IMPROVING SAFETY OF TEENAGE AND YOUNG ADULT DRIVERS IN KANSAS

by

NIRANGA AMARASINGHA

B.S., University of Moratuwa, Sri Lanka, 2004
M.S., Thammasat University, Thailand, 2008

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Civil Engineering
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2012

Abstract

Young drivers have elevated motor vehicle crash rates compared to other drivers. This dissertation investigated characteristics, contributory causes, and factors which increase the injury severity of young driver crashes in Kansas by comparing them with more experienced drivers. Crash data were obtained from the Kansas Department of Transportation. Young drivers were divided into two groups: 15-19 years (teen) and 20-24 years (young adult) for a detailed investigation.

Using data from 2006 to 2009, frequencies, percentages, and crash rates were calculated for each characteristic and contributory cause. Contingency table analysis and odds ratios (OR) analysis were carried out to identify overly represented factors of young-driver crashes compared to experienced drivers. Young drivers were more likely to be involved in crashes due to failure to yield-right-of way, disregarding traffic signs/signals, turning, or lane changing, compared to experienced drivers.

Ordered logistic regression models were developed to identify severity affecting factors in young driver crashes. According to model results, factors that decreased injury severity of the driver were seat belt use, driving at low speeds, driving newer vehicles, and driving with an adult passenger. The models also showed that alcohol involvement, driving on high-posted-speed-limit roadways, ejection at the time of crash, and trapping at the time of crash can increase young drivers' injury severity.

Based on identified critical factors, countermeasure ideas were suggested to improve the safety of young drivers. It is important for teen drivers and parents/guardians to gain better understanding about these critical factors that are helpful in preventing crashes and minimizing driving risk. Parents/guardians can consider high-risk conditions such as driving during dark, during weekends, on rural roads, on wet road surfaces, and on roadways with high speed limits, for planning teen driving. Protective devices, crash-worthy cars, and safer road infrastructures, such as rumble strips, and forgiving roadsides, will particularly reduce young drivers' risk. Predictable traffic situations and low complexity resulting from improved road infrastructure are beneficial for young drivers. The effectiveness of Kansas Graduated Driver Licensing (GDL) system needs to be investigated in the future.

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Dedication

This piece of work is dedicated to my beloved late parents, Mr. R. P. Amarasingha and Mrs. G. I. A. Gunathilake.

Chapter 1 - Introduction

This chapter presents the background of overall traffic safety and young drivers' traffic safety situation in the United States (U.S.) and Kansas. Further, the problem statement and the objectives of the study are presented.

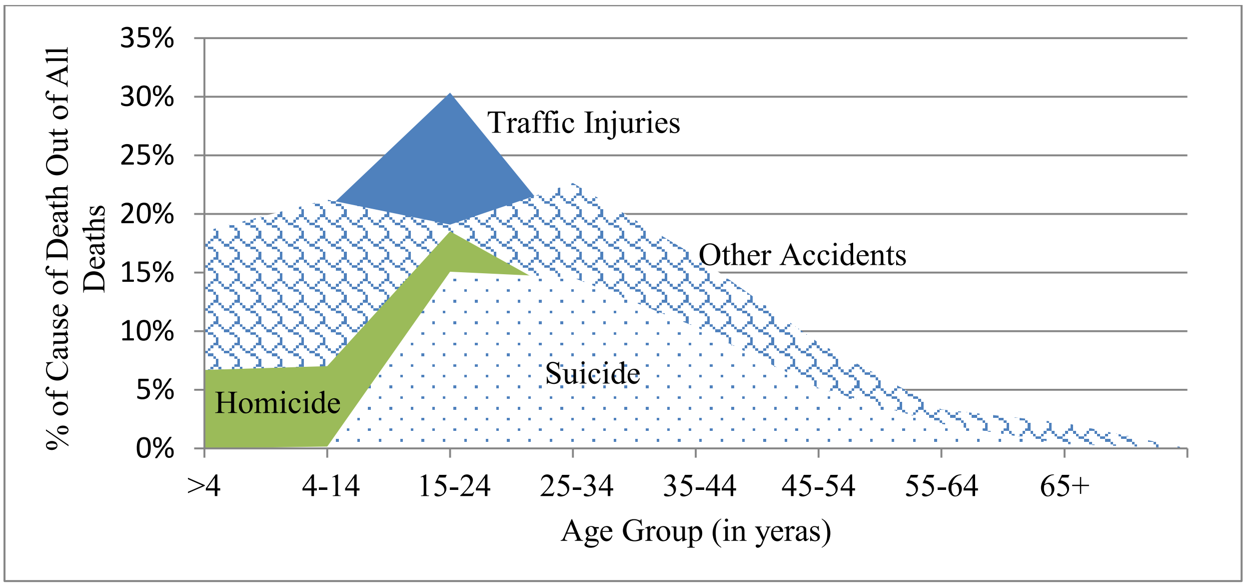
1.1 Background

Road traffic safety is a primary concern globally due to the magnitude of its social and economic impact. According to a report, Global Plan for the Decade of Action for Road Safety*,* each year, nearly 1.3 million fatalities or more than 3,000 fatalities per day, occur due to traffic crashes in the world (WHO 2011). In addition, 20 to 50 million more people suffer injuries from crashes, and these injuries may be a cause of disability. Highway crashes are predicted to become the fifth leading cause of fatalities worldwide unless immediate action is taken (WHO 2011). Also, the same report mentioned that injuries suffered in highway crashes are the third leading cause of deaths for people between five and 44 years of age. The economic consequences of traffic crashes have been estimated to be between 1% and 3% of the respective gross national product (GNP) of the world's countries, which amounts to more than $500 billion. Reducing road injuries and fatalities will reduce peoples' suffering, cut work loss costs, cut medical costs, and unlock economic growth while freeing resources for more productive use.

Even though the overall level of safety on U.S. roadways has improved over the last few decades because of significant highway safety regulations and programs, further improvement is needed. In 2008, 37,267 fatalities and more than 2.35 million injuries were reported on U.S. roadways due to motor vehicle crashes (NHTSA 2011). Ninety percent of victims in traffic crashes were occupants and 24,474 occupant fatalities were reported. The majority of persons killed or injured in traffic crashes were drivers (64 %), followed by passengers (27%), motorcyclists (4%), pedestrians (3%), and pedal cyclists (2%). Injuries to occupants of motor vehicle crashes claim the lives of more people between five and 34 years of age than any other cause of injury (NHTSA 2008). Also, highway crashes are the leading cause of death and injury in the U.S. among people under 25 years old (NHTSA 2008). The National Center of Injury Prevention and Control has reported leading causes of fatalities for each age by states or regions as a web-based, Injury Statistics Query and Reporting System (WISQARS) online database, which provides customized reports of injury data and web based injury statistic queries (CDC 2011). Using these queries, some top causes of fatalities for young people in the year 2008 are shown in Figure 1.1. Year 2008 was the year of the latest data available at the beginning of this study. As shown in Figure 1.1, traffic crashes are the top cause of fatalities of persons aged 15-24, accounting for 30% of total deaths in this age group.

Figure 1.1 Causes of Fatalities in 2008

Source: (CDC 2011)



However, people in general, particularly the young, are potentially the most valuable resources of a country. Also, loss of human lives is the highest price society bears for traffic crashes, but it also bears the many costs associated with these crashes. In 2008, according to the NHTSA, in the 16- to 20-year-old age group, 4,497 persons were killed, 42,000 had non-incapacitating injuries, and 205,000 had other injuries (NHTSA 2008). Also, in the 21- to 24-year-old age group, 3,940 persons were killed, 27,000 had incapacitating injuries, 75,000 had non-incapacitating injuries, and 143,000 had other injuries. Figure 1.2, which was developed using 2008 statistics, shows the percentage of young people killed in crashes as 24%, which is higher than the percentage of the population in this age group. As such, a need exists to revisit the concept of safety programs from a multi-disciplinary perspective in an effort to further improve young peoples' traffic safety.

Figure 1.2 Proportion of Young People Involved in Traffic Fatalities as Compared to the Population

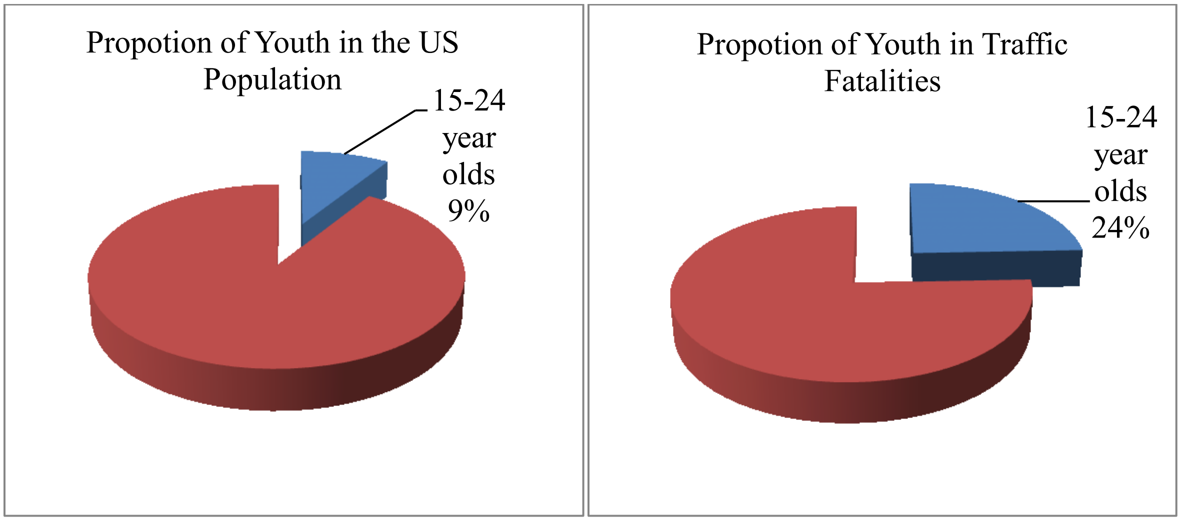
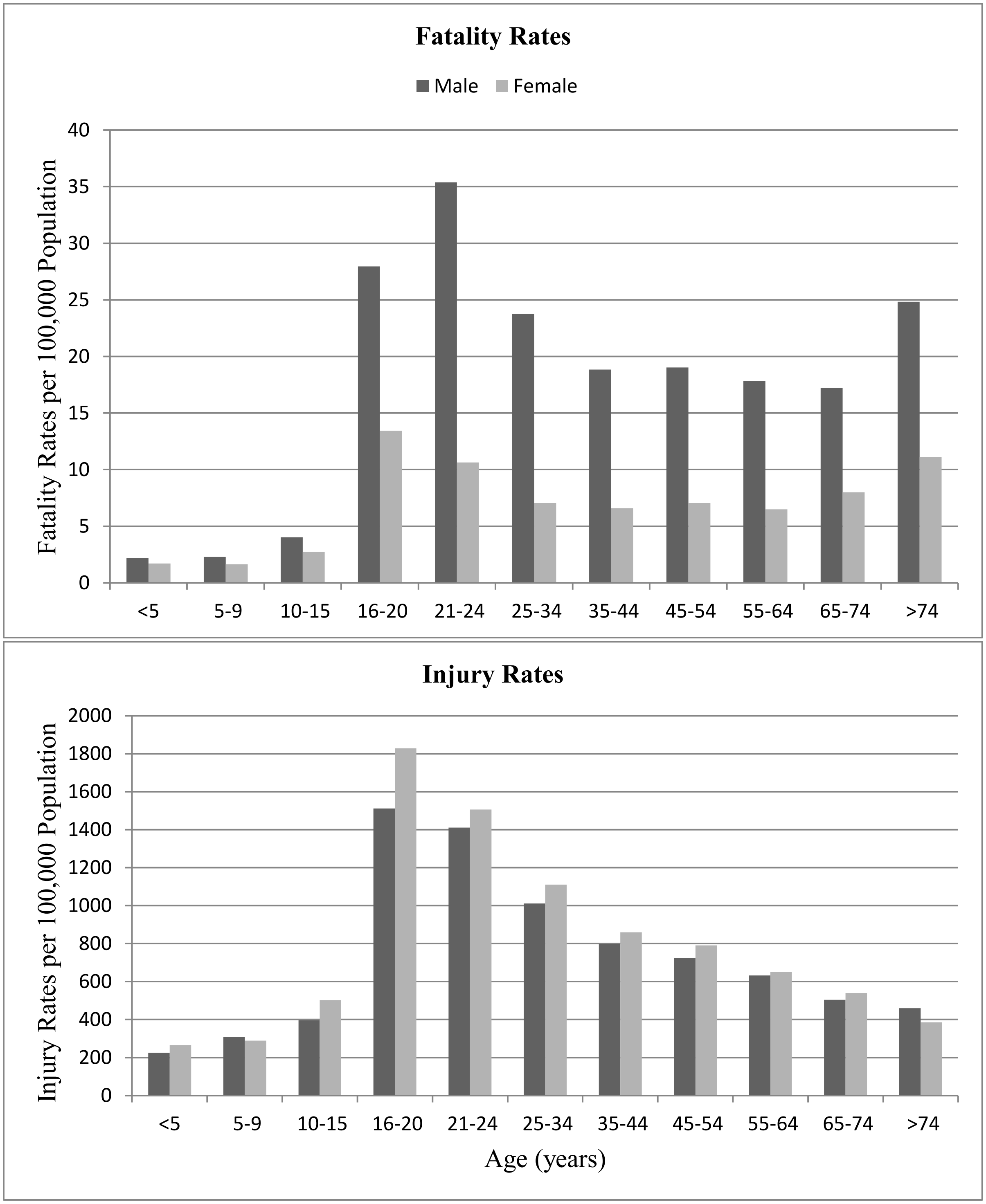


Figure 1.3 illustrates the population-based risk by age and gender for fatalities and injuries. Sixteen to 20 year olds have the highest crash rate for injuries and second highest rate for fatalities. Ages 21-24 years have the highest crash rate for fatalities, and second highest for injuries. Further, for every age group, the fatality rate per 100,000 population was lower for females than for males. The injury rate based on population was higher for females than for males in every age group, except for persons five to nine years old and over 74 years old.

National Statistics show that about 81% of teenage motor-vehicle-crash deaths in 2008 were passenger-vehicle occupants. Both fatalities and crash injuries for people aged 16-25 years are generally substantially higher than any other age group (RMIIA 2011). According to the latest AAA analysis at the time of this report (2006), crashes involving 15 to 17 year olds cost more than $34 billion nationwide in medical treatment, property damage, and other costs. About 63% of teenage passenger deaths in 2008 occurred in vehicles driven by another teenager. Among deaths of passengers of all ages, 19% occurred when a teenager was driving.

Figure 1.3 Fatality (Top) and Injury (Bottom) Rates per 100,000 Population by Age and Gender

Source: Traffic Safety Facts (NHTSA 2008)



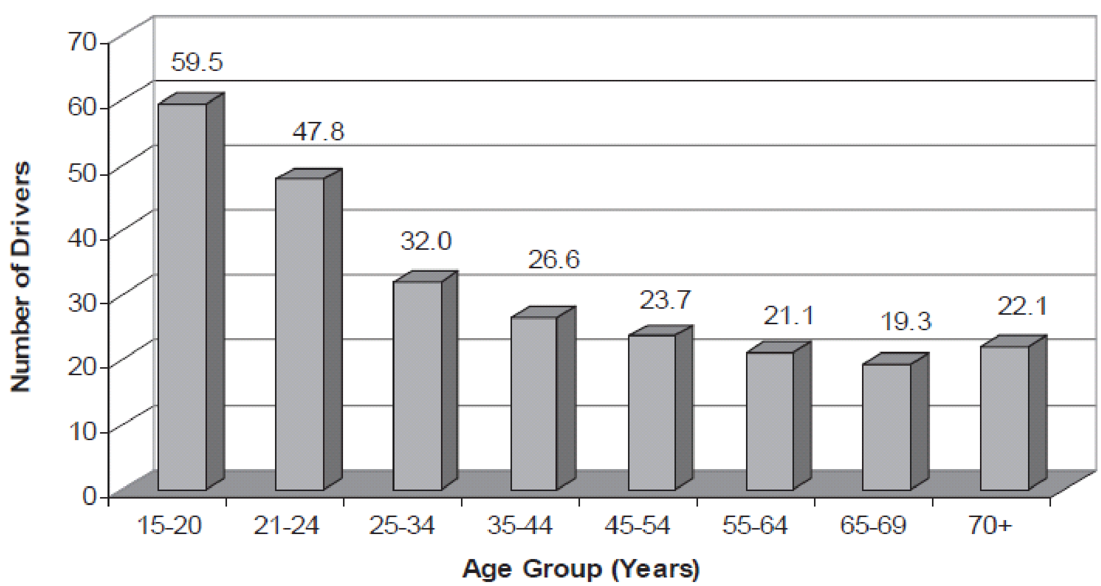
1.2 Young Drivers' Safety

Youth is a time of growth, experimentation, powerful emotions, and learning to drive. This situation is leading to higher traffic safety risk for young drivers, their passengers, and other road users. Young, inexperienced drivers in the U.S. represent an elevated crash risk compared to other drivers (NHTSA 2008). Each year nearly 8,500 youths, in the 16- to 20-year-old age group, die as result of road traffic collisions on U.S. roadways. The number of crashes per 100,000 licensed drivers is one of primary exposure measures used when analyzing driver crash involvement.

According to the latest report to Congress about teen driver crashes, Figure 1.4 shows that in 2006 drivers between 15 and 20 years old had the highest fatal crash involvement rate of any age group, with 59.5 fatal crashes per 100,000 licensed drivers (Compton and Ellision-Pottor 2008). The second highest was drivers between 21 and 24 years old with 47.5 fatal crashes per 100,000 licensed drivers. These rates are significantly higher than any other age group. Also, in 2006, 12.9 percent of all drivers involved in fatal crashes were between 15 and 20 years old. National statistics in 2008 showed that teenage drivers accounted for 12% of all drivers involved in fatal crashes and 14% of all drivers involved in all police-reported crashes. Also, beginning drivers were three times more likely to die in a motor vehicle crash than an experienced driver.

Figure 1.4 Drivers Involved in Fatal Crashes per 100,000 Licensed Drivers

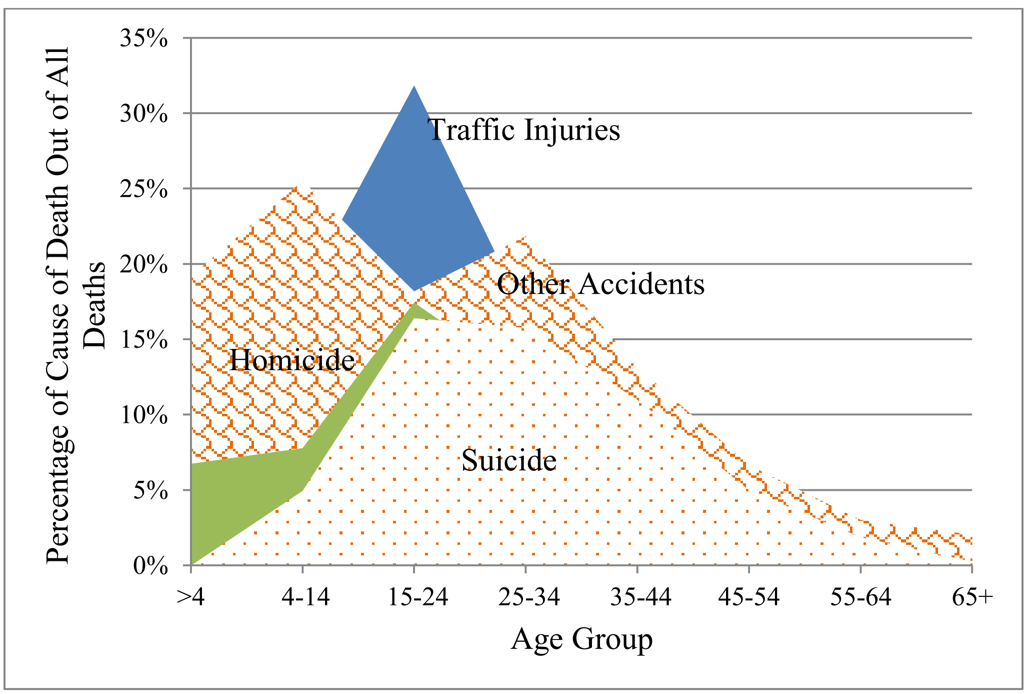
Source: Teen Driver Crashes: A Report to Congress (Compton and Ellision-Pottor 2008)



Traffic crashes are also the leading cause of death for young people 15-24 year old, accounting for approximately 31% of deaths in this age group in the Midwestern region, as shown in Figure 1.5. Rural roadways have higher crash incidence and crash injury rates than other types of roadways (Peek-Asa 2010). This differential may be attributed to many factors including road design, reduced use of safety restraints, reduced enforcement of traffic safety laws, and less and/or delayed access to acute medical care. Motor vehicle crashes are also the leading cause of death for young people, accounting for approximately 35% of deaths in this age group in Kansas. Despite the state's ongoing efforts toward highway safety, on Kansas roadways, an average of 112 youth (aged 15 to 24) deaths and thousands of young people injuries occurred annually in traffic crashes from 2004 to 2008.

Figure 1.5 Causes of Fatalities in Midwestern States at Year 2008

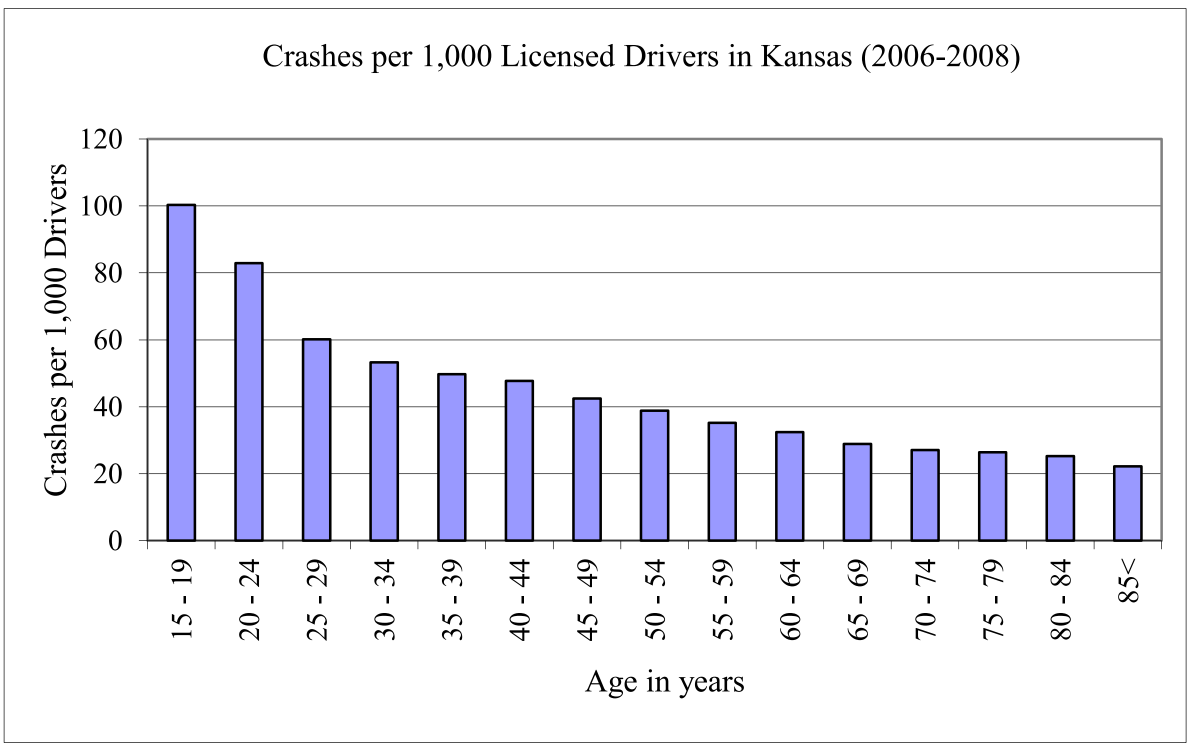
Source: (CDC, 2011)



The trend of elevated crash risk for young drivers could be also observed among Kansas drivers as shown in Figure 1.6. Based on the years 2006, 2007, and 2008 data, a peak crash rate of 100 per 1,000 licensed drivers was recorded for drivers between 15 and 19 years old. The second highest crash rate was recorded among 2o- to 24-year-old drivers.

Many approaches have been taken to reduce young driver crashes in Kansas. These have included laws and sanctions, licensing programs, and education programs. According to the Federal Uniform Drinking Age Act in 1984, Kansas implemented zero-tolerance laws that made it unlawful for drivers under age 21 years to operate vehicles with any detectable amount of alcohol in their system (KLRD 2011). In 2010, the primary seat belt laws were implemented for young drivers less than 17 years old. The primary seat belt laws allowed enforcement officers to stop the motorist and issue tickets for non-use of seat belts. Also, a Graduated Driver Licensing (GDL) law implemented in 2010 required adults' supervision, restriction of night time driving, and restrictions on peer passengers for drivers who have a learner's permit. More details about the GDL law are discussed in "Effectiveness of GDL system" and "Kansas Law Related to Young Drivers" section.

Figure 1.6 Drivers Involved in Crashes per 1,000 Licensed Drivers in Kansas



Driver education is usually designed to teach young drivers basic techniques and skills for safe driving habits. Kansas requires pre-licensing education for teens to prepare for the permit exam that includes theory, rules of the roads, safe/defensive driving techniques, and risk assessment. If this is not completed, license applicants must pass a written test. Beginning drivers must obtain in-vehicle training to learn vehicle control techniques.

1.3 Problem Statement

Motor vehicle crashes are the leading cause of death for 15 to 24 year olds in the Midwest region (CDC 2012). Also in Kansas, young driver safety issues have been identified by the Kansas Strategic Highway Safety Plan as one of the major concerns that leads to increased fatalities and serious injuries (KDOT 2010). Hence, it is important to investigate the characteristics and contributory circumstances related to young driver crashes and associated severities, while identifying over-represented factors. Such results can be used to recommend better crash mitigation strategies.

Kansas is a Midwestern state where the characteristics and contributory causes of young driver crashes, or factors which increase the injury severity of young drivers, have not been investigated using crash data from Kansas, and those factors were not directly take into account to improve young driver safety programs in the state. An area-specific investigation is important in identifying the most effective countermeasures for utilizing limited resources, as crash characteristics and factors which increase the injury severity may be different from state to state. The effectiveness of any countermeasure can vary from state to state or from community to community. Also, the best countermeasure may have little effect if it is not implemented strongly, publicized extensively, and funded satisfactorily. A better understanding of the driving characteristics of young drivers in Kansas, contributory causes, and possible countermeasures is needed to tackle this problem.

1.4 Objectives of the Study

The following are the objectives of this study:

- To identify key elements of young driver crash risk in Kansas, factors that contribute to it, and countermeasures which address it;
- To investigate young drivers' over representation in various crash characteristics and contributory factors of young-driver-involved crashes compared to experienced drivers; and

- To purpose countermeasures to reduce injury severity of drivers by studying the factors which increase injury severity of highway crashes involving young drivers, and by developing severity models.

1.5 Organization of the Dissertation

This dissertation consists of five chapters and four appendixes. Chapter one contains background information and objectives of this study. Chapter two provides a summary of previous studies conducted in relation to the topic. Chapter three presents details of the data, and methodologies used in achieving the objectives of this study. Results obtained are presented in chapter four. Chapter five presents the summary, conclusions, and recommendations for improving young drivers' safety.

Chapter 2 - Literature Review

Numerous studies have been conducted on various aspects of young driver safety, both internationally and nationally. This section reviews previous finding concerning characteristics of young drivers, injury severity of young drivers, unlicensed drivers, effect of restraint systems, effect of passenger presence, and effect of distractions.

2.1 Characteristics of Young Drivers

Vachal and Malchose (2009) studied the North Dakota injury crash records of teen drivers to gain insight into the influence of licensing age in teen driver crash risk, along with other driver, vehicle, and road factors. North Dakota offered an unrestricted driving license to residents at age 14 years and six months. Drivers aged 14-17 years accounted for about 4% of the driver population and about 10% of crashes. These teen drivers were compared with experienced drivers aged 25-55 years, using Chi-Square statistics. Teen drivers were at fault in significantly more crashes than experienced drivers. During the time of young drivers traveling to and from school accounted for most of the increased crash incidences. Then a logistic regression model was developed to investigate the relative risk of young drivers involved in crashes. The dependent variable, injury severity, was a binary variable which had two outcomes, i.e. non-severe driver injury and severe/fatal driver injury. Driver's age, gender, seat belt use, driving behavior, passenger presence, and environment-, vehicle- and road-related characteristics were considered as independent variables. Odds ratios (ORs) were estimated using logistic regression models and those were interpreted to gain insight into the role of individual variables. For example, based on the ORs of the developed model, teens were about six times more likely to die or be disabled in crashes occurring on rural roadways than urban roadways. Teens who failed to use seat belts were 165% more likely to die or suffer disabling injuries in crashes. Also alcohol- or drug-using teen drivers were 3.3 times more likely to be involved in fatality or disabling injury crashes. These findings provided a local perspective for potentially reducing teen traffic deaths in North Dakota.

Another study of fatal crashes in Colorado used data from FARS to study vehicle, crash and environment-related characteristics and to compare the demographic attributes, crash characteristics, and driver behaviors of novice drivers with experienced drivers (Gonzales et al.

2005). Frequency distributions for each environment, crash, and driver-related characteristic were calculated for novice and experienced drivers. Using ORs, the strength of the associations between crash and driver-related characteristics of novice drivers and that of experienced drivers were tested. Driver behavior such as safety belt nonuse, speeding, and driving under the influence of alcohol were associated with gender and rural/urban nature. Hence, multiple logistic regression analysis was carried out taking gender and urban/rural nature, and age as independent variables. Novice drivers showed higher rates of risk looking at behaviors such as speeding, reckless driving, and disobeying traffic laws. This study also showed that novice drivers were more likely to be involved in single-vehicle crashes, rollover crashes, and run-off-the road crashes. However, novice drivers had a much lower rate of alcohol involvement. It was recommended that primary enforcement of safety belt laws, and more severe penalties when novice drivers were charged with speeding, reckless driving, safety belt nonuse, or other traffic law violations be implemented. Parent-initiated interventions, passenger and driving restrictions, and guidance to choose safer vehicles may be effective countermeasures. Potential engineering strategies such as black boxes for parental review and devices that can mitigate rollover risk and lane departures will be helpful in increasing novice drivers' safety.

Gregersen and Bjurulf (1996) presented a model of young drivers' crash involvement, including the most important processes in the development of their driving behavior. According to the developed model, a sound learning process and experience are important factors in reduction of crash involvement. Main branches of the learning process are described as the initial learning process and long-term experiences, while the feedback from traffic was important for risk evaluation. Experience was also important for the skill acquisition process where behavior patterns were automated and the mental workload during the novice period was reduced. Lack of experience was a problem and has been interpreted as an important level of mental work. The whole traffic environment with its rules and demands on specific behavior also adds to demands on cognitive resources. Another study finding was preventing novice drivers from adopting bad habits and poor informal rules in traffic such as fast driving and neglecting to use direction indicators. The study identified that one potential strategy for improving safety among young drivers lies in early exclusion of dangerous drivers. In order to identify dangerous drivers, factors such as personality, lifestyle, and social background can be used, but not enough is known about these factors.

Differences in crash characteristics and crash rates among 16- to 21-year-old drivers were examined by Ballesteros and Dischinger (2002). From 1996 to 1998, crash data were extracted from the Maryland Accident Analysis System police reports. Crash rates of a number of licensed drivers and annual miles driven were calculated for each age from 16 to 21. The trends at each age were evaluated using Mantel-Haenszel Chi-Square tests. Crashes involving the youngest drivers were likely to be frontal, in clear weather conditions, and occurring during the afternoon and early evenings. Drivers closer to the legal drinking age of 21 were more likely to have been drinking compared to younger teens. The older group had more crashes in the high-speed limits. Overall, results reflected that youngest drivers have the highest rate of motor vehicle crashes per licensed driver and per annual miles driven. High rates of traffic crashes among young drivers were addressed by implementing a graduated license system, which has three levels of licensure designed to introduce beginning drivers in stages to the complex task of motor vehicle operation.

McKnight and McKnight (2003) studied behavioral antecedents of young driver accidents, including any subset of antecedents that could account for an inordinately high initial accident rate. To identify any subset in which novices were over-represented, accidents involving 16-17 year olds were compared with a sample involving drivers in the 18- to 19-year-old age group. Reports of 1000 accidents involving young drivers at each of the two age groups and experiences were obtained from the states of California and Maryland. Young and less experienced drivers had a significantly greater proportion of crashes due to lack of visual search prior to left turns, not watching the car ahead, driving too fast for conditions, and failure to adjust for wet roads. They had a significantly smaller proportion of crashes due to following too closely and alcohol impairment. Then behavioral causes of crashes were analyzed by gender and state to see if results were similar, to allow them to be combined. Males were statistically significantly over-represented in crashes involving speeds that were unsafe for conditions, and driving while impaired by fatigue or by alcohol. Females were statistically significantly over-represented in crashes involving inadequate search before left turns and before crossing intersections. However, differences of patterns of behavioral contributors by gender were small in number and magnitude. The authors commented that if it had been possible to subdivide the young drivers on the basis of driving experience rather than age, somewhat larger differences might have been observed.

Young unlicensed drivers' involvement in fatal crashes is also a considerable problem in the U.S. Hanna et al. (2006) investigated the context and factors of young unlicensed drivers who were involved in fatal crashes in the U.S. Data were extracted from FARS from 1998 to 2002. A total of 2,452 fatal crashes involving young unlicensed drivers occurred over a five-year study period, representing 10.8% of all young drivers' fatal crashes. Variables were selected to understand the demographics and attributes of young unlicensed drivers' fatal crash involvement. Characteristics such as age, gender, region of residence, year of crash, month, week, hour, speed limit zone, number of vehicles, number of occupants, restraint, injury severity, vehicle ownership, and driver contributing factors were tested using Pearson Chi-Square tests. About 74.5% of unlicensed drivers in fatal crashes were male, and about 72.5% of unlicensed drivers in fatal crashes were 16 years of age or older. Fatal crashes peaked in the months of June, July, and August, while peak days were Friday, Saturday, and Sunday.

Quasi-induced exposure techniques and logistic regression analysis were used by Padlo et al. to assess the relative propensity of young and older drivers in Connecticut to be at fault in a traffic crash: when they travel at night, when they travel different classes of roadways, and when they travel with different numbers of passengers (Padlo et al. 2005). The data were obtained from the Office of Inventory and Data in the Bureau of Policy and Planning at the Connecticut Department of Transportation. In this study, Relative Accident Involvement Ratios (RAIR) were compared between several groups of drivers such as men versus women, subcategories of age, road type, light conditions, and number of passengers. Logistic analysis was used to test whether individual RAIRs were statistically different from 1.0. A crash involvement ratio greater than 1.0 corresponded to increased likelihood that a particular group of drivers or crash circumstances cause a crash. This study showed that teenage drivers aged 16 and 17 years old were more likely to cause both single and two-vehicle crashes when compared with their 18- to 20-year-old counterparts. Young drivers were more likely to cause single-vehicle crashes when driving on interstate highways relative to other roads. They were less likely to be at fault in two-vehicle crashes during dark driving hours. The propensity of a young driver to cause a single-vehicle crash increased as both number of total or peer passengers in the vehicle increased. Also risk was greater for peer passengers versus any other passengers. Also, the propensity to cause a two-vehicle crash increased with the number both total and peer passengers, but this increase was slight. Results did not provide strong evidence that peer-passenger restrictions alone benefitted the young driver. Young drivers had a relatively lower risk with the presence of some peer passengers, than to driving alone, for single-vehicle crashes.

2.2 Injury Severity of Young-Driver-Involved Crashes

The objective of this study was to identify the determinants of higher crash and injury severity of fixed-object passenger car crashes among young drivers (Dissanayake and Lu 2002). The data were obtained from the Florida Traffic Crash Database from 1996 to 1998. Crash data of 1997 and 1998 were used to develop four, sequential, binary logistic regression models. For crash severity, the dependent variable was defined as four sequential binary variables. Two formats, from least severe to most severe and from most severe to least severe, were used. The first format was as follows:

1. No injury (coded as 0), Least possible injury (coded as 1)
2. Possible injury (coded as 0), Least incapacitating injury (coded as 1)
3. Non incapacitating injury (coded as 0), Least incapacitating injury (coded as 1)
4. Incapacitating injury (coded as 0), Fatality (coded as 1)

To eliminate the impact of developing the sequential structure, the second format was defined as most severe to least severe. Strongly correlated variables to severity in the dataset were used as independent variables. Then, the logistic regression model was verified with 1996 crash data. Influence of alcohol or drugs, ejection in the crash, point of impact, rural crash locations, existence of curve or grade at crash location, and speed of the vehicle were the most important factors towards increasing severity of the crash.

Mercier et al. assessed whether age and gender, or both, influenced injury severity in head-on automobile collisions on rural roads (Mercier et al. 1997). Data were obtained from the Iowa Department of Transportation's Accident File, beginning from 1986 through part of 1993. All collisions were divided into three groups: head-on, broadside, and angle approach. Since head-on collisions were the most severe crashes the study was limited for those crashes. Also, the scope for this study was limited for crashes on paved surfaces and front seat occupants. Principle components logistic regression and hierarchical logistic regression models were developed using injury severity as the dependent variable, which was measured as fatal, major, or minor. In the preliminary analysis 14 independent variables were considered. Results showed that age remained as a very important factor for predicting injury severity. Air bags seemed more beneficial for women than for men, whereas use of lap and shoulder restraints appeared be more beneficial for men. This study recommended reexamining the design parameters for protective systems in automobiles.

2.3 Presence of Passengers

Fu and Wilmot studied the effect of passenger age and gender on young driver fatal crash risk using police-reported crash data in Louisiana from 1999 to 2004 (Fu and Wilmot 2008). Young drivers were divided into three age groups: 16, 17, and 18-20, and by gender. Passengers were grouped into 15-17 and 18-20 years of age and by gender. Crash rates were calculated by the number of crashes per 100,000 licensed drivers. Sixteen-year-old drivers were associated with the highest crash rates when their same gender and peer age group passengers were present. Male drivers had crash rates of 19.7 per 100,000 licensed drivers while female drivers had 15.1 per 100,000 licensed drivers. Crash rates for 18- to 20-year-old drivers were much smaller but crash rates with their peer passengers higher than with other age groups. Then, crash ratios were derived by dividing the crash rate for each target group by rate for 21-year-old drivers and older as a reference group in order to standardize the measures. A series of trend analyses of young drivers and young passengers were conducted to study their risks of being involved in fatal crashes. It was found that young drivers were negatively impacted by young passengers. In particular, passengers 15 to 17 years of age had a stronger negative impact on drivers 18 to 20 years than passengers 18 to 20 years of age had on 16- and 17-year-old drivers.

The risk of a collision with another vehicle due to the presence of passengers was studied using Police-recorded data in Germany, from 1984 to 1997 (Vollrath, 2003). In this analysis, drivers were divided into two groups: driver being responsible for crash and others who were just involved in the crash. Then these two groups were compared with regard to all situational conditions of crashes such as location, weather conditions, road surface, time of the day, visual conditions, type of the road, traffic density, and day of the week. A relative crash risk for driving with passengers was estimated by an ORs. However, in this study risk factors which were responsible for single-vehicle crashes were not considered in the analysis for multi-vehicle crashes. Also, this analysis did not address age or gender of the passengers, but only their absence or presence. Logistic models were used to calculate the ORs. The dependent variable was the driver as responsibility that is whether the driver was responsible for the crash or just involved it. Including the presence of passengers as an independent variable in the model's two way interactions with passengers was investigated. For example, to evaluate the influence of gender, a logistic regression model was developed including the presence of passengers and gender as independent variables. However, these different factors were not independent from one another. Hence, multidimensional logistic regression was also developed, including the interaction of those factors. Presence of passengers, gender, age, type of road, day of week, and type of collision had the main effects on crash risk. In fact, passengers were shown to have a decreased crash risk. The protective effect of passengers was reduced in some situations and for the sub-group of drivers, such as young drivers. Driver-assistance systems like autonomic cruise control and collision warning systems were proposed as countermeasures. The authors suggested an improved autonomic cruise control which is constructed to react to the presence of passengers, to verbal interactions, or to telephone communications by reducing speed and increasing the distance towards preceding cars, thus supporting compensational strategies of the drivers. They further suggested collision warning systems which are used to direct the attention of the driver towards relevant cues in critical situations.

Cooper et al. (2005) examined whether the new passenger restrictions in California had an impact on crashes involving 16-year-old drivers and their passengers. Passenger restrictions for new teenage drivers became law in 1998 in California. Crash and passenger data were obtained from the California Statewide Integrated Traffic Record System. Only fatal and injury crashes from 1991 to 1997 were used for initial comparisons. The percentage of 16 year old drivers who were at fault in crashes and carrying at least one teenage passenger was compared to 16-year-olds who were not at fault in crashes and were carrying at least one teenage passenger. The same comparison was also carried out for 15- to 17-year-old drivers and passengers. A two-sample *t* test was performed assuming equal variances and differences were identified. Also, graphical comparisons of percentage of at fault and non-at-fault drivers were presented. The 16-year-old drivers were graphically compared to 25- to 54-years-old drivers. Regression analysis was done with the average number of passengers in vehicles driven by 16-year-olds involved in crashes as the dependent variable. Using the regression coefficients, the average number of teenage passengers was computed without a law-related variable to forecast what the average number of teen passengers would have been had the law not been passed. The study concluded that the presence of teen passengers was a causal factor in crashes by 16 year old drivers and the law has been effective in reducing the number of those passengers.

Geyer and Ragland (2005) examined the association between vehicle occupancy and a driver's risk of causing a fatal crash, not wearing a seat belt, and using alcohol. The data were taken from the FARS database between 1992 and 2002, and then the drivers were categorized by five-year age group and gender. Drivers who had passengers on board at the time of the collision were compared to drivers without passengers, using the Mantel-Haenszel adjusted Odd Ratios (ORs). For each gender and age category, and for eight independent variables, sets of two-by-two matrices were constructed. Those were weighted by the total number of collisions in each matrix. An ORs' value greater than 1.0 implies a passenger presence was correlated with increased risk. Results suggested the presence of passengers had a strong correlation with risk of causing a fatal collision. Both teenage male and female drivers driving with teenage passengers were less likely to wear a seat belt than solo drivers. Also, teen drivers who travel with passengers were more likely to have consumed alcohol before the crash. However, presence of passengers correlated positively with seat belt use in the case of experienced drivers. The passenger effect was explained using four factors: 1) presence of passengers, 2) helping driver which is not related to the driver, 3) helping directly in driving-related tasks, and 4) providing distraction. Presence-of-passenger affect on the driver not only makes the driver feel responsibility but also the driver is self-conscious about his or her driving abilities. These two possibilities might be helpful for future crash prevention programs.

The relationship between the presence of passengers and fatal-crash-involved drivers was investigated using the Fatality Analysis Reporting System (FARS) data from 1990 to 1995 (Preusser et al. 1998). The study examined driving situations using a technique called indirect or induced exposure. Induced exposure is based on the concept that a driver on the road may be the victim in a multiple-vehicle crash of some other driver's mistake. Not-at-fault crashes can be used as a surrogate measure of exposure to highway risk. In this study, highway crash risk was expressed relative to drivers aged 30-59. In this study, the focus was on teenage drivers. Vehicle drivers were categorized as being alone in the vehicle at the time of crash or as having passengers. In particular, teenage drivers accompanying teenage passengers were considered. Among teenage drivers and young drivers up to 25 years, passengers were more common in night than day crashes. Teenage drivers were less often at fault when the driver was alone than a driver with passengers. However, passenger presence did not affect at-fault percentages for drivers older than 25 years. The results also showed that the risk of being involved in a fatal crash was much higher for teenage drivers when passengers were present. Also, one of parents' concerns was security issues when the child is driving alone. However, the authors recommended that teenage drivers not be permitted to transport other teenage passengers.

Aldridge et al. (1999) investigated the effect of passengers on young driver accident propensity using crash data which were extracted from a Kentucky accident database between 1994 and 1996. In this study, young drivers were individuals between the ages of 16 and 20 years, and peers to young drivers were individuals between ages of 12 and 24 years. Three passenger groups–solo, peer, and adult or child–were considered. The analysis was done using the induced-exposure technique which measures the Relative Accident Ratio (RAIR) by taking the ratio of the percentage of at-fault drivers in a specific subgroup to the percentage of not-at-fault drivers for the same subgroup. Seven possible interaction variables: driver, gender, total occupant gender, time of the week, time of the day, vehicle age, and safety restraint usage were considered. Young drivers have a high propensity for causing single-vehicle crashes when travelling with peers, but they have lower propensity to cause either single-vehicle crashes or multi-vehicle crashes when they are travelling with adult/child passengers. The findings of this study supported for Kentucky's graduated license program. Further, it suggested increased education and a training period under adult supervision for young drivers.

2.4 Seat Belt Use

Safety belt use and its predictors were investigated using the Hawaii State Wise Motor Vehicle Crash Database by Li et al. (1999). Data from the 'Injury in Hawaii Study" was linked to a crash database in order to avoid misreporting seat belt use of the crash database, because it was recognized that motorists tend to over report their seat belt use to police as the state had a mandatory seat belt law. By comparing police-reported safety belt use and physician-reported safety belt use, the misreporting was identified. Logistic regression models were developed to examine the predictors of safety belt use among crash-involved drivers and passengers. First a model was developed for the front seat occupants regardless of injury severity. Secondly, another model was developed those drivers and front seat passengers who sustained at least non-incapacitating injuries on the standard KABCO scale. In KABCO, injury severity was classified as fatal (K), incapacitating (A), non-incapacitating (B), possible (C), and no injury (O). Age, gender, alcohol involvement, time of the day, and area were strongly associated with seat belt use. The motorists were less likely to wear seat belts during weekdays and rainy weather conditions. Being a male driver, having alcohol involvement, and driving during the night were related to lower seat belt use. The findings from this study agreed with those from roadside interviews.

Seat belt use for teenage (16–19 years old) drivers who were fatally injured in traffic crashes occurring in the U.S. during 1995–2000 was studied by McCartt and Northrup (2004). Vehicle, driver, and crash factors which were potentially related to seat belt use were examined. State differences in belt-use rates among fatally injured teenage drivers were related to states' observed belt-use rates for all ages and other state-level variables. Results showed that mean belt use was 36% among fatally injured teenage drivers and 23% among fatally injured teenage passengers. One of the strongest predictors of higher belt use for both drivers and passengers was whether the crash occurred in a state with a primary seat belt law. Belt-use rates for 1995–2000 for fatally injured teenage drivers ranged from 20% or less in six states to more than 60% in two states. States with the highest use rates were those with strong primary belt-use laws and those with high rates of observed belt use for all ages. Lower belt use among fatally injured teenage drivers was associated with increasing age; male drivers; drivers of SUVs, vans, or pickup trucks rather than cars; older vehicles; crashes occurring late at night; crashes occurring on rural roadways; and single-vehicle crashes. Teenage driver belt use declined as the number of teenage passengers increased, but increased in the presence of at least one passenger 30 years or older. It was suggested that to increase teenage belt use, states should enact strong primary belt-use laws and mount highly publicized efforts to enforce these laws. Graduated driver licensing systems should incorporate strong provisions that require seat belt use by teenage drivers and passengers.

2.5 Alcohol Involvement

Jones et al. (1992) examined the effect of legal drinking age on fatal injuries in persons aged 15 to 24 years in the U.S. Effect of pre-legal drinking age for teens, adolescents targeted by legal drinking age, initiation at legal drinking age, and post-drinking-age drinking experience were assessed. Information on legal drinking age was obtained from the Insurance Institute for Highway Safety and fatality data from the National Center for Health Statistics. A logistic regression having the dependent variable fatality rate was used for analysis. It showed that a higher legal drinking age was also associated with reduced fatality rates for motor vehicle drivers, pedestrians, unintentional injuries excluding motor vehicle injuries, and suicide. An initiation effect on homicides was also identified. In general, a higher legal drinking age reduced deaths among adolescents and young adults for various categories of violent death.

Hingson et al. (1996) assessed whether a community program that organized multiple city departments and private citizens could reduce alcohol-impaired driving related to driving risk and traffic death injuries. Trends in fatal crashes and injuries per 100 crashes were compared in the program cities and rest of the cities. Four statewide telephone surveys had monitored self-reported driving after drinking. Results showed that in program cities relative to the rest of cities during the five years of the program, in comparison with the previous five years, fatal crashes declined 25%. Fatal crashes involving alcohol decreased 42%, and visible injuries 5%. The proportion of vehicles observed speeding and teenagers who drove after drinking were cut in half.

2.6 Distraction

Neyens and Boyle (2007, and 2008) investigated how different driver-distraction factors impact crash types that are common among teenage drivers. Data were obtained from the General Estimates System (GES), which was a part of national automotive system in 2003. Detailed descriptions of the vehicles involved, demographics of the driver(s) and their passenger(s), distracted state of the driver(s) involved in the crashes, and crash characteristics were taken into account. The multinomial logit model was used to predict the likeliness of teenage driver involvement in a distraction-related crash. Factors that have previously been identified as influencing teenage drivers' crash types were included as independent variables in the multinomial logit model. Driver inattention, passenger-related, cell phone, and in-vehicle distractions were the four major categories used in this study. Each of the driver-distraction variables was included for these categories. Maximum likelihood methods were used to create the set of regression coefficients for the ordered logit model, which had the dependent variable, injury severity. Odds of severe injuries for teenage drivers were predicted using explanatory variables, which included occupant type, gender, and interaction between occupant and gender, control for differences in injury severity and driver population, seat belt usage, adverse weather conditions, and speeding. Results showed the majority of distraction-related and inattentive-related crashes resulted in non-severe injuries. The model showed that females were more likely to be involved in severe crashes than male drivers. Seat belt usage significantly reduced the severity.

2.7 Evaluation of Effectiveness of GDL

GDL is a three-stage approach to granting teen drivers full license privileges. It consists of a learner's permit, an intermediate license, and a full license. As of 2012, all 50 states and the District of Columbia had adopted a three-stage GDL system. There is no a national GDL law and each state has different GDL state laws, as summarized in Appendix A (GHSA 2010). Many states have spent enough time after implementation of the law, and evaluation results are available. Early evaluations of a single state provided valuable information about the effects of newly implemented GDL programs.

Shope (2007) has summarized the published GDL evaluation results from 2002 to 2007. A summary table of early evaluations of single-state evaluation studies developed in this study are included Appendix B. Methods in these studies vary from pre-post comparisons to trend analysis. The analytical methods used for these studies are simple counts, descriptive statistics, rates, adjusted rates, rate ratio, relative risk, adjusted relative risks, odds ratios, regressions, structural models, and intervention time series analysis. Some studies use both methods for the evaluations. Also, different studies reports different degrees of effectiveness pre and post evaluations. This may because different states had different licensing laws before the implementation of the GDL. Most of the studies have reported positive results, such as reduction of crashes after the GDL was adapted.

Neyens et al. assessed the effectiveness of the Iowa's GDL program in reducing crashes (Neyens 2008). Ten-year crash data that were obtained from the Iowa Department of Transportation were used for the analysis. Crash and vehicle characteristics, driver and passenger demographics characteristics, and injury severity variables were in the dataset. Time series analysis for 16-, 17- and 18-year-old drivers was done. An intervention time series analysis examined system-wide changes in a time-based data series. Crash rates for the 25- to 54-year-old crashes per 10,000 licensed drivers were included as a covariate to reduce biases in the analysis. It was found a significant reduction in crash rates of 16 year olds but not 18 year olds. It was concluded that crash risks of teenage drivers remain relatively high compared to other age groups. Even though the program appears to be working well, further analyses were recommended as what factors are preventing risk for teen drivers.

Recently, Rogers et al. (2011) evaluated Connecticut's GDL impact over the past 10 years using Connecticut crash data from 1999 to 2008. The analysis included percent change; and crash rates per 10,000 registered drivers by gender, age, during the nighttime restrictions, and crashes with passengers. It also estimated a linear regression model to find the decrease of crash rate. Results showed the decrease of crash rate by 40% for 16-year-old and 30% for 17-year-old drivers. During the nighttime restriction times, crash rates decreased by 54% among 16-year-old and 49% among 17-year-old drivers. Crash rates with passengers decreased by 65% for 16-year-old and 53% for 17-year-old drivers. It was concluded that implementation of Connecticut's GDL is effective in reducing crash rates among teen drivers.

While other states are conducting studies to investigate the long-term effects of GDL systems, Kansas needs an evaluation GDL system, which was implemented in 2010.

2.8 Countermeasures

Morton and Hartos (2003) described the nature of young driver crash risk, status of countermeasures for motor vehicle crashes among young drivers, and potential approaches to increasing the effectiveness of existing countermeasures. This study discussed three areas of countermeasures for decreasing young driver risk: driver education, licensing policies, and parental management. Driver education was an essential part of teaching adolescents the rules of the road and about operating a vehicle. However, it had not proven to prevent crashes among young drivers. GDL was a policy innovation that delayed licensure and restricted driving among novice drivers under the most dangerous conditions. These programs had effectively reduced motor vehicle crashes where adopted. However, adoption and effectiveness of these policies varied throughout the country. Parental management of teen driving might be an important part of reducing teen driving risk. According to previous research, Morton and Hartos (2003) indicated that parents place most restrictions on their teens' driving and that restrictions were related to fewer risky driving behaviors, tickets, and crashes. The Checkpoints Program aimed to increase parental management of teen driving and had been shown to do so in short-term follow-ups in several randomized trials. Each countermeasure was important to teen safety and may need improvements; however, the greatest protection against crashes among young drivers would be to provide better integration among, and wider implementation of, countermeasures.

King et al. (2008) evaluated the short- and long-term efficacy of a teen driving countermeasure called "You Hold the Key" (YHTK). YHTK was developed by the Hamilton County General Health District in Cincinnati, Ohio, to increase safe driving and passenger behavior among teens 15–19 years of age in Hamilton County, Ohio. YHTK is a 10-week comprehensive, school-based program consisting of safety promotion education, cooperative learning, student-oriented discussion, interactive lessons, prevention videos, and presentations from safety experts. YHTK concentrated on a variety of teen driving behaviors including distractions, passengers, seat belt use, drinking and driving, resistance skills, and strategies to reduce crashes. YHTK was evaluated by a survey which was completed by high school students. Results showed that YHTK was associated with significant immediate and long-term improvements in teen seat belt use, safe driving, and perceived confidence in preventing drunk driving. Compared to before the program, students at immediate and long-term times after the program more frequently wore seat belts when driving or riding, required passengers to wear seat belts, and limited the number of passengers to the number of seat belts in the vehicle. Also, after the program, students were more likely to avoid drinking and driving, and to say no to riding with a friend who had been drinking. The study identified the association of YHTK with increases in safe teen driving and passenger behaviors. It was concluded that success of YHTK was most notably due to its comprehensive nature. Future programs should consider comprehensive strategies when attempting to modify teen behaviors.

Simons-Morton and Hartos (2003a) reviewed the literature on the role and efficacy of parenting in influencing driving behavior and crash risk in solo driving. They noted that "the existing research indicated that parental management practices are important influences on teen driving practices and safety when imposed; but unfortunately, parents do not perceive teen driving as highly risky and establish few restrictions on teens after licensure. While a great deal remains to be learned, we have demonstrated in several small randomized trials the efficacy of brief motivational interventions for increasing parental restrictions on teen driving during the first month of licensing."

McGehee et al. (2007) examined the ability of an event-triggered video system to extend parental involvement into the independent driving phase of newly licensed teen drivers. The event-triggered video system was placed in the vehicles of 25 rural high school teen drivers, whose ages were 16-17 years, in Tiffin, Iowa. They obtained their driver's licenses six to 12 months before the study. The first nine weeks established a within-subject baseline, and no parental or system feedback was given during this time. During the next 40 weeks, feedback was provided to the teen driver in the form of a blinking LED on the camera and a weekly report card mailed to the parents. This system was a palm-sized device that integrated two video cameras, a two-axis accelerometer, and a wireless transmitter. Video data was continuously buffered 24 hours/day, but only wrote to internal memory when an acceleration threshold was exceeded. DriveCam used thresholds that roughly corresponded to g-forces (+/- 10 percent). These thresholds referred to accelerometer readings that reflect changes in vehicle velocity or the lateral forces acting on the vehicle when cornering. If the acceleration exceeded the threshold value, then an event was triggered. The trigger thresholds for this research project were 1.50 shock, 0.55 lateral, and 0.50 longitudinal. Each video clip captured the 10 seconds preceding and the 10 seconds following the threshold exceedance. Throughout the entire study, the teens were asked to manually activate the camera and provide a weekly odometer reading. All data were automatically downloaded from the device via a secure wireless network whenever the participant parked in the high school parking lot. Members of the research team reviewed all video clips. Any video data captured while a non-consented driver was using a participant's vehicle were deleted and not viewed. False triggers, such as hitting a pothole, were tabulated separately and were accompanied with a brief narrative describing what caused the trigger. This information was included in the weekly report sent to parents, giving opportunity to teen driver and parents to review and learn mistakes and good responses. The report showed the driver's weekly and cumulative performance regarding unsafe behaviors and seat belt use relative to the other participants. Results revealed two distinct groups: one that triggered few events and one that triggered many events. Combining this emerging technology with parental weekly review of safety-relevant incidents resulted in a significant and lasting decrease in events for most of the teens that triggered many events. A multi-year longitudinal study was proposed to assess the long-term effects of this intervention.

Mayhew et al. (2006) cited analysis whereby parents of adolescent drivers involved in crashes were less likely to report having "excellent" or "very good" communications with their children, in comparison with parents of drivers not involved in crashes. They suggest the development of education and awareness initiatives to help parents of young, novice drivers, including with a focus on communication. Mulvihill et al. (2005) emphasized the need for an active role for parents to moderate high risk among young, novice, solo drivers. They concluded that many programs and instructional materials have been developed to help parents teach adolescents to drive, but few educational materials have been developed to encourage and teach parents how to manage young driver risks.

The province of Ontario, Canada, deals with the speeding issue by limiting young drivers' access to certain highways where speed limits are particularly high, and where driving conditions might be especially complex (2003). This was found to result in a 61% decline in learners' collisions on these highways. Hernetkoski and Keskinen (2003) identified inappropriate speed as one of the greatest specific safety problems of young drivers in traffic. Special speed limits for beginner drivers have been proposed and used to reduce the risk in early stages of driving, although this measure is not unanimously supported among experts. Low compliance among the target group and the introduction of speed differences in traffic, which is a risk factor itself, are pointed out as critical issues. Considering these objections, the authors of the European Union project of Description and Analysis of Measures for Novice Drivers did not include the proposal of special speed limits for novice drivers in their recommendations.

Chapter 3 - Data and Methodologies

The following sections provide detailed discussion of the data used in this study and relevant methodologies. This study used methodologies such as Chi-Square test and logistic regression to investigate critical factors of young-driver-involved crashes.

3.1 Data

Initially, the study used highway crash data from the Kansas Accident Reporting System (KARS) database, which comprises all police-reported crashes in Kansas. As of the beginning date of this study, 2009 crash data were not available for analysis. Crash data from 2006 to 2008 were obtained for the preliminary analysis. There were two reasons for this delay: in 2009, KDOT introduced a new Kansas Motor Vehicle Accident Report form (KDOT Form 850A Rev 1-2009). Concurrent with this, KDOT implemented a new crash database called Kansas Crash and Analysis Reporting System (KCARS). The other reason was during its 2010 session, the Kansas Legislature considered a bill that would eliminate KDOT's ability to use prison labor to enter crash data from accident reports into the database. The bill was stopped with assurance from the Governor's office that KDOT would install the necessary safeguards to prevent prisoners from having access to personal information. As a result of this, KDOT staff needed to work on these safeguards instead of the 2009 data close-out (USDOT 2010). Later in July 2012, all crash data up to 2011 had been updated in the new database. Previous crash data had also been imported to the new data format, and all those were available for the public as the KCARS database.

3.1.1 Kansas Crash and Analysis Reporting System (KCARS)

Crash data from 2006 to 2011 were obtained from the Kansas Department of Transportation (KDOT). This data set, Kansas Crash and Analysis Reporting System (KCARS) database, is comprised of all police-reported crashes that occurred in Kansas. The KCARS database consisted of several tables such as ACCIDENTS, DRIVERS, OCCUPANTS, PEDESTRIANS, TRUCKS, VEHICLES, ACCIDENT_CANSYS, SPECIAL_CONDITIONS, TRAFFIC_CONTROLS, IMPAIRMENT_TESTS, SUBSTANCE_ABUSE, and CC_DRIVER, CC_ENVIRONMENT, CC_ROADWAY, and CC_VEHICLE. The ACCIDENT table contains details of each crash such as crash location, light conditions, weather conditions, road surface type, road conditions, road character, road class, road maintenance information, date of crash, time of crash, day of crash, accident class, and manner of collision. The VEHICLE table contains all characteristics pertaining to the vehicle such as vehicle model, vehicle year, registration year, direction of travel, vehicle maneuver, vehicle damage, and number of occupants. The OCCUPANT table consists of age, gender, safety equipment use, and injury severity and ejection information of each occupant in the vehicle. Additionally, more information about the driver such as date of birth, license compliance, restriction compliances, and alcohol impairment were included into the DRIVER table. However, the researchers did not have access to private information like the license number of the driver and name of the driver. The CC_DRIVER table contained driver-related contributing causes and CC_ENVIRONMENT, CC_ROADWAY, and CC_VEHICLE tables containing environmental, road, and vehicle-related contributing causes, respectively.

The tables of ACCIDENTS, DRIVERS, OCCUPANTS, VEHICLE, CC_DRIVER, CC_ENVIRONMENT, CC_ROADWAY, CC_VEHICLE, and ACCIDENT_CANSYS provided sufficient information to investigate young drivers involved in crashes. Hence, these 10 tables were combined and queries were used to filter out the young drivers, involved in crashes based on the driver's age. In determining the age of young drivers several factors were taken into account as explained in the "Kansas Law Related to Young Driver" section. Different states laws for a beginning driver's licensing process and granting drivers' licenses for different ages is shown in Appendix A *(34).* In Kansas, the minimum age to have a restricted license is 15 years. Most of the past studies which focused on young drivers commonly investigated the age limit from the time a restricted license was granted to 25 years old (Ballestesteros 2002, McKnight and McKnight 2003, IIHS 2008). This age range showed similar driving behavior and crash risk (KDOT 2010). Hence, the drivers' age range of 15- 24 was used for this analysis. This study investigated the crashes involving automobile, van, pickup truck, and camper recreational vehicle drivers. Hence, "young driver" in this study means an automobile, van, pickup truck or camper recreational vehicle driver whose age was between 15 and 24. In order to investigate the young driver characteristics in detail, they were further divided into two groups: the "teen driver" group aged from 15 to 19 years and "young adult driver" group aged from 20 to 24 years. Again, the 10 tables mentioned were combined and queries were made to filter middle-age drivers involved in crashes in order to compare young driver characteristics with these drivers' characteristics. Middle-age drivers were defined as "experienced drivers" whose age ranged from 25-64 (Ballesteros and Dischinger 2002, Cooper et al. 2005). The age above 65 years was not considered to compare with young drivers because those older driver characteristics may be different from the 25 to 64 years and older drivers have also been found to have unique highway safety challenges (Cooper et al. 2005, Kostyniuk and Shope 2003).

The KCARS database from 2006 to 2011 contained 169,710 young-driver-involved crashes that accounted for 28% of total crashes occurring during 2006-2011 in Kansas. The driver-contributing causes for 91,609 crashes were recorded out of 169,710 young-driver-involved crashes. There was more than one contributing cause recorded in the traffic crash database for some crashes, while contributory causes were not recorded at all in other crashes. A total of 49,525 teen-driver-contributed crashes were recorded out of 87,284 teen-driver-involved crashes. The number of young-adult-driver contributed crashes was 42,525 out of 82,426, and experienced-driver-contributed crashes were 91,102 out of 184,079 crashes.

3.1.2 Kansas Law Related to Young Drivers

Prior to 2010, the minimum age to obtain a learner's (instruction) permit in Kansas was 14 years, with the requirement of adult supervision at all times. Restricted licenses were issued at 15 years for driving only to, from, or in connection with any job or employment-related work or school. Even then, the most direct and accessible route between the driver's home and school or work should be used. However, the restricted license holder could drive anywhere, any time with licensed adult driver supervision. Passenger restrictions included transportation of non-sibling minor passengers. At the age of 16 years, a full license was granted, if a 50 hour affidavit proving completion of 50 hours of driving had been turned in. The law changed in 2010, with the current law allowing a lesser restricted license at 16 years instead of a full license, and after six months, a full license is granted. The Kansas law covering gradated licenses, K.S.A. 2010 Supp. 8-2,101, is quoted in Appendix C (Kansas Legislature 2011). Even though the law changed in 2010, it would not have any effect on this study because all data on this analysis was from before that period.

3.1.3 Exposure Data

The number of licensed drivers, which was recorded by the Federal Highway Administration (FHWA), was considered a good exposure number to investigate young drivers involved in crashes. FHWA published the number of licensed drivers in each age, state, and year in tabular format on the web. Hence the driver's license information for 2006 to 2010 was obtained and crashes per number of licensed drivers were calculated (USDOT 2010, UDSOT 2009, USDOT 2008, USDOT 2007, USDOT 2006). Table 3.1 shows the number of drivers for each age and year in Kansas.

Table 3.1 Number of Licensed Drivers in Kansas (Source: FHWA)

Age of Licensed Driver	Year 2010	Year 2009	Year 2008	Year 2007	Year 2006
15 years	33,891	40,639	28,329	29,912	31,338
16 years	25,813	28,210	27,872	28,355	30,086
17 years	30,421	31,680	31,998	33,488	33,790
18 years	33,673	34,023	35,372	35,656	35,599
19 years	34,965	35,955	36,084	36,311	35,850
Total of drivers aged 15 -19 years	158,763	170,507	159,655	163,722	166,663
20 years	36,360	35,709	35,734	35,637	36,026
21 years	33,289	33,122	33,766	35,507	36,174
22 years	34,782	34,669	36,021	36,987	36,884
23 years	35,307	35,683	36,249	37,014	36,417
24 years	35,938	35,191	35,637	36,027	36,115
Total of drivers aged 20 -24 years	175,676	174,374	177,407	181,172	181,616
Experienced drivers aged 25 -64 years	1,371,650	1,371,255	1,361,297	1,355,390	1,343,497

From 2006 to 2010, the number of licensed teenage drivers has decreased from 166,663 to 158,763, and licensed young drivers have dropped from 181,616 to 175,676 in Kansas. However, the number of experienced drivers has increased from 1,343,497 to 1,371,650. Vehicle Miles Traveled (VMT) was also a commonly used exposure data in young driver safety literature in order to understand their characteristics. One VMT can be defined as the movement of one vehicle for one mile, regardless of the number of people in the vehicle. For example, if one person drives 12 miles by car, it is 12 VMT. If two people travel two miles by car, two VMT of travel have been made. For this study, VMT was calculated using National Household Travel Survey (NHTS) data, because this was the most reliable information available (NHTSA 2009). For NHTS data, vehicle miles were restricted to privately operated vehicles as vehicle trips; that is, a household-based car, van, sport utility vehicle, pickup truck, or recreational vehicle. Sample sizes of Kansas in the 2009 study were 59, 26, and 1,014 for teen, young adult, and experienced drivers, respectively. These were too small to use to calculate the rates, hence data for the

Midwest region was used to calculate VMT. These data covered the states of Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, and Wisconsin. Sample sizes of all these states were 3,047; 1,909; and 57,401 for teen, young adult, and experienced drivers, respectively. VMT driven by drivers were extracted for the Midwest using NHTS data, which was then subcategorized under each age group. This gave the total VMT by the interviewed drivers in each age, and the VMTs were divided by the respective sample size to obtain VMT per driver. VMT per driver were categorized for each age group and then, multiplying those values by the number of Kansas drivers in respective age group, total annual VMT by Kansas drivers in each age group was estimated. Estimated Kansas VMT for teen, young adult, and experienced groups were 920, 1,724, and 17,750 million per year, respectively (NHTSA 2009). Those values were then multiplied by number of years in order to obtain total VMT for the time duration. Crash rates per VMT were calculated for each age group by dividing the number of crashes of age group by VMT of the respective age group.

3.2 Methodologies

The analysis in this study involved the investigation of young drivers involved in crashes, and calculating their crash frequencies, percentages, and crash rates. Crash rates in this study were calculated considering two exposure measures: numbers of young drivers involved in crashes per licensed young driver, and numbers of young drivers involved in crashes per VMT. Then a detailed investigation involving the Chi-Square test of independence, logistic regression, and ORs as described below, was used to investigate crash involvement, injury severity, and other specific characteristics.

3.2.1 Contingency Table Analysis (Chi-Square Test)

The association between age groups and characteristics of crashes were tested using the Chi-Square test statistic. The Chi-Square test of independence is a statistical test commonly used for determination of significant association between two variables. Requirements needed to satisfactory to perform the Chi-Square test are as follows (Anderson et al. 2005, Chi-Squared Test 2010):

- There must be a representative sample.
- The data must be in frequency form, i.e. not percentages or ratios.
- Individual observations must be independent of each other.

- Sample size must be adequate, i.e. the expected value in any category is greater than 5.
- The sum of observed frequencies must equal the sum of expected frequencies.

As the Chi-Square test uses the cross-classification table format, it is sometimes referred to as contingency table. Let *X* and *Y* denote two categorical variables, *X* having *i* number of levels and *Y* having *j* number of levels. The *ij* possible combinations of outcomes could be displayed in a rectangular table having *i* rows for the categories of *X* and *j* columns for the categories of *Y*. As an example, Table 3.2 shows a contingency table of injury severity (X) and driver group (Y). The cells of the table represent the *ij* observed frequencies.

Table 3.2 Cross-Classification of Data on Gender and Driver Groups in Kansas

X Gender	Y=Driver group	
	Young driver	Experienced driver
Female	m_{11}	m_{12}
Male	m_{21}	m_{22}

These frequencies are called the observed frequency, which is obtained for a sample. The expected frequency is the one which is expected to occur under similar conditions. Testing the hypothesis and calculating Chi-Square are carried out as follows:

1. State the hypothesis being tested and the predicted results.
2. Determine the expected numbers for each observational class.
3. Calculate Chi-Square using the formula (3.2).
4. Use the Chi-Square distribution table to determine significance of the value.
5. State the conclusion in terms of the hypothesis.

If the p-value for the calculated Chi-Square is greater than 0.05, accept the hypothesis at a 95% confidence level. If the p value for the calculated Chi-Square is less than 0.05, reject the hypothesis, and conclude that some factor other than chance is operating for the deviation to be so great.

An example calculation of the Chi-Square test is given below.

H_0: Number of young driver-involved-crashes by gender is similar to experienced-driver-involved crashes by gender.

H_a: Number of young-driver-involved crashes by gender is not similar to experienced-driver-involved crashes by gender.

The observed number of crashes for each driver group is shown in Table 3.2. Expected frequencies for the cells of the contingency table are calculated based on the observed frequencies as in the following equation:

$$Expected\ \ frequency = \frac{(Row\ i\ Total) \times (Colum\ \ j\ Total)}{Sample\ size} \tag{3.1}$$

The equations to obtain the expected values are shown in Table 3.3.

Table 3.3 Expected Frequencies on Gender and Driver Groups in Kansas

X Gender	Y=Driver group	
	Young driver	Experienced driver
Female	$m_{..} \times \frac{m_{1.}}{m_{..}} \times \frac{m_{.1}}{m_{..}}$	$m_{..} \times \frac{m_{1.}}{m_{..}} \times \frac{m_{.2}}{m_{..}}$
Male	$m_{..} \times \frac{m_{2.}}{m_{..}} \times \frac{m_{.1}}{m_{..}}$	$m_{..} \times \frac{m_{2.}}{m_{..}} \times \frac{m_{.2}}{m_{..}}$

where,

$$m_{i.} = \sum_{j=1}^{n} m_{ij}\ ;\ m_{.i} = \sum_{j=1}^{n} m_{ji}\ ;\ m_{..} = \sum_{i=1}^{n}\ \sum_{j=1}^{n} m_{ij}$$

Then the Chi-Square $\left(X^2\right)$ value was calculated using the formula:

$$X^2 = \sum \frac{(F_o - F_e)^2}{F_e} \tag{3.2}$$

where,

F_o - Observed number of given type of crashes

F_e - Expected number of given type of crashes

Form the X^2 distribution table, the p value was obtained from calculated X^2 considering degrees of freedom. If it is less than the significance level of .05, the null hypothesis can be rejected, and it can be concluded that the number of young-driver-involved crashes by gender is not similar to experienced-driver-involved crashes by gender.

3.2.2 Logistic Regression

Logistic regression was used to determine the relative effect of different environmental, vehicle, driver and road factors into injury severity of young drivers involved in crashes. Injury severity was selected as the dependent variable in a model which investigated the critical factors and contributory causes increasing injury severity. The dependent variable, injury severity, had several discrete categories. The categorical nature of the dependent variable facilitated the application of logistic regression analysis, for which the probability of severe injury versus slight injury categories was estimated by the maximum likelihood method (Allison 2001). Logistic regression-based models have been widely used for traffic safety analysis.

The logistic regression model takes the natural logarithm of the odds as a regression function of the predictors. The logistic regression model was first introduced in the context of binary choice where the logistic distribution was used. The binary logistic regression model has its basis in the odds of a two-level outcome of interest. Practitioners and researchers have used, refined, and extended the binary logistic regression model to obtain a class of models based on similar assumptions. This class of models is referred to as the logistic family (Long 1997).

A logistic regression model can be used to identify variables expected to have an explanatory effect on injury severity of young drivers involved in crashes. Using the coefficient of the explanatory variables, risk factors which increase young driver injury severity could be determined. The dependent variable, injury severity, has several discrete categories. The dichotomous nature of the dependent variable facilitates the application of logistic regression analysis, for which the probability of fatal injury against other injury-severity categories is estimated by the maximum likelihood method (Long 1997). The probability of driver n being injured with severity outcome i is

$$\Pi(x)_{ni} = P(U_{ni} \geq U_{ni'}), \quad \forall' \in I, \quad i' \neq i, \tag{3.3}$$

where,

$\Pi(x)$ = probability of x injury category,

n = a driver,

i = injury severity of n driver (eg: fatal injury, incapacitating injury, minor injury, no injury),

U_{ni} = a function determining injury severity outcome i of the n driver,

$U_{ni'}$ = a function determining injury severity outcome i' of the n driver, and

I = a set of I possible, mutually exclusive severity categories.

The logistic regression model assumes a driver-injury-severity function has a linear-in-parameters form as:

$$U_{ni} = \beta_i x_n + \varepsilon_{ni} \tag{3.4}$$

where,

β_i = a vector of estimable coefficients for injury severity i and x_i is a vector of variables for driver n; and

ε_{ni} = a random component which has identically and independently distributed error terms.

Then the logistic regression model is defined as follows (Long 1997):

$$\Pi(x)_{ni} = \frac{e^{\beta_i x_n}}{\sum_{\forall i' \in I} e^{\beta_{i'} x_n}} \tag{3.5}$$

The maximum likelihood method is then employed to measure the associations by constructing the likelihood function as follows:

$$l(\beta) = \prod_{i=1}^{n} \pi(x_i)^{y_i} \left(1 - \pi(x_i)\right)^{1-y_i} \tag{3.6}$$

where

$l(\beta)$ = the likelihood function;

$\pi(x_i)$ = the conditional probability of the dependent variable;

y_i = the i^{th} observed outcome, with the value of either 0 or 1 only; and

i = 1, 2, 3, …, n, where n is the number of observations.

The log likelihood expression is considered to maximize the likelihood function in order to obtain the following coefficients estimates:

$$LL(\beta) = \ln\left(l(\beta)\right) = \sum_{i=1}^{n}\left\{y_i \ln\left(\pi\left(x_i\right)\right) + \left(1-y_i\right)\ln\left(1-\pi\left(x_i\right)\right)\right\} \tag{3.7}$$

where,

LL(β) = log likelihood function;

l(β) = likelihood function;

$\pi(x_i)$ = conditional probability of the dependent variable;

y_i = i^{th} observed outcome, with the value of either 0 or 1 only; and

i = 1, 2, 3, …, n, where n is the number of observations.

Maximization typically requires an iterative numerical method, which means that it involves successive approximations. Hence, the best estimate of β could be obtained by a numerical method using statistical software.

When injury severity, the dependent variable, is ordered, it is much easier to interpret. The ordered logistic regression model is also known as the cumulative logistic model or oridinal logistic regression model. In the ordered logistic regression model, the dependent variable can be defined as set of categories as shown in Table 3.4. Hence, each estimated coefficient gives the probability of being in the set of categories on the left versus the set of categories on the right.

Table 3.4 Definition of Dependent Variable in an Ordered Logistic Regression Model

Equation	Pooled categories	Comparison	Pooled categories
Equation 1	Fatal/disable injury	Compared to	Not-incapacitating/possible/No injury
Equation 2	Fatal/disable/ Not incapacitating injury	Compared to	Possible/No injury
Equation 3	Fatal/disable/ Not incapacitating/Possible injury	Compared to	No injury

3.2.2.1 Goodness-of-Fit Measure

The goodness-of-fit of the predictive model could be assessed for significance and predictive power. To evaluate the significance and predictive power of the logistic regression model, the change in deviance can be determined by comparing the log likelihood functions between the unrestricted model and the restricted model, under the null hypothesis that coefficients for the predictive model are equal to zero, with the following expression (Long 199):

$$G = -2\left(LL(c) - LL(\theta)\right) \tag{3.8}$$

where,

$LL(c)$ = log likelihood function of the restricted model,

$LL(\theta)$ = log likelihood function of the unrestricted model, and

G = goodness-of-fit value.

If G is significant at the 5% level, then the null hypothesis would be rejected, and one could conclude that the proposed model generally fit well with the observed outcome.

3.2.2.2 Likelihood Ratio (LR)

The Likelihood Ratio (LR) Chi-Square test is where at least one of the predictors' regression coefficients is not equal to zero in the model. The LR Chi-Square statistic can be calculated by;

$$\text{LR} = -2 \text{ Log } \text{L(null model)} - 2 \text{ Log L(fitted model)} \tag{3.9}$$

where,

L(null model) = the Intercept Only model, and

L(fitted model) = the Intercept and Covariates model.

The LR test can be used to compare any pair of nested models, but it requires using the same sample for all models being compared. Hence, it is important to ensure the sample size does not change by excluding every observation that has missing values for any of the variables used in any of the models being tested (Long 1997).

3.2.2.3 Score

The Score Chi-Square test is where at least one of the predictors' regression coefficients is not equal to zero in the model.

3.2.2.4 Akaike Information Criterion (AIC)

This is calculated as;

$$AIC = -2 \text{ Log L} + 2((k-1) + s) \quad (3.10)$$

where,

L = likelihood of the model,

k = the number of levels of the dependent variable, and

s = the number of predictors in the model.

AIC is used for the comparison of models from different samples or non-nested models that cannot be compared with an LR test. Ultimately, the model with the smallest AIC is considered the best. All else being equal, the model with the smallest AIC is considered the better fitting model (Allison 2001).

3.2.2.5 Schwarz Criterion (SC)

This is defined as;

$$SC= - 2 \text{ Log L} + ((k-1) + s)\times \log(\Sigma f_i) \quad (3.11)$$

where,

L = likelihood of the model,

f_i = the frequency values of the *i*th observation,

k = the number of levels of the dependent variable, and

s = the number of predictors in the model.

Like AIC, SC penalizes for the number of predictors in the model and the smallest SC is most desirable.

3.2.2.6 Hosmer and Lamsehow (H-L) Statistic

The H–L statistic is a Pearson Chi-Square statistic, which is an inferential goodness-of-fit test for logistic regression models. The test evaluates whether the logistic regression model is well calibrated, so that probability predictions from the model reflect the occurrence of events in the data. Obtaining a significant result on the test would indicate the model is not well calibrated, so the fit is not good. In other words, the null hypothesis of a good model fit to data was tenable. In this test, the data are divided into approximately 10 groups of roughly the same size based on the percentile of the estimated logistic probabilities. The predicted probability of having the event according to the model: group 1 has data with predicted probabilities in the 1st to 10th percentiles; group 2 has data with predicted probabilities in the 11th to 20th percentiles, and continuing. If the observed and expected numbers of events are very different in any group, then the model is judged not to fit (Valley 2011).

3.2.2.7 Multicollinearity

In some cases, logistic regression results may seem paradoxical, which means the model fits the data well, even though none of the independent variables has a statistically significant impact on predicting the dependent variable. This has happened due to the correlation of two independent variables. Neither variable may contribute significantly to the model after the other one is included. However, model fit would be worse if both variables were removed from the model. This is because the independent variables are collinear and the results show multicollinearity. In traffic safety analysis, the goal is to understand how the various independent variables impact the dependent variable; hence, multicollinearity is a considerable problem (Allison 2001). One problem is that even though the variable is important, model results show that it is not significant. The second problem is that the confidence intervals on the model coefficients will be very wide. To help to assess multicollinearity, the correlation matrix of the independent variables can be investigated. If the element of correlation matrix has high value, model fit is affected by multicollinearity of the independent variable correspondent to that element. Also, each independent variable can be predicted from other independent variables. The model-fit statistic such as individual R^2 value and a variance inflation factor (VIF) are high for any of the independent variables, and model fit is affected by multicollinearity.

3.2.2.8 R^2 for Logistic Regression

In logistic regression, there is not a defined true R^2 value, as in ordinary least-squares regression analysis (Allison 2001). However, because deviance can be thought of as a measure of how poorly the model fits, that is a lack of fit between observed and predicted values, it can be made to the sum of squares' residual in ordinary least squares. The proportion of unaccounted for variance that is reduced by adding variables to the model is the same as the proportion of variance accounted for, or R^2.

$$R^2_{\text{logistic}} = \frac{-2LL_{null} - 2LL_k}{-2LL_{null}} \tag{3.12}$$

where,

LL = log likelihood of the model,

Null = model with just the constant, and

K = model with all the predictors.

This concept was developed by Cox and Snell and by Nagelkerke. The Cox and Snell R-square is computed as follows (Allison 2001):

$$R^2 = 1 - \left[\frac{-2LL_{null}}{-2LL_k}\right]^{2/n} \tag{3.13}$$

where,

LL = log likelihood of the model,

Null = model with just the constant,

K = model with all the predictors, and

n = observations in the dataset.

Because this R-squared value cannot reach 1.0, Nagelkerke modified it. The correction increases the Cox and Snell version to make 1.0 a possible value for R-squared.

$$R^2 = \frac{1 - \left[\frac{-2LL_{null}}{-2LL_k}\right]^{2/n}}{1 - \left(-2LL_{null}\right)^{2/n}} \tag{3.14}$$

where,

LL = log likelihood of the model,

Null = model with just the constant,

K = model with all the predictors, and

n = observations in the dataset.

3.2.3 Odds Ratios

Binary logistic regression can be employed in calculating ORs. To measure the strength of the association between the variables, ORs and 95% Confidence Intervals (CIs) were calculated. OR is a widely used statistic in traffic safety studies for comparing whether the probability of a certain event is the same for two groups (Allison 2001). The "odds" of an event (y) is defined as the probability of the outcome event occurring $(y = 1/x_1, x_2, ..., x_p)$, divided by the probability of the event not occurring, $(y = 0/x_1, x_2, ..., x_p)$. Then the odds ratio is given by;

$$Odds = \frac{P(y = 1/x_1, x_2, ..., x_p)}{P(y = 0/x_1, x_2, ..., x_p)} \tag{3.15}$$

where,

$P(y = 1/x_1, x_2 \dots, x_p)$ – probability of the outcome event occurring, and

$P(y = 0/x_1, x_2 \dots, x_{p)}$ - probability of the outcome event not occurring.

The OR for a predictor is defined as the relative amount by which the odds ($odds_1$) of the outcome increase (OR > 1.0) or decrease (OR < 1.0), when the value of one of the predictor variables ($odds_0$) is increased by 1.0 unit.

$$odds\ ratio = \frac{odds_1}{odds_0} \tag{3.16}$$

In the logistic regression analysis, the influence of particular attribute *k* on injury outcome could be revealed by OR.

$$OR = \exp(\beta_j) \tag{3.17}$$

where,

β_j = the corresponding coefficient of the j^{th} independent variable of a logistic regression model.

The confident interval at 95% is given by,

$$(\exp(\beta_j - 1.96 s_{\beta_j}), \exp(\beta_j + 1.96 s_{\beta_j})) \tag{3.18}$$

where,

s_β = the standard error of the coefficient β.

An odds ratio greater than 1 indicates the concerned attribute leads to a higher injury risk, and vice versa. These might be better described as adjusted ORs because they control for other variables in the model.

Chapter 4 - Results and Discussion

This chapter presents crash frequencies, percentages, and crash rates for each characteristic and contributory cause of young drivers involved in crashes, compared to experienced drivers before the law was changed. Further, injury severity models for young driver crashes and initial effects for young driver crashes due to implementation of the law have been presented. Finally, a comparison between crashes involving 15-year-old drivers in 2009 and 2011 has been carried out using the OR analysis.

4.1 Characteristics and Contributory Causes

Frequencies, percentages, and crash rates of crash characteristics and contributory-causes-related variables were investigated because they could be addressed through policies and laws, driver education/training, or other interventions. Motor vehicle drivers involved in crashes on highways during 2006 to 2009 were used for this analysis. The KCARS database from 2006 to 2009 contained 119,927 young-driver-involved crashes and 225,397 experienced-driver-involved crashes.

Descriptive data such as numbers of crashes and percentages for each characteristic and contributory cause were presented in tabular format. The variables were organized under driver, environmental, road, vehicle, and crash-related characteristics, and contributory causes. The percentages were calculated per all drivers involved in crashes for the particular age group. Information such as "unknown" and/or "other" for some of variables was not presented in the tables. Hence, the sum of the percentage for a particular variable is slightly less than 100. These tables also presents the crash rates of each level of particular variable for each age group. Crash rates were calculated per 1,000 drivers and million VMT. Teen driver crashes per 1,000 drivers was 95.2 while the young-adult-driver crash rate was 79.8 per 1,000 drivers, and the experienced-driver crash rate was 45.3 per 1,000 drivers. Teen driver crashes per million VMT was 17.6, while rates were 8.1 and 3.2 per million VMT for young adult and experienced drivers, respectively. Crash rates were higher for teen drivers than for young adult drivers and experienced drivers. Teenage-driver crashes per 1,000 licensed drivers were about twice that of experienced drivers. Teenage-driver crashes per million VMT were approximately five times that of experienced drivers, while young-adult-driver crashes per million VMT were about two times that of experienced drivers. This indicated that teenage drivers have more critical highway safety concerns on a per-miles-driven basis.

Then, characteristics and contributory causes of young driver crashes compared to experienced drivers were investigated using the observed and expected frequencies of the contingency table when the Chi-Square was statistically significant. Also, ORs were used to investigate the relative crash characteristics and contributory causes of young driver crashes. These contingency tables and ORs were also organized under driver, environmental, road, vehicle, and crash-related characteristics, and contributory causes. Chi-Square tests and ORs were used to assess whether differences between teen and experienced drivers, between teen and young adult drivers, and between experienced drivers and young drivers, were statistically significant.

4.1.1 Driver-Related Characteristics

The frequencies, percentages, and crash rates for driver-related characteristics are given in Table 4.1.

Table 4.1 Crash Frequencies, Percentages, and Crash Rates by Driver Group: Driver-Related Characteristics

Driver-Related Characteristics	Number of Crashes Involving Drivers						Crashes per 1,000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young adult	Exp.	Teen	Young adult	Exp.
	Number	%	Number	%	Number	%						
Gender												
Female	29,519	47	25,797	45	102,927	46	44.7	36.1	19.0	8.3	3.7	1.5
Male	33,350	53	31,191	55	122,341	54	50.5	43.7	22.5	9.4	4.4	1.7
License Compliance												
Valid licensed	59,004	94	51,522	90	211,523	94	89.3	72.1	38.9	16.6	7.3	3.0
Not valid licensed	3,217	5	4,840	8	11,592	5	4.9	6.8	2.1	0.9	0.7	0.2
Restriction Compliance												
No restrictions on driver license	40,730	65	36,849	65	134,167	60	61.7	51.6	24.7	11.4	5.2	1.9
Restricted license	18,612	30	16,409	29	81,085	36	28.2	23.0	14.9	5.2	2.3	1.2
Safety Equipment used												
Safety belt used	55,721	89	50,189	88	205,634	91	84.4	70.2	37.9	15.6	7.1	2.9
Safety belt not used	3,576	6	3,193	6	7,431	3	5.4	4.5	1.4	1.0	0.5	0.1
Airbag												
Airbag deployed	3,232	5	2,907	5	8,737	4	4.9	4.1	1.6	0.9	0.4	0.1
Airbag not deployed	56,447	90	51,258	90	209,953	93	85.5	71.7	38.7	15.8	7.3	3.0
Alcohol/drug related												
Alcohol/drug related	1,721	3	3,295	6	7,902	4	2.6	4.6	1.5	0.5	0.5	0.1
No alcohol or drug	61,194	97	53,726	94	217,495	96	92.6	75.2	40.0	17.2	7.6	3.1
Total	62,906	100	57,021	100	225,397	100	95.2	79.8	41.5	17.6	8.1	3.2

Male driver crash percentage (53%) was higher than that of female drivers (47%). Male drivers have higher crash rates per 1,000 drivers than female drivers as shown in Table 4.1. Female drivers' crash rate per 1,000 drivers was 44.7, while male drivers' crash rate per 1,000 drivers was 50.7. Male, young-adult-driver crashes per 1,000 licensed drivers were almost two times that of experienced drivers. Similar comparisons can be observed among female drivers. Both teen male- and female-driver crashes per million VMT were approximately five times that of experienced drivers, while young-adult-driver crashes per million VMT were about 2.5 times that of experienced drivers.

A majority of drivers involved in crashes held valid driver licenses. Approximately 30% of teen drivers had restrictions on their driver licenses at the time of crash. About 6% of teen drivers were not wearing seat belts, while about 3% of teen drivers were under the influence of alcohol at the time of the crash. Figure 4.1 shows the crash rate per 1,000 licensed drivers for some of the driver-related characteristics. For most of driver-related characteristics, teen driver crash rate per 1,000 licensed teen drivers was about twice that of experienced driver crash rates. Young-adult-driver crash rates per 1,000 licensed young adult drivers were slightly less than crash rates per 1,000 licensed teen drivers for those characteristics. The teen driver crashes per VMT were approximately five times more than experienced-driver-involved crashes per VMT for most driver-related characteristics. Those teen crash rates per VMT were about two times more than young-adult-driver-involved crashes per VMT.

The contingency tables for three comparisons of related-driver characteristics are shown in Table 4.2. The expected number of crashes and observed number of crashes for teen drivers, young adult drivers and experienced drivers were presented. Resulting p values for most comparisons were significant (<0.05). According to the Table 4.2, in examining expected numbers of crashes and observed numbers of crashes for teen versus experienced drivers, teen drivers were more likely to be involved in a crash in which a driver being a female and was driving with restricted license. Teen drivers' overrepresentation in crashes for driver being a female and driving without a valid license can also be observed when examining the teen versus young adult drivers. According to the young driver versus experienced driver contingency tables, young female drivers were more likely to be involved in a crash than experienced female drivers. Additionally, differences between young versus experienced drivers showed significantly increased crash involvement of young people driving without a license. Teens that drive without seat belts showed overrepresentation in crashes compared to experienced drivers. The young drivers' overrepresentation in crashes without seat belts can also be observed when examining the young versus experienced drivers.

Figure 4.1 Crash Rates per 1,000 Drivers for Driver-Related Characteristics

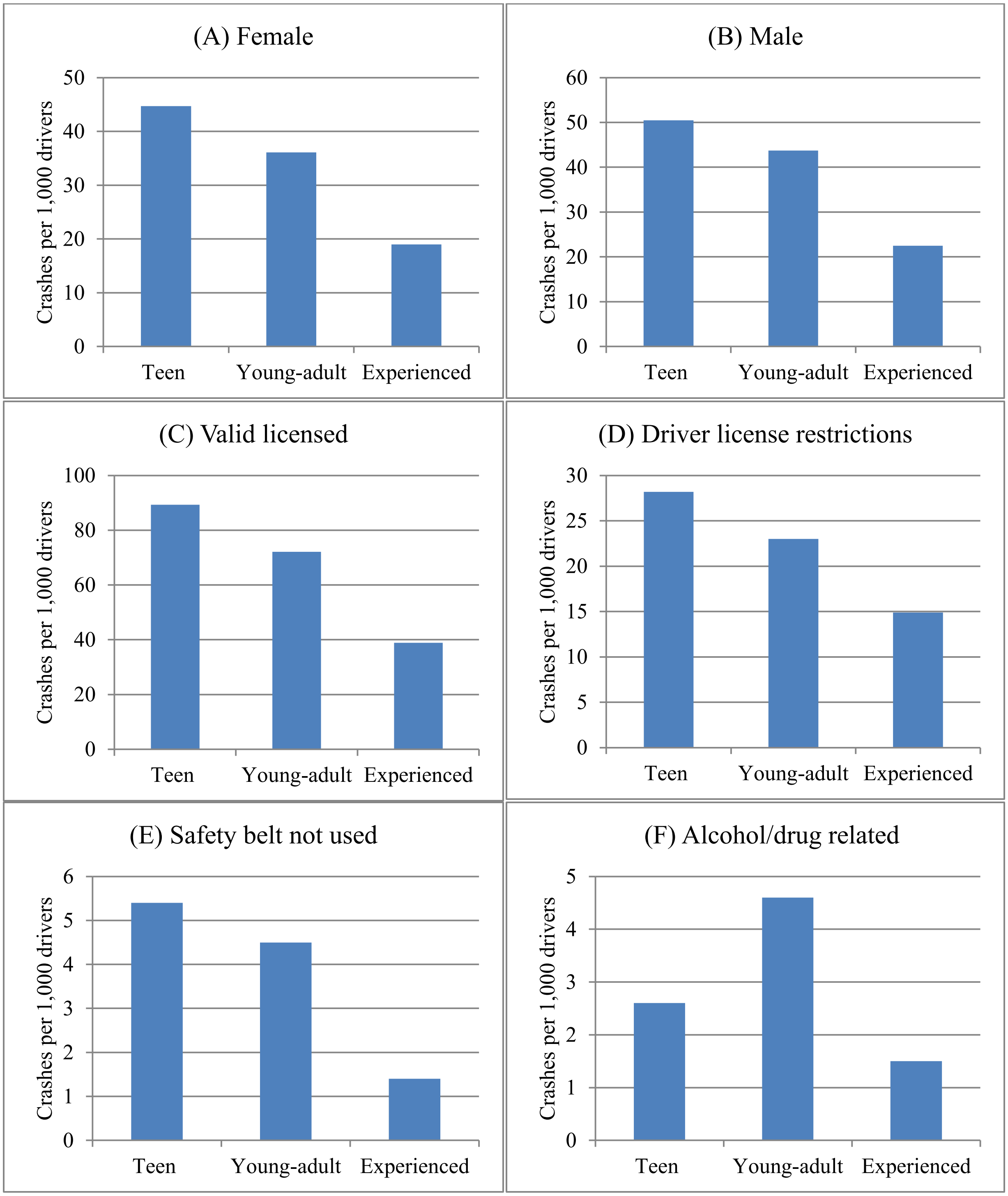


Table 4.2 Contingency Table Analysis for Driver-Related Characteristics

Driver-Related Characteristics	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes		p	Observed crashes		Expected crashes		p	Observed crashes		Expected crashes		p
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers		Teen drivers	Young adults	Teen drivers	Young adults		Young drivers	Exp. drivers	Young drivers	Exp. drivers	
Gender															
Female	29,519	102,927	28,899	103,547		29,519	25,797	29,015	26,301		55,316	102,927	54,956	103,287	
Male	33,350	122,341	33,970	121,721	.00	33,350	31,191	33,854	30,687	.00	64,541	122,341	64,901	121,981	.01
License Compliance															
Valid licensed	59,004	211,523	58,992	211,535		59,004	51,522	57,993	52,533		110,526	211,523	111,764	210,285	
Not licensed	3,217	11,592	3,229	11,580	.80	3,217	4,840	4,228	3,829	.00	8,057	11,592	6,819	12,830	.00
Restriction Compliance															
No restrictions on driver license	40,730	134,167	37,797	137,100		40,730	36,849	40,885	36,694		77,579	134,167	72,724	139,022	
Restricted license	18,612	81,085	21,545	78,152	.00	18,612	16,409	18,457	16,564	.05	35,021	81,085	39,876	76,230	.00
Safety Equipment used															
Safety belt used	55,721	205,634	56,901	204,454		55,721	50,189	55,735	50,175		105,910	205,634	107,767	203,777	
Safety belt not used	3,576	7,431	2,396	8,611	.00	3,576	3,193	3,562	3,207	.73	6,769	7,431	4,912	9,288	.00
Airbag															
Airbag deployed	3,232	8,737	2,566	9,403		3,232	2,907	3,218	2,921		6,139	8,737	5,093	9,783	
Airbag not deployed	56,447	209,953	57,113	209,287	.00	56,447	51,258	56,461	51,244	.72	107,705	209,953	108,751	208,907	.00
Alcohol Related															
drivers with alcohol flag	1,721	7,902	2,100	7,523		1,721	3,295	2,631	2,385		5,016	7,902	4,486	8,432	
no of drivers without alcohol flag	61,194	217,495	60,815	217,874	.00	61,194	53,726	60,284	54,636	.00	114,920	217,495	115,450	216,965	.00

Examining young drivers versus experienced drivers by alcohol flag, alcohol impairment was shown to be a statistically significant difference in which young drivers were more likely involved in alcohol-related crashes compared to experienced drivers. However, by examining teen versus young adult drivers, young adult drivers were more likely to be involved alcohol-related crashes.

ORs were also used to investigate the relative crash involvement of young drivers compared to experienced drivers. Calculated OR values for driver-related characteristics are shown in Table 4.3.

Table 4.3 Odds Ratios (ORs) and Confidence Intervals (CI) for Driver-Related Characteristics

Driver-Related Characteristics	Teen versus Experienced			Teen versus Young-Adult			Young versus Experienced		
	ORs	95% CI		**ORs**	95% CI		**ORs**	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
Gender									
Female	**1.06**	1.04	1.07	**1.07**	1.05	1.10	**1.02**	1.00	1.03
Male	**0.95**	0.93	0.96	**0.93**	0.91	0.96	**0.98**	0.97	0.99
License Compliance									
Valid licensed	**0.99**	0.96	1.03	**1.61**	1.55	1.68	**0.77**	0.75	0.79
Not licensed	**0.99**	0.96	1.04	**0.58**	0.56	0.61	**1.33**	1.29	1.37
Restriction Compliance									
No restrictions on driver license	**1.20**	1.18	1.22	**1.04**	1.01	1.07	**1.25**	1.23	1.26
Restricted license	**0.80**	0.78	0.81	**1.01**	0.98	1.03	**0.73**	0.72	0.75
Safety Equipment used									
Safety belt used	**0.81**	0.78	0.83	**1.06**	1.02	1.09	**0.73**	0.71	0.74
Safety belt not used	**1.54**	1.48	1.60	**1.02**	0.97	1.07	**1.76**	1.70	1.82
Airbag									
Airbag deployed	**1.26**	1.21	1.31	**1.01**	0.96	1.06	**1.39**	1.29	1.38
Airbag not deployed	**0.71**	0.69	0.73	**0.98**	0.95	1.02	**0.65**	0.63	0.67
Alcohol Flag									
no of drivers without alcohol flag	**1.48**	1.40	1.55	**2.19**	2.07	2.33	**0.83**	0.80	0.87
drivers with alcohol flag	**0.68**	0.64	0.71	**0.46**	0.43	0.48	**1.20**	1.16	1.24

The second main column shows ORs and CI of teen drivers compared to experienced drivers, while the third main column provides the ORs and CI of teen drivers compared to young adult drivers. Also, crash involvements of young drivers from age 15 to 24 were assessed using ORs compared to experienced drivers, and were tabulated in the fourth main column. When interpreting results, ORs greater than one showed greater association from the particular factor for a driver-age group being investigated than the other driver-age group. For example, in the teen versus experienced driver comparison OR, value 1.06 for female means female teen drivers were 1.06 times the odds more likely to be involved in crashes than experienced female drivers. According to ORs values with 95% of CI, when evaluating teen versus experienced drivers, it was clearly shown that teen drivers were more likely to be involved in a crash when driving with an invalid license. Teen drivers' over-representation in crashes for these conditions can also be observed when examining teen versus young drivers. Teen drivers were more likely to be involved in crashes when they traveling without wearing seat belts. These results were compatible with results obtained from the contingency table analysis.

4.1.2 Environmental-Related Characteristics

About 27% of teen-driver-involved crashes and 30% of young-adult-driver involved crashes occurred in the dark as shown in Table 4.4. During nighttime (11:00 pm- 5:00 am), the percentage of teen driver crashes (17%) was slightly higher than that of experienced drivers. Both teen and young adult driver crash rates per 1,000 licensed teen drivers, when they were traveling in the nighttime, were approximately three times that of experienced drivers. On weekends, teen driver crash involvement (24%) was slightly higher than that of experienced drivers (21%). Most other cases crash-involvement percentage distributions of environmental-related variables were approximately similar among teen and young adult drivers, as well as experienced drivers. Teen driver crash rates per 1,000 licensed teen drivers, when they were traveling on rural roads, were about three times that of experienced drivers. For most other cases, teen crash rates per 1,000 drivers for environmental-related variables were approximately two times more than experienced drivers. Teen driver crash rates per million VMT, when they were traveling on rural roads or during the weekends, were about six to seven times that of experienced drivers. For most other cases, teen crash rates per million VMT for environmental-related variables were approximately five times more than experienced drivers.

Contingency tables for the three comparisons, which are calculated by the equation in Table 3.3 and related to environmental characteristics, are shown in the Table 4.5. Light conditions, weather conditions, and the day of the week differed in which teens were more likely to be involved in a crash driving during the dark, driving in normal weather conditions, and driving on weekends, compared to experienced drivers. Examining teen drivers versus young adult drivers, light conditions, weather conditions, and the day of the week were shown to be statistically significant differences in which teen drivers were more likely to be involved in a crash driving during daylight conditions, normal weather conditions, and on week days, compared to young adult drivers. In examining young versus experienced drivers by those characteristics, young drivers were more likely to be involved in a crash driving during the dark, in normal weather conditions, and on weekends compared to experienced drivers. The functional class shown to be a statistically significant differences between teen and young adult driver groups, in which teen drivers were more likely to be involved in a crash driving on rural roads. In examining teen versus experienced drivers by functional class, there were statistically significant differences showing that teen drivers had increased involvement on rural roads compared to experienced drivers.

Table 4.4 Crash Frequencies, Percentages, and Crash Rates by Driver Group: Environmental-Related Characteristics

Environmental-Related Characteristics	Number of Crashes Involving Drivers						Crashes per 1,000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young adult	Exp.	Teen	Young adult	Exp.
	Number	%	Number	%	Number	%						
Light Conditions												
Daylight	45,965	73	39,508	69	169,029	75	69.6	55.3	31.1	12.9	5.6	2.4
Dark	16,808	27	17,374	30	55,920	25	25.4	24.3	10.3	4.7	2.5	0.8
Weather Conditions												
Normal conditions	52,801	84	46,602	82	186,859	83	79.9	65.2	34.4	14.8	6.6	2.7
Adverse conditions	9,882	16	10,218	18	37,842	17	15.0	14.3	7.0	2.8	1.4	0.5
Functional Class												
Rural roads	17,751	28	13,338	23	62,053	28	26.9	18.7	11.4	5.0	1.9	0.9
Urban roads	45,134	72	43,657	77	163,218	72	68.3	61.1	30.1	12.7	6.2	2.3
Construction/Maintenance Zone												
Work zone	1,373	2	1,582	3	6,915	3	2.1	2.2	1.3	0.4	0.2	0.1
No work zone	61,349	98	55,246	97	217,850	97	92.9	77.3	40.1	17.2	7.8	3.1
Time of Crash												
5.00-9.00-Morning	7,845	12	7,045	12	39,220	17	11.9	9.9	7.2	2.2	1.0	0.6
9.00-13.00-Noon	28,778	46	24,852	44	103,331	46	43.6	34.8	19.0	8.1	3.5	1.5
13.00-17.00-Afternoon	8,834	14	9,513	17	41,268	18	13.4	13.3	7.6	2.5	1.3	0.6
17.00-21.00-Evening	15,644	25	13,955	24	55,730	25	23.7	19.5	10.3	4.4	2.0	0.8
21.00-5.00-Night	10,639	17	11,169	20	27,116	12	16.1	15.6	5.0	3.0	1.6	0.4
Day of Week												
Week days	47,945	76	42,456	74	177,066	79	72.6	59.4	32.6	13.5	6.0	2.5
Week end	14,939	24	14,551	26	48,297	21	22.6	20.4	8.9	4.2	2.1	0.7
Total	62,906	100	57,021	100	225,397	100	95.2	79.8	41.5	17.6	8.1	3.2

Table 4.5 Contingency Table Analysis for Environmental-Related Characteristics and Crash Location

Environmental-Related Characteristic	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes			Observed crashes		Expected crashes			Observed crashes		Expected crashes		
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p	Teen drivers	Young adults	Teen drivers	Young adults	p	Young drivers	Exp. drivers	Young drivers	Exp. drivers	p
Light Conditions															
Daylight	45,965	169,029	46,906	168,088		45,965	39,508	44,841	40,632		85,473	169,029	88,369	166,133	
Dark	16,808	55,920	15,867	56,861	.00	16,808	17,374	17,932	16,250	.00	34,182	55,920	31,286	58,816	.00
Weather Conditions															
Normal conditions	52,801	186,859	52,274	187,386		52,801	46,602	52,140	47,263		99,403	186,859	99,386	186,876	
Adverse conditions	9,882	37,842	10,409	37,315	.00	9,882	10,218	10,543	9,557	.00	20,100	37,842	20,117	37,825	.87
Functional Class															
Rural roads	17,751	62,053	17,416	59,613		17,751	13,338	16,308	13,812		31,089	62,053	32,351	58,088	
Urban roads	45,134	163,218	45,469	162,883	.00	45,134	43,657	46,577	42,214	.00	88,791	163,218	87,529	164,480	.00
Construction/Maintenance Zone															
Work zone	1,373	6,915	1,808	6,480		1,373	1,582	1,550	1,405		2,955	6,915	3,427	6,443	
No work zone	61,349	217,850	60,914	218,285	.00	61,349	55,246	61,172	55,423	.00	116,595	217,850	116,123	218,322	.00
Time of Crash															
5.00-9.00-Morning	7,845	39,220	9,978	37,087		7,845	7,045	7,725	7,165		14,890	39,220	18,477	35,633	
9.00-13.00-Noon	28,778	103,331	28,006	104,103		28,778	24,852	27,825	25,805		53,630	103,331	53,597	103,364	
13.00-17.00-Afternoon	8,834	41,268	10,621	39,481		8,834	9,513	9,519	8,828		18,347	41,268	20,357	39,258	
17.00-21.00-Evening	15,644	55,730	15,131	56,243		15,644	13,955	15,357	14,242		29,599	55,730	29,137	56,192	
21.00-5.00-Night	10,639	27,116	8,004	29,751	.00	10,639	11,169	11,315	10,493	.00	21,808	27,116	16,706	32,218	.00
Day of Week															
Week days	47,945	177,066	49,088	175,923		47,945	42,456	47,416	42,985		90,401	177,066	92,879	174,588	
Week end	14,939	48,297	13,796	49,440	.00	14,939	14,551	15,468	14,022	.00	29,490	48,297	27,012	50,775	.00

When examining the expected and observed number of crashes between teen and experienced drivers by construction/maintenance zone, teens were shown to have an over representation in non-work zone crashes. Time of crash showed significant differences between experienced and teen driver groups in which teens were more likely to be involved in a crash driving evening or night time.

Table 4.6 shows the ORs and CI values for environmental-related characteristics. According the ORs, teens were more likely to be involved in a crash when driving in the dark and driving in normal weather conditions compared to experienced drivers. Also, young drivers were more likely to be involved in a crash during the dark compared to experienced drivers. Also, young adults drivers were more likely to be involved in a crash during the dark compared to teen drivers. According to ORs, teens had a higher crash involvement when they were driving on rural roads compared to young adults drivers or experienced drivers. Young drivers showed overrepresentation in crashes when they were traveling on urban roads.

Table 4.6 Odds Ratios (ORs) and Confidence Intervals (CI) for Environmental-Related Characteristics

Environmental-Related Characteristics	Teen versus Experienced			Teen versus Young-Adult			Young versus Experienced		
	ORs	95% CI		**ORs**	95% CI		**ORs**	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
Light Conditions									
Daylight	**0.96**	0.94	0.98	**1.20**	1.17	1.23	**0.83**	0.81	0.84
Dark	**1.04**	1.02	1.06	**0.83**	0.81	0.85	**1.21**	1.19	1.23
Weather Conditions									
Normal conditions	**1.10**	1.07	1.12	**1.17**	1.13	1.20	**1.00**	0.98	1.02
Adverse conditions	**0.91**	0.89	0.93	**0.85**	0.83	0.88	**0.99**	0.98	1.02
Functional Class									
Rural roads	**1.08**	1.06	1.10	**1.29**	1.25	1.32	**0.92**	0.91	0.94
Urban roads	**0.93**	0.91	0.95	**0.78**	0.76	0.80	**1.09**	1.07	1.10
Construction/Maintenance Zone									
Work zone	**0.72**	0.68	0.76	**0.78**	0.73	0.84	**0.80**	0.76	0.83
No work zone	**1.35**	1.27	1.42	**1.27**	1.18	1.36	**1.21**	1.16	1.26
Time of Crash									
5.00-9.00-Morning	**0.73**	0.71	0.75	**1.01**	0.98	1.05	**0.67**	0.66	0.69
9.00-13.00-Noon	**1.02**	1.00	1.03	**1.09**	1.07	1.12	**0.96**	0.94	0.97
13.00-17.00-Afternoon	**0.75**	0.73	0.76	**0.81**	0.79	0.84	**0.81**	0.79	0.82
17.00-21.00-Evening	**1.01**	0.99	1.03	**1.02**	1.00	1.05	**1.00**	0.98	1.01
21.00-5.00-Night	**1.30**	1.27	1.33	**0.84**	0.81	0.86	**1.63**	1.59	1.66
Day of Week									
Week days	**0.92**	0.90	0.94	**1.10**	1.07	1.13	**0.84**	0.82	0.85
Week end	**1.09**	1.07	1.11	**0.91**	0.89	0.93	**1.20**	1.18	1.22

Both teen drivers and young drivers showed decreased crash involvement in work zones compared to experienced drivers. Calculated ORs show teens and young drivers were more likely to be involved in crashes during the night. On weekends, teens and young drivers were more likely to be involved in a crash compared to experienced drivers. Young adult drivers were a more risk group than teen drivers for those characteristics, as ORs of teens versus young adults was lower than 1.0.

4.1.3 Road-Related Characteristics

Frequencies, percentages, and crash rates for road-related characteristics were shown in Table 4.7. Teen drivers and young adult drivers had higher crash percentages (9%) in off-roadway crashes than experienced drivers. For off-roadway crashes, the teen driver crash rate per 1,000 licensed teen drivers was about 3.7 times that of experienced drivers. Teen drivers had slightly higher crash involvement (43%) at intersections than experienced drivers or young adult drivers.

Table 4.7 Crash Frequencies, Percentages, and Crash Rates by Driver Group: Road-Related Characteristics

Road-Related Characteristics	Number of Crashes Involving Drivers						Crashes per 1,000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young adult	Exp.	Teen	Young adult	Exp.
	Number	%	Number	%	Number	%						
Crash Location												
On roadway	29,859	47	29,234	51	123,160	55	45.2	40.9	22.7	8.4	4.1	1.8
Intersection	27,275	43	22,875	40	89,443	40	41.3	32.0	16.5	7.7	3.2	1.3
Off roadway	5,745	9	4,877	9	12,707	6	8.7	6.8	2.3	1.6	0.7	0.2
Road Surface Type												
Concrete	15,179	24	16,381	29	65,441	29	23.0	22.9	12.0	4.3	2.3	0.9
Black top	42,081	67	37,254	65	148,790	66	63.7	52.1	27.4	11.8	5.3	2.1
Gravel/brick or other	5,442	9	3,179	6	10,469	5	8.2	4.4	1.9	1.5	0.4	0.1
Road Surface Condition												
Dry	49,473	79	43,362	76	175,996	78	74.9	60.7	32.4	13.9	6.1	2.5
Wet	8,301	13	7,923	14	28,771	13	12.6	11.1	5.3	2.3	1.1	0.4
Debris	4,823	8	5,454	10	19,671	9	7.3	7.6	3.6	1.4	0.8	0.3
Road Surface Character												
Straight and level	46,277	74	41,870	73	165,230	73	70.1	58.6	30.4	13.0	5.9	2.4
Straight not level	11,719	19	10,489	18	43,428	19	17.7	14.7	8.0	3.3	1.5	0.6
Curved	4,440	7	4,263	7	15,207	7	6.7	6.0	2.8	1.2	0.6	0.2
Posted Speed Limit												
Less than 35 mph	23,199	37	19,512	34	66,661	30	35.1	27.3	12.3	6.5	2.8	0.9
35-60 mph	33,590	53	28,237	50	115,895	51	50.9	39.5	21.3	9.4	4.0	1.6
More than 60 mph	6,117	10	9,272	16	42,841	19	9.3	13.0	7.9	1.7	1.3	0.6
Total	62,906	100	57,021	100	225,397	100	95.2	79.8	41.5	17.6	8.1	3.2

For intersection-related crashes, teen driver crash rate per million VMT was about six times that of experienced drivers. The majority of crashes occurred on black-top roadways and dry road surfaces. Over the half of crashes involving teen drivers occurred on roadways with posted speed limits from 35 to 60 mph, while about 37% of teen driver crashes occurred on roadways with posted speed limits less than 35 mph. Teen driver crash rates per 1,000 licensed teen drivers, when they were traveling on roadways with posted speed limits less than 35 mph, were about 6.7 times that of experienced drivers.

The expected number of crashes and observed number of crashes for three comparisons related to road characteristics are presented in Table 4.8. When examining teen versus experienced drivers by crash location, teens were overrepresented in intersection-related crashes and run-off-the-road crashes. Also, young drivers were more likely to be involved in these crashes compared to experienced drivers. Road surface type showed significant differences between experienced and teen driver groups in which teen drivers were more likely to be involved in a crash driving on black-tops or gravel/brick. Examining teen and experienced drivers by road surface conditions showed significant differences in which teen drivers were shown to have a higher involvement in crashes driving on dry surfaces compared to experienced drivers. According to the teen driver versus experienced driver contingency table for road surface characters, teens were shown to have a higher crash involvement driving on straight and level roads. Posted speed limits showed significant differences between experienced and teen driver groups in which teens were more likely to be involved in a crash driving at a speed limit lower than 60 mph, compared to experienced drivers. The teens' higher crash involvement for driving on black-tops, driving on dry road surfaces, driving on straight and level roads, and driving at speed limits lower than 60 mph can also be observed when examining teens versus young adult drivers.

Calculated OR values for road-related characteristics are shown in Table 4.9. ORs values replicate the same crash-involvement characteristics identified from the contingency table analysis, i.e. teen drivers are more likely to be involved in a crash on dry roads, black-tops, and speed limits lower than 60 mph, compared to experienced drivers. ORs further showed teen drivers were more likely to be involved in intersection-related crashes and run-off-the-road crashes compared to experienced drivers as well as young adult drivers.

Table 4.8 Contingency Table Analysis for Road-Related Characteristics

Road-Related Characteristic	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes		p	Observed crashes		Expected crashes		p	Observed crashes		Expected crashes		p
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers		Teen drivers	Young adults	Teen drivers	Young adults		Young drivers	Exp. drivers	Young drivers	Exp. drivers	
Crash Location															
On roadway	47,945	177,066	49,088	175,923		29,859	29,234	30,999	28,094		59,093	123,160	63,289	118,964	
Intersection	28,778	103,331	28,006	104,103		27,275	22,875	26,308	23,842		50,150	89,443	48,475	91,118	
Off roadway	10,639	27,116	8,004	29,751	.00	5,745	4,877	5,572	5,050	.00	10,622	12,707	8,101	15,228	.00
Road Surface Type															
Concrete	15,179	65,441	17,589	63,031		15,179	16,381	16,557	15,003		31,560	65,441	33,680	63,321	
Black top	42,081	148,790	41,642	149,229		42,081	37,254	41,622	37,713		79,335	148,790	79,208	148,917	
Gravel/brick or other	5,442	10,469	3,471	12,440	.00	5,442	3,179	4,523	4,098	.00	8,621	10,469	6,628	12,462	.00
Road Surface Condition															
Dry	49,473	175,996	49,171	176,298		49,473	43,362	48,696	44,139		92,835	175,996	93,321	175,510	
Wet	8,301	28,771	8,085	28,987		8,301	7,923	8,510	7,714		16,224	28,771	15,619	29,376	
Debris	4,823	19,671	5,342	19,152	.00	4,823	5,454	5,391	4,886	.00	10,277	19,671	10,396	19,552	.00
Road Surface Character															
Straight and level	46,277	165,230	46,125	165,382		46,277	41,870	46,226	41,921		88,147	165,230	87,969	165,408	
Straight not level	11,719	43,428	12,026	43,121		11,719	10,489	11,646	10,562		22,208	43,428	22,788	42,848	
Curved	4,440	15,207	4,285	15,362	.00	4,440	4,263	4,564	4,139	.02	8,703	15,207	8,301	15,609	.00
Posted Speed Limit															
Less than 35 mph	23,199	66,661	19,607	70,253		23,199	19,512	22,403	20,308		42,711	66,661	37,984	71,388	
35-60 mph	33,590	115,895	32,617	116,868		33,590	28,237	32,430	29,397		61,827	115,895	61,721	116,001	
More than 60 mph	6,117	42,841	10,682	38,276	.00	6,117	9,272	8,072	7,317	.00	15,389	42,841	20,223	38,007	.00

Table 4.9 Odds Ratios (ORs) and Confidence Intervals (CI) for Road-Related Characteristics

Road-Related Characteristic	Teen versus Experienced			Teen versus Young-Adult			Young versus Experienced		
	ORs	95% CI Lower	95% CI Upper	**ORs**	95% CI Lower	95% CI Upper	**ORs**	95% CI Lower	95% CI Upper
Crash Location									
On roadway	**0.77**	0.76	0.79	**0.86**	0.84	0.88	**0.81**	0.80	0.82
Intersection	**1.16**	1.14	1.18	**1.14**	1.12	1.17	**1.09**	1.08	1.11
Off roadway	**1.52**	1.47	1.56	**1.07**	1.03	1.12	**1.63**	1.58	1.67
Road Surface Type									
Concrete	**0.78**	0.76	0.80	**0.79**	0.77	0.81	**0.87**	0.86	0.89
Black top	**1.05**	1.03	1.07	**1.07**	1.05	1.10	**1.01**	0.99	1.02
Gravel/brick or other	**1.87**	1.81	1.93	**1.60**	1.53	1.68	**1.59**	1.54	1.64
Road Surface Condition									
Dry	**1.06**	1.04	1.08	**1.16**	1.13	1.19	**0.96**	0.95	0.98
Wet	**1.02**	0.99	1.04	**0.94**	0.91	0.97	**1.07**	1.05	1.09
Debris	**0.85**	0.82	0.88	**0.79**	0.75	0.82	**0.98**	0.96	1.01
Road Surface Character									
Straight and level	**1.01**	0.99	1.03	**1.01**	0.98	1.03	**1.01**	0.99	1.03
Straight not level	**0.97**	0.95	0.99	**1.02**	0.99	1.05	**0.95**	0.94	0.97
Curved	**1.03**	0.99	1.06	**0.94**	0.90	0.98	**1.08**	1.05	1.11
Posted Speed Limit									
Less than 35 mph	**1.33**	1.31	1.36	**1.12**	1.10	1.15	**1.32**	1.30	1.34
35-60 mph	**1.10**	1.08	1.12	**1.17**	1.14	1.20	**1.01**	0.99	1.02
More than 60 mph	**0.48**	0.46	0.49	**0.56**	0.54	0.57	**0.63**	0.62	0.64

The calculated ORs values replicate young drivers' overreaction in crashes when traveling on wet road surfaces. According to ORs values, when evaluating teen versus young adult drivers, it was clearly shown that teen drivers were more likely to be involved in a crash on dry roads, black-tops, and with speed limits lower than 60 mph, compared to young adult drivers.

4.1.4. Vehicle-Related Characteristics

Teen drivers had higher crash involvement when they were in automobiles (68%) than experienced drivers (49%) as shown in Table 4.10. Teen drivers involved in crashes per 1,000 licensed teen drivers while operating an automobile had approximately three times those of experienced drivers. About 14% of teens were involved in crashes when they were driving vehicles which were 15 years or older, while only 9 % of experienced drivers were involved in crashes when driving that age of vehicle. Teen drivers involved in crashes per 1,000 licensed teen drivers while operating an older vehicle had about 3.5 times those of experienced drivers. In addition, teen drivers and young adult drivers were overrepresented in crashes when they were traveling with a teen passenger (15%), compared to experienced drivers (3%). Teen drivers involved in crashes per 1,000 licensed teen drivers when traveling with teen passengers had approximately nine times those of experienced drivers.

Table 4.10 Crash Frequencies, Percentages and Crash Rates by Driver Group: Vehicle-Related Characteristics

Vehicle-Related Characteristics	Number of Crashes Involving Drivers						Crashes per 1,000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young adult	Exp.	Teen	Young adult	Exp.
	Number	%	Number	%	Number	%						
Vehicle Type												
Automobile	42,831	68	37,908	66	109,966	49	64.8	53.1	20.2	12.0	5.4	1.6
Van	1,780	3	1,829	3	22,697	10	2.7	2.6	4.2	0.5	0.3	0.3
Pickup-truck, camper-rv	10,425	17	9,465	17	49,587	22	15.8	13.2	9.1	2.9	1.3	0.7
Sport utility vehicle	7,870	13	7,812	14	43,147	19	11.9	10.9	7.9	2.2	1.1	0.6
Vehicle Age												
Year 4 or newer	9,593	15	13,999	25	75,964	34	14.5	19.6	14.0	2.7	2.0	1.1
5-9 years	26,587	42	25,496	45	91,934	41	40.2	35.7	16.9	7.5	3.6	1.3
10-14 years	22,566	36	15,855	28	50,350	22	34.2	22.2	9.3	6.3	2.2	0.7
Year 15 or older	8,966	14	5,537	10	19,470	9	13.6	7.7	3.6	2.5	0.8	0.3
Occupants												
Only driver	40,359	64	40,265	71	159,726	71	61.1	56.3	29.4	11.3	5.7	2.3
Driver and passengers	22,508	36	16,722	29	65,517	29	34.1	23.4	12.1	6.3	2.4	0.9
Teen Passengers												
No	53,345	85	48,244	85	218,083	97	80.8	67.5	40.2	15.0	6.8	3.1
Yes	9,561	15	8,777	15	7,314	3	14.5	12.3	1.3	2.7	1.2	0.1
Total	62,906	100	57,021	100	225,397	100	95.2	79.8	41.5	17.6	8.1	3.2

The expected number of crashes (calculated by the equations in Table 3.3) and observed number of crashes for the three comparisons related to vehicle characteristics are presented in Table 4.11. When examining teen versus experienced drivers by vehicle type, teens were over-represented in crashes when operating automobile. Also, young drivers were more likely to be involved in crashes while operating an automobile compared to experienced drivers. Examining teen and young adult drivers by vehicle type showed significant differences in which teens were shown to have a higher involvement in crashes when driving automobiles. This may because teens probably drive automobiles more than other type of vehicle. The vehicle age showed significant differences between experienced and teen driver groups in which teen drivers were more likely to be involved in a crash when driving a vehicle older than five years.

Table 4.11 Contingency Table Analysis for Vehicle-Related Characteristics

Vehicle-Related Characteristic	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes			Observed crashes		Expected crashes			Observed crashes		Expected crashes		
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p	Teen drivers	Young adults	Teen drivers	Young adults	p	Young drivers	Exp. drivers	Young drivers	Exp. drivers	p
Vehicle Type															
Automobile	42,831	109,966	33,339	119,458		42,831	37,908	42,353	38,386		80,739	109,966	66,227	124,478	
Van	1,780	22,697	5,341	19,136		1,780	1,829	1,893	1,716		3,609	22,697	9,135	17,171	
Pickup-truck, camper-rv	10,425	49,587	13,094	46,918		10,425	9,465	10,434	9,456		19,890	49,587	24,128	45,349	
Sport utility vehicle	7,870	43,147	11,132	39,885	.00	7,870	7,812	8,226	7,456	.00	15,682	43,147	20,430	38,399	.00
Vehicle Age															
Year 4 or newer	9,593	75,964	18,967	66,590		9,593	13,999	12,422	11,170		23,592	75,964	34,950	64,606	
5-9 years	26,587	91,934	26,275	92,246		26,587	25,496	27,424	24,659		52,083	91,934	50,559	93,458	
10-14 years	22,566	50,350	16,165	56,751		22,566	15,855	20,230	18,191		38,421	50,350	31,164	57,607	
Year 15 or older	8,966	19,470	6,304	22,132	.00	8,966	5,537	7,636	6,867	.00	14,503	19,470	11,927	22,046	.00
Occupants															
Only driver	40,359	159,726	43,660	156,425		40,359	40,265	42,290	38,334		80,624	159,726	83,475	156,875	
Driver and passengers	22,508	65,517	19,207	68,818	.00	22,508	16,722	20,577	18,653	.00	39,230	65,517	36,379	68,368	.00
Teen Passengers															
No	53,345	218,083	59,224	212,204		53,345	48,244	53,287	48,302		101,589	218,083	111,018	208,654	
Yes	9,561	7,314	3,682	13,193	.00	9,561	8,777	9,619	8,719	.35	18,338	7,314	8,909	16,743	.00

According to contingency tables for teen passengers, teen drivers were more likely to be involved in these crashes riding with teen passengers, compared to experienced drivers. Teen driver overrepresentation in a crash when riding with teen passengers was also true compared to young drivers.

The ORs for vehicle-related characteristics are shown in Table 4.12. Teen and young adult drivers were more likely to be involved in a crash when they were operating an automobile, compared to experienced drivers. The calculated ORs values show similar findings, which were identified from the contingency table analysis, i.e. teen drivers were more likely to be involved in a crash when they were operating an automobile, operating a vehicle older than five years, and riding with teen passengers.

Table 4.12 Odds Ratios (ORs) and Confidence Intervals (CI) for Vehicle-Related Characteristics

Vehicle Related Characteristic	Teen versus Experienced			Teen versus Young-Adult			Young versus Experienced		
	ORs	95% CI		**ORs**	95% CI		**ORs**	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
Vehicle Type									
Automobile	**1.94**	1.91	1.98	**1.08**	1.05	1.10	**2.16**	2.13	2.20
Van	**0.31**	0.29	0.32	**0.88**	0.82	0.94	**0.28**	0.27	0.29
Pickup-truck, camper-rv	**0.75**	0.73	0.77	**1.00**	0.97	1.03	**0.71**	0.69	0.72
Sport utility vehicle	**0.65**	0.63	0.67	**0.90**	0.87	0.93	**0.64**	0.62	0.65
Vehicle Age									
4 years or newer	**0.38**	0.38	0.39	**0.55**	0.54	0.54	**0.48**	0.47	0.49
5-9 years	**1.03**	1.01	1.05	**0.91**	0.89	0.93	**1.11**	1.10	1.13
10-14 years	**1.83**	1.79	1.86	**1.45**	1.42	1.49	**1.64**	1.61	1.67
Year 15 or older	**1.71**	1.67	1.76	**1.55**	1.49	1.60	**1.46**	1.42	1.49
Number of Occupants									
Only driver	**0.74**	0.72	0.75	**0.75**	0.73	0.76	**0.84**	0.83	0.86
Driver and passengers	**3.26**	3.20	3.32	**1.34**	1.31	1.38	**3.98**	3.91	4.05
Teen Passengers									
No	**0.34**	0.33	0.35	**1.02**	0.98	1.05	**0.19**	0.18	0.19
Yes	**4.99**	4.85	5.14	**0.99**	0.96	1.02	**40.05**	37.58	42.69

4.1.5 Crash-Related Characteristics

Frequencies, percentages, and crash rates for crash-related characteristics are given in Table 4.13. There were 111 teen drivers killed on Kansas roadways over four year time. About 16% of teen drivers, out of all crashes involving drivers, suffered injuries. Teen involvement in crashes were (19%) higher when they were turning or changing lanes, compared to experienced drivers. A higher percentage of vehicles were destroyed at the time of teen drivers' crashes compared to those of experienced drivers. Teen drivers also had a higher crash-involvement percentage in collisions with a fixed object than experienced drivers.

Table 4.13 Crash Frequencies, Percentages, and Crash Rates by Driver Group: Crash-Related Characteristics

Crash-Related Characteristics	Number of Crashes Involving Drivers						Crashes per 1,000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young adult	Exp.	Teen	Young adult	Exp.
	Number	%	Number	%	Number	%						
Injury Severity												
Fatal injury	111	< 1	138	< 1	519	< 1	0.2	0.2	0.1	0.03	0.02	0.01
Disabled injury	627	1	556	1	2,159	1	0.9	0.8	0.4	0.18	0.08	0.03
Injury	4,423	7	3,775	7	12,537	6	6.7	5.3	2.3	1.24	0.53	0.18
Possible injury	4,346	7	4,061	7	16,282	7	6.6	5.7	3.0	1.22	0.57	0.23
Not injured	50,721	81	46,208	81	185,093	82	76.8	64.7	34.1	14.23	6.54	2.63
Ejection												
Ejected	329	1	255	0	689	0	0.5	0.4	0.1	0.09	0.04	0.01
Not ejected	59,368	94	54,094	95	213,935	95	89.9	75.7	39.4	16.66	7.66	3.04
Trapped	370	1	303	1	1,382	1	0.6	0.4	0.3	0.10	0.04	0.02
Vehicle Damage												
Not damage	1,164	2	1,058	2	5,311	2	1.8	1.5	1.0	0.33	0.15	0.08
Minor damage	14,628	23	13,344	23	63,308	28	22.1	18.7	11.7	4.10	1.89	0.90
Functional	21345	34	20,218	35	84,461	37	32.3	28.3	15.6	5.99	2.86	1.20
Disabling	20,485	33	18,241	32	60,336	27	31.0	25.5	11.1	5.75	2.58	0.86
Destroyed	4,873	8	3,796	7	10,405	5	7.4	5.3	1.9	1.37	0.54	0.15
Vehicle Maneuver Before Un-stabilized Situation												
Straight-following	38,080	61	22,053	39	134,066	59	57.6	30.9	24.7	10.68	3.12	1.91
Turn or changing lanes	12,070	19	9,291	16	31,320	14	18.3	13.0	5.8	3.39	1.32	0.45
Avoiding maneuver	2,221	4	2,019	4	6,353	3	3.4	2.8	1.2	0.62	0.29	0.09
Stopped, parking or backing	9,668	15	9,921	17	51,017	23	14.6	13.9	9.4	2.71	1.40	0.73
Accident Class												
Collision with vehicle	47,412	75	42,109	74	167,023	74	71.8	58.9	30.8	13.30	5.96	2.38
Collision with object	9,484	15	8,397	15	14,507	6	14.4	11.8	2.7	2.66	1.19	0.21
Collision with animal	2,856	5	4,096	7	29,312	13	4.3	5.7	5.4	0.80	0.58	0.42
Collision with pedestrian	337	1	337	1	1,343	1	0.5	0.5	0.2	0.09	0.05	0.02
Non-collision & overturned	2,793	4	2,047	4	5,487	2	4.2	2.9	1.0	0.78	0.29	0.08
Manner of Collision												
Head on	1,322	2	1,214	2	4,188	2	2.0	1.7	0.8	0.37	0.17	0.06
Rear end	19,828	32	17,452	31	71,532	32	30.0	24.4	13.2	5.56	2.47	1.02
Angle side impact	18,748	30	16,484	29	63,314	28	28.4	23.1	11.7	5.26	2.33	0.90
Sideswipe	3,910	6	3,917	7	15,896	7	5.9	5.5	2.9	1.10	0.55	0.23
Backed into	1,084	2	1,012	2	5,359	2	1.6	1.4	1.0	0.30	0.14	0.08
Total	62,906	100	57,021	100	225,397	100	95.2	79.8	41.5	0.37	0.17	0.06

Teen crash involvement percentages for many other crash-related characteristics were similar to the young adult drivers as well as experienced drivers. Teen drivers involved in crashes per 1,000 licensed teen drivers while making a turn were about three times that of experienced drivers. Also, teen driver crash rates for vehicle being destroyed, non-colliding/overturning, or colliding with an other vehicle were much higher than that of experienced drivers. Teen driver crashes per Million VMT in vehicle being destroyed, or turning, non-colliding and overturning, avoiding maneuver, and colliding with a fixed object, were eight times greater than that of experienced drivers.

The contingency tables for the three comparisons related to crash characteristics are shown in the Table 4.14. The injury severity differed in which teens were more likely to be involved in injury crashes or disabled injury crashes compared to experienced drivers. Teen drivers were more likely to be involved in injury crashes or disabled injury crashes compared to experienced drivers. "Ejected" showed significant differences between experienced and teen driver groups in which teen drivers were more likely to be ejected during the crash. According to ORs values with 95% of CI, when evaluating teen versus young adult drivers, it was clearly shown that teen drivers were more likely to be ejected at the time of crash compared to young adult drivers. Vehicle damage showed significant differences between experienced and teen driver groups in which the vehicles of teen drivers were more likely to disabled or destroyed at the time of the crash. Examining teen and experienced drivers by vehicle maneuver before an un-stabilized situation showed significant differences in which teen drivers were over represented in straight following, attempting to turn, or changing lanes. Teen drivers' over-representation on straight-following maneuvers can also be observed when examining teen versus young adult drivers. According to the young driver versus experienced driver contingency table for vehicle maneuvers, young drivers were shown to be over-represented when attempting to turn or change lanes. The accident class showed significant differences between experienced and teen driver groups, in which teens were more likely to be involved in a collision with objects or non-collision, overturn crashes. When examining teen versus experienced drivers by manner of collision, teens were shown to have an increased involvement of head-on crashes and angle-side-impact crashes. The young drivers' higher crash involvement for collision with objects, head-on crashes, or angle-side-impact crashes can be observed when examining young versus experienced drivers.

Table 4.14 Contingency Table Analysis for Crash-Related Characteristics

Crash-Related Characteristic	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes			Observed crashes		Expected crashes			Observed crashes		Expected crashes		
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p	Teen drivers	Young adults	Teen drivers	Young adults	p	Young drivers	Exp. drivers	Young drivers	Exp. drivers	p
Injury Severity															
Fatal injury	111	519	137	493		111	138	130	119		249	519	266	502	
Disabled injury	627	2,159	606	2,180		627	556	620	563		1,183	2,159	1,159	2,183	
Injury	4,423	12,537	3,690	13,270		4,423	3,775	4,295	3,903		8,198	12,537	7,190	13,545	
Possible injury	4,346	16,282	4,488	16,140		4,346	4,061	4,404	4,003		8,407	16,282	8,561	16,128	
Not injured	50,721	185,093	51,307	184,507	.00	50,721	46,208	50,779	46,150	.00	96,929	185,093	97,790	184,232	.00
Ejection															
Ejected	329	689	221	797		329	255	306	278		584	689	442	831	
Not ejected	59,368	213,935	59,464	213,839		59,368	54,094	59,409	54,053		113,462	213,935	113,565	213,832	
Trapped	370	1,382	381	1,371	.00	370	303	352	321	.06	673	1,382	713	1,342	.00
Vehicle Damage															
Not damage	1,164	5,311	1,413	5,062		1,164	1,058	1,165	1,057		2,222	5,311	2,617	4,916	
Minor damage	14,628	63,308	17,011	60,925		14,628	13,344	14,671	13,301		27,972	63,308	31,712	59,568	
Functional	21,345	84,461	23,095	82,711		21,345	20,218	21,800	19,763		41,563	84,461	43,782	82,242	
Disabling	20,485	60,336	17,641	63,180		20,485	18,241	20,312	18,414		38,726	60,336	34,415	64,647	
Destroyed	4,873	10,405	3,335	11,943	.00	4,873	3,796	4,547	4,122	.00	8,669	10,405	6,626	12,448	.00
Vehicle Maneuver Before Un-stabilized Situation															
Straight-following	38,080	134,066	37,500	134,646		38,080	22,053	35,420	24,713		60,133	134,066	62,344	131,855	
Turn or changing lanes	12,070	31,320	9,452	33,938		12,070	9,291	12,582	8,779		21,361	31,320	16,912	35,769	
Avoiding maneuver	2,221	6,353	1,868	6,706		2,221	2,019	2,498	1,742		4,240	6,353	3,401	7,192	
Stopped, parking or backing	9,668	51,017	13,219	47,466	.00	9,668	9,921	11,539	8,050	.00	19,589	51,017	22,667	47,939	.00
Accident Class															
Collision with vehicle	47,412	167,023	48,062	166,373		47,412	42,109	46,962	42,559		89,521	167,023	91,105	165,439	
Collision with object	9,484	14,507	5,377	18,614		9,484	8,397	9,380	8,501		17,881	14,507	11,502	20,886	
Collision with animal	2,856	29,312	7,210	24,958		2,856	4,096	3,647	3,305		6,952	29,312	12,878	23,386	
Collision with pedestrian	337	1,343	377	1,303		337	337	354	320		674	1,343	716	1,301	
Non-collision & overturned	2,793	5,487	1,856	6,424	.00	2,793	2,047	2,539	2,301	.00	4,840	5,487	3,667	6,660	.00
Manner of Collision															
Head on	1,322	4,188	1,206	4,304		1,322	1,214	1,340	1,196		2,536	4,188	2,330	4,394	
Rear end	19,828	71,532	19,989	71,371		19,828	17,452	19,696	17,584		37,280	71,532	37,698	71,114	
Angle side impact	18,748	63,314	17,955	64,107		18,748	16,484	18,614	16,618		35,232	63,314	34,142	64,404	
Sideswipe	3,910	15,896	4,333	15,473		3,910	3,917	4,135	3,692		7,827	15,896	8,219	15,504	
Backed into	1,084	5,359	1,410	5,033	.00	1,084	1,012	1,107	989	.00	2,096	5,359	2,583	4,872	.00

According to the ORs of crash-related characteristics in Table 4.15, teen drivers were more likely to be involved in an injury or disabled injury crash compared to experienced drivers. Also, teen drivers and young drivers were more likely to be ejected at the time of the crash, compared to experienced drivers.

Table 4.15 Odds Ratios (ORs) and Confidence Intervals (CI) for Crash-Related Characteristics

Crash-Related Characteristic	Teen versus Experienced			Teen versus Young-Adult			Young versus Experienced		
	ORs	95% CI		**ORs**	95% CI		**ORs**	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
Injury Severity									
Fatal injury	**0.76**	0.66	0.93	**0.73**	0.57	0.94	**0.91**	0.78	1.05
Disabled injury	**1.04**	0.95	1.14	**1.03**	0.91	1.15	**1.03**	0.96	1.11
Injury	**1.24**	1.20	1.28	**1.07**	1.02	1.12	**1.25**	1.21	1.29
Possible injury	**0.96**	0.93	0.99	**0.97**	0.93	1.02	**0.97**	0.95	1.00
Not injured	**0.92**	0.90	0.95	**0.99**	0.95	1.02	**0.91**	0.90	0.93
Ejection									
Ejected	**1.57**	1.38	1.78	**1.17**	0.99	1.38	**1.60**	1.43	1.78
Not ejected	**0.90**	0.87	0.94	**0.91**	0.86	0.96	**0.94**	0.91	0.97
Trapped	**0.99**	0.88	1.10	**1.11**	0.95	1.29	**0.92**	0.84	1.01
Vehicle Damage									
Not damage	**0.82**	0.77	0.87	**1.00**	0.92	1.09	**0.78**	0.74	0.82
Minor damage	**0.81**	0.80	0.83	**0.99**	0.97	1.02	**0.78**	0.77	0.79
Functional	**0.87**	0.86	0.89	**0.94**	0.91	0.96	**0.89**	0.87	0.90
Disabling	**1.25**	1.23	1.28	**1.03**	1.00	0.02	**1.31**	1.29	1.33
Destroyed	**1.59**	1.53	1.64	**1.18**	1.13	1.23	**1.61**	1.56	1.66
Vehicle Maneuver Before Un-stabilized Situation									
Straight-following	**1.03**	1.01	1.05	**0.97**	0.95	0.99	**1.06**	1.05	1.08
Turn or changing lanes	**1.41**	1.38	1.45	**1.22**	1.18	1.26	**1.34**	1.32	1.37
Avoiding maneuver	**1.20**	1.14	1.26	**1.00**	0.94	1.06	**1.26**	1.22	1.32
Stopped, parking or backing	**0.66**	0.65	0.68	**0.86**	0.84	0.89	**0.67**	0.66	0.68
Accident Class									
Collision with vehicle	**1.07**	1.05	1.09	**1.08**	1.06	1.11	**1.03**	1.01	1.05
Collision with object	**1.47**	1.43	1.50	**1.03**	1.00	1.06	**1.61**	1.58	1.64
Collision with animal	**0.36**	0.34	0.37	**0.62**	0.59	0.65	**0.41**	0.40	0.42
Collision with pedestrian	**0.90**	0.80	1.01	**0.91**	0.78	1.05	**0.94**	0.86	1.04
Non-collision & overturned	**1.70**	1.62	1.77	**1.25**	1.18	1.32	**1.69**	1.62	1.75
Manner of Collision									
Head on	**1.10**	1.04	1.17	**0.99**	0.91	1.07	**1.14**	1.09	1.20
Rear end	**1.00**	0.98	1.02	**1.04**	1.02	1.07	**0.97**	0.96	0.99
Angle side impact	**1.08**	1.06	1.10	**1.04**	1.02	1.07	**1.07**	1.05	1.08
Sideswipe	**0.88**	0.85	0.91	**0.90**	0.86	0.94	**0.92**	0.90	0.95
Backed into	**0.76**	0.71	0.81	**0.97**	0.89	1.06	**0.73**	0.69	0.77

Further, young drivers were more likely to have suffered injuries or be ejected due to crashes than experienced drivers. Compared with experienced drivers, both teen and young adult drivers' vehicles were more likely to be disabled or destroyed at the time of crash. According to the ORs, teen drivers showed higher crash involvement when they were driving on straight-level roads, attempting to turn, or change lanes than experienced drivers. Teen drivers were a more valuable group for these types of crashes. ORs values replicate the "same crash involvement" characteristics identified from the contingency table analysis, i.e. teen drivers are more likely to be involved in non-collision, overturn crashes; collision with objects; head on crashes; and angle-side-impact crashes.

4.1.6 Contributory Causes

Contributory causes for young driver crashes were also investigated using Kansas crash data. Many factors might have combined to produce circumstances that led to a traffic crash, i.e. there was rarely a single cause of such an event. Mainly these contributory causes could be divided into four categories: driver, roadway, environment, and vehicle-related factors. Driver-related contributory causes involve actions taken by, or the condition of, the driver of the vehicle. Contributory causes for to teen, young adult, and experienced drivers are provided in Table 4.16.

These contributory causes were recorded for 54% of young adult and teen drivers involved in crashes. That means driver contributory causes were giving by the investigating officer in 54% of the recorded crashes, according to the opinion of the investigating officer. For other crashes the investigating officer's opinion was other factors not related to the driver. Inattention (24%) was the top-ranked driver contributory cause in teen driver crashes followed by driving too fast (15%), failure to yield right-of-way (10%), and disregarding traffic sign/signals (5%). Those same driver-related contributory causes were also the most critical factors among young adult and experienced drivers. Crash rates for teen-driver-related contributory causes per 1,000 licensed drivers were about three times that of experienced drivers. Correspondingly, young-adult-driver-contributed crash rates were about two times that of experienced drivers. Teen-driver-involved crashes per VMT due to inattention, failure to yield right-of-way, speeding, and disregarding traffic signs and signals were about eight times that of experienced drivers and about twice that of young adult drivers.

Environmental-related contributory causes were recorded for 5,974 crashes involving teen drivers, 5,301 crashes involving young-adult drivers, and 31,906 crashes involving experienced drivers. The most frequent environmental-related contributory causes for teen-driver-involved crashes were identified as hitting an animal. Teen drivers' crash percentage due to hitting an animal was similar to that of young adult drivers and less than that of experienced drivers. Crash rates per 1,000 licensed drivers due to environmental, vehicle and road-related contributory causes for teen drivers were higher than that of young adult drivers and experienced drivers.

Table 4.16 Crash Frequencies, Percentages, and Crash Rates for Contributory Causes

Contributory Causes	Number of Crashes Involving Drivers						Crashes per 1,000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young adult	Exp.	Teen	Young adult	Exp.
	Number	%	Number	%	Number	%						
Driver Action Related												
Speeding	9,400	15	8,764	15	21,238	9	14.2	12.3	3.9	2.64	1.24	0.30
Failure to yield right of way	6,094	10	5,288	9	14,507	6	9.2	7.4	2.7	1.71	0.75	0.21
Disregarded traffic signs/signals	2,903	5	2,713	5	7,150	3	4.4	3.8	1.3	0.81	0.38	0.10
Turning or lane changing	2,199	3	2,065	4	6,162	3	3.3	2.9	1.1	0.62	0.29	0.09
Improper action	2,051	3	1,796	3	6,172	3	3.1	2.5	1.1	0.58	0.25	0.09
Aggressive driving	1,489	2	1,430	3	2,521	1	2.3	2.0	0.5	0.42	0.20	0.04
Avoidance/ evasive or slow	1,453	2	1,328	2	3,824	2	2.2	1.9	0.7	0.41	0.19	0.05
Driver Condition Related												
Alcohol impaired	2,181	3	2,102	4	6,888	3	3.3	2.9	1.3	0.61	0.30	0.10
Ill, falling asleep or fatigued	816	1	715	1	2,400	1	1.2	1.0	0.4	0.23	0.10	0.03
Driver Distractions Related												
Inattention	14,970	24	13,550	24	35,318	16	22.7	19.0	6.5	4.20	1.92	0.50
In vehicle distraction	1,375	2	1,280	2	2,498	1	2.1	1.8	0.5	0.39	0.18	0.04
Total Crashes Occurred Due to Driver Factors	34,065	54	31,064	54	84,387	37	51.6	43.5	15.5	9.56	4.40	1.20
Environmental Related												
Animal	2,771	4	2,457	4	19,917	9	4.2	3.4	3.7	0.78	0.35	0.28
Weather related	2,409	1	2,217	4	9,543	4	3.6	3.1	1.8	0.68	0.31	0.14
Vision obstruction	854	1	679	1	2,728	1	1.3	1.0	0.5	0.24	0.10	0.04
Total Crashes Occurred Due to Environmental Factors	5,974	9	5,301	9	31,906	14	9.0	7.4	5.9	1.68	0.75	0.45
Total Crashes Occurred Due to Vehicle Factors	716	1	660	1	1,816	1	1.1	0.9	0.3	0.20	0.09	0.03
Total Crashes Occurred Due to Road Factors	3,866	6	3,627	6	14,020	6	5.9	5.1	2.6	1.08	0.51	0.20

The contingency tables for the three comparisons related to contributory causes are shown in Tables 4.17 and 4.18.

Table 4.17 Contingency Table Analysis for Driver-Action-Related Contributory Causes

Contributory Causes	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes			Observed crashes		Expected crashes			Observed crashes		Expected crashes		
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p
Driver Action Related															
Speeding															
Yes	9,400	21,238	16,071	14,567		9,400	8,764	9,528	8,636		18,164	21,238	13,684	25,718	
No	53,506	35,783	46,835	42,454	0.00	53,506	48,257	53,378	48,385	0.04	101,763	204,159	106,243	199,679	0.00
Failure to yield right of way															
Yes	6,094	14,507	10,806	9,795		6,094	5,288	5,970	5,412		11,382	14,507	8,991	16,898	
No	56,812	42,514	52,100	47,226	0.00	56,812	51,733	56,936	51,609	0.01	108,545	210,890	110,936	208,499	0.00
Disregarded traffic signs/signals															
Yes	2,903	7,150	5,273	4,780		2,903	2,713	2,946	2,670		5,616	7,150	4,433	8,333	
No	60,003	49,871	57,633	52,241	0.00	60,003	54,308	59,960	54,351	0.24	114,311	218,247	115,494	217,064	0.00
Turning or lane changing															
Yes	2,199	6,162	4,386	3,975		2,199	2,065	2,237	2,027		4,264	6,162	3,621	6,805	
No	60,707	50,859	58,520	53,046	0.00	60,707	54,956	60,669	54,994	0.24	115,663	219,235	116,306	218,592	0.00
Improper action															
Yes	2,051	6,172	4,313	3,910		2,051	1,796	2,018	1,829		3,847	6,172	3,479	6,540	
No	60,855	50,849	58,593	53,111	0.00	60,855	55,225	60,888	55,192	0.28	116,080	219,225	116,448	218,857	0.00
Aggressive driving															
Yes	1,489	2,521	2,103	1,907		1,489	1,430	1,531	1,388		2,919	2,521	1,889	3,551	
No	61,417	54,500	60,803	55,114	0.00	61,417	55,591	61,375	55,633	0.11	117,008	222,876	118,038	221,846	0.00
Avoidance/ evasive or slow															
Yes	1,453	3,824	2,768	2,509		1,453	1,328	1,459	1,322		2,781	3,824	2,294	4,311	
No	61,453	53,197	60,138	54,512	0.00	61,453	55,693	61,447	55,699	0.83	117,146	221,573	117,633	221,086	0.00

Table 4.18 Contingency Table Analysis for Driver Condition, Distraction, and Environmental-Related Contributory Causes

Contributory Causes	Teen versus Experienced					Teen versus Young Adult					Young versus Experienced				
	Observed crashes		Expected crashes			Observed crashes		Expected crashes			Observed crashes		Expected crashes		
	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p	Teen drivers	Exp. drivers	Teen	Young-adult	p	Teen drivers	Exp. drivers	Teen drivers	Exp. drivers	p
Driver Condition Related															
Alcohol impaired															
Yes	2,181	6,888	4,757	4,312		2,181	2,102	2,247	2,036		4,283	6,888	3,880	7,291	
No	60,725	50,133	58,149	52,709	0.00	60,725	54,919	60,659	54,985	0.04	115,644	218,509	116,047	218,106	0.00
Ill, falling asleep or fatigued															
Yes	816	2,400	1,687	1,529		816	715	803	728		1,531	2,400	1,365	2,566	
No	62,090	54,621	61,219	55,492	0.00	62,090	56,306	62,103	56,293	0.51	118,396	222,997	118,562	222,831	0.00
Driver Distractions Related															
Inattention															
Yes	14,970	35,318	26,378	23,910		14,970	13,550	14,960	13,560		28,520	35,318	22,170	41,668	
No	47,936	21,703	36,528	33,111	0.00	47,936	43,471	47,946	43,461	0.89	91,407	190,079	97,757	183,729	0.00
In vehicle distraction															
Yes	1,375	2,498	2,032	1,841		1,375	1,280	1,393	1,262		2,655	2,498	1,790	3,363	
No	61,531	54,523	60,874	55,180	0.00	61,531	55,741	61,513	55,759	0.49	117,272	222,899	118,137	222,034	0.00
Environmental Related															
Animal															
Yes	2,771	19,917	11,901	10,787		2,771	2,457	2,742	2,486		5,228	19,917	8,733	16,412	
No	60,135	37,104	51,005	46,234	0.00	60,135	54,564	60,164	54,535	0.42	114,699	205,480	111,194	208,985	0.00
Weather related															
Yes	2,409	9,543	6,269	5,683		2,409	2,217	2,427	2,199		4,626	9,543	4,921	9,248	
No	60,497	47,478	56,637	51,338	0.00	60,497	54,804	60,479	54,822	0.60	115,301	215,854	115,006	216,149	0.00
Vision obstruction															
Yes	854	2,728	1,879	1,703		854	679	804	729		1,533	2,728	1,480	2,781	
No	62,052	54,293	61,027	55,318	0.00	62,052	56,342	62,102	56,292	0.01	118,394	222,669	118,447	222,616	0.08
Vehicle Related															
Yes	716	1,816	879	1,653		716	660	478	898		1,376	1,816	1,109	2,083	
No	119,211	223,581	119,048	223,744	0.00	119,211	224,737	119,449	224,499	0.00	118,551	223,581	118,818	223,314	0.00
Road Related															
Yes	3,866	14,020	6,212	11,674		3,866	3,627	2,602	4,891		7,493	14,020	7,471	14,042	
No	116,061	211,377	113,715	213,723	0.00	116,061	221,770	117,325	220,506	0.00	112,434	211,377	112,456	211,355	0.75

In examining teen versus experienced drivers, statistically significant differences showed that teen drivers were more likely to be involved in crashes due to all of the driver, environmental, vehicle and road-related contributory causes than experienced drivers. In examining young versus experienced drivers, statistically significant differences showed increases in young driver crashes due to driver, vehicle and road-related contributory causes over experienced driver crashes. In examining teen versus young adult drivers, statistically significant differences showed increases in teen driver involvement in failure to give time and attention and increased young adult driver involvement in alcohol-impaired driving. In teen versus young adult driver comparisons, there were no statistically significant differences for all other contributory causes.

ORs were also used to investigate relative crash involvement when comparing teen drivers to experienced drivers, teen drivers to young adult drivers, and young drivers to experienced drivers. Calculated OR values for driver-related characteristics are shown in Table 4.19.

Table 4.19 Odds Ratios (ORs) and Confidence Intervals (CI) for Contributory Causes

Contributory Causes	Teen versus Experienced			Teen versus Young-Adult			Young versus Experienced		
	ORs	95% CI		**ORs**	95% CI		**ORs**	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
Driver Action Related									
Speeding	**1.48**	1.44	1.52	**0.97**	0.94	1.00	**1.72**	1.68	1.75
Failure to yield right of way	**1.42**	1.38	1.47	**1.05**	1.01	1.09	**1.52**	1.49	1.56
Disregarded traffic signs/signals	**1.34**	1.28	1.40	**0.97**	0.92	1.02	**1.50**	1.45	1.55
Turning or lane changing	**1.21**	1.15	1.27	**0.96**	0.91	1.03	**1.31**	1.26	1.37
Improper action	**1.16**	1.11	1.22	**1.04**	0.97	1.11	**1.18**	1.13	1.23
Aggressive driving	**1.71**	1.61	1.82	**0.94**	0.88	1.01	**2.21**	2.09	2.33
Avoidance/ evasive or slow	**1.27**	1.20	1.35	**0.99**	0.92	1.07	**1.38**	1.31	1.45
Driver Condition Related									
Alcohol impaired	**1.09**	1.04	1.15	**0.94**	0.88	1.00	**1.18**	1.13	1.22
Ill, falling asleep or fatigued	**1.18**	1.09	1.27	**1.04**	0.94	1.15	**1.20**	1.13	1.28
Driver Distractions Related									
Inattention	**1.49**	1.46	1.52	**1.00**	0.98	1.03	**1.68**	1.65	1.71
In vehicle distraction	**1.65**	1.55	1.75	**0.97**	0.90	1.05	**2.02**	1.91	2.13
Environmental Related									
Animal	**0.54**	0.51	0.56	**1.02**	0.97	1.08	**0.47**	0.46	0.49
Weather related	**0.92**	0.88	0.96	**0.98**	0.93	1.04	**0.91**	0.88	0.94
Vision obstruction	**1.13**	1.05	1.22	**1.14**	1.03	1.26	**1.06**	0.99	1.13

When interpreting results, ORs greater than one showed greater contribution from a particular factor for a driver-age group being investigated than the other driver-age group. For example, in a teen versus experienced driver comparison OR value 1.48 for speeding means teen drivers were 1.48 times the odds more likely to be involved in crashes as experienced drivers due to speeding. Similarly, teen drivers were more likely to be involved in crashes due to failure to yield right-of-way; disregarding traffic signs/signals; turning or lane changing, improper action, aggressive driving; avoidance/ evasive or slow driving; alcohol-impaired driving; ill, falling asleep, or fatigued; inattention; in-vehicle distraction; and vision obstruction, compared to experienced drivers. Also, teen drivers were significantly more likely to have crashes due to failure to yield right-of-way or vision obstruction compared to young adult drivers. The findings for young versus experienced drivers are identical to those of teen versus experienced drivers.

4.2 Injury Severity of Young-Driver-Involved Crashes

Investigation of injury severity of young drivers and identification of characteristics and contributory causes for severe injuries are very important because it helps determine countermeasures which help to prevent severe injuries and save lives. The effects of characteristics and contributory causes can be determined by investigating the coefficients of severity models. In severity models, all characteristics and contributory causes that are expected to have some effect on injury severity are included. The objective of developing severity models in the field of traffic safety is to understand the effect of the variables related to severity. Hence, all variables were maintained in the final model without removing any on the basis of low statistical significance.

4.2.1 Logistic Regression Model for Young Drivers

An ordered logistic regression model was developed to investigate injury severity of crashes involving young drivers 15 to 24 years. The dataset included 119,927 crashes involving drivers from 2006 to 2009. The dependent variable had four categories: fatally/severely injured, injured, possible injured, or not injured. All characteristics in Tables 4.1, 4.4, 4.7, 4.10 and contributory causes in Table 4.14 were considered to develop the model. All of these independent variables were treated as categorical variables. Thus, the numbers in those tables are summary statistics for variables in the estimations.

The highly correlated independent variables were excluded once the Correlation Coefficient Matrix was developed. Then several models were developed, inserting the correlated variable one at a time while keeping everything else constant. The best model was selected using model diagnostics statistics such as AIC and SC values. The lower value shows the best model compared to the others. The highly correlated pairs were dark and night, adverse weather condition and wet roads, turning/ lane changing and straight following maneuver, run off the road and collision with an object, and vehicle disabled and vehicle functional. Among these pairs, variables of night, wet road surfaces, run off the road, straight following, vehicle functional, and stopped/ backing, were included in the final model. Results of the young driver injury severity model, which included four injury severity levels, are presented in Table 4.20.

The model diagnostics showed a Likelihood Ratio, Chi Square statistic of 20,502, whose p-value is < 0.001. In addition to the overall p-value, the ordered logistic regression model also reported the individual standard error and p-value for each independent variable. The individual standard errors are used to calculate individual p-values. A low p-value means this particular independent variable significantly improved the fit of the ordered logistic regression model, showing that the variable has a significant impact on the model. Those significant variables are directly associated with injury severity of young drivers involved in crashes. The coefficients were considered as significant when the p-value is less than 0.05.

Some of significant variables had limited observations, but the results were not affected when those variables were removed or combined. The estimated model intercepts represent the mean impact of all variables that influence each injury severity level that were not included in the model. Negative coefficient estimates of the developed model show the reduced probability of potential injury severity, while positive coefficient estimates show the increased probability of potential injury severity. The significant variables in the model were being a male, seat belt use, air bag deployed, alcohol involvement, driving on rural roads, run off the road, driving on wet road surfaces, driving on debris-filled road surface, speed, vehicle year, driving with passengers, driver ejection, driver trapped, vehicle damage, driving on straight following roads, avoiding maneuver, stopping or backing up before unstabilized situation, vehicle overturn, collision with pedestrian, collision with a vehicle, collision with an animal, head-on collision, angle collision, and avoidance/backing-related crashes. The effects of each of these variables are explained in the following paragraphs.

Table 4.20 Young Driver Injury Severity Model Results

Label	Parameters	Coef.	Std. Error	p	Label	Parameters	Coef.	Std. Error	p
Intercept	Fatal/severe injury	2.430	0.759	0.001	TRAP	if trapped =1, otherwise 0	2.991	0.080	<.0001
Intercept	Injury	5.060	0.758	<.0001	NODAM	If vehicle has not damage=1, otherwise 0	-1.660	0.166	<.0001
Intercept	Possible injury	7.247	0.758	<.0001	MDAM	If has minor damage=1, otherwise 0	-2.054	0.060	<.0001
MALE	If driver is male=1, otherwise 0	-0.433	0.026	<.0001	FUNCT	If vehicle is functioning =1, otherwise 0	-1.523	0.040	<.0001
VALID	If driver has valid license=1, otherwise 0	-0.065	0.040	0.106	DISTRO	If vehicle is destroyed =1, otherwise 0	1.108	0.031	<.0001
RETRIC	If restricted driver license=1, otherwise=0	-0.008	0.027	0.755	STFOLL	If straight following roads=1, otherwise 0	0.185	0.034	<.0001
SEATB	If seat belt used=1, otherwise 0	-1.100	0.031	<.0001	AVOILD	If avoidance or slow =1, otherwise 0	0.181	0.060	0.003
AIRB	If air bag deployed=1, otherwise 0	0.820	0.036	<.0001	STOPB	If stopped or backing=1, otherwise 0	0.395	0.057	<.0001
ALOD	If alcohol or drug related=1, otherwise 0	0.493	0.045	<.0001	OVERTN	If non-collision or overturned=1, otherwise 0	0.119	0.045	0.008
WEATR	If normal weather =1, otherwise 0	0.008	0.051	0.882	PED	If collision with pedestrians=1, otherwise 0	-0.944	0.364	0.010
RURAL	If rural roads=1, otherwise 0	0.237	0.033	<.0001	CVEHI	If collision with a vehicle=1, otherwise 0	-0.386	0.076	<.0001
WZONE	If work zone=1, otherwise 0	-0.067	0.084	0.428	FIXED	If collision with animal=1, otherwise 0	-1.723	0.107	<.0001
MORNIN	If 5.00 a.m. – 9.00 a.m.=1, otherwise 0	-0.019	0.043	0.658	HEAD	If head on collision=1, otherwise 0	0.934	0.092	<.0001
DAYT	If 9.00 a.m. – 1.00 p.m.=1, otherwise 0	0.007	0.035	0.845	REAR	If rear collision=1, otherwise 0	0.009	0.079	0.907
AFNOON	If 1.00 a.m. – 5.00 p.m.=1, otherwise 0	0.056	0.040	0.160	ANGLE	If angle collision=1, otherwise 0	0.387	0.078	<.0001
NIGHT	If 9.00 p.m. – 5.00 a.m..=1, otherwise 0	-0.006	0.038	0.869	WIPE	If sideswipe collision=1, otherwise 0	-0.038	0.099	0.704
WEEKE	If week ends=1, otherwise 0	-0.027	0.028	0.320	BACK	If collision when backing up=1, otherwise 0	-1.961	0.417	<.0001
OFFR	If off roadway=1, otherwise 0	0.181	0.038	<.0001	YEILD_C	If fail to yield right of way =1, otherwise 0	0.032	0.041	0.438
INTER	If intersection on roadway=1, otherwise 0	-0.011	0.033	0.733	SIGNAL_C	If disregard traffic sing or signal=1, otherwise 0	-0.026	0.058	0.647
CON	If concrete surface=1, otherwise 0	-0.016	0.030	0.586	SPEED_C	If speeding =1, otherwise 0	-0.042	0.035	0.229
GRA	If gravel/brick =1, otherwise 0	-0.005	0.043	0.903	AGGRE_C	If aggressive driving=1, otherwise 0	-0.072	0.081	0.375
WET	If road surface is wet=1, otherwise 0	-0.203	0.053	0.000	TURN_C	If turning or lane changing=1, otherwise 0	0.010	0.065	0.872
DEBRI	If road surface is debris=1, otherwise 0	-0.487	0.056	<.0001	SLOW_C	If avoidance/ evasive or slow=1, otherwise 0	0.155	0.078	0.047
STNLE	If road not level=1, otherwise 0	0.028	0.031	0.373	ACT_C	If improper action=1, other 0	0.051	0.068	0.452
NSTLE	If curved and level=1, otherwise 0	0.001	0.042	0.973	ALCO_C	If alcohol impaired=1, otherwise 0	0.092	0.066	0.163
LSPEED	If speed is less than 35 mph=1, otherwise 0	-0.193	0.031	<.0001	DCON_C	If other driver conditions=1, otherwise 0	0.030	0.106	0.779
HSPEED	If speed is more than 60 mph=1, otherwise 0	0.308	0.037	<.0001	INATTN_C	If inattention=1, otherwise 0	0.005	0.029	0.849
BODY	If automobile =1, otherwise 0	-0.011	0.027	0.693	DISTRA_C	If distraction=1, otherwise 0	0.047	0.081	0.561
NEW	If vehicle newer than 4 years =1, otherwise 0	-0.146	0.033	<.0001	ANIM_C	If crash due to animal=1, otherwise 0	-0.106	0.061	0.083
OLD	If vehicle older than 15 years =1, otherwise 0	0.259	0.035	<.0001	WEA_C	If crash due to weather factors=1, otherwise 0	-0.093	0.070	0.184
PASSEN	If with passengers =1, otherwise 0	-0.070	0.026	0.007	OBST_C	If vision obstruction=1, otherwise 0	0.163	0.102	0.110
TEEN	If with teen passengers =1, otherwise 0	0.034	0.033	0.302	VEHI_C	If crash due to vehicle factors=1, otherwise 0	0.023	0.112	0.835
EJECT	If eject =1, otherwise 0	2.671	0.088	<.0001	RD_C	If crash due to road factors=1, otherwise 0	0.030	0.056	0.591
AIC		55,230			Likelihood Ratio		20,511		<0.001
SC		55,868			Score		27,316		<0.00.1
-2logL		55,099							

According to the coefficients of the estimated ordered logistic regression model, the negative coefficient of the variable male indicates that being a young male involved in a crash tends to decrease the probability of having a more severe injury. Seat belt-restrained young drivers were less likely to suffer severe injuries when involved in crashes. Effectiveness of seat belt restraint in reducing crash injuries is well known. The positive coefficient of the airbag deployed variable indicates that young drivers were more likely to suffer severe injuries when they were involved in crashes. This is not an expected result because generally air bags are used to reduce injury severity when involved in crashes. It may be because air bags only activate for serious head-on crashes but not for minor crashes. Alcohol involvement was a significant factor which increased young driver injury severity. Alcohol increases the probability of severe injuries among young drivers.

Increased injury severities could be expected when driving on rural roads, because of higher speeds and limited enforcement in rural areas. According to the developed model, young drivers were more likely to suffer severe crashes when driving on rural roads. The estimated coefficient for off-roadway crashes had a positive sign as expected. This means that young drivers' injury severity was higher when they were involved in run-off-the-road crashes. Young drivers were less likely to suffer severe injuries when involved in crashes on wet or road surfaces with debris. This may be because they may drive with proper precaution on road surfaces with debris. Driving on higher-posted-speed-limit roadways was also a significant factor which increased young drivers' injury severity. Driving on lower-posted-speed-limit roadway decreased young drivers' injury severity as expected.

Driving old vehicles, which may not have proper protective devices, contributed to greater severity. Young drivers driving older vehicles were more likely to suffer severe injuries when involved in a crash. Youth driving newer vehicles were less likely to suffer severe injuries as expected. Driving with passengers tends to decrease the probability of having a more severe injury. Conditions of ejection, and trapped at the time of crash, increased injury severity. Vehicle damage was a significant factor which decreased young driver injury severity, whether the vehicle was not damaged, had minor damage, or was functional at the time of the crash. If the vehicle is destroyed, the probability of having a more severe injury will increase.

Young drivers were more likely to suffer severe injuries in crashes occurring when the maneuver at the time of the crash was on a straight following road, attempting avoidance/

evasive of a crash, or stopping or backing. Also, involvement of non-collision and overturn crashes showed a higher injury severity for young drivers. Collisions with fixed objects, other vehicles, and pedestrians decreased young driver injury severity. Head-on collisions and angle collisions showed increased injury severity as expected. Youth-involved crashes due to attempting avoidance/evasive or driving maneuvers too slow showed increased injury severity. Driving slow may cause a crash and severe injuries because of the differential speeds on the road.

Identified relationships for variables gender, seat belt use, airbag deployed, alcohol involvement, ejection, and speed were also found in previous other young-driver-related research (Vachal and Malchose 2009, Dissanayake and Lu 2002). Variables such as valid licenses, restrictions on driver's licenses, normal weather conditions, driving in work zone, driving time, driving on not-level straight roads, driving on curved roads, driving with teen passengers, rear collision, and sideswipe collision were not significant at the 95% confidence interval. Also, contributory causes such as failure to yield right-of-way, disregarding traffic signs or signals, speeding, turning or lane changing, improper action, alcohol-impaired driving, other driver conditions, inattention, animal on the road, weather conditions, vision obstruction, vehicle factors, and road factors were not significant at the 95% confidence interval.

Characteristics of teen drivers were different than young adult drivers, as shown in section 4.1. Hence, separate ordered logistic regression models were developed for teen drivers and young adult drivers involved in crashes and are documented in following sections.

4.4.2 Logistic Regression Model for Teen Drivers

An ordered logistic regression model was developed to investigate injury severity of crashes involving teen drivers 15 to 19 years. The dataset included 62,906 crashes involving drivers from 2006 to 2009. The variables considered for this model were similar to the model developed for young drivers. The dependent variable injury severity had four levels of severity: fatally/severely injured, injured, possibly injured, or non-injured. Crash, vehicle, roadway, environmental, driver-related characteristics, and contributory causes were included as the independent variables. In the case of highly correlated variables, only one of them was included. Numbers in Tables 4.1, 4.4, 4.7, 4.10 and 4.14 are summary statistics for variables in the estimations. Several models were developed, including one of correlated variables, one at a time, while keeping everything else the same, and best model was selected. The best model had the lowest ACI, SC, and -2logL values.

Model diagnostics in Table 4.21 showed a Likelihood Ratio Chi Square statistic of 11,095, whose p-value is < 0.001. The statistical significant coefficients had the identical sign as the previous model, which was developed for young drivers involved in crashes. However, the significance of certain variable estimates has been lost from the young driver injury severity model to the teen driver injury severity model. Those variables included driving when passengers on board and crashes due to improper action. Even in the teen driver injury severity model had some of the significant variables with limited observations, but the results were not affected when those variables were removed or combined. The estimated model intercepts represent the mean impact of all variables that influence each injury severity level not included in the model.

Negative coefficient estimates of the developed model show the reduced probability of potential injury severity, while positive coefficient estimates show the increased probability of potential injury severity. The significant variables in the model were being a male, seat belt use, air bag deployed, alcohol involvement, driving on rural roads, run off the road, driving on wet road surfaces, driving on road surface with debris, speed, vehicle year, driver ejection, driver trapped, vehicle damage, driving on straight-following roads, avoiding maneuver, stopping or backing up before un-stabilized situation, vehicle overturn, collision with a pedestrian, collision with a vehicle, collision with an animal, head-on collision, angle collision, and avoidance/backing-related crashes. The effects of each of these variables are explained in the following paragraphs.

According to the coefficients of the estimated ordered logistic regression model, the negative coefficient of the variable male indicates that being a teen male involved in a crash tends to decrease the probability of having a more severe injury. Seat-belt-restrained teen drivers were less likely to suffer severe injuries when involved in crashes. Effectiveness of seat belt restraint in reducing crash injuries is well known. The positive coefficient of the airbag deployed variable indicates that teen drivers were more likely to suffer severe injuries when they were involved in crashes. This is not an expected result because generally air bags are used to reduce injury severity when involved in crashes. This may be because air bags only activate for more serious head-on crashes and not for minor crashes.

Table 4.21 Teen Driver Injury Severity Model Results

Label	Parameters	Coef.	Std. Error	p	Label	Parameters	Coef.	Std. Error	p
Intercept	Fatal/severe injury	4.236	1.242	0.001	TRAP	if trapped =1, otherwise 0	2.976	0.108	<.0001
Intercept	Injury	6.923	1.240	<.0001	NODAM	If vehicle has not damage=1, otherwise 0	-1.700	0.238	<.0001
Intercept	Possible injury	9.232	1.241	<.0001	MDAM	If has minor damage=1, otherwise 0	-2.141	0.087	<.0001
MALE	If driver is male=1, otherwise 0	-0.424	0.035	<.0001	FUNCT	If vehicle is functioning =1, otherwise 0	-1.523	0.056	<.0001
VALID	If driver has valid license=1, otherwise 0	-0.028	0.063	0.661	DISTRO	If vehicle is destroyed =1, otherwise 0	1.088	0.041	<.0001
RETRIC	If restricted driver license=1, otherwise=0	-0.032	0.037	0.381	STFOLL	If straight following roads=1, otherwise 0	0.203	0.046	<.0001
SEATB	If seat belt used=1, otherwise 0	-1.096	0.042	<.0001	AVOILD	If avoidance or slow =1, otherwise 0	0.161	0.082	0.049
AIRB	If air bag deployed=1, otherwise 0	0.795	0.050	<.0001	STOPB	If stopped or backing=1, otherwise 0	0.354	0.081	<.0001
ALOD	If alcohol or drug related=1, otherwise 0	0.489	0.070	<.0001	OVERTN	If non-collision or overturned=1, otherwise 0	0.085	0.058	0.144
WEATR	If normal weather =1, otherwise 0	-0.026	0.072	0.721	PED	If collision with pedestrians=1, otherwise 0	-1.552	0.720	0.031
RURAL	If rural roads=1, otherwise 0	0.257	0.044	<.0001	CVEHI	If collision with a vehicle=1, otherwise 0	-0.362	0.105	0.001
WZONE	If work zone=1, otherwise 0	-0.047	0.123	0.704	FIXED	If collision with animal=1, otherwise 0	-1.801	0.158	<.0001
MORNIN	If 5.00 a.m. – 9.00 a.m.=1, otherwise 0	-0.091	0.059	0.123	HEAD	If head on collision=1, otherwise 0	0.830	0.129	<.0001
DAYT	If 9.00 a.m. – 1.00 p.m.=1, otherwise 0	-0.066	0.047	0.157	REAR	If rear collision=1, otherwise 0	-0.166	0.110	0.129
AFNOON	If 1.00 a.m. – 5.00 p.m.=1, otherwise 0	0.069	0.055	0.213	ANGLE	If angle collision=1, otherwise 0	0.325	0.108	0.003
NIGHT	If 9.00 p.m. – 5.00 a.m..=1, otherwise 0	-0.045	0.051	0.379	WIPE	If sideswipe collision=1, otherwise 0	-0.063	0.137	0.648
WEEKE	If week ends=1, otherwise 0	-0.007	0.038	0.857	BACK	If collision when backing up=1, otherwise 0	-2.529	0.717	0.001
OFFR	If off roadway=1, otherwise 0	0.142	0.051	0.005	YEILD_C	If fail to yield right of way =1, otherwise 0	0.014	0.056	0.807
INTER	If intersection on roadway=1, otherwise 0	-0.082	0.045	0.069	SIGNAL_C	If disregard traffic sing or signal=1, otherwise 0	0.149	0.077	0.053
CON	If concrete surface=1, otherwise 0	-0.040	0.043	0.346	SPEED_C	If speeding =1, otherwise 0	-0.071	0.049	0.144
GRA	If gravel/brick =1, otherwise 0	0.018	0.055	0.737	AGGRE_C	If aggressive driving=1, otherwise 0	-0.231	0.116	0.046
WET	If road surface is wet=1, otherwise 0	-0.226	0.075	0.003	TURN_C	If turning or lane changing=1, otherwise 0	-0.019	0.091	0.831
DEBRI	If road surface is debris=1, otherwise 0	-0.518	0.079	<.0001	SLOW_C	If avoidance/ evasive or slow=1, otherwise 0	0.084	0.109	0.441
STNLE	If road not level=1, otherwise 0	0.045	0.042	0.291	ACT_C	If improper action=1, other 0	0.078	0.091	0.395
NSTLE	If curved and level=1, otherwise 0	-0.087	0.058	0.131	ALCO_C	If alcohol impaired=1, otherwise 0	0.157	0.091	0.085
LSPEED	If speed is less than 35 mph=1, otherwise 0	-0.122	0.042	0.004	DCON_C	If other driver conditions=1, otherwise 0	0.036	0.146	0.807
HSPEED	If speed is more than 60 mph=1, otherwise 0	0.387	0.053	<.0001	INATTN_C	If inattention=1, otherwise 0	-0.015	0.039	0.713
BODY	If automobile =1, otherwise 0	0.005	0.037	0.892	DISTRA_C	If distraction=1, otherwise 0	0.144	0.107	0.181
NEW	If vehicle newer than 4 years =1, otherwise 0	-0.163	0.050	0.001	ANIM_C	If crash due to animal=1, otherwise 0	-0.066	0.083	0.423
OLD	If vehicle older than 15 years =1, otherwise 0	0.288	0.046	<.0001	WEA_C	If crash due to weather factors=1, otherwise 0	-0.049	0.096	0.605
PASSEN	If with passengers =1, otherwise 0	-0.040	0.035	0.250	OBST_C	If vision obstruction=1, otherwise 0	0.238	0.133	0.073
TEEN	If with teen passengers =1, otherwise 0	0.046	0.046	0.319	VEHI_C	If crash due to vehicle factors=1, otherwise 0	0.019	0.155	0.902
EJECT	If eject =1, otherwise 0	2.603	0.118	<.0001	RD_C	If crash due to road factors=1, otherwise 0	0.037	0.076	0.624
AIC		29,125			Likelihood Ratio		11,095		<0.001
SC		29,719			Score		14,615		<0.00.1
-2logL		28,993							

Alcohol involvement: was a significant factor which increased teen driver injury severity. Alcohol increases the probability of severe injuries among teen drivers. The variable "rural" had a positive sign meaning that teen drivers were more likely to suffer severe crashes when involved in crashes on rural roads. Increased injury severities could be expected when driving on rural roads, where because of limited enforcement drivers may tend to speed. The estimated coefficient for run-off-the-road crashes had a positive sign as expected. This means that teen drivers' injury severity was higher when they were involved in run-off-the-road crashes. Teen drivers were less likely to suffer severe injuries when involved in crashes on wet or debris-filled road surfaces. This may be because they may drive with proper precautions on debris-filled road surfaces. Driving on higher-posted-speed-limit roadways was also a significant factor which increased teen drivers' injury severity. Driving on roadways with lower posted speed limits showed decreased injury severity for teen drivers involved in a crash as expected. Driving old vehicles, which do not have proper protective devices, is risky. Teen drivers were more likely to suffer severe injuries when involved in a crash while traveling in older vehicles. The negative sign of the "new" variable indicated that teens driving newer vehicles were less likely to suffer severe injuries as expected. Conditions of ejection and trapped at the time of crash increased injury severity. Vehicle damage was a significant factor which decreased teen driver injury severity, whether it was not damaged, minor damage, or functional at the time of crash. If the vehicle is destroyed, the probability of having a more severe injury will increase.

Teen drivers were more likely to suffer severe injuries in crashes occurring when they were having maneuvers such as straight following, attempting avoidance of a crash, and stopping or backing. Also, involvement of non-collision and overturn crashes showed a higher injury severity for teen drivers. Collisions with fixed objects, other vehicles, and pedestrians decreased teen driver injury severity. Head-on collisions and angle collisions showed increased injury severity as expected. In crashes involving attempting to back up, drivers had decreased injury severity. This can be expected because when backing up a vehicle needs to be operated slowly with precautions.

Variables such as valid licenses, restrictions on driver's licenses, normal weather conditions driving in a work zone, driving time, driving on not-level straight roads, driving on curved roads, driving when having passengers, driving when having teen passengers, rear collision, and sideswipe collision were not significant at the 95% confidence interval. Also, any contributory causes in the model were not significant at the 95% confidence interval.

4.4.3 Logistic Regression Model for Young Adult Drivers

All available characteristics and contributory causes of 57,021 crashes involving young adult drivers from 2006 to 2009 were used for the development of an ordered logistic regression model. This can be used to investigate the injury severity of crashes involving young-adults drivers, 15 to 19 years. The dependent variable injury severity had four levels of severity: fatally/severely injured, injured, possibly injured, or non-injured. Numbers in Tables 4.1, 4.4, 4.7, 4.10 and 4.14 are summary statistics for variables in the estimations. Several models were developed, including one of correlated variables, one at a time, while keeping everything else the same, and best model was selected based on the ACI, SC, and -2logL values. In the best model as shown in Table 4.22, Likelihood Ratio, Chi Square statistic is 9,507, whose p-value is < 0.001.

The statistical significant coefficients had the identical sign as the previous models which were developed for young drivers and teen drivers involved in crashes. In the young adult driver injury severity model, some of significant variables had limited observations, but the results were not affected when those variables were removed or combined. The estimated model intercepts represent the mean impact of all variables that influence each injury severity level not included in the model. Negative coefficient estimates of the developed model show the reduced probability of potential injury severity, while positive coefficient estimates show the increased probability of potential injury severity.

Significant variables in the model were being a male, seat belt use, air bag deployed, alcohol involvement, driving on rural roads, run off the road, driving on wet road surfaces, driving on road surface with debris, speed, vehicle year, driving having passengers, driver ejection, and driver trapped. Also, vehicle damage, driving on straight-following roads, avoiding maneuver, stopping or backing up before un-stabilized situation, vehicle overturn, collision with a pedestrian, collision with a vehicle, collision with an animal, head-on collision, angle collision, and avoidance/backing-related crashes were significant variables. Effects of each of these variables are similar to the effect of variables explained in the young driver injury severity model.

Table 4.22 Young- Adult Driver Injury Severity Model Results

Label	Parameters	Coef.	Std. Error	p	Label	Parameters	Coef.	Std. Error	p
Intercept	Fatal/severe injury	0.968	1.014	0.340	TRAP	if trapped =1, otherwise 0	3.015	0.119	<.0001
Intercept	Injury	3.543	1.012	0.001	NODAM	If vehicle has not damage=1, otherwise 0	-1.612	0.231	<.0001
Intercept	Possible injury	5.630	1.011	<.0001	MDAM	If has minor damage=1, otherwise 0	-1.973	0.084	<.0001
MALE	If driver is male=1, otherwise 0	-0.442	0.038	<.0001	FUNCT	If vehicle is functioning =1, otherwise 0	-1.526	0.057	<.0001
VALID	If driver has valid license=1, otherwise 0	-0.086	0.053	0.106	DISTRO	If vehicle is destroyed =1, otherwise 0	1.132	0.046	<.0001
RETRIC	If restricted driver license=1, otherwise=0	0.021	0.039	0.595	STFOLL	If straight following roads=1, otherwise 0	0.158	0.050	0.002
SEATB	If seat belt used=1, otherwise 0	-1.106	0.045	<.0001	AVOILD	If avoidance or slow =1, otherwise 0	0.199	0.090	0.027
AIRB	If air bag deployed=1, otherwise 0	0.852	0.052	<.0001	STOPB	If stopped or backing=1, otherwise 0	0.400	0.081	<.0001
ALOD	If alcohol or drug related=1, otherwise 0	0.516	0.060	<.0001	OVERTN	If non-collision or overturned=1, otherwise 0	0.151	0.069	0.028
WEATR	If normal weather =1, otherwise 0	0.032	0.074	0.663	PED	If collision with pedestrians=1, otherwise 0	-0.579	0.429	0.178
RURAL	If rural roads=1, otherwise 0	0.224	0.050	<.0001	CVEHI	If collision with a vehicle=1, otherwise 0	-0.391	0.109	0.000
WZONE	If work zone=1, otherwise 0	-0.084	0.116	0.468	FIXED	If collision with animal=1, otherwise 0	-1.614	0.147	<.0001
MORNIN	If 5.00 a.m. – 9.00 a.m.=1, otherwise 0	0.082	0.064	0.200	HEAD	If head on collision=1, otherwise 0	1.031	0.132	<.0001
DAYT	If 9.00 a.m. – 1.00 p.m.=1, otherwise 0	0.111	0.053	0.037	REAR	If rear collision=1, otherwise 0	0.187	0.115	0.103
AFNOON	If 1.00 a.m. – 5.00 p.m.=1, otherwise 0	0.024	0.058	0.681	ANGLE	If angle collision=1, otherwise 0	0.444	0.113	<.0001
NIGHT	If 9.00 p.m. – 5.00 a.m..=1, otherwise 0	0.058	0.057	0.306	WIPE	If sideswipe collision=1, otherwise 0	-0.024	0.143	0.867
WEEKE	If week ends=1, otherwise 0	-0.052	0.040	0.195	BACK	If collision when backing up=1, otherwise 0	-1.487	0.515	0.004
OFFR	If off roadway=1, otherwise 0	0.231	0.057	<.0001	YEILD_C	If fail to yield right of way =1, otherwise 0	0.056	0.061	0.352
INTER	If intersection on roadway=1, otherwise 0	0.076	0.047	0.108	SIGNAL_C	If disregard traffic sing or signal=1, otherwise 0	-0.222	0.088	0.011
CON	If concrete surface=1, otherwise 0	-0.002	0.042	0.958	SPEED_C	If speeding =1, otherwise 0	-0.008	0.051	0.868
GRA	If gravel/brick =1, otherwise 0	-0.067	0.072	0.355	AGGRE_C	If aggressive driving=1, otherwise 0	0.095	0.114	0.405
WET	If road surface is wet=1, otherwise 0	-0.181	0.076	0.018	TURN_C	If turning or lane changing=1, otherwise 0	0.049	0.092	0.593
DEBRI	If road surface is debris=1, otherwise 0	-0.446	0.080	<.0001	SLOW_C	If avoidance/ evasive or slow=1, otherwise 0	0.234	0.111	0.034
STNLE	If road not level=1, otherwise 0	0.007	0.046	0.881	ACT_C	If improper action=1, other 0	0.014	0.102	0.890
NSTLE	If curved and level=1, otherwise 0	0.084	0.060	0.162	ALCO_C	If alcohol impaired=1, otherwise 0	0.014	0.096	0.885
LSPEED	If speed is less than 35 mph=1, otherwise 0	-0.273	0.045	<.0001	DCON_C	If other driver conditions=1, otherwise 0	0.026	0.155	0.866
HSPEED	If speed is more than 60 mph=1, otherwise 0	0.228	0.052	<.0001	INATTN_C	If inattention=1, otherwise 0	0.031	0.042	0.454
BODY	If automobile =1, otherwise 0	-0.030	0.039	0.454	DISTRA_C	If distraction=1, otherwise 0	-0.076	0.123	0.540
NEW	If vehicle newer than 4 years =1, otherwise 0	-0.143	0.044	0.001	ANIM_C	If crash due to animal=1, otherwise 0	-0.150	0.092	0.102
OLD	If vehicle older than 15 years =1, otherwise 0	0.218	0.057	0.000	WEA_C	If crash due to weather factors=1, otherwise 0	-0.148	0.102	0.149
PASSEN	If with passengers =1, otherwise 0	-0.099	0.039	0.012	OBST_C	If vision obstruction=1, otherwise 0	0.064	0.160	0.690
TEEN	If with teen passengers =1, otherwise 0	0.023	0.048	0.629	VEHI_C	If crash due to vehicle factors=1, otherwise 0	0.038	0.162	0.815
EJECT	If eject =1, otherwise 0	2.779	0.134	<.0001	RD_C	If crash due to road factors=1, otherwise 0	0.020	0.082	0.805
AIC		26,132			Likelihood Ratio		9,507		<0.001
SC		26,720			Score		12,762		<0.00.1
-2logL		26,000							

Variables such as valid licenses, restrictions on driver's licenses, normal weather conditions, driving on work zone roadways, driving time, driving on not level but straight roads, driving on curved roads, driving with teen passengers, rear collision, and sideswipe collision were not significant at the 95% confidence interval. Also, contributory causes such as failure to yield right-of-way, disregarding traffic sign or signals, speeding, turning or lane changing, improper action, alcohol-impaired driving, other driver conditions, inattention, animal on the road, weather conditions, vision obstruction, vehicle factors, and road factors were not significant at the 95% confidence interval.

Then three models were compared using the Negelkerke R-Square value and Cox and Snell R-Square values. The R-Square values of all three models do not show many differences as given in Table 4.23. Hence, it can be concluded that, in general, the results were identical in the three models.

Table 4.23 Comparison of Injury Severity Models

Indices	Model 1- Young driver crashes	Model 2 Teen driver crashes	Model 3 Young Adult driver crashes
Cox and Snell R-Square	0.2172	0.2247	0.2111
Nagelkerke R-Square	0.3172	0.3246	0.3073

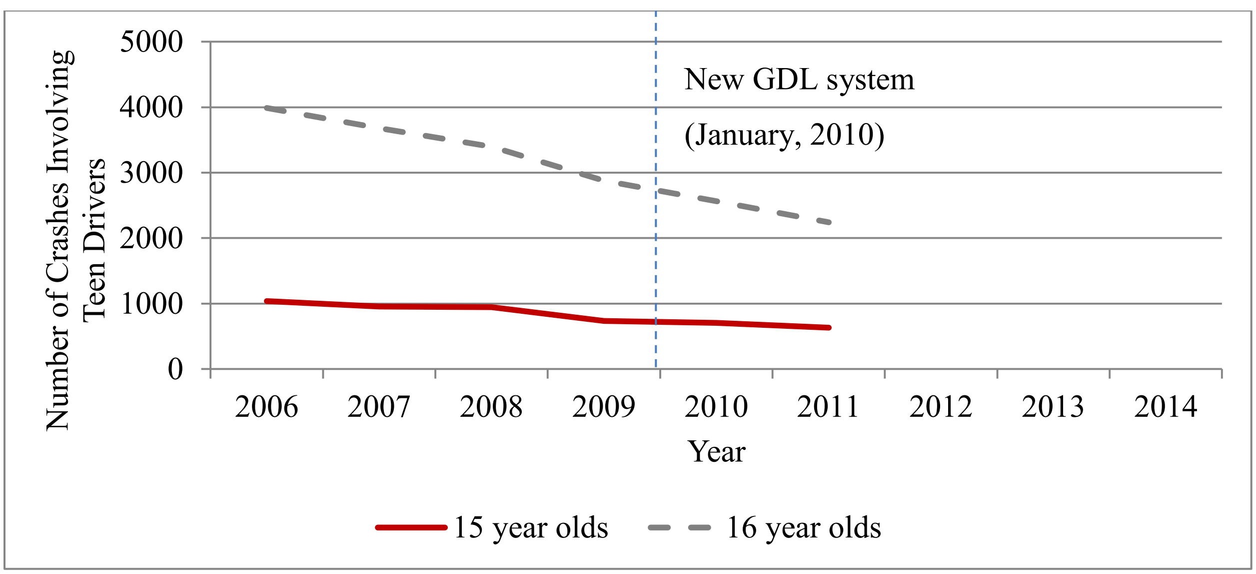
4.3 GDL Law implementation

Under new GDL law for drivers younger than 17 entering the licensing system on or after January 01, 2010, a three-stage approach to granting teen drivers full license privileges was implemented. In that situation, some teens rushed to apply for a learner's permit earlier than they normally would have to avoid being under the new law (Koranda 2009). If an applicant had obtained at least the learner's permit before January 01, 2010, the GDL requirements did not apply to the applicant. A news article that explains the observed situation was published in December 2009 and is attached in Appendix D. Hence, there can be a gradual increase in the proportion of teen drivers under the program over time. In 2011, all drivers under 14, in 2012 all drivers under 15, and in 2013 all drivers under 16, are expected to be under the new law.

In the GDL system, the first stage is the learner stage which requires extensive supervised practice and wireless communication devices are prohibited. After holding a learner's permit for at least a year, and upon reaching age 15, teens can drive to/from work or to/from school in the second stage of the GDL system. During this stage, drivers are subjected to nighttime restrictions and minor passenger restrictions. In the third stage, lesser-restrictions are applicable for driving time and minor passengers. Six months of holding the lesser restricted driver's license is required. After that, if the licensee has complied with all laws, the restrictions will no longer be applied. A comparison chart of the law prior to 2010 and the current law, published by the Kansas Department of Revenue, is attached in Appendix E (Kansas Department of Revenue 2009). A violation of any of the driving restrictions is punishable with penalties and suspension of the driver's license. KDOT published a table of punishable restrictions and charges effective since January, 2010. It is attached in Appendix F (KDOT 2012a, KDOT 2012b).

At the time of this report, crash data up to 2011 were available for the analysis. Figure 4.2 shows the number of crashes involving 15- and 16-year-old drivers over this time. This included all crashes involving 15- to 16-year-old drivers under all crash types such as fatal injury, disabled injury, injury, possible injury, and no injury. A proportion of 15-year-old drivers may be in the new GDL program after 2010 January. After December 2011, all 15-year-old drivers are expected to be in the program.

Figure 4.2 Number of Crashes Involving 15- and 16-Year-Old Drivers Over Time



The crash database does not have the information such as learner's permit issue date or driver's license issue date that were needed to determine whether crashes involving drivers were under the new GDL or not. Hence, proper comparison of drivers who are under the new GDL and drivers prior to GDL law is impossible at this transition period. However, a comparison between crashes involving 15-year-old drivers in 2009 and 2011 has been done through OR analysis. Also, characteristics and contributory causes of crashes involving 15-year-old drivers during 2010-2011 and during 2008-2009 were compared. Calculated ORs and CI related all characteristics and contributory causes of both comparisons and are shown in Appendix G. Some variables in the 2009 versus 2011 comparison are significant, and those variables were tabulated in Table 4.24. When interpreting results, ORs lower than one showed reduced chances of crashes during 2011 than those occurring in 2009. For example, OR value 0.45 for valid licensed means 15-year-old drivers who have valid licenses were 0.45 times the odds likely to be involved in crashes during 2011 compared to those drivers in 2009.

As shown in Table 2.24, 15-year-old drivers in 2011 were less likely to be involved in crashes when driving with a valid license, driving on urban roads, driving during evenings, driving at intersections, and driving on wet surfaces than 15-year-old drivers in 2009. In 2011, they were less likely to be involved in run-off-the road crashes, sideswipe crashes, or crashes due to inattention than in 2009. Therefore, under the transition period to the new GDL system, improvement for a few factors could be observed.

Table 4.24 Frequencies, Percentages, and ORs of Crashes Involving 15-Year-Old Drivers

Characteristics and Contributory Causes	*Number of Crashes Involving Drivers*				2009 versus 2011		
	2009	*%*	*2011*	*%*	**ORs**	95% CI Lower	95% CI Upper
Valid licensed	573	77.9	388	61.1	**0.45**	0.35	0.57
Urban roads	418	56.8	330	52.0	**0.82**	0.67	1.02
Time of crash (17.00-21.00) -Evening	227	30.8	137	21.6	**0.62**	0.48	0.79
Intersection	322	43.8	220	34.6	**0.68**	0.55	0.85
Wet	83	11.3	46	7.2	**0.61**	0.42	0.90
Off roadway	132	17.9	84	13.2	**0.70**	0.52	0.94
Sideswipe	53	7.2	29	4.6	**0.62**	0.39	0.98
Inattention	178	24.2	121	19.1	**0.74**	0.57	0.96

4.4 Countermeasure Ideas

Driving is a complex activity that requires understanding of the rules on the roads and proper practice to improve the vehicle controlling skills. The countermeasure ideas are organized under sub topics of education, enforcement, engineering, and management-related in following paragraphs.

4.4.1 Education-Related Countermeasure Ideas

Driver education includes both classroom instruction about rules of road and in-car training. A driver's safety-related characteristics are formed well before the age at which he or she legally begins driving; hence, education programs and communication programs in schools can be focused on children at much younger ages than the legal driving age (OEOD 2006). Failure to give attention, failure to yield right-of-way, driving too fast for conditions, and following too closely were the main contributory causes that could be included in education programs in order to increase awareness. These are also effective countermeasures for decreasing young driver risk. Training programs could be focused more on straight following, backing up, and avoidance or evasive action, because young drivers show high injury severity for those maneuvers when they are involved in crashes. Another fact is preventing teen drivers from adopting bad habits and informal rules in traffic such as fast driving, drinking while driving, etc. (OEOD 2006).

Risk factors identified in this study can also be used in parent/guardian education programs. Parents/guardians need to know about their children's risk for crashes. Crash rates show teen drivers' involvements in crashes are higher than young adult drivers. According to the model developed, teen drivers are at high risk for injuries. Hence, parental management practices may be important influences on teen driver practices and safety, as they are involved in children's driving from the beginning. Parents/guardians need to teach driving, to manage access to the vehicle, and set up family driving guidelines (Simons-Morton and Hartos 2003b).

Parents/guardians need to know about the new GDL law such as nighttime restrictions and minor passenger restrictions. Higher percentages of teens were involved in crashes in nighttime and dark. Teens were more likely to be involved in crashes during weekends, driving on rural roads, driving on wet road surfaces, and driving on roadways with high speed limits. These conditions need to be considered when governing teen driving and setting up teen driving guidelines. Parents/guardians need take actions to prevent teens driving without a valid license, alcohol impaired, and unrestrained. Driving without a valid license increases teen crash involvement, and alcohol-impaired driving or unrestrained driving increases injury severity when involved in a crash.

Parents/guardians and adults who supervise practice driving also need to know how to manage risk on the road. If they have knowledge of the most frequent teen driver contributory causes and critical vehicle maneuvers, this will be very useful for risk management. Risk management is needed for driving maneuvers such as straight following, turning, lane changing, and avoidance or evasive action because developed model results showed teens were more likely to suffer severe injuries while having one of these maneuvers.

Education and training programs are required components for beginning drivers to learn how to operate a vehicle according to the rules. Also, it is important to continue driver education and training. By increasing the quality of driver education and training, more safety objectives can be achieved.

4.4.2 Enforcement-Related Countermeasure Ideas

Enforcement will have a proportionately higher impact on young drivers, as they more frequently violate these traffic rules such as driving without a valid driving license and not obeying driver's license restrictions (Hanna et al. 2006). Results showed that 5% of young drivers were not licensed and 37% had restrictions on their licenses. Special attention should be paid to unlicensed driving, because the more regulated and demanding the driving process becomes, the more tempted teens will be to drop out of the licensing process and drive without a license. However, it is difficult for police to specifically identify young drivers on the road, making young-driver-specific enforcement difficult.

A considerable percentage of teens violated traffic rules such as driving without being restrained, alcohol-impaired driving, and driving after illegal drug use. Avoiding alcohol-involved driving is an important factor in reducing injury risk. It is also a factor in reducing crash involvement. Age 21 is the legal drinking age in Kansas, so young drivers are restricted from alcohol use, but alcohol-involved crashes are a significant factor for increased crash injuries. Hence, enforcement is needed, especially in locations where high alcohol use is expected. Distraction is a main contributory cause of teen driver crashes. Many drivers use audio entertainment systems and mobile phones, but very few use on-vehicle visual displays such as a

DVD *(65)*. Implementation of laws, such as stopping visual displays would, be beneficial, particularly for young drivers.

4.4.3 Engineering-Related Countermeasure Ideas

Young drivers' crash rates are higher than that of experienced drivers,' and therefore, protective devices, crash-worthy cars, and safer road infrastructures such as rumble strips and forgiving roadsides in particular will reduce young drivers' risk. As shown in ordered logistic regression model results developed in this study, high speeds were one of the risk factors for young drivers. While driving, a young driver's behavior is influenced by his or her general frame of mind, which among other things, reflects the situation just behind or approaching. Hence, predictable traffic situations, and low complexity resulting from an improved road infrastructure, are beneficial for young drivers. In particular, rural road and off-roadway crash involvement, and high-injury risk could be reduced by safer road infrastructures such as rumble strips and lane-departure warnings. Also road infrastructures such as fences can be used to avoid animals on the road. This is a main road-related contributory factor for crashes in Kansas. Protective devices such as air bags and seat belt reminders are helpful to reducing injury severity in case of a crash. Results of this study shows teen drivers were more likely to be involved in intersection-related crashes. Hence, poor intersections should be improved for safer vehicle operation.

4.4.4 Management-Related Countermeasure Ideas

In particular, the GDL system is designed to address teen and inexperienced young drivers' crash risk by letting them acquire driving experience under low-risk conditions (Williams et al. 2003). The goal of the licensing process, including training, should be to create drivers who are safe, increasing awareness of their own limitations and of the risks inherent to drivers. The GDL system has been identified as an effective countermeasure for reducing teen driving risk. It encourages beginners to obtain on-road driving experience under conditions of lower risk, and keep them out of high risk situations such as nighttime driving, weekend driving, and traveling with peer passengers. Some studies have shown that GDL reduces crashes generally by 20-30% (Williams 2006). The GDL system was implemented in Kansas in 2010 as a mechanism to decrease teen driver crashes. Effectiveness of the Kansas GDL system needs to be investigated, but as explained in section 4.3, with current data, proper assessment cannot be done.

According to the developed model, one of the significant variables for reducing injury risk is increasing seat belt usage. In 2010, Kansas turned to a primary seat-belt-restraint law from a secondary law for teen drivers aged 15 to 17. A primary seat-belt-restraint law allows a law enforcement officer to stop a vehicle and issue a citation for not wearing a seat belt. A secondary seat-belt-restraint law only allows for a citation to be issued if the vehicle is stopped for another primary violation.

Speeding is one of the main contributory causes which increases teen crash involvement. Hence, speed management cameras will be beneficial to prevent driving too fast. Distraction is also a main contributory cause for teen drivers. This includes nontechnology-based activities such as eating, drinking, smoking, and reading, as well as technology-based activities. Implementation of laws, such as prohibiting mobile phone use while driving and stopping use of visual displays would be beneficial, particularly for young drivers.

Measures focusing on improving the safety of all road users under all conditions will also be beneficial for young drivers, who frequently exhibit dangerous behaviors. Not all effective countermeasures can be implemented simultaneously. However, some countermeasures are less effective when introduced in isolation (OEOD 2006).

Chapter 5 - Results and Discussion

This study explored detailed characteristics of teen- and young-adult-driver-involved crashes and contributory factors in Kansas, and compared those with experienced drivers. Furthermore, ordered logistic regression models were developed for young-driver-involved crashes and recommendations were presented according to identified critical factors.

5.1 Summary

Motor vehicle crashes are the leading cause of death for young people, accounting for approximately 35% of deaths in this age group in Kansas (CDC 2011). The purpose of this report is to identify key elements of young drivers' crash risk in Kansas, the factors contributing to it, and countermeasures that mitigate it.

Crash data were obtained from the Kansas Department of Transportation, driver's license data were obtained from the U.S. Department of Transportation, and annual vehicle miles driven were obtained from the National Household Travel Survey 2009. Young drivers were further divided into two groups: teens and young adults. Detailed frequency analysis and crash rate analysis were carried out for both groups. Furthermore, detailed frequency analysis was carried out for experienced drivers and comparisons were made with young, young adult, and teen drivers. The number of teen drivers in crashes per 1000 licensed teen drivers was higher than that of young adult and experienced drivers. The number of teen drivers in crashes per million annual vehicle miles traveled was twice that of young adult drivers. Teen drivers in Kansas were at considerable risk of motor vehicle crashes compared to experienced drivers.

Crash statistics highlight some conditions such as nighttime driving, weekend driving, and travelling with teen passengers, as factors that increase risk for teen drivers. Also, factors which increase young drivers' risk, such as driving older vehicles, and run-off-the road, can be used for young driver crash-prevention efforts. To prevent run-off-the road crashes, safe infrastructure such as rumble strips, lane-departure warning signs, and forgiving roadsides can be implemented. Parents/guardians need to help their children to find a safe vehicle. Alcohol involvement needs to be prevented. Many complex factors influence and contribute to teen driving behavior. Increased crash frequency and risk for this age group has been attributed to speeding, failure to yield right-of-way, disregarding traffic sign and signals, making improper turns or lane changes, making other improper actions, inattention, or distraction compared to experienced drivers. Teen drivers need proper training on these factors in order to prevent or reduce crashes.

Both OR analysis and Chi-Square analysis gave mostly similar results, providing teen drivers were more likely to be involved in crashes compared to young adult drivers and experienced drivers in Kansas. Also, young adult drivers were more likely to be involved in crashes than experienced drivers. These results provide a deep understanding of the various characteristics and contributory causes, which have greater association with teen drivers, young adult drivers, and young drivers involved in crashes when compared to experienced drivers. By addressing the issues related to greater association with young drivers, young-driver-involved crashes can be reduced. To improve young driver safety, factors identified in ORs and Chi-Square analysis can be used. Those factors should lead to reduced driving with restricted licenses; wearing the seat belts while driving; preventing alcohol-impaired driving; and measures to reduce run-off-the road, overturning crashes. Also, young drivers need to get enough training for operation of vehicles at intersections and for maneuvers such as making turns, changing lanes, avoidance, or making improper evasions while controlling the vehicle. Young drivers need to drive carefully at night, evenings, weekends, and even on the lower-posted-speed-limit roadways. The faults, such as speeding, failure to yield right-of-way, disregarding traffic sign and signals, making improper turns or lane changes, aggressive driving, driving too slow for the traffic, falling asleep, illness or fatigue, distracted driving, and not giving proper attention to driving, should be prevented.

Ordered logistic regression models were developed for young drivers, teen drivers, and young adult drivers involved in crashes in order to investigate their injury severity. The dependent variable for all these models was injury severity, defined as a discrete variable where a young driver was fatal/severely injured, injured, possibly injured, or not injured. All available meaningful crash, vehicle, roadway, environmental, and driver-related characteristics and contributory courses were used as the independent variables. Results of the injury severity models had many significant variables, which were directly associated with injury severity of crashes involving young drivers. Most significant variables are identical in the three models. Identification of variables that can be addressed to decrease injury severity is important, because it helps improve young driver safety.

Factors which decrease young drivers' injury severity were seat belt use, driving on roadways which have lower speed limits, driving newer vehicles, and driving with an adult passenger. Reducing the factors which increase young drivers' injury severity, such as alcohol involvement, failure to keep the vehicle on road, driving on high-posted-speed limit roadways, driving old vehicles, ejection, trapping at the time of crash, and involvement in head-on collisions and angle collisions can be used for young driver safety efforts. For example, seat belt reminders help to increase the seat belt use and avoid ejections at the time of a crash. Road infrastructures such as rumble strips and lane-departure warning sign can be used to keep vehicles on the road. In order to prevent alcohol-impaired driving and to increase safety belt use, more enforcement programs are needed.

5.2 Conclusions and Recommendations

Many complex factors influence and contribute to teen driving behavior. Increased crash frequency and risk for this age group has been attributed to failure to pay attention, failure to yield right-of-way, driving too fast, disregarding traffic sign or signals, taking improper action while controlling the vehicle, taking improper action turning or lane changing, aggressive driving, and distraction compared to experienced drivers. Based on identified critical factors, countermeasure ideas were suggested to improve the safety of young drivers. Understanding these contributory causes could lead to better crash-mitigation strategies. It is important for teen drivers and parents/ guardians to gain better education on these critical factors that are helpful to prevent crashes and minimize driving risk. Training programs could be focused more on maneuvers such as straight following, backing up, proper avoidance, or evasive action.

Teens and parents/guardians need to know about the new GDL law, such as nighttime restrictions and minor passenger restrictions, and follow the law. Also, parents/guardians can consider high-risk conditions such as driving during nighttime, and weekends; driving on rural roads and on wet road surfaces; and driving on roadways with high speed limits when planning teen driving and setting up teen driving guidelines. Parents/guardians can take actions to prevent teen driving without a valid license, alcohol impairment, or unrestrained drivers. Risk management associated with supervision of the teen practices is needed to focus on driving maneuvers such as straight following, turning, lane changing, and avoidance or evasive action and contributory causes such as speeding, failure to give time and attention, and disregarding traffic sign and signals.

Special attention should be paid to unlicensed driving because the more regulated and demanding the driving process becomes, the more tempted teens will be to drop out of the licensing process and drive without a license. Implementation and enforcement of laws, such as prohibiting mobile phone use while driving and stopping visual displays, would be beneficial, particularly for young drivers.

Protective devices, crash-worthy cars, and safer road infrastructures such as rumble strips and forgiving roadsides will particularly reduce young drivers' risk. Protective devices such as air bags and seat belt reminders are also helpful. Predictable traffic situations and low complexity resulting from an improved road infrastructure are beneficial for young drivers. Off-roadway crash involvement could be reduced by safer road infrastructures such as rumble strips and lane-departure warnings. Also road infrastructures such as fences can be used to prevent animals in the road. Poor intersections should be improved for safe vehicle operation.

The GDL system was implemented in Kansas in 2010 as a mechanism to decrease teen driver crashes. Effectiveness of the Kansas GDL system needs to be investigated in the future. In July 2011, Kansas turned to a primary seat-belt-restraint law from a secondary law for teens aged 14 to 18. This is helpful for decreasing young driver injury risk. Speed management cameras would be beneficial to prevent driving too fast.

Measures focusing on improving the safety of all road users under all conditions will also be beneficial for young drivers, who frequently exhibit dangerous behaviors. Not all effective countermeasures can be implemented simultaneously (OECD 2006).

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Appendix A - Graduated Driver Licensing Laws of Each State

Table A.1 Graduated Driver Licensing Laws of Each State

Source: Governors Highway Safety Association *(GHSA 2010)*

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license Age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
Alabama	15	6	30hr. (1 hr. nighttime) (None with driver education)	16	12 am - 6 am	17	No more than 3 passengers	17	17
Alaska	14	6	40 hr (including 10 hr. nighttime or inclement weather)	16	1 am - 5 am	16 + 6 months	No passengers below 21	16 + 6 months	18
Arizona	15+ 6 months	6	30 hr. (including 10 hr. nighttime)	16	12 am - 5 am	16 + 6 months	No more than 1 passenger below 18	16 + 6 months	18
Arkansas	14	6	None	16	None	18 (Primary seat belt restrictions remove)	None	_	18

Table A.1 Graduated Driver Licensing Laws of Each State Continued

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license Age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
California	15+ 6 months	6	50 hr. (including 10 hr. nighttime)	16	11 p.m. – 5 a.m.	17	No passengers below 20	17	18
Colorado	15	12	50 hr. (including 10 hr. nighttime)	16	12 a.m. – 5 a.m.	17	First 6 months No passengers; Then No more than 1 passenger	17	18
Connecticut	16	6 (4 with driver education)	20 hr.	16 + 4 months	11 p.m. – 5 a.m.	18	No passengers	16 + months	18
Delaware	16	6	50 hr. (including 10 hr. nighttime)	16 + 6 months	10 p.m. – 6 a.m.	17	No more than 1 passenger	17	17
District of Columbia	16	6	40 hr in learner's at age + 10 hr. at night in intermediate stage	16 + 6 months	Sep -June : 11p.m. - 6a.m. (SU-TH) 12am- 6 a.m. (FRI-SA) / July-Aug: 12a.m.- 6 a.m.	18	First 6 months No passenger; Then No more than 2 passengers below 21	18	18
Florida	15	12	50 hr. (including 10 hr. nighttime)	16	11 p.m. – 6 a.m. (age 16); 1 a.m. - 5a.m. (age 17)	18	Non	_	18

Table A.1 Graduated Driver Licensing Laws of Each State Continued

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
Georgia	15	12	40 hr. (including 6 hr. nighttime)	16	12 a.m. – 6 a.m.	18	No more than I passenger below 21	18	18
Hawaii	15 + 6 months	6	None	16	11 p.m. – 5 a.m.	17	No more than I passenger below 18	17	17
Idaho	14 + 6 months	6	50 hr. (including 10 hr. nighttime)	15	Sunset to Sunrise	16	No more than I passenger below 17	15 + 6 months	17
Illinois	15	3	50 hr. (including 10 hr. nighttime)	16	11p.m. - 6a.m. (SU-TH) 12 a.m.- 6a.m. (FRI-SA)	17	No more than I passenger below 20	16 + 6 months	18
Iowa	14	6	20 hr. (including 2 hr. nighttime)	16	12.30 p.m. – 5 a.m.	17	None	_	17
Kansas	14	6	50 hr. (including 10 hr. nighttime, 25 hr. must complete at learner's phase)	15	9 p.m. – 5 a.m.	16	No passengers below 18	16	16
Kentucky	16	6	60 hr. (including 10 hr. nighttime)	16 + 6 months	12 a.m. – 6 a.m.	17	No more than I passenger below 20	17	17
Louisiana	15	6	None	16	11 p.m. – 5 a.m.	17	None	_	17

Table A.1 Graduated Driver Licensing Laws of Each State Continued

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
Maine	15	6	35 hr. (including 5 hr. nighttime)	16	12 p.m. – 5 a.m.	16 + 6 months	No passengers	16 + 6 months	16 + 6 months
Maryland	15 + 9 months	6	60 hr. (including 10 hr. nighttime)	16 + 3 months	12 a.m. – 5 a.m.	17 + 9 months	No passengers below 18	16 + 8 months	17 + 9 months
Massachusetts	16	6	40 hr	16 + 6 months	12.30 p.m. - 5 a.m.	18	No passengers below 18	17	18
Michigan	14 + 9 months	6	50 hr. (including 10 hr. nighttime)	16	12 p.m. – 5 a.m.	17	None	_	17
Minnesota	15	6	30 hr. (including 10 hr. nighttime)	16	12 p.m. – 5 a.m.	17	First 6 months 1 passenger below 20; Then No more than 3 passengers below 20	17	18
Missippi	15	6	None	15 + 6 m	10 p.m. – 6 a.m.	16	None	_	16
Missouri	15	6	40 hr. (including 10 hr. nighttime)	16	1 a.m. – 5 a.m.	17 + 11 months	First 6 months 1 passenger below 19; Then No more than 3 passengers below 19	17 + 11 months	18
Montana	14 + 6 months	6	50 hr. (including 10 hr. nighttime)	15	11 p.m. – 5 a.m.	16	First 6 months 1 passenger below 18; Then No more than 3 passengers below 18	16	18
Nebraska	15	6	50 hr. (including 10 hr. nighttime)	16	12 a.m. – 6 a.m.	17	No more than I passenger below 19	16 + 6 months	18

Table A.1 Graduated Driver Licensing Laws of Each State Continued

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
Nevada	15 + 6 months	6	50 hr. (including 10 hr. nighttime)	16	10 p.m. – 5 a.m.	18	No passengers below 18	16 + 3 months	18
New Hampshire	15 + 6 months	None	20 hr.	16	1 a.m. – 5 a.m.	17 + 1 months	No more than I passenger below 25	16 + 6 months	18
New Jersey	16	6	None	17	12 a.m. – 5 a.m.	18	No more than 1 passenger	18	18
New Mexico	15	6	50 hr. (including 10 hr. nighttime)	15 + 6 months	12 a.m. – 5 a.m.	16 + 6 months	No more than I passenger below 21	16 + 6 months	16 + 6 months
New York	16	6	20 hrs.	16 + 6 months	9 p.m. – 5 a.m.	17	No more than 2 passengers below 21	17	18
North Carolina	15	12	None	16	9 p.m. – 5 a.m.	16 + 6 months	No more than 1 passenger below 21	16 + 6 months	16 + 6 months
North Dakota	14	6	None	_	_	_	_	_	14 + 6 months
Ohio	15 + 6 months	6	50 hr. (including 10 hr. nighttime)	16	12a.m. - 6a.m. (aged 16); 1a.m. - 5 a.m. (aged 17)	18	No more than 1 passenger	17	18
Oklahoma	15 + 6 months	6	40 hr. (including 10 hr. nighttime)	16	11 p.m. – 5 a.m.	16 + 6 months	No more than 1 passenger below 21	16 + 6 months	16 + 6 months

Table A.1 Graduated Driver Licensing Laws of Each State Continued

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
Oregon	15	6	50 hr.	16	12 a.m. – 5 a.m.	17	First 6 months 1 passenger below 20; Then No more than 3 passengers below 20	17	18
Pennsylvania	16	6	50 hr.	16 + 6 months	11 p.m. – 5 a.m.	17	None	–	17 + 6 months
Rhode Island	16	6	50 hr. (including 10 hr. nighttime)	16 + 6 months	1 a.m. – 5 a.m.	17 + 6 months	No more than 1 passenger below 20	17 + 6 months	17 + 6 months
South Carolina	15	6	40 hr. (including 10 hr. nighttime)	15 + 6 months	6 p.m. -12 a.m. (with licensed driver age above 21) 12a.m. - 6 a.m. (with parents or guardian)	16 + 6 months	No more than 2 passenger below 21	16 + 6 months	17
South Dakota	14	6 (3 with driver education)	None	14 + 6 months	10 p.m. – 6 a.m.	No passengers without exception	None	–	16 + 6 months
Tennessee	15	6	50 hr. (including 10 hr. nighttime)	16	11 p.m. – 6 a.m.	17	No more than 1 passenger below 21	17	18
Texas	15	6	None	16	12 a.m. – 5 a.m.	16 + 6 months	No more than 1 passenger below 21	16 + 6 months	16 + 6 months

Table A.1 Graduated Driver Licensing Laws of Each State Continued

State	Learners stage			Restrictions on driving while unsupervised					Regular full unrestricted license age
	Minimum entry age	Mandatory holding period (months)	Minimum Amount of Supervised Driving	Minimum age	Prohibited nighttime	nighttime restriction remove age	Restriction on passengers	Passenger restriction remove age	
Utah	15	6	40 hr. (including 10 hr. nighttime)	16	12 a.m. – 5 a.m.	17	No more than 1 passenger below 18	18	18
Vermont	15	12	40 hr. (including 10 hr. nighttime)	16	None	–	No passengers without exception	16 + 6 months	18
Virginia	15	9	40 hr. (including 10 hr. nighttime)	16 + 3 months	12 a.m. – 4 a.m.	18	First 6 months 1 passenger below 18; Then No more than 3 passengers below 18	18	18
Washington	15	6	50 hr. (including 10 hr. nighttime)	16	1 a.m. – 5 a.m.	17	First 6 months 1 passenger below 20; Then No more than 3 passengers below 20	17	18
West Virginia	15	6	30 hr. (including 10 hr. nighttime)	16	11 p.m. – 5 a.m.	17	No more than 3 passengers below 19	17	17
Wisconsin	15 + 6 months	6	30 hr. (including 10 hr. nighttime)	16	12 a.m. – 5 a.m.	16 + 9 months	No more than 1 passenger	16 + 9 months	18
Wyoming	15	.3 (10 days)	50 hr. (including 10 hr. nighttime)	16	11 p.m. – 5 a.m.	16 + 6 months	No more than 1 passenger below 18	16 + 6 months	17

Appendix B - Studies Evaluating GDL System within the State

Table B.1 Studies Evaluating GDL System within the State

Source: Shope 2007

Jurisdiction/ GDL Date/Citation	Population	Outcome	Data Base	Method	Analyses	Results	Other Issues Studies
BRITISH COLUMBIA Aug 1998 Wiggins (2004)	New drivers including learners (80%<18 yr)	Crash rates	Insurance Corp of BC: Driver Licensing, Driver Training, Traffic Accidents, Business Information, Contraventions 1996-1999	Pre/Post (3.4 yr) comparison of rates per licensed driver	Crash involvement rates, adjusted for age and sex Comparison with experienced drivers	Crash rates down 16% but decrease due to learners No change among intermediates Crash severity-no change	Driver education time incentive
GEORGIA July 1997 Rios et al. (2006)	16 and 17 yr drivers	Fatal crashes	FARS 1992-2002	Pre/Post (5.5 yr) Comparison Comparisons with AL, SC, TN	Chi-Square Generalized linear models	16 yr down 30% 17 yr down 19%	Speed and alcohol crashes
IOWA Jan 1999 Falb (2005)	16 yr drivers	Crashes Convictions as intermediate driver	IA DOT 1998-2004	Pre/Post (6 yr) comparison	Counts Percentage change in counts	Crashes down 37% Convictions down 53%	18 yr drivers
IOWA Jan 1999 Hallmark et al. (2006)	14, 15, 16 and 17 yr drivers	Crashes	IA DOT 1995-2004	Pre/Post (4 yr) Comparison of crash rates per licensed driver, with 34-44 yr as reference	Ratio of teen rate to 35-44 yr rate Observed to expected crashes	14, 16, 17 yr rates down 15 yr rates up	Fatal crashes Alcohol Occupant Time of day School permits Induced exposure

Table B.1 Studies Evaluating GDL System within the State Continued

Jurisdiction/ GDL Date/Citation	Population	Outcome	Data Base	Method	Analyses	Results	Other Issues Studies
MANITOBA Apr 2002 Strategic Research (2006)	15-19 yr drivers	MPI clains, collisions,	MPU data Police data Driver Records 200-2005	Pre/post (3 yrs) comparison of rates per driver	Percent change in rates	MPI Data Collisions down 44% Bodily injury claims down 49% Phys. Damage claims down 45% Police data Crashes down 47% Convictions down 62%	At-fault crashes conviction types GDL restriction violations Driver improvement
MARILAND July 1999 Friendlander et al.	16 yr. drivers	Fatal/ disabling injury crashes	MID Automated Accident Reporting System 1997-2002	Pre/post (3 yrs) comparison	Relative risk adjusted for 20-24 yr drivers	Crashes down 21% At-fault down 28%	Other injury crashes
MICHIGAN April 1997 Shope and Molnar (2004)	16 yr. drivers	Crash involveme nt	MI state Police crash records; Library of MI driver licence numbers by age 1996-2001	Pre/post (4.5 yrs) comparison	Relative risk adjusted for 25+ yr drivers	Fatal crashes down 44% Non-fatal injury crashes down 38% Single-vehicle crashes down 32% Multi-vehicle crashes down 28% All crashes down 29%	Crash rates per licensed driver Male/female Passengers Time of day
NORTH CAROLINA Dec 1997 Morgolis et al. (2007)	16 and 17 yr drivers	MVC hospitaliza tion rate MVC hospital charges	NC Hospital Discharge Database; NC Census data; NC Licensing data 1996-2001	Time series (4 yrs post)	ARIMA interrupted time series, controlling for rates of 25-54 yr drivers	16 yr rates per population, Hospitalization rate down 37% Hospital charges down 31%; 17 yr rates per population Hospitalization rate down 12%	Licensure

Table B.1 Studies Evaluating GDL System within the State Continued

Jurisdiction/ GDL Date/Citation	Population	Outcome	Data Base	Method	Analyses	Results	Other Issues Studies
NORTH CAROLINA Dec 1997 Foss et al. (2007)	16, 17, 18 and 19 yr drivers	Crash rates Fatal/injury Crash rates per capita And per licensed driver	NC Crash Data System NC State Demographer; NC driver history 1991-2004	Time series (7 yrs post)	ARIMA time series with 25-54 yr rates as covariates	16 yr per capita, down 39%; 16 yr per licensee, down 7%; 17 yr. per capita, down 20% 17 yr per licensee, down 5%	Night restriction Passenger restriction Fatal/injury crashes
NOVA SCOTA Oct. 1994 Mayhew et al (2003)	16 and 17 yr drivers 18+ yr. novice drivers	Crash rates per driver	Nova Scotia driver records 1992-1996	Pre/post (3 yrs) comparison	Z test for comparison of rates and proportions	16 and 17 yr first year (mostly learners), crash rate down 29%, 16 and 17 yr intermediate stage, down 9% first year and 11% second year	Night driver education Comparison of young novices and older novices
ONTARIO Apr 1994 Carpenter (2006)	16 and 17 yr drivers	Self reported drunk driving	Ontario Student drug use survey 1993-2001	Pre/post (7 yrs) comparison	Difference in differences	5% reduction not attributable to GDL/ZT	Zero Tolerance introduced as part of GDL
ONTARIO Apr 1994 Mayhew et al. (2002)	16-19 yr. drivers	Crashes	Ontario Road Safety Annual Report, Quebec Road Safety Annual Report, Ontario Accident Data System, Statistics Canada population data 1993-1999	Pre/post (5.5 yrs) comparison of per capita crash rates compared to Ontario 25-54 yr and Quebec 16-19 and 25-54 yr Monthly seres of crashes	Crash rate ratios and confidence intervals ARIMA modeling	16 yr all crashes down 73% casualty crashes down 72%; 17 yr all crashes down 26%, casualty crashes down 28%; 18 yr all crashes down 29%, casualty crashes down 38%; 19 yr all crashes down 10%	Compliance Progress of drivers Licensure rates Crashes prevented Costs saved Driver education

Table B.1 Studies Evaluating GDL System within the State Continued

Jurisdiction/ GDL Date/Citation	Population	Outcome	Data Base	Method	Analyses	Results	Other Issues Studies
PENNSYLVANIA Jan 2000 Coben and McKay (2003)	16 yr drivers	Crashes	PENN DOT accident reporting system1996-2000	Pre/post (1 yr) comparison	Crash counts Percent change	Crashes down 28% Fatal crashes down 49% Fatal crashes down 49% Injury crashes down 30%; Drivers killed down 62% Deaths down 61%	Licensure age
TEXAS Jan 2002 Willis (2006)	16 yr drivers	Fatal crashes	FARS 2000-2004	Pre/post (3 yr) comparison	Crash counts Percent change	Fatal crashes down 22% Per driver fatal crashes: slight increase	Licensure Restraint use Crash characteristic s
UTAH July 1999 Hyde et al. (2005)	16 yr drivers	Crashes	UT Motor Vehicle Crash Data Base; UT DE Data Base; UT Hospital Inpatient Data Base; UT Driver License Data Base; Probabilistic linkage of records 1996-2001	Pre/post (2.5 yr) time series	Descriptive statistics Rate ratios Test of trend Intervention time series analysis	Crash rate down 5%	Night seat belts Crash severity Citations passengers
WISCONSIN Sept 2000 Fohr et al. (2005)	16 and 17 yr drivers	Crashes	WI DOT motor vehicle accident reports UW-population 1999-2003	Pre/post (3.5 yrs) comparison of crash rates with 25-59 yr as reference	Population crash rate ratios, Odds ratio of at-fault crash (induced exposure)	16 yr crashes down 14% Injury crashes down 16% 17 yr crashes down 6%	Presence of adult and teen passengers

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Appendix C - Current Graduated License Law in Kansas

"8-2,101. Restricted license; conditions, restrictions and requirements.

Source: Kansas Legislature 2011

The division of vehicles may issue a restricted class C or M driver's license in accordance with the provisions of this section. A restricted class C license issued under this section shall entitle the licensee, while possessing the license, to operate any motor vehicle in class C, as designated in K.S.A. 8-234b, and amendments thereto. A restricted class M license shall entitle the licensee, while possessing such license, to operate a motorcycle.

(a) The division may issue a restricted class C or M driver's license to any person who:

(1) Is at least 15 years of age;

(2) has successfully completed an approved course in driver training;

(3) has held an instructional permit issued under the provisions of K.S.A. 8-239, and amendments thereto, for a period of at least one year and has completed at least 25 hours of adult supervised driving; and

(4) upon the written application of the person's parent or guardian, which shall be submitted to the division. Any licensee issued a restricted license under this subsection, shall provide prior to reaching 16 years of age, a signed affidavit of either a parent or guardian, stating that the applicant has completed the required 25 hours prior to being issued a restricted license and 25 hours of additional adult supervised driving. Of the 50 hours required by this subsection, at least 10 of those hours shall be at night. The adult supervised driving shall be conducted by an adult who is at least 21 years of age and is the holder of a valid commercial driver's license, class A, B or C driver's license.

(b) (1) A restricted license issued under subsection (a) shall entitle a licensee who is at least 15 years of age but less than 16 years of age, to operate the appropriate motor vehicles at any time:

(A) While going to or from or in connection with any job, employment or farm-related work;

(B) on days while school is in session, over the most direct and accessible route between the licensee's residence and school of enrollment for the purposes of school attendance;

(C) when the licensee is operating a passenger car, at any time when accompanied by an adult, who is the holder of a valid commercial driver's license, class A, B or C driver's license and who is actually occupying a seat beside the driver; or

(D) when the licensee is operating a motorcycle, at any time when accompanied by an adult, who is the holder of a valid class M driver's license and who is either operating a motorcycle in the general proximity of the licensee or is riding as a passenger on the motorcycle being operated by the licensee.

(2) For a period of six months, a restricted license issued under subsection (a) shall entitle a licensee who is at least 16 years of age to operate the appropriate motor vehicles at any time:

(A) From 5:00 a.m. to 9:00 p.m.;

(B) while going to or from or in connection with any job, employment or farm-related work;

(C) while going to or from authorized school activities;

(D) while going directly to or from any religious worship service held by a religious organization;

(E) when the licensee is operating a passenger car, at any time when accompanied by an adult, who is the holder of a valid commercial driver's license, class A, B or C driver's license and who is actually occupying a seat beside the driver; or

(F) when the licensee is operating a motorcycle, at any time when accompanied by an adult, who is the holder of a valid class M driver's license and who is either operating a motorcycle in the general proximity of the licensee or is riding as a passenger on the motorcycle being operated by the licensee.

After such six-month period, if the licensee has complied with the provisions of this section, such restricted license shall entitle the licensee to operate the appropriate motor vehicles at any time without any of the restrictions required by this section.

(c) (1) The division may issue a restricted class C or M driver's license to any person who is under 17 years of age but at least 16 years of age, who:

(A) Has held an instructional permit issued under the provisions of K.S.A. 8-239, and amendments thereto, for a period of at least one year; and

(B) has submitted a signed affidavit of either a parent or guardian, stating that the applicant has completed at least 50 hours of adult supervised driving with at least 10 of those hours being at night. The required adult supervised driving shall be conducted by an adult who is at least 21 years of age and is the holder of a valid commercial driver's license, class A, B or C driver's license.

(2) For a period of six months, a restricted license issued under subsection (c)(1) shall entitle a licensee to operate the appropriate motor vehicles at any time:

(A) From 5:00 a.m. to 9:00 p.m.;

(B) while going to or from or in connection with any job, employment or farm-related work;

(C) while going to or from authorized school activities;

(D) while going directly to or from any religious worship service held by a religious organization;

(E) when the licensee is operating a passenger car, at any time when accompanied by an adult, who is the holder of a valid commercial driver's license, class A, B or C driver's license and who is actually occupying a seat beside the driver; or

(F) when the licensee is operating a motorcycle, at any time when accompanied by an adult, who is the holder of a valid class M driver's license and who is either operating a motorcycle in the general proximity of the licensee or is riding as a passenger on the motorcycle being operated by the licensee. After such six-month period, if the licensee has complied with the provisions of this section, such restricted license shall entitle the licensee to operate the appropriate motor vehicles at any time without any of the restrictions required by this section.

(d) (1) Any licensee issued a restricted license under subsection (a):

(A) Who is less than 16 years of age shall not operate any motor vehicle with nonsibling minor passengers; or

(B) who is at least 16 years of age, for a period of six months after reaching 16 years of age, shall not operate any motor vehicle with more than one passenger who is less than 18 years of age and who is not a member of the licensee's immediate family.

(2) Any licensee issued a restricted license under subsection (c), for a period of six months after such restricted license is issued, shall not operate any motor vehicle with more than one passenger who is less than 18 years of age and who is not a member of the licensee's immediate family.

(3) Any conviction for violating this subsection shall be construed as a moving traffic violation for the purpose of K.S.A. 8-255, and amendments thereto.

(e) Any licensee issued a restricted license under this section shall not operate a wireless communication device while driving a motor vehicle, except that a licensee may operate a wireless communication device while driving a motor vehicle to report illegal activity or to summons medical or other emergency help.

(f) (1) A restricted driver's license issued under this section is subject to suspension or revocation in the same manner as any other driver's license.

(2) A restricted driver's license shall be suspended in accordance with K.S.A. 8-291, and amendments thereto, for any violation of restrictions under this section.

(3) The division shall suspend the restricted driver's license upon receiving satisfactory evidence that the licensee has been involved in two or more accidents chargeable to the licensee and such suspended license shall not be reinstated for one year.

(g) Evidence of failure of any licensee who was required to complete the 50 hours of adult supervised driving under this section shall not be admissible in any action for the purpose of determining any aspect of comparative negligence or mitigation of damages.

(h) Any licensee issued a restricted license under:

(1) Subsection (a) who:

(A) Is under the age of 16 years and is convicted of two or more moving traffic violations committed on separate occasions shall not be eligible to receive a driver's license which is not restricted in accordance with the provisions of subsection (b)(1) until the person reaches 17 years of age;

(B) is under 17 years of age but at least 16 years of age and is convicted of two or more moving traffic violations committed on separate occasions shall not be eligible to receive a driver's license which is not restricted in accordance with the provisions of subsection (b)(2) until the person reaches 18 years of age; or

(C) fails to provide the affidavit required under subsection (a) shall not be eligible to receive a driver's license which is not restricted in accordance with the provisions of subsection (b)(1) until the person provides such affidavit to the division or the person eaches 17 years of age, whichever occurs first. (2) Subsection (c) who is under the age of 17 years and is convicted of two or more moving traffic violations committed on separate occasions shall not be eligible to receive a driver's license which is not restricted in accordance with the provisions of subsection (c) until the person reaches 18 years of age.

(i) This section shall be a part of and supplemental to the motor vehicle driver's license act. ”

Appendix D - A News Article

Source: The Wichita Eagle

The Wichita Eagle
Kansas.com

Posted on Mon, Dec. 21, 2009

Teen drivers face new restrictions on Jan. 1

BY JEANNINE KORANDA

Eagle Topeka Bureau

TOPEKA — Elizabeth Hunt and her 16-year-old son, Ryan Hunt, plan to hit the driver's exam station this week.

After Jan. 1, teen drivers will face more rules on when they can drive and who can be in the car with them, but those in the system by the end of this year will fall under the current rules.

"We expect it to be pretty busy there," said the Wichita mother. "But we want to get in before the deadline."

Hunt said she understands the new rules are an attempt to make teens safer drivers, but she is feeling the pressure from her son to get it done now.

"Yeah, all my friends are getting theirs now," Ryan said. "I really don't want to be the only one without it."

The Hunts aren't the only family hustling to get their teen driver a license or permit.

"We're seeing a lot of kids coming in... a lot of parents rushing those kids in here because they want to get the kids those license or permits," said Noni Stuart, public service administrator for Wichita Division of Motor Vehicles.

Some parents, like Hunt, have said they are bringing their teenagers in specifically so they will fall under the old laws, she said.

After Jan. 1, 16-year-old drivers will face restrictions for at least the first six months behind the wheel. Currently, 16-year-olds can get an unrestricted license.

Teens will still be able to get a learner's permit at 14, but the law increases restrictions on when they can drive and who can be in the car.

Danielle Simon, 14, took the exam for her driving permit Thursday but missed too many questions to pass. She said she is going to take it again soon.

"I'm going to study a lot and then ask my mom to take me back," she said.

Her mother, Janet Simon, of Wichita, said she appreciates what the government is trying to achieve with the new regulations, but she doesn't think it's necessary.

"I already planned on spending a lot of time teaching Danielle how to be safe," she said. "I don't think the extra six months would really make a difference."

The rules are intended to give inexperienced drivers more supervised time behind the wheel to learn how to safely handle a vehicle, said Pete Bodyk, manager of traffic safety for Kansas Department of Transportation.

"The goal is to make it safer for everyone on the road," he said.

The new rules also bar teens from using cell phones or other wireless devices while driving.

Kansas is the 49th state to increase the restrictions on teen drivers. Only North Dakota has not taken similar steps.

The most significant changes to the law include restrictions on the number of passengers teen drivers can carry and rules barring them from driving after 9 p.m., Bodyk said.

Fewer young passengers means young drivers will be less distracted, and prohibiting late-night driving can help prevent more serious crashes, Bodyk said.

"Teens think we are picking on them, but just the opposite is true," said Darlene Whitlock, trauma prevention coordinator for Stormont-Vail Healthcare in Topeka.

Whitlock, who is also the president-elect of the Kansas Emergency Nurses Association, said most nurses working in emergency rooms have seen the toll of inexperienced drivers firsthand.

While teen drivers make up 7 percent of people operating a vehicle, they are involved in 20 percent of the recorded crashes and 30 percent of the fatal crashes, said Jim Hanni, executive vice president of AAA Kansas during a recent press event promoting the new law.

Contributing: Eagle correspondent Chandra Stauffer

Read more here: http://www.kansas.com/2009/12/21/v-print/1107120/teen-drivers-face-new-restrictions.html#storylink=cpy

Appendix E - Comparison of Current Law and Law Prior to 2010

Graduated Driver License Requirements for Teen Drivers
(Source: Kansas Department of Revenue) http://www.ksrevenue.org/dmvgdl.html

From the GDL Bill (HB 2143)
"any person who held any valid restricted class C or class M driver's license, instruction permit, restricted instruction permit or farm permit on the effective date of this act may continue to operate motor vehicles subject to the conditions, limitations and restrictions contained in KSA 8-237, 8-239 and 8-296, and amendments thereto, as in effect on December 31, 2009."

To correctly determine how the Graduated Driver's License law will affect you as a teenager, you must first answer this question –
• Did you (or will you) obtain an instruction permit, farm permit or restricted license prior to January 1 2010?

- If the answer to that question is Yes – then all of the requirements and restrictions that were in effect prior to January 1 2010 are what apply to you (shown in the comparison chart on the next 3 pages)
- If the answer to that question is No – then all of the new requirements and restrictions that take effect on January 1 2010 are what apply to you (shown in the comparison chart on the next 3 pages)

Table E.1 Graduated Driver Licensing – Instruction Permit - Comparison Chart

	Previous Law - Prior to 1/ 1/ 2010	Current Law - Effective 1/ 1/ 2010
	Instruction Permit	Instruction Permit
Age	Minimum 14 years old	Minimum 14 years old
Testing Required	Vision Written - or certificate of completion from driver education	Vision Written - or certificate of completion from driver education
Parental Approval Required	Yes for 14 and 15 year olds	Yes for 14 and 15 year olds
Driver Education Required	No	No
Driving Restrictions	Licensed adult in front seat at all times	Licensed adult in front seat at all times - *minimum age 21*
Wireless Restriction	No	No *use of wireless communication devices except to report illegal activity or to summons medical or emergency help*
Passenger Restriction	No	No
Time Required to be held	6 months to advance to restricted license	1 year to advance to restricted license

Table E.2 Graduated Driver Licensing – Restricted License - Comparison Chart

	Previous Law - Prior to 1/ 1/ 2010	Current Law - Effective 1/ 1/ 2010
	Restricted License - 15 year old	Restricted License - 15 year old
Age	Minimum 15 years old but less than 16	Minimum 15 years old but less than 16
Testing Required	Vision	Vision
Parental Approval Required	Yes	Yes
Driver Education Required	Yes	Yes
Instruction Permit Required	Yes - must have held at least 6 months	Yes - must have held at least 1 year
50 Hour Affidavit Required	No - must provide prior to 16 to move to unrestricted	No - must provide prior to 16 to move to lesser restrictions
Driving Restrictions	To or from work To or from school Anytime/ anywhere with licensed adult	To or from work To or from school Anytime/ anywhere with licensed adult
Wireless Restriction	No	No use of wireless communication devices except to report illegal activity or to summons medical or emergency help
Passenger Restriction	May not transport any non sibling minor passengers	May not transport any nonsibling minor passengers
Time Required to be held	At 16 will become unrestricted if 50 hour affidavit has been turned in	At 16 will move to lesser restrictions if 50 hour affidavit has been turned in

Table E.3 Graduated Driver Licensing – Lesser Restricted License - Comparison Chart

	Previous Law - Prior to 1/ 1/ 2010	Current Law - Effective 1/ 1/ 2010
	Lesser Restricted License - 16 year old	Lesser Restricted License - 16 year old
Age	N/A	*Minimum 16 years old but less than 17*
Testing Required	N/A	*Vision* *Written & Drive - or certificate of completion from driver* *education*
Parental Approval Required	N/A	*No*
Driver Education Required	N/A	*No*
Instruction Permit Required	N/A	*Yes - must have held at least 1 year*
50 Hour Affidavit Required	N/A	*Yes*
Driving Restrictions	N/A	*Anywhere from 5am to 9pm* *Anytime going to or from work* *Anytime going to or from authorized school activities* *Anytime/ anywhere with licensed adult*
Wireless Restriction	N/A	*No use of wireless communication devices except to report illegal activity or to summons medical or emergency help*
Passenger Restriction	N/A	*No more than one passenger who is less than 18 and who is not a member of the licensee's immediate family*
Time Required to be held	N/A	*6 months - after licensee has held the restricted DL for 6 months, if they have complied with all laws the restrictions will no longer apply*

Appendix F - Punishable Restrictions and Charges

Table F.1 New Laws for Teen Drivers Effective from January 01, 2010 (KDOT 2010)

GDL-January 1, 2010	Restrictions	Charging
instruction Permit KSA 8-239 Ages: 14-15 Duration: 12 months • Minimum age 14; valid for one year • If under age 16, written application of parent/guardian required • Must pass vision and written examinations	• Must be accompanied by adult* in front seat who holds a valid driver's license with at least one year of driving experience • NO person except supervising driver can be in front seat • NO wireless communication device while driving except to report illegal activity or to summon emergency help	Penalties apply to all teen drivers KSA 8-291 subject to suspension or revocation as any other driver's license Shall be suspended for any violation of restrictions • **1st Offense** – 30-day suspension • **2nd Offense** – 90-day suspension • **3rd Offense** – One-year suspension
Restricted License KSA 8-237 Ages: 15-16 Duration: 12 months • Minimum age 15 • Written application of parent/guardian required • Must have held instruction permit for at least one year and completed at least 25 hours of supervised driving • Must have successfully completed an approved Driver Education course (not required if applying at age 16)	**If under age 16, may drive at any time:** • To/from or in connection with any job, employment or farm-related work • Over the most direct and accessible route between home and school for the purpose of attendance • When accompanied by an adult* in front seat who holds a valid driver's license **During this time:** • Must complete additional 25 hours of supervised driving (10 of the 50 hours total must be at night) • NO non-sibling minor passengers are allowed • NO wireless communication device while driving except to report illegal activity or to summon emergency help **If over age 16, first 6 months, may drive at any time:** • From 5 a.m. to 9 p.m. • To/from or in connection with any job, employment or farm-related work • To/from authorized school activities • When accompanied by an adult* in front seat who holds a valid driver's license **During this time:** • One non-immediate family member minor passenger (less than 18 years old) is allowed • NO wireless communication device while driving except to report illegal activity or to summon emergency help	Penalties apply to all teen drivers KSA 8-291 subject to suspension or revocation as any other driver's license Under 16 – Two or more crashes – no license until age 17 • **1st Offense** – 30-day suspension • **2nd Offense** – 90-day suspension • **3rd Offense** – One-year suspension

Table F.1 New Laws for Teen Drivers Effective from January 01, 2010 (Continued)

GDL-January 1, 2010	Restrictions	Charging
Full License KSA 8-235d Age: 17	**Age 17 – if applying as a first-time applicant** • Must pass vision, written, and driving exams with appropriate license in hand • Must provide proof of age and identification • Signed affidavit of parent or guardian, stating applicant has legally completed at least 50 hours of adult*-supervised driving with at least 10 of those hours being at night *** at least age 21**	Subject to all penalties under KSA 8-291

Current Violation of Restrictions on Driver's License or Permit; Misdemeanor; Penalties

Source: Kansas Legislature *(64)*

Chapter 8: Automobiles And Other Vehicles

Article 2: Drivers' Licenses

Statute 8-291: Violation of restrictions on driver's license or permit; misdemeanor; penalties. (a) It is a misdemeanor for any person to operate a motor vehicle in violation of the restrictions on any driver's license or permit imposed pursuant to any statute.

(b) Except as provided in subsection (c):

(1) Any person guilty of violating this section, upon the first conviction, shall be fined not to exceed $250, and the court shall suspend such person's privilege to operate a motor vehicle for not less than 30 days and not more than two years.

(2) Any person guilty of violating this section, upon a second or subsequent conviction, shall be fined not to exceed $500, and the court shall suspend such person's privilege to operate a motor vehicle for not less than 90 days and not more than two years.

(c) Any person guilty of violating this section, for violating restrictions on a driver's license or permit imposed pursuant to K.S.A. 8-237, 8-296, K.S.A. 2009 Supp. 8-2,100 or 8-2,101, and amendments thereto:

(1) Upon first conviction, the court shall suspend such person's privilege to operate a motor vehicle for 30 days;

(2) upon a second conviction, the court shall suspend such person's privilege to operate a motor vehicle for 90 days; and

(3) upon a third or subsequent conviction, the court shall suspend such person's privilege to operate a motor vehicle for one year.

(d) Nothing in this section shall limit a court in imposing penalties, conditions or restrictions authorized by any other statute arising from the same occurrence in addition to penalties and suspensions imposed under this section.

History: L. 1983, ch. 27, § 1; L. 1994, ch. 353, § 8; L. 2009, ch. 34, § 7; Jan. 1, 2010.

Appendix G - Crash Frequencies and ORs of 15-Year-Old Drivers

Table G.1 Crashes Involving 15-Year-Old Drivers by Year: Driver Related Characteristics

Driver Related Characteristics	*Number of Crashes Involving Drivers*								(2010 & 2011) versus (2009 & 2008)			2009 versus 2011		
	2008	*%*	*2009*	*%*	*2010*	*%*	*2011*	*%*	ORs	95% CI Lower	95% CI Upper	**ORs**	95% CI Lower	95% CI Upper
Gender														
Female	436	46.0	341	46.3	336	47.5	296	46.6	1.04	0.90	1.20	**1.01**	0.82	1.25
Male	512	54.0	392	53.3	369	52.2	338	53.2	0.92	0.98	1.01	**0.99**	0.98	1.01
License Compliance														
Valid licensed	832	87.8	573	77.9	459	64.9	388	61.1	0.34	0.29	0.40	**0.45**	0.35	0.57
Not licensed	108	11.4	152	20.7	230	32.5	227	35.7	2.83	2.38	3.37	**2.14**	1.68	2.72
Restriction Compliance														
Not a restricted license	183	19.3	151	20.5	109	15.4	116	18.3	0.81	0.68	0.98	**0.87**	0.66	1.13
Restricted license	660	69.6	497	67.5	516	73.0	430	67.7	1.09	0.93	1.27	**1.01**	0.80	1.27
Safety Equipment used														
Safety belt used	827	87.2	665	90.4	638	90.2	572	90.1	1.18	0.93	1.49	**0.97**	0.68	1.39
Safety belt not used	49	5.2	35	4.8	30	4.2	25	3.9	0.81	0.58	1.15	**0.82**	0.49	1.39
Airbag														
Airbag deployed	49	5.2	24	3.3	33	4.7	30	4.7	1.09	0.77	1.54	**1.47**	0.85	2.55
Airbag not deployed	856	90.3	678	92.1	584	82.6	584	92.0	1.11	0.85	1.43	**0.98**	0.66	1.45
Alcohol Flag														
no alcohol flag	12	1.3	8	1.1	3	0.4	7	1.1	1.60	0.75	3.43	**1.01**	0.37	2.81
drivers with alcohol flag	936	98.7	728	98.9	704	99.6	628	98.9	0.63	0.29	1.34	**0.99**	0.36	2.73

Table G.2 Crashes Involving 15-Year-Old Drivers by Year: Environmental Related Characteristics

Environmental Related Characteristic	*Number of Crashes Involving Drivers*								(2010 & 2011) versus (2009 & 2008)			2009 versus 2011		
	2008	*%*	*2009*	*%*	*2010*	*%*	*2011*	*%*	ORs	95% CI Lower	95% CI Upper	**ORs**	95% CI Lower	95% CI Upper
Light Condition														
Daylight	775	81.8	592	80.4	566	80.1	515	81.1	0.96	0.80	1.15	**1.04**	0.80	1.37
Dark	173	18.2	144	19.6	139	19.7	118	18.6	1.02	0.85	1.23	**0.94**	0.72	1.23
Weather Condition														
Normal conditions	810	85.4	639	86.8	622	88.0	578	91.0	1.37	1.10	1.71	**1.54**	1.09	2.18
Adverse conditions	132	13.9	97	13.2	80	11.3	53	8.3	0.70	0.56	0.88	**0.60**	0.42	0.85
Functional Class														
Rural roads	392	41.4	318	43.2	314	44.4	299	47.1	1.15	1.00	1.33	**1.17**	0.95	1.45
Urban roads	555	58.5	418	56.8	392	55.4	330	52.0	0.85	0.74	0.98	**0.82**	0.67	1.02
Construction/Maintenance Zone														
Work zone	20	2.1	9	1.2	10	1.4	9	1.4	0.82	0.46	1.47	**1.16**	0.46	2.95
No work zone	928	97.9	718	97.6	692	97.9	625	98.4	1.22	0.73	2.21	**1.57**	0.72	3.42
Time of Crash														
5.00-9.00-Morning	182	19.2	132	17.9	150	21.2	138	21.7	1.19	1.00	1.43	**1.27**	0.97	1.66
9.00-13.00-Noon	445	46.9	308	41.8	301	42.6	287	45.2	0.96	0.84	1.11	**1.15**	0.93	1.42
13.00-17.00-Afternoon	110	11.6	82	11.1	69	9.8	77	12.1	0.95	0.76	1.19	**1.10**	0.79	1.53
17.00-21.00-Evening	222	23.4	227	30.8	179	25.3	137	21.6	0.85	0.72	1.00	**0.62**	0.48	0.79
21.00-5.00-Night	99	10.4	69	9.4	77	10.9	73	11.5	1.14	0.90	1.43	**1.26**	0.89	1.78
Day of Week														
Week days	757	79.9	613	83.3	588	83.2	507	79.8	1.02	0.85	1.22	**0.80**	0.60	1.05
Week end	191	20.1	123	16.7	119	16.8	128	20.2	0.98	0.82	1.18	**1.26**	0.96	1.66

Table G.3 Crashes Involving 15-Year-Old Drivers by Year: Road Related Characteristics

Road Related Characteristic	*Number of Crashes Involving Drivers*								(2010 & 2011) versus (2009 & 2008)			2009 versus 2011		
	2008	*%*	*2009*	*%*	*2010*	*%*	*2011*	*%*	ORs	95% CI		**ORs**	95% CI	
										Lower	Upper		Lower	Upper
Crash Location														
On roadway	354	37.3	281	38.2	344	48.7	329	51.8	1.69	1.46	1.96	**1.76**	1.42	2.19
Intersection	396	41.8	322	43.8	301	42.6	220	34.6	0.85	0.74	0.99	**0.68**	0.55	0.85
Off roadway	197	20.8	132	17.9	60	8.5	84	13.2	0.50	0.40	0.61	**0.70**	0.52	0.94
Road Surface Type														
Concrete	195	20.6	138	18.8	129	18.2	107	16.9	0.87	0.72	1.04	**0.88**	0.67	1.16
Black top	611	64.5	456	62.0	456	64.5	386	60.8	0.97	0.84	1.13	**0.95**	0.77	1.18
Gravel/brick or other	139	14.7	139	18.9	117	16.5	139	21.9	1.19	0.99	1.44	**1.20**	0.93	1.57
Road Surface Condition														
Dry	764	80.6	599	81.4	589	83.3	551	86.8	1.33	1.10	1.61	**1.50**	1.12	2.02
Wet	124	13.1	83	11.3	70	9.9	46	7.2	0.68	0.53	0.86	**0.61**	0.42	0.90
Debris	55	5.8	49	6.7	43	6.1	34	5.4	0.93	0.68	1.25	**0.79**	0.51	1.25
Road Surface Character														
Straight and level	693	73.1	531	72.1	518	73.3	455	71.7	0.92	0.76	1.10	**0.98**	0.77	1.24
Straight not level	181	19.1	132	17.9	125	17.7	107	16.9	1.20	0.92	1.55	**0.93**	0.70	1.23
Curved	65	6.9	65	8.8	57	8.1	65	10.2	1.20	0.92	1.55	**1.18**	0.82	1.69
Posted Speed Limit														
Less than 35 mph	373	39.3	300	40.8	309	43.7	261	41.1	1.11	0.96	1.28	**1.01**	0.82	1.26
35-60 mph	519	54.7	398	54.1	354	50.1	329	51.8	0.87	0.75	1.00	**0.91**	0.74	1.13
More than 60 mph	56	5.9	38	5.2	44	6.2	45	7.1	1.20	0.89	1.62	**1.40**	0.90	2.19

Table G.4 Crashes Involving 15-Year-Old Drivers by Year: Vehicle Related Characteristics

Vehicle Related Characteristic	*Number of Crashes Involving Drivers*								(2010 & 2011) versus (2009 & 2008)			2009 versus 2011		
	2008	*%*	*2009*	*%*	*2010*	*%*	*2011*	*%*	ORs	95% CI		**ORs**	95% CI	
										Lower	Upper		Lower	Upper
Vehicle Body Type														
Automobile	535	56.4	399	54.2	395	55.9	347	54.6	1.02	0.88	1.18	**1.02**	0.82	1.26
Van	39	4.1	29	3.9	22	3.1	23	3.6	0.83	0.56	1.21	**0.92**	0.53	1.60
Pickup-truck, camper-rv	202	21.3	170	23.1	170	24.0	150	23.6	1.11	0.93	1.31	**1.03**	0.80	1.32
Sport utility vehicle	182	19.2	138	18.8	120	17.0	115	18.1	0.91	0.75	1.09	**0.96**	0.73	1.26
Vehicle Age														
Year 4 or newer	133	14.0	88	12.0	84	11.9	71	11.2	0.91	0.72	1.15	**0.93**	0.67	1.29
5-9 years	416	43.9	286	38.9	259	36.6	239	37.6	0.86	0.74	1.00	**0.95**	0.76	1.18
10-14 years	342	36.1	303	41.2	275	38.9	263	41.4	1.02	0.88	1.18	**1.01**	0.81	1.25
Year 15 or older	142	15.0	121	16.4	134	19.0	109	17.2	1.20	1.00	1.44	**1.05**	0.79	1.40
Number of Occupants														
Only driver	584	61.6	449	61.0	438	62.0	383	60.3	0.99	0.86	1.15	**0.97**	0.78	1.21
Driver and passengers	364	38.4	285	38.7	263	37.2	247	38.9	0.98	0.84	1.13	**1.01**	0.81	1.25
Teen Passengers														
No	800	84.4	626	85.1	618	87.4	551	86.8	1.22	0.99	1.51	**1.15**	0.85	1.57
Yes	148	15.6	110	14.9	89	12.6	84	13.2	0.82	0.67	1.01	**0.87**	0.64	1.18

Table G.5 Crashes Involving 15-Year-Old Drivers by Year: Crash Related Characteristics

Crash Related Characteristic	*Number of Crashes Involving Drivers*								(2010 & 2011) versus (2009 & 2008)			2009 versus 2011		
	2008	*%*	*2009*	*%*	*2010*	*%*	*2011*	*%*	ORs	95% CI Lower	95% CI Upper	**ORs**	95% CI Lower	95% CI Upper
Injury Severity														
Fatal injury	754	79.5	591	80.3	561	79.3	519	81.7	0.41	0.04	3.96	**0.58**	0.05	6.36
Disabled injury	61	6.4	59	8.0	56	7.9	51	8.0	0.99	0.46	2.12	**0.29**	0.06	1.35
Injury	79	8.3	58	7.9	63	8.9	50	7.9	1.02	0.79	1.32	**0.99**	0.67	1.47
Possible injury	7	0.7	8	1.1	10	1.4	2	0.3	1.11	0.85	1.46	**1.00**	0.67	1.47
Not injured	1	0.1	2	0.3	0	0.0	1	0.2	0.95	0.78	1.15	**1.07**	0.81	1.43
Ejection														
Ejected	11	1.2	3	0.4	3	0.4	5	0.8	0.72	0.30	1.71	**1.94**	0.46	8.15
Not ejected	89	9.4	712	96.7	682	96.5	617	97.2	1.57	1.08	2.28	**1.15**	0.62	2.15
Trapped	7	0.7	7	1.0	10	1.4	4	0.6	1.26	0.60	2.65	**0.66**	0.19	2.27
Vehicle Damage														
Not damage	25	2.6	18	2.4	5	0.7	9	1.4	0.40	0.22	0.74	**0.57**	0.26	1.29
Minor damage	217	22.9	169	23.0	178	25.2	151	23.8	1.09	0.92	1.29	**1.05**	0.82	1.35
Functional	281	29.6	219	29.8	207	29.3	184	29.0	0.97	0.83	1.14	**0.96**	0.76	1.22
Disabling	303	32.0	259	35.2	236	33.4	208	32.8	0.99	0.85	1.15	**0.90**	0.72	1.12
Destroyed	115	12.1	62	8.4	71	10.0	72	11.3	1.02	0.80	1.28	**1.39**	0.97	1.99
Vehicle Maneuver Before Un-stabilized Situation														
Straight-following road	565	59.6	414	56.3	396	56.0	355	55.9	0.92	0.79	1.06	**0.99**	0.80	1.22
Turn or changing lanes	208	21.9	170	23.1	158	22.3	123	19.4	0.92	0.77	1.09	**0.80**	0.62	1.04
Avoiding maneuver	36	3.8	28	3.8	33	4.7	43	6.8	1.52	1.08	2.14	**1.84**	1.13	2.99
Stopped, parking or backing	129	13.6	106	14.4	106	15.0	103	16.2	1.14	0.93	1.39	**1.15**	0.86	1.55
Accident Class														
Collision with vehicle	673	71.0	509	69.2	501	70.9	421	66.3	0.93	0.80	1.09	**0.88**	0.70	1.10
Collision with object	174	18.4	129	17.5	123	17.4	143	22.5	1.13	0.94	1.35	**1.06**	0.57	1.95
Collision with animal	15	1.6	22	3.0	17	2.4	20	3.1	1.26	0.80	2.00	**1.37**	1.05	1.78
Collision with pedestrian	7	0.7	5	0.7	3	0.4	4	0.6	0.73	0.29	1.86	**0.93**	0.25	3.47
Non-collision & overturned	79	8.3	69	9.4	62	8.8	45	7.1	0.90	0.69	1.17	**0.74**	0.50	1.09
Manner of Collision														
Head on	21	2.2	13	1.8	25	3.5	21	3.3	1.72	1.10	2.70	**1.90**	0.95	3.83
Rear end	251	26.5	188	25.5	196	27.7	153	24.1	1.00	0.85	1.17	**0.93**	0.72	1.18
Angle side impact	269	28.4	198	26.9	207	29.3	162	25.5	0.99	0.84	1.16	**0.93**	0.73	1.19
Sideswipe	57	6.0	53	7.2	45	6.4	29	4.6	0.84	0.62	1.13	**0.62**	0.39	0.98
Backed into	12	1.3	16	2.2	18	2.5	22	3.5	1.82	1.12	2.96	**1.61**	0.84	3.10

Table G.6 Crashes Involving 15-Year-Old Drivers by Year: Contributory Causes

Contributory Causes	*Number of Crashes Involving Drivers*								(2010 & 2011) versus (2009 & 2008)			2009 versus 2011		
										95% CI			95% CI	
	2008	*%*	*2009*	*%*	*2010*	*%*	*2011*	*%*	ORs	Lower	Upper	**ORs**	Lower	Upper
Driver Action Related														
Speeding	149	15.7	111	15.1	110	15.6	103	16.2	1.03	0.85	1.26	**1.09**	0.81	1.46
Failure to yield right of way	92	9.7	66	9.0	73	10.3	48	7.6	0.96	0.75	1.23	**0.83**	0.56	1.22
Disregarded traffic signs/signals	41	4.3	38	5.2	32	4.5	32	5.0	1.02	0.73	1.43	**0.98**	0.60	1.58
Turning or lane changing	28	3.0	17	2.3	21	3.0	14	2.2	0.98	0.62	1.53	**0.95**	0.47	1.95
Improper action	23	2.4	20	2.7	18	2.5	19	3.0	1.08	0.69	1.69	**1.11**	0.58	2.09
Aggressive driving	21	2.2	17	2.3	12	1.7	17	2.7	0.96	0.59	1.56	**1.16**	0.59	2.30
Avoidance/ evasive or slow	20	2.1	26	3.5	19	2.7	23	3.6	1.15	0.75	1.76	**1.03**	0.58	1.82
Driver Condition Related														
Alcohol impaired	40	4.2	19	2.6	23	3.3	27	4.3	1.07	0.73	1.57	**1.68**	0.92	3.04
Ill, falling asleep or fatigued	7	0.7	10	1.4	19	2.7	6	0.9	1.86	1.00	3.46	**0.69**	0.25	1.92
Driver Distractions Related														
Inattention	234	24.7	178	24.2	111	15.7	121	19.1	0.65	0.54	0.77	**0.74**	0.57	0.96
In vehicle distraction	18	1.9	21	2.9	29	4.1	24	3.8	1.73	1.14	2.64	**1.34**	0.74	2.43
Environmental Related														
Animal	44	4.6	28	3.8	44	6.2	26	4.1	1.23	0.88	1.73	**1.08**	0.63	1.86
Weather related	36	3.8	30	4.1	32	4.5	27	4.3	1.13	0.79	1.62	**1.05**	0.61	1.78
Vision obstruction	9	0.9	5	0.7	9	1.3	7	1.1	1.44	0.70	2.96	**1.63**	0.51	5.16