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Statistical Analysis of Vehicle Crashes in Mississippi Based on Crash Data from 2010 to 2014

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Abstract

Traffic crash data from 2010 to 2014 were collected by Mississippi Department of Transportation (MDOT) and extracted for the study. Three tasks were conducted in this study: (1) geographic distribution of crashes; (2) descriptive statistics of crash data; and (3) probability analysis of crash factors. Geographic Information System (GIS) was applied to show the historical crash data statewide distribution, crash distributions on primary and secondary road segments in the public road system, and crash distribution in MDOT maintenance districts. The results show a similar distribution pattern in the three crash severities in Mississippi as in other states, i.e., property damage only counts the highest, injury the second, and fatality the lowest. It also shows that large numbers of the crashes happened on specific locations and there are high crash frequencies on highway segments in Jackson metropolitan area, Hattiesburg urban area, and Gulf coastal metropolitan area. Based on the historical data and geographic distribution results, three comparison scenarios were investigated in Scenario I between US 49 and MS 25, Scenario II for statewide urban and rural areas, and Scenario III for coastal urban and hinterland urban areas. Crash data descriptive statistics for the three scenarios were initially achieved in SAS and the characteristics of differing crash frequencies and severities with the three scenarios were calculated. In order to estimate the probability of each possible causing factor to the crash severity level, the Type III analysis of variance (ANOVA) approach was adopted to assess the significance level of each crash factor, and the multinomial logit model approach with maximum likelihood estimate was applied to conduct the probability analysis and evaluate the significance of each crash factor. The strategies that may potentially decrease the crash frequencies at crash severity levels were discussed based on the probability analysis results.

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1 Project Description

Vehicle crashes are considered as one of the top 10 leading causes of deaths in the United States. According to the data from the National Highway Traffic Safety Administration (NHTSA), more than 30,000 people died from vehicle crashes every year since 1949. The numbers of people that died from vehicle crashes are 32,479, 33,782, and 32,719 for the years 2011, 2012, and 2013, respectively, while the numbers of people who were injured in these three years are 2,217, 2,362 and 2,313 thousands respectively (1). Vehicle crashes, which take a major weight of traffic safety, have been a nationwide problem in the United States.

Mississippi has been one of the states with the highest crash rates. NHTSA data show that vehicle crashes caused around 600 fatalities in Mississippi in each year of 2011 to 2013. The fatality rate per capita at around 20 fatalities per million population which is almost twice as high as the US average level, is actually among the highest in the country (1, 2). The fatality rate assessed at over 1.5 fatalities per 100 million vehicle miles travelled (VMT), is also much higher than that of the nationwide average. The current traffic safety situation in Mississippi has been of great concerns.

In 2014 the Mississippi Department of Transportation (MDOT) published the Strategic Highway Safety Plan to address the issues of vehicle crashes and to improve traffic safety in the state. However, vehicle crashes are widely distributed in geographic areas and on highway facilities. It is not economical to apply countermeasures on all components of the highway transportation system in order to reduce the crash rates. Obviously the identification of high-risk locations, highway facilities, driving behavior and/or environment, and driver populations for different types of crashes and apply proper countermeasures could significantly and cost-efficiently help improve the traffic safety in Mississippi. The objectives of this project are: (1) to characterize the geographical distributions of highway vehicle crashes in Mississippi; (2) to categorize the possible factors for the vehicle crashes in Mississippi; and (3) to evaluate the effects of the factors using statistical analyses and regressions.

Table 1 lists the numbers of fatalities caused by vehicle crashes and the related traffic and population data for the US and Mississippi in 2011, 2012, and 2013 (1). The "Fatalities per 100,000 Drivers", "Fatalities per 100,000 Registered Vehicles", and "Fatalities per 100,000 Population" of Mississippi almost more than doubled the national averages in the three years, which well indicated the critical situation of traffic safety in the state.

Table 1 Traffic Crash Data for MS vs. US

Data Item	2011		2012		2013	
	US	MS	US	MS	US	MS
Licensed Drivers (thousand)	211,875	1,927	211,815	1,958	212,160	1,969
Fatalities per 100,000 Drivers	15.28	32.70	15.84	29.72	15.42	31.13
Registered Vehicles (thousand)	257,512	2,037	265,647	2,052	269,294	2,074
Fatalities per 100,000 Registered Vehicles	12.57	30.94	12.63	28.36	12.15	29.56
Population (thousand)	311,592	2,979	313,914	2,985	316,129	2,991
Fatalities per 100,000 Population	10.39	21.15	10.69	19.50	10.35	20.49
Vehicle Miles Travelled (million)	2,946,131	38,851	2,968,815	38,667	2,988,280	38,758
Fatalities per 100,000,000 Vehicle Miles Travelled	1.10	1.62	1.13	1.51	1.10	1.58
Total Killed	32,367	630	33,561	582	32,719	613

The average trip distance calculated by dividing the total VMT by the total number of licensed drivers in Table 1, is higher in Mississippi than the US average (20.2 vs. 13.9 thousand vehicle miles per driver, respectively). Therefore, drivers in Mississippi face more risks of crash because they tend to drive 45.3% more distances than average US drivers. According to the 2013 American Community Survey from the US. Census Bureau, an estimated 19% of the US population lived in rural areas, but the rural crash deaths accounted for 54.1% of all traffic fatalities. Actually, the fatality rate per 100 million VMT in rural areas is 2.6 times higher than that in urban areas (1.88 and 0.73, respectively). In 2010, the percentage of urban population in Mississippi is 49.4%, which is much lower than 80.7%, the US average level. These numbers imply that Mississippi rural areas have high crash risks (1, 2).

In addition, the Jackson metropolitan area and Mississippi coastal area are areas that draw most attention on the vehicle crashes because these areas have large population densities and high frequencies of vehicle crashes. Based on 2010 census estimates, the populations of Jackson metropolitan area and Mississippi coastal area are 491,877 and 379,007 respectively (3). Considering the state population of 3 million in 82 counties, more than 870,000 people residing in 6 counties means a great difference in population densities. It has been of great interests to characterize the crash frequency and severity of vehicle crashes for different areas in Mississippi to better understand the vehicle crashes in Mississippi.

For statistical modelling approaches, in the past decades, researchers have applied numerous statistical models to identify crash causal factors and factors contributing to crash severities including generalized linear models (GLM), probability distribution models, and time series models, etc. (2). Logistic regression model as a generalized linear model describes the relationship between explanatory variables and a discrete response variable. The explanatory variables can be either categorical or numerical, or a mixture of both. A logistic regression model is generally applied to handle categorical variables. In this modelling approach, maximum likelihood method is applied to estimate the coefficient vector. For goodness of fit test, researchers usually use Pearson chi-squared statistic, likelihood-ratio, pseudo-R-square, and the Hosmer-Lemeshow statistic which is a Pearson-like statistic without a chi-squared distribution. Multinomial logit model as a logistic regression model has been widely used and a lot of work has been conducted on the crash severities with research focus on statistic model choice and characteristics of explanatory variables.

Since the Markov switching multinomial logit model was studied and applied to accident injury severities by Malyshkina and Mannering in early time (4, 5), it has been widely used for the crash causal factors identification to find the probability of a random variable indicating the choice made. The model involves choice specific coefficients and only individual specific regressors (6, 7, 8, 9, 10) and maximum likelihood method is used to find the value of one or more parameters for a given statistic which makes the known likelihood distribution a maximum (6). In addition to the multinomial logit model, the ordered probit model and mixed logit model are also generally applied to accident injury severities (7, 11). But for different crash data sample sizes, the three models have different evaluation performances. For example, when a small sample size is below 500, all the three models perform poorly with outcomes of very high values of mean of absolute-percentage-bias, max of absolute-percentage-bias, and total root-mean-square-error. As a medium sample size is at 2000 observations even increases to high sample size at 20000 observations, both of multinomial logit model and ordered probit model show the better performances by the lower mean of absolute-percentage-bias, max of absolute-percentage-bias, and total root-mean-square-error (8). Therefore the multinomial logit model was selected in this study because we have a medium to high sample size of crash observations.

To achieve the crash severity analysis using the multinomial logit model, the selection of explanatory variables, namely potential causal factors would be another research focus. Pavement characteristics such as rut depth, roughness index, and pavement condition rating (7, 12, 13, 14), and surface friction conditions such as dry, wet, or snow/ice surface (15) are always considered as road explanatory factors. Weather conditions such as rain, snow, visibility, light condition, and wind speed (11, 16, 17) are considered as weather explanatory factors. In addition, traffic conditions such as annual average daily traffic (AADT) and speed limit (12, 17), as well as geometric conditions such as number of lanes, and divided or undivided median type (18) are frequently considered as explanatory factors in the crash severity analysis.

In this study, considering the historical crash patterns in Mississippi, the geographic distributions of vehicle crashes will be characterized using the Mississippi crash data of 2010-2014. While the rural characteristics are given emphasis, other relevant characteristics in Mississippi are investigated to understand the possible causal factors for crash frequencies and severities in Mississippi. Statistical modeling and tests are used as the analytical tools to numerically evaluate these effects and relationships.

The remainder of this project is organized as follows: In Section 2 studying tools and mathematics statistical models are introduced, and the Analysis of Variance (ANOVA) and the Multinomial Logit Model (MNL) are introduced to analyze the possible factors and variables related to the crashes. Section 3 presents the crash distribution and factor categorization analysis results. The ANOVA and MNL models are applied to the historical crash data collected to identify possible factors and variables related to crashes. In Section 4 possible implementations of the research results are discussed. Finally findings and conclusions are summarized in Section 5.

2 Methodological Approach

2.1 Studying Tools

Considering study tools, the ArcGIS spatial analyst extension is a tool to present the geographic distribution of data (19) and SAS is a tool to analyze the factor probabilities for the dependent variable and explanatory variables (20). The Geographic Information System (GIS) has been widely applied for road networks, such as graphical visualization of traffic condition, climate change impact on road network, and flood risk analysis for road network in the coastal areas of Mississippi (21, 22, 23, 24). SAS is an analytics software, which helps assess, manage, analyze and report on data to aid in decision-making (20, 25,26). It is practical to classify and execute the mathematics statistical models in terms of simple criteria, such as the presence of random effects, the presence of nonlinearity, characteristics of the data, and the magnitude of data sizes. The relatively large size of crash data with more than 600,000 lines of crash entries for Mississippi in 2010-2014 has literally required the use of statistical software with performance of computation speed and capacity. Therefore ArcGIS and SAS will be applied to analyze the geographic distribution characteristics and the effects of causal factors of vehicle crashes in Mississippi.

2.2 Mathematics Statistical Models

2.2.1 Analysis of Variance (ANOVA) Model

To statistically test the effects of factors, the analysis of variance (ANOVA) or sum of squares (SS) is frequently employed. In the last section, we have targeted several possible factors for crash severity. For ease of presentation a two-way ANOVA model is used. A two-way ANOVA can test several sample means for two different effects, for example the "Speed Limit" and "Light Condition" effects. The linear model for a two-way ANOVA is shown in Equation (1),

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \varepsilon_{ijk} \quad \begin{cases} i = 1,2,\cdots,a \\ j = 1,2,\cdots,b \\ k = 1,2,\cdots,n \end{cases} \qquad (1)$$

Where y_{ijk} is the response of interest (say probability of crash severity or a variate) for the *i*-th level of factor *A*, say "Speed Limit", the *j*-th level of factor *B*, say "Light Condition", and the *k*-th replicate in the test scenario. μ is the overall mean, τ_i is the effect of the *i*-th level of factor *A*, β_j is the effect of the *j*-th level of factor *B*, $(\tau\beta)_{ij}$ is the effect of the interaction between τ_i and β_j, and ε_{ijk} is a random error component. The objective of the two-way ANOVA is to test two null hypotheses of equality of all treatments in each effect, i.e., $H0_1: \tau_1 = \tau_2 = \cdots = \tau_a = 0$, and $H0_2$: $\beta_1 = \beta_2 = \cdots = \beta_b = 0$. The variability in data due to the treatment under each test effect is compared to the variability due to random errors and the resulting ratio is an *F*-value for that test effect. The *F*-value is then compared to a standard critical table value in the *F*-distribution to check the significance of that test effect. A *P*-value could be given to show how likely the specific H0 is true in the case of the computed *F*-value. A large *F*-value and a small *P*-value can normally lead to a rejection of the null hypothesis H0.

2.2.2 Type III Effect Analysis

There are four types of test models in SAS to analyze various factor effects, Type I, Type II, Type III, or Type IV (33). The model in Equation (1) shows a balanced dataset with the parameters a, b, and n specified. The Type III SS model is adopted in this study because the crash dataset is unbalanced and the interactions between different factors are considered in the test. The Type III model is actually a multi-way analysis of variance and covariance.

2.2.3 Multinomial Logit Model

In this study, a multinomial logit model (MNL) approach is employed to explore the potential unobserved heterogeneous effects associated with each categorical group and log-likelihood function is applied to estimate the multinomial discrete choice model for given outcomes. Multinomial logit model is defined as the following formula when explanatory variables contain only individual characteristics (34, 35).

$$P(Y_i = j) = P_{ij} = \frac{e^{(X_i \cdot \lambda_j)}}{1 + \sum_{k=0}^{J-2} e^{(X_i \cdot \lambda_k)}}, \quad \forall \ j = 0, \ldots, (J-1) \tag{2}$$

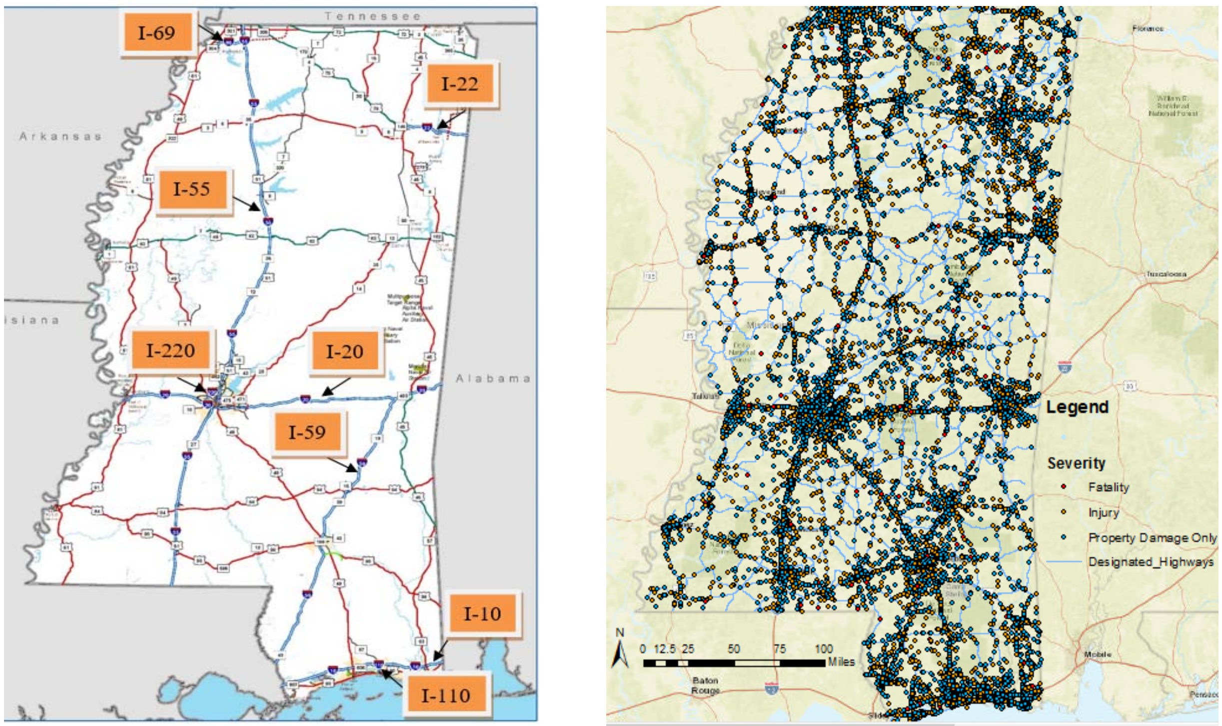
Where parameter *i* stands for the individual crash record *i* and Y is a random variable that indicates the choice made out of the *J* outcomes. Symbol X_i is a row vector of characteristics for the explanatory variables specific to the individual crash record *i*. Parameter *j* stands for the discrete outcome *j*, namely, crash severity category. Symbol λ_j is a column vector of estimable parameters specific to the alternative *j*, and $\lambda_{J-1} = 0$. The $P(Y_i = j) = P_{ij}$ stands for the probability of having the discrete outcome *j* based on the individual crash record *i*. The maximum likelihood function of the multinomial logit model is calculated by Equation (3).

$$LL = \sum_{i=0}^{N-1} \sum_{j=0}^{J-1} \delta_{ij} \ln(P_{ij}) \tag{3}$$

Where *N* is the total number of individuals and *J* is the total number of outcomes, δ_{ij} is defined as being equal to 1 if individual i chooses alternative outcome j . The coefficient vector λ_j can be estimated based on the multinomial logit regression with the dataset of *N* records to optimize the maximum likelihood.

3 Results/Findings

3.1 Crash Statewide Distribution



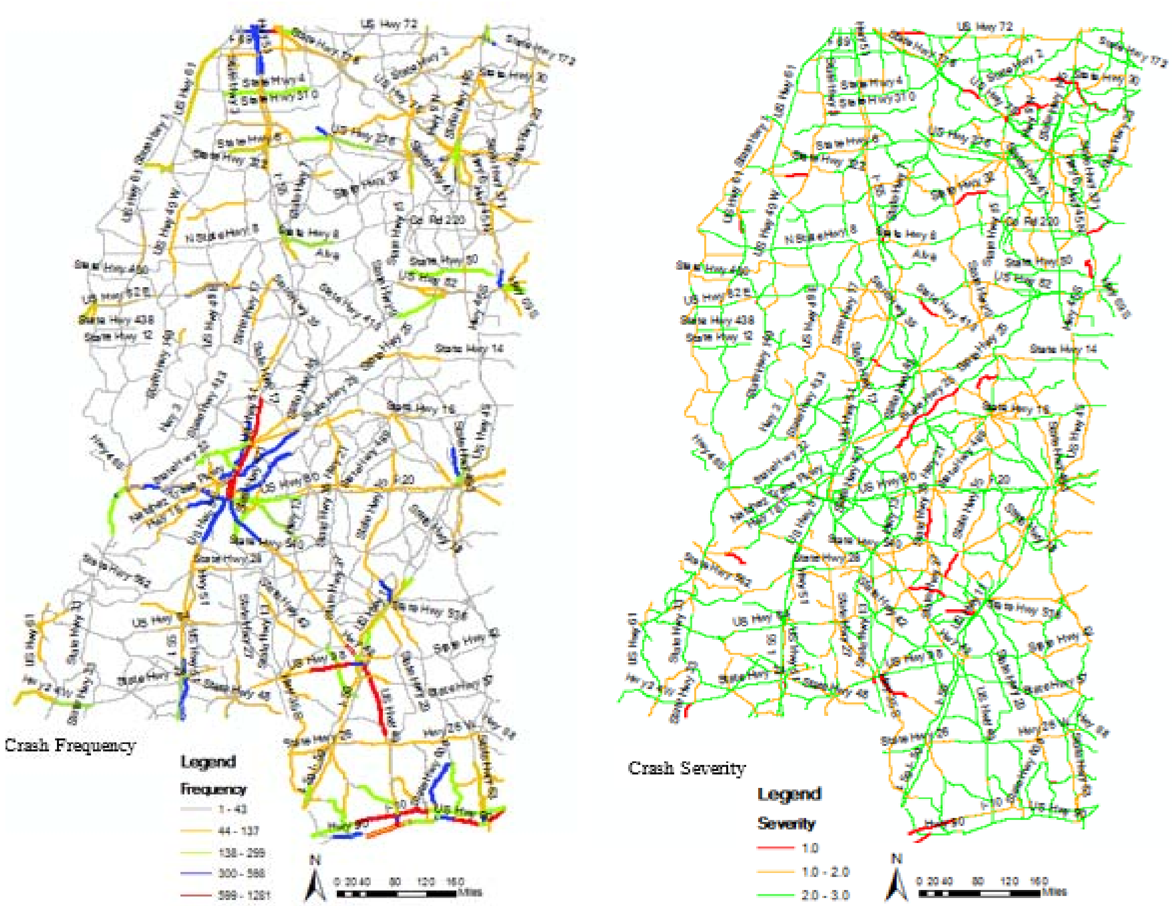
(a) Map of highways (b) Crash distribution

Figure 1 Geographic distribution of crashes in Mississippi

Geographic distributions of vehicle crashes are assessed and visualized using the spatial analysis tools in GIS (25). These include the statewide distribution, the distribution in statewide road system, and the distribution in MDOT maintenance districts of the vehicle crashes. Figure 1 (a) and (b) show the map of major highways and crash distribution in Mississippi. The dot density and color in Figure 1 (b) represent crash frequency and severity respectively. There are three crash severity levels: property damage only, injury, and fatality. Figure 1(b) shows that crashes are more often and severe along major highways and in metropolitan areas such as Jackson at I-55 and I-20, Biloxi at I-10 and US-49, Hattiesburg at I-59 and US-49, and Tennessee border at I-55 and I-69. The distribution also shows that among the three severity levels, the frequency of property damage only is the highest, and that of fatality is the lowest.

3.2 Crash Distribution in Public Road System

Crash distribution on the primary and secondary highway segments in statewide public road system is presented in Figure 2: (a) for crash frequency, and (b) for crash severity.



(a) Crash frequency distribution (b) Crash severity distribution

Figure 2 Crash distribution on highways in Mississippi

As shown in Figure 2(a), the following information is observed: (1) Most frequent crashes have happened on highway corridors including I-10, US-90, US-49, US-98, US-51, US-45, MS-25, I-20, MS 198, and MS 302; (2) The high crash frequencies are generally associated with metropolitan areas. For example, segments on US-49, US-51, and MS-302 near Tennessee border and Memphis Metro area; segments of US-51, US-49 and MS-25 at the Jackson Metro area; segments of US-98, US-49 and MS-198 in the Hattiesburg urban area; and segments of I-10, I-110, and US-90 at the Gulf coast area (Biloxi-Gulfport-Pascagoula Metro area).

As recorded in the crash dataset collected, the three levels of crash severity are defined by MDOT, namely, level 1 (high) for fatality, level 2 (medium) for injury, and level 3 (low) for property damage only. As shown in Figure 2 (b), the following information is observed: (1) The most fatal crashes have happened on I-10, US-90, MS-25, and sporadic highway segments and points in rural areas; (2) High crash severity does not seem to be correlated to high population density in metropolitan areas. For example, highway segments with high crash frequencies in Figure 2 (a) have low crash severities while highway segments with low crash frequencies in Figure 2 (a) tend to have more fatal crashes.

3.3 Crash Distribution in Maintenance Districts

According to MDOT, there are six maintenance districts in Mississippi (27, 28). Crash frequency and average crash severity in each district are presented in Figure 3. Based on the lowest crash frequency in District 3 with a total number of 4217 crashes, the base crash frequency increases by 6.92% in District 7, 130.33% in District 1, 141.71% in District 2, 300.85% in District 5, and 373.96% in District 6, respectively. The top three districts with the highest crash frequencies are: District 6 (Biloxi-Gulfport-Pascagoula Metro area), District 5 (Jackson Metro area), and District 2 (Memphis Metro area). There are quite mild differences (lower than 4%) of average crash severities among the districts. The top three districts with the most severe crashes are: Districts 7, 3, and 2. Although District 2 has a major metropolitan area, Districts 7 and 3 with the most severe crashes are typically rural areas.

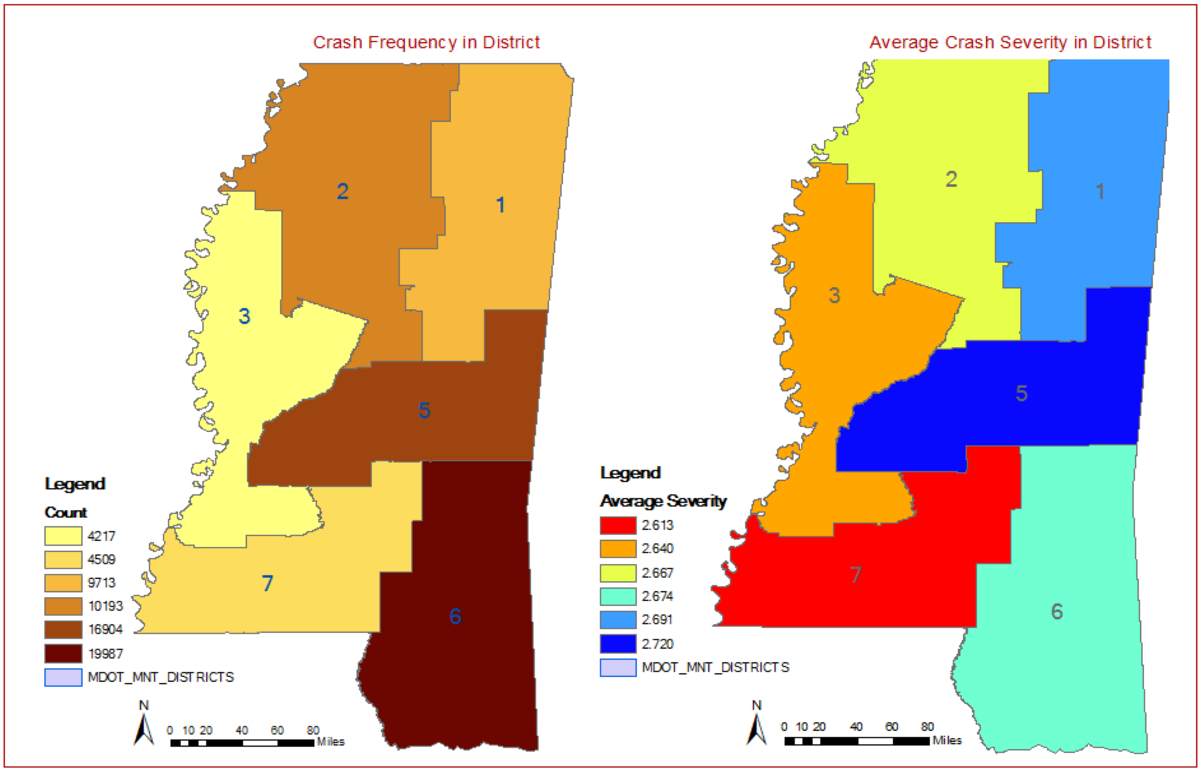


Figure 3 Crash distribution in MDOT maintenance districts

3.4 Factor Categorization of Crashes

With the differing crash distributions of frequency and severity, crash causal factors are further researched with features of targeted highways, urban/rural areas, and coastal/hinterland areas. The top seven crash-prone highway locations and numbers of crashes during 2010-2014 are: 1) US-98/Hardy Street, Hattiesburg, 7649; 2) MS-25/ Lakeland Drive, Jackson, 7229; 3) MS-302/ Goodman Road, Memphis, 6909; 4) US-90/ Bienville Blvd, Biloxi, 4209; 5) US-45, Meridian, 2287; 6) US-49, Hattiesburg, 2192; and 7) US-51, Jackson, 1552.

MS-25/Lakeland Drive in Jackson Metro area and US-49 in Hattiesburg urban area are selected for factor investigation. MS-25 and US-49 are selected not only because of the high numbers of crashes but also for their important geographical characteristic and heavy traffic loads. Also of significance and research interest is the fact that the highway segments on MS-25 in Jackson Metro area and US-49 in Hattiesburg urban area both have records of severe crashes. MS-25 is a 150 miles

(240 km) of continuous four-lane divided highway between Starkville, MS and Jackson, MS. There are thirteen cities on the route MS-25 from south to north in Mississippi (29). It runs through both urban and rural areas. It is always loaded with heavy traffic volumes in Jackson Metro area. MS-25, renamed as Lakeland Drive as an urban principal arterial, has an AADT of 47,000 to 58,000 vehicles (29). US-49 is a north–south US highway passing through ten rural counties and seventeen cities in Mississippi. US-98/Hardy St. has the highest number of crashes and is actually at the intersection with US-49. US 49 as an urban principal arterial from Pass Rd to Arkansas Ave, the AADT is 42,635 vehicles (30, 31).

Table 2 lists the definitions and descriptive statistics regarding the possible explanatory variables related to the severity of crashes for US-49 and MS-25. In the crash severity descriptive outcomes, the total number of crashes of US-49 is 2,192 in the four years, and 7,229 for MS-25. From the data descriptive statistics in the two tables, the following information could be initially obtained:

(1) In the data analysis for crash factor categorization, the response variable is crash severity, while the explanatory variables are determined by the reviews of past researches and data availability. There are totally nine explanatory variables for crashes on US-49 and MS-25. The nine explanatory variables are: AADT, Location, Median Type, Number of Lanes, Speed Limit, Surface Condition, Surface Type, Weather, and Light Condition.

(2) In reviewing the crash severity categories, the percentages of property damage only, injury, and fatality crashes for US-49 and MS-25 are 67.20%, 32.30%, 0.50% and 77.51%, 22.47%, 0.03% respectively. The descriptive statistics for the explanatory variables indicate that the crashes on the two crash-prone highway locations most likely happened in the following conditions: 1) with AADT of more than 10,000 vehicles, 2) at an intersection, 3) on a divided highway, 4) with multiple lanes, 5) with 30 mph or higher speed limit, 6) on dry road surface, 7) on asphalt pavement, 8) in a clear or cloudy day, and 9) with daylight.

Table 2 Definitions and Descriptive Statistics of Variables for Crash-prone Highways

Variables	Category		Number of Crashes			
	Value	Description	US-49	Percent (%)	MS-25	Percen t (%)
Crashes from 2010 to 2014			2192	-	7229	-
Response Variable						
Crash Severity	0	Property Damage Only	1473	67.20	5603	77.51
	1	Injury	708	32.30	1624	22.47
	2	Fatality	11	0.50	2	0.03
Explanatory Variables						
AADT	0	≤ 2500 veh/day	288	13.14	176	2.43
	1	>2500 and ≤ 10,000 veh/day	84	3.83	0	0.00
	2	>10,000 and ≤ 25,000 veh/day	913	41.65	111	1.54
	3	>25,000 veh/day	907	41.38	6942	96.03
Location	0	Intersection/Concurrent intersection	1339	61.09	5866	81.15
	1	Route/Concurrent route	853	38.91	1363	18.85
Median Type	0	Divided	2105	96.03	7229	100.00
	1	Undivided	87	3.97	0	0.00
Number of Lanes	0	1 lane	264	12.04	176	2.43
	1	2-3 lanes	684	31.20	2391	33.08
	2	4 lanes and above	1244	56.75	4662	64.49
Speed Limit	0	<=30 mph	331	15.10	286	3.96
	1	>30 mph and <60 mph	1617	73.77	6918	95.70
	2	>= 60 mph	244	11.13	25	0.35
Surface Condition	0	Wet	344	15.69	1133	15.67
	1	Dry	1829	83.44	6045	83.62
	2	Other	19	0.87	51	0.71
Surface Type	0	Asphalt	1746	79.65	4699	65.00
	1	Concrete	440	20.07	2522	34.89
	2	Other	6	0.27	8	0.11
Weather	0	Clear	1450	66.15	5483	75.85
	1	Rain	240	10.95	788	10.90
	2	Cloudy	489	22.31	932	12.89
	3	Other	13	0.59	26	0.36
Light Condition	0	Daylight	1738	79.29	5988	82.83
	1	Dark lighted	290	13.23	932	12.89
	2	Dark unlighted	127	5.79	110	1.52
	3	Dusk/Dawn	37	1.69	199	2.75

3.5 Descriptive Statistics of Crash Outcomes

Two comparison scenarios are researched to understand the crash factors. One scenario (Scenario I) of the crash causal factor categorization is conducted for statewide urban and statewide rural areas (32), respectively. The other scenario (Scenario II) of the crash causal factor categorization is conducted for coastal urban (Biloxi-Gulfport-Pascagoula Metro area) and hinterland urban areas (Jackson Metro area).

Table 3 and Table 4 list the descriptive statistics of number of crashes for each level of the identified causal factor variables (or categories) and the crash percentages associated with the three crash severities (property damage only or PDO, Injury, and Fatality) under the category level for the research scenario of Rural/Urban and scenario of Coast/Hinterland, respectively. It should be noted that variables "AADT" and "Median Type" are not included in the results in Tables 3 and 4 due to unavailability of data.

As shown in Table 3, the severity percentages in "Injury" and "Fatality" columns under "Rural" are almost all greater than the corresponding values under "Urban", indicating the crashes in rural areas are more severe or fatal than the crashes in urban areas. Similarly the data in Table 4 shows that compared with the hinterland Jackson Metro area, crashes in the Mississippi Gulf coastal area are significantly more severe or damaging. Possible reasons for the high crash severities in the rural areas could be speeding, run-off, and driving in poor lighting condition. Possible reasons for the high crash severities in the coastal area could be speeding, driving in poor lighting condition, and vulnerability to extreme weather conditions and flooding. The intermodal transports to and from the seaport at the Mississippi coastal area may have increased the volumes of heavy trucks in the traffic stream composition which may have contributed to the increased damaging effect of a crash in the area.

Table 3 Descriptive Statistics of Crash Outcomes and Variables in Comparison Scenario I

Variable	Value	Urban (254,732 crashes)				Rural (248,648 crashes)			
		No. of Crashes	Severity (%)			No. of Crashes	Severity (%)		
			PDO	Injury	Fatality		PDO	Injury	Fatality
Location	0	157184	70.50	29.18	0.32	140287	67.51	31.93	0.56
	1	97548	69.88	29.21	0.92	108361	66.50	31.89	1.60
Number of Lanes	0	21889	85.16	14.66	0.17	22598	83.68	16.06	0.26
	1	124104	68.37	31.04	0.58	153444	64.67	34.21	1.12
	2	108739	69.42	30.00	0.58	72606	66.97	32.00	1.03
Speed Limit	0	62132	78.37	21.41	0.22	72010	77.54	22.21	0.26
	1	163223	68.25	31.28	0.47	150642	62.88	35.99	1.13
	2	29377	64.30	34.01	1.68	25996	62.35	35.16	2.49
Surface Condition	0	39589	69.55	30.13	0.32	40668	67.15	32.14	0.72
	1	213133	70.40	29.01	0.59	204842	67.05	31.88	1.07
	2	2010	70.25	29.60	0.15	3138	67.40	31.45	1.15
Surface Type	0	237253	70.13	29.34	0.53	233342	66.88	32.14	0.98
	1	16059	72.48	26.81	0.72	11513	71.84	26.59	1.57
	2	1420	67.96	30.77	1.27	3793	64.49	34.06	1.45
Weather	0	195674	70.28	29.14	0.57	188959	66.89	32.06	1.05
	1	29059	69.84	29.91	0.24	29925	68.05	31.15	0.80
	2	28401	70.97	28.39	0.64	27740	67.48	31.60	0.92
	3	1598	62.77	36.23	1.00	2024	63.59	33.99	2.42
Light Condition	0	195826	71.71	27.91	0.39	189946	68.40	30.83	0.77
	1	33334	67.31	32.16	0.53	23229	67.37	32.12	0.51
	2	20262	61.89	36.09	2.02	30554	59.29	37.85	2.86
	3	5310	67.36	31.60	1.04	4919	62.76	35.88	1.36

Table 4 Descriptive Statistics of Crash Outcomes and Variables in Comparison Scenario II

Variable	Value	Coastal (85,738 crashes)				Hinterland (127,938 crashes)			
		No. of Crashes	Severity (%)			No. of Crashes	Severity (%)		
			PDO	Injury	Fatality		PDO	Injury	Fatality
Location	0	52974	65.56	34.03	0.41	83755	74.44	25.40	0.16
	1	32764	66.18	33.01	0.81	44183	72.91	26.49	0.60
Number of Lanes	0	4752	79.80	20.03	0.17	12144	85.02	14.82	0.16
	1	44207	65.20	34.26	0.54	58558	72.70	26.97	0.33
	2	36779	64.70	34.65	0.65	57236	72.79	26.88	0.32
Speed Limit	0	24285	71.95	27.70	0.35	27557	82.23	17.66	0.11
	1	52772	63.34	36.18	0.48	85672	72.23	27.49	0.28
	2	8681	63.47	34.82	1.70	14709	68.12	31.02	0.86
Surface Condition	0	13769	65.26	34.38	0.36	19386	73.38	26.45	0.18
	1	71329	65.91	33.48	0.61	107627	73.99	25.68	0.34
	2	640	63.91	36.09	0.00	925	76.54	23.46	0.00
Surface Type	0	81074	65.91	33.55	0.54	117657	73.78	25.91	0.30
	1	4047	63.83	35.33	0.84	9862	75.32	24.27	0.41
	2	617	63.37	35.01	1.62	419	76.85	22.67	0.48
Weather	0	65814	65.98	33.44	0.58	100313	73.77	25.89	0.33
	1	9701	65.34	34.43	0.23	14370	73.47	26.40	0.14
	2	9477	65.69	33.48	0.83	12573	75.61	24.04	0.34
	3	746	56.70	43.03	0.27	682	72.29	27.27	0.44
Light Condition	0	65608	67.72	31.95	0.34	99983	75.12	24.63	0.25
	1	11311	59.41	39.78	0.80	17844	70.39	29.30	0.31
	2	6880	58.82	38.92	2.25	7495	66.99	31.86	1.15
	3	1939	62.66	36.46	0.88	2616	71.60	27.94	0.46

The above descriptive statistics of the characteristics of crash-prone highway locations and crash causal factor scenarios for rural/urban areas and coast/hinterland areas initially analyzed the factors that possibly impact the crash frequencies and severities in Mississippi. The statistical analyses of the probabilities of the crash severities due to these causal factors (categories) or explanatory variables are conducted using rigorous statistical models to test the significance of the factors and quantify the relationships.

3.6 Analysis of Crash Factors

The Type III analysis results of tests of the effects of the aforementioned explanatory variables are presented in Table 5.

Table 5 Type III Analysis Results of Effects

Factors	P-values					
	Crash-prone Highways		Comparison Scenario I		Comparison Scenario II	
	US 49	MS 25	Statewide Urban	Statewide Rural	Coastal Urban	Hinterland Urban
AADT	0.000*	0.007*	-	-	-	-
Location	0.022*	0.044*	0.000*	0.000*	0.002*	0.000*
Median Type	0.815	-	-	-	-	-
Number of Lanes	0.011*	0.055	0.000*	0.000*	0.000*	0.000*
Speed Limit	0.002*	0.037*	0.000*	0.000*	0.000*	0.000*
Surface Condition	0.734	0.076	0.000*	0.000*	0.216	0.003*
Surface Type	0.010*	0.035*	0.000*	0.000*	0.000*	0.012*
Weather	0.336	0.032*	0.000*	0.000*	0.000*	0.000*
Light Condition	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

– Indicates that the coefficient is statistically insignificant; * Indicates level of significance > 95%.

The results in Table 5 indicate the effects of significance of the explanatory variables in the selected crash-prone highways and for the two comparison scenarios. For the two selected highways US-49 and MS-25, the explanatory variables of AADT, Location, Speed Limit, Surface Type, and Light Condition are all significant with respect to the dependent variable Crash Severity by the small P-values (≤ 0.05) at the 95% confidence. While the Weather factor is only significant to MS 25. For the statewide urban area and rural area in Scenario I, all the explanatory variables are highly significant. In Scenario II, all the explanatory variables are significant except that the Surface Condition factor is insignificant to the coastal urban area.

The multinomial logit regression analysis results to quantify the relationships of the response variable of crash severity and the explanatory variables. The estimated coefficients λ_j obtained from the regressions are shown as Tables 6, 7, and 8 for the selected highways, comparison scenario I, and comparison scenario II, respectively.

Table 6 MNL Regression Analysis Results for Crash-prone Highways

Variable	Category Value	US-49				MS-25			
		Severity Value				Severity Value			
		0		1		0		1	
		Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Intercept		16.572	NA	11.907	NA	21.128	NA	25.968	NA
AADT	0	10.830	0.005	11.336	0.006	5.915	0.007	5.698	0.006
	1	0.277	0.000	0.186	0.000	-	-	-	-
	2	-4.599	0.007	-4.401	0.006	-3.780	0.002	-3.512	0.003
Location	0	2.259	0.010	2.309	0.008	-2.387	0.026	-2.319	0.024
Number of Lanes	0	0.206	0.000	-1.310	0.000	-0.879	0.372	-0.851	0.350
	1	0.812	0.000	1.578	0.001	-	-	-	-
Speed Limit	0	2.431	0.160	2.402	0.166	3.992	0.000	4.538	0.001
	1	2.827	0.005	3.054	0.004	-2.014	0.000	-1.646	0.000
Surface Condition	0	-1.061	0.000	-1.343	0.000	-1.848	0.001	-1.464	0.000
	1	-0.551	0.000	-0.778	0.000	-2.767	0.002	-2.457	0.001
Surface Type	0	-2.320	0.000	1.323	0.000	-2.076	0.000	-2.583	0.000
	1	-7.787	0.003	-3.838	0.001	4.257	0.000	3.886	0.000
Weather	0	-3.858	0.001	-3.38	0.001	-4.702	0.008	-4.663	0.007
	1	-3.544	0.001	-3.165	0.001	1.223	0.001	0.821	0.000
	2	3.405	0.001	3.662	0.001	1.845	0.002	1.803	0.002
Light Condition	0	2.898	0.000	2.358	0.000	2.233	0.001	1.864	0.000
	1	-5.778	0.001	-6.184	0.001	2.582	0.000	2.731	0.001
	2	-3.249	0.000	-3.228	0.000	3.706	0.000	3.814	0.000

– Indicates that the coefficient is statistically insignificant.

Table 7 MNL Regression Analysis Results for Comparison Scenario I

Variable	Category Value	Statewide Urban				Statewide Rural			
		Severity Value				Severity Value			
		0		1		0		1	
		Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Intercept		5.074	NA	4.274	NA	4.371	NA	3.605	NA
Location	0	0.355	0.000	0.349	0.000	0.348	0.000	0.371	0.000
Number of Lanes	0	0.653	0.000	0.157	0.176	0.600	0.000	0.129	0.184
	1	-0.691	0.000	-0.358	0.000	-0.824	0.000	-0.471	0.000
Speed Limit	0	1.004	0.000	0.657	0.000	1.327	0.000	0.885	0.000
	1	0.137	0.001	0.214	0.000	-0.084	0.021	0.071	0.053
Surface Condition	0	-0.434	0.039	-0.363	0.085	0.236	0.007	0.321	0.000
	1	-0.906	0.000	-0.879	0.000	-0.603	0.000	-0.615	0.000
Surface Type	0	0.547	0.000	0.367	0.000	0.569	0.000	0.376	0.000
	1	0.371	0.000	0.140	0.185	-0.174	0.014	-0.389	0.000
Weather	0	-0.028	0.762	-0.045	0.626	0.212	0.001	0.299	0.000
	1	0.594	0.000	0.502	0.001	-0.092	0.353	-0.212	0.033
	2	-0.300	0.001	-0.354	0.000	0.184	0.006	0.208	0.002
Light Condition	0	0.710	0.000	0.544	0.000	0.318	0.000	0.189	0.000
	1	0.115	0.096	0.181	0.009	0.344	0.000	0.351	0.000
	2	-0.569	0.000	-0.460	0.000	-0.558	0.000	-0.492	0.000

Table 8 MNL Regression Analysis Results for Comparison Scenario II

Variable	Category Value	Coastal Urban				Hinterland Urban			
		Severity Value				Severity Value			
		0		1		0		1	
		Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Intercept		7.645	NA	7.180	NA	8.523	NA	7.347	NA
Location	0	0.145	0.005	0.162	0.002	0.537	0.000	0.519	0.000
Number of Lanes	0	0.934	0.000	0.520	0.039	0.204	0.223	-0.155	0.355
	1	-0.603	0.000	-0.366	0.006	-0.372	0.000	-0.132	0.182
Speed Limit	0	0.629	0.001	0.409	0.000	1.022	0.000	0.626	0.000
	1	0.229	0.000	0.355	0.000	-0.095	0.263	0.011	0.894
Surface Type	0	0.761	0.000	0.507	0.000	0.254	0.005	0.228	0.361
	1	0.461	0.005	0.379	0.022	0.061	0.818	-0.040	0.879
Weather	1	0.386	0.159	0.330	0.230	0.610	0.035	0.562	0.053
	2	-0.941	0.000	-0.993	0.000	-0.170	0.392	-0.237	0.235
Light Condition	0	0.977	0.000	0.771	0.000	0.551	0.000	0.382	0.000
	1	-0.220	0.038	-0.075	0.482	0.149	0.252	0.236	0.071
	2	-0.764	0.000	-0.677	0.000	-0.601	0.000	-0.514	0.000

As shown in Table 6, the MNL regression analysis results show that the MNL regression model in Equation (2) works quite well to present the relationship of crash severity with the crash factors for the crashes on US-49 and MS-25. A coefficient is considered as weak and highlighted in the table cells if a greater than 0.05 P-value is received. In table 6, only one level of each of the variables “Number of Lanes” and “Speed Limit” could not show significant effect in the regression results. The MNL regression results in Table 7 and 8 show that the model in Equation (2) can well present the relationships of crash severity category with the identified explanatory variables for the crashes in the statewide rural scenario and for the crashes in the coastal area in Mississippi. However, the MNL regression results for the crashes in statewide urban and the crashes in hinterland area receive several weak effects in the regressed relationships.

4 Impacts/Benefits of Implementation

From literatures Table 9 summarizes the possible countermeasures to reduce the occurrence of crashes and Table 10 summarizes the possible countermeasures to reduce crash severity.

The countermeasures mentioned in Tables 9 and 10 may effectively improve traffic safety for the areas in Mississippi. However, an important consideration on effective countermeasures would be the cost-effectiveness performance of the countermeasures, especially for Mississippi where there is a relatively high percentage of low-income population frequently living in underinvested and underserved communities. Therefore, it would be necessary to revisit the traffic safety countermeasures for the study areas in Mississippi and possibly refine the countermeasures with a cost-effectiveness point of view.

The analyses in Section 3 showed that the frequencies of vehicle crashes in a metropolitan area are relatively high and the severities of crashes in the rural and coastal areas are relatively high. In the following paragraphs, the refinements of crash countermeasures for crash frequency and severity are discussed.

Table 9 Summary of Prospective Countermeasures to Crash Occurrence

<table>
<tr><td colspan="2">Contributing Factor</td><td>Prospective Countermeasures</td></tr>
<tr><td colspan="2">DUI</td><td>1. DUI Program
2. Driver Education</td></tr>
<tr><td rowspan="5">Driver Error</td><td>Wrong Side of Road</td><td>1. Install RPMs
2. Upgrade Centerline
3. Add/ Upgrade Section/ Intersection Lighting
4. Add Turn Lane
5. Modify Superelevation/ Cross Slope
6. Add/ Upgrade No-Passing Lines
7. Improve Roadway Access Management
8. Eliminate Uneven Transition</td></tr>
<tr><td>Failed to Stop</td><td>1. Install Rumble Strips at Intersection
2. Add/ Upgrade Intersection Lighting
3. Improve Sight Distance
4. Install Warning Signs (e.g. “Stop Ahead”)
5. Add/ Upgrade Pavement Marking (e.g. Stop Bar)
6. Enlarge Stop Signs</td></tr>
<tr><td>Failed to Yield</td><td>1. Improve Sight Distance
2. Install Warning Signs (e.g. “Side Road Crossing”)</td></tr>
<tr><td>Inattentive</td><td>1. Install Rumble Strips
2. Install In-Vehicle Radar Warning System
3. Install Brake Activation System</td></tr>
<tr><td>Improper Passing</td><td>1. Add Passing Lane
2. Add/ Upgrade No-passing Zone Lines</td></tr>
<tr><td colspan="2">Curving to the Right with No Shoulder</td><td>1. Add Chevron Alignment Sign
2. Add Post Delineator
3. Install RPMs
4. Upgrade Centerline
5. Install Rumble Strips
6. Widen Travel Lane
7. Modify Horizontal Geometric Alignment
8. Modify Superelevation/ Cross Slope
9. Install Advisory Operating Speed Sign
10. Add/ Upgrade No-Passing Line
11. Add Paved Shoulder
12. Improve Sight Distance
13. Install Warning Sign at Sharp Curves</td></tr>
<tr><td colspan="2">No Paved Shoulder</td><td>1. Pave Existing Graded Shoulder
2. Add Paved Shoulder</td></tr>
</table>

		3. Widen Travel Lane 4. Flatten Side Slope
Curving to the Left with Narrow Lane (< 10 feet)		1. Add Chevron Alignment Sign 2. Add Post Delineator 3. Widen Travel Lane 4. Add Paved Shoulder 5. Install Rumble Strips 6. Install RPMs 7. Modify Horizontal Geometric Alignment 8. Install Advisory Operating Speed Sign 9. Modify Superelevation/ Cross Slope 10. Add/ Upgrade Section Lighting 11. Widen Clear Zone 12. Upgrade Edgeline 13. Install Warning Sign at Sharp Curves
Narrow Travel Lane Width		1. Widen Travel Lane 2. Add Paved Shoulder
Speeding (Including Driving Too Fast for Weather Condition)		1. Install Roadside Speed Radar Detector 2. Install Advisory Operating Speed Sign 3. Improve Drainage System 4. Improve Pavement Condition
Young Driver Driving Under Unrecoverable Roadside Hazard		1. Pave Existing Graded Shoulder 2. Flatten Side Slope 3. Widen Clear Zone 4. Relocate Roadside Hazard 5. Remove Roadside Hazard 6. Construct Traversable Drainage Structure 7. Rise Legal Driver Age 8. Graduated Licensing 9. Driver Education
Curving to the Left		NA
Unrecoverable Roadside Hazard		NA
Driver Condition	Health Problem	1. Restrict Elder Driver Licensing
	Fatigued or Drowsy	1. Install Rumble Strips 2. Vehicle-Based Drowsy Driver Detection

Table 10 Summary of Prospective Countermeasures to Crash Severity

Contributing Factor		Prospective Countermeasures
Trapped Inside Vehicle		NA
Age		NA
Usage of Safety Restraints		1. Buckle-Up Program 2. Driver Education
Run-Off-Road (Roadside Obstacles)		1. Install Guardrail 2. Flatten Side Slope 3. Pave Existing Graded Shoulder 4. Relocate Fixed Object 5. Remove Fixed Object 6. Widen Graded Shoulder 7. Widen Paved Shoulder 8. Widen Clear Zone 9. Construct Traversable Drainage Structure 10. Convert Object to Breakaway
Type of People	Pedestrian	1. Add/ Upgrade Section/ Intersection Lighting
	Bicyclist	1. Add Bicycle Lane
	Motorcyclist	NA
	Heavy Vehicle Passenger	NA
Airbag		1. Install Airbag as a Standard Safety Feature for Vehicles
Overturn		1. Install Guardrail 2. Flatten Side Slope 3. Widen Clear Zone 4. Eliminate Uneven Transition 5. Construct Traversable Drainage Structure

In the Jackson Metro Area, vehicle crashes were concentrated on city streets. The following is a review of the characteristics of the crashes on city streets in the area:

1. 84.8-percent of the crashes were two vehicle crashes.
2. 40.9-percent of the crashes were rear-end crashes, 25.2-percent were angle crashes, and 14.8-percent were sideswipe crashes.
3. 80.8-percent of the crashes occurred on weekdays.
4. 85.2-percent of the crashes took place at intersections.
5. Most of the vehicles involved in the crashes were travelling under 40mph.

From the above characteristics, it would be quite obvious to state that most of crashes in the Jackson Metro area were between vehicles driven by commuters at or near intersections. And the major types of crashes were of rear-end, angle, and sideswipe.

Accordingly, to reduce the crash frequencies economically some relevant countermeasures could be taken. In driver education, emphasis should be placed on slowing down before going through an intersection. In implementation and deployment of traffic control devices and facilities, installation of rumble strips at intersections, installation of larger and/or more legible warning signs and improvement of traffic signal system at intersections would be recommended to reduce traffic conflicts for the area.

As to countermeasures for high severities of crashes, one of the reasons that led to the high severity was that a greater proportion of the crashes were run off road crashes. Fatigue driving is a major cause of run off road crashes. Installation of rumble strips is an effective and economic solution to improve this situation especially in rural areas without light illumination at night time. Also, no restraint usage increased the crash severity. An enhanced buckle-up education program and increased exposure and awareness of crash severity to young drivers can effectively improve the traffic safety to the targeted areas. More data collection about traffic safety performance of heavy vehicles in or near the Mississippi Coastal area may be needed to find more evidence of connections to the relatively high frequency and severity of vehicle crashes in the area.

5 Recommendations and Conclusions

Based on the Mississippi crash data from 2010 to 2014, the project characterizes the distributions of vehicle crash frequency and severity in geographical areas and public road system in Mississippi, defines and categorizes possible factors for the crashes, and studies the possible relationships of the probabilities of crash severities with the explanatory variables by using the spatial analysis tools in ArcGIS, and analysis of variance and multinomial logit models in SAS. Based on the study results, the following findings are observed.

(1) The high crash frequencies are generally associated with metropolitan areas. For example, segments on US-49, US-51, and MS-302 near Tennessee border and Memphis Metro area; segments of US-51, US-49 and MS-25 at the Jackson Metro area; segments of US-98, US-49 and MS-198 in the Hattiesburg urban area; and segments of I-10, I-110, and US-90 at the Gulf coast area (Biloxi-Gulfport-Pascagoula Metro area).
(2) The crash distribution in MDOT maintenance districts shows that high crash severity is not correlated with high population density in a metropolitan area. The top three districts with the highest crash frequencies are: District 6 (Biloxi-Gulfport-Pascagoula Metro area), District 5 (Jackson Metro area), and District 2 (Memphis Metro area). The top three districts with the most severe crashes are: Districts 7, 3, and 2. Although District 2 has a major metropolitan area, Districts 7 and 3 are typically rural areas.
(3) The crashes in rural areas are more severe or fatal than the crashes in urban areas. Similarly compared with the hinterland Jackson Metro area, crashes in the Mississippi Gulf coastal area are significantly more severe or damaging. Possible reasons for the high crash severities in the rural areas could be speeding, run-off, and driving in poor lighting condition. Possible reasons for the high crash severities in the coastal area could be speeding, driving in poor lighting condition, and vulnerability to extreme weather conditions and flooding. The intermodal transports to and from the seaport at the Mississippi coastal area may have increased the volumes of heavy trucks in the traffic stream composition which may have contributed to the increased damaging effect of a crash in the area.
(4) The analysis of variance and multinomial logit models can be effectively used to study the effects of factors for crashes and the relationships of a crash severity with the explanatory variables such as AADT, Location, Speed Limit, Surface Type, Surface Condition, Weather, and Light Condition. Other variables such as driver age, drug use, driver behavior, vehicle type etc. could also be considered in a future study to better understand the relationships.

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