FACTORS AFFECTING MOTORCYCLE FATALITIES IN KANSAS

by

MOHAMMAD SAAD B. SHAHEED

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Major Professor
Sunanda Dissanayake

Abstract

Over the past few years, motorcycle fatalities have increased at an alarming rate in the United States. Motorcycle safety issues in Kansas are no different from the national scenario. Accordingly, this study attempted to investigate motorcycle crashes in Kansas to identify critical characteristics and to evaluate the effect of those on motorcycle crash injury outcomes.

State-level motorcycle rider fatality rates were investigated while considering various factors including helmet laws, using generalized least squares regression modeling. A detailed characteristic analysis was carried out for motorcycle crashes, using Kansas crash data. Comparisons were made between several aspects of motorcycle crashes and other vehicle crashes. Analysis using Logistic regression was performed on Kansas motorcycle crash data to identify factor affecting fatal motorcycle crashes. In addition, a survey was conducted focusing on identifying motorcycle rider behaviors, helmet usage patterns, perception towards helmet laws in Kansas, potential problems, crash contributory factors, and difficulty levels of different motorcycle maneuvers to execute. Ordered probit modeling was used to identity factors contributing to increased severity of Kansas motorcycle riders involved in crashes.

Results from state-level modeling showed statistically significant relationships between motorcycle fatality rates in a given state as well as several other factors. These factors included weather-related conditions, helmet laws, per capita income, highway mileage of rural roads, population density, education, demographic distributions, and motorcycle registrations in the state. The study showed that states with mandatory helmet laws had 5.6% fewer motorcycle fatalities per 10,000 registrations and 7.85% fewer motorcycle fatalities per 100,000 populations. Characteristic analysis of motorcycle crashes in Kansas revealed that motorcycle maneuvers such as overtaking, motorcyclists being older than 40 years, using motorcycle helmets, using

motorcycle helmets and eye protection simultaneously, daytime riding, crashes occurring on roadside shoulders, and influence of alcohol among the riders during crashes had higher risk of ending up as a fatal motorcycle crash in Kansas. Results from the survey conducted among motorcycle riders in Kansas revealed that 71% of respondents thought drivers of other vehicles were the single biggest threat to their own safety. Survey results also revealed that 64% of respondents opposed a mandatory law requiring motorcycle riders and passengers to wear helmets in Kansas. Result from the ordered probit modeling of motorcycle rider injury severity showed that overturned and fixed-object motorcycle crashes, helmet use, younger motorcycle riders, speeding, presence of alcohol among motorcycle riders, and good weather contributed to increased severity of injury of motorcycle riders involved in crashes in Kansas.

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Finally, I wish to express my sincere respect to my parents and siblings for their continuous support and blessings that helped me to be what I am today.

Dedication

This thesis is dedicated to my mother, **Mrs. Umme Salma,** and my father, **Mr. Ebney Hyder Mohammad Shaheed**, for their endless support.

Preface

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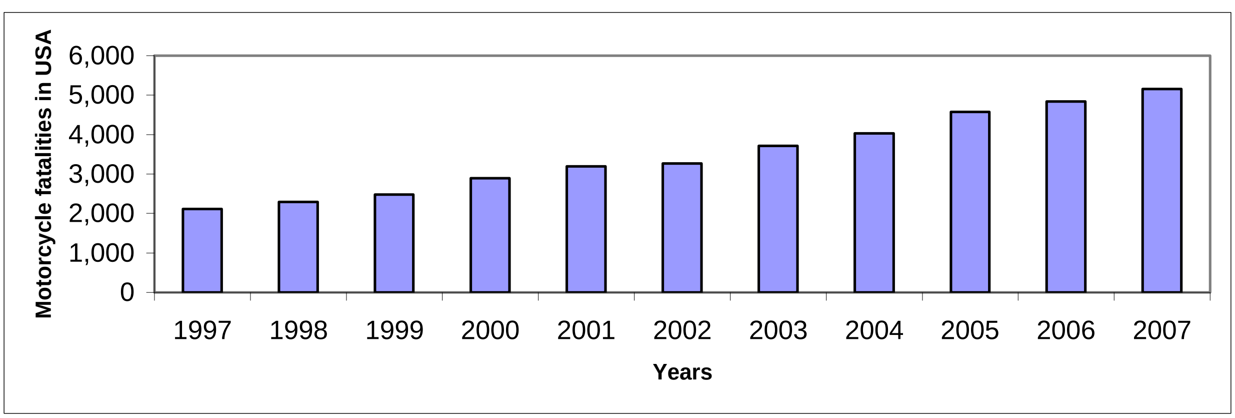
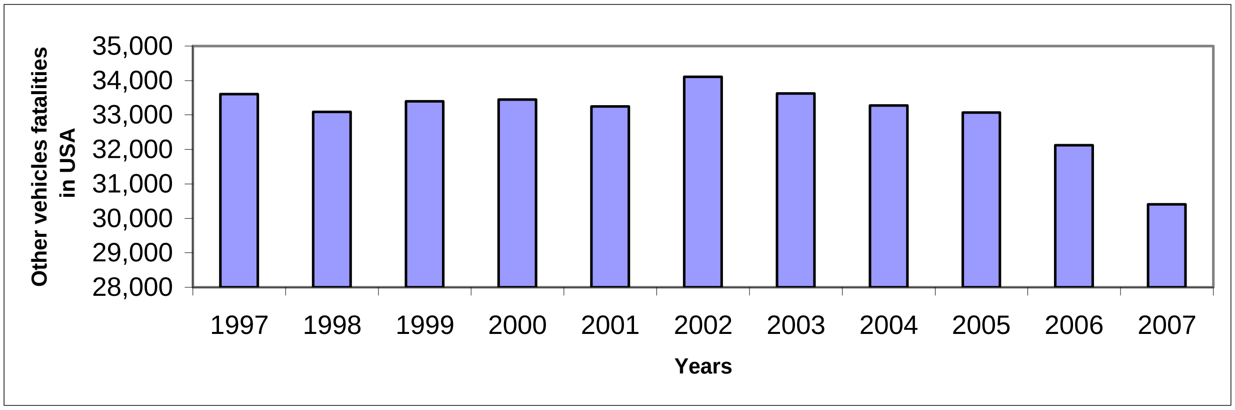
Chapter 1 - Introduction

1.1 Background

An estimated 148,000 motorcyclists have died in traffic crashes since enactment of the Highway and National Traffic and Motor Vehicle Safety Act of 1966 according to the National Highway Traffic Safety Administration (1). The aim of this act was to reduce traffic crashes as well as the number of fatalities and injuries to persons involved in traffic crashes. Motorcycles made up of nearly 3 % of all registered vehicles in the United States in 2008 and accounted for only 0.4 % of all vehicles miles traveled (1). However, motorcycle fatalities in 2008 accounted for 14% of total traffic fatalities in the United States compared to 5.92% in 1997. The Number of motorcycle fatalities in the U. S. increased 150% from 2,116 in 1997 to 5,290 in 2008 (1). During the same period, passenger car and light truck fatality rates decreased by 26.74% and 13.54% respectively. Considering per vehicle miles traveled in 2008, motorcyclists were 37 % more likely than drivers of passenger cars to die in a motor vehicle crash and nine times more likely to be injured (1). Figures 1.1 and 1.2 show the trend in motorcycle and non-motorcycle fatalities in the United States for the 10-year period from 1997 to 2007.



(Source: Traffic Safety Facts: 2008, NHTSA)
Figure 1.1 Trend in Motorcycle Fatalities in the U.S., 1997-2007



(Source: Traffic Safety Facts: 2008, NHTSA)

Figure 1.2 Trend in Other Vehicle Fatalities in the U.S., 1997-2007

Kansas shows a similar trend as the U.S. in motorcycle fatalities. While some highway safety improvements have been achieved in certain categories, number and percentage of motorcycle crashes in Kansas have increased significantly. For example, in 2008, the number of motorcycle crashes as a percentage of total crashes was only about 1.7% but motorcycle crashes accounted for 12.6% of all fatal crashes, indicating motorcycle riders are more vulnerable than other road users. Table 1.1 depicts the trend of motorcycle crashes in Kansas from 2000 to 2008.

Table 1.1 Motorcycle Crash Scenario in Kansas, 2000-2008

Year	All Crashes	All fatal Crashes	All Motorcycle Crashes		Fatal Motorcycle Crashes	
	Number	Number	Number	% of all crashes	Number	% of all fatal crashes
2000	78,241	656	700	0.9	21	3.2
2001	78,856	643	762	1	27	4.2
2002	78,314	690	819	1	29	4.2
2003	75,009	604	857	1.1	32	5.3
2004	74,117	392	988	1.3	31	7.9
2005	68,740	384	1,041	1.5	33	8.6
2006	65,460	468	1,103	1.7	58	12.4
2007	70,589	379	1,110	1.6	47	12.4
2008	65,788	349	1,138	1.7	44	12.6

(Source: Kansas Traffic Crash Facts)

Figure 1.3 depicts the trend of motorcycle fatal crashes and injury crashes in Kansas from 1997 to 2008. The figure shows motorcycle fatal crashes reached their peak during 2006 before decreasing slightly in the following year. But motorcycle injury crashes increased almost consistently during the time period.

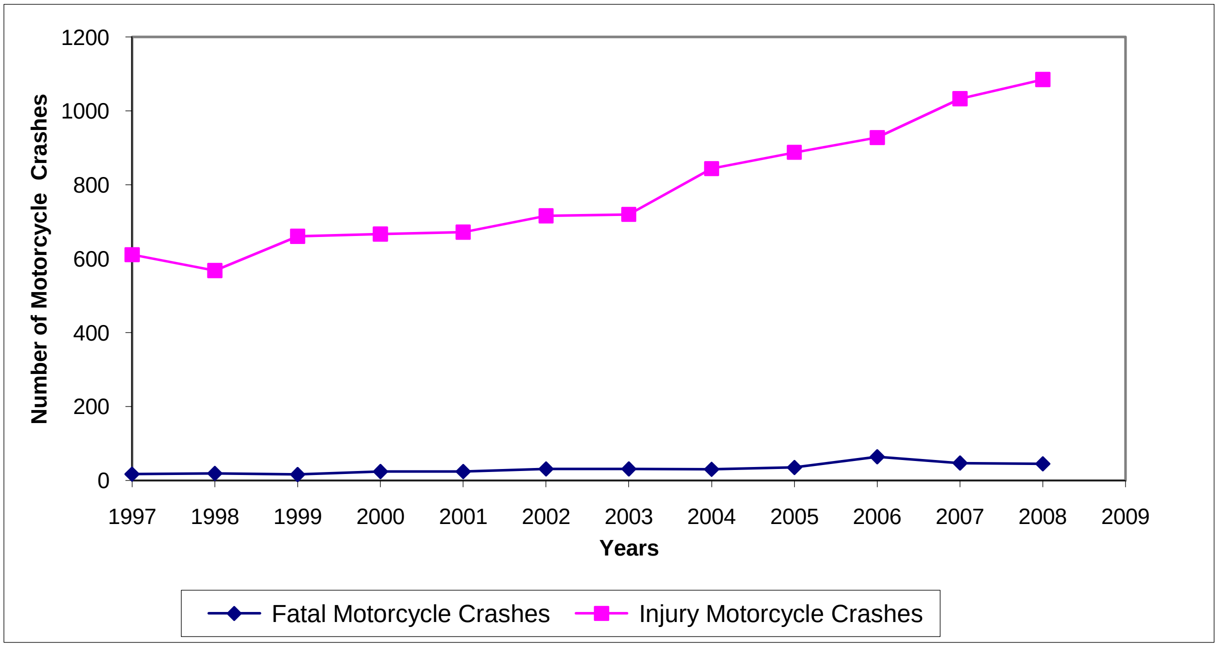


Figure 1.3 Trend of Motorcycle Fatal and Injury Crashes in Kansas, 1997-2008

One area of immediate attention in terms of motorcycle safety is use of helmets. Motorcycle helmet laws in the United States vary significantly among the states. By the end of 2008, there were 20 states with mandatory helmet laws, 27 states with partial helmet laws and 3 states with no helmet laws at all (2). In Kansas, the law requires only those riders under 18 years to wear a helmet that complies with minimum federal safety standards. In 2008, only 39% of Kansas motorcycle riders involved in crashes were wearing helmets, but only 26% motorcycle riders fatally injured were wearing helmets (2). Figures 1.4 and 1.5 depict the Kansas motorcycle riders' fatalities and injuries based on helmet use during motorcycle crashes from 1997 to 2008.

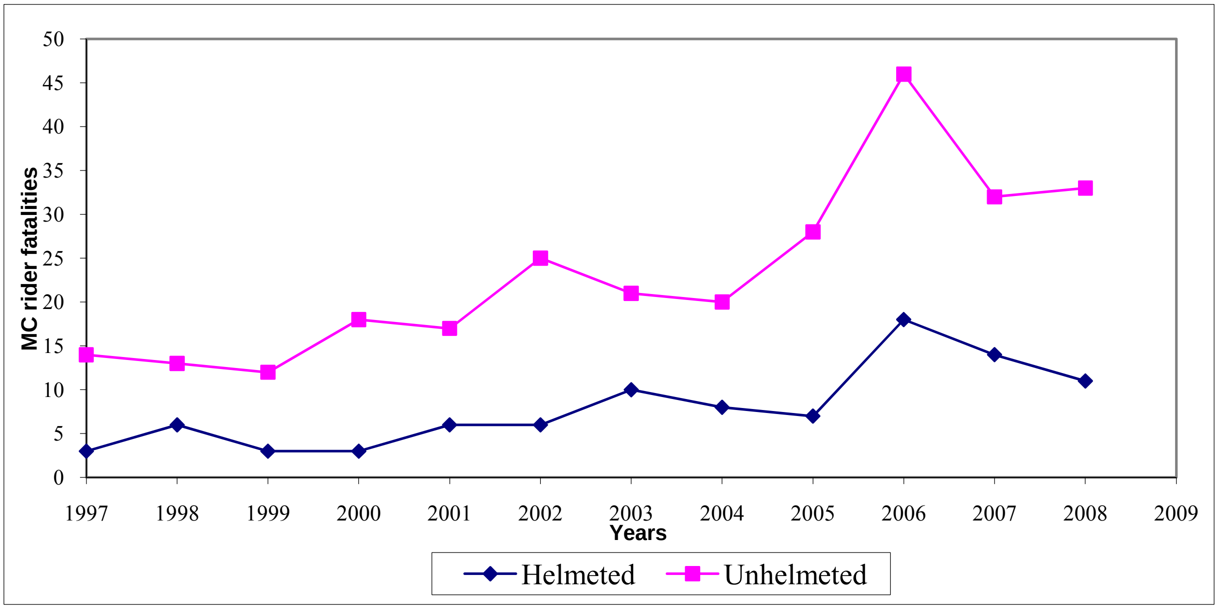


Figure 1.4 Kansas Motorcycle Rider Fatalities (Helmeted and Unhelmeted), 1997-2008

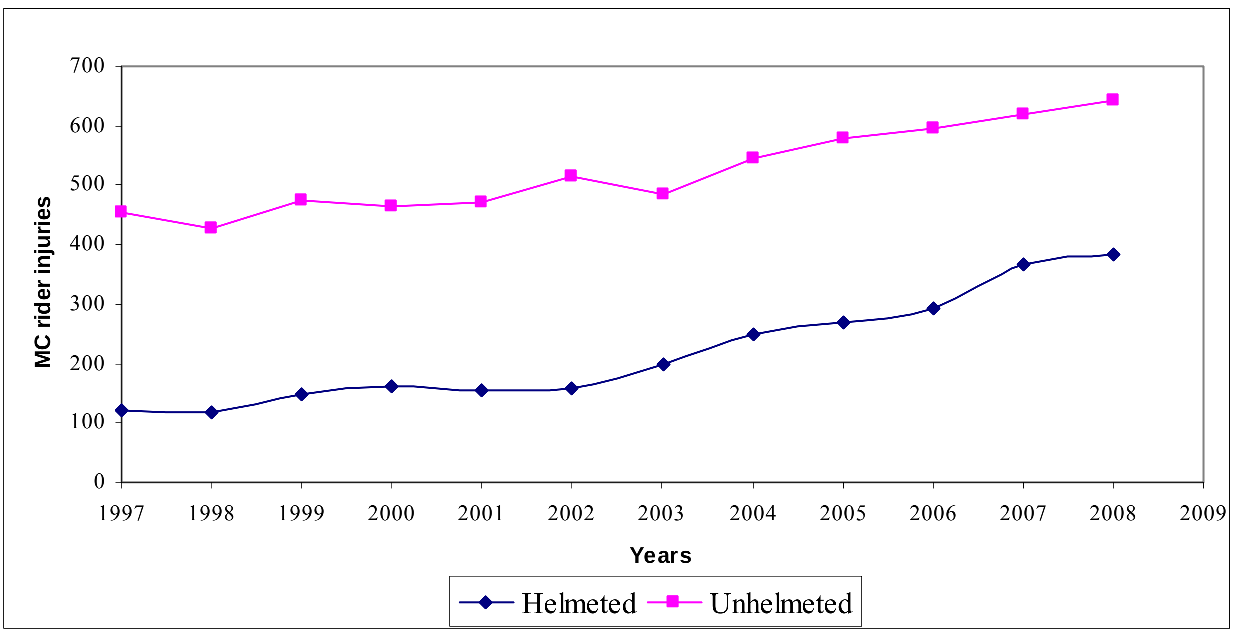


Figure 1.5 Kansas Motorcycle Rider Injuries (Helmeted and Unhelmeted), 1997-2008

By considering Figures 1.4 and 1.5, it is evident unhelmeted motorcycle riders had more fatalities compared to helmeted riders. Data to generate Figures 1.4 and 1.5 are provided in Appendix A. Opponents of mandatory helmet laws, however, have suggested that although effective in reducing injuries, helmets may increase a rider's risk of crashing by interfering with the ability to see and hear surrounding traffic.

1.2 Problem Statement

Motorcycle registrations in the United States have grown each of the past 10 years; from 3,850,000 registrations in 1997 to 6,700,000 registrations in 2006, a 75% increase overall (3). Sales of new street-legal motorcycles grew even more sharply over the same period, from 260,000 in 1997 to 892,000 in 2006 (a 243% increase), but declined slightly to 885,000 in 2007 (3). Consequently, there has been an increase in the number of motorcycle riders as well. It is evident that as the roadways are getting safer for other vehicles, motorcyclists are becoming the vulnerable group which needs immediate attention to improve its safety. This is also true for Kansas. The number of fatal motorcycle crashes as a percentage of all fatal crashes in Kansas remains high. It is important to combat preventable motorcycle fatalities and injuries in Kansas by identifying causes of motorcycle crashes and providing motorcycle awareness information to both motorcyclists and other motorists on Kansas' roadways.

If Kansas is to keep reducing total fatalities and achieve the goals of the Kansas Highway Safety Plan (i.e. to reduce number of fatalities to less than 400 by 2008 and less than 365 by 2010), it is extremely important to look at motorcycle crashes and identify characteristics of problem areas so that motorcycle safety can be improved. Accordingly, this study proposes to investigate characteristics of motorcycle crashes in Kansas, with the intention of identifying critical areas and issues. In addition, other critical matters, such as causes of motorcycle crashes and comments and experiences of Kansas motorcycle riders, will be sought. The relationship between motorcycle injury outcome and helmet usage in Kansas will also be examined in this study.

1.3 Objectives

The main objectives of this study were to investigate characteristics of motorcycle crashes in Kansas in order to identify critical characteristics and evaluate the effect of helmet use and other factors on motorcycle crash injury outcomes. Statistical models were developed to predict state-level motorcycle safety parameters, while taking other factors into account. Analysis of all motorcycle crash data in Kansas was performed over a reasonable period of time. Relations between the outcome of Kansas motorcycle crashes and many other contributory factors were revealed through statistical analysis over recent years. A survey among Kansas motorcycle riders was conducted to determine personal and other related factors associated with the decision-making process related to use of helmets. This project would identify factors that contribute to increased severity of motorcycle crashes and concerns that motorcyclists have regarding wearing helmets, thereby evaluating the overall motorcycle safety situation in Kansas.

1.4 Outline of the Thesis

This thesis is divided into five chapters. The first chapter covers a brief introduction about the motorcycle safety situation and motorcycle crashes, problem statement, study objective, and outline of the thesis. Chapter 2 covers the review of literature on helmet use and its effectiveness, factors related to motorcycle fatalities, motorcycle crash types and trends, and statistical methodologies. Chapter 3 describes the analysis methodologies and data used for the current studies. Chapter 4 presents results and discussions of analyses. Finally, chapter 5 presents the conclusions and recommendations based on the present study.

Chapter 2 - Literature Review

Motorcycle-safety related studies in the past addressed helmet use, helmet-use laws in different states, effects of helmet use on motorcycle crash outcomes, factors related to motorcycle fatalities, and injuries, using a variety of databases. Past researchers have used various statistical modeling techniques to predict or explain the nature of motorcycle crashes or injuries. Furthermore, different types of motorcycle crashes have been examined by these studies, narrowing them down to identify more specific factors related to selected states. In this chapter, an extensive discussion of past findings is presented under the following subsections: helmet use, helmet-use laws and their effectiveness, factors related to motorcycle crashes, and statistical methodologies.

2.1 Helmet Use, Helmet-Use Laws and Their Effectiveness

Branas and Knudson investigated motorcycle rider fatality rates between states with mandatory motorcycle helmet laws and those without the laws (4). Competing influences of variables such as population density, weather conditions, alcohol consumption, maximum speed limit, urban vs. rural roads, motorcycle engine size, and age of the motorcycle riders were analyzed on the fatality rates of motorcyclists. Bivariate analyses demonstrated that states with motorcycle helmet laws have significantly higher fatality rates per 10000 registered motorcycles compared to states without helmet laws. After simultaneously adjusting for other factors using multivariate regression models, fatality rates in states with mandatory motorcycle helmet laws were shown to be lower than those of states without helmet laws.

Peek-Asa et al. examined the prevalence of non-standard helmet use among motorcycle riders following introduction of a mandatory helmet law and the prevalence of head injuries among a sample of non-standard helmet users involved in motorcycle crashes (5). Among the injured riders examined in 1992, exactly one-third, whose crash reports indicated non-standard helmet use, had 15.5% fatalities of non-helmeted riders compared to 13.6 % of helmeted riders. Among the riders wearing non-standard helmets, 75% sustained head injuries of any severity which was significantly greater than riders not wearing a helmet, of which 51.9% had any injuries. Average head injury severity for riders identified as wearing non-standard helmets was 2.65, which was significantly higher than 1.56 for riders not wearing helmets and 0.96 for riders wearing standard helmets.

Results of surveys conducted by Williams et al. indicated when helmet use is legally required of all motorcyclists, nearly 100% wear helmets (6). Helmet-use rates were substantially lower when use is not required of any motorcyclists, or when helmet-use laws covering all motorcyclists are amended so that only those under age of 18 years are covered. Amending helmet-use laws so that only young motorcyclists are required to wear helmets appears to have little impact on user rates. Overall helmet-use rate in New Orleans, Louisiana, Phoenix, Arizona, and Texas, where such laws existed, was 48%, similar to the use rate in Los Angeles, California (46%), where such helmet use is not required of any motorcyclists.

An analysis by Mayrose showed that from 1995-2003, mandatory helmet law states had a 22.3% rise in total fatalities, with a 3% increase in helmet use among fatally injured riders in these states (7). Partial-law states had a 32.9% increase in total motorcycle fatalities with a 1.2% increase in helmet use, while the three other states with no helmets law at all had a 21.78% increase in total motorcycle fatalities with only a 2% increase in helmet use. The increase in fatalities can be attributed to an increased number of motorcyclists on the road over this time period. It was found that motorcyclists are more likely to wear helmets in states with mandatory helmet laws than their counterparts in states with only partial helmet laws or no laws at all.

Rutledge et al. studied the association of helmet use with the outcome of motorcycle crashes, controlling for severity of the crash as measured by a modified injury severity score that excluded head injury (8). Risk of head injuries was found to be nearly twice as high in unhelmeted riders. This study illustrated the increased likelihood of head injury when a helmet is not worn, but also showed helmet use is not a significant factoring determining morbidity rates, hospital charges, and length of stay. There were, however, some unanticipated findings in the study. There were no significant differences in overall mortality, mean trauma scores, mean hospital stays, mean hospital charges, or percentage of cases discharged to rehabilitation facilities between helmeted and unhelmeted patients.

Wilson found that although effectiveness of helmet use depends on many factors (e.g. driver age, speed, crash direction), and the matched-pairs technique has limitations in assessing effectiveness, motorcycle helmets are estimated to be 29% effective in preventing motorcycle rider fatalities (9). Further, although motorcycle helmets saved an estimated 670 lives in 1987, they could have prevented an additional 693 fatalities if 100% of motorcycle riders wore helmets. In examining the data, it was evident there is a consistency in helmet usage patterns between the rider and the passenger, such that when the rider is helmeted so tends to be the passenger. This is also true when the rider is unhelmeted.

Fatalities suffered by motorcyclists 15-20 years of age for the 50 states and Washington D.C over the years 1975-2004 was examined by Houston (10). Two-way, fixed-effects models were estimated using negative binomial regression. After controlling for other state policy and demographic variables likely related to occurrence of these fatalities, it was found that mandatory helmet laws are quite effective at reducing young motorcyclist fatalities. A 31% reduction in fatality rates experienced by motorcyclists 15-20 years of age is attributable to the presence of a law mandating that all riders wear a helmet. In contrast, partial-coverage helmet laws are not statistically related to changes in fatalities. Even partial-coverage laws that require all motorcyclists 15-20 years of age to wear a helmet provide no apparent safety benefits to this target population. These findings are consistent with the argument that partial-coverage helmet laws are difficult to enforce and that these laws reduce the motive of fear that leads individuals to obey the law.

Results of the study performed by McKnight indicated that wearing helmets did not restrict the ability to hear horn signals nor did it have an appreciable effect upon likelihood of visually detecting a vehicle in an adjacent lane prior to initiating a lane change (11). Wearing of helmets did result in increase of head rotation that did not result in any increase in the time that gaze was diverted from straight ahead. With respect to hearing, differences in hearing thresholds across helmet conditions were not only nonsignificant, but also nonexistent. Significant increased in the hearing threshold with increased vehicle speed strongly suggests the experimental procedure was capable of detecting true effects upon ability to hear. While helmets did not appear to degrade hearing, neither did they enhance it. The extent of head rotation seemed to be greatest among riders with the least experience, those who thought helmets restricted vision, and those who believed the helmet was a good thing.

Evans and Frick found three factors associated with lower fatality risk to motorcycle riders, in all three cases the reduction in fatality risk being about 30 % (12). Wearing a helmet compared to not wearing one, being a passenger rather than being a driver, and being male rather than female were the three factors. The result depended on the assumptions on which the double-pair comparison method rests; in particular, on the assumption that effectiveness of helmets for drivers travelling accompanied by passengers is sufficiently similar to the effectiveness for drivers travelling alone. The main finding of the study was that helmet use reduced fatality risk to motorcycle drivers and passengers by (28±8) %. Information for female passengers indicated that a female passenger is 5.5% less likely to be killed than a male driver. Results indicated that female passengers are 33.3% more likely to be killed than are male passengers of the same age.

Gilbert et al. conducted multiple logistic regression analyses to explore helmet use and injury levels after law changes to before law changes (13). Given the association between helmet use and injury status, two separate models were produced to show the effect of each on the outcome of pre- and post-law status. These analyses included the ability to account for, and mathematically remove, effects of other potentially confounding variables. There were no significant effects of gender or race in either model. The logistic regression showed a strong positive effect of helmet use post-law reinstatement. Odds of wearing a helmet in a crash post-law reinstatement were 11.7 times greater in comparison to wearing a helmet during the pre-law time period ($p < 0.001$).

Using cross-sectional time data for the 50 states and Washington, D.C., covering the period 1975-2004, Houston and Richardson estimated fixed-effects regression models that examined the effects of mandatory and partial helmet laws on three different motorcyclist fatality rates (14). These fatality rates were fatalities per 10,000 registered motorcycles, fatalities per 100,000 population, and fatalities per 10 billion VMT. Regardless of what fatality rate measure was used, it was found that mandatory helmet laws were correlated with a substantial reduction in motorcycle fatalities. Partial-helmet laws also correlated with lower fatality rates, although these reductions were modest in comparison to those associated with mandatory coverage. Again, other factors were found to be correlated with the MC fatality rates. The higher the number of motorcycles per capita, income per capita, and alcohol consumed per capita in a state, the higher its fatality rates. In contrast, higher levels of advanced education and population density correlated with lower fatality rates. Motorcyclist fatality rates were higher in states with longer riding seasons.

A study conducted by Morris evaluated the association of mandatory helmet laws with U.S motorcyclist fatality rates from 1993 to 2002 using climatic measures as statistical controls for motorcycling activity via quasi-maximum likelihood generalized linear regression analyses (15). Results revealed that motorcyclist fatalities and injuries are strongly associated with normalized heating-degree days and precipitation inches, and that mandatory helmet laws were associated with lower motorcycle fatality rates when these climate measures and their interaction are statistically controlled. An association of state helmet laws with reduced state fatality rates was likely to be hard to detect statistically for several reasons.

Mandatory helmet laws have been effective in increasing helmet use in the United States (16). California's helmet usage rate increased from 50% to 99% after implementing the mandatory helmet law in the state (17). In recent years, helmet use in states with mandatory helmet law was found to be 73%, which was greater than the 50% usage of helmet in states without mandatory coverage (18).

In contrast, some other studies did not find any correlation between mandatory helmet laws and motorcycle fatality rates. Sosin and Sacks concluded that while mandatory helmet laws were associated with reductions in frequency of head injury from motorcycle crashes, there was no difference in total motorcycle fatality rates based on helmet law status (19). A major limitation of this study, however, was that Sosin and Sacks did not control for other factors that might influence fatality rates. Similarly, Stolzenberg and D'Alessio found no significant change in Florida's fatality rate after the repeal of mandatory coverage (20). However, one limitation was that the study inappropriately controlled for the fatality rate of young motorcyclists still covered by the law, assuming that behavior of the young motorcyclists would not change after the repeal.

2.2 Other Factors Related to Motorcycle Fatalities

Previous studies showed that many other factors may contribute to motorcycle fatalities. Population density has been hypothesized to specifically affect motorcycle rider fatalities, as well as highway mortality rates. In general, when the population density is higher, there are frequent stops, opposed to lower population density where people can drive without much interruption (21, 22, 23, and 24). These studies were related to seat belts. However, in the case of motorcycle crashes, it was found that population density is positively related to motorcycle fatalities (4). Motorcycle operators have the highest incidence of alcohol use among all motor vehicle drivers (25), and fatal motorcycle crashes are more likely to involve alcohol than fatal automobile crashes (5, 25, and 26).

In previous studies, it was found that temperature was positively correlated to motorcycle fatalities, but annual precipitation was negatively correlated to motorcycle fatalities (4, 14). But in another study by Morris (15), it was found that annual precipitation was positively correlated with motorcycle fatalities but negatively correlated with the square of annual precipitation. Normalized heating-degree days were found to be positively correlated with motorcycle fatalities in the same study. The study revealed quadratic an association of fatality rates with annual precipitation. During the study period of 2001-2002, the largest percentage of motorcycle fatalities (13.5%) and injuries (13.1%) occurred during the month of August, which was associated with the second smallest percentage of normalized heating-degree days (0.3%) and the third largest percentage of precipitation inches (8.8%) (15).

Higher levels of education have been considered as a factor to promote healthy behavior (27). Healthy behavior means compliance with existing laws like wearing seat belts, wearing motorcycle helmets, obeying traffic rules and regulations, etc. Studies have shown that higher education levels increase usage of seat belts. Studies show that education is negatively correlated with motor vehicle fatality rates (22, 28, and 29). Typically, income is posited to be negatively correlated with traffic fatalities, as wealthy people are generally more aware and put a higher value on safety, and possess the means to enhance it (30). However, in the case of motorcycles, previous studies showed a different relation for income. Income per capita was found to be positively correlated with motorcycle fatalities in a previous study (14). According to Houston and Richardson (14), motorcycles, being expensive and luxurious, are more often used as recreational vehicles rather than a primary mode of transportation.

Paulozzi took the approach of calculating motorcycle mortality rates per 10,000 motorcycles sold (30). The study found that higher mortality rates had been consistently associated with newer motorcycles. As newer motorcycles with higher mortality rates became a larger share of the motorcycles on the road after 1997, overall motorcycle mortality rates rose accordingly. Brisk sales of new motorcycles appeared to be driving the increase in motorcycle fatalities. There were at least two possible explanations for the inverse relationship between motorcycle age and mortality risk according to the study. First, motorcycles might be ridden less each year after their purchase. A second possible explanation was driver inexperience. An increase in the popularity of motorcycling in recent years may have caused some new drivers to purchase used motorcycles or caused drivers who had not ridden for some time to resume use of motorcycles they had purchased previously. This might explain the observed increase in fatality rates for motorcycles 4-6 and 7-11 years old after 1997.

2.3 Motorcycle Crash Types and Trends

Preusser carried out a study paper dealing with crash-type analysis of motorcycle crashes (31). Numerically coded information contained in the FARS census was used to prepare a "crash report" for each crash event. That is, the process by which the narrative information in police crash reports was converted to standardize numerical codes for data processing was reversed. Distribution of motorcycle crash types by single-vehicle and multiple-vehicle crashes were ran off road-41%, ran traffic control-18.1%, oncoming-10.8%, left turn oncoming-8.5%, motorcycle down-7.3%, rundown-3.3%, stopped/stopping-3.2%, road obstacle-2.5%, lane change-1.4%, cutoff-1.2%, and others/unknown-2.4%.

Kraus et al. carried out a study in which the data substantiated the high risk associated with youthful operators of motorcycles (32). Older drivers represented survivors from the younger ages that were at high risk, so that experience with motor-driven vehicles may be another reflection on the age of the driver. Age-limited discriminant analysis identified prior motorcycle crash injuries, prior motorcycle violations, and automobile driving experience as risk factors in motorcycle crashes. Identification of motor vehicle violations and prior collisions as factors suggested some drivers were less mindful of customary courtesies and precautions in motor vehicle operation, irrespective of whether they were driving automobiles or motorcycles.

Mannering and Grodsky found that most of motorcyclists were generally aware of factors that contribute to crash risk (33). The survey on this study revealed that more than 70% of riders reported driving the motorcycles above 100 mph, while more than 57% said they have ridden within one hour of drinking alcohol.

Hurt et el. performed a study on factors causing motorcycle crashes and identification of countermeasures (34). A high crash involvement was found in unlicensed and young riders. About 50% of those killed were found to be legally drunk at the time of fatality.

2.4 Statistical Methodologies

To understand risk factors that increase the probability of injury severity in crashes, various disaggregated analysis techniques have been used in past research. These techniques include logistic regression, ordered logit and probit models, multinomial logit models. Very few studies focused on the totality of factors, which collectively affect the risk of a fatal motorcycle crash to occur. However, there have been some studies relating various factors to motorcycle crash severity.

Shanker and Mannering performed multinomial logit analysis of single-vehicle motorcycle crash severity in a study and showed the multinomial logit formulation is a promising approach to evaluate the determinant of motorcycle crash severity (35). They found that no-helmet use, in interaction with a fixed object, and alcohol-impaired riding increased the likelihood of a disabling injury or fatality. The same study found that use of alcohol, speeding, and other motorcyclists were associated with a higher likelihood of severe injury. Quddus et al. used the ordered probit model to study how various factors, including specific characteristics of the roadway and riders, can lead to different levels of injury severity and damage severity to the motorcycle (36). This study adopted the ordered probit model to model categorical dependent variables. Factors found to lead to increases in the probability of severe injuries include increased engine capacity, headlight not turned on during daytime, collision with pedestrians and stationary objects, driving during early morning hours, having a pillion passenger, and when the motorcyclist is determined to be at fault for the crash.

Deo Chimba et al. used multinomial logit and the multinomial probit distribution models to analyze motorcycle crash injury severities and found that increase in the number of lanes, alcohol and drug use, higher posted speed limits, curved roadway sections, turning movements, ramps, and driving with no adequate daylight increased the probability of severe injury (37).

Bedard conducted multivariate logistic regression to determine the independent contribution of several driver, crash, and vehicle characteristics affecting the fatality risk of drivers involved in crashes (38). Kockelman and Kweon described use of ordered probit models to examine the risk of different injury levels sustained under all crash types, two-vehicle crashes, and single vehicle crashes (39). The researchers said they used the ordered probit model rather than multinomial logit and probit models, which neglect the data's ordinality, require estimation of more parameters, and are associated with undesirable properties such as the independence of irrelevant alternatives.

Yamamoto and Shankar conducted a bivariate ordered-response probit model of drivers' and most severely injured passengers' severity in collisions with fixed objects (40). A bivariate ordered-response probit model is an extension of a univariate ordered-response probit model. Elasticity and pseudo elasticity of both continuous and dichotomous variables were also calculated in this paper.

Three types of crashes were investigated by Riffat and Chin using an ordered response probit model (41). In the proposed ordered probit model, the dependent variable used was crash severity, which might take on one of three values based on the recorded degree of injury involved. They also estimated the probability of injury severity for combined factors for two-vehicle, single-vehicle and pedestrian crashes.

Chapter 3 - Methodology

This chapter describes the methodologies and data used for performing the analyses in this study. State-level modeling of motorcycle fatality rates was performed using the generalized least-square regression method. Statistical tests of independence were carried out to investigate the relationship between crash severity and other factors in Kansas. Logistic regression was performed to identify characteristics affecting fatal motorcycle crashes in Kansas. Finally, ordered probit modeling of motorcycle rider injury severity was performed to look into the factors having influence on increased injury severity of motorcycle riders in Kansas.

3.1 State-Level Modeling of Motorcycle Fatalities Considering All States

Development of statistical models to predict state-level motorcycle safety parameters while taking other factors into account was accomplished using generalized least-square regression modeling. Regression analysis was performed based on three years' crash data to establish the relationship between helmet laws and motorcycle fatality rates, while controlling for other factors which might have a significant relationship with fatalities of motorcycle riders. Such additional factors included demographic characteristics, weather factors, income, highway mileage of rural roads, motorcycle registration, education levels etc.

3.1.1 Generalized Least-Square Regression

Linear regression is one of the most widely studied and applied statistical and econometric techniques. Linear regression is used to model a linear relationship between a continuous dependent variable and one or more independent variables. Most applications of regression seek to identify a set of independent variables that are thought to covary with the dependent variable. The assumption in regression is that the response is continuous; that is, it can take any value within a range of values. The form of the regression model requires that the relationship between variables be inherently linear. The simple linear regression is given by

$$Y = \beta_0 + \beta_1 x_{1i} + \varepsilon_i \qquad \textbf{3.1}$$

where,

Y = the dependent variable;

β_0 = a constant term (the point where the line crosses the Y axis);

β_1 = a constant term;

x_1 = independent variable x for observation 1;

ε = disturbance term; and

i = the subscript corresponds to the individual or observation, where i = 1, 2, 3… n.

In most applications, response variable Y is a function of many independent variables. In these cases, it is more efficient to express the linear regression model in the matrix notation

$$Y_{nx\,1} = X_{nxp}\,\beta_{px\,1} + \varepsilon_{nx\,1} \qquad \textbf{3.2}$$

where,

X = an n x p matrix of the observations;

n = the number of observations; and

p = the number of variables measured on each observation.

The equation 3.2 is the regression model in the matrix terms, where the subscripts depict the size of the matrices.

The objective of linear regression is to model the relationship between a dependent variable Y with one or more independent variable X. The ability to say something about the way X affects Y is through the parameters in the regression model, the betas. Regression seeks to provide information and properties about the parameters in the population model by inspecting properties of the sample-estimated betas, how they behave, and what they can tell us about the sample and thus the population (42).

Least-squares estimation is a commonly employed estimation method for regression applications. Often referred to as “ordinary least square” or OLS, it represents a method for estimating regression model parameters using the sample data. In a simple regression case, the expression $Y = X\beta$ consists of the following matrices:

$$\underbrace{\begin{bmatrix} y_1 \\ . \\ . \\ . \\ . \\ . \\ y_n \end{bmatrix}}_{Y} = \underbrace{\begin{bmatrix} 1 & x_1 \\ . & \\ . & \\ . & \\ . & \\ . & \\ 1 & x_n \end{bmatrix}}_{X} \underbrace{\begin{bmatrix} \beta_1 \\ \beta_0 \end{bmatrix}}_{\beta} \qquad \textbf{3.3}$$

The generalized least-square model is a flexible generalization of ordinary least-squares regression. It generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value. The link function provides the relationship between the linear predictor and the mean of the distribution function. There are many commonly used link functions, and their choice can be somewhat arbitrary. The link function used for generalized linear modeling in this study is

$$X\beta = \log(Y) \qquad \textbf{3.4}$$

where,

X = predictor variables;

β = parameter estimates; and

Y = response variable.

According to this methodology, a generalized least-square regression procedure was utilized using statistical analysis software SAS version 9.1 to identify different factors affecting response variables, which were the logarithm of total number of motorcyclists killed per 10,000 motorcycle registrations and motorcycle fatalities per 100,000 populations in this study (43).

3.1.2 Data for State-Level Generalized Least-Square Regression Modeling

Number of motorcycle rider fatalities for all 50 states and the District of Columbia obtained from the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS) for the years 2005, 2006, and 2007 were used in this analysis. Various other factors that could be independent variables were chosen to perform the regression analysis. Data for these variables were extracted from different sources. The Statistical Abstract of U.S. Census Bureau website was used to obtain data states for several factors such as population per square mile, percentage of bachelor's degree holders, property crime rate, total unemployment percentage, per capita income, and demographic distribution for all the states between 2005 and 2007 (44). Number of registered motorcycles, fuel tax, and highway mileage of rural roads for each state were obtained from the Federal Highway Administration's (FHWA) annual highway statistics series website (45). Percentage of valid license holders for fatally injured motorcyclists, helmet law information, and number of fatally injured older motorcycle riders for all states were obtained from the National Highway Traffic Safety Administration (NHSTA) state data program website (46). Weather related data were obtained from the National Climatic Data Center (NDCD) website (47). The National Institute of Health (NIH) website was used to obtain data for per capita alcohol consumption (gallons/year) for all states (48).

3.2 Characteristic Analysis of Motorcycle Crashes in Kansas

When motorcycle safety is analyzed, it is also important to compare factors related to motorcycle crashes and other vehicle crashes, because there might be a common problem pertaining to other vehicle crashes that may not be specific to motorcycle crashes. In that regard, a comparison between motorcycle crashes and other vehicle crashes would be more appropriate in identifying problems and issues limited to motorcycle crashes. Therefore, a comparison between motorcycle crashes and other vehicle crashes was performed for several factors. The comparisons were performed using Kansas Accident Records System (KARS) data for the 10 year period from 1999 to 2008. Trends of motorcycle crashes and other vehicle crashes for the five-year period from 2004 to 2008 were also derived for several factors.

In order to see whether there was a relationship between crash severity and other categories under occupant, crash, and vehicle, a contingency table analysis was carried out. This analysis was performed for various factors mentioned and motorcycle crash severity in Kansas using five years of data from 2004 to 2008.

Once the contingency table analysis was carried out relating motorcycle crash severity and several factors, it was important to look at motorcycle crashes to identify characteristics affecting fatal motorcycle crashes in Kansas. The aim of this analysis was to indentify factors such as crash characteristics, motorcycle occupants, vehicles, and contributing circumstances affecting fatal motorcycle crashes in the state of Kansas using five years of KARS data from 2004 to 2008. The analysis was performed using logistic regression and considering fatal motorcycle crashes as a dichotomous dependent variable and various factors as independent variables.

3.2.1 Contingency Table Analysis

Contingency table analysis is a method to test whether a relationship exists between two independent variables which are discrete in nature. The contingency table analysis was performed to examine any relationships exist between various factors and motorcycle crash severity in Kansas. A table similar to Table 3.1 is referred to as a contingency table. As the test of independence uses the contingency table format, it is sometimes referred to as a contingency table test. An example can be illustrated showing the contingency table analysis between two categorical variables denoted as x and y with 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 categories of y. In Table 3.1, the categorical variable x denotes crash classes of sample of crash data, and y denotes crash severities.

Table 3.1 Cross Classification Table for Crash Class and Motorcycle Crash Severity

Variables (x)	Crash Severity (y)			Total
Crash Classes	Fatal	Injury	No Injury	Total
Collision w/ fixed object	48	699	76	823
Overturned	37	1,097	130	1,264
Collision w/ other MV	98	1,671	467	2,236
Collision w/ animal	17	229	65	311
Other non-collision	12	402	64	478
Total	212	4,098	802	5,112

The cells of the table represent ij possible outcomes. Since i = 5 and j = 3 in this case, there are fifteen possible outcomes.

The test of independence addresses the question of whether the crash class is independent of crash severity. The hypotheses for this test of independence are as follows:

$\mathbf{H_0}$: Crash class is independent from crash severity; and

H_1: Crash class is not independent from crash severity

where,

H_0 is the null hypothesis and H_a is the alternative hypothesis.

Expected frequencies for cells of the contingency table are calculated based on the assumption the null hypothesis is true. Let e_{ij} denotes the expected frequency for the contingency table category in row i and column j.

Expected frequencies are calculated as

$$e_{ij} = \frac{(\text{row } i \text{ total}) \times (\text{column } j \text{ total})}{\text{Sample Size}} \qquad \textbf{3.5}$$

The expected number of observations for each cell can be calculated according to the null hypothesis. For example, the expected number of observations for other non-collision fatal crashes are (478*212)/5112 = 19.82. Similarly, expected observations for other cells can be calculated in the same way. The test procedure for comparing observed frequencies and expected frequencies uses the following formula and a Chi-Square value is calculated.

$$\chi_{estimated}^{2} = \sum_{i}\sum_{j}\frac{(n_{ij} - e_{ij})^2}{e_{ij}} \qquad \textbf{3.6}$$

where,

$\chi^2 estimated$ = estimated Chi-Square value;

n_{ij} = real number of observations for i^{th} row and j^{th} column; and

e_{ij} = expected number of observations for i^{th} row and j^{th} column.

Degree of freedom for this table is (r-1)*(c-1), where r = number of rows and c = number of columns in the table, which is (5-1)*(3-1) = 8 in this case. Once the Chi-Square value is calculated for the data, it can be compared with the tabular values at user-defined confidence levels.

For the example in Table 3.1, the value of the test statistic is χ^2 = 125.8. At a 95% confidence level, the value shown in the table for eight degrees of freedom is 15.51. Since the calculated $\chi 2$ > the table value, the null hypothesis is rejected and it can be concluded that crash class is not independent of crash severity.

According to this methodology, the contingency table analysis was performed for various factors and motorcycle crash severity in Kansas using five years of data from 2004 to 2008. In section 4.2.2, results of calculated chi-square values for different categories, along with their respective degrees of freedom, are presented.

3.2.2 Logistic Regression

The goal of a logistic regression analysis is to find the best fitting and most parsimonious model to describe the relationship between an outcome and a set of independent variables. The factor that distinguishes logistic regression from linear regression is that the outcome variable in the logistic regression is categorical, and most likely takes the form of a binary or dichotomous variable.

In any regression problem, the key quantity is the mean value of the outcome variable, given the value of the independent variable. This quantity is called the conditional mean and is expressed as *E(Y/x)*, where *Y* denotes the outcome variable and x denotes a value of the independent variable (49). In linear regression, it is assumed this mean may be expressed as an equation linear in *x*, such as,

$$E(Y/x) = \beta_0 + \beta_1 x \quad \textbf{3.7}$$

where,

β_o = intercept; and

β_1 = parameter estimate of the variable *x*.

To simplify the notation, let $\Pi(x) = E(Y/x)$ represent the conditional mean of Y given x. The logistic regression model can be expressed as

$$\pi(x) = \frac{\exp(\beta_0 + \beta_1 x)}{1 + \exp(\beta_0 + \beta_1 x)} \qquad \textbf{3.8}$$

The logit transformation defined in terms of $\Pi(x)$ is as follows:

$$g(x) = \ln\left[\frac{\pi(x)}{1 - \pi(x)}\right] = \beta_0 + \beta_1 x \qquad \textbf{3.9}$$

In the case of logistic regression, the error term has a distribution with mean zero and variance equal to $\Pi(x)\ [1 - \Pi(x)]$. That is, the conditional distribution of the outcome variable follows a binomial distribution with probability given by the conditional mean, $\Pi(x)$ (50).

Univariate logistic regressions were conducted to examine the independent contributions of motorcycle maneuvers, gender, age group, safety equipment used, light conditions, time of crashes, on-road surface characteristics, crash locations, weather conditions, crash classes, contributing circumstances, etc. to fatal motorcycle crashes in the state of Kansas. The dependent variable for the logistic regression was a dichotomous variable indicating whether the motorcycle crash was a fatal one or not. Kansas motorcycle crashes considered from the Kansas Crash Records System (KARS) database include both single-vehicle motorcycle crashes and multi-vehicle motorcycle crashes. To determine whether different characteristics were associated with fatal motorcycle crashes, the odds ratio (OR) along with a 95% confidence interval of a fatal motorcycle crash were calculated for each variable. The reference group in each and every variable had the value of odds ratio equal to unity.

Each and every independent variable considered for logistic regression was a discrete variable and had two or more categories. Independent variables having more than two categories are known as polytomous variables. For example, there were variables that denote different types of motorcycle maneuvers under the variable name motorcycle maneuver, different age groups under the variable name age, different types of crashes under variable name crash classes, etc. An example can be illustrated in the following section to better understand the process of specifying design variables for different subcategories of a variable. The variable LIGHT CONDITION was coded at four levels and the cross classification of LIGHT CONDITIONS by crash severity in the state of Kansas yielded the data presented in Table 3.2.

Table 3.2 Cross-Classification of Data on Light Conditions and Motorcycle Crash Severity in Kansas, 2004-2008

Light Conditions	Fatal	Injury	No injury	Total
Daylight	197	4,934	1,033	6,164
Dawn and dusk	15	363	86	464
Dark-street light on	67	1,214	230	1,511
Dark-no street lights	64	598	124	786
Total	343	7,109	1,473	8,925

Estimates of the odds ratio were obtained from a logistic regression program with an appropriate choice of design variables. The method for specifying design variables involves setting all of them equal to zero for the reference group and then setting a single design variable equal to one for each of the other groups. This is illustrated in Table 3.3.

Table 3.3 Specifications of Design Variables for Light Conditions Using Daylight as the Reference Group

Variables	Design Variables		
Light Conditions	D1	D2	D3
Daylight	0	0	0
Dawn and dusk	1	0	0
Dark-street light on	0	1	0
Dark-no street lights	0	0	1

The dependent variable considered in this study has two possible outcomes, 1 and 0, corresponding to whether motorcycle crashes were fatal or not, respectively. Odds in favor of an event occurring is defined as the probability the event will occur divided by the probability the event will not occur. In logistic regression, the event of interest is always y=1 given a particular set of values for the independent variables, the odds in favor of y=1 can be calculated as follows:

$$odds = \frac{p\left(y = 1 \middle| x_1, x_2, \ldots\ldots\ldots x_p\right)}{P\left(y = 0 \middle| x_1, x_2, \ldots\ldots\ldots x_p\right)} \qquad \textbf{3.10}$$

where,

$p\left(y = 1 \middle| x_1, x_2, \ldots\ldots x_n\right)$ = probability of event occurring; and

$p\left(y = 0 \middle| x_1, x_2, \ldots\ldots x_n\right)$ = probability of event not occurring.

The odds ratio measures the impact on the odds of a one-unit increase in only one of the independent variables. The odds ratio looks at the odds that y=1 given that one of the independent variables is increased by one unit (odds_1), divided by the odds that y=1 given no change in the value of the independent variables (odds_0)

$$\text{odds ratio} = \frac{\text{odds}_1}{\text{odds}_0} \qquad \textbf{3.11}$$

Use of any logistic regression program with design variables coded as shown in Table 3.3 yields the estimated logistic regression coefficients, which will be mentioned later in the results section. Logistic regression was performed for different factors considered as variables and crash severity to examine whether there was any relation between them. Statistical analysis software SAS version 9.1 was used to perform the logistic regression analysis in this study (43).

3.2.3 Crash Data for Characteristics Analysis of Motorcycle Crashes

Crash data obtained from the Kansas Accident Records System (KARS) were used in this study for characteristic analysis of motorcycle crashes and modeling of injury severity of motorcycle riders in Kansas. This data set, Kansas Accident Records System (KARS), comprises all police-reported crashes in the state of Kansas. One point to note is that all crashes occurring in Kansas are not eligible to be reported by the police. Only crashes causing damages of $500 or more are reported by the police in Kansas. This database is maintained by the Kansas Department of Transportation. Crash, driver, occupant, and vehicle-related Kansas crash data are available in the KARS database. For the analysis in this study, crash data from years 1999 to 2008 were considered.

This part of the analysis focused mainly on identifying characteristics more common among motorcycle crashes in Kansas. Therefore, crash data were analyzed based on various aspects such as occupant, crash, vehicle, and environmental factors. All data for motorcycle crashes from 1999 to 2008 were used for comparing motorcycle crashes and other vehicle crashes. There were total of 8,750 motorcycle crashes in Kansas for this 10 year period, where 331 crashes were fatal, 6,960 were injury crashes, and 1,359 were property damage only (PDO) crashes.

In the contingency table analysis and logistic regression, KARS data for the five-year period from 2004 to 2008 were used.

3.3 Motorcycle Safety Survey

3.3.1 Survey Data

Analysis of motorcycle safety situations based solely on crash data might not be enough to arrive at conclusions about motorcycle riders, since those characteristics are linked only with a special segment of motorcycle riders who having crash experience. In other words, there are many motorcycle riders who have not met with crashes during the last few years, and their representation is unobserved in such analysis. However, their characteristics should also be taken into consideration to make fair conclusions about motorcycle rider characteristics in Kansas. A questionnaire was prepared with the intention of identifying issues and difficulties highlighted in the basic crash data. The survey was carried out to understand behavior of motorcycle riders and their perception towards the helmet law in Kansas. The survey form consisted of mainly demographic, helmet law, crash contributory factors, and difficult maneuver-related questions. The objective of this survey was to obtain information from motorcycle riders irrespective of being involved in a crash, in order to get a general idea about their behavior, perception towards helmet laws, and different types of difficult maneuvers associated with them.

A motorcycle safety survey was a challenging task to conduct among motorcycle riders who are a special population group. Their expected attitude towards participating in a motorcycle safety survey was quite uncertain. A good study of this nature requires a reasonable number of responses distributed throughout the state to overcome any sort of biases or misrepresentations. It was decided to distribute the survey forms in Kansas by locating different motorcycle events or rallies taking place during the motorcycle riding season. Accordingly, several motorcycle events taking place in Kansas were noted and survey forms were distributed to the motorcycle riders by verbally talking to them. In some cases, it was difficult to pursue the riders to participate in the survey as quite a few of them were skeptical about the helmet law. They had a fear in their minds that participating in this survey would result in manipulation of the current helmet law in Kansas which is a partial-helmet law.

The survey forms were kept in a mail-back envelope to make it easier for the participants to return them. Survey forms were also distributed at Kansas State University and Wichita State University by locating motorcycle parking spots. Some survey forms were also distributed to motorcycle selling places in Kansas like Harley-Davidson shops, Free-State Cycles, Indian Motorcycles, etc. But response rates from these sources were pretty low. It was decided to go to different motorcycle events or rallies in Kansas, and the survey was carried out in Manhattan, Lawrence, Wichita, Kansas City, Cassidy, Winfield, Herrington, Topeka, Salina, Council Groove, Perry lake, Lenexa, Junction City, and Wamego.

3.4 Factors Contributing to Motorcycle-Rider Injury Severity

Ordered probit modeling was performed to investigate the effect of various factors towards personal injury severity of motorcycle riders. In other words, one variable at a time was considered to see its relationship or how much it affected injury severity of motorcycle riders in Kansas. However, in the analysis using ordered probit modeling, the objective was to incorporate all variables into a single formula to see multiple or combined effects of such variables toward injury severity of motorcycle riders.

3.4.1 Ordered Probit Modeling

Several econometric models have been adopted in the literature to isolate factors that affect injury severities sustained by various road users. Long suggested that unordered multinomial or nested logit or probit models, while accounting for the categorical nature of the dependent variable, disregard the ordinal nature of injury severity levels and are associated with undesirable properties, such as the independence of irrelevant alternatives (IIA) (50, 51). Several researchers have proposed ordered-discrete choice models (i.e. the ordered probit/logit models: OP/OL) for modeling injury severities and suggested an ordered-discrete choice model is able to account for unequal differences between categories in the dependent variable, as well as being able to relax the restriction of the IIA (36, 53).

The ordered probit model is usually in a latent (i.e. unobserved) variables framework and the general specification is

$$y_i^* = \beta' x_i + \varepsilon_i \qquad \textbf{3.12}$$

where,

y_i^* = the latent and continuous measure of injury severity faced by a crash victim *i* in a crash;

β' = the vector of estimated parameters;

x_i = the (K x 1) vector of observed non-stochastic explanatory variable; and

ε_i = normally distributed error term with zero mean and unit variance for the ordered probit model, but logistically distributed for the ordered logit model.

Note here the error terms for different crash victims are assumed to be uncorrelated (i.e. disturbance term is assumed to be heteroskedastic, representing the variance of the disturbance term can vary from one victim to another). Standard regression techniques cannot be applied to calculate Eq. 3.12 because the dependent variable y_i^* is unobserved. Instead the data used in this study include observed data y_i, a coded discrete variable measuring the injury level sustained by a crash victim i: y_i=1 no injury; y_i= 2 for possible injury; y_i= 3 for injury (non-incapacitating); y_i= 4 for injury (incapacitating); and y_i= 5 for fatal injury Thus the observed and coded discrete injury severity, y_i, can be determined from the following formulae:

$$y_i = \begin{cases} 1 \text{ if } -\infty < y_i^* \le \mu_1 \text{ (no injury)} \\ 2 \text{ if } \mu_1 < y_i^* \le \mu_2 \text{ (possible injury)} \\ 3 \text{ if } \mu_2 < y_i^* \le \mu_3 \text{ (injury-non incapacitating)} \\ 4 \text{ if } \mu_3 < y_i^* \le \mu_4 \text{ (injury- incapacitating)} \\ 5 \text{ if } \mu_4 < y_i^* < +\infty \text{ (fatal injury)} \end{cases} \qquad \textbf{3.13}$$

where the threshold values μ_1, μ_2, μ_3, and μ_4 are unknown parameters to be estimated. The predicted probabilities of the five coded injury severity levels by a victim i, for given x_i are

$P(y_i = 1 | \text{no injury crash}) = \Phi(\mu_1 - \beta' x_i)$; **3.14**

$P(y_i = 2 | \text{possible injury crash}) = \Phi(\mu_2 - \beta' x_i) - \Phi(\mu_1 - \beta' x_i)$; **3.15**

$P(y_i = 3 | \text{injury-non incapacitating injury crash}) = \Phi(\mu_3 - \beta' x_i) - \Phi(\mu_2 - \beta' x_i)$; **3.16**

$P(y_i = 4 | \text{injury-incapacitating injury crash}) = \Phi(\mu_4 - \beta' x_i) - \Phi(\mu_3 - \beta' x_i)$; and **3.17**

$P(y_i = 5 | \text{fatal crash}) = 1 - \Phi(\mu_4 - \beta' x_i)$ **3.18**

where,

$\Phi(u)$ = the cumulative density function of the random error term ε_i evaluated at u.

The method of maximum likelihood is used for estimating parameters of the ordered probit model. For the ordered probit model, ε_i is normally distributed with mean 0 and variance 1 and the cumulative density function is

$$\Phi(\varepsilon) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\varepsilon} \exp(-\frac{t^2}{2})\text{dt}$$ **3.19**

3.4.1.1 Goodness-of-Fit Measure

In linear regression models, the goodness of fit is usually measured by the R^2 value, whereas there is no such straightforward measure to evaluate model fitness of ordered probit models. Mcfadden suggested using a likelihood ratio index analogous to the R^2 in the linear regression model (54).

$$\rho^2 = 1 - [\ln(L_b) / \ln(L_0)]$$ **3.20**

where,

$\ln(L_b)$ = the maximized likelihood function; and

$\ln(L_0)$ = the likelihood assuming all model slope coefficients are equal to 0.

This measure is bounded by 0 and 1 and as it approaches 1, model fit improves. Similarly, a few other values are given in the SAS output such as Estrella, Adjusted Estrella, Veal Zimmermann, and Mckelvey-Zavoina, which can also be considered in evaluating goodness of fit of a model.

In regression modeling, significance of individual parameters toward the model is important, and overall goodness-of-fit also plays a vital role in that aspect. In SAS output for an ordered probit model, the number of goodness of fit measurements was given because unlike other regression modeling, there is no such single value which can determine the model fitness consistently. As a result, various values given in terms of probabilities were considered when selecting models, and out of that, McFadden's LRI was considered in this study. Similarly, the Estrella value is also desirable in discrete modeling. Zimmermann values and Mckelvey-Zavoina values are also reported for the ordered probit model in the results section.

3.4.2 Crash Data for Ordered Probit Modeling

For the ordered probit analysis, Kansas Accident Records System (KARS) was used utilizing a five-year period of data from 2004 to 2008. Data line for a variable was deleted when data for that particular variable were missing. After doing that, 5,087 crashes involving motorcycles on roadways of Kansas remained for analysis for the five-year period.

Chapter 4 - Results and Discussion

This chapter presents results and discussions of the analyses done in this study. This starts with state-level modeling of motorcycle fatality rates and includes the illustration and discussion of results from comparisons of motorcycle crashes with other vehicle crashes, contingency table analysis, univariate logistic regression, survey responses, and ordered probit modeling of motorcycle rider injury severity.

4.1 State-Level Modeling of Motorcycle Fatality Rates

The main objective of this portion of the study was to evaluate the effect of helmet laws and other factors on motorcycle fatality rates at the state level. Numbers of motorcycle rider fatalities for all the 50 states and the District of Columbia were obtained for the years 2005, 2006, and 2007, as mentioned in Chapter 3. A regression analysis was performed involving factors which might potentially be related to motorcycle fatalities in a given state. Variables were chosen for regression modeling after testing the correlation among those. Dependent variables used for the modeling were the motorcycle riders' fatalities per 10,000 motorcycle registrations in a given state and motorcycle riders' fatalities per 100,000 populations in a given state for the three years of the study period (2005 - 2007) in the present models.

Two models were developed in this study to compare motorcyclist fatality rates (log of motorcyclist fatalities per 10,000 motorcycle registration and log of motorcyclist fatalities per 100,000 populations in all states) by treating helmet laws as a binary variable. This section discusses the potential effect of statistically significant factors on motorcycle fatality rates in both models.

4.1.1 Predictor Variables Selection for Statistical Modeling of Motorcycle Fatalities

Once the candidate variables were selected for the state-level model, as mentioned in Chapter 3, the first step in the model-building process was to develop and check the linear correlation matrix. Correlation means a relationship or association between the variables and the correlation coefficient describes the magnitude of this association. A high correlation coefficient between the response variable and the predictor variable would result in a better prediction for the response variable (55). Conversely, high correlation between the predictor variables implies there is some overlapping information. In that case, it becomes difficult to disentangle the effects of one predictor variable from another, and the parameter estimates may be highly dependent on which variables are used in the model. If two independent variables have a correlation coefficient close to 1.0, it is impossible to separate their effects. For multiple regressions, it is important that predictor variables are independent of each other so that the analysis is not distorted. Hence, it is necessary to include only those predictor variables, which do not have a high correlation among them. Spearman's correlation coefficient was used to find variables that were independent of each other. A correlation matrix was developed for the variables selected, primarily using the SAS software. Independent variables with a correlation coefficient higher than 0.5 (or 50% correlation) were considered for elimination from the variable set considered for modeling with motorcycle fatalities per 10,000 motorcycle registrations. This was executed by keeping one of the variables, which resulted in a better model, and removing other variables which resulted in a weaker model. This prompted to ruling out variables like violent crime rate per 100,000 populations, female and male young drivers, middle and old-age drivers, population per square mile, percentage of bachelor's degree holders, etc. A correlation coefficient of 0.65 was used for modeling motorcycle fatalities per 100,000 population, as motorcycle fatalities per motorcycle registrations is more a direct way to measure risk exposure compared to fatalities per 100,000 populations. In order to accurately identify and effectively address the growing problem of motorcycle fatalities, the United States Department of Transportation re-baselined its motorcycle fatality rate measure for FY 2008 to reflect a change of focus from fatalities per 100 million vehicle miles traveled (VMT) to fatalities per 100,000 registrations in a given state. To date, most states do not report motorcycle VMT. Accuracy of motorcycle VMT reported by a small number of states is also quite speculative (3). This might justify the decision of setting a stricter threshold of correlation coefficient for the model with motorcycle fatalities per 10,000 motorcycle registrations in a given state. In this way, variables having little correlation will be included in the model.

Variables were also checked for multicollinearity. Sometimes one predictor variable could be correlated with more than one other predictor variable, resulting in multicollinearity. Multicollinearity results in overlapping information among more than two predictors, where one predictor would explain the same variability already explained by other predictors. As a result, some predictors may not provide any additional information. Presence of multi-collinearity results in significance changes in slope coefficients. As the magnitude of correlation between predictors increases, standard error of regression coefficients also increases (55). Multicollinearity could be measured by the variance inflation factor (VIF). It measures the increase in variability of a coefficient due to collinearity. Variance here is referred to as the square of the standard error. The critical value used for the variation inflation factor is generally 10, and variables having VIF above 10 are considered to be highly correlated with other predictors. All variables with VIF above 10 were removed from the model.

After ruling out inappropriate predictor variables, analysis was performed for the competing influences of the following variables on the fatality rate of motorcyclists. Table 4.1 describes all variables along with their simple statistics and variance inflation factor (VIFs), that were taken into account for the two models after performing the collinearity tests. From the table it is evident that none of the variables selected for modeling purposes had VIFs greater than 10, satisfying the criteria of multi-collinearity.

Table 4.1 Predictor Variables Selected for Motorcycle Fatality Rate Modeling

Variable	Max	Min	Avg	VIF
Population per square mile	9,581.30	1.2	374.7	3.61
Motorcycles registered per 1000 population	89.7	2.0	26.5	3.01
Per capita alcohol consumption (gallons/year)	4.2	1.3	2.4	1.98
Annual daily mean temperature (^{0}Fahrenheit)	75.7	32.0	53.7	4.83
Annual precipitation (inches)	69.8	8.0	36.3	2.64
Helmet law (mandatory or not)	1	0	-	1.6
Percentage of bachelor degree holders or more	47.5	16.5	26.9	4.2
Property crime rate per 100,000 population	4,889.80	1,619.60	3,307.20	2.3
Unemployment percentage	7.8	2.5	4.6	2.09
Per capita income (in $ 1,000)	6,514.40	3,293.80	4,722.70	4.21
Percentage of African Americans	57.3	0.5	11.5	5.25
Percentage of Hispanics	44.4	0.9	9.3	3.84
Percentage of Whites	96.7	24.7	78.7	3.16
Fuel tax (in cents per gallon)	34	7.5	21.2	1.24
Percentage holding valid license for fatally injured motorcyclists	100.0	25.0	75.3	1.61
Number of older motorcycle riders killed	330	0	62.28	2.16
Highway mileage of rural roads (in 1000 miles)	221.7	0	58.3	1.69

4.1.2 Generalized Least-Square Regression for Motorcyclist Fatalities per 10,000 Motorcycle Registrations

While the number of motorcycle registrations for individual states is available, the number of motorcycle miles travelled is not. There is no single approach to normalize fatalities by risk exposure. The number of fatalities per vehicle miles traveled (VMT) provides a direct means of normalizing for the amount of travel by all motor vehicles. Separate data for motorcycles alone do not exist for any of the states. Numbers of motorcyclist fatalities per 10,000 motorcycle registrations and per 100,000 populations for all the states were considered in the present models as response variables representing motorcycle fatality rates for the three years from 2005 to 2007. The logarithm of the motorcyclist fatalities per 10,000 registered motorcycles and per 100,000 populations for all the states was taken. Logged fatality rates were used to reduce concern about the assumption of ordinary-least square regression. Using logged dependent variables has the added benefit of resulting in coefficients that can be interpreted as the approximate proportion change in the dependent variable for a one-unit increase in a predictor variable (14). Table 4.2 summarizes results of the regression analysis of the model with motorcycle fatalities per 10,000 motorcycle registrations.

Table 4.2 Results of Generalized Least-Square Regression for Log of Motorcycle Fatalities per 10,000 Motorcycle Registrations

Variables	Variable Label	Parameter Estimate	Pr>t
Intercept	Intercept	0.19955	0.3624
Per Capita Alcohol Consumption	ALCO	-0.01937	0.5036
Annual Daily Mean Temperature (^{0}F)	ADMT	0.01468	**<0.001***
Annual Precipitation (inches)	AP	-0.00127	0.2378
Helmet Law	HL	-0.05492	**0.0722***
Total Unemployed Percent	UNEMPL	0.01975	0.1804
Per Capita Income (10,000)	PCI	-0.0674	**0.0136***
Percentage of African Americans	AFAM	0.0095	**<0.001***
Fuel Tax (in cents per gallon)	FT	0.0021	0.3787
Older Motorcyclists Killed	OD	-0.000085	0.7418
Highway Mileage of Rural Roads (1000mile)	HMRR	-0.00074	**0.0677***
Value of R^2	0.61		
Adjusted R^2	0.58		

* (Statistically Significant at 90% Confidence Level)

In the mathematical form, the model could be written as follows:

$$Y = 0.19955 + 0.01468ALCO - 0.0722HL - 0.0674PCI + 0.0095AFAM - 0.0677HMRR \quad \textbf{4.1}$$

where,

Y = Log of motorcycle fatalities per 10,000 motorcycle registrations.

The significant factors identified through modeling are discussed in the following sections. Goodness-of-fit measures in both models were considered as R^2 and $R^2_{adjusted}$, where the values were 0.61 and 0.58, respectively. Considering the values of R^2 and $R^2_{adjusted}$ from similar regression models in other studies, values in the present models are considered to be reasonable (56).

4.1.2.1 Helmet Laws

In the model, it was evident that mandatory helmet laws were associated with lower fatality rates. One thing to note is that states with no helmet law were included in the partial-helmet law states in the present model, because the numbers of no-law states were very few (only 3). The p-value for the helmet law parameter estimate was 0.0722 which is statistically significant at $p<0.1$. The exact change in the response variable for a 1-unit increase in the predictor variable is computed using the following equation:

Y = 100[exp (β) -1] (14) **4.2**

where,

Y = exact change in the response variable for a unit increase in the predictor variable; and

β = parameter estimate of the predictor variable.

The exact decrease in motorcycle fatalities per 10,000 motorcycle registrations was calculated by putting the value of β = 0.05492 for helmet laws in the model. This resulted in a 5.6 percent decrease in motorcycle fatalities when a mandatory helmet law was considered in a state. In comparison with the experience under the partial-coverage or no-helmet law, states with mandatory helmet laws had 5.6 percent fewer motorcycle fatalities per 10,000 motorcycle registrations under the present model.

4.1.2.2 Weather Conditions

One of the weather considerations taken into account for the present study was annual daily mean temperature in ^{0}F. The model showed a statistically significant positive correlation between annual daily mean temperature and motorcyclist fatality per 10,000 motorcycle registrations. The p-value for the annual daily mean temperature is found to be <0.001. This was an expected finding. Motorcycle activities increase during warm days, increasing the likelihood of more motorcycle crashes and more fatalities. The other weather condition, annual precipitation did not show any statistically significant relation with the motorcycle fatality rate.

4.1.2.3 Per Capita Income

Average per capita income for each state was negatively correlated with motorcyclist fatalities per 10,000 motorcycle registrations. It was found to be statistically significant with a p-value of 0.0136. As discussed in section 2.2 of the literature review, income has been found to be negatively correlated with traffic fatalities as wealthy people tend to be more aware and put a higher value on safety, and possess the means to enhance it. Accordingly, the higher the per capita income in a given state, the lower the motorcycle fatalities in the current model.

4.1.2.4 Demographic Distribution

Demographic distribution of African American, Hispanic, and White population percentages were included in the model to test the effect of these groups of people on the motorcycle fatality rate. Only the African American population was included in the model, as the collinearity matrix showed a high correlation among the other two population groups and other factors such as young drivers, per capita income. The p-value for the African American percentage was found to be <0.0001. The percentage of African American was found to be positively correlated with motorcyclist fatalities per 10,000 motorcycle registrations. According to the model result, if the percentage of African American population increases in a given state, motorcycle fatalities per 10,000 motorcycle registrations also increases.

4.1.2.5 Highway Mileage of Rural Roads

Highway mileage of rural roads in each state was considered as a predictor variable, which was found to be negatively correlated with motorcyclist fatalities per 10,000 motorcycle registrations with a p-value of 0.0677. This finding was not consistent with previous research findings, which revealed that the percentage of urban roads per state is negatively correlated with the motorcyclist fatality rate (4). Normally, motorcycles tend to be abundant in urban areas and very few numbers of motorcycles are likely to be found in rural areas. So, motorcycle crashes are likely to increase if there is an increase in urban roads. Results from the model also support this. According to the model results, as highway mileage of rural roads increases, motorcycle fatalities per 10,000 motorcycle registrations also increase.

4.1.3 Generalized Least-Square Regression for Motorcyclist Fatalities per 100,000 Population

Table 4.3 shows the other model in which motorcycle fatalities per 100,000 population was used as a response variable.

Table 4.3 Results of Generalized Least-Square Regression for Log of Motorcycle Fatalities per 100,000 Population

Variables	Variable Label	Parameter Estimate	Pr>t
Intercept	Intercept	-0.13264	0.6567
Population per 1000 square mile	POPSQ	-0.0378	**0.0099***
Motorcycle registered per 1000 population	MCR	0.005935	**<.0001***
Per capita alcohol consumption(ethanol gallons)	ALCO	0.03978	0.1438
Annual daily mean temperature(^{0}F)	ADMT	0.00814	**0.0018***
Annual precipitation (inches)	AP	0.000022	0.9847
Helmet laws	HL	-0.07561	**0.0043***
Percentage of bachelor's degree holder or more	BGRAD	-0.0073	**0.0610***
Property crime rate per 100,000	PRCRM	1.984	0.2975
Total unemployed percent	UNEMPL	-0.01539	0.2733
Per capita income $1000	PCI	-0.0055	0.1022
Percentage of African Americans	AFAM	0.00366	**0.0757***
Percentage of Hispanics	HIS	0.0003	0.8868
Percentage of Whites	WHT	0.00197	0.1102
Fuel tax (in cents per gallon)	FT	-0.0004	0.8461
Percentage of valid licenses for fatally injured MC drivers	MCDF	-0.00083	0.4069
Older motorcyclists killed	OD	-0.0003	0.1884
Highway mileage of rural roads (per 1000 miles)	HMRR	-0.00088	**0.0073***
Value of R^2	0.62		
Adjusted R^2	0.57		

* (Statistically Significant at 90% Confidence Level)

In mathematical form, the model could be written as follows:

$$Y = -0.13264 - 0.0378POPSQ + 0.005935MCR + 0.00814ADMT$$
$$-0.07561HL - 0.0073BGRAD + 0.00366AFAM - 0.00088HMRR \quad \textbf{4.3}$$

where,

Y = log of motorcycle fatalities per 100,000 population.

Statistically significant factors affecting motorcyclist fatalities per 100,000 population are discussed in this section. The goodness-of-fit values for R^2 and $R^2_{adjusted}$ are 0.62 and 0.57, respectively, in the current model.

4.1.3.1 Helmet Laws

This model also showed mandatory helmet laws were associated with lower fatality rates. The p-value for the helmet law parameter estimate is 0.0043, with statistical significance at $p<0.1$ level. Helmet laws were found to be negatively correlated with motorcycle fatalities per 100,000 population in the model. The exact change in the response variable for a 1-unit increase in the predictor variable is computed using the following equation:

Y = 100[exp (β) -1] (14) **4.4**

where,

Y = exact change in the response variable for a unit increase in the predictor variable; and

β = parameter estimate of the predictor variable.

The exact decrease in motorcycle fatalities per 100,000 population was calculated by putting the value of β = 0.07561 for helmet laws in the model. The value of percent decrease was 7.85. In comparison with the experience under the partial-coverage or no-helmet law, states with mandatory helmet laws had 7.85 percent fewer motorcycle fatalities per 100,000 population under the present model. So, when the per capita measure is being used, the mandatory helmet laws become more effective though motorcycle fatalities per 100,000 population is not a good variable to measure the exposure of motorcycle riding.

4.1.3.2 Population Density

Population per 1,000 square miles, which was included in the present model to represent the contribution of population density toward motorcycle fatalities, was found to be negatively correlated with motorcyclist fatalities per 100,000 population. This relationship was found to be statistically significant with a p value of 0.0099 at a 90% confidence level. So, as the population increases, it becomes more difficult for motorcycle riders to drive uninterruptedly, lowering the risk of getting involved in a crash.

Branas and Knudson (4) previously found a statistically significant positive relation between population density (residents per 10 square mile) and percentage change in fatalities per 10,000 registered motorcycles (natural log transformation). In another study, a statistically significant negative relationship between population per square mile and motorcycle fatality rates was found (14).

4.1.3.3 Motorcycle Registrations

Motorcycle registrations per 1000 population were found to be positively correlated with motorcyclist fatalities per 100,000 population. The relationship between motorcycle registrations and motorcycle fatalities per 100,000 population was found to be statistically significant with a p value of <0.0001. Increases in motorcycle registration mean increases in number of motorcycles on roads. This would increase the number of crashes, resulting in an increase of motorcycle fatalities. Results from the model also showed that the higher the number of motorcycle registrations in a given state, the higher the per capita motorcycle fatalities.

A previous study also found that the increase in number of fatalities associated with motorcycles less than four years old, between 1997 and 2003, accounted for 78.1% of the total increase in motorcyclist fatalities over this time period (57).

4.1.3.4 Weather Conditions

The present model showed a statistically significant positive correlation between annual daily mean temperatures and motorcyclist fatalities per 100,000 population. This is the same finding as the previous modeling. The p-value for annual daily mean temperature was found to be 0.0018. The model implies that states with longer, warm and dry seasons have more motorcycle fatalities per 100,000 population. This result is justified as motorcycle riding tends to be highly dependent on weather conditions. The other weather condition, annual precipitation, did not show any statistically significant relation to per capita motorcycle fatalities.

4.1.3.5 Education

Percentage of bachelor's degree holders for each state was considered as a predictor variable, which was found to be negatively related with motorcycle fatalities in the present model as expected. The relationship is found to be statistically significant with a p-value of 0.0610. According to the model, as the number of educated people increases in a given state, motorcycle fatalities decrease. As the number of educated people increases, it also increases the chance for the motorcycle riders to be more aware about their safety. It also develops a sense of responsibility and compliance toward existing laws.

4.1.3.6 Demographic Distribution

The p-value for the African American percentage was found to be 0.07575 at a 90% confidence level. This variable is positively correlated with per capita motorcycle fatalities. This finding is the same as the previous modeling. According to the model result, if the percentage of African American population increases in a given state, motorcycle fatalities per 100,000 population also increase.

4.1.3.7 Highway Mileage of Rural Roads

Highway mileage of rural roads was also found to be negatively correlated with motorcyclist fatalities per 100,000 population with a p value of 0.0073 at a 90% confidence level. This finding is similar with the previous model. Results indicate that if highway mileage of rural roads increases in a given state, motorcycle fatalities per 100,000 population decrease. Normally, motorcycles are plentiful in urban areas and roads, and more motorcycle crashes are likely to occur on urban roads compared to rural roads.

4.1.4 Checking for Homoscedastic Disturbances

Constancy of disturbances is called homoscedasticity. When disturbances are not homoscedastic, they are said to be heteroskedastic. This requirement is derived from the variance term in the regression model, which is assumed to be constant over the entire regression. A multiple-linear regression model assumes the variance of the error is constant. Scatter plots are used to assess homoscedasticity. A plot of model-fitted value vs. residuals is typically inspected first. If residuals are evenly distributed along the horizontal line (residual =0), variance can be assumed to be constant. The motorcycle fatality model with fatalities per 10,000 motorcycle registrations provided a reasonably good fit with an R^2 value of 0.61. It was necessary to check the homoscedasticity of the model by verifying the assumptions of constant variance of disturbance. The assumption of constant variance was verified using the standardized residual plot in Figure 4.1, which did not show any pattern that would suggest presence of a non-constant variance or non-linearity. So, the assumption of constant variance of error term is validated from Figure 4.1 for the model. Thus, the motorcycle fatality model with fatalities per 10,000 registrations is homoscedastic.

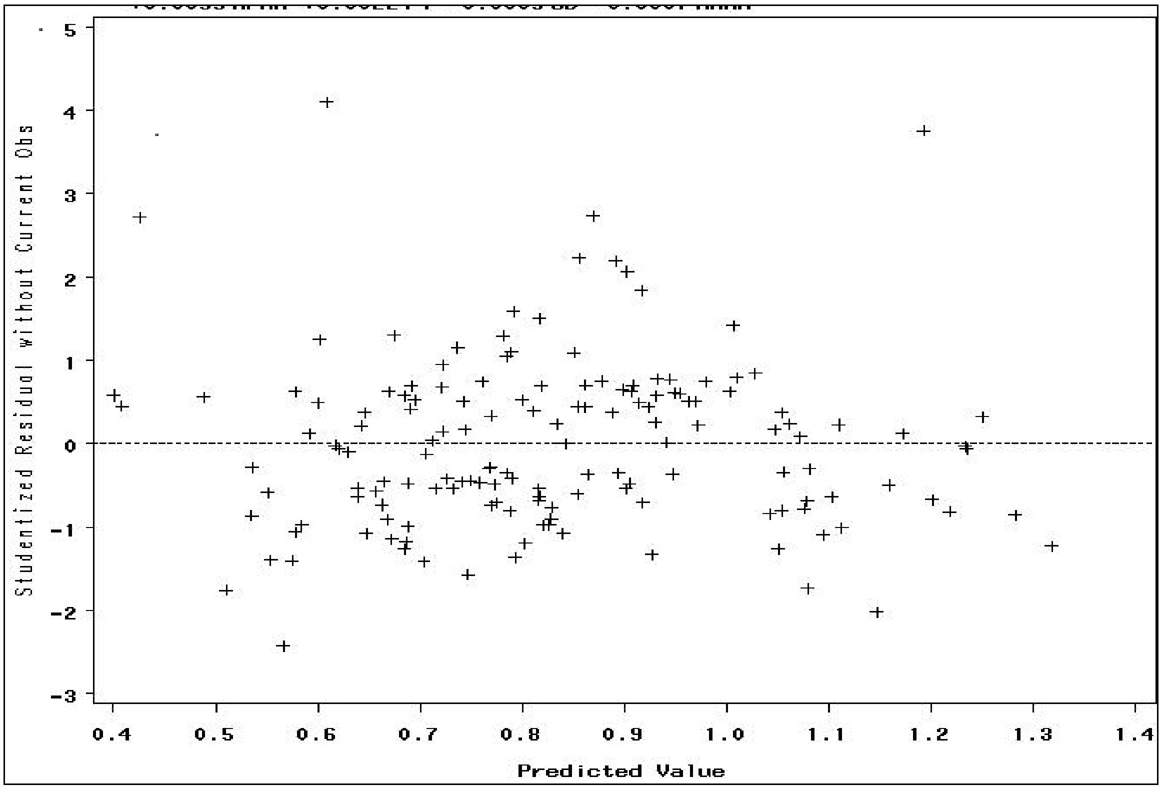


Figure 4.1 Standardized Residual Plots for the Model with MC Fatalities per 10,000 MC Registrations

4.2 Characteristics of Motorcycle Crashes in Kansas

One of the objectives was to identify characteristics of motorcycle crashes occurring in Kansas from 2004 to 2008. Accordingly, percentages of motorcycle crashes for different severity levels and different factors in Kansas from 2004 to 2008 were calculated. These percentages were calculated by extracting data from Kansas Accident Records System Database (KARS) to have an idea about general characteristics of motorcycle crashes in Kansas. Then a comparison was made between motorcycle crashes and other vehicle crashes in Kansas, using the KARS database to identify factors affecting motorcycle crashes. Relationships between different crash categories and several factors were also identified using the test of independence as explained in the methodology section. The calculated chi-square values, degree of freedom values, and probabilities are presented in this section. Finally, an analysis was performed using univariate logistic regression to indentify factors such as crash characteristics, motorcycle occupants, vehicles, and contributing circumstances affecting fatal motorcycle crashes in the state of Kansas.

4.2.1 General Characteristics of Motorcycle Crashes in Kansas

Table 4.4 shows percentages of motorcycle crashes for different severity and different factors in Kansas from 2004 to 2008. From this table, it is evident that among all motorcycle maneuvers, fatal motorcycle crashes with overtaking had the highest percentage while fatal motorcycle crashes with slowing or stopping had the lowest percentage. Motorcycle crashes involving aggressive maneuvers had the highest share of injury crashes compared to other maneuvers. Slowing or stopping maneuvers had the highest share of property-damage-only crashes. Crashes involving right turns had the lowest percentage of fatal crashes. Gender of motorcyclists did not have any affect on fatal motorcycle crashes, as the percentage of fatal motorcycle crashes was almost the same for both male and female motorcyclists. No use of motorcycle helmet had the highest percentage of fatal motorcycle crashes compared to other types of safety equipment used. This was also true for property-damage-only crashes. But motorcycle crashes with riders wearing helmets had a higher share of injury crashes compared to crashes with riders using other safety equipment. No adverse weather conditions had a higher percentage of fatal motorcycle crashes than rain, mist, drizzles, and wind conditions. Among light conditions, motorcycle crashes with dark-no streetlights had the highest percentage of fatal motorcycle crashes, and daylight crashes had the lowest percentage of fatal motorcycle crashes. It was vice versa for injury crashes during the same time period. Among crash classes, collision with fixed objects had the highest percentage of fatal motorcycle crashes. But overturned crashes

Table 4.4 Percentages of Different Crash Severities for Different Factors for Motorcycles in Kansas, 2004-2008

Motorcycle Crash Severity	Fatal	Injury	PDO	Total
MC Maneuvers				
Straight following road	5.01	79.71	15.28	100
Left turn	4.31	79.28	16.41	100
Right turn	2.95	77.05	20	100
Overtaking	8.53	73.64	17.83	100
Chasing lanes	2.25	81.46	16.29	100
Aggressive maneuver	3.44	83.05	13.51	100
Slowing or stopping	2.09	75.46	22.45	100
Gender				
Male	4.53	78.34	17.13	100
Female	4.86	76.73	18.4	100
Safety Equipment Used				
MC helmet and eye protection	3.07	80.46	16.47	100
MC helmet	2.87	81.32	15.81	100
No use of MC helmet	4.6	76.72	18.68	100
Weather Conditions				
No adverse conditions	4.16	80.14	15.7	100
Rain, mist, drizzle and winds	3.07	79.82	17.11	100
Light Conditions				
Daylight	3.2	80.05	16.76	100
Dawn and dusk	3.23	78.23	18.53	100
Dark-street light on	4.43	80.34	15.22	100
Dark-no street lights	8.14	76.08	15.78	100
Crash Class				
Other non collision	2.51	84.1	13.39	100
Overturned	2.93	86.79	10.28	100
Collision w/ other MV	4.38	74.73	20.89	100
Collision w/ animal	5.47	73.63	20.9	100
Collision w/ fixed object	5.83	84.93	9.23	100
Day of the Week				
Weekdays	3.8	79.77	16.43	100
Weekends	4.71	80.71	14.59	100
Substance Abuse				
Alcohol contributing to crash	6.32	88.16	5.53	100
Riders under the influence of alcohol	11.4	85.11	3.55	100

Table 4.4 Percentages of Different Crash Severities for Different Factors for Motorcycles in Kansas, 2004-2008. (Continued)

Motorcycle Crash Severity	Fatal	Injury	PDO	Total
Contributing Circumstances				
Driver	5.45	81.62	12.93	100
Environment	4.95	78.07	16.98	100
Crash Location				
Non-intersection-on roadway	3.98	81.77	14.25	100
Intersection-on roadway	4.23	80.45	15.33	100
Intersection-related-on roadway	3.04	75.64	21.31	100
Parking lot-driveway access-on roadway	3.07	78.26	18.67	100
Interchange area-on roadway	3.31	76.16	20.53	100
Roadside-including shoulder-off roadway	8.01	80.62	11.37	100
Surface Characteristics				
Straight and Level	2.84	79.89	17.27	100
Straight and grade	6.17	78.33	15.5	100
Straight at hillcrest	9.78	73.91	16.3	100
Curve and level	5.55	84.08	10.38	100
Curve and grade	5.58	83.26	11.16	100

had the highest share of injury crashes. Motorcycle crashes occurring during weekends had higher fatal crashes than crashes occurring during weekdays. Percentage of fatal crashes with motorcycle riders under the influence of alcohol was higher than that of alcohol contributing to fatal crashes. When it came to contributing circumstances, motorcycle riders (drivers) contributed more to fatal motorcycle crashes than the environment. The same was true for injury crashes, but the environment contributed to more percentage of property damage crashes than riders. Among crash locations, roadside areas, including shoulder-off roadway, had the highest percentage of fatal motorcycle crashes. When surface characteristics were considered, the highest percentage of fatal motorcycle crashes occurred on straight surfaces at hillcrests.

4.2.2 Contingency Table Analysis

A Chi-Square test or contingency table analysis was performed to test whether there was any relation among different factors and motorcycle crash severity in Kansas from 2004 to 2008. From results presented in Table 4.5, it was evident most of the factors were related to motorcycle crash severity. Only weather conditions, day of the crashes, and on-road surface types did not have any effect on motorcycle crash severity in Kansas. Gender of motorcyclists and contributing circumstances were significant at the $p<0.1$ level but all other factors and motorcycle crash severities were related at the $p<0.01$ or 99% confidence level.

When motorcycle maneuvers were considered at the point of fatal crashes, a majority of the motorcycles were following the road straight and 13.29 % were left turns. The Chi-Square value indicates a higher level of interdependency between crash severity and maneuvers.

Gender distribution of motorcycle riders involved in crashes showed male riders were more involved all types of crashes than female riders. A majority of motorcycle riders involved in fatal crashes belonged to the 20 -29 years age category with 22.47 %. Age groups of motorcycle riders are also related to the motorcycle crash severity with high Chi-Square value.

Only 9.23 % of motorcycle riders involved in fatal motorcycle crashes were wearing helmets at the time of the crashes, whereas the percentages were higher for injury and no-injury crashes. This was also true for the motorcycle riders using motorcycle helmets and eye protection simultaneously at the time of the crashes. When helmet usage was considered, riders of only 16.53% of fatal crashes were wearing helmets. Higher levels of interdependency were evident between different types of safety equipments used and crash severity. Chi-Square value also indicated interdependence between helmet usage and motorcycle crash severity.

Table 4.5 Contingency Table Analysis for Motorcycle Crash Severity and Various Factors in Kansas, 2004-2008

Description	Fatal		Injury		Property Damage Only		Total
	Number	%	Number	%	Number	%	Total
Motorcycle maneuver							
Straight following road	232	73.42	3,688	68.07	707	64.74	4,627
Left turn	42	13.29	773	14.27	160	14.65	975
Right turn	9	2.85	235	4.34	61	5.59	305
Overtaking	11	3.48	95	1.75	23	2.11	129
Aggressive maneuver	14	4.43	338	6.24	55	5.04	407
Slowing or stopping	8	2.53	289	5.33	86	7.88	383
Total	316	100.00	5,418	100.00	1092	100.00	6,826
Chi-Square value = 33.08 DF = 10 P = 0.0003							
Gender							
Male	328	72.4	5,420	73.5	1131	71.67	6,879
Female	125	27.59	1,954	26.49	447	28.32	2,526
Total	453	100.00	7,374	100.00	1578	100.00	9,405
Chi-Square value = 4.71 DF = 2 P = 0.095							
Age (years)							
16 to 19 years	115	15.29	1,742	14.27	396	14.92	2,253
20 to 29 years	169	22.47	3,223	26.41	736	27.73	4,128
30 to 39 years	119	15.82	2,236	18.32	476	17.94	2,831
40 to 49 years	145	19.28	2,401	19.67	494	18.61	3,040
50 to 59 years	109	14.49	1,618	13.26	354	13.34	2,081
60 to 69 years	63	8.38	577	4.73	114	4.3	754
70 and above years	32	4.26	407	3.33	84	3.17	523
Total	752	100.00	12,204	100.00	2654	100.00	15,610
Chi-Square value = 35.33 DF = 12 P = 0.0004							
Type of Safety Equipment Used							
MC helmet and eye protection	39	15	1,021	20.47	209	18.3	1,269
MC eye protection	88	33.85	1,347	27	229	20.05	1,664
MC helmet	24	9.23	679	13.61	132	11.56	835
Shoulder lap	109	41.92	1,942	38.93	572	50.09	2,623
Total	260	100.00	4,989	100.00	1142	100.00	6,391
Chi-Square value = 63.29 DF = 6 P<0.0001							
Helmet Usage							
Helmet used	39	16.53	1021	23.69	209	20.69	1,269
No use of helmet	197	83.47	3289	76.31	801	79.31	4,287
Total	236	100.00	4310	100.00	1010	100.00	5,556
Chi-Square value = 9.75 DF = 2 P = 0.004							

Table 4.5 (Continued)

Description	Fatal		Injury		Property Damage Only		Total
	Number	%	Number	%	Number	%	
Weather Conditions							
No adverse conditions	207	96.73	3,991	95.64	782	95.25	4,980
Rain, mist, or drizzle	3	1.40	106	2.54	28	3.41	137
Strong winds	4	1.87	76	1.82	11	1.34	91
Total	214	100.00	4,173	100.00	821	100.00	5,208
Chi-Square value = 4.22 DF = 4 P = 0.6373							
Light Conditions							
Daylight	197	57.43	4,934	69.40	1033	70.13	6,164
Dawn n dusk	15	4.37	363	5.11	86	5.84	464
Dark-street light on	67	19.53	1,214	17.08	230	15.61	1,511
Dark-no street lights	64	18.66	598	8.41	124	8.42	786
Total	343	100.00	7,109	100.00	1473	100.00	8,925
Chi-Square value = 51.09 DF = 6 P<0.0001							
Crash Class							
Other non collision	12	5.66	402	9.81	64	7.98	478
Overturned	37	17.45	1,097	26.77	130	16.21	1,264
Collision w/ other MV	98	46.23	1,671	40.78	467	58.23	2,236
Collision w/ animal	17	8.02	229	5.59	65	8.10	311
Collision w/ fixed object	48	22.64	699	17.06	76	9.48	823
Total	212	100.00	4,098	100.00	802	100.00	5,112
Chi-Square value = 261.57 DF = 8 P<0.0001							
Day of the week							
FR	26	11.98	663	15.77	141	17.07	830
SA	53	24.42	850	20.22	159	19.25	1,062
SU	39	17.97	727	17.3	126	15.25	892
MO	21	9.68	452	10.75	82	9.93	555
TU	22	10.14	470	11.18	97	11.74	589
WE	30	13.82	532	12.66	121	14.65	683
TH	26	11.98	509	12.11	100	12.11	635
Total	217	100.00	4,203	100.00	826	100.00	5,246
Chi-Square value = 10.21 DF = 12 P=0.5978							
Times of Crashes (hours)							
0000 to 0259	21	9.68	251	5.98	42	5.08	314
0300 to 0559	6	2.76	83	1.98	17	2.06	106
0600 to 0859	9	4.15	302	7.19	66	7.99	377
0900 to 1159	19	8.76	403	9.60	77	9.32	499
1200 to 1459	30	13.82	769	18.31	138	16.71	937
1500 to 1759	57	26.27	1,108	26.38	231	27.97	1,396
1800 to 2059	32	14.75	814	19.38	162	19.61	1,008
2100 to 2400	43	19.82	470	11.19	93	11.26	606
Total	217	100.00	4,200	100.00	826	100.00	5,246
Chi-Square value = 29.89 DF = 14 P=0.0079							

Table 4.5 (Continued)

Description	Fatal		Injury		Property Damage Only		Total
	Number	%	Number	%	Number	%	
Contributing Circumstances							
Driver	312	93.69	4,671	93.38	740	91.13	5,723
Environment	21	6.31	331	6.62	72	8.87	424
Total	333	100.00	5,002	100.00	812	100.00	6,147
Chi-Square value = 5.69 DF = 2 P=0.0579							
On-Road Surface Characteristics							
Straight and level	94	45.63	2,641	63.59	571	70.41	3,306
Straight and grade	45	21.84	571	13.75	113	13.93	729
Straight at hillcrest	9	4.37	68	1.64	15	1.85	92
Curve and level	31	15.05	470	11.32	58	7.15	559
Curve and grade	27	13.11	403	9.70	54	6.66	484
Total	206	100.00	4,153	100.00	811	100.00	5,170
Chi-Square value = 57.96 DF = 8 P<0.0001							
On-Road Surface Types							
Concrete	51	23.83	1,070	26.28	222	28.28	1,343
Blacktop	163	76.17	3,001	73.72	563	71.72	3,727
Total	214	100.00	4,071	100.00	785	100.00	5,070
Chi-Square value = 2.16 DF = 2 P= 0.34							
Crash Location	91	42.52	1,870	44.94	326	39.61	5,141
Non-intersection-on roadway	51	23.83	971	23.34	185	22.48	1,365
Intersection-on roadway	19	8.88	472	11.34	133	16.16	2,539
Intersection-related-on roadway	12	5.61	306	7.35	73	8.87	175
Parking lot-driveway access-on roadway	10	4.67	230	5.53	62	7.53	115
Interchange area-on roadway	31	14.49	312	7.50	44	5.35	206
Roadside-including shoulder-off roadway	214	100.00	4,161	100.00	823	100.00	9,541
Total							
Chi-Square value = 47.47 DF = 10 P<0.0001							

When it came to the weather conditions, almost all fatal, injury and no-injury, motorcycle crashes occurred during no adverse weather conditions. No interdependence was found from the Chi-Square value between weather conditions and motorcycle crash severity. A majority of fatal motorcycle crashes occurred in daylight, with 57.43 %, and light conditions during crashes were found to be related to motorcycle crash severity. 46.23% of fatal motorcycle crashes involved in collisions with other motor vehicles. Higher Chi-Square value indicated strong interdependence between crash classes and crash severity. Saturday was the day with the highest percentage of fatal motorcycle crashes, 24.42 %, and no relation was found between day of the crashes and crash severity. But high Chi-Square value indicated strong dependence between times of crashes and motorcycle crash severities. Drivers or motorcycle riders contributed to a majority of the fatal motorcycle crashes, 93.69 %, and contributory circumstances was found to be related to motorcycle crash severity from the Chi-Square value. Fatal motorcycle crashes of 46.53 % occurred on straight and level roads and on-road surface characteristics were strongly interdependent with motorcycle crash severities. But no interdependence was found between on-road surface types and motorcycle crash severity. The highest percentage of fatal motorcycle crashes occurred on non-intersection roadways, 42.52 %, and crashes with different locations had a high Chi-Square value, indicating a higher level of interdependency between crash locations and motorcycle crash severities.

4.2.3 Comparison of Characteristics between Motorcycle Crashes and Other Vehicle Crashes

To better understand characteristics of motorcycle crashes in Kansas, several comparisons were produced between motorcycle crashes and other vehicle crashes in Kansas from 1999 to 2008. The average percentage of motorcycle crashes and other vehicle crashes for several factors were compared with the intention of identifying factors which were more common among motorcycle crashes than other vehicle crashes. Trend comparisons were also made between motorcycle crashes and other vehicle crashes from 2004 to 2008. The tables used to produce the following comparisons are provided in Appendix B.

When considering vehicle maneuvers for the 10 year period from 1999 to 2008, a similar distribution for different maneuvers was observed from Figure 4.2. Straight-following roads involved the highest percentage of crashes for both motorcycles and other vehicles. Other maneuvers also followed pretty much the same pattern for both motorcycle crashes and other vehicle crashes.

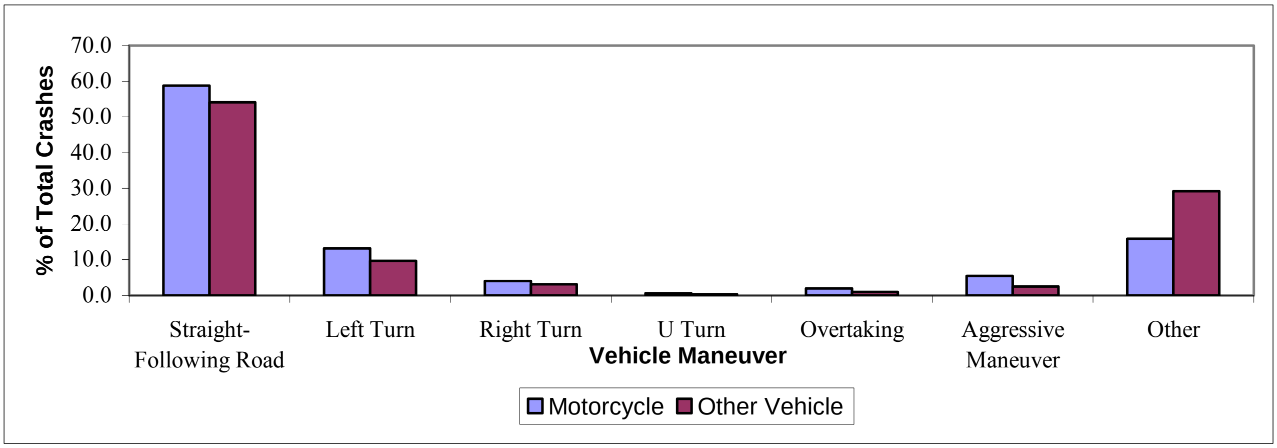


Figure 4.2 Average Percentage Comparison between MC and Other Vehicle Crashes for Vehicle Maneuvers

Trends for different maneuvers for motorcycle crashes and other vehicle crashes for the five-year period (2004-2008) are shown in Figure 4.3. It is important to note most of the vehicle maneuvers had higher percentages of crashes involving motorcycles than other vehicles. Slowing or stopping maneuvers had an increasing trend for motorcycle crashes over the period from 2004 to 2008. Other maneuvers did not follow any exact trend.

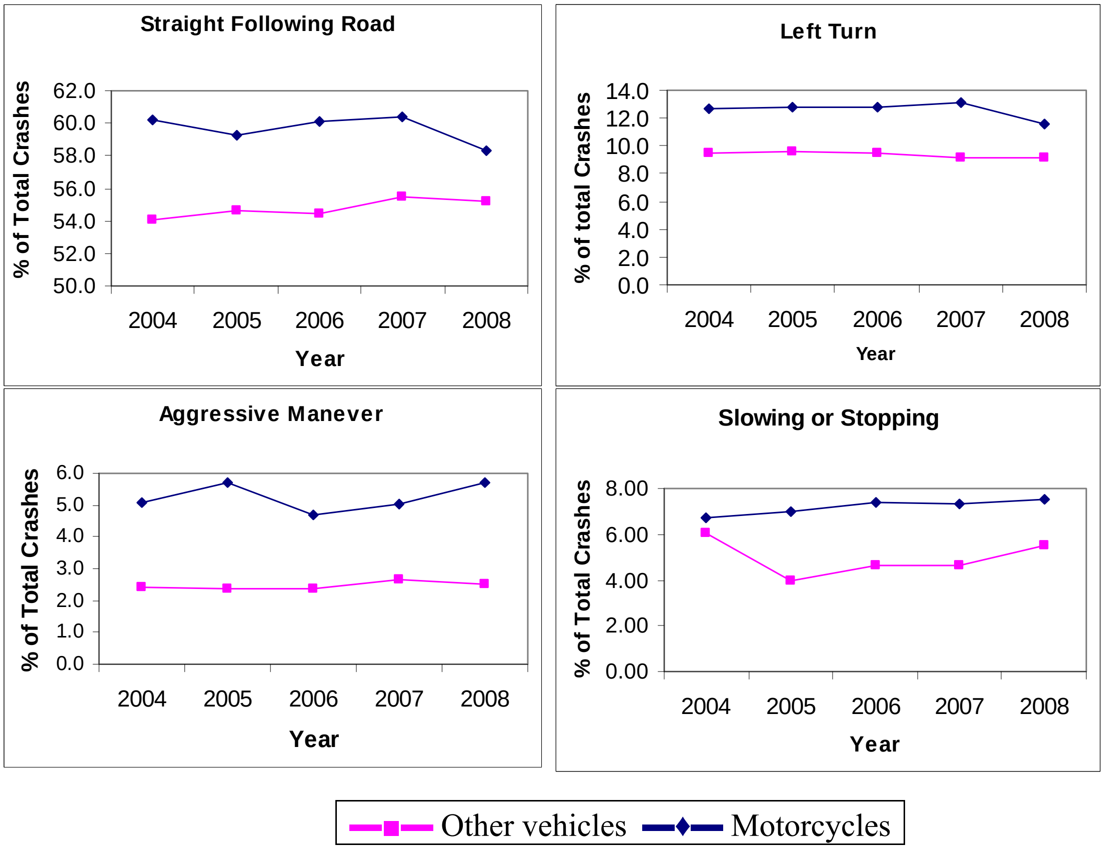


Figure 4.3 Trend of Crashes Involving Motorcycles and Other Vehicles Based on Vehicle Maneuvers

When considering age of the driver (rider in case of motorcycles), younger drivers and older drivers had higher percentages of involvement in crashes for other vehicles than motorcycles as shown in Figure 4.4. For all other age categories, percentages of motorcycle crashes were higher than other vehicle crashes. Drivers were divided into three age groups: as younger, middle aged, and older drivers. Drivers aged upto 29 years consisted of younger drivers. Drivers from 30 to 59 years were labeled of the middle-aged drivers, and drivers 60 years and over were considered older drivers.

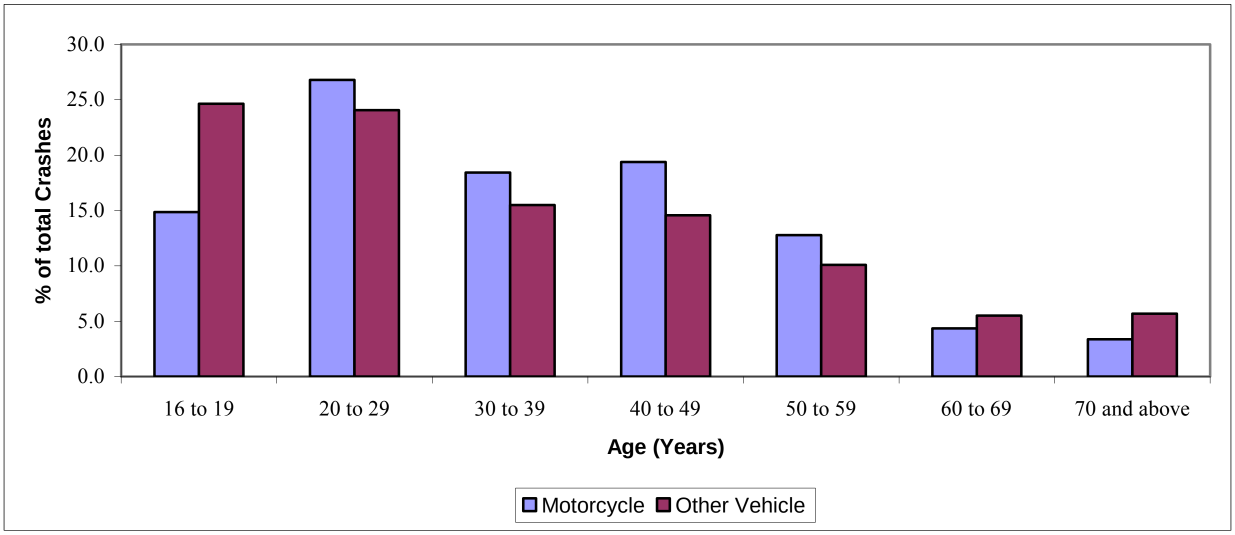


Figure 4.4 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for Driver Age

Figure 4.5 shows the trend for young, middle-aged, and older driver crashes for motorcycles and other vehicles. From the figure, it is evident the percentage of crash involvement for middle-aged motorcycle riders was higher than other vehicle drivers. Crashes involving young motorcycle riders and middle-aged riders did not show any exact trend over the five-year period. Crashes involving older motorcycle riders had an increasing trend compared to the fairly constant trend of other vehicle crashes involving older drivers. This is because motorcycle demographics have changed significantly in the United States for the last 10 years, shifting median age of motorcycle riders from 25 to 41 (59). Other vehicle crashes involving young and middle aged-drivers showed a constant trend compared to the unpredictable trend of motorcycle riders involving those age groups.

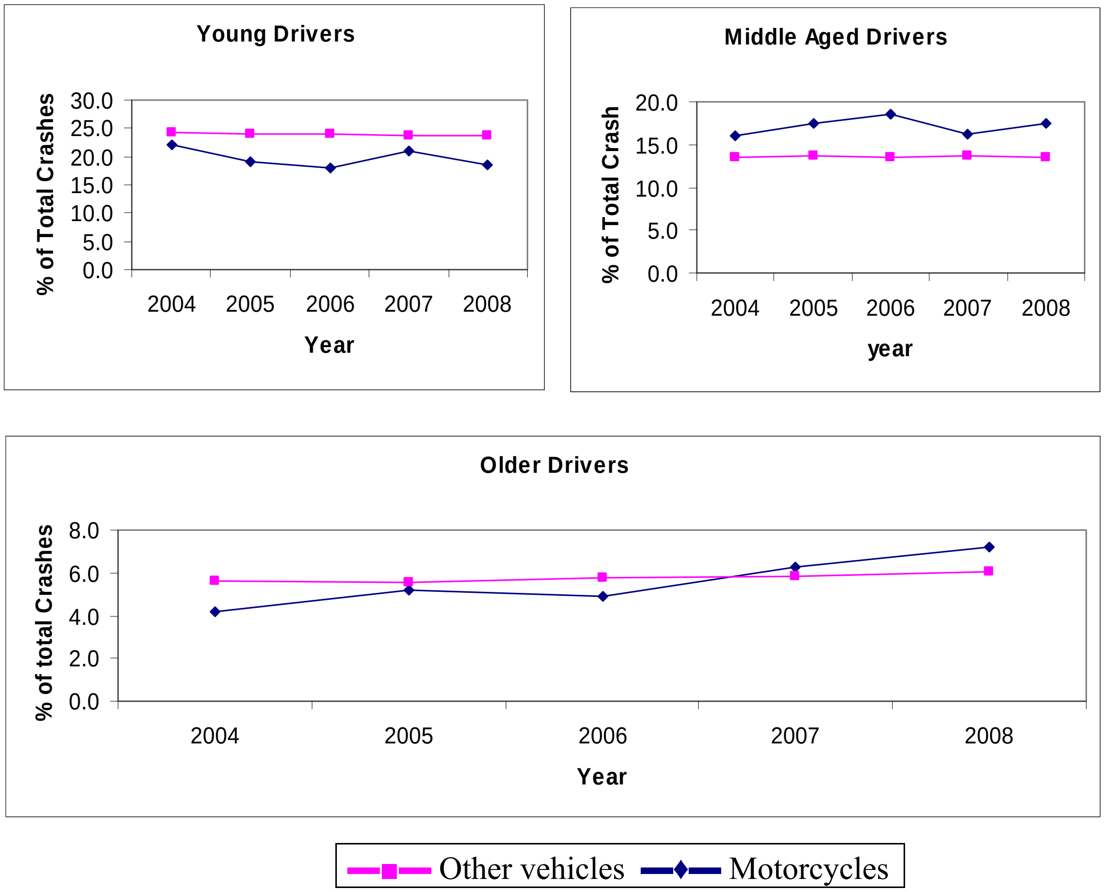


Figure 4.5 Trend of Crashes Involving Motorcycles and Other Vehicles Based on Age of the Drivers

Figure 4.6 shows the average percentage comparison between motorcycle crashes and other vehicles crashes for different light conditions. Percentages of motorcycle crashes in dark conditions (with streetlights on) were higher than those of other vehicle crashes, but daylight and dark conditions (with no streetlights) crashes had a lower percentage of motorcycle crashes.

Figure 4.7 shows the trend of motorcycle crashes and other vehicle crashes based on different light conditions. Figure 4.7 shows an increasing trend of motorcycle crashes in daylight conditions, whereas the trend was the opposite for other vehicle crashes. Motorcycle crashes with dark conditions (streetlights on) had a decreasing trend and vice versa for other vehicle crashes. Motorcycle riding is a highly seasonal activity and motorcycle riders normally prefer sunny and warm days to ride. Accordingly, the percentage of motorcycle crashes with daylight conditions was highest.

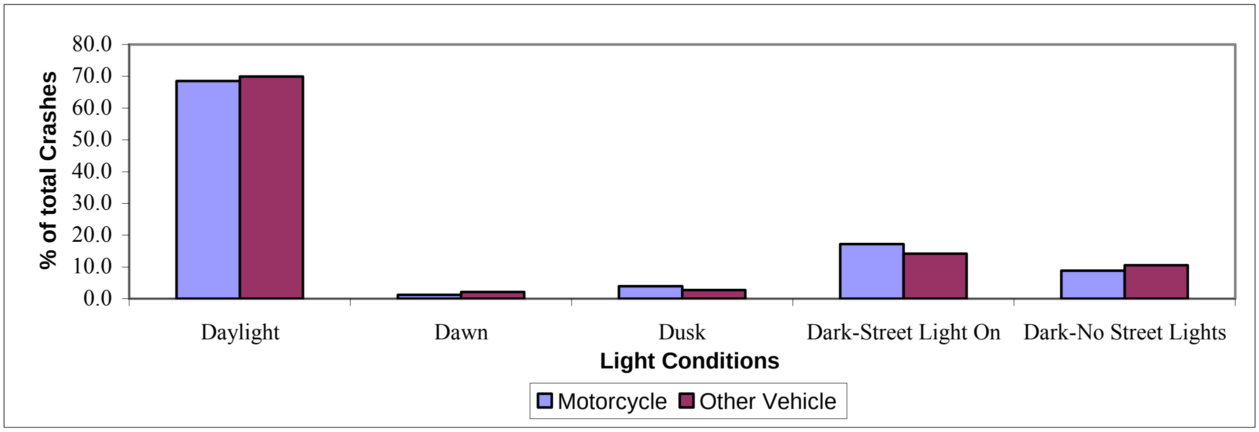


Figure 4.6 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for Light Conditions

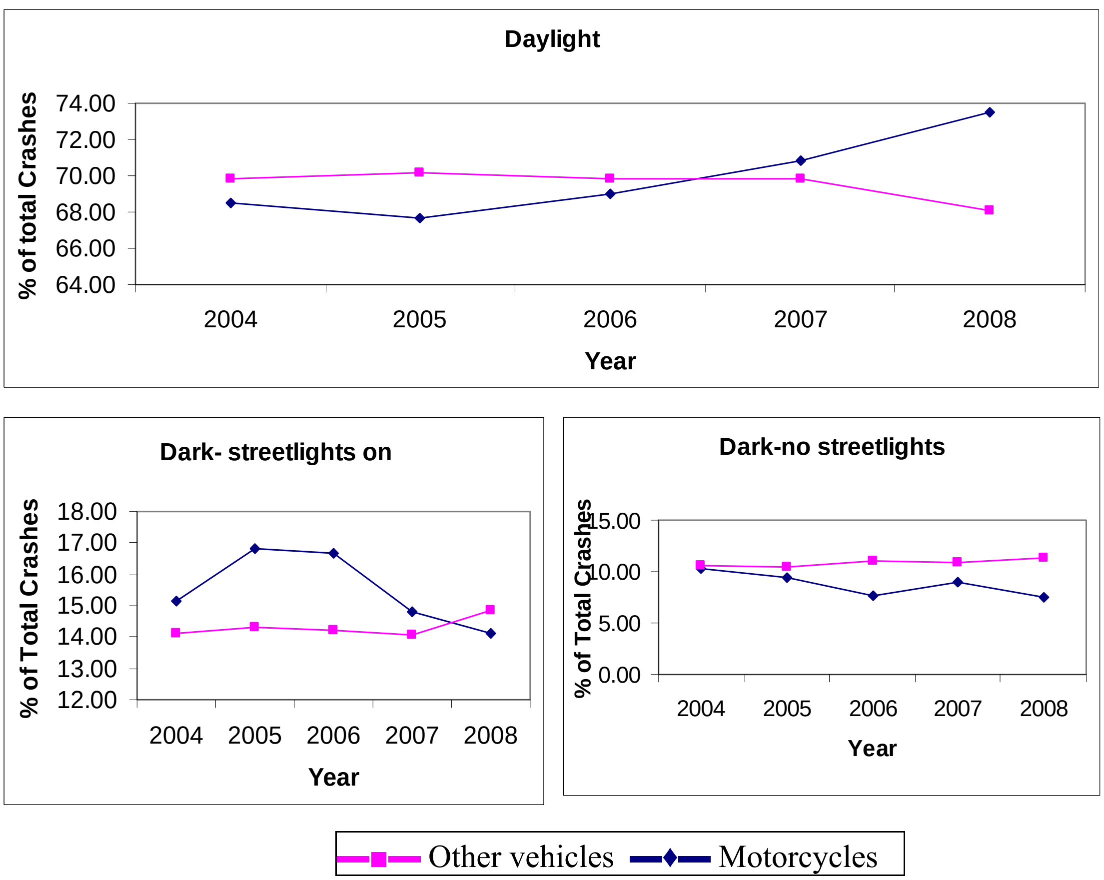


Figure 4.7 Trends of Crashes Involving Motorcycles and Other Vehicles Based on Light Conditions

Figure 4.8 shows the distribution of different crash classes for motorcycle and other vehicle crashes in Kansas considering data from 2004 to 2008. Percentage of overturned motorcycle crashes was considerably higher than those of other vehicles. More motorcycle crashes involving collisions with fixed objects occurred than those of other vehicle crashes. So it is clear that motorcycle crashes tended to be involved in collisions with fixed object. Motorcycle crashes colliding with other motor vehicles had a lower percentage than other vehicle crashes. This makes sense as motorcycles are more likely to be involved in a fatal collision with a fixed object than are other vehicles (25). Trends of motorcycle crashes and other vehicle crashes for these crash classes are represented in Figure 4.9. Trends of overturned motorcycle crashes and collisions with other motor vehicles remained more or less constant over the time period. But an increasing trend can be noticed for motorcycle crashes involved in collisions with fixed objects. This increasing trend was also true for other vehicle crashes involved in fixed objet collisions.

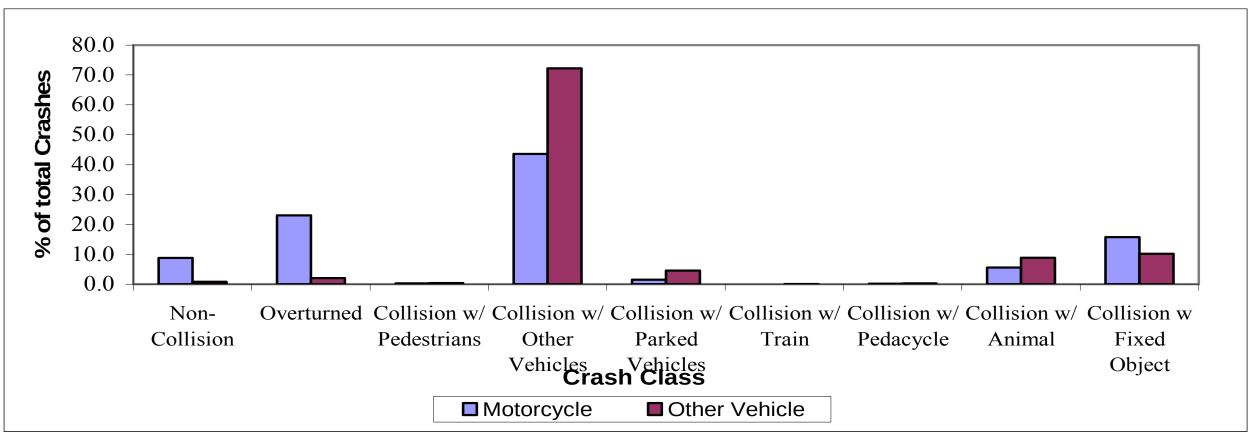


Figure 4.8 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for Crash Classes

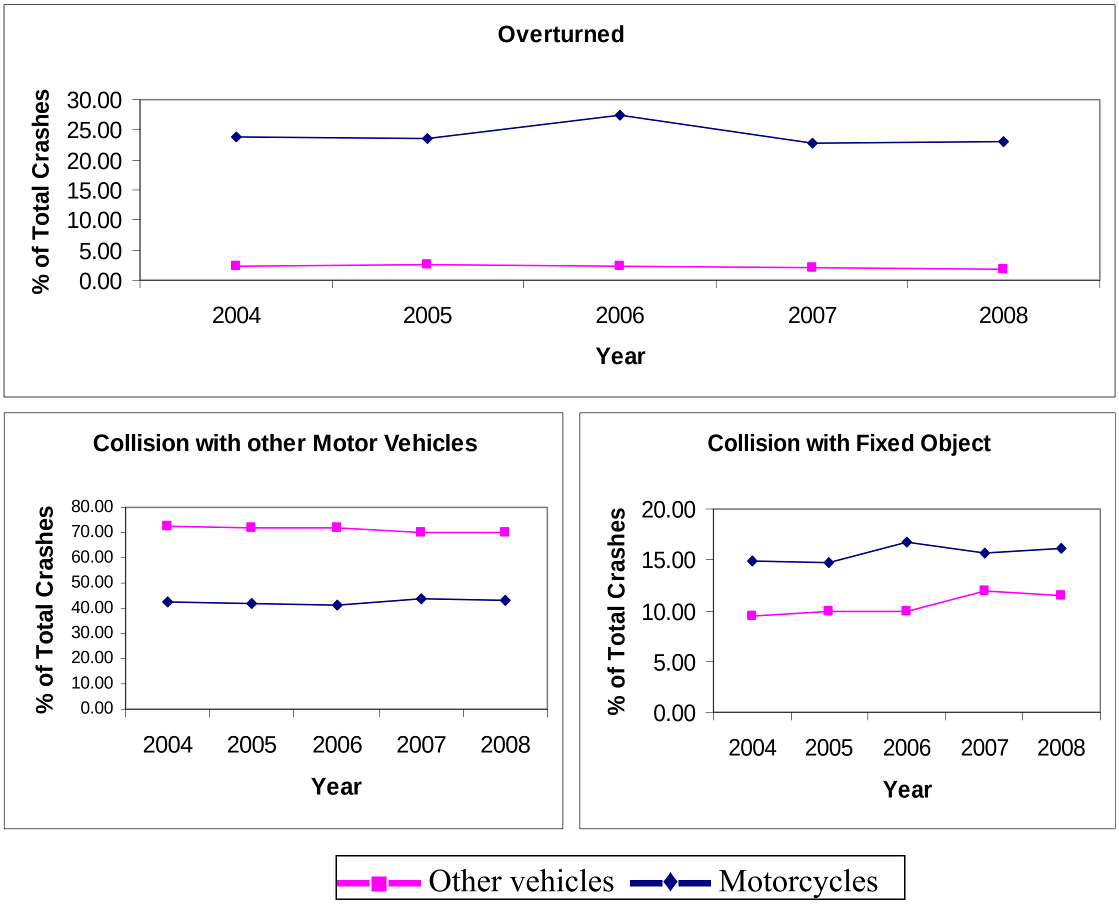


Figure 4.9 Trend of Crashes Involving Motorcycles and Other Vehicles Based on Crash Classes

Figure 4.10 shows the distribution of motorcycle and other vehicle crashes occurring on different days of the week. One interesting point to note from this figure is that a higher percentage of motorcycle crashes occurred during weekends than other vehicle crashes. The contingency table analysis did not find any significant dependence between motorcycle crash severity and day of the crash. Trends in Figure 4.11 do not show any exact pattern for motorcycle crashes occurring during weekdays or weekends for the five-year period from 2004 to 2005. Percentage of motorcycle crashes remained steady for crashes occurring on weekdays. Though percentage of motorcycle crashes during weekends decreased intermediately, it was more or less the same as 2004 at the end of 2008.

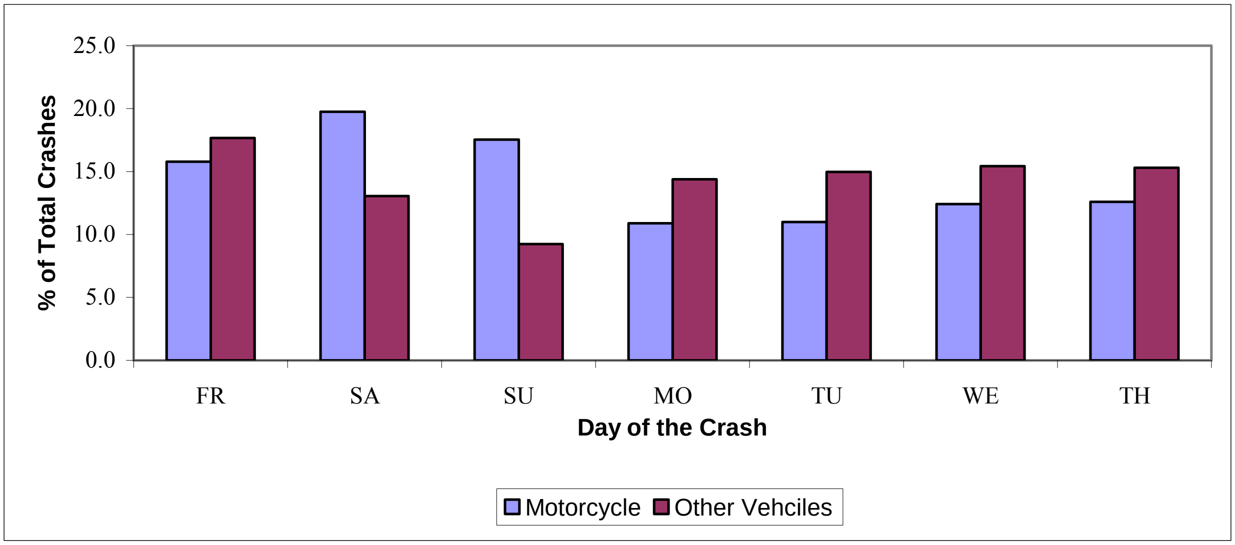


Figure 4.10 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes by Day of the Crashes

Figure 4.12 shows the distribution of motorcycle crashes and other vehicle crashes by time of the crashes occurred. Motorcycle crashes occurring from 6:00 p.m. to 9:00 p.m., from 9:00 p.m. to 12:00 a.m., and from 12:00 a.m. to 3:00 a.m. had higher incidence percentages compared to other vehicle crash percentages. All three time periods were during the night starting from 6:00 p.m. to 3:00 a.m.

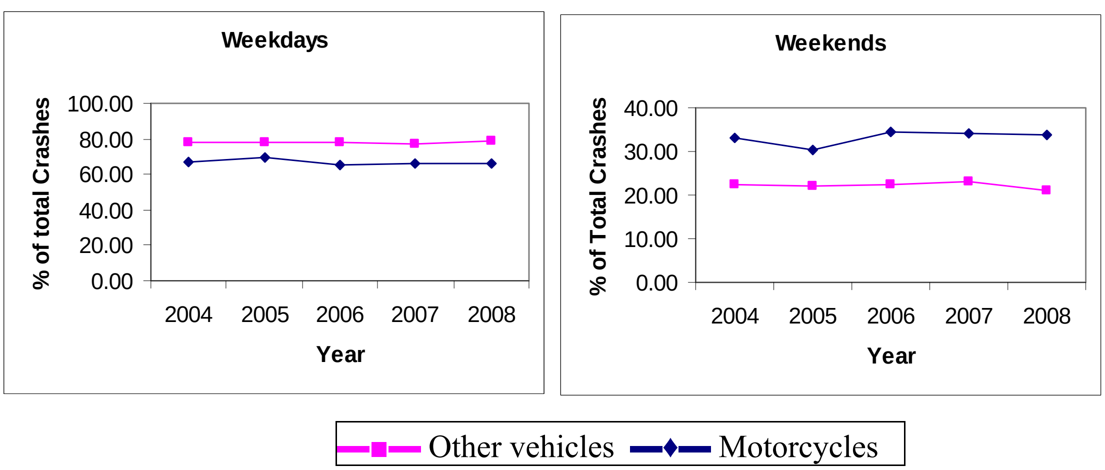


Figure 4.11 Trend of Crashes Involving Motorcycles and Other Vehicles Based on Day of the Crashes

The trend for one of these time periods, 9:00 p.m. to 12:00 a.m., showed a decreasing pattern over time compared to the steady pattern for other vehicle crashes as shown in Figure 4.13. The other time period, 6:00 p.m. to 9:00 p.m. did not show any consistent pattern.

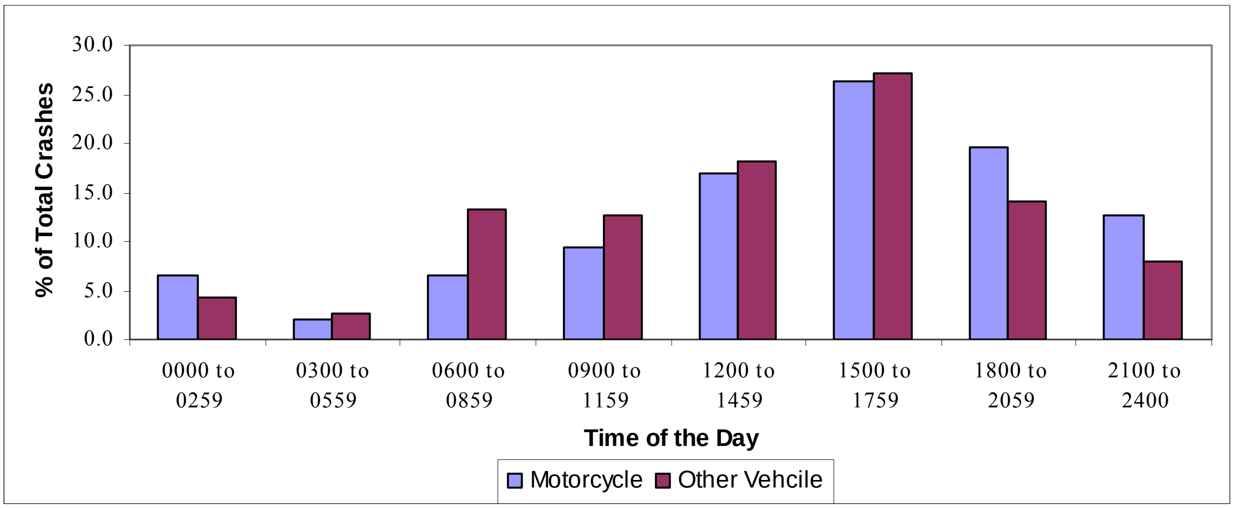


Figure 4.12 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes in Kansas for Time of the Crashes, 1999-2008

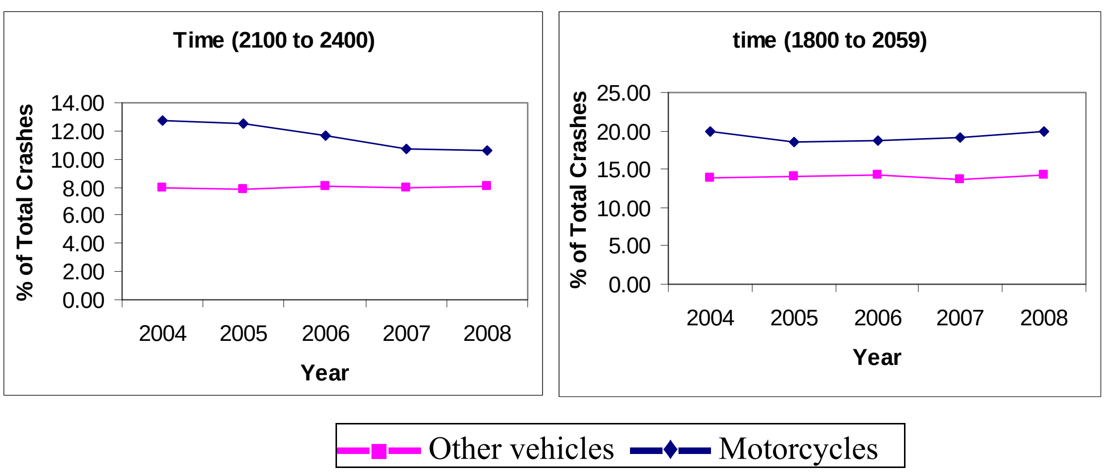


Figure 4.13 Crashes Involving Motorcycles and Other Vehicles Based on Time of the Crashes

When considering contributing factors, Figure 4.14 shows the percentage of motorcycle crashes contributed to by motorcycle riders was higher than other vehicle crashes. Environment contributed to a lesser percentage of motorcycle crashes than other vehicle crashes. Percentage of motorcycle crashes contributed to by the environment did not show any trend, as shown in Figure 4.15, but motorcycle-rider-contributing crashes displayed a decreasing trend over the five- year time period from 2004 to 2008. This might be the reason motorcycle riders became more careful and used various types of safety gear to protect themselves from crashes.

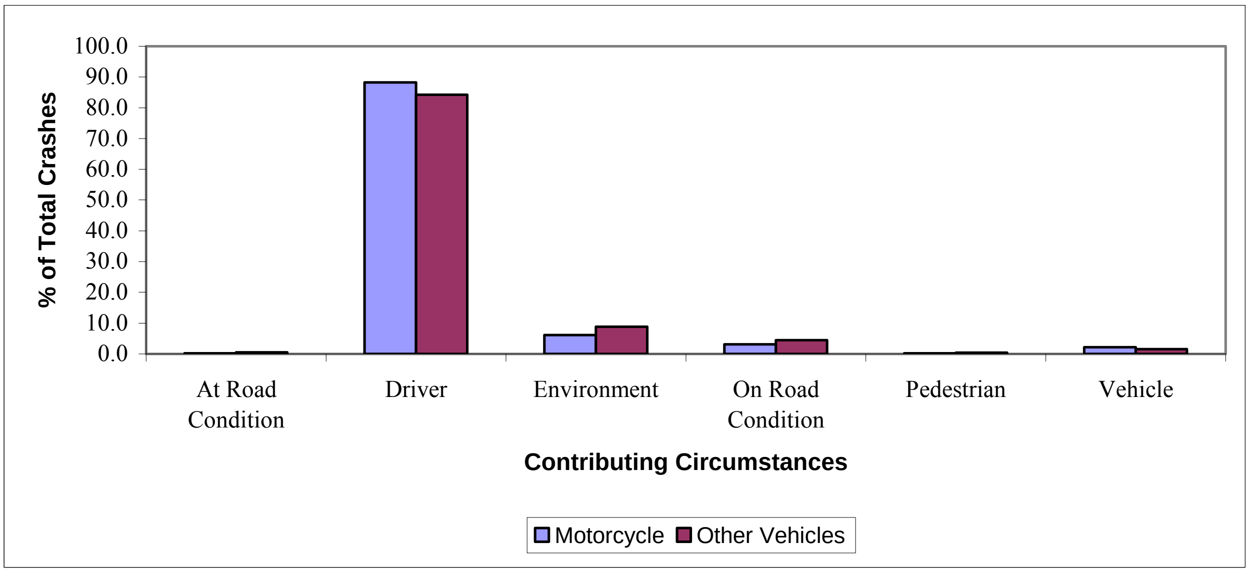


Figure 4.14 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for Contributing Factors

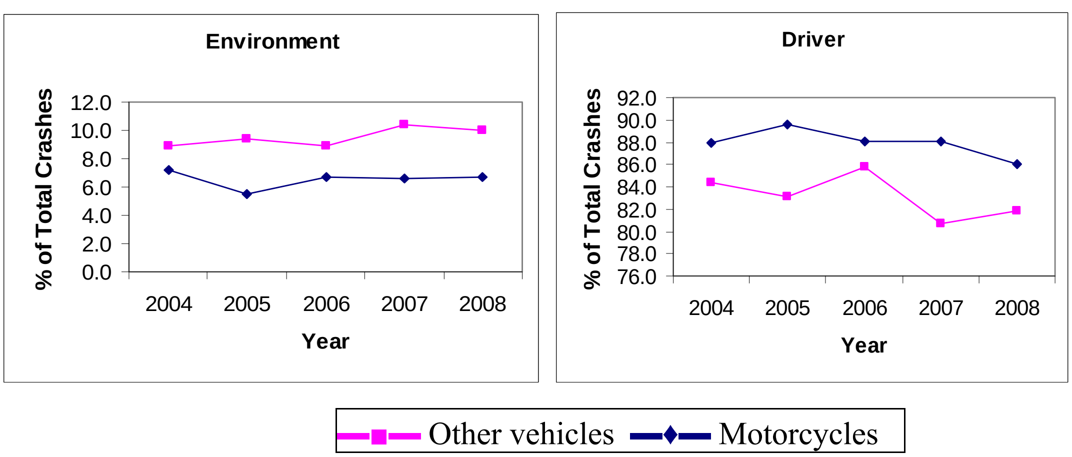


Figure 4.15 Trends of Crashes Involving Motorcycles and Other Vehicles Based on Contributing Factors

Figure 4.16 shows all driver contributory factors where the percentage of motorcycle crashes was more than those of other vehicle crashes. Influence of alcohol, exceeding speed limit, too fast for conditions, evasive actions, etc. had a higher percentage of motorcycle crashes compared to other vehicle crashes.

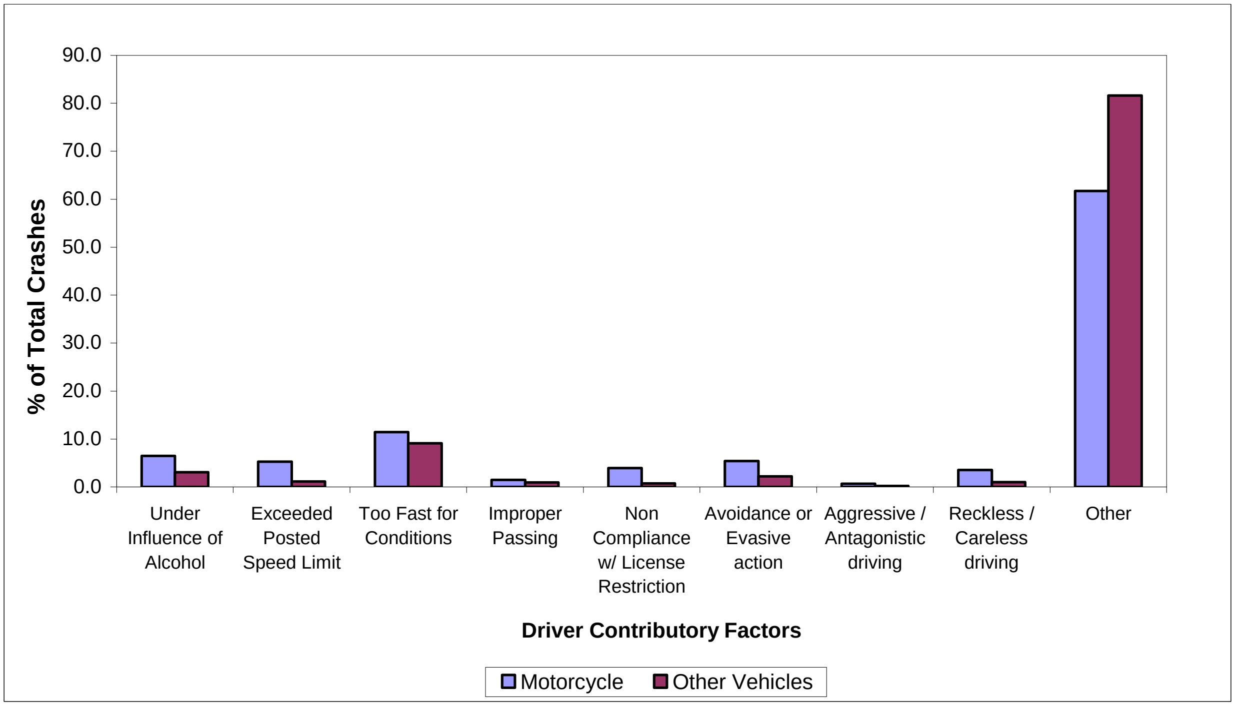


Figure 4.16 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for Driver Contributory Factors

Figure 4.17 shows the percentage of motorcycle and other vehicle crashes based on road surface characteristics. Motorcycle crashes occurring on straight and level roads had lower percentages than other vehicle crashes. But motorcycle crashes occurring on curved and level roads had higher percentages than other vehicle crashes. The same was true for motorcycle crashes occurring on sloppy and curved roads. Trends for motorcycle crashes occurring on curved and level or curved on grade roads did not follow any pattern over the time period from

2004 to 2008 as shown in Figure 4.18. The Chi-Square test (Table 4.5) showed a higher level of interdependency between on-road surface characteristics and motorcycle crash severity.

Figure 4.19 shows the percentage of nonintersection motorcycle crashes was higher than other vehicle crashes, but the percentage of motorcycle crashes occurring at intersection was lower than those of other vehicle crashes. The reason for this might be that motorcycle riders may tend to ride at higher speeds on nonintersection roadways than intersection roadways. The data for motorcycle crashes and other vehicle crashes followed similar trend over the five-year period in Figure 4.20. Also, the Chi-Square test showed a higher level of interdependency between crash location and motorcycle crash severity.

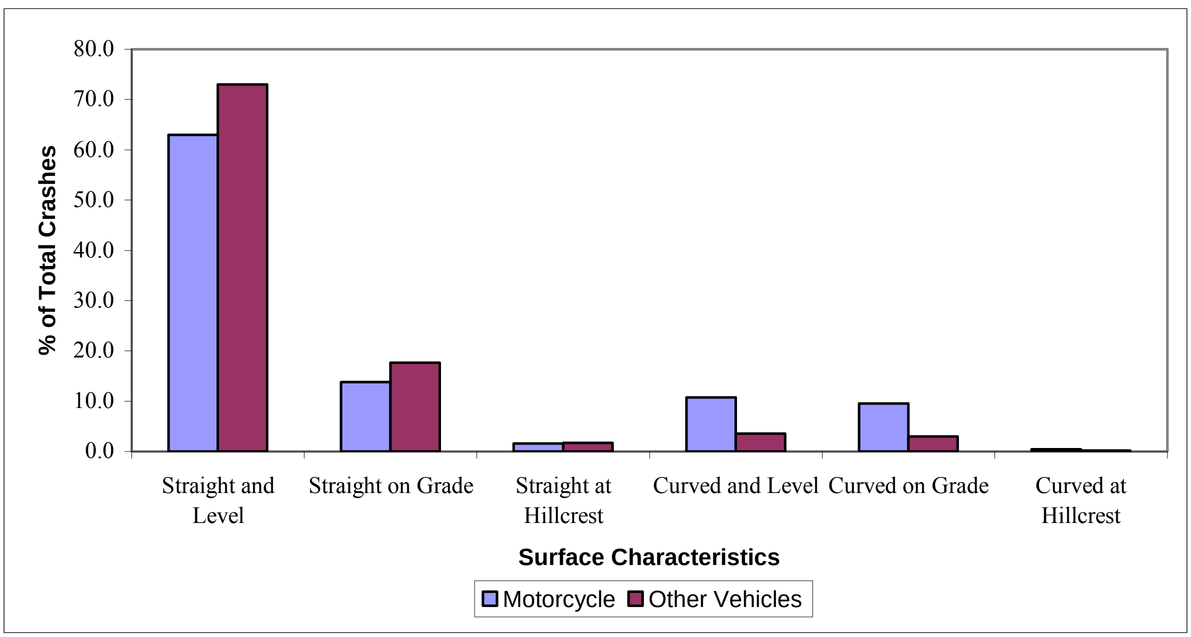


Figure 4.17 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for On-Road Surface Characteristics

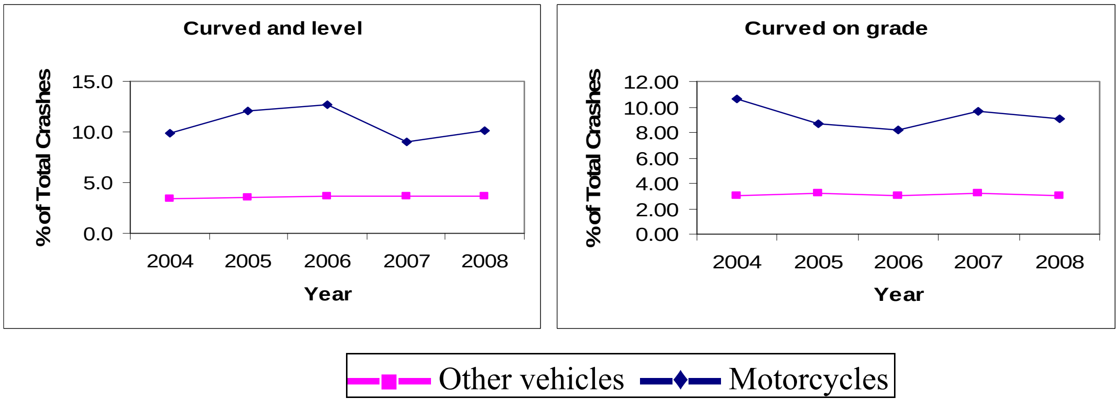


Figure 4.18 Trend of Crashes Involving Motorcycles and Other Vehicles Based on On-Road Surface Characteristics

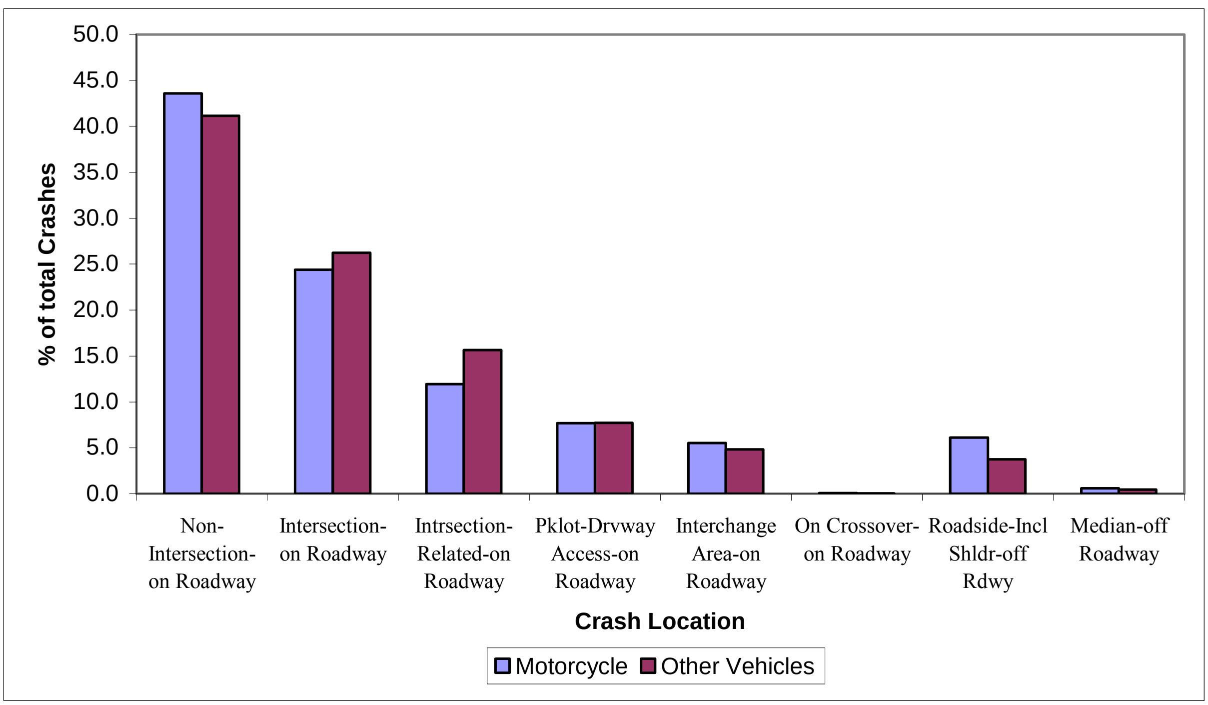


Figure 4.19 Average Percentage Comparison between Motorcycle and Other Vehicle Crashes for Crash Location

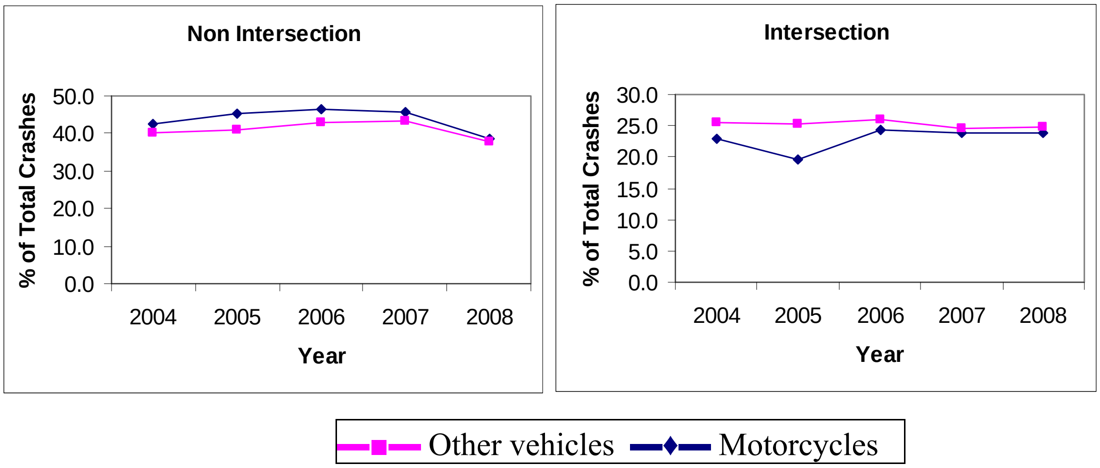


Figure 4.20 Crashes Involving Motorcycles and Other Vehicles Based on Crash Location

From the comparative study between motorcycle crashes and other vehicle crashes for several factors, motorcycle crashes were found to have higher percentages than other vehicle crashes for quite a few factors. Percentage of motorcycle crashes were higher during weekends compared to other vehicles crashes. Some vehicle maneuvers, such as straight following road, left turn, right turn, U turn, overtaking, and aggressive maneuvers, had a higher percentage of motorcycle crashes than other vehicle crashes. Most driver related factors had a higher percentage of motorcycle crashes than other vehicle crashes.

4.2.4 Univariate Logistic Regression

By conducting univariate logistic regression to analyze motorcycle fatal crashes in Kansas, important characteristics affecting motorcycle fatalities could be identified. The following section discusses the effect of each factor in detail. For study purposes, one of the subcategories for every factor was treated as a reference group. Subcategory odds ratios were compared to the reference group odds ratios to understand the relative effect of those on motorcycle fatal crashes in Kansas. Statistical significance was concluded at the $p<0.1$ level. Table 4.6 shows results of the logistic regression. Odds ratio for a subcategory resulting in greater than unity compared to the reference group indicates higher likelihood of that subcategory affecting motorcycle fatal crashes.

4.2.4.1 Motorcycle Maneuvers

Motorcycle maneuvers were considered a factor from the KARS database. There were several sub-categories in the KARS database under motorcycle maneuvers such as straight following road, left turn, right turn, overtaking, chasing lanes, aggressive maneuver, and slowing or stopping. It is important to note all these maneuvers were recorded by police officers at the scene of the crashes from the information gathered after the crashes took place. Straight following road was considered as the reference group in this case, and the odds ratio was 1. Study results revealed the risk of motorcycle fatal crashes was higher for overtaking maneuvers and lower for slowing or stopping maneuvers with statistical significance. The odds ratios for overtaking and slowing or stopping maneuvers were 1.766 and 0.404 respectively, when compared to the reference maneuver straight following road. This indicates that the odds of a fatal motorcycle crash increased almost 77% for overtaking and decreased by almost 60% for

Table 4.6 Results of Univariate Logistic Regression of Motorcycle Fatal Crashes in Kansas

Factors and their sub-categories	Odds Ratio	Pr>Chisq	95% CI	
MC MANEUVER (Reference group = Straight following road)				
Left turn	0.853	0.3532	0.609	1.194
Right turn	0.576	0.1098	0.293	1.133
Overtaking	1.766	0.0776*	0.939	3.322
Chasing lanes	0.436	0.1033	0.16	1.184
Aggressive maneuver	0.675	0.1605	0.39	1.169
Slowing or stopping	0.404	0.0127*	0.198	0.824
GENDER (Reference group = male)				
Female	1.04	0.715	0.842	1.285
AGE GROUP (Reference group = 30 to 39 years)				
16 to 19 years	0.882	0.5383	0.591	1.1316
20 to 29 years	1.169	0.3403	0.848	1.612
40 to 49 years	1.362	0.0676*	0.978	1.896
50 to 59 years	1.318	0.1245	0.927	1.875
60 to 69 years	2.317	<0.0001*	1.551	3.461
70 years and above	1.592	0.0857*	0.937	2.704
TYPES OF SAFETY EQUIPMENTS USE (Reference group = No use of motorcycle helmet)				
MC Helmet	0.614	0.0265*	0.4	0.945
MC Helmet and eye protection	0.658	0.019*	0.464	0.934
LIGHT CONDITIONS (Reference group = daylight)				
Dawn and dusk	1.012	0.9654	0.593	1.725
Dark-street light on	1.405	0.0185*	1.059	1.865
Dark-no street lights	2.685	<0.0001*	2.004	3.597
TIME OF THE CRASHES (Reference group = 0300 to 0600 hours)				
0000 to 0300 hours	1.195	0.7095	0.469	3.044
0600 to 0900 hours	0.408	0.0959*	0.142	1.172
0900 to 1200 hours	0.66	0.3872	0.257	1.694
1200 to 1500 hours	0.551	0.1949	0.224	1.357
1500 to 1800 hours	0.709	0.437	0.299	1.686
1800 to 2100 hours	0.546	0.1861	0.223	1.339
2100 to 2400 hours	1.273	0.5909	0.528	3.07
OR SURFACE CHARACTERISTICS (Reference group =straight and level)				
Straight on grade	2.248	<0.0001*	1.561	3.238
Straight at hillcrest	3.705	0.0003*	1.808	7.595
Curved and level	2.006	0.001*	1.323	3.042
Curved on grade	2.019	0.0017*	1.301	3.132
CRASH LOCATION (Reference group = interchange are on roadway)				
Non-intersection-on roadway	1.21	0.5738	0.623	2.351
Intersection-on roadway	1.288	0.4718	0.646	2.568
Intersection-related-on roadway	0.917	0.8273	0.421	1.997
Parking lot-driveway access-on roadway	0.925	0.8569	0.394	2.17
Roadside-including shoulder-off roadway	2.544	0.0121*	1.227	5.275
WEATHER CONDITIONS (Reference group = no adverse conditions)				
Rain, mist, drizzle, and winds	0.731	0.4218	0.34	1.571

Table 4.6 (Continued)

Factors and their sub-categories	Odds Ratio	Pr>Chisq	95% CI	
CRASH CLASS (Reference group= other non-collision)				
Overturned	1.171	0.6391	0.605	2.265
Collision w/ other MV	1.78	0.063*	0.969	3.269
Collision w/ animal	2.245	0.0353*	1.057	4.769
Collision w/ fixed object	2.405	0.0075*	1.265	4.575
DAY OF THE WEEK FOR CRASHS (Reference group =Monday)				
FR	0.822	0.5125	0.458	1.477
SA	1.336	0.2717	0.797	2.238
SU	1.163	0.5854	0.677	1.998
TH	1.086	0.7837	0.604	1.952
TU	0.987	0.9655	0.536	1.815
WE	1.168	0.5924	0.661	2.064
CONTRIBUTORY FACTORS (Reference group = driver)				
Environment	0.904	0.6616	0.574	1.422
SUBTANCE ABUSE (Reference group = alcohol present among the riders)				
Alcohol contributing to motorcycle crash	0.527	0.0586*	0.271	1.024

CI = Confidence Interval

*** (**statistically significant at 90% confidence level)

slowing or stopping maneuvers compared to straight following road maneuvers. These results are realistic as the overtaking maneuver is likely to increase the chance of getting involved in a more severe crash. On the other hand, slowing or stopping might potentially reduce the risk of motorcycle fatal crashes.

4.2.4.2 Gender

From the study, the odds ratio of female motorcycle occupants, including riders and passengers, was found to be slightly higher than male motorcycle occupants in Kansas. Previous studies have shown that women were found to have a higher probability of more severe injuries relative to men (38). But the odds of a fatal motorcycle crash for women occupants increased only by 4% when compared to male occupants and that is also not with statistical significance.

4.2.4.3 Age Group

Age of motorcyclists in Kansas was divided into several sub groups. Previously Mannering and Grodsky found those aged 26 to 39 years were positively associated with medium-risk categories of injury (33). So, the reference age group in this study was selected as 30-39 years for the motorcyclists. Results showed motorcyclists aged 40-49 years, 60-69 years and >70 years had considerable higher odds of being involved in motorcycle fatal crashes. The age group 60-69 years was more than 200 % more likely to be involved in a fatal motorcycle crash when compared to motorcyclists in the age group 30-39 years with a statistical significance of $p<0.1$. This finding was in agreement with another study that also found older motorcycle riders had an increased likelihood of fatalities and disabling injuries (36). Although older motorcyclists may tend to ride at lower speeds and are less likely involved in a crash, once in a crash they may tend to have more severe injuries. Another reason for the increased severe crashes for older motorcyclists may be motorcycle demographics. There has been a dramatic change in the demographics of the motorcycle riders in USA for the past few years. The average buyer of motorcycles is now over the age of 35. Motorcycle riders aged 40 and over have seen a fatality rate increase from 14% in 1990 to 45% in 2003 (59).

4.2.4.4 Types of Safety Equipment Used

This factor was subcategorized into motorcycle helmet and eye protection, motorcycle helmet only, and no use of motorcycle helmet, which were the safety equipment typically used by motorcyclists in Kansas. The reference group was chosen as the “no use of motorcycle helmet” in this case to examine the effect of helmet use with respect to non use. No use of motorcycle helmet included shoulder lap, eye protection only, lap belt only, airbag deployed only, etc. Results showed the risk of motorcycle fatal crashes was less for the case of motorcycle helmet use and use of motorcycle helmet and eye protection together. The odds ratio for motorcycle helmet use was 0.614 compared to no use of helmet, indicating the risk of fatal crashes decreased by almost 40% when the rider used a helmet. Also the odds ratio for helmet use and eye protection simultaneously was 0.658, indicating a decreased risk of almost 35% compared to not using a helmet. In both cases, results were statistically significant at a level of $p<0.1$.

4.2.4.5 Light Conditions

Light conditions during the time of the crashes were also considered to conduct logistic regression relating to fatal motorcycle crashes. Light conditions were divided into four subcategories as daylight, dawn and dusk, dark-streetlight on, and dark-no streetlights. The daylight condition was used as the reference group to examine the effects of other light conditions. It was found all other light conditions had a higher risk of motorcycle fatal crashes than daylight conditions. It was statistically significant at the level of $p<0.1$. The odds ratios for dark-streetlight on and dark-no streetlights were 1.405 and 2.685, respectively, with respect to daylight conditions. Odds of a motorcycle fatal crash increased more than 200% for dark conditions with no streetlights when compared to daylight conditions.

4.2.4.6 Time of Crashes

Time of crashes was measured with dummy variables for 3-h time intervals, using late night (3:00 a.m. to 6:00 a.m.) as the reference time period. Most time periods showed odds ratios less than 1 when compared to the reference time period, except the two periods, 9:00 p.m. to 12:00 a.m., and 12:00 a.m. to 3: a.m. One daytime period, 6:00 a.m. to 9:00 a.m., showed a decreased odds of a fatal crash of about 60% compared to the reference group with a statistical significance at the level of $p<0.1$. So, it was clear more fatal crashes occurred from nighttime to early morning periods than during the day. This result was in agreement with a previous research finding (37).

4.2.4.7 On-Road Surface Characteristics

From the results, it was evident that on-road surface characteristics played an important role when it came to the risk of motorcycle fatal crashes. Straight and level road was the reference group in this case. It was found that all other types of road characteristics significantly increased the risk of involvement in motorcycle fatal crashes compared to straight and level roads. Road surfaces straight at hillcrests had an odds ratio of 3.705 reflecting a huge increase in the risk of fatal crashes. Straight on grade, curved and level, and curved on grade roadways had odds ratio of 2.248, 2.006 and 2.019 respectively. All results were significant at a level of $p<0.1$. These results do make sense as it is always easier to operate a motorcycle on straight and level roads. But it requires skill and experience to deal with roads at hillcrests, curved on grade, etc. So, risks of fatal motorcycle crashes increase with these types of road characteristics.

4.2.4.8 Weather Conditions

Two types of weather conditions were taken into account in this analysis. Those were no adverse conditions and adverse conditions (rain, mist, drizzle and winds). The "no adverse conditions" was taken as the reference group. Odds ratio for adverse conditions (rain, mist, drizzle, and winds) came out to be less than one with no statistical significance. Generally, motorcycle riding is a recreational activity with all riders interested in riding the bikes when the weather is sunny, clear, and good.

4.2.4.9 Crash Locations

The reference group considered in the crash locations factor was “interchange present on roadway” when the crash took place. The odds of a motorcycle fatal crash increased more than 250% for “roadsides including shoulder” compared to the reference group. This result was statistically significant at a level of $p<0.1$.

4.2.4.10 Crash Classes

This factor was important to understand the characteristics of motorcycle crashes in Kansas. The reference group in this case was non-collision motorcycle crashes. From the results, it was evident that all other crash classes had higher risks of motorcycle fatal crashes compared to non-collision type crashes. Especially, collisions with animals and collisions with fixed objects had odds of more than 200% for a motorcycle fatal crash than non-collision crashes. These were statistically significant with p values of 0.0353 and 0.0075, resepctively. The odds ratio for collisions with other motor vehicle was 1.78, compared to non-collision crashes with a p value of 0.063.

4.2.4.11 Day of the Week for Crashes

All days in a week were considered for motorcycle fatal crashes occurring in Kansas. The reference day was Monday in this case. Results showed no effect of a day of the week on motorcycle fatal crashes in Kansas. Though results showed the odds ratio was higher for Wednesday, Thursday, Saturday, and Sunday, but there was no statistical significance.

4.2.4.12 Contributing Circumstances

Only two categories were considered for this factor as driver and environment. There were other categories like pedestrians, vehicles, at-road conditions, on-road conditions, etc. Motorcycle crash data were not available for those categories in KARS. The odds ratio for the environment compared to the driver was lower, with a value of 0.904, but with no statistical significance.

4.2.4.13 Substance Abuse

In the KARS database, there were six categories dealing with alcohol contributing to the crashes or present during crashes, illegal drugs contributing to the crashes or present during the crashes and medication contributing or present during the crashes. Among these, frequencies for illegal drugs and medications were too low to consider for logistic regression. Thus, the only two categories considered in this case were the alcohol contributing to the crashes and alcohol present in the blood of riders during the crashes. Alcohol present during the crashes was considered as the reference group to examine the effect of alcohol contributing to fatal motorcycle crashes. Alcohol's presence during the crashes refers to those crashes where motorcycle riders were under the influence of alcohol. Results revealed the odds ratio for alcohol contributing to motorcycle fatal crashes was lower than alcohol present during the crash, with a statistical significance at the level of $p<0.1$.

4.3 Motorcycle Safety Survey

4.3.1 Survey Responses

Analysis and results based on the motorcycle riders' survey are discussed in this section whereas the survey form is provided in Appendix C. As the first step, simple percentages were calculated for the survey questions to get an idea about the overall situation. When looking at the percentages from Tables 4.7 and 4.8, 98% of the respondents were registered motorcycle owners in Kansas. A majority of the respondents owned Harley-Davidsons (42%). Honda and Kawasaki followed with 17% and 12%, respectively. Seventy-one percent of the respondents owned a motorcycle with model year between 2000 -2010. Thirty-five percent of the respondents owned a motorcycle with engine size 1001-1500cc. Percentage of respondents with motorcycle engine size greater than 1500cc was 30%. Among respondents who were Kansas motorcycle riders, both touring and cruiser type of motorcycle riding was dominant with 32% each. When it came to the motorcycle riding experience, 46% of the respondents had been riding motorcycles for more than 20 years. Twenty-seven percent of the riders had motorcycle riding experience of 0-5 years, followed by riders having riding experience of 5-10 years at 17%. When it came to motorcycle riding exposure, 24% of the motorcycle riders were riding between 5,000 to 7,999 miles per year, the highest percentage. Respondents riding between 3,000 to 4,999 miles per year closely followed with 21%. Thirty-two percent of the respondents commonly travel on two-lane, out-of-town roadways, whereas 30% of the respondents commonly travel on city/town roads. When it came to the primary reason for riding motorcycles, a majority of the respondents (55%) were riding for recreational purposes.

Table 4.7 Frequencies and Percentage of Responses to General Survey Questions by Motorcycle Riders

Question	Frequency	Percentage
Are you a registered motorcycle owner?		
Yes	267	98%
No	5	2%
What is the brand of your current motorcycle?		
Honda	47	17%
Yamaha	28	10%
Harley Davidson	115	42%
Suzuki	25	9%
Kawasaki	32	12%
BMW	6	3%
Others	19	7%
What is your motorcycle model year?		
Before 1980	10	4%
1980-1984	8	3%
1985-1989	11	4%
1990-1994	13	5%
1995-1999	37	13%
2000-2010	191	71%
What is the engine size of your motorcycle?		
500cc or less	18	7%
501-1000cc	71	27%
1001-1500cc	92	35%
More than 1500c	83	31%
Which of the following types of motorcycles do you ride most frequently?		
Touring	87	32%
Sport	50	19%
Standard	27	10%
Cruisers	86	32%
Dual	8	3%
Others	10	4%
How long have you been riding motorcycles?		
0-5 years	65	27%
5-10 years	42	17%
10-15 years	10	4%
15-20 years	16	6%
more than 20 years	112	46%

Table 4.8 Frequencies and Percentage of Responses to General Survey Questions by Motorcycle Riders

Question	Frequency	Percentage
Approximately How many miles did you ride in the past year?		
1,000 or less	36	15%
1,000-2,999	46	19%
3,000-4,999	52	21%
5,000-7,999	59	24%
8,000-10,000	26	11%
above 10,000	27	10%
What type of roadway do you commonly travel by motorcycle?		
City/Town Roads	190	30%
Two-Lane Out of Town	202	32%
Interstate/Divided Highway	162	24%
Rural Road	87	14%
What is the primary reason for riding a motorcycle?		
To make task related trips	40	11%
Recreational purposes	193	55%
To get good mileage	68	19%
As it is fast and maneuverable	25	7%
For its easiness of parking	28	8%
How frequently do you ride motorcycles?		
Everyday	46	18%
During weekend only	24	10%
1-3 days a week	97	39%
4-6 days a week	81	33%
What type of weather do you most prefer while riding motorcycle?		
Hot and Sunny	100	35%
Rainy	3	1%
Cold	7	2%
Humid	7	2%
Mild	174	60%

Only 18% of the respondents were riding motorcycles every day, whereas a majority of the others rode at least two or three days a week. One interesting point to note is that although only 10% of the respondents said they ride during the weekend only, Kansas crash data shows that 33% of all motorcycle crashes in Kansas from 2004 to 2008 occurred during weekends.

Sixty percent of the respondents rode motorcycles in mild weather with only 35% riding in hot and sunny weather. When considering motorcycle crashes in different weather conditions in Kansas, it also showed similar trend where almost 96% of crashes occurred during no adverse weather conditions for the five-year period from 2004 to 2008.

Frequencies and relevant percentages pertaining to demographic, social-economic, and educational background-related questions are presented in Table 4.9. Ninety-one percent of the respondents were male motorcycle riders compared to only 9% female motorcycle riders among the respondents. When looking at the age distribution of the sample, 38% of the respondents were 52 years of age or above. Twenty-six percent of the respondents were between the ages of 43 and 51 years, 12% were between the ages of 34 and 42 years, 8% were between the ages of 25 and 33 years, and 16% were between the ages of 16 and 25 years. When the age of distribution of motorcyclists involved in crashes in Kansas for the five-year period from 2004-2008 was looked into, 40% of the victims were above the age of 40 years. Though only around 22 % of respondents were of 40 years of age or below, crash percentages among those age groups were quite high at around 60%.

All respondents had at least been to high school and there were no respondents without any formal schooling. Forty-four percent of the respondents had some college education while 20% had graduate college experience. When it came to marital status of the respondents, 62% were married, with 20% single and 15% separated or divorced or widowed. Seventy percent of the respondents work full time while 15% were students. Most of the motorcycle riders' annual household income was greater than $19,999, and a majority of the respondents (58%) had a household income of $60,000 or greater.

Table 4.9 Frequencies and Percentage of Responses to Demographic, Socio-Economic, and Economic Background-Related Questions by Motorcycle Riders

Question	Frequency	Percentage
Your gender?		
Male	224	91%
Female	23	9%
Your age (in years)?		
16-24	38	16%
25-33	20	8%
34-42	29	12%
43-51	64	26%
52 and above	94	38%
Marital status?		
Single (never married)	54	23%
Married/living with partner	148	62%
Separated/divorced/widowed	36	15%
Your educational qualifications?		
No formal schooling	0	0%
High school	35	15%
Some college	105	44%
Four year college	50	21%
Graduate college	48	20%
Present job situation?		
Full-time work	169	70%
Part-time work	18	7%
Student	37	15%
Home maker	2	1%
Pension or unemployed	13	5%
Other (please specify)	3	1%
How much is your household income?		
$0 to 19,999	32	14%
$20,000 to 39,999	30	13%
$40,000 to 59,999	32	14%
$60,000 or above	132	58%

Table 4.10 Frequencies and Percentage of Responses to Helmet and Helmet Law-Related Questions by Motorcycle Riders

Question	Frequency	Percentage
Did you wear a helmet riding a motorcycle on public roadway last time?		
Yes	105	68%
No	50	32%
How often do you wear a helmet while riding a motorcycle?		
Always	118	48%
Sometimes	72	29%
Seldom	30	12%
Never	27	11%
If you don't always wear a helmet, what are the reasons?		
I'm not worried about having a crash	17	6%
Freedom of choice	108	36%
I don't believe a helmet makes me safer	21	7%
It is too hot	47	16%
It creates problem with my hearing	35	12%
It creates problem with my vision	36	12%
Weather conditions making riding more hazardous	6	2%
Laziness/Forgetfulness	18	6%
Other, specify	14	5%
Do you know what type of helmet law Kansas currently has?		
Mandatory helmet law	4	2%
No law	96	39%
Partial helmet law	134	54%
Don't know	12	5%
What is the main reason you oppose the mandatory helmet law for?		
Helmets are uncomfortable	17	7%
Helmets are not effective in preventing motorcycle crashes	31	12%
Helmets are not safe	5	2%
Waste of government time and resources	34	14%
Personal freedom	146	58%
It creates hearing problem	18	7%

Table 4.11 Frequencies and Percentage of Responses to Helmet and Helmet Law-Related Questions by Motorcycle Riders in Kansas (Continued)

What kind of impact would a mandatory helmet law have on your riding?	Frequency	Percentage
Significantly decrease	24	10%
Somewhat decrease	36	15%
Will have no effect	181	74%
Somewhat increase	3	1%
Significantly Increase	0	0%
Would you support or oppose a law requiring MC riders and passengers to wear helmets?		
Support	88	36%
Oppose	156	64%

Table 4.10 shows helmet and helmet law-related questions and their response frequencies and percentages by the respondents. Sixty-eight percent of respondents said they wore a helmet the last time they were riding before responding to the survey question. When it came to the question of how often respondents were wearing helmets, 48% said they always used to wear helmets. However, Kansas crash data shows that only 32% of motorcyclists involved in crashes during five-year period from 2004 to 2008 were wearing helmets at the time of the crash. Eleven percent of respondents said they never wore helmets while riding motorcycles. Twenty-nine percent were wearing helmets sometimes while riding motorcycles and 12% of the respondents seldom wore helmets.

Respondents were asked to reveal the reasons they do not always wear a helmet while riding motorcycles. Thirty six-percent chose freedom of choice as the reason for not always wearing a helmet. Sixteen percent had the feeling that it felt too hot while wearing a helmet. Twelve percent of the respondents were concerned that wearing a helmet would create hearing problems for them and 12% believed they would have a conspicuity problem while wearing a helmet. When respondents were asked about the status of current helmet laws in Kansas, 54%

responded correctly by saying Kansas had a partial helmet law in effect. Thirty nine percent of the respondents said Kansas did not have any laws about wearing a helmet while 2% thought Kansas had a mandatory helmet law. Fifty eight percent of the respondents said they would oppose a mandatory helmet law in Kansas because of personal freedom. Fourteen percent thought it would be a waste of government time and resources to enforce a mandatory helmet law. Twelve percent of the respondents believed helmets were not effective in preventing motorcycle crashes. However, 74% of the respondents believed that enforcing a mandatory helmet law would not have any effect on the amount of their motorcycle riding. A majority of the respondents opposed a law requiring motorcycle riders and passengers to wear helmets.

Respondents of the motorcycle survey were asked questions about the conspicuity of other drivers on roadways, safety gears they used, crash experience, etc. Table 4.12 shows frequencies and percentages from these types of questions. Twenty percent of the respondents said they would make sure all lights were working properly to ensure other motorists' visibility. Nineteen percent of respondents said they would use blinkers, and 19% said that they would stay out of motorists' blind spots. Eleven percent would use their horns also to ensure other motorists' visibility. When respondents were asked about using safety gear other than helmets while riding motorcycles, 33% said they would wear gloves. Twenty-four percent also preferred to wear special shoes, while 16% responded with goggles. Thirteen percent would also wear bright-colored or reflective jackets. When it came to crash experience of the respondents, thirty seven percent of the respondents had crash experience while riding a motorcycle and 63% had not faced any crashes involving motorcycles. When it came to injury severity of the respondents facing a crash, 22% said that someone had been killed while 46% said no one had been injured.

Table 4.12 Responses to Safety Gears Crash Experience-Related Questions by Motorcycle Riders

Question	Frequency	Percentage
What special effort do you make while riding to ensure other motorists can see you?		
Make sure all lights are working	230	20%
Use blinkers	221	19%
Wear bright-colored or reflective clothing	104	9%
Stay out of motorists' blind spots	220	19%
Use horn	122	11%
Increase engine noise	94	8%
Hand signal	96	8%
Other (specify)….	50	4%
What other safety gear do you use than a helmet while riding motorcycles?		
Bright-colored or reflective jackets	76	13%
Gloves	196	33%
Goggles	94	16%
Flashing lights	16	3%
Special shoes	143	24%
Others	46	8%
None	15	3%
Have you ever had a crash while riding on a public roadway?		
Yes	90	37%
No	155	63%
What was the worst level of injury sustained by you or someone else involved in a MC crash?		
Someone was killed	39	22%
Treated at scene	31	17%
Someone else was treated at scene	28	16%
No one else was injured	82	46%
What do you feel is the single biggest threat to your own safety while riding a motorcycle?		
Drivers of other vehicles	230	71%
Not wearing a helmet while riding	6	2%
Weather	11	3%
Lack of personal experience	19	6%
Road surface conditions	34	10%
Lack of adequate training	13	4%
Other (specify)….	13	4%

Seventy one percent of the respondents thought drivers of other vehicles were the biggest threat to their own safety while riding a motorcycle on a public roadway. Road surface conditions were considered a potential threat to 10% of the respondents.

Unlike quantitative type questions, qualitative questions are more difficult to compare. A section in this survey asked the respondents to rate several factors according to their contributions to causing a crash, with options from most contributive to the least. Thus, a common methodology which has been extensively used in the past was used here to evaluate the answers. This method assigns different weights to each factor with selected weights ranging from 0 to 100. Following this, an average weighted value was calculated for each factor, which will represent the standpoint of the respondents in a quantitative manner. Further, this number will describe the likelihood of occurrence as a probability. Calculated value for each question is presented in the last column of Tables 4.13, 4.14, and 4.15, headed as likelihood of occurrence. Likelihood of occurrence indicates the chance of a randomly selected person being in compliance with a particular event. The assigned weights are as below:

- Least – 0
- Not significant – 25
- Average -50
- Significant – 75
- Most – 100

Accordingly, 30 percent of the respondents said they considered tip over as a contributive factor in causing a motorcycle crash. In other words, if a motorcycle rider was selected randomly, there was a 30 % chance of that rider indicating that he/she considered tip over as a contributory factor to motorcycle crashes. One point to note is that the value of likelihood of occurrence was the highest for conflicts with cars, and the lowest was for the factor tip over. Seventy-two percent of respondents stated they considered going too fast to a curve contributed significantly to motorcycle crashes. Conflict with cars was a contributory factor for 88% of respondents. In the case of weather, 65% of the respondents thought bad weather could cause motorcycle crashes. Speeding was considered as a contributory factor to cause motorcycle crashes by 69% of the respondents. Fifty-one percent of the respondents said not being able to see far enough could cause a motorcycle crash on roadways.

Alcohol or drugs was considered as a significant contributing factor by 74% of respondents. Road surface features like pavement markings were considered as a contributory factor to cause motorcycle crashes by 47% of the respondents. Fifty-eight percent of respondents considered both the maintenance issue and misjudged speed of other vehicles as contributory factors to cause a motorcycle crash. Fatigue was considered as a significant contributory factor by 55% of respondents. Sixty-three percent of respondents considered distraction as a contributory factor to a motorcycle crash. One important point was that only 32% of respondents thought that not using a helmet would significantly cause motorcycle crashes to occur. Sixty-nine percent of the respondents considered lack of training would cause motorcycle crashes with 48% of respondents thinking overtaking could be the reason for motorcycle crashes. Finally, 63% of respondents considered traffic hazards as a potential factor to cause motorcycle crashes.

Table 4.13 Responses by Motorcycle Riders for Crash Contributing Factors

Contributory Factors	Frequency	Percentage	Likelihood of Occurrence
Tip over			
Most	10	4%	30
Significant	26	11%	
Average	45	19%	
Not significant	70	30%	
Least	81	35%	
Too fast in curve			
Most	58	24%	72
Significant	118	50%	
Average	46	19%	
Not significant	12	5%	
Least	4	2%	
Conflicts with cars			
Most	154	64%	88
Significant	57	24%	
Average	27	11%	
Not significant	3	1%	
Least	0	0%	
Poor road surfaces			
Most	56	23%	72
Significant	112	47%	
Average	64	27%	
Not significant	3	1%	
Least	5	2%	
Bad weather			
Most	42	18%	65
Significant	94	39%	
Average	73	31%	
Not significant	24	10%	
Least	4	2%	
Speed			
Most	68	28%	69
Significant	79	33%	
Average	69	29%	
Not significant	20	8%	
Least	5	2%	
Couldn't see far enough			
Most	10	4%	51
Significant	67	29%	
Average	96	41%	
Not significant	46	20%	
Least	14	6%	

Table 4.14 Responses by Motorcycle Riders for Crash Contributing Factors (continued)

Contributory Factors	Frequency	Percentage	Likelihood of Occurrence
Alcohol or drugs			
Most	101	42%	74
Significant	70	29%	
Average	42	17%	
Not significant	16	7%	
Least	13	5%	
Road surface features			
Most	11	5%	47
Significant	50	21%	
Average	102	43%	
Not significant	53	22%	
Least	23	10%	
Worn tires or maintenance issue			
Most	25	11%	58
Significant	82	34%	
Average	89	37%	
Not significant	26	11%	
Least	16	7%	
Misjudged speed of other vehicles			
Most	19	8%	58
Significant	92	38%	
Average	88	37%	
Not significant	28	12%	
Least	12	5%	
Fatigue			
Most	26	11%	55
Significant	70	29%	
Average	91	38%	
Not significant	36	15%	
Least	17	7%	
Distraction			
Most	42	18%	63
Significant	83	35%	
Average	83	35%	
Not significant	22	9%	
Least	9	4%	

Table 4.15 Responses by Motorcycle Riders for Crash Contributing Factors (Continued)

Contributory Factors	Frequency	Percentage	Likelihood of Occurrence
Not using a helmet			
Most	23	10%	32
Significant	25	11%	
Average	42	18%	
Not significant	56	24%	
Least	92	39%	
Lack of adequate training			
Most	55	23%	69
Significant	102	43%	
Average	61	26%	
Not significant	12	5%	
Least	9	4%	
Overtaking			
Most	14	6%	48
Significant	43	18%	
Average	108	46%	
Not significant	50	21%	
Least	21	9%	
Traffic hazard			
Most	33	14%	63
Significant	82	34%	
Average	102	43%	
Not significant	15	6%	
Least	6	3%	

4.3.2 Differences Based on Age of Respondents

From the survey responses, several factors associated with age of respondents were looked into. When looking at the motorcycle engine size based on age group of the respondents from Figure 4.21, a tendency among younger riders (16-24 years) and older riders (52 years and above) to own high-powered bikes with engine size ranging from 1001cc to 1500cc (cubic centimeters of displacement) was observed. The rider group from 25 to 33 years owned more bikes with engine size greater than 1500cc (50%) than any other engine size. Younger riders owned lower-powered bikes (10%) more than the riders aging between 25 to 33 years and 34 to 42 years, 5% and 6.3% respectively. However, there was no correlation between age of motorcycle riders and motorcycle engine size, (χ^2 = 0.36, p = 0.17).

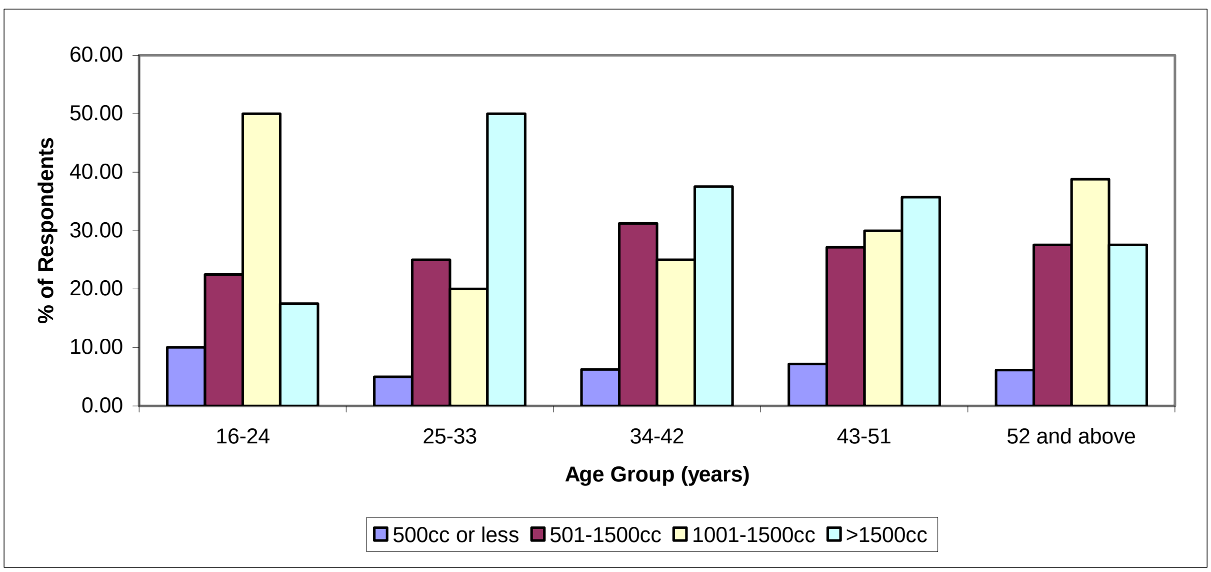


Figure 4.21 Responses by Motorcycle Riders Based on Different Age Groups for Motorcycle Characteristics (Motorcycle Engine Size)

Variation in types of motorcycles used by the respondents of different age groups was observed from the survey results. Figure 4.22 reveals young motorcyclists between 16 to 24 years were more likely to own sport bikes (63.2%) and less likely to own touring and cruiser bikes compared to the other age groups. Rider groups between 25 to 33 years also owned a very small percentage of touring bikes (10%) compared to the other older groups. Motorcyclists in their 40s were more likely to own cruisers (40%) and touring bikes (23.3%) than sports bikes (20%), as were those in their 50s and 60s. Further, there was a high co-relation between motorcycle types and age of the motorcycle riders ($\chi^2 = 68.91$, $p<0.001$), confirming that as age of motorcycle riders increases, usage of touring and cruiser types of bikes increases. This is understandable, as young riders are more inclined towards sports bikes and older riders choose to ride on touring and cruiser types of motorcycles (3).

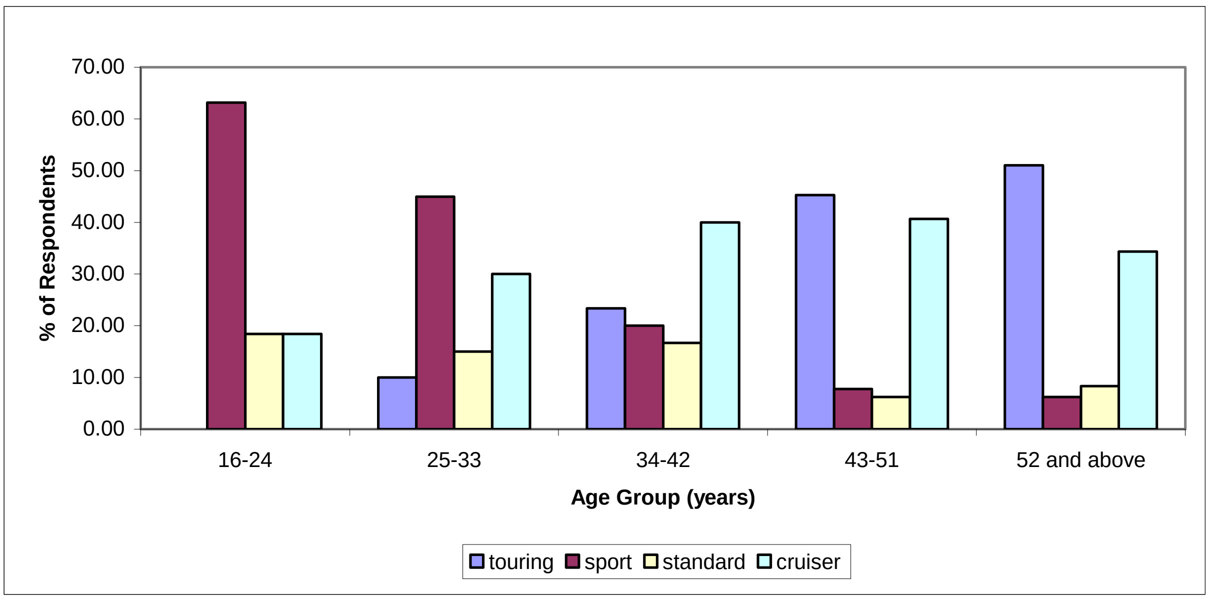


Figure 4.22 Responses by Motorcycle Riders Based on Different Age Groups for Motorcycle Characteristics (Motorcycle Types)

A similar tendency was observed among rider groups between 34 to 42 years, 43 to 51 years, and 52 years and above, when it came to riding exposure as shown in Figure 4.23. The younger rider groups from 16 to 33 years preferred to ride on city or town roads. But rider groups from 34 to 42 years, 43 to 51 years, and 52 years and above had a similar tendency to travel most frequently on two-lane, out-of-town roads with the highest percentage of 30.4%, 31.8%, and 32.1%, respectively, and there was no correlation between types of roadways travelled and age of motorcycle riders (χ^2 = 7.91, p = 0.39). When it came to riding experience based on age, it was clear older riders would have more riding experience than younger riders. Figure 4.24 confirms the fact that relatively older riders (from 42 to 51 years and 52 years and above) had riding experience of more than 20 years with percentages of 68.9% and 66.7%, respectively. Further, there was a high co-relationship between riding experience and age of the motorcycle riders (χ^2 = 49.63, $p<0.001$).

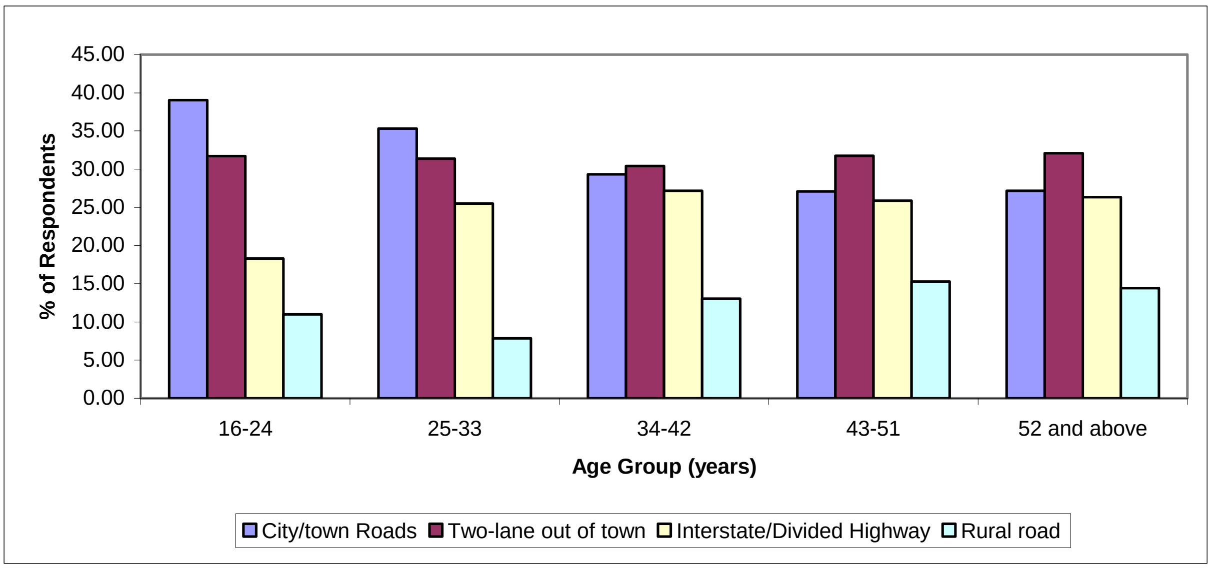


Figure 4.23 Responses by Motorcycle Riders Based on Different Age Groups for Motorcycle Riding Exposure (Types of Roadways)

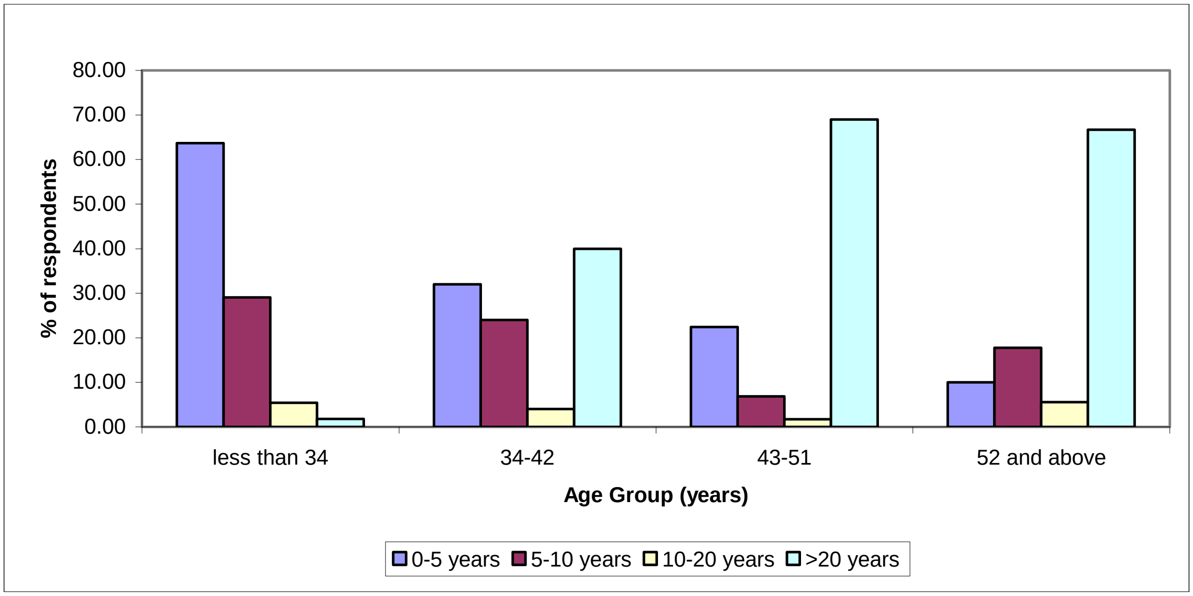


Figure 4.24 Responses by Motorcycle Riders Based on Different Age Groups for Motorcycle Riding Experience

When helmet use while riding was considered based on the age group of respondents, it can be seen from Figure 4.25 that the oldest rider group had the highest percentage (57.9%) of always wearing a helmet and the rider group 34 to 42 years had the highest percentage (17.2%) of not wearing a helmet. In total, 47.8% of respondents used to always wear a helmet, while 11% of the respondents never wore a helmet while riding a bike. No co-relationships were found between helmet usage and the age of the motorcycle riders ($\chi^2 = 6.55$, $p = 0.34$).

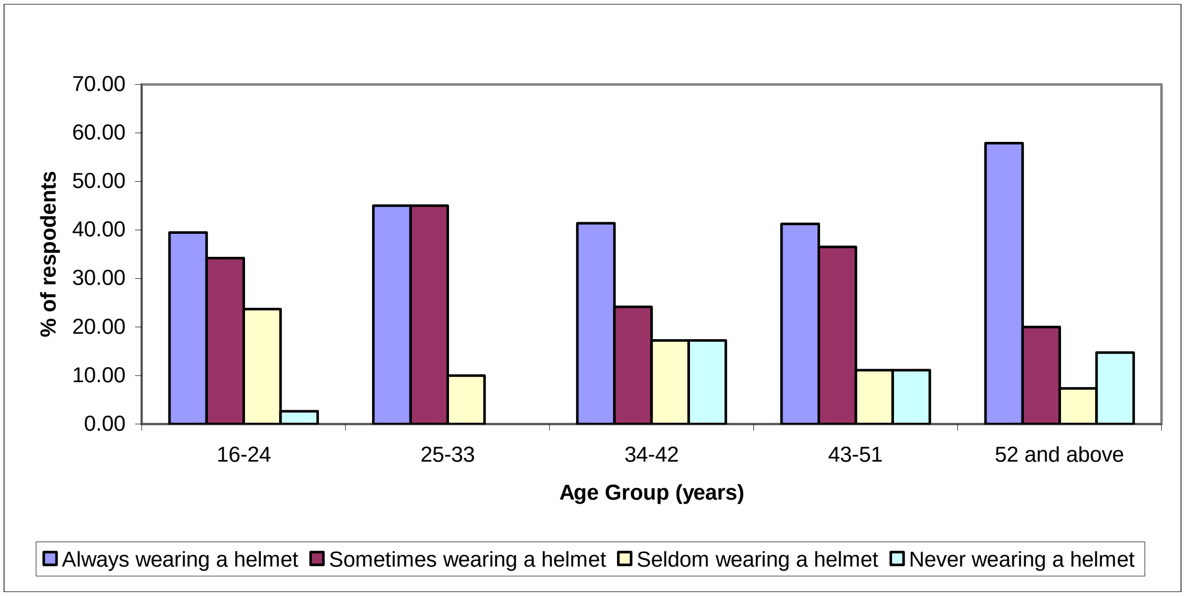


Figure 4.25 Responses by Motorcycle Riders Based on Different Age Groups for Helmet Use

Figure 4.26 shows all the rider groups, based on age, had a higher percentage of opposing the mandatory helmet law when compared with supporting the mandatory helmet law. In total, 35.9% of the respondents supported the mandatory helmet law and 64.1% of the respondents opposed the mandatory helmet law in Kansas. The rider age group from 34 to 42 years had the highest percentage (78.6%) opposing the mandatory helmet law in Kansas. One point to note is that the percentage (37.8%) supporting the mandatory helmet law among the youngest rider group, from 16 years to 24 years was higher than riders between 25 to 33 years (20%) and 34 to 42 years (21.4%). There was also no co-relationships between perception of helmet law and age of motorcycle riders ($\chi^2 = 7.28$, $p = 0.47$). A similar pattern was observed among all age groups (Figure 4.27) when it came to difficulty in executing motorcycle maneuvers. Thirty-five percent of respondents said riding in thunderstorms was the most difficult maneuver to execute while riding a motorcycle. Only 9.2% of the respondents said a low-speed parking maneuver was the most difficult maneuver to execute while riding a motorcycle.

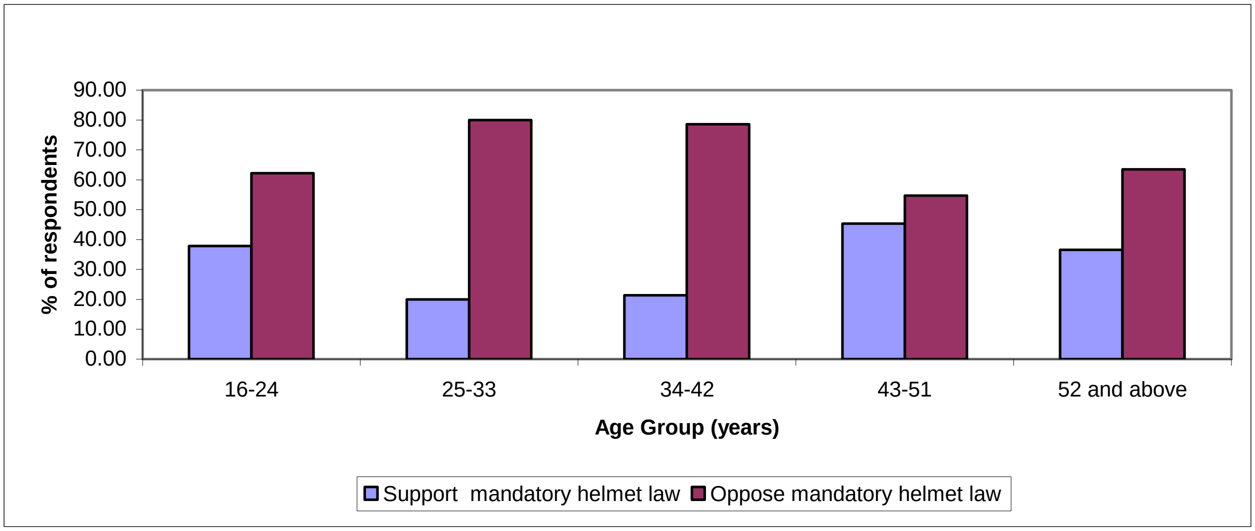


Figure 4.26 Responses by Motorcycle Riders Based on Different Age Groups for Helmet Law Opinion

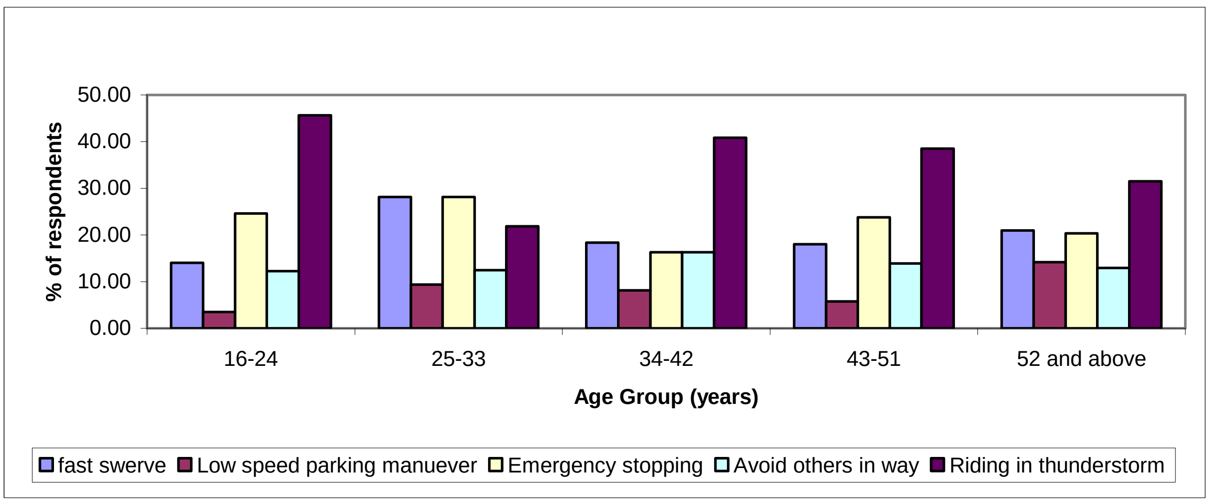


Figure 4.27 Responses by Motorcycle Riders Based on Different Age Groups for Most Difficult Maneuver to Execute

Overall, 36.33% of the respondents indicated they had ever crashed or fallen while the motorcycle was moving. Figure 4.28 represents crash experience based on rider age group for the respondents. It can be observed from the figure that the youngest rider group had a relatively higher percentage (33.3%) of crash experience compared to all other age groups in the past 12 months. When limited to last 12 months of period, 5.74 % of the respondents said they had been involved in a crash during that time period.

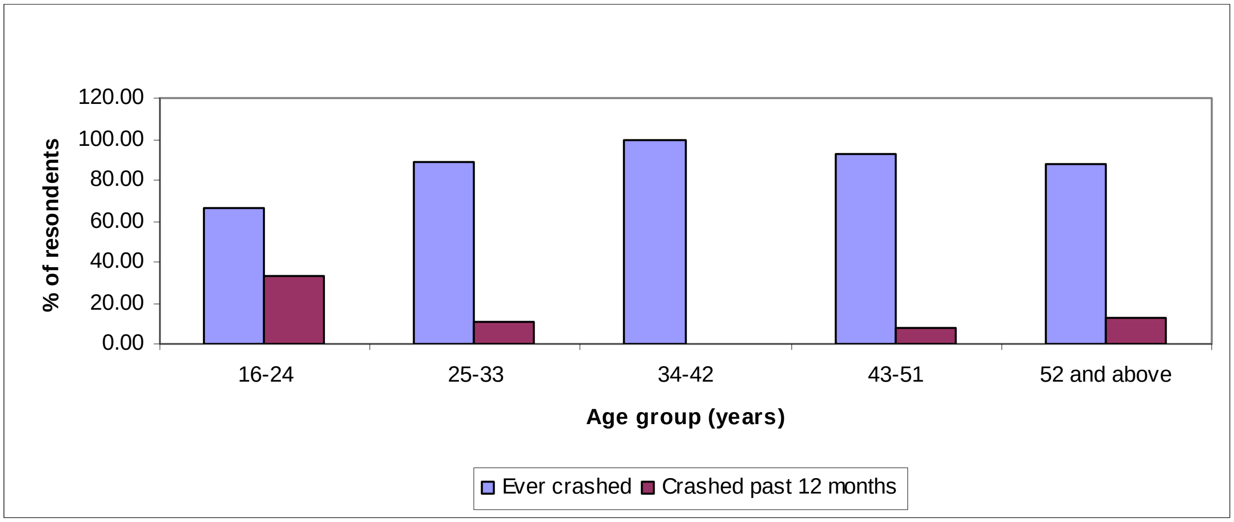


Figure 4.28 Responses by Motorcycle Riders Based on Different Age Groups for Crash Experience

4.3.3 Crashes and Contributing Factors

Crude odds ratios were calculated and presented in Table 4.16 for some selected variables from the survey questionnaire. The methodology is explained in detail in section 3.2.3. Questions were selected from demographic, general, exposure, contributory factors, and difficulty to execute maneuver sections where there could be a possibility of a relationship in connection with crash involvement. Even though answers for the contributory factors questions were in ordinal format, it can be considered that either the factors had no/least contribution to the crashes or had contributions in some degree to the crashes and therefore were reclassified as a binary ("yes" or "no") variable. In the marital status situation, it was considered as married vs. single (including divorce, separated, and widowed). For questions with ordinal responses, the first option was selected as the reference group and odds were calculated for others relative to the first.

Odds ratio values are based on respondents who had met with crashes at least once while riding motorcycles on a public roadway and the "respondents" will refer to the same definition hereafter in this discussion. When looking at the contributory factors to motorcycle crashes in Kansas, there were quite a few factors with odds ratio more than 1. Poor road surfaces (potholes, loose gravel, oil, etc.) contributing to crashes were 2.31 times higher among respondents who thought of it as a contributory factor compared to the others. Speeding as a crash contributory factor was also 2.3 times higher among respondents compared to those who didn't consider it as a crash contributory factor. Conspicuity problem (couldn't see far enough) as a crash contributory factor was 1.025 times higher among respondents who did consider it as a crash contributory factor compared to the others. Road surface features (like pavement markings) as a crash contributory factor were only 7.3% higher among respondents compared to others who did not judge it as a contributory factor. Odds of worn tires or maintenance issues as contributory factors among the respondents thinking of them as contributory factors were 2.6 times those of respondents not considering these as contributory factors. Distraction and lack of adequate training contributed more than 1.4 times higher among respondents who considered those as crash contributory factors compared to those who did not. When it came to non-use of a helmet while riding as a crash contributory factor, numbers were only 10% higher among the respondents believing it as a contributory factor compared to others who did not think so. Some odds ratios were calculated based on a few demographic questions in order to see how they were related to crash involvement of motorcycle riders in Kansas. When considering motorcycle rider groups based on age, the 16 to 24 years age group was considered the reference group, and odds ratios have revealed that other riders older than the 16 to 24 years group were overly involved in crashes compared to the reference group.

Table 4.16 Crude Odds Ratio and 95% Confidence Intervals for Crash Involvement

Variable		Odds Ratio	95% Confidence Interval	
Tip over		0.87	0.50	1.53
Poor road surfaces		2.31	0.25	20.98
Speed		2.31	0.25	20.99
Couldn't see far enough		1.02	0.33	3.16
Alcohol or drugs		0.91	0.29	2.86
Road surface features		1.07	0.44	2.64
Worn tires or maintenance issue		2.6	0.72	9.39
Misjudged speed of other vehicles		0.79	0.24	2.56
Fatigue		0.8	0.29	2.18
Distraction		1.14	0.28	4.69
Not using a helmet		1.10	0.64	1.91
Lack of adequate training		1.14	0.28	4.69
Overtaking		0.92	0.36	2.31
Traffic		0.37	0.06	2.26
Married		1.39	0.80	2.42
Age	16-24 years	Reference		
	25-33 years	1.84	0.61	5.60
	34-42 years	1.18	0.43	3.28
	43-51 years	1.35	0.58	3.15
	52 years and above	1.42	0.64	3.16
Income	$0-19,999	Reference		
	$20,000-$39,999	1.91	0.69	5.25
	$40,000-$59,999	1.47	0.54	3.99
	$60,000 and above	0.75	0.32	1.68
Education	High school			
	Some college	0.35	0.16	0.76
	Four year college	0.29	0.12	0.73
	Graduate college	0.34	0.14	0.85
Frequency	Everyday	Reference		
	Weekends only	0.71	0.23	2.16
	1-3 days a week	1.23	0.59	2.59
	4-6 days a week	1.48	0.68	3.10
Exposure	1000 miles or less	Reference		
	1,000 to 2,999 miles	0.75	0.304	1.83
	3,000 to 4,999 miles	0.95	0.40	2.25
	5,000 to 7,999 miles	0.67	0.28	1.57
	8,000 to 10,000 miles	1.2	0.43	3.32
	above 10,000 miles	0.82	0.30	2.29

Furthermore, it is important to highlight the age group 25 to 33 years had a 1.84 times higher involvement rate compared to the reference group. A similar pattern can be observed with respect to income levels except the group earning $60,000 or above yearly. For this group, likeliness of involvement in crashes was lower compared to the reference group which was earning 0 to $19,999 yearly. This might be because higher income people put more effort into safety and take the precautions necessary to avoid crashes by equipping themselves and their bikes with safety gear. When looking at the education of the respondents, it was clear that respondents with higher levels of education were less likely to be involved in crashes. Riding frequency showed that respondents who ride on weekends have a lower likeliness of being involved in crashes compared to those who ride every day. But riders who ride one to three days per week and three to six days per week had higher involvement rates compared to respondents who ride every day. As number of miles ridden increased, chances of being involved in a crash decreased, according to the ratios. But the exception was for the group who ride 8,000 to 10,000 miles per year. Normally, the lower odds ratio compared to the reference group of 1,000 miles or less was due to the increased number of miles per year increasing their experience.

For difficulty-level questions, respondents were asked to choose the most difficult maneuver to execute while riding a motorcycle in question 31 of the survey form. Table 4.17 shows odds ratios for different motorcycle maneuver difficulties to be executed by the respondents.

Table 4.17 Crude Odds Ratio and 95% Confidence Intervals for Crash Involvement Based on Difficulty Levels of Motorcycle Maneuvers

Variable	Odds Ratio	95% Confidence Interval	
Left turn	1.61	0.80	3.23
Change a lane	0.41	0.05	3.70
Make an exit on freeway	0.27	0.03	2.26
Merge from an exit	0.53	0.17	1.70
Fast swerve	0.93	0.54	1.62
Low-speed parking maneuver	1.34	0.67	2.68
Emergency stopping	1.06	0.63	1.83
Negotiate a curve	0.74	0.25	2.20
Slow down suddenly	1.40	0.64	3.06
Avoid others in way	0.71	0.38	1.33
Riding in thunderstorm	1.01	0.60	1.71

From Table 4.17, it is clear that quite a few maneuvers based on difficulty level had higher representations from the respondents. The odds of difficulties for riders to make a left turn in front of oncoming traffic were 1.61 times higher compared to those respondents not experiencing such difficulty. Slowing down suddenly was associated with a 40% increased odds ratio for respondents who experienced such difficulty. Moreover, the odds of difficulties associated with low-speed parking maneuvers was 1.34 times higher compared to respondents who didn’t experience such difficulties. For, emergency stopping and riding in thunderstorms, calculated odds ratios were 1.06 and 1.01, respectively. It should be noted, the margins were less than five percent for emergency stopping and riding in thunderstorm maneuvers and therefore, it was not advisable to disregard these completely.

4.4 Analysis Using Ordered Probit Modeling

The ordered probit modeling technique was used to identify contributing factors for motorcycle rider injury severity. An ordered probit model was developed to assess motorcycle rider injury severity in Kansas by considering nearly 35 explanatory variables using statistical modeling software, SAS version 9.2. Variable names, description about how variables are determined, corresponding mean values, and standard deviations are presented in Table 4.18

A 95% confidence level was used for most of the variables to be included in the model in which the probability should be less than 0.05. A 10% confidence level was also used rarely in which the probability level should be less than 0.1. Co-linearity of variables was also checked before considering variables into the model and if such a relationship existed, one of the two correlated variables was discarded based on the mean value criterion.

Model results are given in Table 4.19 for motorcycle crashes taking place in Kansas from 2004 to 2008. Coefficients were estimated using the maximum likelihood method as explained in section 3.2.4. Likelihood Ratio Indexes (LRI) are presented for the model along with Estrella values, Veal-Zimmermann values, and Mckelvey-Zavoina values. These have been discussed in the methodology section. The likelihood ratio index value for the injury severity model is 0.0347. Past studies based on ordered probit modeling have shown the goodness of fit value is typically low. Goodness-of-fit value indicates how good the model fit is. In the motorcycle injury severity model developed by Quddus et al. (36), it was around 0.05 and in the vehicle crash models developed by Kockelman and Kweon (39), the highest LRI value was around 0.08. Therefore, reliability of the overall model can be considered as typical.

Table 4.18 Description of Variables Considered for Ordered Probit Modeling

Explanatory Variable	Categories of Each Variable	Description	Mean	Standard Deviation
Crash class	1. Overturned	if yes=1, otherwise=0	0.24	0.43
	2. Collision w/ other vehicles	if yes=1, otherwise=0	0.44	0.0.50
	3. Collision w/ fixed object	if yes=1, otherwise=0	0.15	0.36
	4. other non collision	Reference case		
Crash location	1. Intersection or related on roadway	if yes=1, otherwise=0	0.35	0.48
	2. No intersection on roadway	if yes=1, otherwise=0	0.43	0.50
	3. Parking lot access	if yes=1, otherwise=0	0.07	0.26
	4. Others	Reference case		
Age of rider (years)	1. Up to 19 years	if yes=1, otherwise=0	0.07	0.26
	2. 20 to 29 years	Reference case		
	3. 30 to 39 years	if yes=1, otherwise=0	0.18	0.39
	4. 40 to 49 years	if yes=1, otherwise=0	0.22	0.41
	5. 50 to 59 years	if yes=1, otherwise=0	0.18	0.39
	6. 60 years and above	if yes=1, otherwise=0	0.10	0.31
Alcohol flag	1. Alcohol flag	if yes=1, otherwise=0	0.09	0.28
Day of the crashes	1. Weekday (Monday to Friday)	if yes=1, otherwise=0	0.37	0.48
Safety equipment used	1. Helmet used	if yes=1, otherwise=0	0.20	0.40
Light conditions	1. Dark during the crash	if yes=1, otherwise=0	0.21	0.41
MC maneuvers	1. Straight-following road	if yes=1, otherwise=0	0.75	0.43
Crashes	1. Multi-vehicle Crashes	if yes=1, otherwise=0	0.43	0.50
On road surface characteristics	1. Straight	if yes=1, otherwise=0	0.80	0.40
	2. Curved	Reference case		
On road surface condition	1. Concrete	if yes=1, otherwise=0	0.26	0.44
Speed	Speed	Continuous	42.89	13.61
Crash time (hours)	1. 0000-0359 hours	if yes=1, otherwise=0	0.07	0.25
	2. 0400-0759 hours	if yes=1, otherwise=0	0.06	0.24
	3. 0800-1159 hours	Reference case		
	4.1200-1559 hours	if yes=1, otherwise=0	0.27	0.44
	5. 1600-1959 hours	if yes=1, otherwise=0	0.32	0.47
	6. 2000-2359 hours	if yes=1, otherwise=0	0.17	0.38
Weather conditions	1. No adverse conditions	if yes=1, otherwise=0	0.95	0.21
Gender	1. Male	if yes=1, otherwise=0	0.94	0.22

Table 4.19 Results of Ordered Probit Modeling for Motorcycle Rider Injury Severity

Categories of Each Variable	Variable name	Estimate	t value	Approx Pr>t
Overturned	OT	0.1378	2.82	**0.0048**
Collision w/ other vehicles	CWV	-0.0362	-0.44	0.6596
Collision w/ fixed object	CWF	0.2897	5.18	**<0.0001**
Intersection or related on roadway	IORR	0.0194	0.36	0.7188
No intersection on roadway	NOR	0.0339	0.69	0.4929
Parking lot access	PLA	0.0332	0.45	0.6531
Up to 19 years	AGE1	0.3327	5.26	**<0.0001**
30 to 39 years	AGE2	-0.0133	-0.28	0.7762
40 to 49 years	AGE3	0.0483	1.08	0.2787
50 to 59 years	AGE4	-0.1179	-2.52	**0.0117**
60 and above years	AGE5	-0.2311	-4.05	**<0.0001**
Alcohol flag	ALCO	0.5949	10.58	**<0.0001**
Weekday (Monday to Friday)	WEEKDAY	0.0388	1.22	0.2226
Helmet used	HU	-0.0697	-0.57	**0.0364**
Dark during the crash	DARK	-0.0383	-0.9	0.3675
Straight following road	STRMAN	-0.1598	-4.49	**<0.0001**
Multi-vehicle crash	MULTIVEH	-0.0559	-0.72	0.4702
Straight	STRAIGHT	-0.0899	-2.18	**0.0295**
Concrete	CONCRETE	-0.0177	-0.51	0.6106
Speed	SPEED	0.01148	10.3	**<0.0001**
0000-0359 hours	TIME1	-0.0848	-1.12	0.2648
0400-0759 hours	TIME2	-0.0718	-0.96	0.3389
1200-1559 hours	TIME3	-0.0573	-1.09	0.277
1600-1959 hours	TIME4	-0.0884	-1.72	**0.0863**
2000-2359 hours	TIME5	0.0579	0.95	0.342
No adverse conditions	NACWEA	0.2290	3.2	**0.0014**
Male	MALE	-0.0008	-0.01	0.9899
_limit2		0.5238	29.73	<0.0001
_limit3		1.8901	70.08	<0.0001
_limit3		2.8963	74.93	<0.0001
Estrella	0.0918			
Adjusted Estrella	0.0803			
McFadden's LRI	0.035			
Veall-Zimmermann	0.1181			
Mckelvey-Zavoina	0.1024			

(Bold numbers indicate statistical significance)

The variables considered in this analysis can be broadly classified under four sections: driver related (motorcycle rider in this case), crash related, roadway related, and environment related. Thus, discussion of the model is also presented under the same sections for better understanding.

4.4.1 Motorcycle Rider-Related Factors

Motorcycle rider-related factors considered in this model are age of motorcyclists, alcohol flag for motorcyclists during the crashes, helmet use by riders during crashes, and gender of motorcyclists. Motorcycle riders aging up to 19 years have a positive estimate and motorcycle rider groups from 50 to 49 years and 60 years and above have negative estimates with statistical significance at a 95% confidence level. Younger motorcycle riders up to 19 years are found to be more prone to be severely injured compared to motorcycle riders from 50 to 59 years and 60 years and above. Normally, younger riders are usually expected to have an increased probability of being involved in crashes, which is also the case in the current model (36). Those aged 50 years or older tend to be more experienced motorcyclists and have better skills in motorcycle riding compared to younger riders. Also, older riders may tend to ride at more reasonable speeds and are less likely to be involved in crashes. These might be the reasons for them to be less likely to be severely injured in motorcycle crashes.

The variable associated with the alcohol flag has a positive estimate in the model, which is also statistically significant. This means motorcycle riders riding under the influence of alcohol have higher injury severities when involved in motorcycle crashes. This finding is consistent with a previous study that has reported that alcohol has a strong association with an increase in traumatic injury in motorcycle crashes (35).

The variable representing gender has a negative estimate in the model with no statistical significance. So gender of motorcyclists does not seem to have any effect on injury severity in this model.

One of the most important variables in this model is whether riders use helmet during crashes or not. Helmet use during crashes has a negative estimate in this model with the variable being statistically significant. This variable indicates that nonhelmeted riders face a greater risk of severe injury. It can be inferred from the model result that motorcyclists using helmets have a lower likelihood of being severely injured once they are involved in crashes. It is generally believed that helmet use tends to decrease the occurrence and severity of head injuries. It is also widely believed that helmets are most effective in reducing fatalities when head injuries are the primary cause of death.

4.4.2 Motorcycle-Crash Related Factors

Crash-related variables considered in this model are crash classes, motorcycle maneuvers during crashes, multivehicle crashes, and time of the crashes. When it comes to crash classes, overturned type and collision with a fixed object type crashes have a positive estimate in the model with statistical significance implying that motorcyclists involved in these types of crashes have higher injury severity. Injury severity is greatest for motorcyclists when colliding with a fixed object. This finding is consistent with a previous study (35). Motorcyclists of Kansas also have increased injury severity when they are involved in overturned crashes. Though injury severity of motorcyclists is not related to involvement of motorcycle crashes, it is important to note that in 2008, 47% of all motorcycles involved in fatal crashes collided with other vehicles, and motorcycles were more likely to be involved in fatal collisions with a fixed object than other vehicles (58).

Weekdays of the crashes has a positive estimate in the model with no statistical significance. It is normally expected that days the crashes occurred is not supposed to have any effect on injury severity of the motorcyclists involved in crashes. Multivehicle crashes also do not have any effect on injury severity of motorcyclists in Kansas.

When it comes to motorcycle maneuvers during crashes, straight following road maneuvers have a negative estimate. This implies this simple motorcycle maneuver appears to reduce injury severity of the motorcyclists compared to other complex motorcycle maneuvers.

Time of day effects in the model are measured with dummy variables for 4-h time intervals, with the reference group as 8.00 a.m. to noon. Only time of crashes between 4.00 p.m. to 8.00 p.m. shows statistical significance at the 90% confidence level with a negative estimate. This implies less severe injuries among motorcyclists during this later part of the day compared to the reference group.

4.4.3 Roadway-Related Factors

Roadway-related variables considered in this modeling are crash locations, on-road surface characteristics, on-road surface conditions, and posted speed limits on the roads where crashes occurred. Crash locations, like crashes on intersections, non-intersections, or parking lot accesses, do not have any statistical significance with all having positive estimates. Straight roadways have a negative estimate compared to curved roadways with statistical significance at the 95% level. This implies motorcycle riders crashing on straight roadways have less severity compared to crashes occurring on curved roadways. This makes sense as crashes on curved roadways may result in motorcyclists leaving travel lanes and overturning or striking an off-road object such as a guardrail, rock, or tree. This finding is also consistent with a previous study (60). The concrete roadway variable is not statistically significant with a negative estimate.

Posted speed limit has a positive estimate in the model with statistical significance. Motorcycle injury severity in general appears to increase with an increase in speed limit. An increased speed limit may cause the rider to increase speed, resulting in a more severe collision. This finding is also consistent with a previous study (35).

4.4.4 Environment-Related Factors

Riding under good weather appears to result in more severe injuries for motorcycle riders in the current model. A likely explanation for this interesting result needing more investigation is that while bad weather might act as a deterrent to speeding and inconsiderate road behaviors, motorcyclists might ride more recklessly and incautiously in good weather, increasing the likeliness of more severe injuries for the riders.

4.5 Kansas Motorcycle Crash Reports in Newspapers

Newspaper clips related to the reporting of motorcycle crashes in Kansas were found in various daily newspapers circulated in Kansas. Clips from the newspapers related to motorcycle crash reports in Kansas are attached in Appendix D. The clips are arranged in chronological order for the last two years from 2009 to 2010. There were 41 motorcycle fatalities in Kansas in 2009 and to date there have been 20 motorcycle fatalities in 2010. Eighteen newspaper clips are included in the study to show a reasonable representation of motorcycle fatal crashes occurring in Kansas. Percentage of newspaper clips reported here is almost 31% of the total number of motorcycle fatal crashes occurring during the last two years. These newspaper clips provide some idea in understanding circumstances regarding motorcycle crashes in Kansas. One thing to note from all the newspaper clips is that most of the motorcycle riders killed or injured in the crashes were above 40 years of age, and most collided with other vehicles like cars, minivans, etc. There were reports of motorcycle crashes caused by collisions with deer and fixed objects.

The first report said the motorcycle rider collided with a minivan while turning left in the city of Manhattan. Another incident reported a 54-year-old motorcyclist being fatally injured after colliding with a guardrail in south Wichita. Two more crashes were reported in the Wichita Eagle where the motorcyclists had collisions with other motorcycles and vehicles. One of these two crashes reported a fatality. A Wichita man was reported to have been fatally injured after swerving to avoid a collision with a deer on the road. A-20-year old man was fatally injured after hitting a median curb in Lawrence. A university student in Emporia was also dead after losing control on a curve while riding a motorcycle. A 56-year-old man was reportedly dead and another injured in a crash where the riders were not wearing helmets. A crash in Seneca left a motorcyclist dead after the motorcycle collided with a left-turning car at an intersection. According to the report, lack of visibility on the part of the motorcyclist might be the reason for this crash. The victim was also not wearing a helmet during the crash. The Wichita Eagle reported a motorcycle crash where minor impact of the motorcycle with the rear end of a minivan caused a fatality to the motorcycle rider. Misjudged speed of the minivan by the motorcyclist was the main reason of the collision. A 23-year-old motorcyclist died in Wichita when his motorcycle was struck by a truck. The helmet of the motorcyclist came off during the crash causing fatal injury to the rider. Not strapping the helmet appropriately to the chin was the reason given for the helmet coming off during the crash.

A newspaper clip is attached describing the motorcycle fatality trends in Kansas during recent times. One hundred and fifty-four motorcyclists were fatally injured from 2006 to 2008 in Kansas. Out of these, 111 were not wearing helmet during the crashes. Other fatal motorcycle crash reports included 63-year-old motorcyclist from Cassidy losing control on a curve and dying on the spot. The passenger accompanying him also suffered a disabling injury. A man from Wichita died after the front wheel of his motorcycle started to wobble. He hit a guardrail, was thrown off of the motorcycle, and died on the spot. A 62-year-old man was fatally injured after crashing a motorcycle into a curb at low speed. The man was not wearing a helmet. A 60-year-man died when his motorcycle was struck by a car which failed to yield. A 53-years-old rider was fatally injured after his motorcycle overturned and left the roadway. One interesting point to note is that most of these crashes occurred from Friday to Sunday. Overturning resulted in similar consequences for a 50-year-old motorcyclist. A rider was reportedly dead at the spot after hitting a delivery van. The rider was speeding during the crash.

Chapter 5 – Summary, Conclusions, and Recommendations

5.1 Summary and Conclusions

State-level motorcycle rider fatality rates were investigated while considering various factors, including helmet laws which were carried out using generalized least-squares regression modeling of statewide rider fatality rates utilizing data for the 50 states and Washington, D.C., covering the period 2005-2007. The intention was to develop statistical models to predict state-level motorcycle safety parameters while taking various factors into account. Crash data from Kansas Department of Transportation from 2004 to 2008 were analyzed with the intention of identifying characteristics and contributory factors related to motorcycle crashes in Kansas. Detailed characteristic and statistical analyses were carried out for motorcycle crashes in Kansas under a number of categories. Comparisons were made between motorcycle crashes and other vehicle crashes in Kansas to identify circumstances or situations more common among motorcycle crashes.

From the GLS modeling carried out in this study, a statistically significant relationship was found between helmet laws and motorcyclist fatalities per 10,000 registered motorcycles and per 100,000 populations in a state. Motorcycle fatalities also increased with an increase in annual daily mean temperature. Motorcycle fatalities decreased with an increased highway mileage of rural roads in a state. Other factors associated with motorcycle fatalities were African American populations and per capita income. Motorcycle fatalities decreased with increase in per capita income in a given state. The models also showed in increase in motorcycle fatalities with increase in African American populations. Motorcycle fatalities per 100,000 populations decreased with an increase in population density. They also increased with an increase in motorcycle registrations per capita.

According to analysis results, contingency tables followed by the Chi-Square test revealed a significant relationship between motorcycle crash severity and several factors. Almost all of the factors considered were found to be related to motorcycle crash severity in Kansas except weather conditions, day of the crashes, and on-road surface types. Day of the crashes also did not play any role in severity of motorcycle crashes. Though on-road surface characteristics were related to motorcycle crash severity, on-road surface types were not related to motorcycle crashes. Motorcycle maneuvers were significantly related to motorcycle crash severity with a majority of motorcycle crashes occurring when following straight roads or making left turns.

Number of male motorcycle riders involved in crashes was much higher than compared to female motorcycle riders, and gender was related to motorcycle crash severity only at a 90% confidence level. Age of motorcycle riders was significantly related to motorcycle crash severity, with riders 20 to 29 years and 40 to 49 years involved in a majority of the crashes.

Type of safety equipment used by motorcycle riders was also related to motorcycle crash severity in spite of only 9.23% of fatal crash victims wearing helmets during crashes. Helmet usage was also significantly related to motorcycle crash severity. Light conditions during the crashes also had an effect on motorcycle crash severity with a majority of motorcycle crashes taking place during daylight.

A majority of the motorcycle crashes were involved in collisions with other vehicles and a significant portion of the crashes were also involved in collisions with fixed objects and overturning. These types of crash classes were also related to the severity of motorcycle crashes. Time of the crashes also affected the motorcycle crash severity, with more than 60% of motorcycle crashes occurring at or after 3.00 p.m. On-road surface characteristics were also significantly related to motorcycle crash severity in Kansas with a majority of the crashes occurring on straight and level roads, followed by straight on grade, curve and level, and curve on grade roadways. Crash location also affected motorcycle crash severity with a higher number of crashes occurring on non-intersection roadways followed by intersected and intersection-related roadways.

A comparison of several factors was generated between motorcycle crashes and other vehicle crashes for a t10 year period from 1999 to 2008 to better understand characteristics of motorcycle crashes in Kansas. Vehicle maneuvers showed similar distribution for both motorcycle crashes and other vehicle crashes, with most motorcycles and other vehicle following straight roads during crashes. When it came to age distribution of motorcycle riders and drivers of other vehicles, middle-age motorcycle riders from 30 to 59 years had a higher percentage of crash involvement compared to drivers of other vehicles. But the case was reversed for teenage motorcycle riders and older motorcycle riders.

Different types of light conditions did not show much difference between the distribution of motorcycle crashes and other vehicle crashes, with motorcycle crashes in dark conditions having a slightly higher percentage compared to other vehicle crashes. When it came to crash classes, motorcycle crashes involved in collisions with other vehicles had a lower percentage compared to other vehicle crashes, but had a much higher percentage when collisions with fixed objects and overturned types of crashes were considered.

Motorcycle crashes taking place during weekends (Saturday and Sunday) had a higher percentage compared to other vehicle crashes. When time of the crashes was considered, motorcycle crashes occurring from 6:00 p.m. up to 3:00 a.m. in the morning had higher percentages compared to the other vehicle crashes. Percentage of driver-contributed motorcycle crashes was higher compared to other vehicle crashes, but it was vice versa for environmental and road condition-contributed crashes. Percentage of motorcycle crashes was higher compared to other vehicle crashes for most of the driver-related factors. Motorcycle crashes occurring on straight and level roads had a lower percentage compared to crashes of other vehicles, but motorcycle crashes occurring on curve and level and curve on grade roadways had a higher percent of crashes compared to other vehicle crashes. Motorcycle crashes occurring on non-intersected roadways had a slightly higher percentage compared to other vehicle crashes of the same crash location.

The univariate logistic regression was used to identify contributions of crash characteristics, motorcycle occupants, vehicles, and contributing circumstances to motorcycle fatal crashes in Kansas. Results from this study revealed that motorcycle maneuvers such as overtaking had a higher risk of ending up as a fatal crash while slowing or stopping had the opposite effect. Motorcyclists older than 40 years were more vulnerable to motorcycle fatal crashes in Kansas. Using a motorcycle helmet and using a motorcycle helmet and eye protection simultaneously reduced the risk of motorcycle fatal crashes. There was more risk of fatality in a motorcycle crash when the crash occurred in dark conditions. Daytime riding was safer than night time, considering the risk of motorcycle fatal crashes. Except straight and level roads, all other types of roads (on grade, curved, at hillcrest) had significant amounts of risk to be involved in motorcycle fatal crashes. Roadside area including shoulders was one significant crash location for motorcycle fatal crashes in Kansas. Weather conditions had no effect on motorcycle fatal crashes. Collisions with other motor vehicles, animals and fixed objects had higher amounts of risk to be involved in motorcycle fatal crashes when compared to non-collision motorcycle crashes. Alcohol present during the crash also contributed to an increased risk of fatalities in motorcycle crashes.

A survey was conducted among the motorcycle riders in Kansas to determine personal and other related factors associated with the decision-making process related to use of helmets. Opinions of the motorcycle riders about causes and issues related to motorcycle crashes were also obtained from the survey.

From the initial percentage calculations, it can be concluded that most motorcycle riders ride touring and cruiser types of motorcycles. About half of the respondents had riding experience of 20 years or more. A majority of the motorcycle riders rode motorcycle one to three days a week, and most of them rode motorcycles in sunny weather. Most of the motorcycle riders were male compared to a small number of female riders. Helmet usage was found to be high among the motorcycle riders, with almost half of the respondents always wearing helmets while riding motorcycles. The main reason for not wearing helmets among the riders was the freedom choice, with quite a few riders mentioning hearing and conspicuity problems due to wearing a helmet. About half of the riders knew the current form of helmet law in Kansas. But the rest of the riders responded incorrectly. A majority of the respondents opposed a mandatory law being enforced in Kansas. Most of the motorcycle riders had not been involved in a crash while riding motorcycles on public roadways. About half of the motorcycle riders involved in crashes had not sustained any injury. A high percentage of the motorcycle riders thought drivers of other vehicles were the biggest threat to their own safety while riding a motorcycle.

When it came to the different factors contributing to motorcycle crashes, most of the riders considered conflict with other cars as one of the most significant factors. Other things considered by the respondents as significant crash-contributory factors were going too fast into a curve, poor road surfaces, alcohol or drugs, lack of adequate training, distractions, etc. Non-use of a helmet was not considered as that much of a significant crash contributory factor by the respondents.

When looking at differences based on different age groups of the respondents, a tendency to own high-powered bikes among younger and older motorcycle riders was observed. Sport motorcycles were particularly popular among young motorcyclists aging 16 to 24 years. Co-relationships were found for motorcycle types and riding experience with age groups of the motorcyclists. One interesting point to note is that motorcycle riders above 40 years had high usage of helmets while riding motorcycles.

Based on respondents who met with at least a crash anytime while riding a motorcycle on a public roadway, some interesting facts were found. Poor road surfaces (potholes, loose gravel, etc.), speeding, conspicuity problems, and road surface features (like pavement markings) were highly crash-contributory factors among riders who considered those as crash-contributory factors. Other crash contributory factors among the respondents involved in motorcycle crashes were distractions, non-use of helmets, and lack of adequate training. Further, statistics showed motorcycle riders older than 24 years were highly involved in crashes and those with elevated income levels had higher involvement in crashes. Motorcycle riders with higher levels of education had lower involvement in crashes; however, when number of miles ridden increased, chances of being involved in crashes decreased. The respondents also reported a higher level of difficulties, especially in association with making a left turn in front of oncoming traffic, slowing down suddenly, low-speed parking maneuver, emergency stopping, and riding in a thunderstorm.

Ordered probit modeling was used to determine the combined effect of variables contributing to higher injury severity. Variables under driver-related, crash-related, roadway-related, and environment-related were considered. Younger motorcycle riders up to19 years were at a higher risk of more severe crashes compared to older age categories. Motorcycle riders under the influence of alcohol during crashes had a higher risk of severe injury. Helmeted motorcycle riders were at a lower risk to be severely injured. Motorcycle riders using helmets were less likely to be involved in severe crashes. Motorcycle crashes involving collisions with fixed objects had a higher risk of severe injury among motorcycle riders. Motorcycle riders involved in overturned-type crashes also had a higher risk of severe injury. Motorcycle riders going straight following the road during the crashes were less likely to be involved in more severe crashes. Motorcycle crashes occurring from 4:00 p.m. to 8:00 p.m. had lower risk for motorcycle riders to be involved in more severe crashes. Motorcycle riders having crashes on straight roadways had lower injury severity compared to curved roads. Also, motorcycle riders having crashes on higher posted speed limit roads had higher injury severity. Motorcycle riders riding under good weather conditions showed a higher risk of more severe injury.

5.2 Recommendations

Future research can be directed to analyze different types of motorcycle crashes (such as single-vehicle crashes, multi-vehicles crashes, fixed-object crashes) with the intention of finding significant characteristics affecting these motorcycle crashes. Collection and use of more exposure-type of motorcycle data would lead to identifying more behavioral factors, which would also help improve the safety of motorcycle riders. However, state reporting of motorcycle vehicle miles traveled (VMT) to the Federal Highway Administration (FHWA) was optional prior to 2007. Even for those states that reported motorcycle VMT, it was often only measured as a standard proportion of total VMT, rather than being collected directly through surveys of roadside counters. So, accurate collection of motorcycle VMT and use of this exposure data would help to initiate further useful research in identifying critical factors affecting motorcycle safety in Kansas.

5.2.1 Possible Countermeasures

Based on the study, a number of countermeasures can be suggested to improve the safety of motorcycle riders in Kansas. In general, implementation of these countermeasures is a lengthy process which will definitely require financing, and each improvement will be associated with a certain amount of cost plus benefits. However, this study does not have the scope to asses all these cost-associated issues. In addition, countermeasures suggested in this section are exclusively based on the approach of improving safety of motorcycle riders and may have different implications towards other driver groups, road users, or other related parties. Thus, careful consideration to state policies, future plans, etc. is necessary for implementation of the selected countermeasures.

The study revealed that motorcyclists older than 40 years were more vulnerable to fatal motorcycle crashes in Kansas, and younger motorcycle riders up to 19 years were at a higher risk of more severe crashes. This gives the impression that current rider training programs for younger or older riders do not appear to reduce crash risk. Therefore, it might be necessary to introduce standards for entry-level motorcycle rider training that will set the baseline for novice or young motorcycle rider training programs in Kansas. At the same time, it might be useful to develop and promote motorcycle safety educational materials to encourage older motorcyclists to take novice and experienced rider training and get properly licensed. Learning or education programs would help to improve the safety of older motorcycle riders to a great extent. Currently, Kansas waives the skill test and issues a license to a rider if he/she completes an approved basic motorcycle rider safety course. This course includes classroom instructions as well as driver training in a controlled, off-street environment. Kansas should also be updated with the release of motorcycle operator licensing guidelines from USDOT (Department of Transportation) to maintain state motorcycle licensing systems and integrate rider-training programs with motorcycle-operator licensing.

The study also revealed that using motorcycle helmets and using motorcycle helmet and eye protection simultaneously reduced the risk of fatal motorcycle crashes. Helmeted motorcycle riders were also at a lower risk of being severely injured. From survey results of motorcycle riders, it was also evident that motorcycle riders do not want a mandatory helmet law to be enforced on them. In fact, most of the survey respondents opposed a mandatory helmet law in Kansas. But at the same time, motorcycle riders are wearing helmets most of the time while riding motorcycles. Therefore, conducting and evaluating a statewide demonstration project to increase helmet use through education and communication programs might be very useful.

Similarly, introduction of best practices through various sources will improve the safety of motorcycle riders as well as others. Use of helmets compliant with federal standards, reducing the number of left turns, reducing the tendency of overtaking and avoiding riding in other demanding conditions, avoiding drunk riding, and no speeding are some of the best practices that can be introduced at this stage. A demonstration program can be developed and implemented combining high-visibility enforcement with enhanced media to test its effectiveness in reducing alcohol-related motorcycle crashes. A training program can be designed specifically to educate police on motorcycle safety. Police officers can also be introduced to enforcement efforts they can undertake to reduce motorcycle crashes. Developing an employer-based motorcycle safety program for employees who ride motorcycles on or off the job can also be introduced in Kansas.

There is room for improvements on roadways to improve safety of motorcycle riders as well. From the study, it was found that except for straight and level roads, all other types of roads (on grade, curved, at hillcrest) had a significant amount of risk of being involved in fatal motorcycle crashes. Therefore, a reduction in major vertical differences and an increase in the radius of curvatures are appropriate in relation to motorcycle rider safety enhancement. Roadside area was one significant crash location for fatal motorcycle crashes in Kansas and consequently, overturned crashes and crashes involving motorcycles struck with fixed objects had a high risk for the motorcycle riders to be severely injured. Thus, the necessity for more clear zones is evident, and these clear zones need to have lesser slopes to prevent overturning. Guard rails and rumble strips will also help in preventing run-off-road crashes, and removal of fixed objects closer to roads will help reduce severity when crashes occur. More road signs may help overcome some driver-related errors contributing to crashes, such as failing to yield, inability to comply with traffic signals, and so on. The study revealed that daytime riding was safer than nighttime considering the risk of fatal motorcycle crashes. Better street lighting facilities will improve visibility at night, and better road or pavement marking will reduce conflicts or misjudgments in motorcycle maneuvering.

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Appendix A - Motorcycle Fatalities and Injuries in U.S., 1997-2008

Table A.1 Motorcycle Fatalities in the United States, 1997-2007

Year	Motorcycle fatalities
1997	2,116
1998	2,294
1999	2,483
2000	2,897
2001	3,197
2002	3,270
2003	3,714
2004	4,028
2005	4,576
2006	4,837
2007	5,154

Table A.2 Other Vehicle Fatalities (Except Motorcycle) in the United States, 1997-2007

Year	Other vehicle fatalities
1997	33,609
1998	33,088
1999	33,392
2000	33,451
2001	33,243
2002	34,105
2003	33,627
2004	33,276
2005	33,070
2006	32,119
2007	30,401

Table A.3 Motorcycle Fatal and Injury Crashes in Kansas, 1997-2008

Year	MC fatal crashes	MC injury crashes
1997	17	611
1998	19	568
1999	16	661
2000	24	667
2001	24	672
2002	31	716
2003	31	720
2004	30	844
2005	35	888
2006	64	928
2007	47	1,033
2008	45	1,085

Table A.4 Kansas Motorcycle Rider Fatalities (Helmeted and Unhelmeted), 1997-2008

Year	MC riders fatalities using helmet	Unhelmeted
1997	3	14
1998	6	13
1999	3	12
2000	3	18
2001	6	17
2002	6	25
2003	10	21
2004	8	20
2005	7	28
2006	18	46
2007	14	32
2008	11	33

Table A.5 Kansas Motorcycle Rider Injuries (Helmeted and Unhelmeted), 1997-2008

Year	MC riders injured using helmets	Injured unhelmeted
1997	120	455
1998	117	429
1999	148	473
2000	163	465
2001	155	472
2002	159	515
2003	198	483
2004	249	546
2005	268	579
2006	293	596
2007	368	619
2008	385	642

Appendix B - Percentage Comparison between Motorcycle and Other Vehicle Crashes in Kansas, 1999-2008

Table B.1 Vehicle Maneuver: Percentage Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	Straight-following road	Left turn	Right turn	U turn	Overtaking	Aggressiv e maneuver	Other
1999	MC	58.2	13.7	3.6	0.8	2.3	5.9	21.4
	OV	53.6	10.1	3.1	0.4	1.1	2.7	31.7
2000	MC	57.7	15.1	3.8	0.5	2.7	6.0	20.2
	OV	53.2	10.1	3.3	0.3	1.1	2.7	32
2001	MC	57.7	14.7	3.8	0.6	2.5	4.9	20.7
	OV	53.5	10.2	3.2	0.4	1.1	2.6	31.6
2002	MC	57.2	13.7	5.2	0.8	2.3	5.7	20.8
	OV	53.6	10.0	3.2	0.3	1.1	2.4	31.8
2003	MC	58.9	11.7	4.4	0.6	1.8	6.0	22.6
	OV	54.1	9.8	3.2	0.3	1.0	2.5	31.6
2004	MC	60.2	12.7	3.3	0.6	1.4	5.1	21.8
	OV	54.1	9.4	3.1	0.3	1.0	2.4	32.1
2005	MC	59.3	12.7	4.3	0.5	1.3	5.7	21.9
	OV	54.6	9.6	3.1	0.3	1.0	2.4	31.4
2006	MC	60.1	12.8	3.9	0.2	1.4	4.7	21.6
	OV	54.4	9.5	3.0	0.3	0.8	2.4	32
2007	MC	60.4	13.1	3.7	0.4	1.8	5.0	20.6
	OV	55.4	9.1	3.0	0.3	0.8	2.6	31.4
2008	MC	58.3	11.6	4.4	1.2	2.3	5.7	22.2
	OV	55.2	9.2	3.0	0.4	0.9	2.5	31.3
Average	MC	58.8	13.2	4.0	0.6	2.0	5.5	21.4
	OV	54.2	9.7	3.1	0.3	1.0	2.5	31.7

Table B.2 Age Distribution: Percentage Comparison between MC and Other Vehicle Crashes, 1999-2008

		Age Group (years)						
Year	Vehicle	10 to 19	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 and above
1999	MC	16.5	30.4	19.3	18.1	10.1	2.6	3.0
	OV	26.8	22.9	16.6	13.9	8.6	5.2	5.9
2000	MC	16.4	27.9	21.3	18.5	9.2	3.8	2.8
	OV	26.2	23.7	16.4	14.2	8.8	4.9	5.7
2001	MC	15.1	28.9	18.2	20.2	11.2	3.6	2.7
	OV	26.1	23.6	16.0	14.6	9.0	5.0	5.7
2002	MC	14.8	25.2	19.9	20.1	12.4	4.0	3.6
	OV	25.3	24.1	15.6	14.7	9.5	5.1	5.7
2003	MC	14.9	24.7	19.2	20.1	12.5	4.7	3.9
	OV	25.2	23.9	15.4	14.7	9.7	5.3	5.8
2004	MC	15.8	28.3	14.3	20.6	13.4	4.2	3.4
	OV	24.5	24.0	14.9	15.0	10.4	5.4	5.8
2005	MC	13.2	25.1	19.4	18.8	14.4	5.2	4.0
	OV	23.5	24.3	15.1	15.2	10.8	5.6	5.5
2006	MC	13.0	23.1	18.4	20.4	16.7	4.9	3.4
	OV	23.5	24.5	14.8	14.6	11.1	5.8	5.7
2007	MC	14.0	27.9	15.9	17.8	14.8	6.2	3.4
	OV	22.5	24.7	15.0	14.5	11.6	6.2	5.4
2008	MC	11.3	25.7	18.0	19.4	15.2	7.2	3.1
	OV	22.5	24.8	14.9	14.1	11.6	6.5	5.6
Average	MC	14.9	26.8	18.4	19.4	12.8	4.4	3.4
	OV	24.6	24.1	15.5	14.6	10.1	5.5	5.7

Table B.3 Light Conditions: Percentage Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	Daylight	Dawn	Dusk	Dark-streetlight on	Dark-no streetlights
1999	MC	64.4	1.0	4.0	19.4	10.8
	OV	70.8	2.1	2.7	13.3	10.4
2000	MC	67.7	1.5	3.9	18.3	7.9
	OV	70.4	1.9	2.8	13.9	10.2
2001	MC	68.6	1.1	2.8	18.9	8.0
	OV	69.9	2.1	2.8	14.2	10.3
2002	MC	66.6	1.1	3.6	19.3	9.4
	OV	69.9	1.9	2.9	14.4	10.2
2003	MC	68.0	1.2	3.4	18.5	8.6
	OV	70.6	1.9	2.7	14.0	10.2
2004	MC	68.5	0.9	4.6	15.2	10.3
	OV	69.9	2.1	2.8	14.1	10.7
2005	MC	67.7	1.1	4.7	16.8	9.5
	OV	70.2	2.2	2.5	14.3	10.5
2006	MC	69.0	1.4	5.1	16.7	7.7
	OV	69.8	2.3	2.3	14.2	11.0
2007	MC	70.8	1.4	3.7	14.8	8.9
	OV	69.8	2.3	2.4	14.1	10.9
2008	MC	73.5	1.9	2.8	14.1	7.4
	OV	68.1	2.4	2.7	14.9	11.3
Average	MC	68.5	1.3	3.9	17.2	8.8
	OV	69.9	2.1	2.7	14.1	10.6

Table B.4 Crash Classes: Percent Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	No collision	Over turn	Collision with pedestrian	Collision with other motor vehicle	Collision with parked motor vehicle	Collision with rail train	Collision with pedacycle	Collision with animal	Collision with fixed object
1999	MC	6.1	23.8	0.6	43.2	1.8	0.0	0.1	5.8	17.3
	OV	0.9	1.3	0.4	74.0	4.2	0.1	0.3	8.7	9.6
2000	MC	10.9	19.5	0.1	43.5	1.7	0.1	0.0	4.5	17.9
	OV	0.8	1.5	0.4	73.7	4.6	0.1	0.3	8.2	10.0
2001	MC	8.1	21.2	0.7	48.0	1.2	0.0	0.3	4.5	14.6
	OV	0.8	1.4	0.4	72.8	4.8	0.1	0.3	8.7	10.1
2002	MC	8.3	23.3	0.3	44.2	2.1	0.0	0.3	4.9	15.5
	OV	0.9	2.7	0.4	73.0	4.8	0.1	0.3	8.1	9.2
2003	MC	8.9	21.9	0.4	44.4	2.3	0.0	0.2	6.3	14.3
	OV	0.9	2.4	0.4	72.4	4.8	0.1	0.3	8.4	9.7
2004	MC	8.9	23.9	0.3	42.4	1.1	0.0	0.1	7.4	14.8
	OV	0.9	2.3	0.4	72.2	4.7	0.1	0.3	9.0	9.5
2005	MC	11.0	23.5	0.1	42.0	1.0	0.0	0.2	5.7	14.8
	OV	1.0	2.6	0.4	72.0	4.3	0.1	0.3	8.7	10.0
2006	MC	6.5	27.5	0.1	41.4	1.2	0.0	0.2	5.3	16.8
	OV	0.7	2.4	0.4	71.9	4.2	0.1	0.3	9.6	9.9
2007	MC	9.2	22.7	0.2	43.9	1.2	0.0	0.1	6.2	15.7
	OV	0.8	2.1	0.4	70.3	4.4	0.1	0.3	9.2	12.0
2008	MC	9.9	23.1	0.3	43.2	1.0	0.0	0.2	5.2	16.2
	OV	0.9	1.9	0.4	70.1	4.7	0.1	0.3	9.8	11.4
Average	MC	8.8	23.0	0.3	43.6	1.5	0.0	0.2	5.6	15.8
	OV	0.9	2.1	0.4	72.2	4.6	0.1	0.3	8.8	10.1

Table B.5 Day of Crashes: Percent Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	FR	SA	SU	MO	TU	TH	WE
1999	MC	15.8	18.5	17.6	12.9	9.1	13.2	12.9
	OV	18.3	12.9	9.1	15.3	14.6	15	14.8
2000	MC	14.7	19	16.3	9.2	12.8	14.7	13.3
	OV	17.6	12.8	9.6	14.8	14.3	15.3	15.6
2001	MC	17.8	21.8	15.4	9.7	11.6	12.8	10.8
	OV	18.2	13.2	8.9	14	15	15.4	15.3
2002	MC	15.9	17.9	19.1	11.4	10.4	13.4	11.9
	OV	17.8	13.5	8.9	14.9	14.2	15.2	15.4
2003	MC	14.6	19.1	21.6	12.8	9.7	11.6	10.6
	OV	17.3	12.8	9.7	14.5	14.9	15.2	15.5
2004	MC	15.7	19.8	18.5	9.6	11.5	11.5	13.4
	OV	17.5	12.6	9.7	14.5	14.8	15.5	15.4
2005	MC	16	20.8	17	13.6	10.5	12.7	9.4
	OV	17.9	13.2	9	14.4	15.3	15	15.3
2006	MC	15.8	20.2	16.2	9.9	11.6	11.9	14.4
	OV	17.4	12.9	9.5	14.3	15.3	15.6	15.1
2007	MC	16	20.3	16.8	9.6	10.7	12.6	14
	OV	17.9	14.2	9.1	13.8	14.7	15.1	15.4
2008	MC	15.4	20.2	16.8	10.6	11.8	11.7	13.5
	OV	16.9	12.3	8.8	13.6	16.6	15.4	16.3
Average	MC	15.8	19.7	17.5	10.9	11	12.6	12.4
	OV	17.7	13	9.2	14.4	15	15.3	15.4

Table B.6 Time of Crashes: Percent Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	0 to 3	3 to 6	6 to 9	9 to 12	12 to 15	15 to 18	18 to 21	21 to 24
1999	MC	7.2	2.4	5.1	8.2	14.6	28.4	19.1	14.9
	OV	3.9	2.4	13.0	12.7	18.7	27.2	14.1	8.1
2000	MC	6.9	2.0	5.4	9.0	15.5	27.0	21.9	12.4
	OV	4.2	2.4	12.9	12.7	18.2	27.4	14.1	8.1
2001	MC	6.8	2.3	6.9	9.7	17.4	23.0	19.7	14.2
	OV	4.2	2.6	13.0	12.2	18.1	27.3	14.5	8.2
2002	MC	8.4	1.1	5.6	9.9	16.0	26.8	19.3	12.8
	OV	4.2	2.4	12.2	12.4	18.4	27.7	14.6	8.1
2003	MC	6.6	2.2	6.2	8.7	17.8	25.2	20.0	13.2
	OV	4.0	2.4	12.9	12.9	18.7	26.9	14.1	8.1
2004	MC	5.7	1.6	5.1	9.4	15.9	29.6	19.9	12.7
	OV	4.2	2.6	13.2	13.0	18.1	27.1	13.9	7.9
2005	MC	6.8	2.2	8.4	10.2	16.4	24.8	18.6	12.6
	OV	4.1	2.8	13.7	12.5	17.9	27.2	14.0	7.8
2006	MC	6.0	2.7	7.2	9.0	18.1	26.6	18.7	11.6
	OV	4.5	2.8	13.5	12.0	17.8	27.1	14.2	8.1
2007	MC	6.5	1.9	7.8	9.4	19.0	25.5	19.0	10.7
	OV	4.2	2.9	14.1	12.9	17.6	26.7	13.6	7.9
2008	MC	5.0	1.6	7.3	9.6	19.2	26.9	19.8	10.6
	OV	4.4	3.0	14.2	12.5	17.2	26.3	14.3	8.1
Average	MC	6.6	2.0	6.5	9.3	17.0	26.4	19.6	12.6
	OV	4.2	2.6	13.3	12.6	18.1	27.1	14.1	8.0

Table B.7 Contributing Factors: Percent Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	At Road	Driver	Environment	On road	Pedestrian	Vehicle
1999	MC	0.1	88.1	5.7	3.7	0.3	2.1
	OV	0.2	85.5	8.2	3.8	0.4	1.9
2000	MC	0.0	87.9	6.1	2.3	0.4	3.2
	OV	0.3	85.1	7.8	4.6	0.4	1.8
2001	MC	0.0	88.9	5.4	2.8	0.1	2.8
	OV	0.3	85.6	8.0	4.0	0.4	1.7
2002	MC	0.0	89.6	5.9	2.6	0.6	1.3
	OV	0.2	85.8	8.0	3.9	0.3	1.7
2003	MC	0.4	88.0	5.1	3.3	0.4	2.8
	OV	0.6	84.3	8.9	4.2	0.4	1.6
2004	MC	0.3	87.9	7.2	3.2	0.0	1.5
	OV	0.6	84.3	8.9	4.2	0.3	1.6
2005	MC	0.5	89.6	5.5	2.9	0.1	1.5
	OV	0.6	83.1	9.4	5.0	0.3	1.5
2006	MC	0.1	88.1	6.7	3.2	0.0	2.0
	OV	0.4	85.8	8.9	2.9	0.4	1.5
2007	MC	0.1	88.0	6.6	3.1	0.0	2.1
	OV	0.8	80.8	10.4	6.4	0.3	1.4
2008	MC	0.4	86.0	6.7	4.3	0.2	2.4
	OV	0.6	81.9	10.0	5.8	0.3	1.4
Average	MC	0.2	88.2	6.1	3.1	0.2	2.2
	OV	0.5	84.2	8.9	4.5	0.4	1.6

Table B.8 On-Road Surface Characteristics: Percent Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	Straight and level	Straight on grade	Straight at hillcrest	Curved and level	Curved on grade	Curved at hillcrest
1999	MC	61.9	14.1	0.7	11.4	10.2	0.7
	OV	72.3	18.1	1.9	3.5	2.9	0.1
2000	MC	60.8	14.6	1.3	11.9	10.0	0.0
	OV	72.1	18.5	1.8	3.4	2.9	0.2
2001	MC	64.3	14.2	1.8	9.2	9.2	0.4
	OV	73.4	17.6	1.7	3.4	2.8	0.2
2002	MC	62.2	13.6	1.9	11.4	9.9	0.5
	OV	73.6	17.2	1.8	3.4	2.9	0.2
2003	MC	66.1	12.2	1.5	9.6	9.8	0.2
	OV	73.1	17.6	1.8	3.6	3.0	0.1
2004	MC	62.7	14.1	2.2	9.9	10.6	0.1
	OV	73.1	17.9	1.6	3.5	3.0	0.1
2005	MC	61.8	14.2	1.4	12.1	8.7	0.5
	OV	72.4	18.1	1.8	3.6	3.2	0.2
2006	MC	61.0	14.1	2.4	12.7	8.2	1.0
	OV	73.5	17.4	1.6	3.6	3.0	0.2
2007	MC	66.0	12.8	1.2	9.1	9.6	0.7
	OV	72.9	17.5	1.7	3.7	3.3	0.2
2008	MC	63.2	14.5	1.7	10.2	9.1	0.2
	OV	73.6	17.0	1.7	3.6	3.1	0.2
Average	MC	63.0	13.8	1.6	10.7	9.5	0.4
	OV	73.0	17.7	1.7	3.5	3.0	0.2

Table B.9 Crash Locations: Percent Comparison between MC and Other Vehicle Crashes, 1999-2008

Year	Vehicle	Non intersection on roadway	Intersection on roadway	Intersection related on roadway	Parking lot, driveway on roadway	Intersection area on roadway	On crossover on roadway	Roadside including shoulder off roadway	Median off roadway
1999	MC	41.1	25.0	12.3	9.4	4.2	0.0	7.5	0.6
	OV	40.9	28.1	14.9	8.7	4.6	0.1	2.4	0.2
2000	MC	43.2	27.7	10.8	7.1	6.3	0.0	4.4	0.6
	OV	42.2	27.7	15.8	6.9	4.6	0.1	2.4	0.3
2001	MC	42.7	27.4	13.4	7.4	4.9	0.3	3.4	0.4
	OV	41.6	26.5	16.4	7.9	4.4	0.1	2.5	0.4
2002	MC	44.3	23.8	12.4	8.0	6.9	0.0	4.5	0.0
	OV	41.2	26.6	16.1	8.2	4.8	0.1	2.7	0.3
2003	MC	46.1	25.5	10.7	7.7	4.1	0.0	5.4	0.5
	OV	40.7	27.0	15.5	8.1	4.8	0.0	3.2	0.4
2004	MC	42.6	22.9	13.3	7.8	6.5	0.1	6.0	0.8
	OV	40.2	25.6	16.5	8.6	4.9	0.1	3.6	0.5
2005	MC	45.3	19.7	12.8	8.2	6.1	0.0	6.9	0.9
	OV	40.8	25.4	16.4	7.4	5.6	0.0	3.7	0.5
2006	MC	46.3	24.4	11.2	6.1	6.5	0.0	4.8	0.6
	OV	43.0	26.1	15.3	6.8	4.8	0.0	3.5	0.4
2007	MC	45.5	23.9	10.4	7.6	4.8	0.0	6.9	0.7
	OV	43.1	24.6	15.1	6.8	4.7	0.1	4.9	0.6
2008	MC	38.8	23.8	12.0	7.6	5.2	0.2	11.5	0.9
	OV	37.9	24.8	14.5	7.7	5.2	0.0	8.7	1.0
Avg	MC	43.6	24.4	11.9	7.7	5.5	0.1	6.1	0.6
	OV	41.1	26.2	15.7	7.7	4.8	0.1	3.8	0.5

Appendix C - Survey Form

This survey is being conducted with the intention of improving MC safety. Information collected will be used for research purposes only. The participation in the survey is completely voluntary and you may quit anytime. For any question feel free to contact Dr. Sunanda Dissanayake, 2118 Fiedler Hall, KSU, Manhattan, KS 66506, Tel: 785-532-1440.

Please check the appropriate response (s)

1. Are you a registered motorcycle owner?
○ Yes ○ No

2. What is the brand of your current motorcycle?
○ Honda ○ Yamaha ○ Harley Davidson
○ Suzuki ○ Kawasaki ○ BMW ○Others

3. What is your MC model year?
○ Before1980 ○ 1980-1984 ○ 1985-1989
○ 1990-1994 ○ 1995-1999 ○ 2000-2010

4. What is the engine size of your motorcycle?
○ 500cc or less ○ 501-1000 cc
○ 1001-1500cc ○ More than 1500cc

5. Which one of the following types of motorcycles do you ride most frequently?
○Touring ○ Sport ○Standard ○ Cruisers ○ Dual ○ Others

6. How long have you been riding motorcycles?
○ 0-5 yrs ○ 5-10 yrs
○ 10-15 yrs ○ 15-20 years ○ more than 20 yrs

7. How many miles did you approximately ride in the past year?
○ 1000 or less ○ 1000-2999
○ 3000-4999 ○ 5000-7999
○ 8000-10,000 ○ above 10,000

8. What type of roadway do you commonly travel by motorcycle? If you use more than one type of road (check all that apply).
○ City/Town roads ○ Two-lane out of-town
○ Interstate/Divided Highways ○ Rural road

9. What is the primary reason for riding motorcycle?
○ To make task related trips
○ Recreational purposes
○ To get good mileage
○ As it is fast and maneuverable
○ For its easiness of parking

10. How frequently do you ride motorcycles?
○ Everyday○ during weekend only ○ 1-3 days a week ○ 4-6 days a week

11. What type of weather you prefer most while riding motorcycle?
○ Hot and sunny ○ Rainy
○ Cold ○ Humid ○ Mild

12. Thinking back the last time you rode a motorcycle on a public roadway, did you wear a helmet?
○ Yes ○ No ○ Don‘t remember

13. How often do you wear a helmet while riding a motorcycle?
○ Always ○ Sometimes
○ Seldom ○ Never

14. If you don't always wear a helmet, what are the reasons? (Check all that apply)
○ I'm not worried about having accident
○ Freedom of choice
○ I don't believe a helmet makes me safer
○ It is too hot.
○ It creates problem with my hearing
○ It creates problem with my vision
○ Weather conditions making riding more hazardous
○ Laziness/Forgetfulness
○Other specify_________

15. Do you know what type of helmet law Kansas currently has?
○ Mandatory helmet law○ No law
○ Partial helmet law ○Don't know

16. If you oppose mandatory helmet law, what is the main reason you would not support it?
○ Helmets are uncomfortable

○ Helmets are not effective in preventing motorcycle accidents
○ Helmets are not safe
○ Waste of government time and resources
○ Personal freedom ○It creates hearing problem

17. What kind of impact would a mandatory helmet law have on the amount you ride a motorcycle?
○ Significantly decrease
○ Somewhat decrease
○ Have had no effect
○ Somewhat increase
○ Significantly increase

18. Would you support or oppose about a law requiring motorcycle riders and their passengers to wear a helmet while riding?
○ Support ○ Oppose

19. What special effort do you make while riding to ensure other motorists can see you? Check all that apply
○ Make sure all lights are working
○ Use blinkers
○ Wear bright-colored or reflective clothing
○ Stay out of motorist blind spots
○ Use your horn ○Increase engine noise
○ Hand signal
○ Other specify_______________

20. What other safety gears do you use than helmet while riding motorcycles?
○ Bright colored or reflective jacket
○ Gloves ○ Goggles ○ Flashing lights
○ Special shoes ○ Others ○ None

21. Have you ever had an accident while riding your motorcycle on a public roadway?
○ Yes ○ No

22. Have you had an accident while riding motorcycle over the last 12 months?
○ Yes ○ No

23. What was the worst level of injury sustained by you or someone else involved in a motorcycle accident?
○ Someone was killed
○ You were treated at scene
○ Someone else was treated at scene
○ No-one else was injured

24. What do you feel is the single biggest threat to your own safety while riding a motorcycle?
○ Drivers of other vehicles
○ Not wearing a helmet while riding
○ Weather
○ Lack of personal experience
○ Road surface conditions
○ Lack of adequate training
○ Other specify________

25. Your gender?
○ Male ○ Female

26. Your age (in years)?
○below 18 ○18-24 ○25-33
○ 34-42 ○ 43-51 ○52 and above

27. Marital status?
○ Single (never married)
○ Married/living with partner
○ Separated/divorced/widowed

28. Your educational qualification?
○ No formal schooling
○ Some High school ○ Some College
○ Four Year College ○ Graduate College

29. Present Job Situation?
○ Full-Time Work ○ Part-Time Work
○ Student ○ Home Maker
○ Pension or Unemployed ○ Other (please specify) _

30. Which category does your household's total annual income fall into?
○ $ 0 to $ 19,999 ○ $20,000-39,999
○ $40,000 -$59,999 ○ 60,000 or above

31. What do you think is the most difficult maneuver to execute while riding a motorcycle? (Check all that apply)
○ To make a left turn in front of oncoming traffic
○ To change a lane
○ To make an exit on the freeway
○ To merge from an exit
○ Fast swerve
○ Low speed parking maneuver
○ Emergency stopping
○ Keep straight
○ Negotiate a curve
○ Slow down suddenly
○ Avoid others in way

○ Riding in thunderstorm

32. Do you prefer riding motorcycle in groups?
○ Yes ○ No

33. Rate the following factors according to their contributions to cause an accident from most contributive to the least.

	Most	Significant	Average	Not significant	Least
Tip over	○	○	○	○	○
Too fast in curve	○	○	○	○	○
Conflicts with cars	○	○	○	○	○
Poor road surfaces (potholes, Loose gravel, oil etc)	○	○	○	○	○
Bad weather (rain, wind etc)	○	○	○	○	○
Speed (Exceeding speed limit)	○	○	○	○	○
Couldn't see far enough	○	○	○	○	○
Alcohol or drugs	○	○	○	○	○
Road surface features (like Pavement markings)	○	○	○	○	○
Worn tires	○	○	○	○	○
Misjudged speed of other vehicles	○	○	○	○	○
Fatigue	○	○	○	○	○
Distraction	○	○	○	○	○
Not using a helmet	○	○	○	○	○
Lack of adequate training	○	○	○	○	○
Over taking	○	○	○	○	○
Traffic hazard	○	○	○	○	○

Appendix D - Newspaper Clips of Motorcycle Crashes in Kansas

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NEWS ARTICLE

July 24, 2009 12:00 AM

Cyclist killed in K-18 crash with minivan

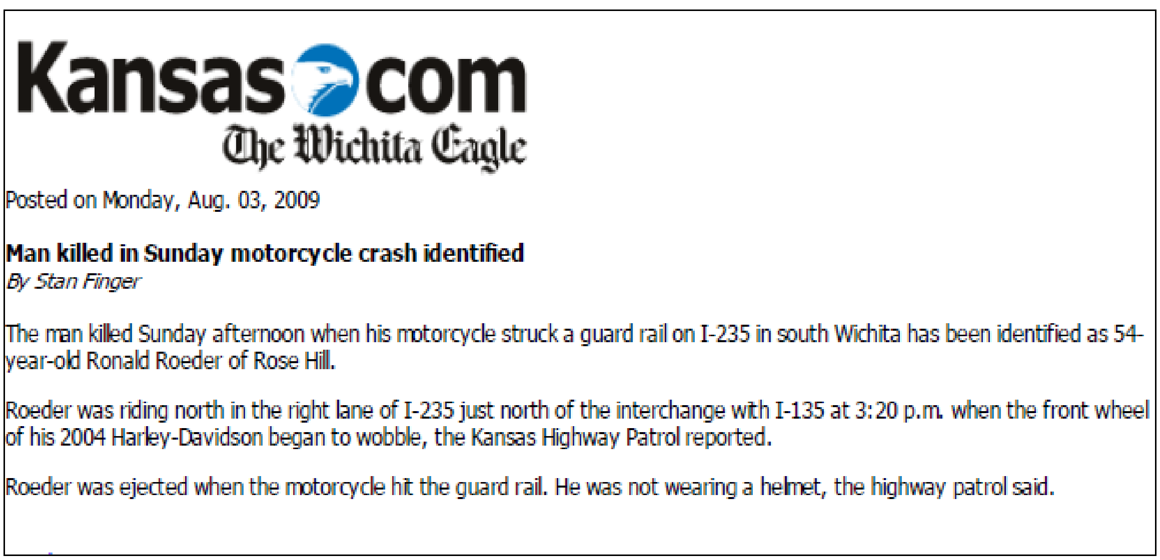
Staff reports

A Manhattan man died Thursday when the motorcycle he was driving was struck by another vehicle on K-18 at Scenic Drive.

Darren Dinger, 44, was driving a 2002 Harley Davidson motorcycle eastbound on K-18 around 4:30 p.m. Thursday.

A Dodge Durango, driven by Candace Marie Wishkeno, 40, of Horton, was turning left onto K-18 from Scenic Drive and Dinger collided with the vehicle, according to the Kansas Highway Patrol.

Figure D.1 Manhattan Mercury News Clip for Motorcycle Crash Caused by Collision with Minivan



Kansas.com
The Wichita Eagle

Posted on Monday, Aug. 03, 2009

Man killed in Sunday motorcycle crash identified
By Stan Finger

The man killed Sunday afternoon when his motorcycle struck a guard rail on I-235 in south Wichita has been identified as 54-year-old Ronald Roeder of Rose Hill.

Roeder was riding north in the right lane of I-235 just north of the interchange with I-135 at 3:20 p.m. when the front wheel of his 2004 Harley-Davidson began to wobble, the Kansas Highway Patrol reported.

Roeder was ejected when the motorcycle hit the guard rail. He was not wearing a helmet, the highway patrol said.

Figure D.2 Wichita Eagle News Clip for Motorcycle Crash Caused by Collision with Guard Rail

Kansas.com
The Wichita Eagle

Posted on Saturday, Aug. 22, 2009

Motorcyclist dies in crash Friday night

WICHITA — Wichita police say a man died Friday night when his motorcycle collided with a vehicle near 22nd and North Kansas, KFDI reported.

KFDI said police reported the motorcyclist was traveling about 11 p.m. Friday at a high rate of speed southbound on Kansas when he crashed into a car turning into a driveway.

He skidded into the vehicle and was thrown from his bike, KFDI said. The driver of the vehicle was not injured.

Figure D.3 Wichita Eagle News Clip for Motorcycle Crash Caused by Collision with a Car

Kansas.com
The Wichita Eagle

Posted on Tuesday, Sep. 08, 2009

Wichita man injured when two motorcycles collide
By STAN FINGER

A 24-year-old Wichita man was hospitalized Monday night after being involved in a collision involving two motorcycles.

The Kansas Highway Patrol said Seth Creason and 31-year-old Craig Robinson of Wichita were southbound on I-235 at a high rate of speed shortly before 6:45 p.m. Sunday when Robinson slowed his motorcycle down quickly about 100 feet from the 25th Street exit.

Creason was unable to slow down in time and struck Robinson's motorcycle in the rear, forcing Creason to lay the bike down on the pavement and skid into the median, the highway patrol reported.

Figure D.4 Wichita Eagle News Clip for Motorcycle Crash Caused by Collision with Motorcycle

Kansas.com
The Wichita Eagle

Posted on Monday, Sep. 21, 2009

Wichita man dies after motorcycle crash trying to avoid deer
By DAN VOORHIS

A Wichita man who was critically injured in a motorcycle crash on Thursday has died.

William A. Rosebaugh, 61, was riding his 2003 Harley-Davidson motorcycle south on South Maize Road at 6:19 a.m. when a deer darted across the roadway.

Rosebaugh swerved to avoid the deer and lost control of the motorcycle, causing it to fall onto its side and slide more than 100 feet.

Figure D.5 Wichita Eagle News Clip for Motorcycle Crash Caused by Collision with a Deer

By Jesse Fray
September 14, 2009

A 20-year-old man was killed after crashing a motorcycle Sunday night, Lawrence police said.

The victim, who was not identified by police Monday, was taken by air ambulance to Kansas University Hospital after the accident, which occurred about 7:55 p.m. Sunday near the intersection of Princeton Boulevard and Peterson Road.

"He struck the median curb, which caused him to become airborne," said Kim Murphree, police spokeswoman. "He landed against a small tree in the median."

Police said the man was not wearing a helmet and died at the hospital.

Figure D.6 LJWorld.com News Clip for Motorcycle Crash Caused by Hitting the Median Curb

Kansas.com
The Wichita Eagle

Posted on Thursday, Nov. 05, 2009

Emporia State student found dead in accident

An Emporia State University student who had not been seen since Sunday has been found dead after an apparent motorcycle accident.

Emporia police say 24-year-old Samuel Jacob Williams, a junior from the Ivory Coast in Africa, was found dead Wednesday afternoon.

Police say Williams apparently was thrown from his motorcycle after apparently losing control on a curve Sunday. A Lyon County sheriff's deputy found his body Wednesday. Police say there were no signs of foul play.

Figure D.7 Wichita Eagle News Clip for Motorcycle Clip Caused by Losing Control on a Curve

Motorcycle Crash Victims Identified

Troopers: Frank X. Zappa Was Not Wearing Helmet

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POSTED: 8:13 pm CST November 7, 2009
UPDATED: 2:14 pm CST November 8, 2009

SHAWNEE, Ks. -- A man is dead and another is injured following a motorcycle crash.

Officers said the men were in a pack of riders heading north on Kansas Highway 7 near 75th Street.

Police said Frank X. Zappa, 56, of Overland Park, was killed. The Kansas Highway Patrol said he was not wearing a helmet.

The other rider, Tory J. King, 37, was taken to an area hospital. There is no word on his condition.

Figure D.8 KMBC.com News Clip for Motorcycle Fatal Crash Victim Identification

Posted on Wed, Jun. 09, 2010

Motorcyclist killed in intersection

0 Comments

BY STAN FINGER
The Wichita Eagle

One of the most common fears among motorcycle riders is that they won't be seen by other drivers.

Scott L. Allen wasn't, police said, until it was too late to avoid the collision that claimed his life Monday.

Allen, 42, was riding north on Seneca shortly before 5:30 p.m. when he entered the intersection at MacArthur, where a 19-year-old man was poised to turn left onto eastbound MacArthur, said Lt. Joe Schroeder of the Accident Follow-Up Unit.

Allen's motorcycle slammed into the driver's-side headlight of the Chevy Silverado. Allen was taken to a local hospital and died Monday evening.

"Most people did not notice the bike until it had entered the intersection, and by that time he's trying to stop," Schroeder said. "He got on the brakes right as he entered the intersection."

But it wasn't enough to prevent the collision. Allen wasn't wearing a helmet, but Schroeder said the impact was so violent he might not have survived even if he had been wearing one.

Schroeder said it's possible that Allen did not see the Silverado either. Witnesses say the motorcycle audibly accelerated just before Allen entered the intersection, Schroeder said.

"I can't imagine that he would accelerate through the intersection if he had" seen the truck, Schroeder said.

Allen's motorcycle was a low-profile, chopper style, Schroeder said. A northbound truck was turning left to westbound MacArthur, he said, and that likely obscured the vision of both Allen and the Silverado driver.

The investigation into the collision continues, Schroeder said. All findings will be presented to the Sedgwick County District Attorney's Office, he said.

Allen's death is the first motorcycle fatality in the city this year, police said.

With summer weather here, more and more motorcycles will be on the streets and freeways in the metropolitan area, Schroeder said.

"Look twice," he said, because motorcycles can easily blend in with surroundings and seem invisible.

Drivers aren't used to watching for the lower profile motorcycles, he said, and that sets the stage for accidents.

Figure D.9 Wichita Eagle News Clip for Motorcycle Crash Caused by Collision in Intersection

Kansas.com
The Wichita Eagle

Posted on Thursday, Jul. 29, 2010

Minor impact leads to motorcyclist's death, police say
By STAN FINGER

WICHITA — He was simply merging onto eastbound Kellogg from Hillside shortly after noon on Wednesday.

But Nichlocs Hartness miscalculated the speed of the minivan exiting in front of him and his motorcycle clipped the back left of the van, police said.

The impact threw him from his bike and he went skidding across a freeway crowded with lunchtime traffic.

Figure D.10 Wichita Eagle News Clip for Motorcycle Crash Caused by Rear Collision with a Minivan

Posted on Tue, Aug. 17, 2010

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Motorcyclist dies after crash on K-42

0 Comments
BY RON SYLVESTER
The Wichita Eagle

WICHITA - WICHITA — A 23-year-old Wichita man died today from injuries sustained when his motorcycle helmet came off during a crash with a truck Monday afternoon.

Jonah Reed was riding his motorcycle over the Big Ditch on K-42 when he collided with a pickup changing lanes in congested traffic, Wichita police said. Reed was taken to Via Christi on St. Francis, where officials there said this afternoon he had died.

Reed's helmet came off and his head struck the bridge embankment, police said. The accident occurred just before 5 p.m.

"Right now, we have been seeing a lot of people wearing helmets and not strapping them on," said Lt. Joe Schroeder of the accident investigation unit. "If you're not using the chin strap, you might as well not be wearing it."

Schroeder said police are continuing to investigate the crash to decide whether to pursue charges against the 29-year-old man driving the truck.

Figure D.11 Wichita Eagle News Clip for Motorcycle Crash Caused by Collision with a Truck

THE TOPEKA CAPITAL-JOURNAL
cjonline.com

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Cycle deaths add to upward trend

DOCUMENT
View the 2008 Kansas Traffic Accident Facts report.

BY JAMES CARLSON
Created August 3, 2009 at 6:49am
Updated August 4, 2009 at 1:41am

Two men who died in separate motorcycle accidents Sunday in south-central Kansas are part of a growing number of motorcycle fatalities in the state, a majority of whom go down without a helmet.

In the three years from 2006 to 2008, 154 people died in motorcycle accidents, 111 of them not wearing helmets, according to statistics from the Kansas Department of Transportation. Those are roughly the same numbers for the previous five years when between 2001 and 2005, 148 motorcyclists died, 112 of them who weren't wearing helmets.

Numbers for 2009 weren't available.

Kansas Highway Patrol spokeswoman Edna Butler, a trooper on the patrol's motorcycle safety committee, said she has been lucky not to work a motorcycle fatality crash in her career. But sh said she knows the horror of that type of scene.

"It's not illegal, but anything you can do to prevent death or serious injury, we hope people do," she said.

Motorcyclists younger than 18 are required to strap on a helmet before riding in Kansas. Adults aren't required to do so.

On Sunday, two men became the latest fatality victims involved in motorcycle accidents.

At 10:15 a.m., James R. Lacey, 63, of Melvern, was driving his Honda motorcycle south on US-177 highway one mile north of Cassoday when he entered a curve, left the west side of the road and struck a sign post.

Lacey, who wasn't wearing a helmet, was pronounced dead at the scene. A passenger -- Joyce Lacey, 62 -- was taken to Wesley Medical Center in Wichita in a condition described by the highway patrol as "disabled."

Later on Sunday at 3:20 p.m., Ronald James Roeder, of Rose Hill, was riding his Harley-Davidson motorcycle northbound on Interstate 235 just north of Interstate 135 junction in Wichita when the front wheel began to wobble, KHP said.

He lost control, hit the guardrail and was thrown from the bike. Roeder, who also wasn't wearing a helmet, died at the scene.

The upward trend in motorcycle accidents runs counter to total statewide accident reports including automobiles, which have decreased from approximately 79,000 in 2001 to 66,000 in

Figure D.12 Topeka Capital-Journal News Clip for Motorcycle Fatality Trend

2 Hurt In K-7 Motorcycle Crash

Rider Was Hit By Car While Guiding Traffic

Email Print

Comments (5)

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POSTED: 9:21 am CDT August 8, 2010

BONNER SPRINGS, Kan. -- Police said two people were injured when a car hit a motorcycle on Kansas Highway 7 in Bonner Springs on Saturday.

Investigators said Amanda Huffman was a passenger on the motorcycle. They said she was directing a group of motorcyclists onto a ramp when she was hit.

The driver of the motorcycle, Earl Huffman, was also injured in the crash, investigators said.

Figure D.13 KMBC.com News Clip for Motorcycle Crash

Posted on Mon, Sep. 27, 2010

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AIM Digg it del.icio.us Facebook

Carrier had heart attack before motorcycle crash

12 Comments

BY BRENT D. WISTROM
The Wichita Eagle

WICHITA — Preliminary autopsy reports show that Public Works Director Chris Carrier had a heart attack before he crashed his motorcycle into a curb in Riverside at low speed, city spokesman Van Williams said this afternoon.

Chris Carrier's impact on Wichita visible throughout city

City public works director Chris Carrier dies in motorcycle crash

A witness who was driving near Carrier saw him veer into a curb at about 10 to 12 miles per hour Sunday afternoon.

Carrier was wearing a helmet.

The witness lifted the Victory motorcycle off Carrier. He was unconscious at the time, the witness told police.

Carrier, 62, was later pronounced dead.

Figure D.14 Wichita Eagle News Clip for Motorcycle Death

Independence Police Investigate Deadly Motorcycle Accident

News 2 months ago on Fox 4 KC Edit Share

One person was killed and two others were hurt in a motorcycle crash early Saturday evening. An 18-year-old woman was turning onto Elsea Smith Rd from 24 Highway when she failed to yield to a motorcycle. A 60-year-old man and his passenger were ejected from the bike.

Figure D.15 Fwix.com News Clip for Motorcycle Fatal Crash Caused by Failure to Yield

DeBord dies in Friday motorcycle accident

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Posted: Monday, October 4, 2010 12:25 pm | Updated: 12:28 pm, Mon Oct 4, 2010.

BURLINGAME, Kan. (AP) — A Nebraska man has died in a motorcycle accident in eastern Kansas.

The Kansas Highway Patrol reports that 53-year-old Bradley DeBord of Kearney, Neb., died in the accident south of Burlingame Friday night. The patrol said the motorcycle DeBord was driving south on U.S. 56 left the roadway and overturned.

The Topeka Capital-Journal reports that Debord was pronounced dead at the scene.

Figure D.16 KearneyHub.com News Clip for Motorcycle Fatal Crash by Overturning

Local News

Fatal Motorcycle Accident Near Kissee Mills

By: Staff
Posted: Sunday, November 21, 2010

A man from Wichita, Kansas was killed Saturday in a motorcycle accident in Taney County.

State troopers say 50-year-old Douglas Holt was westbound on U-S 160 two miles east of Kissee Mills around 3 p.m., when his 1994 Honda motorcycle crossed the center line of the roadway and overturned. The motorcycle was then struck by an eastbound Toyota pickup driven by 63-year-old Ronald Anderson of Isabella.

Holt was pronounced deceased at the scene by Taney County Assistant Coroner Lewis Chapman. Anderson was transported to Skaggs in Branson for treatment of minor injuries.

The accident marks the 98th fatality of 2010 for Troop D of the Missouri State Highway Patrol.

Figure D.17 Hometowndailynews.com News Clip for Motorcycle Fatal Crash by Overturning

Deadly Motorcycle Accident

Published: 11/22 9:58 pm

Updated: 11/22 10:08 pm

A motorcycle driver is dead after crashing into a delivery truck Monday afternoon.
It happened near first street and meridian, where witnesses say the biker may have been speeding as he headed south.
The biker T-Boned the truck after it turned left in front of him.
The biker was pronounced dead at the scene.
The driver of the truck was not hurt.

Figure D.18 Fox Kansas News Clip for Motorcycle Fatal Crash Caused by Crashing into a Truck