HELMET LAW AND OTHER FACTORS CONTRIBUTING TO MOTORCYCLE FATALITIES AT THE STATE LEVEL

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ABSTRACT

With the rapid increase in the number of motorcycle fatalities in the United States, motorcycle safety has taken the front seat in improving overall highway safety experience. In this study, motorcycle rider fatality rates were investigated while considering various factors including helmet law. This was done using generalized least squares regression modeling of rider fatality rates by utilizing data for the 50 states and Washington, DC, covering the period 2005-2007. Results revealed that in comparison with the experience under the partial coverage or no helmet law, states with mandatory helmet law had 5.13 percent fewer motorcycle fatalities per 10,000 registered motorcycles, and 7.15 percent fewer motorcycle fatalities per 100,000 populations as indicated by the models. Results also showed that motorcycle rider fatalities also had statistically significant relationships with population per square mile, motorcycles registered per population, annual daily mean temperature, per capita income, and highway mileage of rural roads etc.

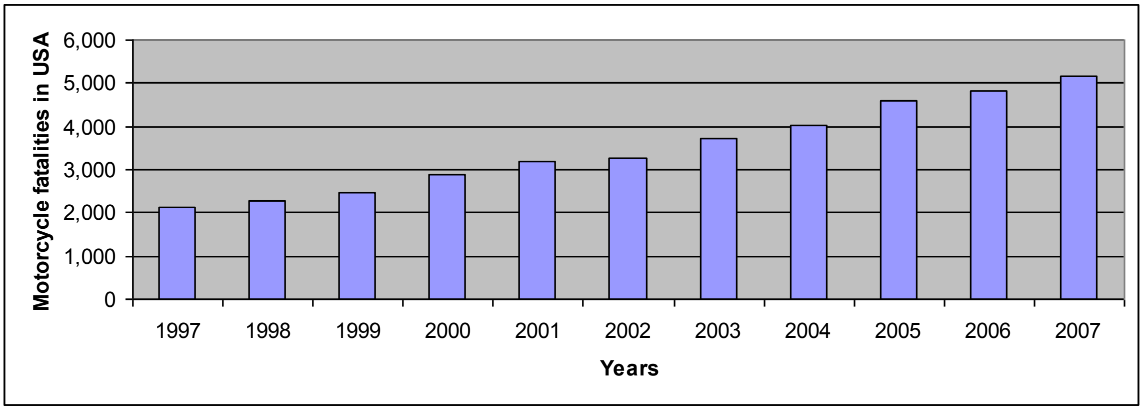
Keywords: Transportation safety, motorcycles, fatal crashes

INTRODUCTION

An estimated 142,000 motorcyclists have died in traffic crashes since the enactment of the Highway and National Traffic and Motor Vehicle Safety Act of 1966 according to the National Highway Traffic Safety Administration, 2007. The aim of this act was to reduce the traffic accidents as well as the number of deaths and injuries to persons involved in traffic accidents. Motorcycles made up of only 3 percent of all registered vehicles of 6.7 million in the Unites States for the year 2006 and had a share of only 0.4 percent of all vehicles miles traveled of 12,401 millions according to the National Highway Traffic Safety Administration, 2007. However, the motorcycle fatalities in the year 2007 consisted of 14.5% of the total fatalities in the Unites States compared to the 5.92% of the total fatalities in 1997. In the year 2007 alone, 5,154 motorcyclists were killed which was an increase of 144% in motorcycle fatalities from the year 1997 when motorcycle fatalities were 2,116

(National Highway Traffic Safety Administration, 2007). During the same period, passenger car and light truck fatality rates decreased by 26.74% and 13.54% respectively. It is evident from these statistics that, as the roadways are getting safer for other vehicles, motorcyclists are becoming the vulnerable group which needs immediate attention to improve their safety. Figure 1 shows the trend in motorcycle and non-motorcycle fatalities for the 10 year period from 1997 to 2007.

(a) Motorcycle Fatalities



(b) Other vehicle Fatalities

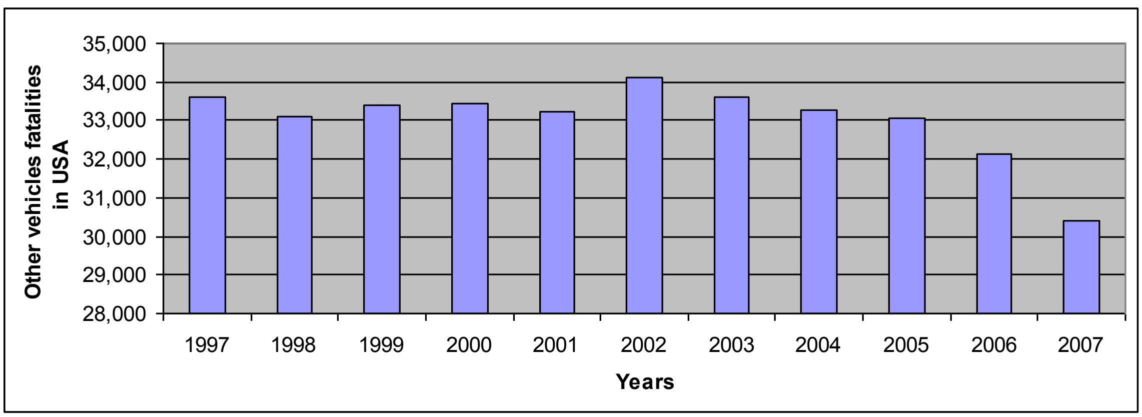


Figure 1 Motorcycle and Other Vehicle Fatalities.

Both medical and non medical literature analyzing motorcycle rider fatalities previously recommended helmet law as a means to prevent fatalities among motorcyclists in the US (*1, 2, 3*). However in non-medical literature, the use of helmet as a means to prevent deaths among motorcyclists was made less uniformly. While there is evidence that wearing a compliant motorcycle helmet reduces the likelihood and severity of severe head injury and death (*4*), several states have recently relaxed motorcycle helmet laws. By the end of the year 2007, there were 20 states having mandatory helmet law, 27 states having partial helmet law and 3 states having no helmet law at all.

Over the study period from 2005 to 2007, 20 states, DC and Puerto Rico had mandatory helmet law requiring all motorcycle riders to wear helmet irrespective of the age. However, during the study duration there were no states repealing helmet law

from mandatory law to partial law or reinstating partial law to mandatory law. From Table 1 it is obvious that states (20 states) with mandatory helmet law over the study period had lower percentage of motorcycle fatalities than states that did not have mandatory law.

Table 1 Comparison of Motorcycle Fatalities and Percent Fatalities per Year between States with Mandatory Helmet Law and Others

Year	Total Fatalities		Motorcycle fatalities			
			Number		Percentage of all Fatalities	
	Mandatory law states	Partial or no helmet law states	Mandatory law states	Partial or no law states	Mandatory law states	Partial or no law states
2005	20,030	23,526	1,711	2,842	8.54	12.08
2006	19,863	22,839	1,850	2,960	9.31	12.96
2007	19,099	21,960	1,971	2,862	10.32	13.03

It is therefore important to identify the relationship between the existing motorcycle helmet law and the motorcycle fatalities in a given state at the present condition. Thereby, this study performs regression analysis based on three years' data to establish the relationship between helmet law and motorcycle fatality rates while controlling for other factors which may have significant relationship with fatalities of motorcycle riders. Such factors include demographic characteristics, weather factors, income, highway mileage of rural roads, motorcycle registration, education levels etc.

LITERATURE REVIEW

Helmet-Use Laws and its Effectiveness

Several past studies attempted to describe the relationship between the existence of helmet laws and motorcycle rider death rates (*5,6,7*). In one of these studies, it was found that there was no statistically significant relationship between existing helmet law and the motorcycle rider fatalities using data for three years from 1994 to 1996 (*5*). Houston and Richardson (*7*) came up with a statistically significant relationship between the helmet law and the motorcycle riders' fatality rates using the state cross sectional time series data covering the 30-year period from 1975 to 2004. Morris (*6*) also performed generalized linear regression analysis to reveal that motorcycle fatalities and injuries were strongly associated with normalized heating degree days and precipitation inches. The results revealed that universal helmet laws were associated with lower motorcycle fatality rates when these climate measures were statistically controlled using 2001-2002 data.

Mandatory helmet laws have been effective in increasing the helmet use in the United States (*8*). California's helmet usage rate increased from 50% to 99% after implementing the mandatory helmet law in the state (*9*). 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 the mandatory coverage (*10*).

Sosin et.al. (*11*) 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. Similarly, Stolzenberg and D'Alessio (*12*) found no significant change in Florida's fatality rate after the repeal of mandatory helmet law.

Other Factors Related to Motorcycle Fatalities

Previous studies showed that many other factors may contribute to the motorcycle fatalities. In the case of motorcycle accidents, it was found that population density was positively related to motorcycle fatalities (*5*). Per capita alcohol consumption variable was previously used to apply for motorcycle studies (*5,7*). Motorcycle operators had the highest incidence of alcohol use among all motor vehicle drivers and fatal motorcycle crashes were more likely to involve alcohol consumption than fatal automobile crashes (*13,14,15*).

Motorcycle riding is a seasonal activity depending on the weather condition. States with higher average temperature and less precipitation are likely to have longer riding period for motorcycle riders resulting in more fatalities. In previous studies, it was found that temperature was positively correlated to motorcycle fatalities but annual precipitation was negatively correlated to motorcycle fatalities (*5,7*). But in another study by Morris (*6*), it was found that the annual precipitation was positively correlated with motorcycle fatalities but negatively correlated with the square of the annual precipitation. Normalized heating degree days were found to be positively correlated with motorcycle fatalities in the same study.

Higher level of education was considered a factor to promote the healthy behavior (*16*). Healthy behavior means compliance with the existing laws like wearing seat belts, wearing motorcycle helmets, obeying traffic rules and regulations etc. In the case of motorcycles, previous studies showed that income per capita was found to be positively correlated with motorcycle fatalities (*7*). According to Houston and Richardson (*7*), motorcycles, being expensive and luxurious, are more often used as recreational vehicles rather than a primary mode of transportation.

METHODOLOGY

Main objective of this study was to evaluate the effect of helmet law and other factors on motorcycle fatality rates. Number of motorcycle rider fatalities for all the 50 states and the District of Columbia were obtained from the NHTSA's Fatality Analysis Reporting System (FARS) for the years 2005, 2006, and 2007. A regression analysis was performed involving factors which might potentially contribute to motorcycle fatalities in a given state. Variables were chosen for regression modeling after testing the correlation among those. The dependent variables used for the modeling were the motorcycle riders' deaths per 10,000 motorcycle registrations and motorcycle riders' deaths per 100,000 populations for the three years of study period in the present study. The data sources used for different factors for modeling motorcycle fatality rates are described in the table below.

Statistical Modeling

Multiple linear regression procedure was utilized using statistical analysis software SAS version 9.1 (*17*) to identify different factors affecting response variables which were total number of motorcyclists killed per 10,000 motorcycle registrations and motorcycle fatalities per 100,000 populations in the model. The model could be expressed as follows

$$Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ...\beta_k x_k \quad (1)$$

Where,

Y = dependent variable, logarithm of motorcycle fatalities per 10,000 motorcycle registrations and per 100,000 populations;

x_1-x_k= explanatory variables representing various factors which may affect motorcycle fatality;

The generalized linear 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. As the dependent variable is transform into logarithm here, so this can be categorized in the generalized linear model also.

Independent Variables Selection for the Statistical Modeling of Motorcycle Fatalities

Once the candidate variables were selected as shown in table 2, the first step in the model building process was to develop and check the linear correlation matrix. A high correlation coefficient between the response variable and the predictor variable would result in a better prediction for the response variable. Conversely high correlation among the predictor variables implies that there is some overlapping information. Collinear independent variables were identified using the spearman's correlation coefficients

Therefore a correlation matrix was developed for the variables selected primarily using the SAS software. Independent variables that had a correlation coefficient higher than 0.5 (or 50% correlation) were removed from the variable set considered for modeling with motorcycle fatalities per 10,000 motorcycle registrations. This was executed by keeping one of the variables in the model and removing other from the model having coefficient value of 0.5 or greater. This prompted to rule 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 degree etc. A correlation coefficient of 0.65 was used for modeling with motorcycle fatalities per 100,000 populations as motorcycle fatalities per motorcycle registrations is more a direct way to measure the risk exposure compared to fatalities per 100,000 populations. The variables were checked for multicollinearity also. Sometimes one predictor variable could be correlated with more than one other predictor variables resulting in multicollinearity. Multicollinearity results in overlapping information among more than two predictors, where one predictor would explain the same variability that is explained by the other predictors. Multicollinearity could be measured by variance inflation factor (VIF). Critical value used for variation inflation factor is generally 10 and variables having

VIF above 10 are considered to be highly correlated with other predictors. All those variables that had VIF above 10 were removed from the model.

Table 2 Data Sources for all the Variables Considered in Modeling for years 2005, 2006, and 2007

Independent Variables Considered for Modeling	Source
Population per Square Mile	Statistical Abstract of U.S Census Bureau
Number of Registered Motorcycles	Annual Highway Statistics Series of FHWA
Per Capita Alcohol Consumption (gallons)	National Institute of Health
Annual Daily Mean temperature (in Fahrenheit)	National Climatic Data Center
Annual Precipitation (in inches)	National Climatic Data Center
Helmet Law	NHTSA
Percentage of Bachelor Degree	Statistical Abstract of U.S Census Bureau
Property Crime Rate	Statistical Abstract of U.S Census Bureau
Total Unemployed Percentage	Statistical Abstract of U.S Census Bureau
Per Capita Income	Statistical Abstract of U.S Census Bureau
Demographic Distribution	Statistical Abstract of U.S Census Bureau
Fuel Tax	FHWA's Highway Statistics
% of Valid License for Fatally Injured Motorcyclists	NHSTA
Number of Older Motorcycle Riders Fatally Injured	NHSTA's FARS
Highway Mileage of Rural Roads	FHWA's Highway Statistics

After ruling out inappropriate predictor variables, analysis was performed for the competing influences of the following variables on the fatality rate of motorcyclists. Table 3 describes all the variables that were taken into account for the two models after performing the collinearity tests.

The final database consisted of 153 records over a three year study period, 51 records per year. All the statistical analyses were done using the SAS software, version 9.1. The variable considered for the helmet law was a dichotomous variable. The states were classified as having mandatory helmet law or not. The value of the dichotomous variable for states having mandatory helmet law was considered as 1,

and otherwise it was 0. States having no helmet law were also included in the partial helmet law states.

Table 3 Independent Variables Selected for Motorcycle Fatalities Modeling

Variable	Max	Min	Avg
Population per square mile	9,581.3	1.2	374.7
Motorcycle registered per 1000 population	89.7	2	26.5
Per capita alcohol consumption (gallons)	4.2	1.3	2.4
Annual daily mean temperature (degree Fahrenheit)	75.7	32	53.7
Annual precipitation (inches)	69.8	8	36.3
Helmet law (universal or not)	1	0	-
Percentage of bachelor degree or more	47.5	16.5	26.9
Property crime rate per 100,000 population	4,889.8	1,619.6	3,307.2
Total unemployed percentage	7.8	2.5	4.6
Median income (in $ 1,000)	6,514.4	3,293.8	4,722.7
Percentage of African Americans	57.3	0.5	11.5
Percentage of Hispanics	44.4	0.9	9.3
Percentage of Whites	96.7	24.7	78.7
Fuel tax (in cents per gallon)	34	7.5	21.2
% of valid license for fatally injured motorcyclists	100	25	75.3
Number of older motorcycle riders killed	330	0	62.28
Highway mileage of rural roads (in 1000 miles)	221.7	0	58.3

Population per 1,000 square mile was taken as a predictor variable. The data were acquired from the U.S Census Bureau for the years 2005-2007 for all the 50 states and the District of Columbia. Number of motorcycle registered per 1000 population was considered as a predictor variable in the statistical modeling for all the states during the year 2005-2007. The data were collected for the 3 years period from the US department of Transportation, Federal Highway Administration's Annual Highway Statistics series. The influence of alcohol in the present model was represented by per capita alcohol consumption (Ethanol gallons). The data were collected from the National Institute on Alcohol Abuse and Alcoholism of the National Institute of Health. The data were collected for population aged 14 and older and were measured in gallons of ethanol (beer, wine, and spirits) (National Institute on Alcohol abuse and Alcoholism 2007). Two variables were considered for representing the weather condition in each state and the District of Columbia. These variables were annual daily mean temperature (measured in degree Fahrenheit) and the annual precipitations (measured in inches). In the present study, the percentage of bachelor degree or more from the population of each state was also considered as a predictor variable.

Some of the demographic attributes related to traffic safety were also included in the model. These attributes included: property crime rate per 100,000 populations, total unemployment percentage for each state, per capita income per $10000 for each state, percentage of African Americans, Hispanics and Whites for each state. All the data were collected form U.S Census Bureau. Another variable that was taken into account was the fuel tax in cents for each state for the years 2005-2007. Number of older motorcycle riders killed in each state for the years 2005-2007 was considered for the modeling of motorcycle fatalities. All the motorcyclists killed within the age range of 30-64 were considered as older motorcyclists. There were no data available for older motorcycle drivers only for each and every state. Highway mileage of rural roads was considered as a predictor variable in the present study

Dependent Variable Selection for the Modeling

Unfortunately, while the number of motorcycle registrations for individual state 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. But this VMT are based on travel by all motor vehicles. Separate data for motorcycle alone does not exist for all of the states. The number of motorcyclist fatalities per motorcycle registrations and per 100,000 populations was included in the present models to consider these as the dependent variables representing motorcycle fatality rates for the three years from 2005 to 2007. The logarithm of the motorcyclist death per 10,000 registered motorcycles and per 100,000 populations was taken. Counts of motorcyclist deaths were obtained from the NHTSA's Fatality Analysis Reporting System for the three years 2005, 2006 and 2007.

RESULTS, FINDINGS, AND DISCUSSION

The model developed in this study compares the motorcyclist fatality rates (log of motorcyclist fatalities per 10,000 motorcycle registrations and per 100,000 populations) under the mandatory helmet law to the experience without the law. Table 4 summarizes the result of the regression analysis of the model with motorcycle fatalities per 10,000 motorcycle registrations.

The model developed in this study compares the motorcyclist fatality rates (log of motorcyclist fatalities per 10,000 motorcycle registrations) under the mandatory helmet law to the experience without the law. The table summarizes the results of the regression analysis. In the present model, it is evident mandatory helmet law is associated with lower fatality rates. . In comparison with the experience under the partial coverage or no helmet law, states with mandatory helmet law have 5.13 percent fewer motorcycle fatalities per 10,000 motorcycle registrations under the present model. States with no helmet law were included in the partial helmet law states in the present model because the numbers of no law states are very few (only 3). The p value for the helmet law parameter estimate in the present model is 0.0722 which is statistically significant at $p<0.1$.

One of the weather considerations taken into account for the present study was annual daily mean temperature in ^{0}F. The present model shows a statistically significant positive correlation between annual daily mean temperature and the

motorcyclist death per 10,000 motorcycle registrations. This is an expected finding as motorcycle fatalities is supposed to be positively related with temperature as motorcycle riding is a highly seasonal activity. The p value for the annual daily mean temperature is found to be <0.0001.

TABLE 4 Results of Generalized Least Regression for Log of Motorcyclist 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	0.5825		

** (Statistically Significant at 95% Confidence Level)
* (Statistically Significant at 90% Confidence Level)

Both the unemployed percent and per capita income for each state were taken into consideration in the model. The per capita income for each state came out to be negatively correlated with the motorcyclist deaths per 10,000 motorcycle registrations. It was found statistically significant with a p value of 0.0136. As already discussed in the literature review, income is supposed 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.

Demographic distribution of African American, Hispanic and White population percentage were included in the model to test if there is any effect of these groups of people on the motorcycle fatality rate. In the present model only the African American population was included as the collinearity matrix showed high correlation among the other two population groups and other factors such as young drivers, per capita income. Percentage of African American was found to be positively correlated with the motorcyclist deaths per 10,000 motorcycle registrations. There were no previous researches indicating any relationship between a certain demographic group and motorcycle fatalities. The p values for the African American percentage is found to be <0.0001.

Highway Mileage of rural roads in each state was considered as a predictor variable in the current modeling. It was found to be negatively correlated with the motorcyclist deaths per 10,000 populations with a p value of 0.0677. This finding was not consistent with previous research findings on motorcycle deaths which revealed that percentage of urban roads per state is negatively correlated with the motorcyclist death rate (*5*). Normally, motorcycles are abundant in urban areas and a very few numbers of motorcycles can be found in rural areas. So, motorcycle accidents are likely to increase if there is an increase in the urban roads.

Table 5 shows the other model in which motorcycle fatalities per 100,000 populations was used as a dependent variable. It also shows that mandatory helmet law is associated with lower fatality rates. Table 5 summarizes the results of the regression analysis of the model with motorcycle fatalities per 100,000 populations as the fatality rates. However, the size of the reductions in motorcycle fatalities differs across the two models. When the per capita (per 100,000 populations) motorcycle fatalities were used, it reduced the motorcycle fatalities by 7.15 percent compared to the 5.13 percent reductions with motorcycle fatalities per 10,000 motorcycle registrations. So, when the per capita measure is being used, the mandatory helmet laws become more effective though the motorcycle fatalities per 100,000 populations is not a good variable to measure to exposure of the motorcycle riding. The p value for the helmet law was 0.0043 with a confidence level of 90 %. Results from this model also revealed that motorcyclist fatalities per 100,000 populations were related to population density, motorcycle registrations, annual daily mean temperature, percentage of bachelor degree or more, percentage of African Americans and highway mileage of rural roads with statistical significance.

ROBUSTNESS OF THE MODEL

The motorcycle fatality model with fatality per 10,000 motorcycle registrations provided a reasonably good fit with a R^2 value of 0.61. It is necessary to check the robustness of the model by verifying the two valid assumptions of multiple linear regression i.e. assumption of constant variance and normality errors. The assumption of constant variance was verified using the standardized residual plot in the figure 3, which did not show any pattern that would suggest presence of a non constant variance or non linearity. Hence it was concluded that the assumption of constant variable is valid. The other assumption is of normality error which was illustrated in the Figure 2.

Table 5 Results of Generalized Least Regression for Log of Motorcyclist Fatalities per 100,000 populations

Variables	Variable Label	Parameter Estimate	Pr>t
Intercept	Intercept	-0.13264	0.6567
Population per 1000 square mile	POPSQ	-0.0378	**0.0099****
Motorcycles registered per 1000 population	MCR	0.005935	**<.0001****
Per capita alcohol consumption	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 Law	HL	-0.07561	**0.0043****
Percentage of bachelors degree 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 in $1000's	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 license 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	0.6190		
Adjusted R^2	0.5710		

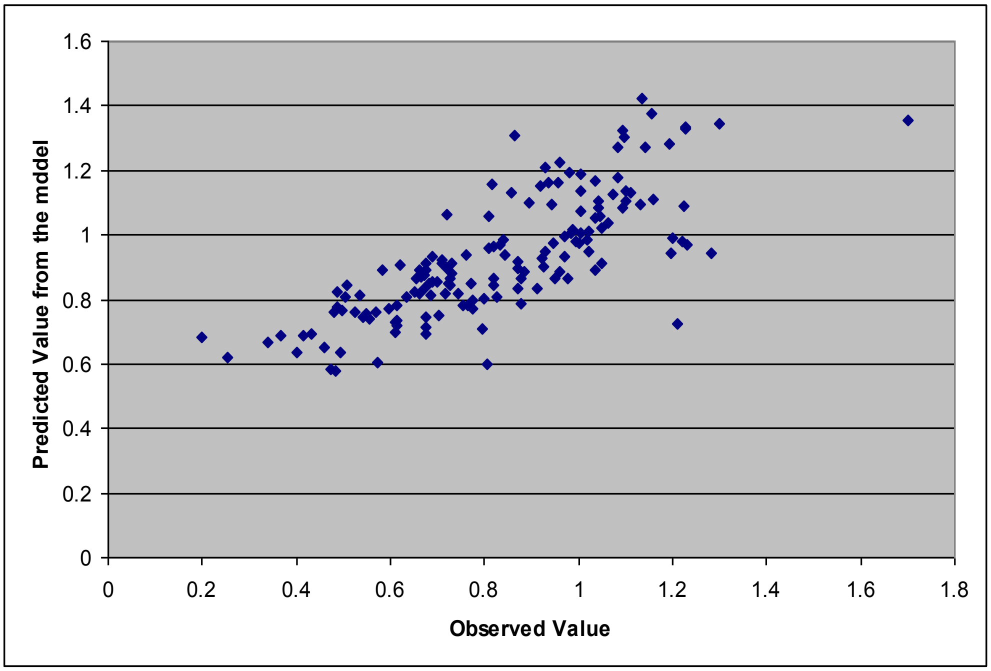


Figure 2 Predicted Vs Observed Values for the Model with Motorcycle Fatalities per 10,000 Motorcycle Registrations.

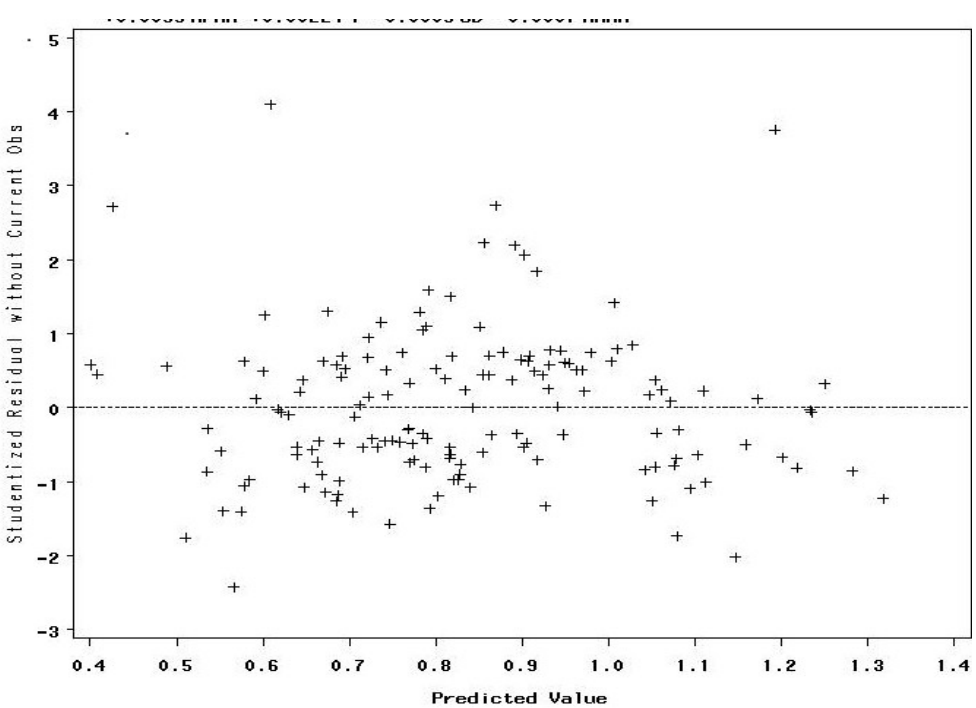


Figure 3 Standardized Residual Plots for the Model with Motorcycle Fatalities Per 10,000 Motorcycle Registrations.

CONCLUSIONS

From 1997 to 2007, motorcyclist fatalities increased almost 144% nationally, while other traffic fatalities decreased by almost 3%, clearly indicating the need for more work in this area. Accordingly this study identified some of the factors related to motorcycle fatality rates at the state level. From the regression analysis carried out in this study using data from 2005 to 2007, a statistically significant relationship was found between helmet law and motorcyclist fatalities per 10,000 registered motorcycles and per 100,000 populations. The reduction in motorcycle fatalities with mandatory helmet law was higher for per capita motorcycle fatalities than per 10,000 registered motorcycles. Motorcycle fatalities also increased with increase in annual daily mean temperature as motorcycle riding is a highly seasonal activity depending on weather condition. Motorcycle fatalities decreased with increased highway mileage of rural roads in a state. Other factors associated with motorcycle fatalities were African American population and per capita income. Motorcycle fatalities decreased with increase in per capita income for the states. The models also showed an increase in motorcycle fatalities with increase in African American populations. More research effort should be dedicated using a large dataset over a large span of time to identify various factors affecting motorcycle fatalities.

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