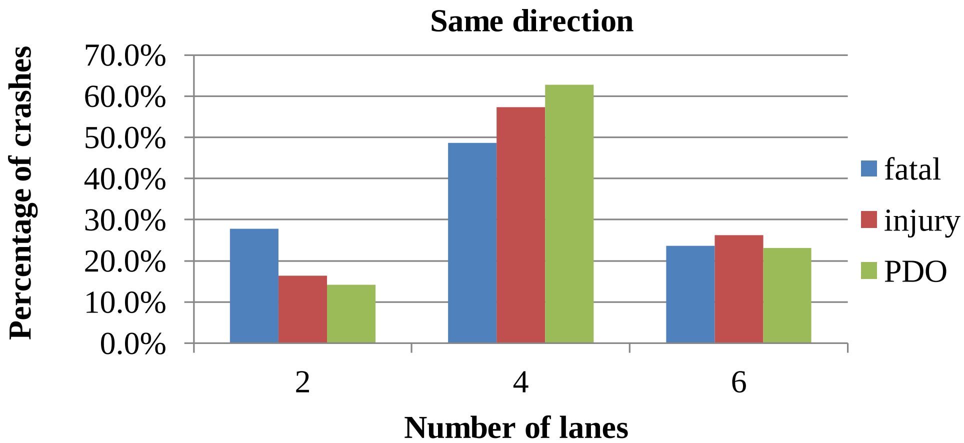


Figure 38
Percentage distribution by highway class for sideswipe crashes

Figure 38's results were corroborated by the analysis of crash percentages by the number of lanes in Figure 39. The same direction sideswipe crashes took place most frequently on four-lane highways, followed by two-lane highways; for opposite direction sideswipe crashes, the majority took place on two-lane highways.



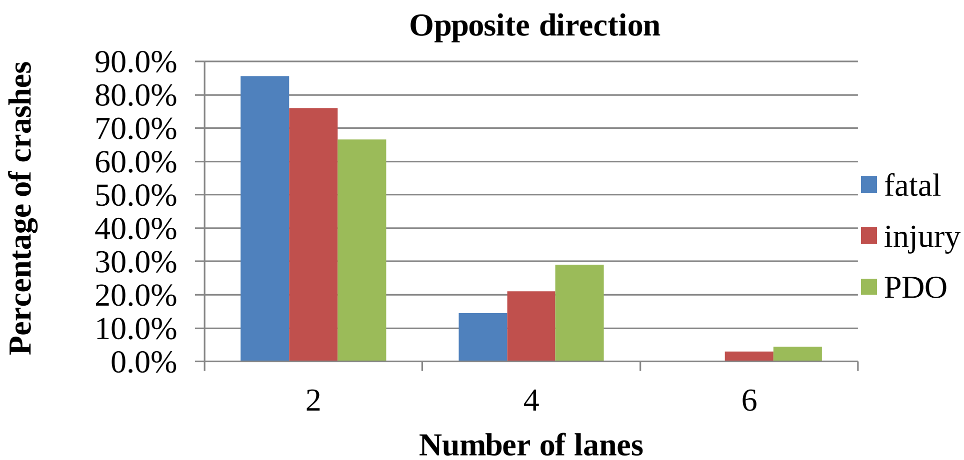
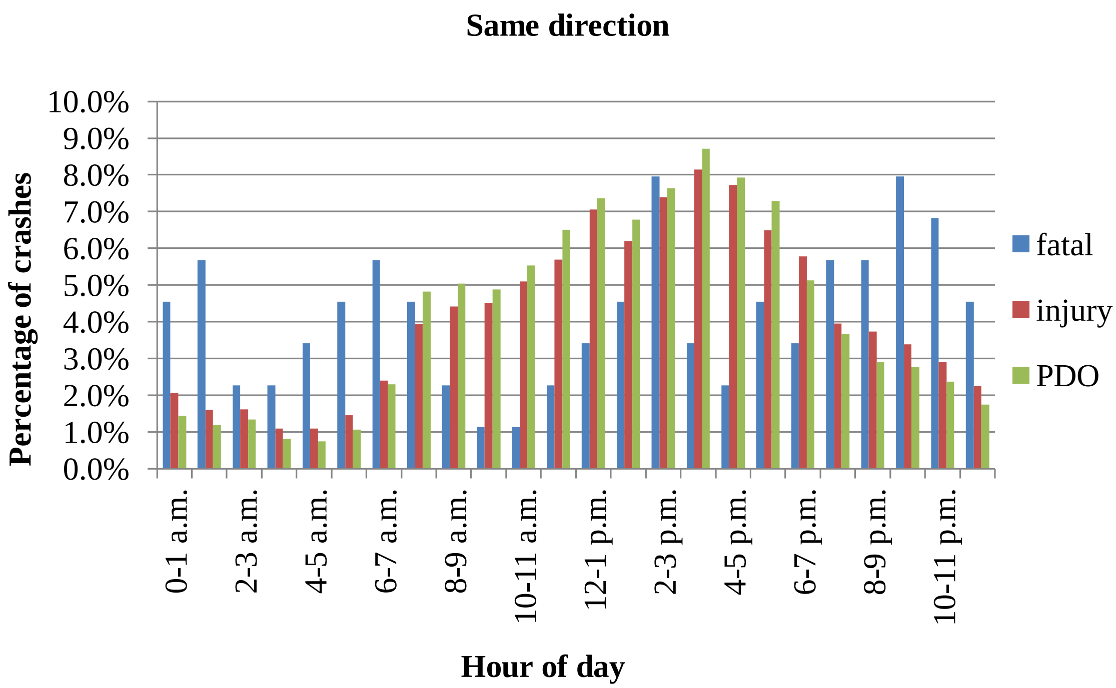


Figure 39
Percentage distribution by number of lanes for sideswipe crashes

The two kinds of sideswipe crashes shared one common characteristic: most of them took place at non-intersections. Over 60 percent of injury and PDO crashes took place at non-intersections, while over 85 percent and 90 percent of fatal crashes took place at non-intersections for same and opposite directions, respectively.

In terms of posted speed limit, the majority of fatal sideswipe crashes took place where the posted speed limits were higher than 55 miles per hour, while more injury and PDO crashes took place where the posted speed limits were lower than 55 miles per hour. For same direction sideswipe crashes, almost 50 percent of fatal crashes involved vehicles that were stopped, while more than 45 percent of injury and PDO crashes involved vehicles that were proceeding straight ahead. However, for opposite direction sideswipe crashes, few crashes involved stopped vehicles. Instead, the majority of the crashes involved vehicles that were proceeding straight ahead and crossed the central line into opposing traffic.

Figure 40 presents the percentage of sideswipe crash distributions by time of day for the same and opposite directions. As can be seen, the distributions for injury and PDO crashes are similar, and different to those of fatal crashes. There were higher percentages of fatal sideswipe for same direction crashes between evening and midnight, while there were more sideswipe opposite direction fatal crashes in the daytime, especially from noon to late afternoon.



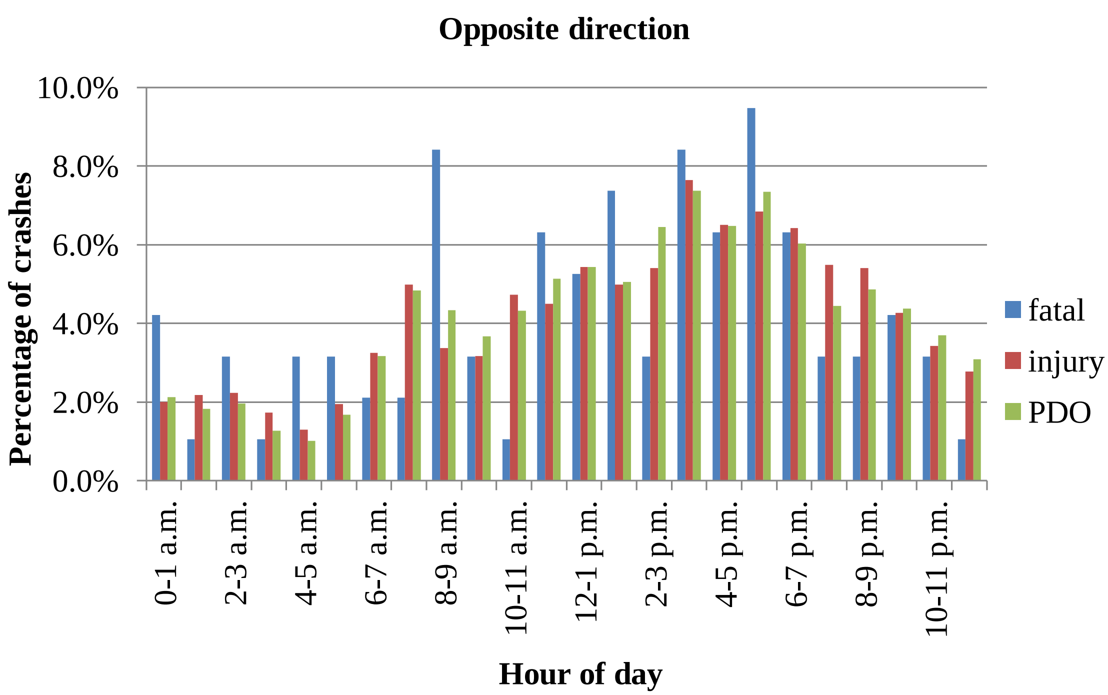


Figure 40
Percentage distribution by time of day for sideswipe crashes

Temporal Distribution. The distribution of crashes by day of week was investigated. The over representation factors of crashes by severity level and day of week is presented in Figure 41. Overall, there is relatively little variation by day of week although fatal crashes are over represented for Saturday and Sunday.

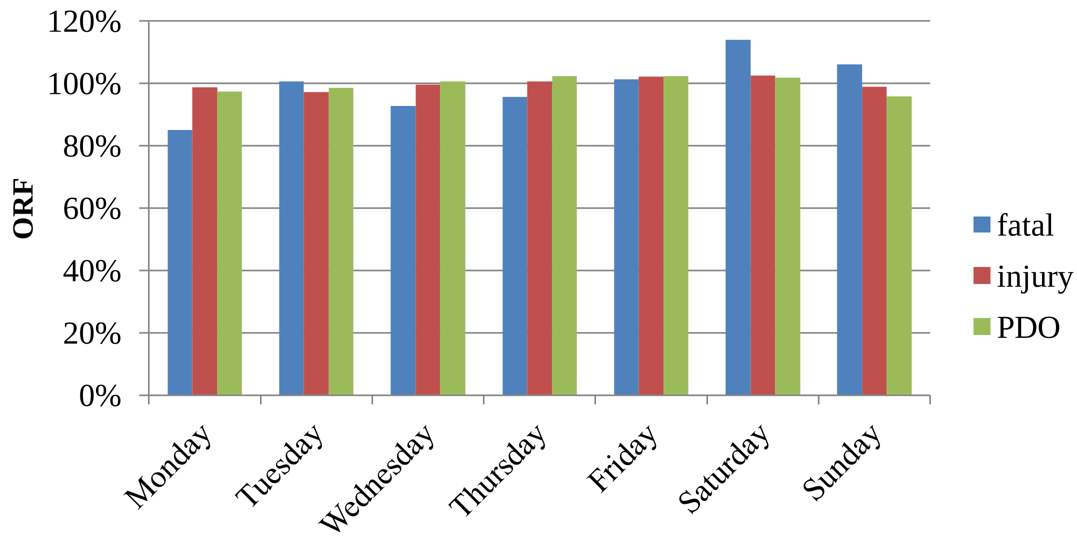


Figure 41
Over representation factors by day of week

The over representation of fatal crashes on Saturday and Sunday are due to alcohol involvement. This was determined by recalculating the ORF after eliminating alcohol-related crashes and establishing that the over representation for Saturday and Sunday completely disappeared.

In terms of hour of the day crash distribution, Louisiana was over represented for the late night and early morning hours from the initial analysis for fatal crashes as well as for early morning hours for injury crashes. PDO crashes were slightly over represented during midday hours from 10 a.m. to 4 p.m. The over representation factors are presented in Figure 42. Note that fatal and injury crashes are high in Louisiana at night, and particularly in the early hours of the morning.

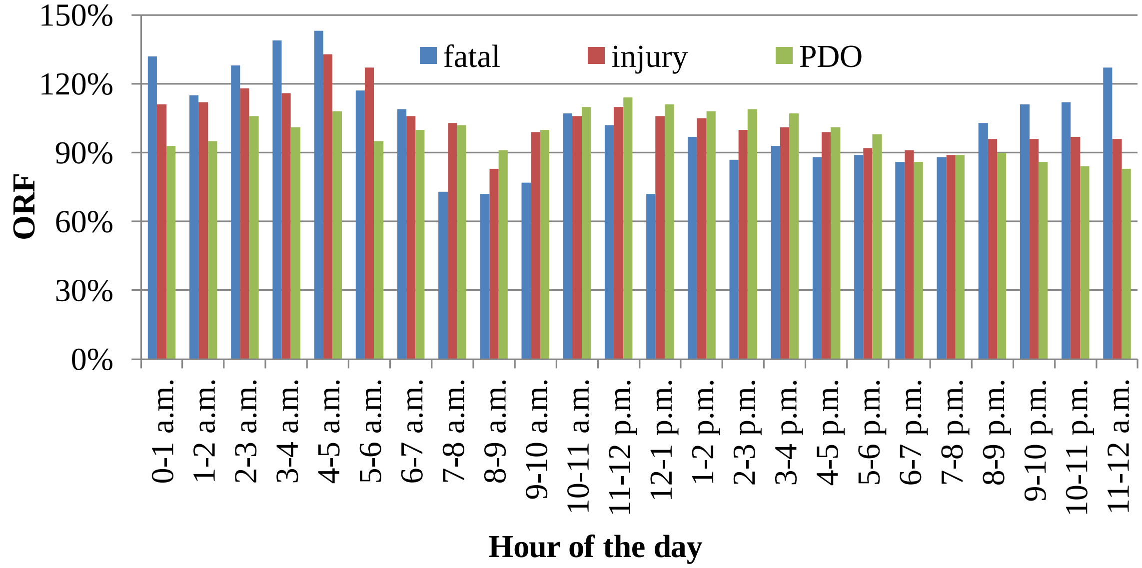


Figure 42
ORF by hour of day

Figure 43 presents the crash percentage distribution by hour of the day for different severities. Injury and PDO crashes are high during the day hours, while fatal crashes are higher at night.

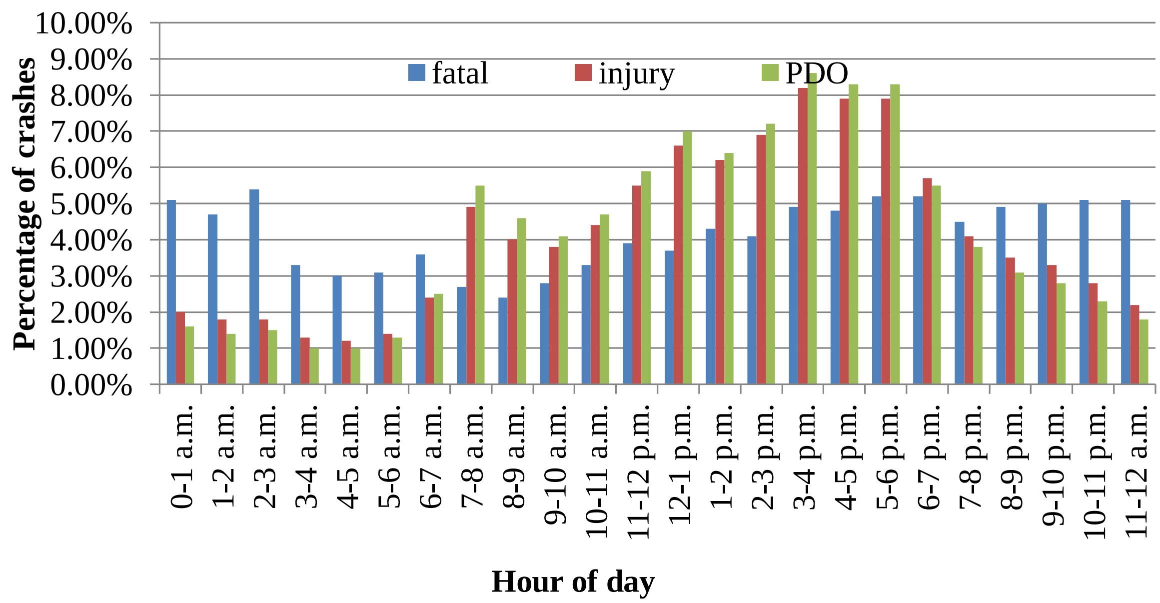


Figure 43
Crash percentage distribution by hour of day

Figure 44 presents the alcohol-related crashes by the hour of the day. Unlike all crashes shown in the previous diagram, the distribution of the three severities by the hour of day follow the same distribution pattern among alcohol-related crashes. In addition, while most crashes occur during the day when traffic volumes are higher, alcohol-related crashes are lower during the daytime and higher at night, peaking in the early hours of the morning.

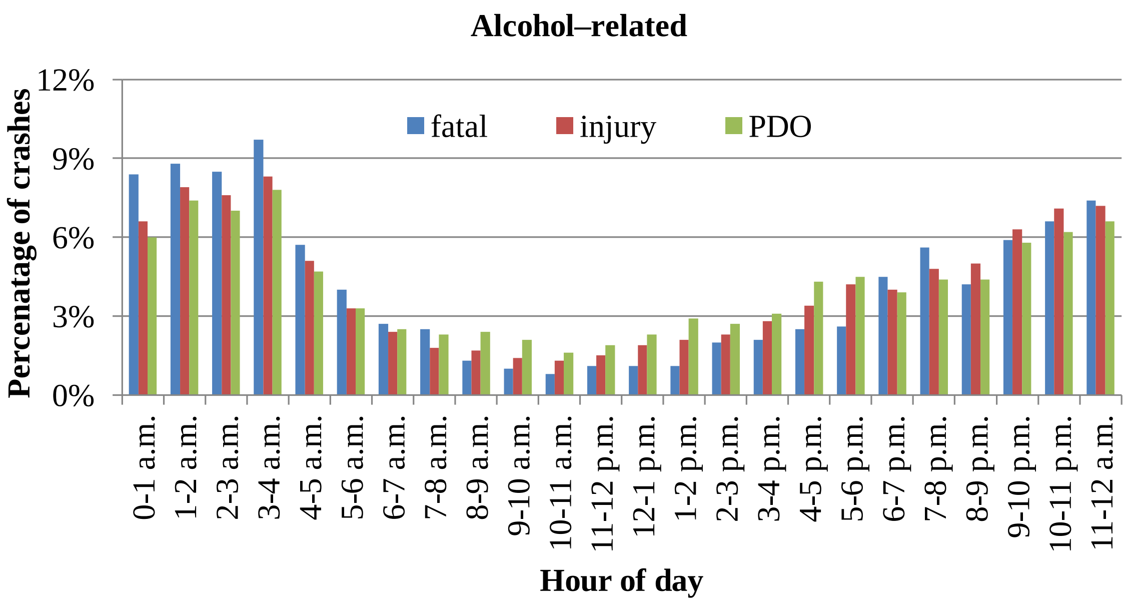


Figure 44
Alcohol-related crash percentage distribution by hour of day

In order to investigate whether the distribution of alcohol-related crashes by the hour of the day shown in Figure 44 varies by the day of the week, the number of alcohol-related crashes that occurred in each hour of the day, each day of the week, in one year in Louisiana was observed.

Figure 45 presents the results of that analysis. As observed earlier, alcohol-related crashes generally occur late at night and most frequently in the early hours of the morning. However, a greater frequency and concentration of crashes occurs in the early hours of the morning over weekends (Saturday and Sunday). This applies to crashes of all severities although dominance of the early morning crashes in the distribution is more pronounced for the more severe type of crashes.

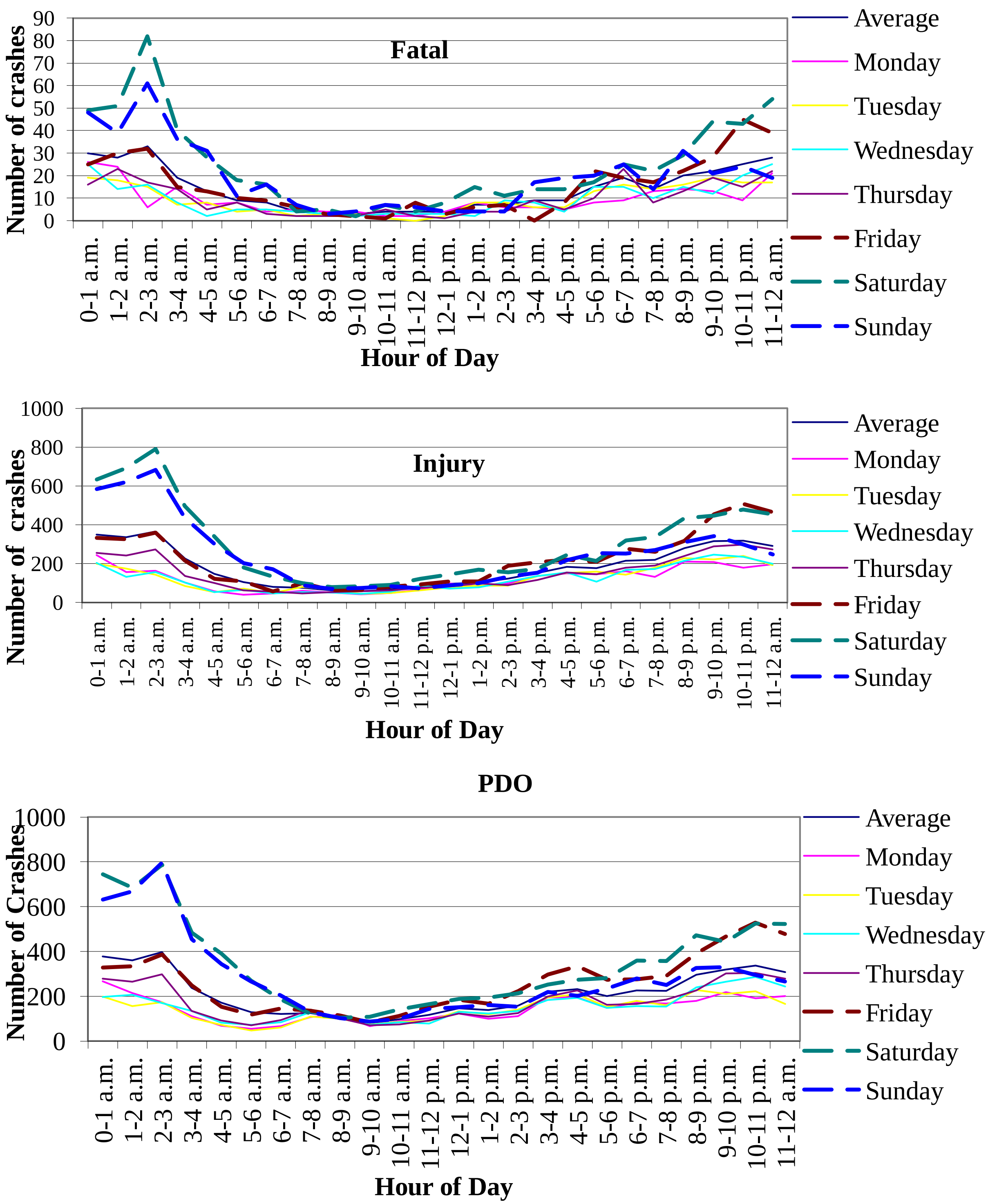
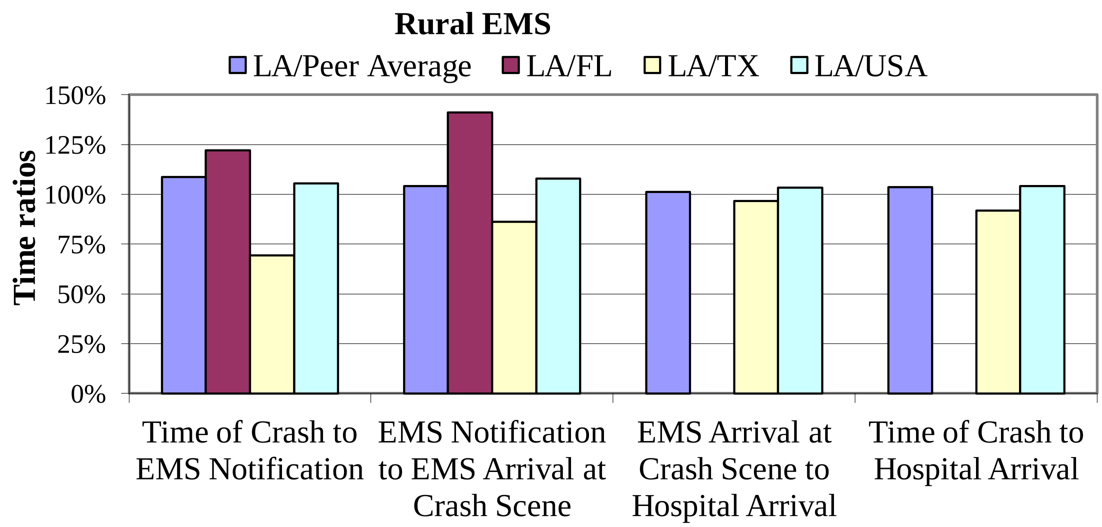


Figure 45

Alcohol-related crash percentage distribution by hour of day and day of week

Emergency Medical Services. The quality of emergency medical services (EMS) was measured by the time elapsed between the occurrence of the crash and the arrival of casualties at the hospital. This time was broken down into the time from the crash to the EMS notification, the time from EMS notification to arrival at the crash scene, and from EMS arrival at the crash scene to arrival at the hospital. EMS was also divided into rural and urban. The EMS time ratios of Louisiana to the peer states and the national average for rural and urban for 2004 are shown in Figure 46.



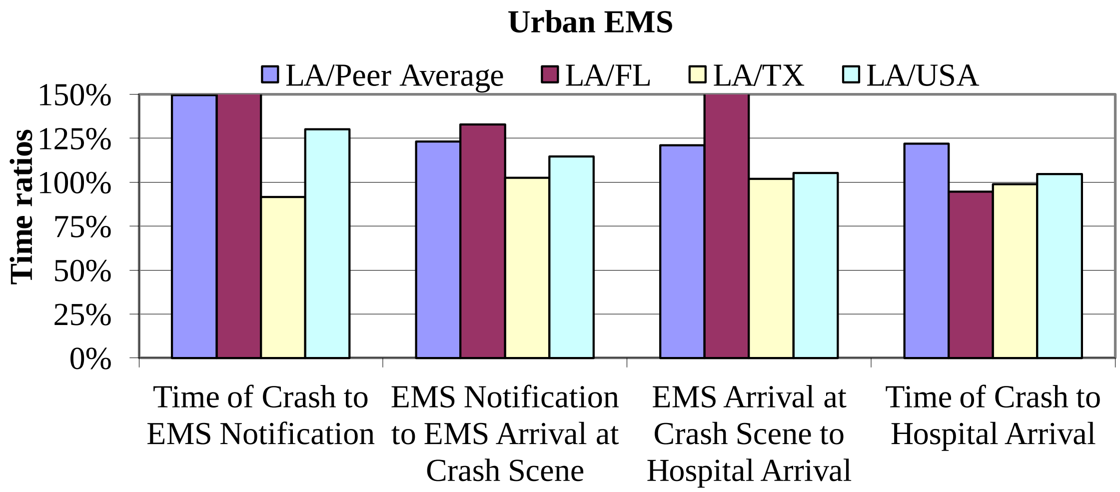


Figure 46
Louisiana EMS response time for rural and urban areas

Florida data have missing values for some categories for rural EMS. For rural EMS, Louisiana had about the same time of crash to hospital arrival as the peer states and national average. However, for urban EMS, Louisiana had a longer time of crash to hospital arrival than the peer states and national average. The rates were 122 percent and 105 percent for the peer states and national average, respectively. Louisiana was slow in all three time components.

A trend analysis of Louisiana urban EMS from 1999-2004 was conducted to determine whether the state was deteriorating with regard to EMS response or improving. The results are shown in Figure 47. The time from crash to EMS notification and the time from notification to arrival have remained relatively unchanged during this period. The major problem for Louisiana is that the time from EMS arrival at crash scene to hospital arrival steadily increased between 2001 to 2004, resulting in an increased overall EMS time (from crash to hospital arrival).

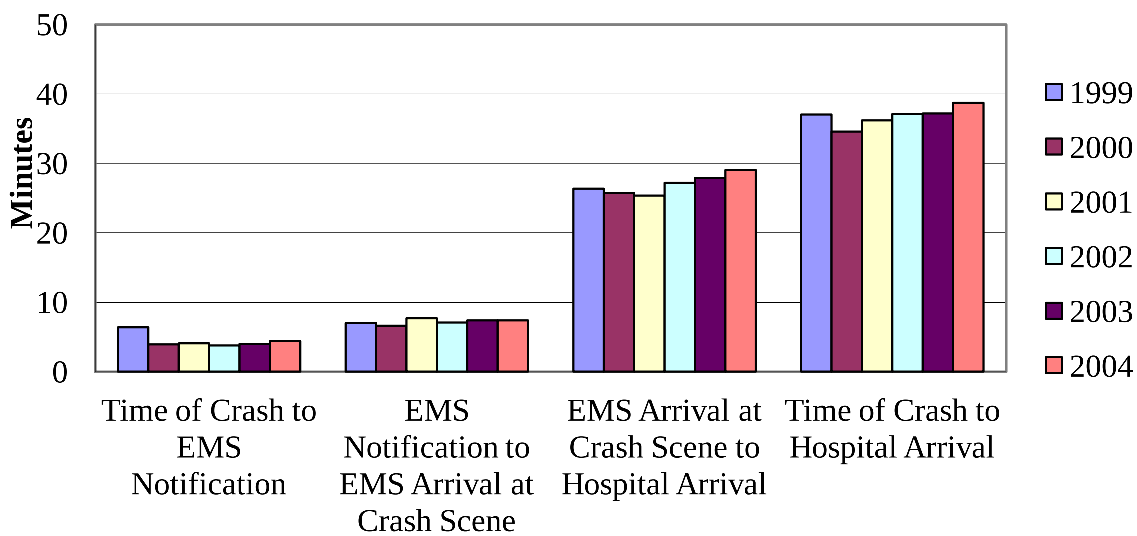


Figure 47

Louisiana urban EMS response time trend 1999-2004

Repeat DUI Crashes. An analysis of the Louisiana crash database was conducted to establish whether information in the crash report can be used to identify the characteristics of repeat DUI offenders. Using a Cox proportional hazards model in which the event is a repeat DUI offense, the model shown in Table 4 was obtained. The variables, which are all categorical, are all significant at the one percent level of significance except for category "other" of variable highway type, which has a p value (probability of falsely rejecting the hypothesis that the coefficient has a value of zero) of 0.057. The log likelihood ratio test was 508 on 16 degrees of freedom with 48,365 observations, which thoroughly rejects the null hypothesis that the coefficients of all variables are zero. The value of the exponential of the coefficient ($e^{coef.}$) in Table 4 gives the hazard of the variable relative to that of the base variable in the category. For example, in the gender category, the exponential of the coefficient for males is 2.11, indicating that males are 2.11 times more likely to repeat a DUI offense than females (the base case in the gender category).

Table 4
Cox model estimation results and sample sizes

feature	variables	category	coef.	$e^{coef.}$	std. error of coef	p	sample size
driver	gender	female (reference)					13023
		male	0.747	2.110	0.134	0.000	40594
	race	non-white (ref.)					16416
		white	0.785	2.193	0.137	0.000	37017
	gender*race		-0.483	0.617	0.145	0.001	
	age	under 21 (ref.)					6297
		21-24	-0.190	0.827	0.064	0.003	9175
		25-34	-0.377	0.686	0.060	0.000	14799
		35-44	-0.196	0.822	0.058	0.001	14223
		45-54	-0.480	0.619	0.076	0.000	6160
		55+	-0.742	0.476	0.109	0.000	3056
vehicle	vehicle type	other (reference)					32813
		truck/pick up	0.100	1.105	0.040	0.012	20680
crash	violation	no (reference)					6134
		yes	0.656	1.927	0.088	0.000	47030
	driver arrested	no (reference)					51038
		yes	0.274	1.315	0.075	0.000	2904
	hit and run	no (reference)					48765
		yes	0.512	1.669	0.056	0.000	5178
location	land use	other (reference)					20860
		residential	0.108	1.113	0.041	0.009	31879
roadway	2-way road no barrier	no (reference)					15480
		yes	0.129	1.138	0.046	0.005	35008
	highway type	city road (ref.)					12518
		state road	0.189	1.208	0.054	0.000	20479
		other	0.105	1.111	0.055	0.057	21208

The model in Table 4 shows that a wide variety of factors are associated with repeat DUI crashes including the characteristics of the drivers (gender, race, and age); the vehicles (light truck/pick up); crash history (hit-and-run, driver violations, and driver arrest); location (residential); and road type (highway).

Among the driver characteristics, gender, race, and age are significant in describing the likelihood of repeat DUI violations. The relative hazard for different combinations of gender and race are plotted in Figure 48, where a non-white female is used as the reference (with relative hazard of 1). A non-white male driver is 1.11 times as likely as the non-white female driver to have a repeat DUI crash, while a white female driver is 1.19 times as likely, and a white male is 1.85 times as likely to have a repeat DUI crash. Such results are in line with the findings from Marowitz (1998) who reported that a male had 160 percent higher odds of recidivating than a female. The association of gender and repeat DUI crashes was also confirmed by other studies (Yu and Williford, 1995; Marques et al., 2001). In terms of race, the result was not surprising based on the reported overwhelmingly higher alcohol usage in whites than in non-whites across all age groups in the US (NIAAA, 2006).

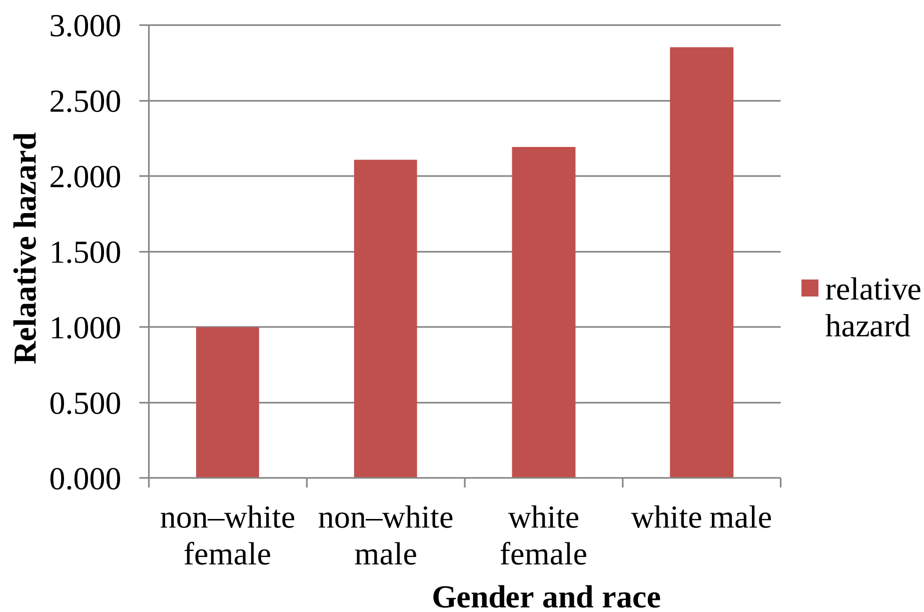


Figure 48

Relative chance of repeat DUI offense by driver gender and race

Driver age could be treated either as a continuous variable or a categorical variable. Initially, it was modeled as a continuous variable. The coefficient was significant at the one percent level of significance with a negative sign, indicating a continuous decreasing hazard as age increases. However, the results were somewhat different when driver age was modeled as a categorical variable, as shown below. Driver ages were categorized into six groups: under 21, from 21 to 24, from 25 to 34, from 35 to 44, from 45 to 54, and 55 and above. Taking the group of under 21 as a reference, all the other groups were significantly different from the reference group, with decreasing hazards in general with the exception for age group from 35 to 44. Figure 49 plots the relative hazards of different age groups with the reference group having a relative hazard of 1.

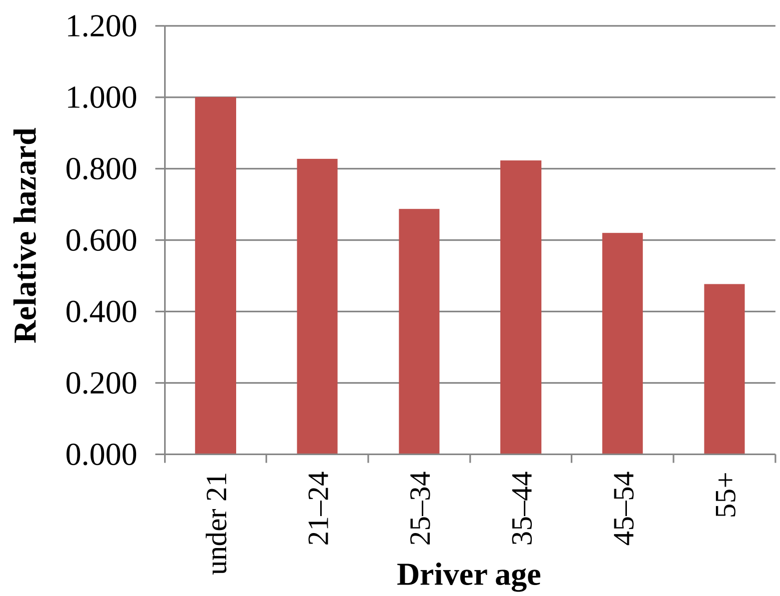


Figure 49
Relative chance of repeat DUI offense by age group

The negative association between age and repeat DUI crashes has been observed by other researchers as well (Yu and Williford, 1995; Marowitz et al., 1998; Marques et al., 2001; Lapham et al., 2000). However, if age was modeled as a continuous variable, as was done by Marowitz (1998) and by the initial effort in this study, the non-linear relationship shown in Figure 49 would have been missed. A possible explanation for the repeat DUI offense rate among 35- to 44-year olds may be due to higher exposure - they typically drink and drive more often compared to other age groups, as illustrated in roadside surveys and with selfreported data. Moreover, this is partially in agreement with what White and Syrcle (2008) pointed out, that DUI recidivists are predominantly between the ages of 25 and 45, and is also supported by the large number of DUI crash drivers for that age group (last column in Table 4). The combined impact of gender and age makes young males the most vulnerable group with the highest hazard of repeat DUI crashes. This is consistent with the finding of Lapham et al. (2000), who studied risk factors for re-arrest of DUI and found that young males had higher recidivism.

Vehicle Characteristics. The type of vehicle probably reflects, to some degree, the characteristics of the driver and was found to be a significant predictor of repeat DUI crashes. Vehicle type was classified into two categories: light trucks and other. The latter was used as the reference category and 89.4 percent of them were passenger cars. The results indicated a 10.0 percent increase of hazard of repeat DUI crashes for those drivers who drive light trucks compared to those who drive other vehicles.

Crash Characteristics. Three factors reflecting the characteristics of DUI crashes were found to be significant in predicting repeat DUI crashes: whether the driver had violations, whether the driver was arrested, and whether the crash was a hit-and-run. The model indicated that if a driver had violations in the crash, then he or she had a 92.7 percent higher hazard of repeat DUI crashes. Violations may be viewed as an indication of excessive alcohol consumption or dangerous driver behavior. If a driver was arrested at the scene, then this driver had a 31.5 percent higher hazard of repeat DUI crashes. Being arrested is an indication of the seriousness of the offense and/or the extent of aggressive unlawful driving. Having both violations and being arrested increased a driver's hazard of repeat DUI crashes by 153.4 percent. The interaction between the two variables was tested and was not found to be significant.

Whether a driver is involved in a hit-and-run crash has a strong impact on the hazard of repeat DUI crashes. In the crash database, hit-and-run was a variable associated with the crash, not with a vehicle or driver, but the alcohol-related driver was most likely to be the hit-and-run party. When involved in a hit-and-run crash, a DUI driver had a 66.9 percent higher hazard of repeat DUI crashes. However, the coefficient of hit-and-run failed the proportionality test, which was a key assumption of the Cox model [equation (3)]. It was not clear whether the finding was merely an artifact of the data, or whether it may actually have a more substantial meaning. Further investigation on this matter is needed.

Crash Location. One location variable was found to be significant in identifying a high hazard of repeat DUI crashes. If the crash takes place in a residential area, then the repeat DUI crash hazard was 11.3 percent higher than in a non-residential area. This was probably because the offenders are more likely to be going to or from places of residence, instead of going to or from work or other destinations.

Roadway Characteristics. The highway type and the type of the roadway are two important factors identified in the model in predicting repeat DUI crashes. Highway type was classified into three categories. They were city roads, state roads, and other. City roads were used as the reference category. Only the coefficient for state roads was significant at the one percent level although category "other" was close to the five percent significance level threshold. The results indicated that a repeat DUI crash was 20.8 percent more likely to occur on state roads than on city roads. Ideally, other highway classifications, such as the number of lanes and rural/urban roads, should be used to better identify the characteristics of the roads. However, such information was not available from the crash database. An investigation of the LADOTD roadway database, which includes only state, US, and interstate highway information, indicated that Louisiana state highways account for 81.4 percent in total mileage among state, US, and interstate highways; rural two-lane highways were 83.7 percent of all state highways; and 53.2 percent of all alcohol-related crashes on state roads took place on rural two-lane highways. As a result, it was suspected that the high hazard on state roads was due to the higher percentage of rural two-lane highways among all roads. Moreover, if the roadway was two-way without a median, then the hazard of repeat DUI crashes was 13.8 percent higher than for one-way or two-way with median. This was a reasonable result because a one-way or a two-way road with median reduces the chance of crashing with a vehicle from the opposing traffic.

Analysis of Vehicle Characteristics

Several cargo vehicles were over represented in the initial analysis. In terms of cargo body type, they were van/enclosed box, cargo tank, flatbed, and garbage/refuse. Since the number of fatal crashes are very small, the over representation are for injury and PDO only, as shown in Figure 50. Even for injury and PDO crashes, the number involving cargo vehicles is small; Louisiana crash database has 1,828,325 vehicle crash records and the total numbers of records for cargo vehicles is only 12,396 for all severities, which is less than 0.6 percent of all vehicle crashes in the database.

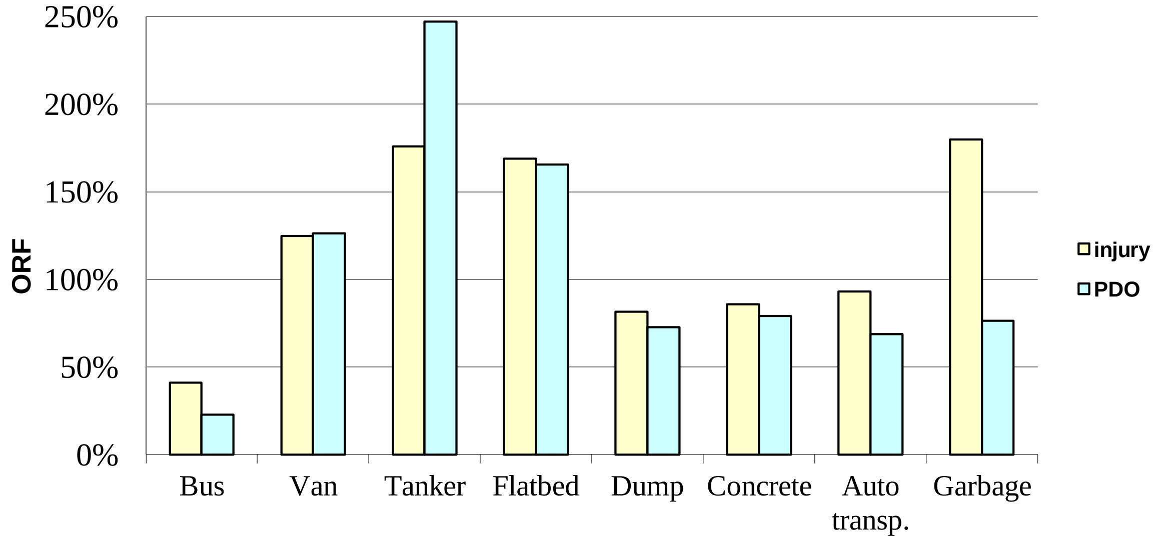


Figure 50
ORF by cargo type

Figure 51 presents the day of week distribution for the three types of cargo vehicles. Van/enclosed box vehicles had the most crashes, followed by cargo tank trucks. There were more crashes during week days than weekends. The distributions of the hour of day for the three cargo types were similar, with most crashes taking place between 5 a.m. and 6 p.m.

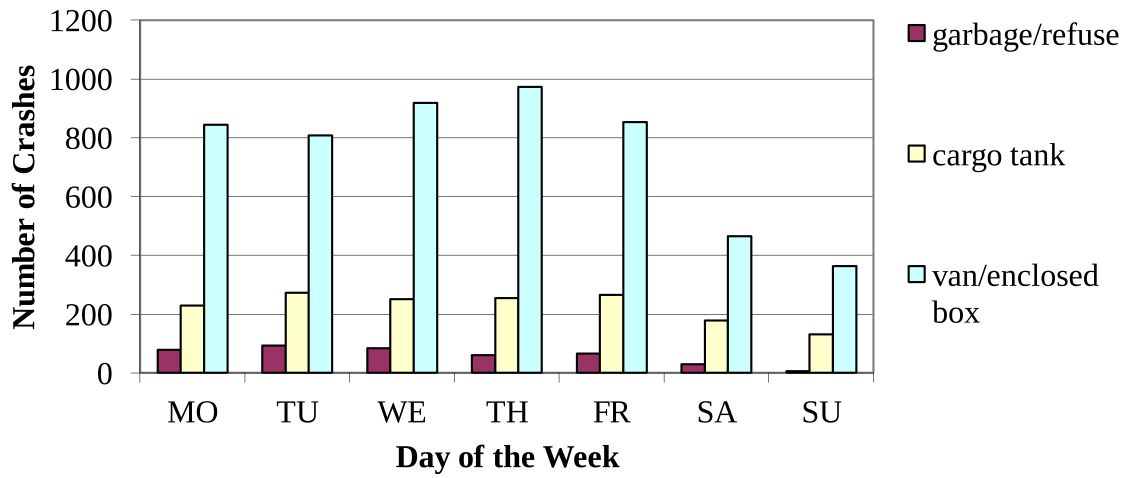


Figure 51
Day of week frequency distribution for three cargo type trucks

Impact of Legislation on Traffic Safety

Some transportation laws implemented in Louisiana were studied to observe how these laws have affected the crash rate in Louisiana. Louisiana crash database from 1995 to 2006 were used in the analysis. During this period, the major traffic laws introduced or amended in Louisiana were the GDL program in 1998, repealing the mandatory motorcycle helmet law in 1999 and reinstating it in 2004, introducing the open alcohol-container law in 2000, and lowering the blood alcohol content (BAC) from 0.10 to 0.08 percent in 2003. Results from the analysis are shown in the following sections. For the detailed analysis of the impact of legislation on traffic safety in Louisiana, please refer to Mudumba (2008).

An investigation was also conducted into the impact of an increase in the statutory speed limit of 55 miles per hour on two-lane rural roads in Louisiana was estimated to have on traffic safety. The study was conducted at the request of a senator in the Louisiana Legislature. The results are reported following the reporting of the impact of past laws on state traffic safety in the sections below.

Identifying the Effect of the Graduated Licensing Law on Traffic Safety

The change in motor vehicle crash rates before and after introducing the GDL program in Louisiana in 1998 is likely due to a number of factors. In order to identify these factors and account for their influence, an ANOVA was applied. This was accomplished by first testing all potential factors that could influence the crash rate of 15- and 16-year-old drivers (i.e., those affected by the GDL) and identifying those that influenced the crash rate in the presence of a change in the GDL. Once identified, the factors were included in an ANOVA with the GDL to detect whether the GDL had a significant impact on crash rates when the influence of these other factors was removed.

The analysis revealed that driver gender, driver age, occupant age, and occupant gender influenced crash rates of 15- and 16-year-old drivers before and after introduction of the GDL. Including them in an ANOVA in which GDL was included as a variable produced the results shown in Table 5. It shows that GDL had a significant impact in reducing injury, PDO, and all crashes combined, but there was insufficient evidence to conclude that fatal crashes were significantly reduced by the GDL program.

Table 5

Effectiveness of GDL law on young driver motor vehicle crash rates

Crash severity	Num. of observations	F-value	P-value	Significance level	Change in crash rates
Fatalities	48	0.40	0.5324	0.05	Insufficient evidence
Injury	96	36.20	<0.0001	0.05	Decreased
PDO	288	19.25	<0.0001	0.05	Decreased
All	288	53.52	<0.0001	0.05	Decreased

Identifying the Effectiveness of Open Container Law

The change in the alcohol-related motor vehicle crash rates due to introduction of the open container law was also associated with changes in driver gender, driver age, occupant age and occupant gender. The effect of the open container law in reducing crash rates when the influence of these factors was removed is shown in Table 6. The open container law was found to have no significant impact at 5 percent significance level on alcohol-related motor vehicle crash rates at all severity levels.

Table 6

Effectiveness of open container law on alcohol-related motor vehicle crash rates

Crash severity	Num. of observations	F-value	P-value	Significance level	Change in crash rates
Fatalities	57	1.07	0.3057	0.05	Insufficient evidence
Injury	57	0.53	0.4710	0.05	Insufficient evidence
All	342	1.70	0.1929	0.05	Insufficient evidence

Identifying the Effectiveness of the BAC Law

The change in the alcohol-related crash rates due to reduction of the BAC from 0.10 percent to 0.08 percent was estimated with the influence of driver gender, driver age, occupant age, and occupant gender removed. Both motor vehicle and motorcycle crashes were studied. With motorcycle crashes, only driver age was a significant extraneous factor. The results for motor vehicle crashes are shown in Table 7. The crash rates for injury, PDO, and all crashes were significantly reduced by introduction of the law, but there was insufficient evidence to conclude that fatal crashes were similarly reduced.

Table 7

Effectiveness of BAC law on alcohol-related motor vehicle crash rates

Crash severity	Num. of observations	F-value	P-value	Significance level	Change in crash rates
Fatalities	474	0.52	0.4714	0.05	Insufficient evidence
Injury	474	9.72	0.0019	0.05	Decreased
PDO	1422	5.22	0.0225	0.05	Decreased
All	474	44.71	<0.0001	0.05	Decreased

The impact of reducing BAC from 0.10 to 0.08 percent on motorcycle crash rates is shown in Table 8. The only significant reduction in crash rates resulting from the BAC reduction legislation among motor cyclists was a reduction in injury crash rates.

Table 8

Effectiveness of BAC law on alcohol-related motorcycle crash rates

Crash severity	Num. of observations	F-value	P-value	Significance level	Change in crash rates
Fatalities	60	0.59	0.4468	0.05	Insufficient evidence
Injury	60	3.96	0.0500	0.05	Decreased
PDO	60	1.03	0.3143	0.05	Insufficient evidence
All	60	1.48	0.2284	0.05	Insufficient evidence

Investigating Speed Limit Increase on Rural Two-Lane Roads in Louisiana

The Louisiana crash database from 1999-2004 was used in this study. Crashes on two-lane rural roads were divided into two groups, one where crashes took place on road sections in which a speed limit increase had been implemented during the 1999-2004 period, and the other where no speed limit change occurred. The data on sections that underwent a speed limit increase were subdivided into before and after subgroups. Crashes were distinguished by severity (fatal, injury, and property damage only) and crash type. Crash rates were calculated by dividing the average number of crashes on a road section per year by its Average Annual Daily Traffic (AADT) and length, and expressing the results as crashes per 100 million vehicle miles of travel.

To control for extraneous factors that affect crash rates and that could be unequally represented in the before and after subgroups (e.g., pavement condition, geometric alignment, lighting, and adjoining land use), a regression tree procedure was employed to establish subdivisions of the data that were as homogeneous as possible with respect to these factors. This allowed any difference in crash rates due to an increase in speed limit to be discernible when comparing between matching subdivisions of data in the before and after data sets, because the influence of the extraneous factors would be negated by being constant between matching pairs of subdivisions of data. In addition, it is possible that an underlying change in crash rates may occur over time due to factors not captured in the data (e.g., improved safety features in vehicles and better emergency response). To capture any trend, crash data from sections in which no speed limit change had occurred between 1999 and 2004 were studied for any distinguishable change in crash rates over time. This was done in each homogeneous subdivision of the data, and when a significant trend was found, the trend was subtracted from observed differences between before and after crash rates.

The analysis resulted in 39 homogeneous subdivisions of the data, distinguished by crash severity, crash type, and other features. After speed limit increase crash rates were adjusted to limit any natural trends, a single tailed t-test was conducted on each homogeneous group to test for statistical difference between the before and after speed limit increase groups. Only 6 of the 39 groups demonstrated a significant increase in the crash rate following a speed limit increase at the 5 percent level of significance. Among injury crashes, the analysis suggested that run off road, crashing with a stationary object, and rear-end crashes would increase significantly with an increase in speed limit. PDO crashes, run off road, overturning, and rear-end crashes were found to increase significantly with an increase in speed limit. However, among fatal crashes no significant difference in crash rate due to an increase in speed limit could be found although this may be due to the high variation in fatal crash rates by road section, rather than an absence of change. It must be noted that the statistical tests conducted in this analysis were set up to identify any significant increase in crash rates with an increase in speed limit; if the test failed, it only meant that the increase was not significant, not that there was no increase at all. Further detail of the study can be found in Wilmot and Jayadevan (2006).

It was estimated that a speed limit increase on two-lane rural roads in Louisiana could cost almost $10 million per year in injury and property damage costs. The study recommended the speed limit on two-lane rural roads in Louisiana not to be increased except when warranted by an engineering study.

Crash Severity Prediction

An ordered mixed logit (OML) model of crash severity was developed in this study by Zhang (2010). It was used to predict the change in crash severity following a change in conditions brought about by introduction of a countermeasure. Estimation results are shown in Table 9. The model has a likelihood ratio index of 0.41 and, when applied to a test data set, demonstrated a prediction accuracy that varied between 87 percent for fatal crashes to 98 percent correct for PDO crashes.

Table 9
Mixed ordered logit model results

Variables	Parameter estimates (P-value)		Standard deviation of random parameter estimates (P-value)
	Fixed	Random	
Constant	6.2691 (0.000)		
Age	—	0.0068 (0.002)	0.0111 (0.000)
Speed	—	-0.0239 (0.000)	0.0055 (0.000)
Alcohol	-0.2548 (0.047)	—	—
Head-on Collision	—	-0.8346 (0.001)	1.5938 (0.000)
Airbag	—	-1.1823 (0.002)	0.0131 (0.048)
Ejection	—	-3.4466 (0.000)	1.1834 (0.000)
Seatbelt	—	1.765 (0.000)	0.1102 (0.003)
Following too close	0.9892 (0.000)	—	—
Gender	—	-0.6663 (0.000)	0.6311 (0.000)

Threshold Parameters for Probabilities		P-value
MU(0)	0	0.0000
MU(1)	1.2858	0.0000
MU(2)	3.7098	0.0000
MU(3)	5.5259	0.0000
Log likelihood at Zero:		-14238.79
Log likelihood at Convergence:		-8443.34
Number of Observations:		19610

One of the applications of the model in this study involved estimating the impact of a reduction in alcohol use on crash severity. For this, 10 percent of crashes in the Louisiana crash database from 1999-2004 with alcohol involvement were randomly selected and their classification of alcohol involvement changed from “yes” to “no.” A new dataset with less alcohol involvement was thus created and the OML model was applied to estimate the change in distribution of crash severities. The results, shown in Table 10, indicate that, besides the reduction in the incidence, the severity among the remaining crashes would be reduced by 4.5 percent for fatal crashes, 8.7 percent for severe injury crashes, 5.9 percent for moderate injury, and 1.9 percent for minor injury. The 0.9 percent increase in PDO crashes balances the reduction among the more severe crashes in the reduced set of crashes.

Table 10

Impact of a 10 percent reduction in alcohol involvement

	Fatal	**Severe injury**	**Moderate injury**	**Minor injury**	**PDO**
Percent reduction by severity	-4.5%	-8.7%	-5.9%	-1.9%	0.9%

Another application involved estimating the impact of increasing seatbelt usage by 10 percent. The results are shown in Table 11. It is noticeable how improved seatbelt use impacts high severity crashes the most and what significant reduction in fatal and injury crashes can be achieved.

Table 11

Impact of 10 percent increase in seatbelt usage

	Fatal	**Severe**	**Moderate**	**Minor**	**PDO**
Percent reduction by severity	-8.4%	-6.02%	-4.9%	-3.0%	1.7%

In another application, the impact on crash severity of reducing vehicle operating speed by 1 mph and 3 mph was tested. The model predicted a reduction in crash severity as shown in Table 12. As can be seen, reducing speed has an overall beneficial effect but the benefits are particularly evident in the reduction of injuries and fatalities.

Table 12

Reduction in crash severity due to speed reduction

Speed reduction	Fatal	Severe Injury	Moderate Injury	Minor Injury	PDO
1 mph reduction	-3.9%	-8.3%	-9.7%	-4.5%	1.9%
3 mph reduction	-8.5%	-10.6%	-11.7%	-6.1%	2.4%

Problems Areas for Which Countermeasures Were Developed

Based on the earlier identification of 23 problem areas that are over represented in Louisiana and the detailed analysis of several of these problem areas in greater detail above, the following eight areas were identified as prime problem areas in Louisiana:

1. Alcohol
2. Young drivers, especially Teen Drivers
3. Seatbelt use
4. Licensing
5. Speed
6. Traffic control: Stop and Red Signal
7. Rural two-lane highways
8. Motorcycle

Countermeasures for the eight major problem areas were identified and then prioritized as described in the next section.

Prioritized Countermeasures

A method to prioritize countermeasures was developed in this study. Rather than being based on cost-effectiveness or cost efficiency as with many other prioritization systems, this procedure employs the collective impact of cost, performance, and the need in identifying priority. That is, countermeasures are prioritized based on their cost of implementation, the extent to which they reduce crashes (performance), and the severity of the problem they address (need). The analyst is able to alter the relative importance of each of these three criteria in the prioritization process.

Fuzzy inference was employed to develop the prioritization procedure because it conveniently accommodates the ambiguities in prioritization, and descriptive terms can be used to describe the input and rule base of the system. Ambiguity exists in the cost and performance (crash reduction capability) of countermeasures.

Countermeasures are aimed at improving conditions in problem areas. The five problem areas for which the countermeasures were prioritized in this study are:

- Alcohol-related crashes
- Young driver crashes
- Low seatbelt use
- High speed-related crashes
- Disregarding stop and red signals

For each problem area, need is measured by the extent that conditions in Louisiana are worse than those in peer states. This is measured by the difference in the proportion of crashes in a problem area in Louisiana to that in peer states, multiplied by the number of crashes in that problem area in Louisiana and the cost of those crashes. Because the cost of crashes vary considerably by severity, crashes of each severity level are handled separately to produce the measure of need shown below:

$$Need_m = \sum_{i=1}^{3} \left(\frac{x_{1im}}{n_{1m}} - \frac{x_{2im}}{n_{2m}} \right) x_{1im} . c_i \qquad (4)$$

In this formula, index *i* indicates the severity class and is equal to one for fatality, two for injury, and three for "property damage only" crashes. The variable x_{1im} is the number of crashes of severity *i* due to problem *m* in Louisiana, and n_{1m} is the total number of crashes due to problem *m* in Louisiana. Variable x_{2im} is the number of crashes of severity *i* due to problem *m* in the peer states, n_{2m} is the total number of crashes due to the problem *m* in the peer states, and c_i indicates the average cost estimated for a typical crash in severity class *i*. According to research, one injury crash costs approximately 20 times the average PDO crash, and one fatal crash costs approximately 20 times the average injury cost (NHTSA, 2002b). Since only relative measures of need are being established, actual values of c_i are not needed and values of 1 for PDO, 20 for injury, and 400 for fatal crashes were used.

The index was applied to each of the five problem areas and then scaled between 0-1. The resulting relative need calculated for the main problem areas in Louisiana are shown in Table 13.

Table 13
Scaled need for the problematic areas

Problematic Area	Scaled Need
Alcohol-related crashes	0.978
Young drivers crashes	0.431
Low seatbelt usage	0.948
High speed-related crashes	0.013
Disregarding stop and red signals	0.408

The “performance” of a countermeasure is considered to be directly related to its crash reduction factor (CRF) and the value of the crashes it prevents. CRFs are the percentage reduction in crashes per unit time expected from implementing a countermeasure. CRF values from NCHRP Report 500 and other sources were used in this study (Agent, Stamatiadis, and Jones, 1996). The value of a crash is the cost saving effected by preventing a fatal, injury, or PDO crash, respectively.

The “cost” of a countermeasure is the total resources including money, time and labor needed to implement a scheme. The estimation of cost was imported from different volumes of NCHRP report 500. Appendix A lists the cost and crash reduction factors estimated for each countermeasure.

The estimates of cost, need, and performance were derived using the previously described procedure for each countermeasure and then submitted to the fuzzy interference system to estimate the priority of each countermeasure. The procedure was initiated by fuzzifying the inputs, which means that, based on the dispersion of data, the number of classes into which the input needed to be classified was determined and inputs were expressed in terms of their membership in each class. The inputs where classified into “low,” “medium,” and “high” classes. Following fuzzification, the rule base was defined, which translates input from the three input criteria into output on a five-point classification scale of prioritization of "low," "relatively low," "medium," "relatively high," and "high."

Three decision criteria (need, performance, and cost) have six permutations and these were used to describe alternative managerial scenarios where the order of the criteria describe the relative importance of the three criteria in the decision process. In each managerial scenario, the criterion that takes first place primarily determines the priority of the countermeasure. The second and the third ranked criteria decide the priority when two countermeasures are roughly the same in terms of the first criterion. Table 14 shows the six scenarios considered in this study and the abbreviations used to depict them.

Table 14
Abbreviations for the six possible scenarios

Scenario	Abbreviation
Cost - Need - Performance	CNP
Cost - Performance - Need	CPN
Need - Performance - Cost	NPC
Need - Cost - Performance	NCP
Performance - Need - Cost	PNC
Performance - Cost - Need	PCN

Rule bases for six scenarios and their corresponding surfaces were drawn. In order to have a consistent rule base, decision surfaces that are derived from drawing the priority versus each pair of inputs have to be monotonically decreasing for need and performance and monotonically increasing for cost. By recognizing the preference expressed in the different scenarios, decision makers are able to select the scenario most applicable to their situation. For example, in times of limited budget, cost may be the most important consideration, followed by the desire to get the most "bang for the buck" achieved in measuring performance, so a cost-performance-need scenario would be appropriate. In contrast, when the desire is to assign funds to those areas where need is the greatest while still obtaining cost-efficiency, a need-performance-cost scenario would be appropriate.

A total of 58 countermeasures were prioritized using this procedure in this study. They were prioritized on all six scenarios to determine whether scenarios produced a different ranking of the countermeasures and whether some countermeasures would consistently rank high among all scenarios, thereby identifying a robust set of countermeasures that retain their priority irrespective of prevailing conditions and managerial preferences. The prioritized list of countermeasures for all six scenarios is given in Appendix B.

To test the similarity of countermeasures' ranking among the scenarios, the Spearman Rank Correlation test was conducted on all pairs of scenarios. Four of the 15 pairs of scenarios were found to produce similar rankings (PNC and CNP, CNP and NPC, NCP and PCN, and PNC and NCP), while the remaining 11 pairs produced dissimilar rankings.

Results from the fuzzy inference prioritization system developed in this study were compared with results from the traditional benefit-cost ratio by comparing the average ranking obtained from PCN and CPN fuzzy scenarios with the ranking obtained from performance over cost (P/C). No significant difference was found in the ranking between the two methods (see Appendix C).

Some priority countermeasures that came out "high" in all six scenarios in Louisiana are given below. These are suggested for implementation as they retained their priority despite changes in managerial preferences:

- Use alcohol interlocks.
- Enforce zero tolerance laws for drivers under age 21.
- Increase belt use law penalties: fines and driver's license points.
- Limit license violators from using vehicles.
- Provide mid-block pedestrian refuge.
- Remove or relocate unnecessary signs.
- Supervise driving for beginners at age 16 for six months.
- Use protected left turns + left turn phase.

CONCLUSIONS

The objective of this study was to identify and quantify the factors leading to the high crash rate in Louisiana. A secondary objective was to develop countermeasures to address these factors and prioritize their application.

Among Louisiana's seven peer states (Alabama, Arkansas, Colorado, Kentucky, Mississippi, Oklahoma, and Tennessee), Louisiana had the second highest fatal crash rate during the period of analysis (1999-2004). In comparison to the national average, Louisiana's fatal, injury, and PDO crash rates were, respectively, 1.5, 1.7, and 1.1 times higher. Thus, as suspected, Louisiana's road safety record is inferior to that of the rest of the nation, and even within peer states, it is amongst the worst.

To identify the root causes of the road safety condition in Louisiana, safety performance in Louisiana was measured in individual areas of road safety and then compared to the road safety record in the same areas in peer states or the nation. Areas in which the proportion of crashes were higher in Louisiana than elsewhere signified a potential problem area. Other aspects considered were the proportion of all crashes represented by the area (to establish the extent of the problem) and the trend in the relationship (to measure whether the problem was deteriorating or improving). This analysis led to the identification of 23 problem areas. In keeping with the findings of phase 1 of this study (Wilmot et al., 2005), much of the poor road safety performance in Louisiana is related to human behavior, so this study concentrated on human factors. Only limited attention was given to the contribution of roadway and vehicle characteristics to road safety.

Human behavior most affecting road safety in Louisiana was the physical and mental condition of drivers (alcohol or drug use, distraction/inattention, fatigue, etc.) and the behavior they manifest (late night drinking and driving, speeding, low or improper seatbelt use, invalid driver's license, repeat offenses, etc.). The behaviors were not uniform across the population; young drivers (age $\leq$ 24) are roughly three times as likely to be killed or injured in road crashes in Louisiana as drivers aged 55-74. Males have twice the fatality and injury rate of females. The reason for these statistics are varied but at least some of the factors that have a bearing on these results are inexperience of the driver, peer influence, distraction, alcohol, and time of day. The GDL law in Louisiana requires that drivers under the age of 17 are not allowed to drive unsupervised between 11 p.m. and 5 a.m., but the crash record of those that violate the law shows they have a relative crash involvement of at least twice that of 17-21 year-old drivers. Crashes are reduced considerably when drivers under 17 years of age drive under the supervision of an adult, but increase with the number, similar age, and gender mix of passengers. GDL schemes that target the number, age, and time of day passengers can be carried are likely to be effective in improving safety.

Alcohol-related crashes are higher in Louisiana than in peer states or the nation. From FARS data, the proportion of alcohol-related fatalities among all road fatalities were 22 percent higher in Louisiana than in peer states and 17 percent higher than in the nation as a whole. The GES data indicate that the proportion of alcohol-related fatal crashes are 31 percent higher in Louisiana than in the nation. Most alcohol-related crashes in Louisiana occur in the early hours of the morning (1-3 a.m.) on weekends, involve young drivers (ages 18-24), and are two to three times more likely to involve a male driver rather than a female driver. Alcohol-related fatal crashes are also associated with low seatbelt use (24 percent seatbelt use in alcohol-related fatal crashes versus 38 percent seatbelt use in all fatal crashes in Louisiana) and driver error such as elevated incidence of head-on crashes and run off road single-vehicle crashes. Thus, sobriety checks in the early hours of the morning over weekends at locations where young males are likely to congregate is likely to result in safer driving behavior (lower DUI, higher seatbelt use), lower crash incidence due to better driver judgment, and lower crash severity due to increased seatbelt use and subsequent lower ejection from the vehicle. Other countermeasures identified as effective in countering driving under the influence of alcohol are the use of ignition interlock devices for repeat offenders, and enforcement of the zero tolerance law for offenders under the age of 21.

A detailed investigation was made into repeat offenses of DUIs in Louisiana, and young white males with a previous crash record were the group with the highest record of repeat DUIs. Other factors included the type of vehicle (pick-up truck) and two-way roads, but the incidence of these factors may be due to the fact that young white males are more likely to use pick-up trucks and drive on two-lane roads. Effective countermeasures are the use of alcohol interlock devices mentioned above, enforcement of the zero tolerance law, and use of the driver point system to track and punish repeat offenses, including suspension or revocation of a driver’s license.

Inadequate driver performance is a widespread problem that includes inattention, distraction, fatigue, illness, sleep, and loss of consciousness of the driver. Louisiana is over represented in crashes associated with these conditions with ORFs relative to the nation of 1.38 for all crashes and 2.69 for fatal crashes (see Table 3). Inattention and distraction can vary from mildly distracting activities such as conversation or listening to music to serious distractions such as arguing, reading, dialing, or texting. It is important to recognize that it is not the nature of the activity (i.e., verbal versus manual, hands-on or hand-free) that presents a problem, but it is the degree of distraction the activity causes. Reducing distractions among young drivers and increasing perception among older drivers should be the focus of countermeasures used to address this problem. Some of the countermeasures that could be used in this regard are restricting the number of young passengers that young drivers may carry, increasing the period and time of supervised driving for young drivers, and prohibiting texting and dialing on cell phones while driving,

One of the areas of human behavior in which Louisiana (and the nation) have improved is the use of seatbelts, although Louisiana does lag behind the rest of the nation (75 percent in Louisiana versus 81 percent in the nation) and has a higher incidence of drivers using a shoulder belt only. Alcohol-involved drivers that were in injury and PDO crashes were found to be three times more likely to not use a seatbelt than all drivers combined, and 76 percent of alcohol-involved drivers and 62 percent of all drivers involved in fatal crashes did not wear safety belts. The age group displaying the highest seatbelt non-use is the 15- to 17-year olds. This is partly due to the fact that approximately 33 percent of 15- to 17-year olds were recorded as sitting in the second row of seats in the Louisiana crash data, where seatbelt use is lower than in the first row of seats, but there is a clear trend for younger people in Louisiana to not use a seatbelt at all. This suggests that education on the benefits of using seatbelts, enforcement of the law that requires seatbelt use on all rows of seats in a vehicle, and promotional campaigns aimed at young people could be effective in this area. Other countermeasures are free checking of the correct installation and use of child restraint systems by trained professionals at fire stations and vehicle emission testing centers, commercials on television on the correct use of child restraint systems, and the introduction of the point system on a driver’s license where the number of points allowed on a drivers license in a specified period is limited and/or is used by insurance companies to establish car insurance premiums.

Speeding and disregarding traffic controls are violations that appear twice as often in crash data in Louisiana as in the rest of the nation. Speeding violations occur on all facility types but, as would be expected, the severity of crashes associated with speeding are highest on rural roads where speed is the highest. Thus, concentrating efforts at speed control on rural roads could have the dual benefit of reducing speed-related crashes and reducing their severity. The most common form of traffic control violation is running a red light (48 percent), followed by disregarding stop signs (36 percent). Drivers most likely involved in these violations are older drivers (65+), and they are more likely to be killed in crashes of this nature than younger people. Countermeasures for speeding and violation of traffic control systems are enforcement of the law and the use of traffic calming measures in residential neighborhoods. Violators can be identified using automated video cameras but imposing a penalty remains at the discretion of law enforcement officers. It is in the area of imposing penalties where law enforcement has the greatest opportunity to get the public on their side with respect to the widespread use of automated equipment - slight or infrequent violations can be treated with a warning, while severe and frequent violations can incur greater fines. Before-and-after statistics must also be provided to document the safety benefit of these devices.

Driver license violations are up to 64 percent higher in Louisiana than the rest of the nation. As mentioned earlier, in Louisiana drivers have their license suspended when any vehicle they own does not have insurance, even though they are legally able to drive another vehicle that does have insurance. To what extent other states have similar regulations is not known, so a direct comparison may not be appropriate. However, the high license driver violations in the state include violations such as having no license, not complying with an endorsed or restricted license, or having an invalid, revoked, or suspended license. No conclusion can be drawn on this matter from the analysis conducted in this study and the matter must be investigated further to get clarity on the magnitude of the problem.

Regarding the impact that road infrastructure has on road safety in Louisiana, crashes on the shoulder and off the roadway are more than 2.5 times more prevalent than in the rest of the nation. Fatal off-roadway crashes are 3.4 times more prevalent in Louisiana than in the rest of the nation and are seven times more prevalent than on-shoulder fatal crashes. Most fatal off-roadway crashes in Louisiana involved an overturned vehicle or collision with a tree suggesting more attention be given in road design to recovery areas off the road and the position of trees within the road reserve. Most fatal off-roadway crashes occur late at night (10 p.m. to 2.00 a.m.) when drivers are most exposed to alcohol and are also most likely to be tired and drowsy.

The role of vehicles in explaining the high crash rate in Louisiana revealed that on the commercial vehicle side, injury and PDO crashes of tanker and flatbed trucks were over represented relative to the rest of the county by between 150 and 250 percent, while fatal crashes were not over represented. The high injury and PDO crash rate may be due to the higher use of these types of trucks in a state that has a strong chemical and industrial base, particularly since other types of trucks in the state (e.g., auto transporter, concrete, and dump) did not display over representation. Thus, the current statistics suggest that there may be a problem with respect to some types of vehicles, but a more in-depth study would be required to determine that. Considering the crashes associated with tanker and flatbed trucks in Louisiana constitute a very small proportion of total crashes, this is not a high priority issue.

Implementation of countermeasures reduces the number of crashes but also often serves to reduce the severity of the remaining crashes. For example, based on the analysis conducted in this study, reducing the proportion of alcohol-related crashes by 10 percent in Louisiana would change the distribution of crash severity by reducing the proportion of fatal crashes by 4.5 percent, serious injuries by 8.7 percent, moderate injuries by 5.9 percent, and minor injuries by 1.9 percent from what they were before. The proportion of PDO crashes in new sets of crashes would increase by 0.9 percent. Because road crashes cost so much, small reductions like those mentioned above can translate into enormous cost savings to the state. For example, in Louisiana a 4.5 percent reduction in fatal crashes translates to a saving of approximately 40 lives each year. If each life is valued at $2.6 million (Judycki, 1994), this represents more than $100 million saving each year. Severe injuries at $180,000, moderate injuries at $36,000, and minor injuries at $19,000 (Judycki, 1994), where the number of injuries in Louisiana of those severities is approximately 1,500, 11,000, and 37,000 per year, respectively, adds another $60 million per year to the $100 million saved in fatalities.

RECOMMENDATIONS

It was concluded from the analysis in this study the major source of the poor road safety record in Louisiana is due to human behavior, particularly among young male drivers. While a detailed study of the most appropriate actions necessary to address the factors affecting road safety in the state is required, the actions below are recommended for implementation as a start to improving driver and occupant behavior. The recommendations have been derived by considering the outcome of the analysis in this study as a whole, taking account of the conclusions drawn, and calling on the author's assessment of the effectiveness and efficiency of individual actions as gained from literature and experience:

- Introduce a point system on driver's licenses where points are withdrawn for violations such as DUI, failure to use a seatbelt, speeding, or repeated violation of a traffic control device.
- Work with insurance companies to use the point history of drivers to set car insurance premiums, require more frequent driver license renewal for drivers with low points, and reward drivers with no point withdrawal with a letter congratulating them on their safe driving and renewing their drivers license without any testing.
- Amend the Graduated Driver Licensing law to include extended supervised driving, require at least 30 hours of supervised night-time driving, and limit passenger carrying capacity of persons of similar age (e.g., 15-17).
- Conduct sobriety checks that target young male drivers.
- Ensure that firemen, state police, and employees of state vehicle inspection facilities are trained in the correct installation and use of child restraint systems. Publicize that advice and checking services are available through these agencies, require state police to check child restraint systems as a secondary enforcement measure, and include checking the correct installation of child restraints systems as an item in the annual vehicle inspection.
- Publicize the correct use of child restraint systems by age and weight, their benefits, and the dangers of improper use.
- Educate the public, particularly the youth, on the benefits of wearing seatbelts
- Investigate the high incidence of drivers operating without a valid driver's license in Louisiana.
- Investigate the safety impact of texting and dialing while driving.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ALR	Administrative License Revocation
ALS	Administrative License Suspension
ANOVA	Analysis Of Variance
AMF	Accident Modification factor
BAC	Blood Alcohol Content
B/C	Benefit-Cost ratio
CDC	Centers for Disease and Control
CDL	Commercial Driver License
CNP	Cost, Need, Performance
CPN	Cost, Performance, Need
CRF	Crash Modification Factor
DOTD	Department of Transportation and Development
DUI	Driving Under Influence
DWI	Drinking While Intoxicated
EMS	Emergency Medical Services
FARS	Fatality Analysis Reporting System
FIS	Fuzzy Interference System
GDL	Graduated Driver's Licensing
GES	General Estimates System
HSRG	Highway Safety Research Group
IID	Ignition Interlock Device
ISDS	Information Systems and Decision Sciences
LADOTD	Louisiana Department of Transportation and Development
LHSC	Louisiana Highway Safety Commission
LSU	Louisiana State University
MADD	Mothers Against Drunk Driving
NCHRP	National Cooperative Highway Research Program
NCP	Need, Cost, Performance
NHSC	National Highway Safety Commission
NHTSA	National Highway Traffic Safety Administration
NPC	Need, Performance, Cost
OML	Ordered Mixed Logit

ORF	Over Representation Factor
PAS	Passive Alcohol Sensor
PBT	Preliminary Breath Tester
PCN	Performance, Cost, Need
P/C	Performance-Cost ratio
PDO	Property Damage Only
PNC	Performance, Need, Cost
RCIR	Relative Crash Involvement Ratio
STEP	Selective Traffic Enforcement Programs
VMT	Vehicle Miles Travelled

BIBLIOGRAPHY

1. Agent, K., Stamatiadis, N., and Jones, S. "Development of Accident Reduction Factors," Report KTC-96-13, Kentucky Transportation Center, University of Kentucky, Lexington, KY, 1996.

2. Akbarzadeh, M. "Prioritization of Safety Countermeasures for the State of Louisiana Using Fuzzy Inference Systems," Masters Thesis, Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA, 2009.

3. Carr, B. R. "A Statistical Analysis of Rural Ontario Traffic Accidents Using Induced Exposure Data." *Proceedings of the Symposium on the Use of Statistical Methods in the Analysis of Road Accidents*, OECD, Paris, France, 1970, pp. 86-72.

4. Dewar, R.E., and Olson, P.L. *Human Factors in Traffic Safety*. Lawyers and Judges Publishing Company, Inc., Tucson, AZ, 2002.

5. Freund, J.E. *Modern Elementary Statistics*, 11^{th} Edition, Pearson Prentice Hall, NJ, 2004. p. 370.

6. Fu, H. and Wilmot, C.G. "Effect Of Passenger Age And Gender On Young Driver Crash Risk." *Proceedings of the 87^{th} Annual Meeting of the Transportation Research Board*, Washington D.C., 2008.

7. Highway Safety Research Group (HSRG). "2002 Louisiana Traffic Records Data Report," Department of Information Systems and Decisions Sciences, E.J. Ourso School of Business, Louisiana State University, Baton Rouge, LA, 2004.

8. Highway Safety Research Group (HSRG). "2004 Louisiana Traffic Records Data Report," Department of Information Systems and Decisions Sciences, E.J. Ourso School of Business,, Louisiana State University, Baton Rouge, LA. 2005.

9. Judycki, D.C., *Motor Vehicle Accident Costs*. T 7570.2, Federal Highway Administration, U.S. Department of Transportation, Oct., 1994. http://safety.fhwa.dot.gov/facts_stat/t75702.cfm Accessed Nov. 2009.

10. Lapham, S.C.; Skipper, B.J.; Hunt, W.C.; and Chang. I. “Do Risk Factors for Re-Arrest Differ for Female and Male Drunk-Driving Offenders? Neurobiological, Behavioral, and Environmental Relations to Drinking,” *Alcoholism: Clinical & Experimental Research* 24 (11) 2000, pp. 1647-1655.

11. Lovell, J. and Hauer, E. “Safety Effect of Conversion to All-Way Stop Control.” *Transportation Research Record 1068*, Transportation Research Board, Washington, D.C., 1986, pp. 103-107.

12. Marowitz, L.A. “Predicting Recidivism: Blood Alcohol Concentration And Driver Record Factors,” *Accident Analysis & Prevention*, 30 (4), 1998, pp. 545-554.

13. Marques, P.R.; Tippetts, A.S.; Voas, R.B.; and Beirness, D.J. “Predicting Repeat DUI Offenses With The Alcohol Interlock Recorder,” *Accident Analysis & Prevention*, 33 (5) 2001, pp. 609-619.

14. McCarthy, M.L.; Sheng, P.; Baker, S.P.; Rebok, G.W.; and Lee, G. “Validity of Police-Reported Alcohol Involvement in Fatal Motor Carrier Crashes in the United States Between 1982 and 2005,” *Journal of Safety Research 40*, Elsevier, 2009, pp. 227-232.

15. Mudumba, V.K. “The Effectiveness of the Introduction and Amendment of Traffic Laws on Louisiana Road Crashes.” Masters Thesis, Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA, 2008.

16. National Highway Traffic Safety Administration, “Transitioning to Multiple Imputation - A New Method to Impute Missing Blood Alcohol Content (BAC) Values in FARS,” Technical report DOT 809 403, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington, D.C., 2002a.

17. National Highway Traffic Safety Administration, “The Economic Impact of Motor Vehicle Crashes 2000,” Technical report DOT 809 446, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington, D.C., 2002b.

18. National Highway Traffic Safety Administration, “Evaluation of the Repeal of the Motorcycle Helmet Laws in Kentucky and Louisiana,” Traffic Safety Facts, DOT HS 810 631, U.S. Department of Transportation, Washington, D.C., 2003.

19. National Highway Traffic Safety Administration, “Traffic Safety Facts 2005,” National Center for Statistics and Analysis, U.S. Department of Transportation, Washington, D.C., 2005.
http://www-nrd.nhtsa.dot.gov/Pubs/TSF2005.PDF. Accessed Nov. 2009.

20. National Highway Traffic Safety Administration. “Seatbelt Use in 2007 - Use Rates in the States and Territories,” Traffic Safety Facts, DOT HS 810 949, United States Department of Transportation, Washington, D.C., 2008.
http://www-nrd.nhtsa.dot.gov/Pubs/810949.PDF. Accessed Nov. 2009.

21. National Institute on Alcohol Abuse and Alcoholism (NIAAA), National Institutes of Health, Department of Health and Human Services, 2006.
http://alcoholism.about.com/gi/dynamic/offsite.htm?zi=1/XJ&sdn=alcoholism&zu=http%3A%2F%2Fwww.niaaa.nih.gov%2FResources%2FDatabaseResources%2FQuickFacts%2FAlcoholConsumption%2Fdkpat3.htm Accessed July, 2006.

22. Pollock, D.A.; Boyle, C.A.; DeStefano, F.; Moyer, L.A.; and Kirk, M.L., “Underreporting of Alcohol-Related Mortality on Death Certificates of Young U.S. Veterans,” *JAMA*, Vol. 258, No. 3, July, 1987, pp. 345-348.

23. Rubin, D.B.; Schafer, J.L.; and Subramanian, R. “Multiple Imputation of Missing Blood Alcohol Concentration (BAC) Values in FARS,” Report number DOT HS 808 816, U.S. Department of Transportation, 1998.

24. Thorpe, J.T., “Calculating Relative Involvement Rates in Accidents Without Determining Exposure.” *Traffic Safety Research Review* 11, 1967, pp. 3-8.

25. White, W.L., and Syrcle, J., “Evaluating the “Hard-Core Drinking Driver,”” *Addiction Professional*, Texas Behavioral Health Institute, 2008.
http://www.addictionpro.com/ME2/dirmod.asp?sid=&nm=&type=Publishing&mod=Publications%3A%3AArticle&mid=8F3A7027421841978F18BE895F87F791&tier=4&id=AE4413DA303E434895CC3356E090C7C5. Accessed May 2008.

26. Williams, A.F., and Wells, J.K. “Factors Associated with High Blood Alcohol Concentrations Among Fatally Injured Drivers in the United States.” *Alcohol, Drugs and Driving, 9,* 1993. pp. 87-96.

27. Wilmot, C.G., “Trends in Highway Construction Costs in Louisiana,” Technical Report 319, Louisiana Transportation Research Center, Baton Rouge, LA, September 1999.

28. Wilmot, C.G.; Zhang, H.; Fu, H.; Jayadevan, A.; Wolshon, B.; Schneider, H.; and Sun, X. “Statewide Traffic Safety Study Phase 1: Review of Current Traffic Safety Research, Practice, Analytical Procedures, and Databases,” Technical Report 399, Louisiana Transportation Research Center, Baton Rouge, LA, May, 2005.

29. Wilmot, C.G., and Jayadevan, A.S. “Effect of Speed Limit Increase on Crash Rate on Rural Two-Lane Highways in Louisiana**”** Technical Assistance Report 07- ITA, Louisiana Transportation Research Center, Baton Rouge, LA, July 2006.

30. Yu, J. and Williford, W. “Drunk-Driving Recidivism: Predicting Factors from Arrest Context and Case Disposition,” *Journal of Studies on Alcohol*, 1995.

31. Zhang, H. “Identifying and Quantifying Factors Affecting Traffic Crash Severity in Louisiana,” Ph.D. dissertation, Department of Civil and Environmental Engineering, Louisiana State University, February 2010.

APPENDIX A

Table 15
Crash reduction factors and costs of countermeasures

Countermeasure	Cost	CRF%
Administrative license revocation or suspension (ALR\ALS)	High	30
Alcohol interlocks	Medium	50
Enforce zero tolerance laws for drivers under age 21	Medium	45
Integrated enforcement	Low	22.5
Mass media campaigns	High	13
Responsible beverage service	Medium	23
Seize vehicles or license plates administratively upon arrest	Low	13
Sobriety checkpoints	High	20
Combined enforcement; nighttime enforcement	Medium	6
Communications and outreach supporting enforcement	Medium	5
Increased belt use law penalties: fines and driver's license points	Low	42
Model prediction of crash severity reduction	Medium	40
Short-term, high-visibility belt law enforcement	Medium	16
State primary enforcement belt use laws	Low	8
Identify license regulation violators	Medium	10.7
Install ignition interlock device (IID)	Medium	65
Limiting license violators from using vehicles	Low	32
Night time driving restrictions for drivers aged…	Low	45
Restrict young drivers from carrying teenage passengers	Low	17
Supervised driving for beginners at age 16 for six months	Low	33
Clear sight triangles	Low	25
Convert a four-leg intersection to two t intersections	High	37
Convert to roundabout	High	40
Convert two-way streets to a one-way pair	High	30
Delineate turn path	Medium	26
Employ emergency vehicle preemption	Medium	70
Employ signal coordination	Medium	6.7
Grooving existing pavement	Medium	14
Implement automated enforcement of approach speeds (cameras)	Medium	40
Implement automated enforcement of red-light running (cameras)	Medium	42
Improve intersection skew angle	High	40
Improve left-turn lane geometry	Medium	30
Install back plates	Low	20
Install larger (12-in.) signal lenses	Low	10
Install left-turn lane	Medium	24
Installing queue detection system	Low	30

(continued)

Installing rumble strips on approaches	Low	30
Lengthen Left-Turn Lane	Medium	15
Optimize clearance intervals	Low	12
Overlaying existing pavement	Medium	27
Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach	Low	15
Provide positive offset for left-turn lanes	Medium	10
Provide right-turn lanes	Medium	13
Provide targeted conventional enforcement of traffic laws	Medium	75
Remove or relocate unnecessary signs	Low	50
Remove unwarranted signal	Low	50
Restrict or eliminate parking on intersection approaches	Low	20
Restrict or eliminate turning maneuvers using channelization or signing	Low	25
Use protected left turns plus left turn phase	Low	35
Use protected left turns without left turn phase	Low	15
Use split phases	Low	10
Convert to 4-way stop from 2-way stop	High	47
Improve super elevation on curves	High	11
Install automated enforcement of red light violations	Medium	7
Install new guardrail	High	44
Install traffic signal	Low	20
Lengthen the yellow change interval to ITE guidelines	Low	8
Provide mid-block pedestrian refuge	Medium	46

APPENDIX B

Table 16
Prioritized countermeasures under cost-need-performance scenario

Priority	Countermeasure
1	Increased belt use law penalties: fines and driver's license points
2	Limiting license violators from using vehicles
3	Integrated enforcement
4	Alcohol interlocks
5	Enforce zero tolerance laws for drivers under age 21
6	Night time driving restrictions for drivers aged…
7	Remove or relocate unnecessary signs
8	Remove unwarranted signal
9	Model prediction of crash severity reduction
10	Install back plates indicating a high risk driver
11	Restrict or eliminate parking on intersection approaches
12	Clear sight triangles
13	Restrict or eliminate turning maneuvers using channelization or signing
14	Supervised driving for beginners at age 16 for six months
15	Use protected left turns plus left turn phase
16	Seize vehicles or license plates administratively upon arrest
17	Restrict young drivers from carrying teenage passengers
18	Installing queue detection system
19	Installing rumble strips on approaches
20	Install ignition interlock device (IID)
21	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
22	Use protected left turns without left turn phase
23	Optimize clearance intervals
24	Employ emergency vehicle preemption
25	Provide targeted conventional enforcement of traffic laws
26	Implement automated enforcement of red-light running (cameras)
27	State primary enforcement belt use laws
28	Implement automated enforcement of approach speeds (cameras)
29	Install traffic signal
30	Responsible beverage service
31	Install larger (12-in.) signal lenses
32	Use split phases
33	Short-term, high-visibility belt law enforcement
34	Improve left-turn lane geometry

(continued)

35	Administrative license revocation or suspension (ALR\ALS)
36	Overlaying existing pavement
37	Delineate turn path
38	Install left-turn lane
39	Convert to roundabout
40	Improve intersection skew angle
41	Convert a four-leg intersection to two t intersections
42	Lengthen left-turn lane
43	Grooving existing pavement
44	Communications and outreach supporting enforcement
45	Combined enforcement; nighttime enforcement
46	Provide right-turn lanes
47	Lengthen the yellow change interval to ITE guidelines
48	Identify license regulation violators
49	Convert two-way streets to a one-way pair
50	Provide positive offset for left-turn lanes
51	Sobriety checkpoints
52	Provide mid-block pedestrian refuge
53	Mass media campaigns
54	Convert to 4-way stop from 2-way stop
55	Install new guardrail
56	Employ signal coordination
57	Install automated enforcement of red light violations
58	Improve super elevation on curves

Table 17
Prioritized countermeasures under cost-performance-need scenario

Priority	Countermeasure
1	Increased belt use law penalties: fines and driver's license points
2	Night time driving restrictions for drivers aged…
3	Remove or relocate unnecessary signs
4	Remove unwarranted signal
5	Use protected left turns + left turn phase
6	Supervised driving for beginners at age 16 for six months
7	Limiting license violators from using vehicles
8	Installing queue detection system
9	Installing rumble strips on approaches
10	Clear sight triangles

(continued)

11	Restrict or eliminate turning maneuvers using channelization or signing
12	Integrated enforcement
13	Install back plates
14	Restrict or eliminate parking on intersection approaches
15	Install traffic signal
16	Restrict young drivers from carrying teenage passengers
17	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
18	Use protected left turns w/o left turn phase
19	Alcohol interlocks
20	Enforce zero tolerance laws for drivers under age 21
21	Model prediction of crash severity reduction
22	Seize vehicles or license plates administratively upon arrest
23	Install ignition interlock device (IID)
24	Optimize clearance intervals
25	Responsible beverage service
26	Short-term, high-visibility belt law enforcement
27	Install larger (12-in.) signal lenses
28	Use split phases
29	Employ emergency vehicle preemption
30	Provide targeted conventional enforcement of traffic laws
31	Implement automated enforcement of red-light running (cameras)
32	Install left-turn lane
33	Implement automated enforcement of approach speeds (cameras)
34	Delineate turn path
35	Overlaying existing pavement
36	Improve left-turn lane geometry
37	State primary enforcement belt use laws
38	Lengthen left-turn lane
39	Lengthen the yellow change interval to ITE guidelines
40	Grooving existing pavement
41	Provide right-turn lanes
42	Identify license regulation violators
43	Convert to roundabout
44	Improve intersection skew angle
45	Convert a four-leg intersection to two t intersections
46	Provide positive offset for left-turn lanes
47	Administrative license revocation or suspension (ALR\ALS)
48	Convert two-way streets to a one-way pair
49	Combined enforcement; nighttime enforcement
50	Provide mid-block pedestrian refuge

(continued)

51	Employ signal coordination
52	Communications and outreach supporting enforcement
53	Sobriety checkpoints
54	Convert to 4-way stop from 2-way stop
55	Install new guardrail
56	Install automated enforcement of red light violations
57	Mass media campaigns
58	Improve super elevation on curves

Table 18
Prioritized countermeasures under need-performance-cost scenario

Priority	Countermeasure
1	Alcohol interlocks
2	Enforce zero tolerance laws for drivers under age 21
3	Increased belt use law penalties: fines and driver's license points
4	Model prediction of crash severity reduction
5	Install ignition interlock device (IID)
6	Limiting license violators from using vehicles
7	Integrated enforcement
8	Night time driving restrictions for drivers aged…
9	Responsible beverage service
10	Remove or relocate unnecessary signs
11	Remove unwarranted signal
12	Employ emergency vehicle preemption
13	Provide targeted conventional enforcement of traffic laws
14	Clear sight triangles
15	Restrict or eliminate turning maneuvers using channelization or signing
16	Install back plates
17	Restrict or eliminate parking on intersection approaches
18	Supervised driving for beginners at age 16 for six months
19	Use protected left turns + left turn phase
20	Seize vehicles or license plates administratively upon arrest
21	Implement automated enforcement of red-light running (cameras)
22	Restrict young drivers from carrying teenage passengers
23	Installing queue detection system
24	Installing rumble strips on approaches
25	Implement automated enforcement of approach speeds (cameras)

(continued)

26	Short-term, high-visibility belt law enforcement
27	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
28	Use protected left turns w/o left turn phase
29	Optimize clearance intervals
30	State primary enforcement belt use laws
31	Provide mid-block pedestrian refuge
32	Administrative license revocation or suspension (ALR\ALS)
33	Install traffic signal
34	Improve left-turn lane geometry
35	Install larger (12-in.) signal lenses
36	Use Split Phases
37	Identify license regulation violators
38	Overlaying existing pavement
39	Delineate turn path
40	Install left-turn lane
41	Combined enforcement; nighttime enforcement
42	Sobriety checkpoints
43	Communications and outreach supporting enforcement
44	Lengthen left-turn lane
45	Grooving existing pavement
46	Mass media campaigns
47	Convert to roundabout
48	Improve intersection skew angle
49	Provide right-turn lanes
50	Convert a four-leg intersection to two t intersections
51	Provide positive offset for left-turn lanes
52	Lengthen the yellow change interval to ITE guidelines
53	Convert two-way streets to a one-way pair
54	Employ signal coordination
55	Convert to 4-way stop from 2-way stop
56	Install new guardrail
57	Install automated enforcement of red light violations
58	Improve super elevation on curves

Table 19
Prioritized countermeasures under need-cost-performance scenario

Priority	Countermeasure
1	Increased belt use law penalties: fines and driver's license points
2	Limiting license violators from using vehicles
3	Integrated enforcement
4	Night time driving restrictions for drivers aged…
5	Remove or relocate unnecessary signs
6	Remove unwarranted signal
7	Clear sight triangles
8	Restrict or eliminate turning maneuvers using channelization or signing
9	Install back plates
10	Restrict or eliminate parking on intersection approaches
11	Supervised driving for beginners at age 16 for six months
12	Use protected left turns + left turn phase
13	Seize vehicles or license plates administratively upon arrest
14	Restrict young drivers from carrying teenage passengers
15	Installing queue detection system
16	Installing rumble strips on approaches
17	Alcohol interlocks
18	Enforce zero tolerance laws for drivers under age 21
19	Model prediction of crash severity reduction
20	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
21	Use protected left turns w/o left turn phase
22	Install ignition interlock device (IID)
23	Optimize clearance intervals
24	State primary enforcement belt use laws
25	Administrative license revocation or suspension (ALR\ALS)
26	Install traffic signal
27	Responsible beverage service
28	Install larger (12-in.) signal lenses
29	Use split phases
30	Short-term, high-visibility belt law enforcement
31	Sobriety checkpoints
32	Employ emergency vehicle preemption
33	Provide targeted conventional enforcement of traffic laws
34	Implement automated enforcement of red-light running (cameras)
35	Install left-turn lane
36	Implement automated enforcement of approach speeds (cameras)

(continued)

37	Convert to roundabout
38	Improve intersection skew angle
39	Delineate turn path
40	Convert a four-leg intersection to two T-intersections
41	Overlaying existing pavement
42	Mass media campaigns
43	Improve left-turn lane geometry
44	Lengthen left-turn lane
45	Grooving existing pavement
46	Communications and outreach supporting enforcement
47	Combined enforcement; nighttime enforcement
48	Provide right-turn lanes
49	Convert two-way streets to a one-way pair
50	Lengthen the yellow change interval to ITE guidelines
51	Identify license regulation violators
52	Provide positive offset for left-turn lanes
53	Provide mid-block pedestrian refuge
54	Install new guardrail
55	Convert to 4-way stop from 2-way stop
56	Employ signal coordination
57	Improve super elevation on curves
58	Install automated enforcement of red light violations

Table 20
Prioritized countermeasures under performance-cost-need scenario

Priority	Countermeasure
1	Increased belt use law penalties: fines and driver's license points
2	Remove or relocate unnecessary signs
3	Remove unwarranted signal
4	Night time driving restrictions for drivers aged…
5	Limiting license violators from using vehicles
6	Use protected left turns plus left turn phase
7	Integrated enforcement
8	Supervised driving for beginners at age 16 for six months
9	Installing queue detection system
10	Installing rumble strips on approaches
11	Clear sight triangles
12	Restrict or eliminate turning maneuvers using channelization or signing
13	Alcohol interlocks

(continued)

14	Enforce zero tolerance laws for drivers under age 21
15	Install back plates
16	Restrict or eliminate parking on intersection approaches
17	Seize vehicles or license plates administratively upon arrest
18	Restrict young drivers from carrying teenage passengers
19	Model prediction of crash severity reduction
20	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
21	Use protected left turns without left turn phase
22	Install ignition interlock device (IID)
23	Optimize clearance intervals
24	State primary enforcement belt use laws
25	Install traffic signal
26	Administrative license revocation or suspension (ALR\ALS)
27	Responsible beverage service
28	Install larger (12-in.) signal lenses
29	Use split phases
30	Employ emergency vehicle preemption
31	Provide targeted conventional enforcement of traffic laws
32	Implement automated enforcement of red-light running (cameras)
33	Implement automated enforcement of approach speeds (cameras)
34	Provide mid-block pedestrian refuge
35	Short-term, high-visibility belt law enforcement
36	Sobriety checkpoints
37	Install left-turn lane
38	Delineate turn path
39	Overlaying existing pavement
40	Mass media campaigns
41	Convert to roundabout
42	Improve intersection skew angle
43	Improve left-turn lane geometry
44	Convert a four-leg intersection to two T-intersections
45	Lengthen left-turn lane
46	Grooving existing pavement
47	Communications and outreach supporting enforcement
48	Combined enforcement; nighttime enforcement
49	Provide right-turn lanes
50	Identify license regulation violators
51	Lengthen the yellow change interval to ITE guidelines
52	Convert two-way streets to a one-way pair

(continued)

53	Provide positive offset for left-turn lanes
54	Convert to 4-way stop from 2-way stop
55	Install new guardrail
56	Employ signal coordination
57	Install automated enforcement of red light violations
58	Improve super elevation on curves

Table 21
Prioritized countermeasures under performance-need-cost scenario

Priority	Countermeasure
1	Alcohol interlocks
2	Increased belt use law penalties: fines and driver's license points
3	Enforce zero tolerance laws for drivers under age 21
4	Model prediction of crash severity reduction
5	Install ignition interlock device (IID)
6	Night time driving restrictions for drivers aged…
7	Remove or relocate unnecessary signs
8	Remove unwarranted signal
9	Integrated enforcement
10	Employ emergency vehicle preemption
11	Provide targeted conventional enforcement of traffic laws
12	Implement automated enforcement of red-light running (cameras)
13	Implement automated enforcement of approach speeds (cameras)
14	Limiting license violators from using vehicles
15	Use protected left turns plus left turn phase
16	Seize vehicles or license plates administratively upon arrest
17	Administrative license revocation or suspension (ALR\ALS)
18	Supervised driving for beginners at age 16 for six months
19	Responsible beverage service
20	Provide mid-block pedestrian refuge
21	Installing queue detection system
22	Installing rumble strips on approaches
23	Improve left-turn lane geometry
24	Sobriety checkpoints
25	Overlaying existing pavement
26	Convert to roundabout
27	Improve intersection skew angle
28	Short-term, high-visibility belt law enforcement
29	Delineate turn path

(continued)

30	State primary enforcement belt use laws
31	Clear sight triangles
32	Restrict or eliminate turning maneuvers using channelization or signing
33	Convert to 4-way stop from 2-way stop
34	Install left-turn lane
35	Install new guardrail
36	Convert a four-leg intersection to two T-intersections
37	Install back plates
38	Restrict or eliminate parking on intersection approaches
39	Restrict young drivers from carrying teenage passengers
40	Mass media campaigns
41	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
42	Use protected left turns without left turn phase
43	Lengthen left-turn lane
44	Convert two-way streets to a one-way pair
45	Grooving existing pavement
46	Optimize clearance intervals
47	Provide right-turn lanes
48	Combined enforcement; nighttime enforcement
49	Communications and outreach supporting enforcement
50	Identify license regulation violators
51	Install larger (12-in.) signal lenses
52	Use split phases
53	Provide positive offset for left-turn lanes
54	Install traffic signal
55	Employ signal coordination
56	Improve super elevation on curves
57	Lengthen the yellow change interval to ITE guidelines
58	Install automated enforcement of red light violations

Table 22
High priority countermeasures

CNP	Improve super elevation on curves
	Install automated enforcement of red light violations
	Employ signal coordination
	Install new guardrail
	Convert to 4 way stop from 2 way stop
	Mass media campaigns
	Private mid block pedestrian refuge
CPN	Improve super elevation on curves
	Mass media campaigns
	Install automated enforcement of red light violations
	Install new guardrail
	Convert to 4-way stop from 2-way stop
	Sobriety checkpoints
NPC	Improve super elevation on curves
	Install automated enforcement of red light violations
	Install new guardrail
	Provide mid-block pedestrian refuge
	Convert to 4-way stop from 2-way stop
NCP	Install automated enforcement of red light violations
	Improve super elevation on curves
	Employ signal coordination
	Convert to 4-way stop from 2-way stop
	Install new guardrail
	Provide mid-block pedestrian refuge
PCN	Improve super elevation on curves
	Install automated enforcement of red light violations
	Employ signal coordination
	Install new guardrail
	Convert to 4-way stop from 2-way stop PNC
PNC	Install automated enforcement of red light violations
	Lengthen the yellow change interval to ITE guidelines
	Improve super elevation on curves
	Employ signal coordination
	Install traffic signal
	Provide positive offset for left-turn lanes

Table 23
Relatively high priority countermeasures

CNP	Sobriety checkpoints
	Provide positive offset for left-turn lanes
	Convert two-way streets to a one-way pair
	Install new guardrail
	Identify license regulation violators
	Lengthen the yellow change interval to ITE guidelines
	Provide right-turn lanes
	Combined enforcement; nighttime enforcement
	Communications and outreach supporting enforcement
	Grooving existing pavement
	Lengthen left-turn lane
CPN	Communications and outreach supporting enforcement
	Employ signal coordination
	Provide mid-block pedestrian refuge
	Combined enforcement; nighttime enforcement
	Convert two-way streets to a one-way pair
	Administrative license revocation or suspension (ALR\ALS)
	Provide positive offset for left-turn lanes
NPC	Employ signal coordination
	Convert two-way streets to a one-way pair
	Lengthen the yellow change interval to ITE guidelines
	Provide positive offset for left-turn lanes
	Convert a four-leg intersection to two T-intersections
	Provide right-turn lanes
	Convert to roundabout
	Improve intersection skew angle
	Mass media campaigns
	Provide positive offset for left-turn lanes
NCP	Identify license regulation violators
	Lengthen the yellow change interval to ITE guidelines
	Convert two-way streets to a one-way pair
	Provide right-turn lanes
	Combined enforcement; nighttime enforcement
	Communications and outreach supporting enforcement
	Grooving existing pavement
	Lengthen left-turn lane

(continued)

PCN	Provide positive offset for left-turn lanes
	Convert two-way streets to a one-way pair
	Lengthen the yellow change interval to ITE guidelines
	Identify license regulation violators
	Provide right-turn lanes
	Combined enforcement; nighttime enforcement
	Communications and outreach supporting enforcement
	Grooving existing pavement
PNC	Install larger (12-in.) signal lenses
	Use split phases
	Identify license regulation violators
	Communications and outreach supporting enforcement
	Combined enforcement; nighttime enforcement
	Provide right-turn lanes
	Optimize clearance intervals
	Grooving existing pavement
	Convert two-way streets to a one-way pair
	Lengthen left-turn lane
	Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach
	Use protected left turns without left turn phase
	Mass media campaigns
	Restrict young drivers from carrying teenage passengers

APPENDIX C

Table 24
Comparison of rankings between FIS and B/C ratio method

Countermeasure	Average of CPN and PCN scenarios	B/C
Administrative license revocation or suspension (ALR\ALS)	5.5	9
Alcohol interlocks	7	13
Clear sight triangles	34.5	31
Combined enforcement; nighttime enforcement	26	23
Communications and outreach supporting enforcement	17	17
Convert a four-leg intersection to two T-intersections	30	41
Convert to 4-way stop from 2-way stop	52	47
Convert to roundabout	22.5	34
Convert two-way streets to a one-way pair	16.5	19
Delineate turn path	41.5	39
Employ emergency vehicle preemption	30	48
Employ signal coordination	42	45
Enforce zero tolerance laws for drivers under age 21	26.5	15
Grooving existing pavement	16.5	22
Identify license regulation violators	19	50
Implement automated enforcement of approach speeds (cameras)	29	32
Implement automated enforcement of red-light running (cameras)	30	28
Improve intersection skew angle	31.5	38
Improve left-turn lane geometry	20	18
Improve super elevation on curves	53	56
Increased belt use law penalties: fines and driver's license points	11	7
Install automated enforcement of red light violations	40.5	27
Install back plates indicating high risk driver	18	16
Install ignition interlock device (IID)	27.5	33
Install larger (12-in.) signal lenses	42.5	29
Install left-turn lane	30.5	36
Install new guardrail	55	46
Install traffic signal	51.5	58
Installing queue detection system	36.5	53
Installing rumble strips on approaches	28.5	20

(continued)

Integrated enforcement	12.5	12
Lengthen left-turn lane	31.5	42
Lengthen the yellow change interval to ITE guidelines	48.5	54
Limiting license violators from using vehicles	10.5	8
Mass media campaigns	29.5	21
Model prediction of crash severity reduction	26.5	25
Night time driving restrictions for drivers aged below 21	32	30
Optimize clearance intervals	26.5	24
Overlaying existing pavement	26.5	26
Provide louvers, visors, or special lenses so drivers are able to view signals only for their approach	30	35
Provide mid-block pedestrian refuge	36.5	40
Provide positive offset for left-turn lanes	35	37
Provide right-turn lanes	37	52
Provide targeted conventional enforcement of traffic laws	44	55
Remove or relocate unnecessary signs	31.5	43
Remove unwarranted signal	45.5	57
Responsible beverage service	31	49
Restrict or eliminate parking on intersection approaches	24.5	5
Restrict or eliminate turning maneuvers using channelization or signing	42	2
Restrict young drivers from carrying teenage passengers	26	1
Seize vehicles or license plates administratively upon arrest	11.5	4
Short-term, high-visibility belt law enforcement	7	11
Sobriety checkpoints	25	10
State primary enforcement belt use laws	24.5	3
Supervised driving for beginners at age 16 for six months	34.5	14
Use protected left turns plus left turn phase	33	44
Use protected left turns without left turn phase	28.5	51
Use split phases	28.5	6