Identification and Analysis of High Crash Segments on Interstate, US, and State Highway Systems of Arkansas

Final Project Report

Project No. 2099

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Sponsoring agency and institution:

Arkansas Highway and Transportation Department
Mack-Blackwell Rural Transportation Center

February 16, 2009

ACKNOWLEDGEMENT AND DISCLAIMER

The authors would like to thank the following individuals for their assistance on this project. Ted English, Jon Waldrip and Sharon Baker from the Arkansas Highway and Transportation Department, and Karen Bonds from the Highway Safety Office. Special thanks to Jack Buffington at the Mack-Blackwell Rural Transportation Center and the Arkansas Highway and Transportation Department for funding this project. Also like to acknowledge and thank the following students who contributed significantly to this project: Jeff Sims and Dan O'Connell from the Missouri University of Science and Technology.

This report reflects the views of the authors. The contents do not necessarily reflect the views or the policies of the Arkansas Highway and Transportation Department, or the Mack Blackwell Transportation Center at the University of Arkansas. This report does not constitute a standard, specification or regulation.

EXECUTIVE SUMMARY

This project report identifies the high crash locations on the Interstate, US, and State highway systems in the state of Arkansas. High crash locations can be defined as any highway location which has a higher frequency of crashes compared to other roadway locations due to local factors including factors such as driver behavior, traffic, geometric and control conditions, etc. There are eight Interstate, nineteen US, and two hundred and thirty nine State highways in Arkansas and all were considered in identifying the high crash locations.

Literature review was conducted on the different methods and based on the literature review three methods were selected for the identification and ranking of high crash locations. Three year crash data, 2004 to 2006 was analyzed and the Empirical Bayes', Crash Rate, and Equivalent Property Damage Only methods were selected to identify the high crash locations. These methods were found to be apt as they involved parameters like the Annual Average Daily Traffic, crash frequency and severity. The Empirical Bayes' method was found to be advantageous as it takes into consideration the effects of random variation in events. The Equivalent Property Damage Only method was useful as it weighted the different characteristics of a crash. The highway segments were ranked using the modified sum-of-the-rank method. Results revealed that the chosen methods yielded good results. The modified sum-of-the-ranks method was found better in approach than the sum-of-the-ranks method as the time taken for the process of analyzing was short and yielded the desired results.

This report identifies the highway segments with high frequency and severity of crashes. It was observed that most of the crashes were on undivided sections of the highways on US and State highway networks. The frequency of crashes was higher when highways pass through the vicinity of major cities pointing to heavy vehicular movement as one of the reasons for higher frequency of crashes.

This report identifies the high crash locations on the three highway networks. Each mile on the three networks was analyzed and top 100 segments for interstate highways and top 500 segments were identified for the US and State highway networks. These "top" mile segments were further investigated and continuous miles of highway segments were identified as high crash locations. Among the interstate highway network, certain locations can be termed as high crash locations. On I-30, the mile segments from 114 to 143 have higher frequency of crashes. On I-40, the mile segments from 126 to 155, and 272 to 285 were found to be high crash locations. Most of the interstate highways had a series of high crash locations. For the US highway network, routes 62, 63, 65, 67, and 71 had high frequency of crashes. The analysis of the State highway network system found that routes such as routes 5, 7, 10 and 16 had high frequency of crashes.

The high crash locations have higher AADT's but it is not always necessary that higher AADT's would lead to higher frequency of crashes. On I-40, mile segments 161 and 162 have similar AADT's compared to some of the mile segments from 126 to 155 and 272 to 284, but higher frequency of crashes were not observed in segments 161 and 162. Similarly, other routes also have certain mile segments whose AADT is similar/higher than the AADT of the identified high crash segments. Hence, it is can be stated that AADT is not the only factor which can be related

to high crash locations. A future report will identify the causes of crashes and propose remedial measures to minimize the number of fatalities and severity of crashes as well as propose measures to reduce the frequency of crashes.

GLOSSARY

Table 1. **List of Acronyms**

Terms	Description/Definition
AADT	Annual Average Daily Traffic
Begin LM	Distance from the start of the starting section of the analysis segment in miles
CD_A	Crash density
CPI	Crash Probability Index
CR	Crash rate method
CR_{PP}	Crash rate based on population
CR_{VV}	Crash rate based on vehicular volumes
DES	Detailed Engineering Study
EB	Empirical Bayes method
End LM	Distance from the start of the ending section of the analysis segment in miles
EPDO, EP	Equivalent Property Damage Only
Fatal	Total number of fatalities
HCS	High Crash Segments
MSR	Modified sum-of-ranks method
RSI	Relative Severity Index
S1	Three year count of crashes involving fatalities
S2	Three year count of crashes involving incapacitating injuries
S3	Three year count of crashes involving moderate injury
S4	Three year count of crashes involving complaint of pain
S5	Three year count of crashes involving property damage only
Section End	Indicates the ending section of the one mile long analysis segment
Section Start	Indicates the starting section of the one mile long analysis segment
SI	Severity index
SPF	Safety performance function
SR	Sum-of-ranks method
SWiP	Site With Promise
Total	Three year count of crashes
VMT	Vehicle miles traveled

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I. INTRODUCTION

In modern day society, traveling has become a common trait in day-to-day life of people. People get to work in the morning and return in the evening. This traveling process uses different modes of transportation which involves possibility of a crash. Crashes cause loss of life and property. In the US alone, a person dies in a vehicle crash every 13 minutes and in 2006, 41,059 fatalities occurred and the number of people injured was 2.49 million (NHTSA, 2007). This is a major concern for transportation engineers and Departments of Transportation all over the US. Figure 1 presents crash statistics for Arkansas, the US average and the state with statistics that are lowest in the US. Figure 1 also shows the fatalities per million VMT and the fatality rate per 100,000 population in Arkansas from 2004 to 2007 and the comparison with the national average.

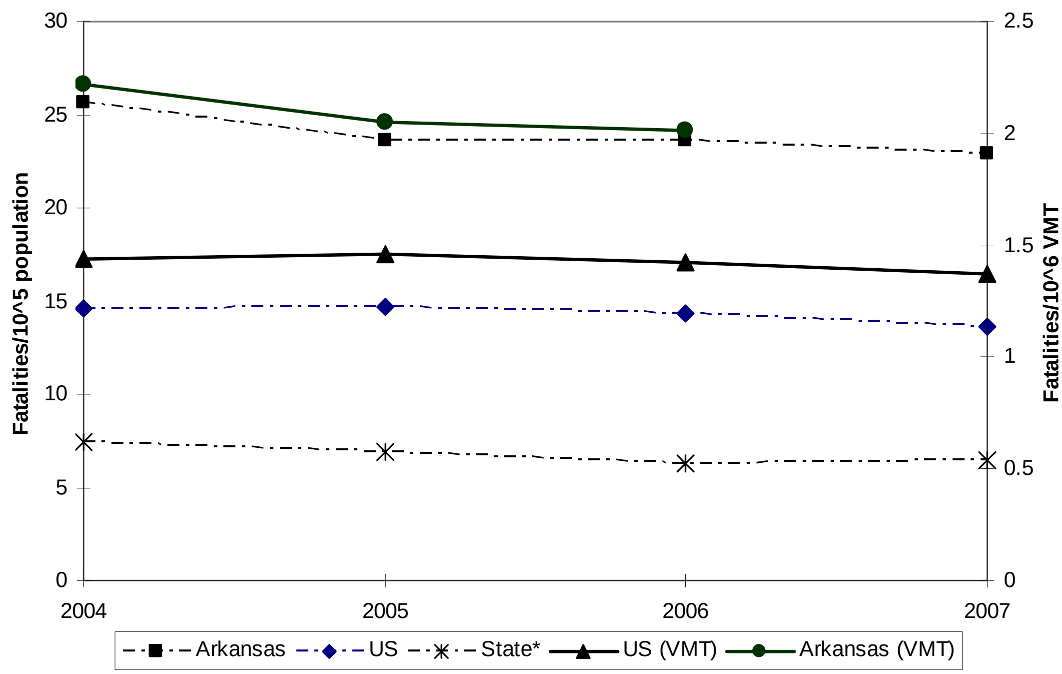


Figure 1. Comparison of Fatalities/100 million VMT, Fatalities/10^5 population for Arkansas, US and State (which had the lowest rates)

From Figure 1 it can be inferred that for the recent years the fatalities/100 million VMT is much higher in the state of Arkansas when compared to the national average. Also, the fatalities/10^5 population for Arkansas is three times the value of the state with the lowest fatalities/10^5 population and this value for Arkansas is nearly 1.5 times the value for the US. Finally, Figure 1 illustrates that in Arkansas the frequency of crashes is higher than the average frequency of crashes in the entire US. When compared to other states in terms of number of fatalities, the number of fatalities in Arkansas increased from 1994 to 2007, from 609 to 650, an increase of 6.73% and Arkansas ranked 18th in terms of difference between the number of fatalities between the years. Montana stood first with an increase of 37.13% and District of Columbia was ranked 51st (last) with a decrease of 36.23%. When compared to other states in terms of number of fatalities for 2007, Arkansas ranked 24th with 650 fatalities, California ranked at the top with 3974 fatalities and DC ranked last with 44 fatalities for 2007. When compared to other states and ranked in terms of fatality rates per VMT traveled between 1994 and 2007, Arkansas stood 20th with a decrease in rate by 19.67%. (FARS, 2009) This quantitatively indicates the high number of fatalities and crashes which occur on Arkansas highways and a detailed study is required to identify these high crash locations.

In addition to the lost of lives, roadside crashes cost society $80 billion per year (RSFRSG, 2007). The economic costs to society in medical expenses, worker losses, property damage, and emergency services compound the personal tragedies resulting from highway fatalities and crashes. With crash rates in Arkansas higher than the national average, this project aims at identifying the hazardous locations on Interstate, US, and State highway routes, the three main highway systems for any state. This report summarizes the methods used for the evaluation of the process of identification, and the benefits and the insufficiencies of various methods used in identifying these hazardous locations on the highway networks.

I. 1. Hazardous Road Location

A hazardous road location is any site at which the site-specific expected number of crashes is higher than similar sites due to the local risk factors present at the site (Elvik, 1988). Any road location can be identified as hazardous in terms of the *expected* number of crashes which may occur rather than the *recorded* number of crashes which have previously occurred. Therefore, an unusually high recorded number of crashes may not necessarily indicate a high *expected* number of crashes but may be the result of random variation. The random variation is taken into account while identifying hazardous locations based on *expected* number and *recorded* number of crashes.

II. REVIEW OF RANKING METHODS

There are many different methods for identifying high crash hazardous locations. In order to decide which method would be best for evaluating the Arkansas highway systems an extensive literature review was conducted with a focus on methods that took into account fatalities, serious injuries, and total crash counts on highway systems. In the following, the finding of this literature review, including a brief description of the methods and the benefits and insufficiencies are described.

II.1. Spot Map Method

The spot map method shows clusters of crashes visually on a map. The map is then examined to find areas of high numbers of crashes to be classified as high risk areas.

<u>Benefits</u>

This method makes identifying high crash locations very quick and simple. To determine high-crash locations, the crashes are located on a map and clustered areas can be seen. This method is good for smaller number of crash locations.

<u>Insufficiencies</u>

The spot map method is a rough estimate and does not provide a list or ranking of high crash locations. It is unable to display larger high crash locations because high crash locations are found visually and many crashes may overlap one another.

II.2. Crash Methods

The crash methods evaluate the total number of crashes and rank them by either frequency of crashes, density, or average daily traffic. These methods are often used as a preliminary step to identify locations to be further analyzed.

II.2.1. Crash Frequency Method

The crash frequency method ranks the number of crashes by crash frequency at a particular spot much like the spot map method. The locations with a higher crash frequency than a predetermined rate are classified as high crash locations and are singled out for further examination. This method is primarily used for generating an initial list of high crash locations which is then further tested using other methods.

Benefits

This method makes identifying high crash locations very quick and simple. This method can be used with only one year's data. The crash frequency method works well for locations with a high number of crashes where as other methods may require three or more years of data.

Insufficiencies

The crash frequency method does not take into account crash severities, such as fatalities and/or serious crashes. This method ranks high-volume locations as high-crash locations which cause some locations that are not high-crash locations to be looked at and further evaluated.

II.2.2. Crash Density Method

Much like the crash frequency method, the crash density method totals the number of crashes per mile for highway sections. A segment usually a mile of highway is defined as a continuous length of roadway where the characteristics stay the same. The road segments are then ranked and compared to a predetermined crash density. The segments that are over the predetermined amount are classified as high-crash locations to be further analyzed using other methods.

Benefits

This method is very quick and easy to use. It will provide a list of road sections that can narrow down the focus of crash locations so that other methods can be applied to certain segments. This method is good for locations with a high volume of crashes.

Insufficiencies

This method does not take into account crash severities, such as fatalities and/or serious crashes. Much like the crash frequency method, the crash density method ranks high-volume locations as high-crash locations which may cause some locations that are not high-crash locations to be looked at and further evaluated.

II.2.3. Crash Rate Method

This method takes into account the total number of crashes, as well as the traffic volume, producing a rate. This rate is compared with other sections of highway to help determine high-crash locations. Crash rates are determined as follows (Powers, 2004):

$$\text{Crash rate} = n(t)/q(t) \qquad (1)$$

where:

n(t) = the number of crashes at a location during a specified time t, and
q(t) = the traffic volume at the location during time t.

When these values are calculated, they are generally small fractions, so a multiplier of one million or one hundred million is used to create a whole number which provides better visualization and simpler calculations. There are two different types of crash rates which are generally computed, depending on whether the location being analyzed is a spot or a section. The equations used are explained in the following. The spot crash rate determines the number of crashes per million of vehicles entering a specific spot (intersection) (Powers, 2004):

$$R_i = 2(A)(1{,}000{,}000)/(T)(V) \qquad (2)$$

where:

R_i = spot crash rate expressed in crashes per million vehicles entering a spot of highway,
A = total number of crashes during the duration of the study,
T = time period in days, and
V = total average daily traffic entering and departing the intersection.

The section rate divides a larger section of highway into smaller sections of varying length. This method takes into consideration length as well as volume, and this varying length provides varying exposure to crashes. These results are often in terms of the number of crashes per one hundred million vehicle miles, however sometimes one million vehicle miles is used instead (Powers, 2004).

$$R_s = (A)(100{,}000{,}000)/(T)(V)(L) \qquad (3)$$

where:

R_s = section rate in crashes per hundred million vehicle miles,
A = total number of crashes during the duration of the study,
V = average annual daily traffic (AADT) on a section (vehicles per day),
T = period (days) for which crashes are counted, usually 365 days, and
L = length of section in miles.

Benefits

Since this method takes AADT into account, higher crash rates are understood to be relative to traffic volume rather than simply the number of crashes which occur in a single location.

Insufficiencies

This method does not take into account crash severity such as fatalities and/or serious crashes. Since severity is not factored in the equation, the areas with higher traffic volumes and higher number of crashes may be classified as high-crash locations when they may not be. In this study, Equation 2 was not considered and Equation 3 was used and the length of the section considered was one mile.

II.3. Frequency-Rate Method

The frequency-rate method is a combination of three methods, the crash frequency, crash density, and crash rate method. Locations are considered high-crash areas if they have a higher rate than a predetermined crash frequency, crash density or crash rate. The method first finds crash frequency and crash densities on a highway segment and then uses the crash rate to reorder the final list.

Benefits

Much like the crash methods, the frequency-rate method is a very fast, easy to use method that provides a list of high-crash locations. Deficiencies of the crash methods are minimized, however not eliminated.

Insufficiencies

The frequency-rate method provides a list of high-crash locations that are then evaluated using other methods. Sites that should be investigated further might not be and sites that should not be investigated might be, causing time to be wasted. This method does not take into account crash severity, such as fatalities and/or serious crashes.

II.4. Quality Control Methods

The quality control methods consider various highway categories to rank high crash locations. The method compares site crash frequencies, densities, or rates against predetermined average values for sites with similar characteristics.

II.4.1 Number Quality Control Method

The number quality control method applies statistical analysis to find a particular crash site's frequency/density and then compares it with the mean frequency/density for similar sites. The number quality control method is used on sites where crash frequency and crash density are much greater than other sites across the region. The formula to find the critical crash rate at a roadway location is as follows (Stokes and Mutabazi, 1996):

$$F_c = F_a + k\sqrt{\frac{F_a}{M}} + \frac{1}{2M} \quad \text{..........} \quad (4)$$

where:

F_c = critical rate for a particular location,
F_a = average crash frequency/density for all road locations of like characteristics,
k = probability factor determined by the level of statistical significance desired for F_c, and
M = number of vehicles traversing particular road section or number of vehicles entering a particular intersection during the analysis period.

Benefits

The number quality control method utilizes a statistical test to refine the decision-making process involved in determining a site's hazardousness. With a site's frequency/density found and compared to other crash sites with similar averages, above average and at risk crash sites can be quickly determined. This method takes into account AADT.

Insufficiencies

This method is somewhat vague because the reasoning behind the use of the probability constant, *k* in the above equation is not clear. This method also does not take into account crash severities such as fatalities and/or serious crashes.

II.4.2. Rate Quality Control Method

The rate quality control method is used in the identification of hazardous road locations by means of a statistical test which compares the traffic crashes rates for roadway segments and intersections with similar characteristics to determine if a site may have a higher rate of traffic crashes. The formula to find the critical crash rate at a roadway location is as follows (Stokes and Mutabazi, 1996):

$$R_c = R_a + k\sqrt{\frac{R_a}{M}} + \frac{1}{2M} \quad \text{.........}(5)$$

where:

- R_c = critical rate for particular location (crashes per million vehicles or crash per million vehicle-km),
- R_a = average crashes rate for all road locations of like characteristics (crashes per million vehicles or million vehicle-km),
- k = probability factor determined to be the level of statistical significance desired for R_c, and
- M = number of vehicles traversing particular road section (millions of vehicle-km) or number of vehicles entering particular intersection (millions of vehicles) during the analysis period.

Benefits

The rate quality control method utilizes a statistical test to refine the decision-making process involved in determining a site's hazardousness. Crash sites that are found to have higher crash frequencies are easily singled out for further examination. Also, it takes into account AADT.

Insufficiencies

Similar to the number quality control, the rate quality control method is somewhat vague because the reasoning behind the use of the probability constant, *k*, in the above equation is not clear. Also, this method does not take into account crash severity, such as fatalities and/or serious crashes.

II.5. Crash Severity Methods

The crash severity methods use a variety of different factors to incorporate rankings such as frequency, density, and/or severity. Crashes and injuries that are more severe are given higher relative weight than those judged less severe. This method allows agencies to devote more of their safety resources to locations with a greater potential for injury or loss of life.

II.5.1. Equivalent Property-Damage-Only (EPDO) Method

The equivalent property-damage-only method assigns weights to a crash based on its severity. For example, a crash that resulted in a fatality is weighted much higher than a crash that only resulted in vehicle damage. The severity index is calculated using (Campbell and Knapp, 2005):

$$SI = [W_K K + W_A A + W_B B + W_C C + P]/T \quad (6)$$

where:

- SI = Severity index for the site,
- W = the respective weight coefficients,
- K = frequency of fatal crashes at the site,
- A = crash frequency involving A-type injuries at the site,
- B = crash frequency involving B-type injuries at the site,
- C = crash frequency involving C-type injuries at the site,
- P = frequency of PDO crashes at the site, and
- T = total crashes at the site.

The EPDO index is calculated using:

$$\text{EPDO Index} = W_K K + W_A A + W_B B + W_C C + P \quad (7)$$

The EPDO rate is calculated using:

$$\text{EPDO Rate} = [\text{EPDO Index} * 10^6 \text{ or } 10^8] / [(\text{Exposure per day}) * \text{Days}] \quad (8)$$

<u>Benefits</u>

This method assigns weights to each crash based on severity. The result is a better indication of the hazardousness of a highway segment, not based solely on the quantity of crashes but taking into account other important variables such as type of injuries.

<u>Insufficiencies</u>

Traffic volume is not taken into account when using this method. Also, this method requires more data than is often provided. The weight of a specific crash is subjective and is not a measurable quantity. They are, therefore, subject to fluctuation.

II.5.2. Relative Severity Index (RSI) Method

Much like the EPDO method, the relative severity index (RSI) method incorporates the amount of damage done at the crash site. Along with the comprehensive cost of the crashes, the severity of the crash is also factored in. This method is typically used for further evaluation of sites that have already been found to be high crash locations by other methods. RSI value for the site is computed as (Al-Masaeid, 1997):

$$RSI = [C_K K + C_A A + C_B B + C_C C + C_P P]/(K + A + B + C + P) \quad \text{.................. (9)}$$

where:

RSI	= Relative Severity Index for the site,
C	= the average comprehensive cost per crash for a crash of severity level "i" from *K* through *P*,
K	= frequency of fatal crashes at the site,
A	= crash frequency involving A-type injuries at the site,
B	= crash frequency involving B-type injuries at the site,
C	= crash frequency involving C-type injuries at the site, and
P	= frequency of PDO crashes at the site.

Benefits

The RSI method factors the number of fatalities and other serious or property damage crashes into the analysis. It also incorporates the information collected about the cost of crashes to individuals and society. This method assigns a weight to each of the severities so the agency evaluating can put strong emphasis on certain types of crashes.

Insufficiencies

Traffic volume is not used in the RSI method, and like the EPDO method, the RSI method uses weights that are subject to error. Also, more data about each individual crash that is often not provided must be found. If the crash frequency is small, the more severe crashes that control the results show a high RSI value that might be caused by other factors unrelated to the highway conditions.

II.6. Index Methods

The index methods combine other methods previously discussed into a single method. It applies different weights to factors, and then adds the factors together to rank high crash locations.

II.6.1.Weighted Rank Method

The weighted rank method uses some of the other methods in calculating an index for each road segment. This method uses up to five different indicators, including, but not limited to crash frequency, crash density, crash severity, and/or number of lanes. A weight is then assigned to each of the indicators and they are then added together.

Benefits

The indicators used and their weighted ranks are able to be chosen based on the items of importance in a particular study. The combination of different indicators may significantly reduce errors in calculations. The benefit to this method is that the agency evaluating the crash site can choose which factors are most important for them.

Insufficiencies

This method is highly subjective if not thoroughly researched. Some factors may be chosen and assigned weighted values that could cause some sites to be classified a high-crash location that are not and some sites that are high-crash location not to be looked at. The weighted rank method requires more effort and time to produce results.

II.6.2. Crash Probability Index (CPI) Method

The crash probability index method is much like the weighted rank method. It combines the results from other methods such as the crash frequency, crash density, crash rate, and severity. The CPI method applies weights to each of the factors to reflect the agency's priorities. When any factor is below the average, it is given penalty points. The penalty points are added up and the segments with the highest amount are classified as high-crash locations.

Benefits

The combination of using results from different methods reduces the misleading results for high and low volume sites, while also including severity. By applying different weights one is able to choose important individual factors.

Insufficiencies

This method takes more time and data than other methods. The weights that are applied to the factors are highly subjective and can lead to ambiguous results. Also the assigning of penalty points can be highly subjective.

II.6.3. Iowa Method

Almost identical to the CPI method, the Iowa method uses three ranking lists that are combined into a single ranked list. The three lists are frequency rank, rate rank, and severity rank. The severity rank is based on value loss at the site where the highest severity (fatality) is assigned a high dollar amount and lower severities (minor injuries) are assigned a low dollar amount.

Benefits

Just like the CPI method, the combination of using results from different methods reduces the misleading results for high and low volume sites, while also including severity. By applying different weights one is able to choose important individual factors.

Insufficiencies

This method takes more time and data than other methods. The weights that are applied to the factors are highly subjective and can lead to ambiguous results. The assigning of dollar amounts for crash severity can also be very subjective.

II.7. Bayes Methods

The Bayes method addresses two issues with estimation. For each road segment, the normal expected number of crashes is estimated by means of a Safety Performance Function (SPF). This can then be combined with records of crashes for each site yielding an estimate of the site-specific expected number of future crashes, allowing researchers to identify hazardous road locations in the future.

II.7.1. Hierarchical Bayes

This method ranks segments of highway by taking into account the number of crashes, the number of fatalities, and the number of severe and minor casualties. This is performed by using a three variable poisson distribution that allows covariance between the variables. Also a cost function is set up for the severity of the crashes. A higher number is designated for more severe crashes.

<u>Benefits</u>

Like the index methods, the combination of using results from different methods reduces the misleading results for high and low volume sites while also including severity. By applying different weights one is able to choose important individual factors. The use of Bayesian estimation values can overcome the problem of random variation in crash counts.

<u>Insufficiencies</u>

This method takes more time and data than other methods. The weights that are applied to the factors are highly subjective and can lead to ambiguous results. The assigning of dollar amounts for crash severity can also be very subjective.

II.7.2. Empirical Bayes (EB) Method

The Empirical Bayes method addresses two problems of safety estimation. For each road location, the normal, expected number of crashes is estimated by means of a safety performance function. This can then be combined with the crashes record for each site, yielding an estimate of the site-specific expected number of crashes. This approach to the identification of hazardous road locations utilizes all information that provides clues to traffic safety.

<u>Benefits</u>

The EB method can use data older than 2- to 3- years. It can also estimate high crash locations with 2- to 3- years of crashes data and it corrects for the regression-to-mean bias. The increase in precision is important when the usual estimate is too imprecise to be useful. The elimination of the regression to mean bias is important whenever the crash history of the entity is connected with the reason its safety is estimated. The theory of the EB method is well developed. It is now used in the Interactive Highway Safety Design Model (IHSDM) and the Comprehensive Highway Safety Improvement Model (CHSIM).

<u>Insufficiencies</u>

The primary disadvantage of the EB method is that the SPF is estimated using an aggregate crash data for more than a year, i.e., crash frequency for three years per roadway segment. Hence, to accurately apply this SPF model, the units of crash frequencies per three years per roadway segment need to be maintained, i.e., annual crash data cannot be used in place of three years aggregated data without re-estimating the SPF model.

III. LITERATURE REVIEW

Several approaches have been used to identify high crash locations and to rank them. These approaches have been applied to highway segments as well as intersections. To name a few, models such as the Crash Severity Model, Equivalent Property Damage Only and the Empirical Bayes' Method have contributed to these approaches. Reviews of these methods are presented in this section.

In Iowa (2007) three ranking lists to identify the high crash locations were generated. The three ranking lists were frequency rank, rate rank, and severity rank and the link-node system was used to rank these sites. The following procedure was used to rank the sites. Initially three different types of sites were defined , a) intersections which include all road-to-road intersections, except complex interchanges, interchange sites and ramp terminals, b) links included section of road between intersections, c) nodes included all types of intersections, grade separations, bridges, turnings which include 90 degree turn, etc. After each of the sites was categorized into one of the above sites, a frequency rank was assigned to each site. Later, a value for rank was generated in descending order. A crash rate ranking was then assigned to each site. The three rankings from the above stages were summed to create a composite rank factor, sorted in ascending order to assign a composite rank.

Hauer (1996) revised the procedure for identification of black spots to select sites to improve safety. The old approach had performed to only identify the black spots in an irregular manner where the overall costs of implementation was high, certain locations which needed less priority was also given much importance leading to tedious and not economical projects. To identify high crash locations, a study was conducted which had the following three steps, a) to identify locations where remedial action is cost effective, b) recognize and rectify locations which are geometrically deficient, and c) identify locations which are more hazardous to users. The task of improving the sites had two stages; one being identification and the other to perform a detailed safety analysis. The result showed that the identification of sites with promise was better if more attention was given to spot clusters and when information was well extracted from entire crashes history of a site, rather than using data of last few years. Hauer (1996) also stated that the identification of hazardous locations was done accurately by many methods but there was little work done in performing a detailed safety analysis.

Elvik (2006) presented a new approach for crashes analysis of hazardous road locations where in old approach the importance of use of statistical tests was neglected. The main objective was to develop an improved criterion to determine the actual high crash locations. During the first stage of analysis, the search pattern in crashes data was carried out using statistical tests. An overall review of the first stage displayed the crashes pattern during night time on a wet road surface. It also suggested that many local risk factors such as amount of pedestrian traffic, surface friction conditions, and obstructions of view were significant. Then hazardous and safe sites were paired up from the data obtained in a crashes prediction model. For each pair, inspection of the local risk factors was analyzed. A criterion was proposed to draw a conclusion from crashes analysis and risk factors at dangerous road locations. To distinguish the hazardous locations four cases were used. In all of these cases a hypotheses was generated and tested, depending on crashes characteristic and risk factors involved. The Empirical Bayes' method was also used for the analysis and the results were satisfying. The study also suggested that the identified high crash locations need certain amount of planning for proposing a cost effective remedial measure.

Hauer (2004) developed a procedure to detect the sites where there is an increase of mean crashes frequency over time. The study was done on a large time scale. The two types of increases that need to be detected were, a) steady but gradual safety deterioration, and b) sudden increase in mean crashes frequency at an unknown time period. The procedure was applied to many sites; these sites were examined in detail. The primary data for each site was the time series of crashes costs. The changes in traffic volume of each site formed the secondary data. The statistical significance tests were performed for both the data. Software was developed for the analysis of significance tests. In the analysis, the user should pre-define the nominal level of significance. The nominal level of significance can be judged using two considerations, a) sites which have an access of performing a detailed examination, and b) sites which have a correctly identified marginal yield.

Tarko and Kanodia's (2004) objective was to develop a crash prediction model that was more accurate in identifying the hazardous locations. The main objective of the safety management system thus developed was to prevent crashes as well as to reduce the risk faced by individual road users. They proposed crash frequency index and crash cost index for identification of high crash locations. They believed that crash cost index would incorporate in crash severity identification. They also used the injury/fatal crashes which had weighted values. When the weighted values were added to the PDO it gave Equivalent Property Damage Only method which also included crash severity. The tests showed that the higher the value of index of crash frequency the higher the probability of the site being a high crash location. Time period for the analysis was considered as multiple of one year to reduce the estimation bias caused by variations in crash frequency. Finally, results stated that it was difficult for both safety and monetary management to be optimal and crash cost index was suggested as a better approach.

Ivan (2004) presented a new approach for crash rate analysis which highlights the limitations of the classic approach in which a) the crash incidence and traffic volume were considered to be linear, and b) rate of flow of traffic is constant throughout the analysis period. He found that an exponential function instead of a linear function is a better predictor of crash frequency in Connecticut. Using parameters such as crash frequency and traffic volume, non linear and the level of service not constant enabled the study to better predict the crashes on highway locations. A model considering the effects of traffic volume contributed to the incidence of crashes in three ways, a) as number of trails exposed to the risk of experiencing a crash to occur, b) occurrence of collisions between vehicles increases as rate of flow increases, and c) particular traffic flow state predicts crashes as a factor of all the three quantities. The study also concluded that it is ideal to use vehicles traveled per year for locating hazardous locations. The effect of varying intensity of traffic flow can be ignored if the time period of study is more than a year.

Kumar and Chin (2004) studied the crashes rates using data from 1980-1994 for 50 countries in the Asia-Pacific region out of which three are developed, four are industrialized and the remaining are under-developed countries. The study was carried out to show that the influence of socio-economic factors plays a vital role for fatal crashes. The factors which were considered were a) size of the road network, which indicates the conflict points, b) vehicular traffic which shows the movement of traffic, c) economic growth, which shows the level of urbanization and industrialization, reflecting the changes in infrastructure of transport facilities, which in turn may lead to fatal crashes. The model used in this study was negative binomial. The results showed that socio-economic and infrastructure factors played a vital role on fatal road crashes. It was also seen that the number of fatal crashes reduced with time.

Hauer et al. (2004) worked on how best to rank the sites where safety can be improved cost effectively. They used the following four step procedure to rank the sites the a) compare the performance of two ranking criteria and apply both criteria to generate two ranked lists of Site with Promise (SWiP), b) perform a Detailed Engineering Study (DES) on those sites which are not common on both lists, c) the DES estimates anticipated costs and safety benefits of the projects, and d) the ranking criteria should lead to more cost beneficial projects. In this study five criteria were used to rank two SWiP's for rural two lane road in mountainous terrain of Colorado. The five criteria were: a) expected crashes frequency, b) severity weighed expected crashes frequency, c) expected excess crashes frequency, d) expected severity-weighed excess crashes frequency, and e) excess crashes frequency. DES was performed to the top 22 sites to estimate costs and safety benefits. Finally, they compared the results of the five criteria with Empirical Bayes' method and found that the severity-weighted expected crashes frequency lead to more cost beneficial projects than the other four ranking criteria.

Guerts et al. (2004) studied the crashes sites in Flanders, Belgium to locate the black spots or dangerous crashes sites. In this study they identified 1,014 crashes locations as dangerous. The study was done by using the data for five years. A combination of weighted values, 1 for each light injury, 3 for each serious injury, and 5 for each deadly injury was used to rank and select the most dangerous crashes locations. The identification of black spots was related to roadway segments of numbered roads of length of 100m, and each intersection was assumed to be a possible black spot. A comparative analysis was later made using Bayesian method. The results showed that the use of Bayesian method was a better approach to the historic count data for ranking of the crashes locations to be dangerous, as it overcame the problem of random variation. Finally, a sensitivity analysis was performed, which showed that the use of weighted values not only had an important effect on identifying the number of crashes locations but also had an important effect on ranking of black spots.

Pulugurtha et al. (2006) illustrate a new method to identify and rank high pedestrian crash zones. The crash data and street networks information for the Las Vegas metropolitan areas were used to demonstrate the method. The crash concentration maps were prepared using the Kernel method (Kernel method is a class of algorithms which are used for mapping the data) .A total of 29 high pedestrian risk zones were identified, 22 of them being linear and 7 being circular zones. The sum-of-rank method and the crash score method were used to identify the risk zones. The sum-of-rank method calculates single rank value for each zone. The sum-of-the rank method is expressed as:

$$SR= \frac{[\text{Rank } (CD_A) + \text{Rank } (CR_{VV}) + \text{Rank } (CR_{PP})]}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

where:

CD_A = Crash density,
CR_{VV} = Crash rate based on vehicular volumes, and
CR_{PP} = Crash rate based on population.

The ranked list is prepared using the methods like crash density, crash rate and crash frequency method. The ranks of each risk zone were summed from each of the above methods to obtain a composite rank. The weighed values were used in the process. The crash score method was also used to rank the high pedestrian crash zones. A normalized value was used to obtain score on each method (crash density, crash rate, and crash frequency). Results showed that the ranking of each zone was consistent when sum-of-rank method and crash score methods were used, reflecting the degree of robustness. Geographical Information System was used for the study of spatial patterns, reducing the subjectivity in the analysis process.

Existing literature review indicates that among the different methods used for identification of high crash locations, EB method has a better approach as it has the ability to estimate high crash locations. The use of EB method would increase the precision in evaluating the number of crashes. The weighted values were used depending upon severity to give a much clear distinguishing feature for the identification of the most dangerous crashes locations. The use of EPDO method included crash severity which had weighted values in the analysis, leading to more accurate ways of identifying crash locations. Based on the review, it was decided to use the Empirical Bayes' (EB) method, Equivalent Property Damage Only (EPDO) method, and the Crash rate method as crash rate method takes into account the total number of crashes and traffic volume. The EPDO and crash rate methods are proposed to evaluate the relationship between property damage and traffic. The sum-of-rank method yielded results for identifying risk zones as a single rank for each zone and summed to get a composite rank, reflecting the degree of robustness. From the literature review, it was found that the time period was considered as multiples of one year as it reduces the estimation bias caused by several crash frequencies. It is also proposed that the time period of study should be three years as, a) it would reduce the estimation bias caused by variations in crash frequency, and b) the effect of varying intensity of traffic flow can be ignored.

IV. SELECTION OF RANKING METHODS

All the methods presented in this report were found to have benefits and insufficiencies and some were not chosen due to different reasons. The methods were narrowed down to three methods to evaluate the highway sections. A pattern was observed in these methods, all of the methods either used the traffic volume or the amount of property damage at a particular segment. Many of the methods involved other steps and more than just those two factors, but they at least used one or the other. This is why it was decided to choose the EPDO and Crate Rate methods as they deal with property damage or traffic volume. These methods were compared to others, and in order to see the relationship between property damage only and traffic, these methods were chosen. The EB method was found to be more complex to implement but can incorporate different variables and therefore used. Based on the benefits and insufficiencies described in the above sections, the Crash Rate Method, the EPDO Method, and the Empirical Bayes (EB) Method were used.

The crash rate method was used because it complements the EPDO method. The crash rate method takes into account the total number of crashes, as well as the traffic volume, producing a rate. This rate is compared with other sections of the highway to help determine high-crash locations. Since this method takes AADT into account, higher crash rates are understood to be relative to traffic volume, rather than simply the number of crashes which occur in a single location.

The Equivalent Property-Damage-Only has been used for a long time and is a very quick and easy way of identifying high crash locations. The EPDO Method assigns weights to a crash based on its severity. For example, if a crash had a severity of 1 it would have a higher multiplier assigned to it than a crash with a severity of 2. The result is a better indication of the hazardousness of a highway segment, not based solely on the quantity of crashes but taking into account other important variables such as the type of injuries or damage.

The EB method was used because it increases the precision in evaluating the number of crashes. The increase in precision is important when the usual estimate is too imprecise to be useful. The EB method uses not only the crash severity but also the traffic volume. This method is becoming widely used and is a powerful tool for safety analysis of highway segments. The crash severity and traffic volume were the two factors that needed to be evaluated to see if they ranked high-crash locations differently. The EPDO and crash rate methods evaluated the two factors separately and the EB method takes both of the factors into account at once.

V. IMPLEMENTION OF RANKING METHODS

The three methods, the Crash Rate Method, the EPDO Method and the Empirical Bayes (EB) Method were implemented on the Interstate, US, and State highway networks. In the following, the methods and their implemented is described.

V.1. Crash Rate Method

The crash rate determines the number of crashes per million vehicle miles of travel on a specific segment of the highway using Equation 3.

V.2. Equivalent Property-Damage-Only Method

The EPDO Method assigns weights to a crash based on its severity. For example, a crash that resulted in a fatality is weighted much higher than a crash that only resulted in vehicle damage. To implement this method, a weight (W1) of 0.35 for crash severity 1, a weight (W2) of 0.25 for severity 2, a weight (W3) of 0.2 for severity 3, a weight (W4) of 0.15 for severity 4, and a weight(W5) of 0.05 for a severity of 5 were assigned. The Severity Index was calculated using the following formula (Campbell and Knapp, 2005):

$$SI = \frac{[W_A A + W_B B + W_C C + W_D D + W_E E]}{T} \quad \text{...... ....(11)}$$

where:

SI	= severity index for the site,
W	= the respective weight coefficients,
A	= crash frequency involving a crash severity 1 at the site,
B	= crash frequency involving a crash severity 2 at the site,
C	= crash frequency involving a crash severity 3 at the site,
D	= crash frequency involving a crash severity 4 at the site,

E = crash frequency involving a crash severity 5 at the site, and
T = total crashes at the site.

The EPDO index was calculated as (Campbell and Knapp, 2005):

EPDO Index = Total crashes * Severity Index ....(12)

And the EPDO rate was calculated as (Campbell and Knapp, 2005):

EPDO Rate = [EPDO Index * 10^6] / [(Exposure per day) * Days] ....(13)

The exposure per day times days is termed as the exposure rate which is the total time in days during the analysis period which is equal to 1095 days (365*3).

V.3. Empirical Bayes (EB) Method

The EB method uses the SPF which is a statistical function that relates the normal, expected number of crashes to a set of explanatory variables. The average crashes at 'similar sites' and the variation around this average are, therefore, brought into the EB procedure by the SPF. The SPF provides an estimate of the average crashes (mile-year), as a function of some trait values (e.g., ADT, lane width…) and other regression parameters. The following form for the SPF is listed for highways using multivariable regression method (Elvik, 1988):

$$SPF = \alpha AADT^{\beta} \qquad (14)$$

The weight given to the estimated normal number of crashes for similar sites when combining it with the recorded number of crashes in order to estimate the expected number of crashes for a particular site is indicated by α which is best estimated as (Elvik, 1988):

$$\alpha = \frac{1}{1+(\lambda \times Y)/\varphi} \qquad (15)$$

where:

λ = the normal, expected number of crashes as estimated by a safety performance function, and

Y = the number of years during which the crash count is materialized.

There is systematic variation in the number of crashes whenever the variance exceeds the mean value. This is usually referred to as the over dispersion. Over dispersion parameter is estimated per unit length for segments. Naturally, entities for which the crash frequency is not proportional to their length (e.g. intersections or rail-highway grade crossings) have an over dispersion parameter that is not estimated per unit length (Elvik, 1988).

$$\varphi = \frac{\frac{Var(x)}{\mu} - 1}{\mu} \qquad (16)$$

where:

φ = over dispersion parameter, and

μ = the mean number of crashes.

The best estimate of the expected number of crashes for a given site is expressed as (Elvik, 1988):

$$E(\lambda / r) = \alpha \cdot \lambda + (1-\alpha) \cdot r \quad \text{...} (17)$$

where:

r = the recorded number of crashes.

The EB method, for each road location estimates the normal expected number of crashes by using the safety performance function. The SPF then combined with the crash record for each site, yields an estimate of the site-specific expected number of crashes. A road location is considered hazardous if the site-specific expected number of crashes is substantially higher than the normal expected number of crashes for similar sites.

V.4. Modified Sum-of-Ranks Method

The sum-of-ranks method expressed as Equation 10 was modified to provide more consistent results that take the three different ranking methods (crash rate, EB and EPDO) into account. The modified sum-of-ranks method (MSR) utilizes the three methods in the calculation of a single rank value for each crash site. A ranked list is prepared for each of the selected methods and then these ranks for each crash site are summed to produce a new rank. The modified sum-of-ranks method is expressed as:

MSR = Rank (EB) + Rank (EPDO) + Rank (CR)…………………………..… (18)

The MSR is better in approach than the SR method as it makes the calculations faster yet yielding the same desired results. Examples of use of this method are presented in the next section.

VI. IDENTIFICATION OF HIGH CRASH LOCATIONS

The EB, crash rate, and EPDO methods yielded very similar results for the three highway systems. Although, the ranking of the top hazardous segments were not exactly the same, the same mile segments were top ranked when the three methods were used. The EB method yields a hazardous index for a segment that is above an average. If a number is not shown on the table, then the EB method does not rate the highway segment to be hazardous. Each of the methods performed well for all the highway networks in Arkansas. The length of the highway, short or long, number of crashes and severity index, high or low, all showed similar mile segments as the high crash locations.

The EPDO method ranks the highway segments using the EPDO rate. The EPDO rate is calculated by dividing the EPDO index by the exposure time. The EPDO index is the total of all the crashes after a weight has been multiplied to the corresponding severity. The EPDO rate is multiplied by one million to get numbers that are easier to sort. The rate is a product of all the crashes and in case of more crashes the rate is higher and the highway segment is considered hazardous.

The Crate Rate method ranks the highway segment in order of their spot crash rate. The spot crash rate is based on the total number of crashes that occur divided by the exposure time and AADT. The higher the spot crash rate, that segment is prone to a crash. Of course, the amount of traffic flow affects this rate and, therefore, it is not recommended for example to compare an interstate segment to a state highway.

The EB method estimates which highway segments are hazardous using an index. The table in the appendix presents the results for different interstate highways. For I-30, the rank using the EB method is the same as the other two methods, however, for I-55 and I-430 the ranks are different from the other two methods, but the difference is minimal. After comparing the three methods, the results from the EB method were more reasonable in terms of the total number of crashes/mile-year, the higher the total number of crashes/mile-year, the more hazardous the segment. Also the estimates from the EB method for the three interstate freeways closely reviewed were found to be very close to the recorded number of crashes/mile for the year 2004.

Normally, a high number of crashes cannot be expected to continue due to chance, a certain regression to the mean is expected, the regression to the mean for the Interstate, US, and State freeways were lower than 10% for most segments which proves that the calibration of SPF is reasonable enough to estimate the normal expected number of crashes.

In general, the EB, CR, and EPDO methods all yielded similar results. Although the ranking of the top sites did not always match, the same mile segments were usually in the top five or ten for all the three methods. Each method performed well for the Interstate, US, and State highways, regardless of length, number of crashes, etc.

<u>Cumulative Score</u>

Since three different methods were used to identify and rank the high crash locations, the research team modified a method that used the three methods to rank the high crash locations. To do so, for each section the sum of the numerical rank from the different methods was used and then re-ranked based on the lowest rank value. For example, if a highway segment was ranked first in the EPDO method, second in the Crash Rate method, and first in the EB method, it would have a cumulative score of four. After the MSR is applied, a list is prepared based on the lowest rank. Table 2 presents an example to illustrate the cumulative score.

Table 2. Ranking of segments, an overview

Interstate	Segment	EB rank	EPDO Rank	CR Rank	Total Cumulative Rank by MSR	Overall rank as high crash segment
30	141	1	2	9	12	1
540	8	43	34	38	125	33
40	152	18	6	3	27	5
55	9	3	23	16	42	10
430	6	39	19	21	79	22

From Table 2, I-30, segment 141 has an overall rank of 1 as the total cumulative rank is the lowest compared to all other highway segments. If only I-30 is considered, then it was found that the total cumulative rank is 12 but is ranked 1 as all other segments have a higher cumulative rank. Segment 8 of I-540 is ranked 125th among the segments, however, the overall rank as a high crash segment is 33. Similarly, other segments are ranked.

VII. HIGH CRASH LOCATION RESULTS

The state of Arkansas has eight Interstate, 19 US, and 239 State highways. To identify high crash locations or hot spots, the top 100 high crash locations were identified for the Interstate highway network, and top 500 high crash locations were identified for the US and State Highway networks.. The results of this analysis are presented in the following sections.

VII.1. Interstate Highways

An initial comparison of the eight interstate highways was first conducted and Table 3 shows the results of the comparison. The interstate highways were ranked for comparison by a severity rate. The severity rate was calculated by adding the total number of crashes that had a severity rate 2 to the total number of fatalities. Once that number was found, it was divided by the total number of crashes over the three year period. In order to compare the results, all the severity rates were multiplied by 100. A crash severity 1 means that at least one fatality occurred during a crash. Instead of adding the number of crashes that were a crash severity 1, the total number of fatalities was added to the number of crashes that were a crash severity 2 because a crash could have resulted in multiple fatalities and those crashes should be weighted higher than a crash that just had one fatality. The interstates with a higher severity rate number had more severe crashes. Table 3 shows results for the three year aggregate, 2004 to 2006.

Table 3. Three Year Crash Data for Interstate Highways of Arkansas

Interstate Routes	Total Length (miles)	Total Crashes	Crashes per mile	Fatalities	Number of Crashes		Severity Rate
					S1	S2	
30	143	4762	33.3	68	59	147	4.5
40	285	5502	19.3	97	85	316	7.5
55*	72	1074	14.9	42	23	88	12.1*
430	13	1121	86.2	5	5	21	2.3
440	14	366	26.1	4	3	9	3.6
530	47	665	14.1	24	20	47	10.7
540	86	2758	32.1	30	26	139	6.1
630	7	1381	197.3	3	3	26	2.1
Total	667	17,629	26.4	273	224	793	6.0

*Note: I-55 had a much higher severity rate due to one crash that occurred in 2004. This crash involved a commercial bus and had 15 fatalities.

From Table 3 it can be inferred that I-40 has the highest frequency of crashes and fatalities compared to other interstate highways because primarily I-40 runs over the entire length of Arkansas. I-630 has the highest crashes per mile as it is at the intersections of interstate highways and also in the vicinity of Little Rock, capital of the state of Arkansas with a population of 183,133; and an average AADT of 52,297 vehs/day for the three years of crash data. The average value of crashes per mile for all the interstate highways was 26.4 (total crashes/total length) which shows high frequency of crashes. I-430 indicates the highest value of crashes per mile, and is also in the vicinity of Little Rock and connects I-30, I-40, and I-630. Though I-530 passes through the vicinity of Little Rock, it has a lower value of crashes per mile but the highest severity rate which means in terms of frequency the route had fewer total crashes but in terms of severity, crashes with high severity occurred. I-530 passes by the end of the city limits in rural areas and hence lower frequency of crashes per mile.

Table 4. Top 100 High Crash Locations on Interstate Highways of Arkansas

			Analysis Methods			*Number of Crashes*						*Other Variables*					*Analysis Methods*			*Number of Crashes*						*Other Variables*	
Rank	Route	Mile	EPDO	CR	EB	Total	S_1	S_2	S_3	S_4	S_5	Fatal	AADT	Rank	Route	Mile	EPDO	CR	EB	Total	S_1	S_2	S_3	S_4	S_5	Fatal	AADT
1	I-30	141	39.7	581.1	299.3	452	2	4	24	159	263	2	98845	51	I-55	7	5.6	165.5	30.6	53	0	6	5	15	27	0	36462
2	I-30	140	42.7	395.7	287.7	470	2	6	40	155	267	2	108779	52	I-540	3	5.9	141.4	28.7	72	0	2	4	19	47	0	47381
3	I-30	126	16.4	909.1	119.4	171	2	1	22	53	93	2	52698	53	I-55	67	4.0	220.7	30.8	46	0	0	3	16	27	0	19041
4	I-30	138	20.2	404.3	119.1	218	1	6	19	69	123	2	80046	54	I-40	133	6.0	109.2	33.3	66	0	0	6	24	36	0	55348
5	I-40	152	19.3	319.6	180.6	234	1	3	11	69	150	1	67786	55	I-540	9	6.3	132.3	24.5	71	0	3	5	20	43	0	49611
6	I-40	277	16.1	419.3	154.6	195	2	8	8	45	132	2	52033	56	I-430	5	7.7	135.0	19.5	90	0	1	9	24	56	0	61342
7	I-630	0	28.7	413.5	81.4	312	0	7	38	87	180	0	79287	57	I-540	4	5.7	134.5	25.1	70	0	0	2	24	44	0	48510
8	I-540	64	13.5	3660.3	111.7	149	3	5	10	39	92	4	41442	58	I-540	67	6.9	126.1	20.5	76	1	3	8	17	47	1	55396
9	I-540	62	13.8	1317.3	105.5	129	3	0	16	54	56	3	28161	59	I-530	33	3.8	233.6	25.3	34	0	1	8	11	14	0	16559
10	I-55	9	12.6	1722.6	78.0	103	2	11	8	46	36	2	22303	60	I-30	137	10.6	102.0	18.4	100	1	2	15	37	45	1	89834
11	I-40	154	16.8	276.3	92.7	190	0	5	21	48	116	0	103447	61	I-430	11	7.9	130.1	15.8	88	0	2	12	21	53	0	62582
12	I-430	9	15.7	252.9	106.9	188	0	1	24	40	123	0	68368	62	I-40	125	5.8	106.5	26.6	50	2	4	0	24	20	2	44734
13	I-40	153	18.0	193.1	109.4	203	1	3	17	61	121	1	100913	63	I-30	129	8.4	118.1	14.0	95	1	1	10	25	58	2	74126
14	I-630	6	18.3	217.1	58.5	223	0	2	20	55	146	0	94152	64	I-530	0	5.8	113.5	24.3	55	0	1	9	20	25	0	45513
15	I-55	8	9.0	812.4	62.3	84	0	8	5	33	38	0	22865	65	I-55	2	5.8	106.9	25.0	58	0	8	3	14	33	0	49872
16	I-40	151	11.3	215.5	104.7	150	0	2	10	30	108	0	63663	66	I-55	0	6.5	103.5	23.3	56	0	9	8	13	26	0	49736
17	I-630	4	17.3	175.3	70.5	202	0	3	11	66	122	0	105527	67	I-630	1	9.9	107.4	12.8	122	0	4	8	27	83	0	104162
18	I-55	10	9.1	795.9	52.2	72	2	1	7	45	17	2	24358	68	I-40	276	5.5	104.2	26.9	50	0	7	3	17	23	0	44186
19	I-40	128	9.9	240.3	74.9	103	0	5	7	36	55	0	42788	69	I-40	199	4.3	132.1	30.2	48	0	3	6	8	31	0	33233
20	I-30	142	20.1	189.9	53.8	217	2	4	15	75	121	3	104441	70	I-540	44	2.5	367.7	19.7	30	0	2	2	5	21	0	17057
21	I-40	147	10.7	211.9	84.7	122	0	3	17	25	77	0	56030	71	I-40	146	5.6	94.0	24.8	64	0	2	6	16	40	0	62506
22	I-430	6	13.6	198.7	69.1	158	0	3	17	38	100	0	73746	72	I-40	284	5.5	97.4	23.0	44	1	12	2	8	21	1	41750
23	I-430	7	14.6	187.7	62.9	155	1	1	16	53	84	1	75886	73	I-40	149	5.2	94.8	25.5	64	1	3	4	10	46	1	61786
24	I-30	130	11.0	238.7	53.1	122	1	1	15	32	73	1	67185	74	I-40	135	4.6	121.7	19.4	52	1	3	2	12	34	1	56306
25	I-30	0	8.5	276.9	58.6	89	1	2	7	31	48	1	30594	75	I-30	113	5.5	102.5	17.3	44	3	1	8	15	17	3	40993
26	I-540	63	8.0	668.0	51.4	79	0	9	8	18	44	0	34757	76	I-40	282	5.3	96.2	22.0	42	0	9	5	11	17	0	40460
27	I-540	65	7.8	2570.1	50.6	79	0	1	16	20	42	0	35492	77	I-540	61	4.3	121.1	19.0	42	0	1	7	14	20	0	31781
28	I-30	120	9.9	184.5	62.7	135	0	1	7	28	99	0	68702	78	I-40	84	3.1	136.1	23.2	38	0	2	6	2	28	0	26153
29	I-30	123	16.6	166.7	48.9	143	1	1	11	89	41	1	79227	79	I-40	129	4.7	91.6	23.4	55	0	2	4	14	35	0	54933
30	I-30	128	12.7	173.5	55.1	143	0	2	8	52	81	0	76342	80	I-30	116	5.0	112.3	12.6	54	1	1	8	11	33	1	52791
31	I-40	150	8.9	161.3	68.6	111	0	3	11	20	77	0	62972	81	I-630	5	12.8	124.0	6.2	141	1	3	16	37	84	1	104147
32	I-30	139	15.4	163.3	35.3	168	1	2	18	51	96	1	94393	82	I-40	242	3.7	106.2	22.6	39	1	1	7	5	25	1	33546
33	I-540	8	9.5	172.0	46.0	92	1	6	9	30	46	1	48968	83	I-30	127	6.3	78.7	19.7	65	0	3	10	15	37	0	76468
34	I-40	278	7.9	204.5	46.0	83	1	6	7	19	50	1	58923	84	I-30	131	8.5	107.9	7.4	85	0	1	17	23	44	0	72716
35	I-630	2	15.8	143.0	36.2	166	2	2	21	49	92	2	106201	85	I-30	124	6.3	75.2	23.1	62	0	3	7	21	31	0	76674
36	I-40	142	8.6	144.6	58.1	101	1	1	11	22	66	1	64088	86	I-40	132	5.9	80.7	17.3	49	1	3	9	18	18	1	55573
37	I-540	66	10.9	153.9	36.9	103	0	6	18	29	50	0	61645	87	I-30	125	6.4	84.9	13.5	69	1	2	3	24	39	1	75370
38	I-540	82	8.8	183.6	34.9	83	0	7	10	26	40	0	50528	88	I-40	281	3.0	275.2	9.5	27	0	3	3	9	12	0	39414
39	I-40	279	8.3	152.5	50.9	87	1	8	7	18	53	1	57556	89	I-30	133	5.3	73.0	26.1	62	0	1	7	14	40	0	78023
40	I-540	71	7.8	176.3	43.6	94	1	0	10	20	63	1	51934	90	I-30	134	5.5	66.6	32.0	57	2	3	4	14	34	2	78530
41	I-30	118	8.1	154.4	44.9	99	0	1	10	22	66	0	59126	91	I-430	3	6.4	90.6	10.4	62	1	2	11	16	32	1	62781
42	I-40	280	7.1	163.3	44.3	66	2	9	5	13	37	2	37235	92	I-430	10	5.4	87.9	15.0	65	0	1	3	20	41	0	67982
43	I-30	115	6.4	170.7	42.4	78	0	0	9	18	51	0	45827	93	I-30	135	5.6	59.5	51.7	56	1	0	4	24	27	1	86270
44	I-430	0	7.4	165.4	33.8	83	0	2	10	21	50	0	45910	94	I-540	81	6.9	105.6	7.4	66	0	5	7	22	32	0	57427
45	I-540	6	8.0	149.9	34.1	81	0	10	4	21	46	0	49717	95	I-530	3	5.1	95.4	11.4	31	5	2	10	6	8	6	33058
46	I-630	7	8.8	98.9	74.6	99	0	1	10	30	58	0	91572	96	I-40	141	5.5	79.7	15.5	55	1	5	3	15	31	1	63245
47	I-40	148	6.0	151.0	48.4	79	1	0	7	13	58	1	51395	97	I-430	1	5.6	89.0	10.5	56	0	3	7	17	29	0	58693
48	I-30	122	10.8	131.9	25.2	103	0	0	10	52	41	0	72359	98	I-40	54	2.5	214.3	10.3	21	1	0	4	8	8	1	16176
49	I-40	271	4.7	344.4	27.5	45	1	6	2	11	25	2	33996	99	I-55	63	2.1	218.2	11.7	21	0	1	2	8	10	0	15019
50	I-55	3	5.6	145.9	38.3	65	0	4	4	15	42	0	41471	100	I-540	33	2.4	263.2	9.4	18	0	3	5	4	6	0	16272

To identify high crash segments on the interstate highway system, each highway segment of length 1 mile was evaluated using the three methods explained in the above sections and sorted and ranked using the modified sum-of-ranks method. Table 4 presents the results of the top 100 segments identified as high crash locations for the three year crash data, 2004 to 2005. From Table 4 it can be found that the total number of crashes for the top 100 segments was 10,112. The average AADT of these top 100 crash segments was 57,872 vehs/day. The average AADT and the severity including fatalities, S1, were highest for I-30. Table 4 indicates that on the interstate highway network, though there is higher AADT, longer length of the highway, higher fatalities, and higher frequency of crashes, etc. the segments can be ranked low as a high crash location, identifying that it depends on a combination of factors to be ranked as a high crash location.

From Table 4, certain segments are observed to be high crash frequency locations e.g. mile 114 to mile 143 on I-30. Similarly, I-40 had mile 126 to mile 155 and mile 272 to 285; I-55 has mile 1 to mile 11; I-430 has mile 1 to mile 12; I-530 has mile 1 to mile 3; I-540 has mile 62 to mile 68; and I-630 has mile 1 to mile 8.

Table 5 summarizes the results of the top 100 segment analysis. From Table 5, it can be inferred that I-40 has the most number of segments in the top 100 compared to other interstates. The high crash segments of I-30, I-40, I-430, I-440, I-530, and I-630 are in the vicinity of Little Rock. The number of fatalities is highest on I-30 for the top 100 segments and the total number of fatalities is highest on I-40 for the three year crash data. Hence, I-30 and I-40 can be considered most prone to crashes. I-630 has the least number of fatalities when compared to other interstate highways.

Table 5. Summary of high crash locations on interstate highways in Top 100 ranked segments

Interstate Routes	**Number of High Crash Segments**	**Segment Ranked Highest (Rank)**	**Number of Fatalities in Top 100 (3 year data)**	**Total Number of Fatalities (3 year data)**
30	25	141 (1)	26	68
40	30	152 (5)	19	97
55	9	9 (10)	4	42
430	9	9 (12)	2	5
440	-	-	-	4
530	3	33 (59)	6	24
540	17	64 (8)	13	30
630	7	0 (7)	2	3
Total	100	-	72	273

Figures A1 to A8 in the appendix plotted between AADT and frequency of crashes, show that high variation in average AADT for the three years of crash data. The maximum average AADT can be observed on I-630 with more than 80,000 vehs/day. The R-square value is reasonable for most of the Interstates showing that at least 25% of the crashes can be estimated. The only Interstate which falls below this category is I-430.

Figure 2 summarizes the crashes by severity by comparing the results of the top 100 segments to the total crash data for all segments for the three years. Figure 2 shows that the severity including property damage only, S5, had the highest frequency compared to any other crash severity. The crash severity including fatalities, S1 had higher frequency for all the segments compared to the top 100 segments. The total frequency of crashes by highest severity for all the segments for S1 is 3.4 times (224/66) (29%) the total frequency of crashes in the top 100 segments. Similarly, it is 2.38 (42%) for S2, 2.17 (46%) for S3, 1.54 (65%) for S4, and 1.57 (64%) for S5. Hence, it was concluded that the crash severity including fatalities, S1 is at a much higher rate for the top 100 segments for the three years of crash data. In terms of percentage, this indicates that 29% of fatal crashes are accounted for in the top 100 segments whereas the property damage only crashes are accounted for 65% in the top 100 segments. This indicates that crash involving fatalities are randomly spread over the entire highway network whereas property damage only type of crashes are present over the entire highway network illustrating that the crashes including property damage only are very high and occurs commonly. Also, for the three year crash data, the total frequency of crashes for the top 100 ranked segments is 60% of the total frequency of crashes for all the segments which shows that the frequency of crashes is highest in the top 100 ranked segments.

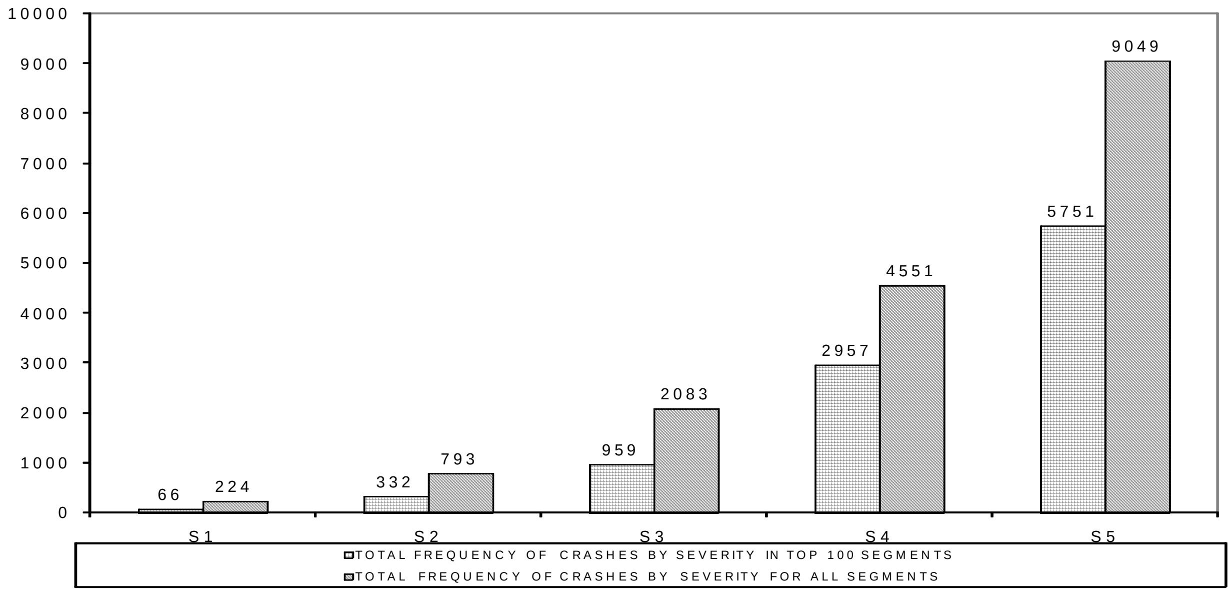


Figure 2. Comparison of total frequency of severities on Interstate Highway by Top 100 ranked segments and all segments for 3 years of crash data

Figure 3 summarizes the crash results by individual interstates and compares the frequency of crashes for the top 100 segments to the total frequency of crashes for all segments for the three year data. Figure 3 indicates that the frequency of crashes on I-30 was the highest among the top 100 ranked segments when compared to other interstate highways. I-440 was found to be the safest interstate highway when compared to other highways as none of the highway segments are ranked among the top 100. I-530 had the lowest percentage of crashes, 18% (120/665) compared to other highways. Conversely, I-630 had the highest percentage, 90% (1247/1381), of crashes in the top 100 segments to the frequency of crashes for all segments. There are five other interstate highways which have nearly 50% or more crashes that occurred in the top 100 segments. The highways are categorized into three groups depending on the percentage. The first group comprises of I-630, I-430, and I-30 form where the frequency of crashes in top 100 segments to frequency of crashes for all segments is 90%, 84%, and 70% respectively. Similarly, I-55, I-540, and I-40 form the second group with 52%, 48%, and 46%, and finally I-530 and I-440 form the third group with 18% and 0% respectively. The interstates in group one are in the vicinity of Little Rock, hence it has the most frequency of crashes. I-440 is located on the outskirts of Little Rock and is one of the safest interstates in Arkansas. I-55 passes through the city of Blytheville which is a major industrial town in the state of Arkansas and has high frequency of crashes and the ratio between the frequency of crashes for top 100 segments to frequency of crashes for all segments is relatively high at 52%. The route also has heavy movement of traffic at 28,702 vehs/day.

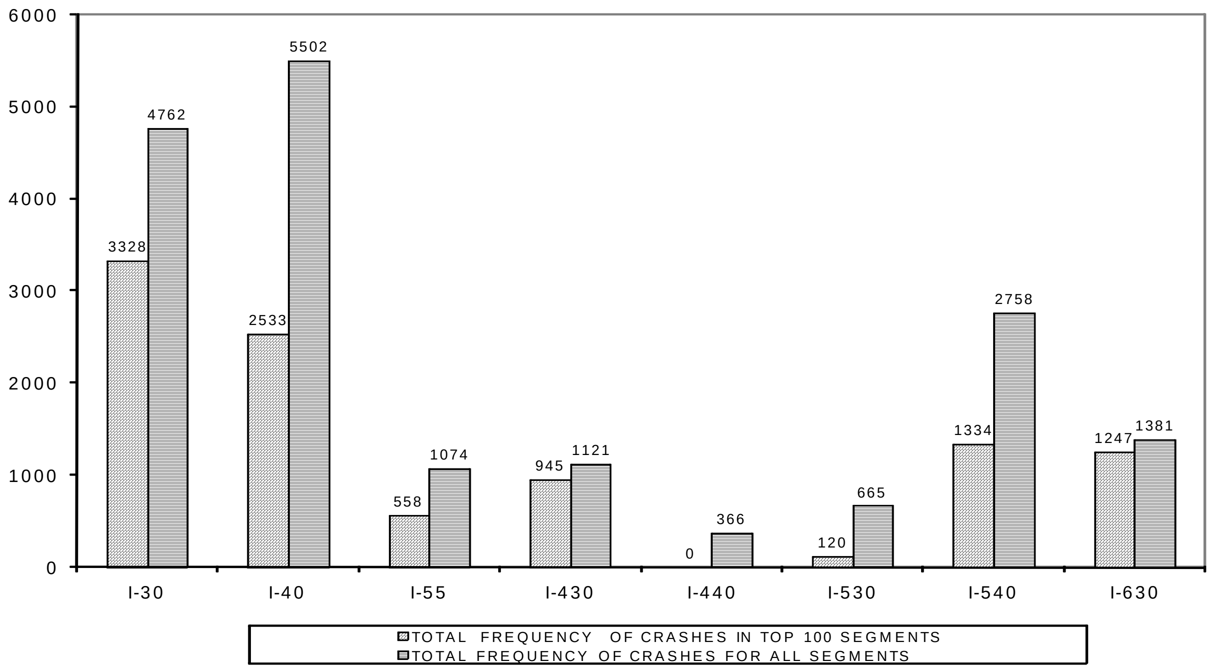
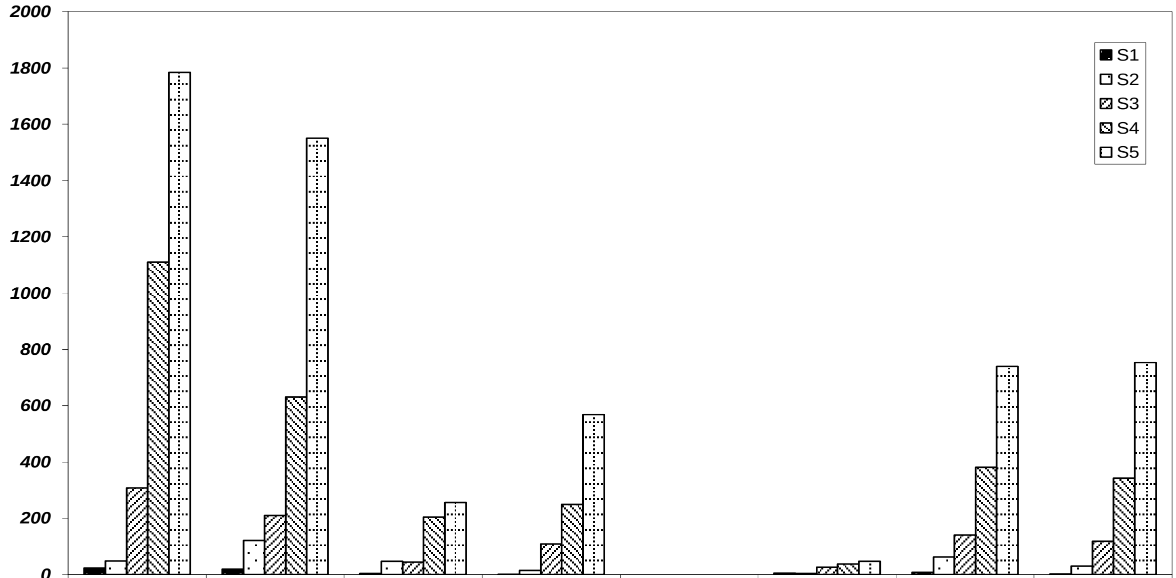


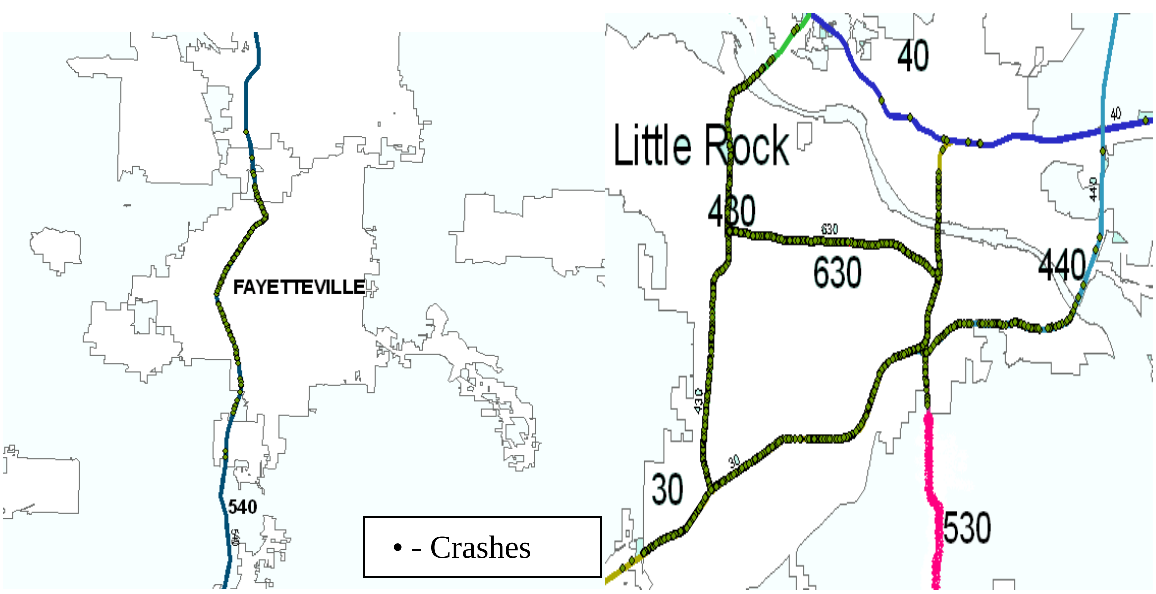
Figure 3. Frequency of crashes on Interstate Highway by of Top 100 ranked segments and all segments for of 3 years of crash data

Figure 4 summarizes and compares the frequency of crashes by severity for each interstate highway for the top 100 segments for the three year data. I-30 is found to be the most crash prone highway with the highest frequency of crashes for S1, S3, S4, and S5 among other highways. I-440 is found to be the safest compared to any other highway. I-30 has higher average AADT, the length of the interstate is comparatively long and it passes through Little Rock. The overall view suggests that the frequency of crashes including property damage only is higher in all the interstate highway segments. The severity including fatalities is randomized over the entire interstate highway network. I-440 which runs through Little Rock has the least frequency of crash severities. I-440 is one of the shortest in length and the average AADT is also low when compared to other interstate highways. Among the interstates which do not pass Little Rock, I-540 which passes through Fayetteville has higher frequency of crashes including severities. For the interstate highway network, the severity incorporating property damage only, (S5) is highest and it decreases with severity incorporating fatalities (S1). Figure 5 shows the location of interstate highways and the cities of Fayetteville and Little Rock.



	I-30	I-40	I-55	I-430	I-440	I-530	I-540	I-630
S1	23	20	4	2	0	5	9	3
S2	49	121	48	16	0	4	63	31
S3	308	211	45	109	0	27	141	118
S4	1110	631	205	250	0	37	382	342
S5	1784	1550	256	568	0	47	739	753

Figure 4. Frequency of Crashes for Interstates Highways for the Top100 ranked segments.



a) Fayetteville, AR **b) Little Rock, AR**

Figure 5. Crashes which took place in Fayetteville and Little Rock, major cities in Arkansas, 04-06 year crash data.

Figure 5a shows Fayetteville which is one of the major cities of Arkansas with a population of 72,202 and an area of 44.5 miles^2. Figure 5b shows Little Rock and I-630 which intersects most of the interstate highways of Arkansas. Little Rock has a total population of 183,133 with an area of 116.8 $miles^2$ (US Census, 2008). The traffic movement is very high in the vicinity of Little Rock as most of the interstate highways pass through the city. As a result of the heavy volume of traffic these highways are prone to crashes.

Analysis of Ranking Methods

From Table 4, it was noticed that segments with high AADT may be ranked low. Similarly, though the total number of crashes is high the rank may be low. This is because the ranking is not only dependent on AADT or total frequency of crashes but depends on different methods and the parameters used such as in the EB method, or the different weights used in the EPDO method for the different crash severities of the severity index, etc. This is explained in more detail in Table 6 and the following paragraphs.

Table 6. Analyses of Ranking Methods

Interstate Routes	Mile	Rank	Total Number of Crashes	EPDO Index	CR	AADT
I-55	10	18	72	9.95	795.9	24358
I-540	8	33	92	10.45	172.0	48968
I-40	271	49	45	5.15	344.4	33996

For, I-55, mile 10, CR can be calculated using Equation 3:

$$R_s = (A)(100{,}000{,}000)/(T)(V)(L)$$

For years 04 to 06, R_s equals 24.6 (100,000,000/3*365*) ((7/28500) + (1/40700)), 200.88 and 570.31. Hence, CR equals 795.9 (24.6+200.88+570.31). In these calculations, 7/28500 represents seven crashes which took place on mile marker 10 with an ADT of 28,500. Similarly for, I-40, mile 271, CR equals 344.4 and for I-540 mile 8; C.R equals to 172.0. For, I-540, mile 8, EPDO index can be calculated using Equation 12: EPDO Index = Total crash * Relative Severity Index.

EPDO Index equals 10.45 [(1*0.35) + (6*0.25) + (9*0.2) + (30*0.15) + (40*0.05)]. In these calculations, S1 = 1, S2 = 6, S3 = 9, S4 = 30, and S5 = 40. Hence, EPDO Index equals 10.45. Similarly for, I-55, mile 10, EPDO Index equals 9.95. For I-40, mile 271, EPDO Index equals 5.15.

Therefore, it can be observed that though the AADT and total number of crashes are high on I-540 mile 8 the rank is less than the rank for I-55 mile 10 because of the reasons stated above. Similarly, the rank of I-40 mile 271 is less than the rank of the other two due to the reasons stated above. Hence, Table 4 is formulated depending on all these factors before they are ranked as high crash locations.

A study of the interstates highways showed that the frequency of crashes was higher for I-30. I-40 being the longest interstate highway in Arkansas also had the highest number of fatalities. The frequency of crashes increased in the vicinity of Little Rock city. The ranking of the segment as a high crash location does not depend on only one variable such as AADT, length of the road, crash severity, but depends upon on a combination of such parameters. The frequency of crashes including property damage only is higher for the top 100 segments and also for all the segments for the three year crash data. The frequency of crashes for the top 100 ranked segments is 60% of the total frequency of crashes for all segments for the three year crash data. The severity including fatalities is high for interstate highways.

Tables A1 to A8 in the appendix present more detailed analysis of each interstate highway for the three year data. From Table A1 for I-30, it can be inferred that most of the high crash segments occurred on mile 110 to 141. These segments are near the vicinity of Little Rock city and 26 fatalities occurred on these segments. From Table A2 for I-40, it can be inferred that most of the high crash segments occurred on mile 125 to 155 and 270 to 285 and 18 fatalities also occurred on these segments. From Table A3 for I-55, it can be inferred that most of the high crash segments occurred on mile 0 to 10 and 24 fatalities also occurred on these segments, out of which a crash on mile 4 incorporated five fatalities. From Table A4 for I-430, it can be inferred that most of the high crash segments occurred on mile 0 to 10 and five fatalities also occurred on these segments. From Table A5 it can be inferred that most of the high crash segments occurred on mile 0 to 10 and four fatalities also occurred on these segments. From Table A6 for I530, it can be inferred that most of the high crash segments occurred on mile 0 to 10 and 16 fatalities also occurred on these segments, out of which a crash incorporated six fatalities on mile 3. From Table A7 for I-540, it can be inferred that most of the high crash segments occurred on mile 60 to 80 and 15 fatalities also occurred on these segments. From Table A8 for I-630, it can be inferred that most of the high crash segments occurred on mile 0 to 10 and three fatalities also occurred on these segments.

VII.2. US Highways

The State of Arkansas has a total of nineteen US highways and Table 7 presents an initial comparison and ranking of highway to provide an overview of the system. The highways were ranked using a severity rate that was calculated similar to the severity rate calculated for the interstate highway system. The US highways with higher severity rate had relatively more high severity crashes. Table 7 shows results for the three year aggregate data from 2004 to 2006.

From Table 7 it is observed that there are more routes in the North to South direction, 12, compared to those from the East to the West, 9. The frequency of crashes is slightly higher for routes from the East to the West, 21,587, compared to those traveling from North to South, 20,473. The frequencies of crashes were more on undivided highway sections compared to divided highway sections. US-71 had the highest frequency of crashes, highest frequency of crashes on undivided highways and also highest frequency of fatalities. US-71 travels along the length of Arkansas connecting some of the major cities with an average AADT of 23,422 vehs/day for the three years of crash data. The longest route is US-67, 307.95 miles with the highest frequency of crashes on divided sections and second highest frequency of crashes. The average AADT is 30,892 vehs/day for the three years of crash data showing heavy vehicular movement. The number of S1 crashes is highest for US-67 and US-71. US-71 also had one of the highest values of crashes per mile. Similarly, US-412 had one of the highest values of crashes per mile. Route US-271 had the highest crashes per mile compared to other US routes. US-271 is one of the major highways which connects Arkansas and Oklahoma passing through Fort Smith and also joining US-71. As this highway connects two states the vehicular movement is higher which leads to higher frequency of crashes. The severity rate is highest for route US-165 which passes through Little Rock.

Table 7. Arkansas US Highways Three Year Crash Data

Route	Total Length (miles)	Total Crashes	Total Crashes		Crashes per mile	Fatalities	Number of Crashes		Severity Rate
			Divided highway	Undivided highway			S1	S2	
49	191.27	2177	478	1699	11.4	33	27	68	4.6
61	51.97	341	13	328	6.6	1	1	9	2.9
62	263.82	3601	498	3103	13.7	46	37	**254**	**8.3**
63	269.04	1914	563	1351	7.1	50	48	92	7.4
64	261.31	3853	834	3019	14.8	43	36	147	4.9
65	247.72	3316	440	2874	13.4	48	41	168	6.5
67	**307.95**	**4793**	**2513**	2280	15.6	56	**50**	149	4.3
70	263.62	4315	1296	3019	16.4	32	28	129	3.7
71	301.66	**8463**	1705	**6758**	**28.1**	**58**	**50**	180	2.8
79	270.12	1191	212	979	4.4	22	20	54	6.4
82	193.54	1210	172	1038	6.3	25	22	56	6.7
165	150.43	421	37	384	2.8	19	16	26	**10.7**
167	192.61	1833	277	1556	9.6	34	26	86	6.5
270	155.26	2223	494	1729	14.3	24	22	111	6.1
271	2.90	105	16	89	**36.2**	0	0	3	2.9
278	223.67	796	105	691	3.6	15	14	40	6.9
371	120.26	275	18	257	2.3	3	3	25	10.2
412	129.77	3876	428	3448	**29.9**	32	30	108	3.6
425	81.21	437	64	373	5.4	8	8	25	7.6
Total	3678.13	45140	10,163	34,975	12.27	549	479	1730	5.0

To identify high crash segments on the US highway system, each highway segment was evaluated using the three methods explained in the above sections and sorted and ranked using the modified sum-of-ranks method. A list of top 500 highway crash highway segments was generated and the crash data analyzed to identify the high crash sections. Table 8 presents the evaluation results of the top 100 highway segments as a long list of top 500 was not considered appropriate to include in the report. Top 500 highway segments were analyzed compared to top 100 for the interstate highway. This was carried out to ensure that a reasonable percent of highway segments were included in the identification of high crash locations and important high crash locations were not left out from consideration.

From Table 8 it was determined that the total number of crashes on the US highways in the top 100 crash segments is 18,994. The average AADT of the top 100 crash segments is 21,998 vehs/day. Also, the analysis of Table 8 is similar to Table 4 for interstate highways. The ranking of segments is not only based on AADT, number of crashes in a particular segment but there are various other factors used in the EB method, or the different weights used in the EPDO method, the different severities in the severity index, etc. Table 8 shows that the combination of all these factors results in the ranking of a crash segment. There are certain sections like 100 on US-67, 20 in US-412, 10 in US-64, 160 in US-71, and 90 in US-65 etc., on which the frequency of crashes is higher identifying sections which are high crash locations. These crash locations identified have more than one crash in the top ranked segments for the three year crash data.

Table 8. Top 100 High Crash Locations on US. Highways of Arkansas

Rank	Route Number	Section Start	Begin LM	Section End	End LM	Analysis Methods			Number of Crashes						Other Vols	
						EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	U-67	100	1.65	100	2.65	28.8	2467.3	236.6	337	3	4	42	67	221	3	30057
2	U-412	020	8.36	020	9.36	37.6	1441.5	429.7	549	0	2	37	78	432	0	34932
3	U-412	080	16.91	080	17.91	32.3	1476.4	220.2	293	2	2	32	149	108	2	18137
4	U-64	090	0.40	090	1.40	43.7	1346.1	349.3	457	0	10	42	167	238	0	31184
5	U-71	160	4.17	160	5.17	29.9	1437.0	251.0	323	0	4	29	114	176	0	29511
6	U-64	000	0.00	010	0.32	25.4	2223.8	189.4	294	0	4	24	87	179	0	14772
7	U-71	160	3.17	160	4.17	30.2	1360.8	264.5	335	0	2	26	120	187	0	27131
8	U-67	120	5.19	120	6.19	35.5	1392.2	203.7	317	0	3	33	175	106	0	20913
9	U-67	100	0.65	100	1.65	24.9	1256.1	215.6	297	1	5	28	69	194	1	52194
10	U-62	010	24.00	020	0.88	27.7	1113.6	245.5	322	0	1	32	92	197	0	30182
11	U-167	010	1.00	010	2.00	26.0	1378.8	162.6	258	0	0	27	115	116	0	17634
12	U-70	130	0.11	130	1.11	18.8	1588.6	182.1	247	0	0	19	54	174	0	15310
13	U-167	010	0.00	010	1.00	23.6	1946.4	125.3	239	1	2	15	109	112	1	11697
14	U-62	110	1.16	110	2.16	18.4	2114.5	149.4	221	3	10	17	37	154	5	14192
15	U-412	020	10.36	020	11.36	20.7	1023.6	229.6	324	0	0	19	36	269	0	31245
16	U-71	160	2.17	160	3.17	20.2	1182.5	173.3	229	0	0	21	75	133	0	21252
17	U-49	030	12.71	030	13.71	22.6	925.2	212.9	290	1	2	20	65	202	1	28668
18	U-71	180	10.89	180	11.89	22.8	899.5	210.3	277	0	2	16	83	176	0	28178
19	U-64	080	4.46	090	0.40	23.4	916.6	164.2	238	0	5	25	90	118	0	24257
20	U-67	120	2.19	120	3.19	22.1	1603.5	99.8	194	0	3	27	98	66	0	12124
21	U-67	120	4.19	120	5.19	24.5	988.9	125.3	205	0	5	28	114	58	0	19353
22	U-71	160	6.17	160	7.17	24.1	779.7	180.9	250	1	3	16	106	124	1	31430
23	U-62	110	2.16	110	3.16	17.5	1115.6	157.6	222	0	9	9	49	155	0	19357
24	U-71	180	8.89	180	9.89	20.9	844.5	174.1	234	1	2	17	79	135	1	25515
25	U-67	100	2.65	100	3.65	21.5	854.1	159.7	230	2	2	27	70	129	2	47866
26	U-270	060	1.62	060	2.62	16.3	1231.1	150.1	204	1	1	17	46	139	1	18729
27	U-70	120	3.26	120	4.26	25.3	819.7	137.5	235	1	8	31	94	101	2	26568
28	U-71	160	5.17	160	6.17	20.4	800.8	159.8	227	1	1	18	78	129	1	31273
29	U-71	140	1.60	140	2.60	18.2	869.0	152.4	206	0	4	22	55	125	0	21986
30	U-71	170	5.92	170	6.92	18.9	759.4	199.3	272	0	1	19	40	212	0	32787
31	U-412	020	12.36	020	13.36	16.9	930.9	154.9	221	0	1	27	32	161	0	22592
32	U-71	140	0.60	140	1.60	17.5	947.3	140.8	192	0	2	14	71	105	0	20961
33	U-412	020	9.36	020	10.36	17.7	793.5	175.5	263	0	1	19	32	211	0	30352
34	U-64	020	0.55	020	1.55	17.9	1119.0	107.0	169	1	1	14	85	68	1	17137
35	U-412	020	11.36	020	12.36	17.2	848.3	170.0	247	1	2	14	37	193	1	26796
36	U-65	010	1.00	010	2.00	16.4	1424.7	103.3	166	1	0	23	59	83	1	11167
37	U-70	130	3.11	130	4.11	16.0	1147.7	127.7	184	0	1	12	63	108	0	14853
38	U-67	120	3.19	120	4.19	19.4	1037.3	93.7	168	0	0	22	95	51	0	15176
39	U-65	090	1.52	090	2.52	17.9	902.7	124.9	176	1	8	17	64	86	1	18491
40	U-70	120	7.26	120	8.26	17.6	913.5	117.9	185	0	1	28	56	100	0	19355
41	U-63	130	1.90	130	2.90	17.9	857.1	111.9	179	0	0	12	88	79	0	19274
42	U-167	170	17.65	180	0.73	17.1	838.5	130.2	203	0	0	15	63	125	0	22430
43	U-412	080	18.91	090	0.53	16.8	912.6	108.2	159	0	1	16	78	64	0	15973
44	U-65	010	20.00	010	21.00	18.2	745.9	124.3	181	0	0	25	71	85	0	22497
45	U-62	010	23.00	010	24.00	21.8	633.9	149.3	210	0	4	25	88	93	0	31499
46	U-71	140	2.60	140	3.60	16.3	812.2	133.7	184	0	2	19	54	109	0	20920
47	U-70	120	4.26	120	5.26	16.4	899.4	99.0	161	1	6	25	47	82	1	18410
48	U-65	090	0.52	090	1.52	17.5	757.7	120.4	178	0	3	17	71	87	0	23089
49	U-71	170	1.92	170	2.92	21.4	584.6	162.4	242	0	2	19	81	140	0	37860
50	U-71	180	11.89	190	0.96	17.6	650.1	141.3	205	1	1	18	58	127	1	30121
51	U-63	130	0.90	130	1.90	15.8	1050.0	79.9	140	2	2	12	75	49	2	13795
52	U-64	010	1.32	010	2.32	13.7	987.9	93.3	155	0	2	15	46	92	0	14416
53	U-71	190	3.96	190	4.96	14.4	676.6	132.4	188	0	2	13	40	133	0	25524
54	U-71	190	2.96	190	3.96	16.4	636.3	128.6	186	1	2	22	47	114	1	26966
55	U-82	050	1.70	050	2.70	12.5	1277.5	61.9	136	0	0	12	51	73	0	10063
56	U-270	050	17.19	050	18.19	16.8	576.3	144.3	204	0	2	18	51	133	0	33728
57	U-412	080	17.91	080	18.91	14.1	732.0	89.8	138	0	0	13	66	59	0	17443
58	U-71	170	4.92	170	5.92	13.7	622.1	130.0	190	0	2	13	31	144	0	28483
59	U-64	010	0.32	010	1.32	10.7	1438.3	56.5	124	1	3	10	31	79	1	8221
60	U-270	050	24.19	060	0.62	11.2	759.5	107.5	153	0	1	13	25	114	0	18886
61	U-49	030	13.71	030	14.71	14.8	589.1	123.7	183	0	1	17	43	122	0	28455
62	U-67	070	17.48	080	0.40	12.6	1045.9	51.4	107	0	2	13	61	31	0	11289
63	U-79	090	11.27	090	12.27	11.0	1582.5	48.7	116	1	2	4	49	60	1	7665
64	U-71	190	1.96	190	2.96	11.9	694.3	102.2	149	0	1	11	37	100	0	21500
65	U-71	180	9.89	180	10.89	16.8	570.3	116.9	175	0	2	18	65	90	0	28075
66	U-70	120	6.26	120	7.26	9.6	1080.0	67.2	106	0	2	11	32	61	0	10121
67	U-70	130	1.11	130	2.11	11.5	779.4	82.4	137	0	1	12	37	87	0	16694
68	U-79	090	4.27	090	5.27	11.9	876.3	61.3	117	0	1	12	52	52	0	12408
69	U-82	030	0.40	030	1.40	11.8	1026.7	54.9	117	1	1	21	34	60	1	11069
70	U-82	050	2.70	050	3.70	11.5	1019.3	51.0	112	0	0	18	43	51	0	10325
71	U-71	180	2.89	180	3.89	14.1	568.4	112.3	169	0	1	22	35	111	0	27460
72	U-64	060	11.71	060	12.71	12.2	598.5	98.2	157	1	4	10	29	113	1	24032
73	U-71	030	1.70	030	2.70	13.9	571.8	97.9	147	0	0	6	70	71	0	23584
74	U-49	100	0.51	100	1.51	11.8	812.4	51.5	94	0	2	11	62	19	0	11729
75	U-70	120	2.26	120	3.26	23.3	542.8	55.1	235	1	0	30	90	114	1	42181
76	U-62	040	10.85	040	11.85	12.0	717.8	57.4	96	0	3	15	55	23	0	12219
77	U-67	010	0.00	010	1.00	9.7	1052.3	43.4	99	0	1	6	46	46	0	9372
78	U-71	170	6.92	170	7.92	11.9	565.0	110.5	166	0	0	19	19	128	0	26869
79	U-270	060	0.62	060	1.62	10.4	657.0	83.7	124	1	3	14	22	84	2	17619
80	U-278	050	0.25	050	1.25	9.5	778.1	64.2	104	0	2	9	34	59	0	13246
81	U-65	080	18.85	090	0.52	15.3	530.7	82.0	149	0	2	20	59	68	0	27270
82	U-65	010	19.00	010	20.00	14.3	528.2	86.3	147	0	1	16	57	73	0	25437
83	U-71	140	4.60	140	5.60	10.9	616.3	84.7	126	0	3	12	32	79	0	18796
84	U-70	130	2.11	130	3.11	11.5	639.7	65.1	120	0	0	21	34	65	0	17421
85	U-71	140	15.60	150	0.99	9.9	685.1	65.3	99	0	0	16	35	48	0	13226
86	U-412	010	0.00	010	1.00	17.7	475.3	73.9	146	0	1	22	86	37	0	28231
87	U-71	180	7.89	180	8.89	13.5	514.6	93.0	146	0	2	13	51	80	0	26342
88	U-70	080	2.05	080	3.05	10.9	668.7	56.9	139	0	1	10	33	95	0	24367
89	U-71	140	3.60	140	4.60	12.4	555.8	79.9	122	0	0	25	37	60	0	20120
90	U-270	050	16.19	050	17.19	11.1	591.7	67.8	107	0	4	14	39	50	0	21258
91	U-64	060	10.71	060	11.71	8.6	645.0	80.4	132	0	1	5	19	107	0	18911
92	U-79	090	1.27	090	2.27	11.1	644.0	55.4	102	0	4	16	39	43	0	15237
93	U-65	090	3.52	090	4.52	12.7	519.8	74.9	136	0	3	11	49	73	0	25853
94	U-425	030	16.45	040	0.69	10.8	615.0	57.5	101	0	1	21	34	45	0	15156
95	U-65	090	18.52	090	19.52	13.6	469.5	73.5	139	0	4	15	49	71	0	27086
96	U-71	140	8.60	140	9.60	11.4	500.6	89.4	141	1	0	10	36	94	1	25768
97	U-62	010	20.00	010	21.00	13.2	471.6	67.4	108	0	3	16	61	28	0	21043
98	U-65	010	0.00	010	1.00	8.7	631.8	56.4	91	1	1	5	37	47	1	13431
99	U-412	010	1.00	010	2.00	17.4	428.4	61.1	132	1	2	18	91	20	1	28248
100	U-64	010	5.32	020	0.55	10.1	606.1	48.1	88	0	0	16	43	29	0	15761

Table 9 provides a summary of the top 500 highway segments. From Table 9 it can be inferred that the frequency of fatalities were relatively high for the three year crash data and the top 500 segments account for 33% of the total fatalities. Route US-71 has the highest frequency of fatalities when compared to other US highway routes. The number of high crash segments is also highest for route US-71 when compared to other routes. Other routes that have significant number of high crashes are 49, 62, 63, 64, 65, 67, 70, 71, 270, and 412. These routes should be considered as the top ten US routes most vulnerable to high severity and frequency of crashes. These routes are in bold in Tables 9 and 10.

Table 9. Summary of high crash locations on US highways in Top 500 ranked segments

US Routes	Number of High Crash Segments	Section Ranked Highest (Rank)	Number of Fatalities in Top 500 (3 year data)	Total Number of Fatalities by route (3 year data)
49	**31**	30(17)	10	**33**
61	7	20(151)	0	1
62	**51**	**10(10)**	**20**	**46**
63	**32**	**130(41)**	**20**	**50**
64	**40**	**90(4)**	6	**43**
65	35	**10(44)**	15	**48**
67	**40**	**100(1)**	**21**	**56**
70	**50**	130(12)	15	32
71	**70**	**160(5)**	**22**	**58**
79	16	90(63)	5	22
82	13	50(55)	5	25
165	8	50(190)	4	19
167	15	10(11)	5	34
270	**29**	60(26)	12	24
271	2	10(258)	0	0
278	16	50(80)	4	14
371	4	20(216)	0	3
412	**37**	**20(2)**	**17**	**30**
425	4	90(95)	0	8
Total	500	-	181	546

To identify the high crash corridors, Table 10 was prepared which provides detailed information on continuous highway segments with begin and end log mile and section numbers that have high crash frequency. From Table 10 it can be inferred that the high crash segments are located in particular regions of each route of the US highway network system. All of the listed segments are in the top 500 ranked segments. These segments should be given high priority in improving the roadway conditions to reduce crash frequency and severity.

Table 10. Summary of High Crash Segments on US Highways

US Routes	Begin LM (Section Start)- End LM (Section End)	S1 Crashes, HCS (3 year data)	S2 Crashes, HCS (3 year data)	S1 + S2 crashes, HCS
49	15.0(10)-2.44(20) 13.44(20)-19.44(20) 8.71(30)-14.71(30), 17.71(30)-1.68(30) 5.97(80)-7.97(80) 21.43(90)-6.51(100) 22.51(100) 24.51(100)	**9**	**31**	**40**
62	14(10)-16(10), 17(10)-3.88(20) 9.97(30)-3.85(40), 9.85(40)-1.95(50) 13.95(50)-15.95(50) 0.16(110)-7.16(110) 0.03(170)-3.03(170) 11.15(190)-0.53(200)	**13**	**92**	**105**
63	5.04(30)-7.04(30) 12.21(60)-15.21(60), 17.21(60)-2.41(70) 13.41(70)-1.50(80) 3.87(120)-4.90(130)	**10**	**9**	**19**
64	0(10)-4.32(10), 5.32(10)-2.55(20) 4.55(20)-6.55(20), 7.55(20)-9.55(20) 11.18(30)-13.18(30) 12.08(40)-1.51(50) 8.71(60)-13.71(60) 1.46(80)-3.46(80), 4.46(80)-2.40(90) 7.40(90)-9.40(90) 14.40(150)-3.33(160)	**4**	**55**	**59**
65	0.0(10)-3.0(10) 18.0(10)-23.0(10) 15.91(70)-3.85(80) 18.85(80)-4.52(90) 9.52(90)-13.52(90), 16.52(90)-20.52(90) 5.83(170)-7.83(170) 16.29(200)-1.16(210)	**11**	**66**	**77**
67	0.0(10)-2.0(10) 12.84(20)-14.84(20) 14.70(50)-0.9(60) 17.48(70)-1.40(80) 6.27(90)-6.65(100) 7.65(100)-11.65(100) 9.31(110)-6.19(120) 0.26(160)-2.26(160) 6.13(180)-1.38(190)	**17**	**61**	**78**
70	2.0(10)-4.0(10), 7.0(10)-9.0(10) 0.05(80)-6.05(80), 9.05(80)-15.05(80) 0.22(90)-3.22(90) 0.26(120)-5.11(130) 11.23(170)-13.23(170) 19.19(180)-0.82(190) 10.77(200)-14.77(200)	**11**	**67**	**78**

Table 10. continued

US Routes	Begin LM (Section Start)- End LM (Section End)	S1 Crashes, HCS (3 year data)	S2 Crashes, HCS (3 year data)	S1 + S2 crashes, HCS
71	11.72(20)-3.70(30) 9.42(40)-11.42(40) 12.49(60)-1.11(70) 2.63(100)-4.63(100) 9.85(130)-9.60(140), 15.60(140)-1.99(150) 0.17(160)-7.17(160) 30.17(160)-3.89(180) 5.89(180)-8.96(190)	**15**	**88**	**103**
79	21.38(30)-1.93(40) 0.94(60)-2.94(60) 6.55(80)-3.27(90), 4.27(90)-6.27(90)	4	8	12
82	0.0(10)-3.0(10) 16.60(20)-1.40(30) 0.70(50)-4.70(50) 8.6(80)-10.60(80)	4	3	7
165	46.83(50)-49.83(50) 5.07(90)-7.07(90)	3	3	6
167	0.0(10)-4.0(10) 11.83(100)-1.33(110) 14.65(170)-0.73(170)	4	13	17
270	12.69(40)-2.19(50) 11.19(50)-20.19(50), 21.19(50)-23.19(50) 24.19(50)-5.62(60) 15.62(90)-0.69(100)	**9**	**38**	**47**
278	1.88(40)-1.25(50), 23.25(50)-25.25(50) 0.84(120)-2.84(120) 10.19(140)-3.58(150)	2	6	8
412	0.0(10)-4.0(10) 5.36(20)-14.36(20) 21.36(20)-3.30(30) 7.30(30)-9.30(30) 15.30(30)-4.55(40) 3.61(60)-0.64(70) 13.91(80)-2.53(90)	**16**	**45**	**61**

Figure 7 shows that the severity including property damage only, S5 has the highest frequency compared to any other crash severity. The total frequency of crashes by severity for all segments for S1 is 2.82 times (473/168) the total frequency of crashes in top 500 segments. Similarly, it is 2.47 for S2, 1.54 for S3, 1.5 for S4, and 1.67 for S5. Hence, it can be concluded that the crash severity including fatalities is at a higher rate for all the segments for the three year crash data. Also, for the three year crash data the total frequency of crashes for the top 100 ranked segments was 42% of the total frequency of crashes whereas for the top 500 crashes the total frequency of crashes represents 76.7%. Hence, the top 500 high crash segments captured significant amount of crashes on the network and they are the most important segments that require improvements to reduce the frequency and the severity of crashes on the US highway network. The S1 type of crashes was randomly present over the entire highway network, the top 500 represents 36% of the S1 crashes compared to the entire network. The S5 type of crashes were present over the entire highway network illustrating that the crashes including property damage only was very high and occurs commonly. The frequency of crashes including fatalities and the number of high crash segments were the highest for US-71 when compared to other routes in the top 500 ranked segments.

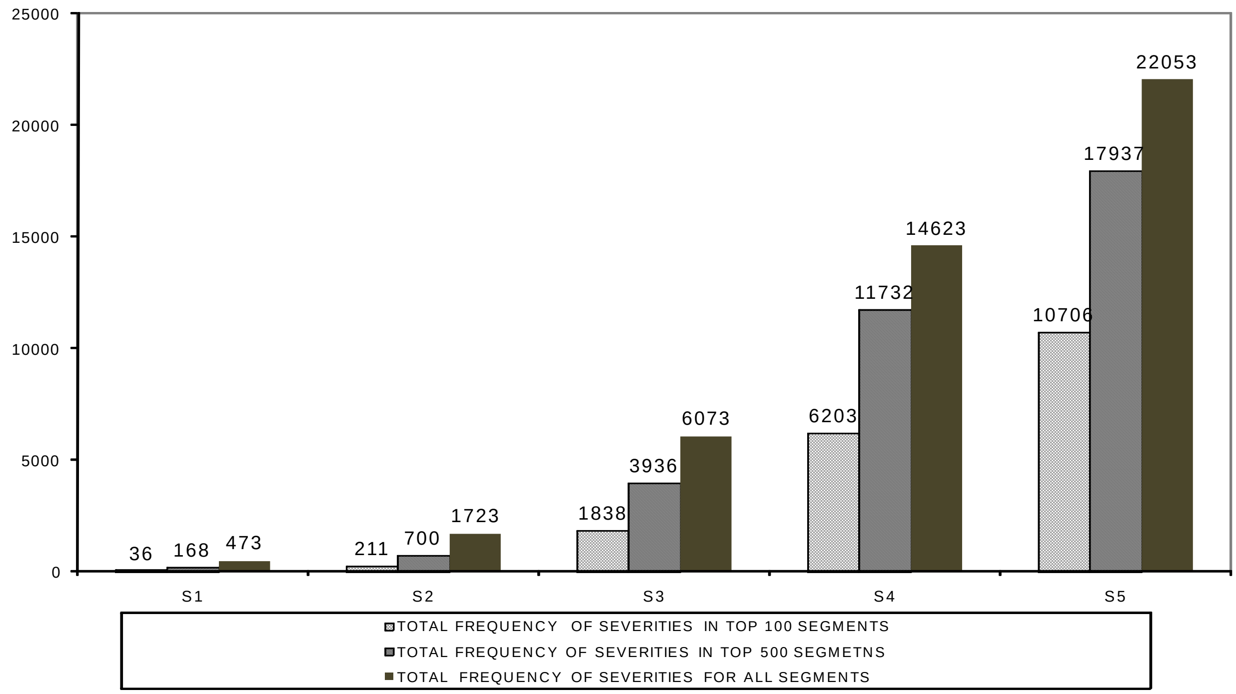


Figure 7. Comparison of total frequency of severities on US Highway by Top 100, Top 500 ranked segments and all segments for 3 years of crash data

From the overall study on the US highways it can be inferred that US-71 has the highest frequency of crashes. The frequencies of crashes on undivided sections are higher compared to frequency of crashes on divided sections of the US highway. The severity including fatalities was highest on US-71 and US-67. US-271 had the highest crashes per mile. The severity including property damage only has highest frequency for the top 100 and top 500 ranked segments and also for all segments for the three year crash data.

VII.3. State Highways

Arkansas has a total of two hundred and thirty nine State highways. Table A9, in the appendix, shows an initial comparison of the state highways in which the highways are ranked by a severity rate for the three years of crash data, 2004 to 2006. The severity rate was calculated using the same methodology as described for interstate and US highways. The State highways with higher severity rates had higher number of serious crashes. Table A10, in the appendix, gives a detailed analysis of the crash frequency for divided and undivided sections of the State highways for the three years of crash data.

On State highways there are more routes which travel in the North-South direction (137) compared to the routes that travel in the East-West direction (102). For the routes in the North-South direction, the frequency of crashes was 29,899 for all segments for the three year crash data and was higher than the frequency of crashes for routes in the East-West direction, 21,075. Table A9 indicates that route S-7 is one of the longest state highway routes with heavy vehicular movement and has the highest frequency of crashes including S1 and S2 crashes. Route S-341 has the highest severity rate, however.

From Table A10, it can be inferred that the frequency of crashes on undivided sections, 42,842 was much higher compared to frequency of crashes on divided sections, 6865. Route S-7 has the highest frequency of crashes, 4725, the highest frequency of fatalities, 46, the highest sum of S1 and S2 crashes, 220 for the three year crash data.

Similar to the Interstate and US highway systems, to identify high crash segments on the State highway system, all highway segments were evaluated using the three methods, i.e. Crash Rate, EPDO and EB explained in the above sections and then sorted and ranked using the modified sum-of-ranks method. A list of top 500 highway crash highway segments was prepared and analyzed. Table 11 presents the evaluation results of the top 100 highway segments only as a long list of top 500 was not considered appropriate to include in the report. From Table 11, the frequency of crashes among the top 100 crash segments were determined to be 14,598. The average AADT of these top 100 segments was found to be 15,686 vehs/day. The analysis also indicated that the ranking of a segment to be a high crash location is based on many factors such as AADT, frequency of crashes, parameters like weights used, etc. The severity including property damage only is the highest for the top ranked segments and also for all the segments for the three year crash data compared to other severities. The overall frequency of crashes for the top 100 ranked segments is 30% (14,598/49,454) compared to the frequency of crashes for all segments. From Table 11 it can also be inferred that the frequency of fatalities are relatively high for the three year crash data when compared to the top 100 crash segments.

Out of a total 239 state routes, 101 routes had no high crash segment identified in the top 500 high crash segments. These were therefore not considered for further analysis. Out of the remaining 138 routes, 55 routes had only one mile segment identified, another 52 routes had 2 one mile segments and another 33 had three 3 mile segments, and so on. These 138 routes were further analyzed and 28 routes were identified which indicated high crash routes. Table 12 provides a summary of the results of the 28 selected highway routes from the top 500 high crash segment analysis. The 28 routes were selected based on the values of total crashes/year/mile, and sum of S1 and S2 crashes/year/mile. Table 12 presents the results by each route, the number of high crash segments, the section ranked highest and its ranking, and the total number of fatalities among the top 500 high crash segments found and the total number of fatalities by route for the three years of crash data. From Table 12, it can be inferred that route S-7 has the highest frequency of fatalities and the highest frequency of crash segments in the top 500 ranked segments when compared to other routes. Route S-7 is also one of the longest state highway routes. From the results of Table 12, out of the 28 route, 13 top state routes were selected and further categorized, nine in the top category and four in the second category. The 13 were identified because of the number of high crash segments and the number of fatalities in the top 500 segments and the total number of fatalities by route during the last three years. The nine are indicated in bold and the remaining four are italicized in Table 12. To identify the high crash segments on these 28 selected routes, Table 13 presents the continuous segments or hot spots that are most vulnerable to high frequency and severity of crashes.

Table 11. Top 100 High Crash Locations on State Highways of Arkansas

Rank	Route Number	Section Start	Begin LM	Section End	End LM	Analysis Methods			Number of Crashes						Other Vbls		Rank	Route Number	Section Start	Begin LM	Section End	End LM	Analysis Methods			Number of Crashes						Other Variables	
						EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT							EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	S-7	090	10.57	090	11.57	25.5	2042.1	236.3	365	0	1	25	57	282	0	18754	51	S-365	120	0.01	120	1.01	11.3	709.9	78.2	115	1	2	14	38	60	1	14827
2	S-7	090	7.57	090	8.57	33.3	1624.2	324.7	461	1	4	33	74	349	1	27103	52	S-10	000	2.00	000	3.00	12.1	713.5	62.6	104	1	0	6	68	29	1	15995
3	S-176	010	0.00	010	1.00	25.2	1766.8	239.6	305	0	2	30	74	199	0	17136	53	S-9	070	3.63	070	4.63	4.5	2266.3	18.6	42	0	1	6	17	18	0	2033
4	S-183	010	8.00	010	9.00	35.5	1483.1	231.9	303	1	1	28	190	83	1	20034	54	S-5	080	3.48	080	4.48	12.0	700.7	70.3	105	0	0	8	67	30	0	14009
5	S-69	020	18.23	030	0.76	22.6	1516.4	176.9	271	0	1	16	86	168	0	19948	55	S-25	030	2.33	030	3.33	8.4	739.3	62.3	92	0	2	5	35	50	0	14451
6	S-22	010	3.00	010	4.00	32.8	1101.4	261.3	415	1	2	25	107	280	1	35398	56	S-175	020	1.05	020	2.05	5.1	1601.9	16.8	34	1	1	7	23	2	1	2012
7	S-22	010	4.00	010	5.00	29.8	1101.4	249.4	390	1	0	20	98	271	1	33416	57	S-112	030	0.04	030	1.04	6.4	794.5	51.7	82	0	0	7	19	56	0	9685
8	S-69	030	0.76	030	1.76	23.2	1179.3	173.0	266	2	0	26	76	162	2	21752	58	S-176	020	1.97	020	2.97	12.6	655.9	87.6	147	0	0	15	42	90	0	20500
9	S-190	050	4.52	050	5.52	15.9	1365.4	89.1	146	0	1	19	71	55	0	10742	59	S-190	050	5.52	050	6.52	5.6	954.1	26.8	52	0	0	7	25	20	0	5325
10	S-88	040	2.37	050	0.46	14.5	1610.1	59.8	186	0	4	12	40	130	0	11754	60	S-367	140	2.97	140	3.97	6.2	781.0	54.9	77	0	0	8	17	52	0	9774
11	S-7	090	9.57	090	10.57	22.1	1101.9	181.1	275	0	4	28	55	188	0	24401	61	S-10	080	9.23	080	10.23	18.0	614.2	125.3	203	0	1	25	56	121	0	30204
12	S-89	010	19.00	010	20.00	12.7	1417.5	96.2	168	1	2	14	27	124	1	14052	62	S-10	080	11.23	080	12.23	12.9	640.1	97.8	155	1	2	11	40	101	1	22263
13	S-112	000	1.00	000	2.00	14.9	1231.5	114.8	179	0	1	18	45	115	0	14922	63	S-51	010	29.82	010	30.82	6.9	744.6	52.5	99	0	4	5	11	79	0	12721
14	S-22	010	5.00	010	6.00	20.4	1107.7	167.5	244	0	1	21	68	154	0	20498	64	S-1	170	2.71	170	3.71	8.6	1133.6	11.9	95	0	1	16	21	57	0	7869
15	S-7	140	2.01	140	3.01	15.6	1161.1	121.1	203	1	3	23	26	150	1	16506	65	S-128	100	2.08	100	3.08	4.6	996.7	27.0	49	0	1	6	15	27	0	4539
16	S-7	090	6.57	090	7.57	24.9	997.9	263.4	373	0	2	16	58	297	0	34143	66	S-69	020	1.23	020	2.23	5.7	834.2	29.6	71	1	0	4	18	48	1	8542
17	S-22	010	2.00	010	3.00	24.9	978.9	183.1	283	0	1	27	89	166	0	26676	67	S-192	010	0.00	010	1.00	3.0	7255.5	18.4	28	1	1	4	8	14	1	790
18	S-59	050	24.50	050	25.50	27.7	946.8	196.9	273	0	1	20	135	117	0	27278	68	S-190	050	1.52	050	2.52	3.6	1368.9	17.1	34	0	0	7	12	15	0	3491
19	S-10	080	10.23	080	11.23	24.0	941.0	184.2	260	2	2	32	75	149	2	26583	69	S-38	000	0.00	000	1.00	5.8	894.1	20.4	65	0	0	14	10	41	0	6660
20	S-7	150	0.03	150	1.03	16.2	997.6	126.1	206	0	2	20	40	144	0	18908	70	S-112	000	2.00	000	3.00	8.2	687.3	49.1	107	0	1	10	19	77	0	14315
21	S-22	010	0.00	010	1.00	15.6	1013.0	124.3	188	0	1	16	51	120	0	17659	71	S-89	010	15.00	010	16.00	8.6	700.6	39.7	102	0	1	16	17	68	0	13351
22	S-161	030	0.00	030	1.00	7.8	1905.7	53.5	78	0	3	5	33	37	0	3762	72	S-5	180	20.14	190	1.00	7.9	653.5	63.5	97	0	8	7	11	71	0	13721
23	S-255	030	5.46	040	0.28	17.5	912.2	145.3	205	0	3	19	55	128	0	20790	73	S-25	030	1.33	030	2.33	7.3	670.6	56.2	84	0	0	5	30	49	0	12933
24	S-36	030	19.33	030	20.33	16.7	914.5	101.0	157	0	2	23	66	66	0	16232	74	S-22	030	10.21	030	11.21	5.8	854.1	21.2	56	1	1	10	16	28	1	6200
25	S-102	030	4.86	030	5.86	23.2	877.9	180.8	299	0	2	27	60	210	0	31196	75	S-59	060	0.22	060	1.22	10.1	648.0	51.4	93	1	0	18	34	40	1	19916
26	S-112	030	1.04	030	2.04	10.6	1043.0	85.4	125	0	2	15	27	81	0	11186	76	S-51	010	30.82	010	31.82	6.7	719.3	35.6	74	0	4	11	12	47	0	9534
27	S-7	090	8.57	090	9.57	22.2	877.5	174.2	263	1	7	22	62	171	1	27814	77	S-77	050	15.99	050	16.99	9.2	632.2	66.9	124	0	0	5	31	88	0	18889
28	S-88	040	1.37	040	2.37	13.8	985.8	63.0	178	0	2	11	42	123	0	16823	78	S-7	140	1.01	140	2.01	8.1	650.7	57.7	108	0	1	12	15	80	0	17071
29	S-18	070	0.42	070	1.42	9.3	1341.3	44.2	87	0	2	11	38	36	0	6614	79	S-161	030	2.00	030	3.00	8.1	680.7	34.0	74	0	0	12	34	28	0	10712
30	S-161	030	10.00	030	11.00	9.0	1071.8	68.6	111	0	1	11	25	74	0	10650	80	S-107	010	8.00	010	9.00	8.1	625.7	54.1	103	0	0	7	27	69	0	15112
31	S-180	000	0.00	000	1.00	29.9	1056.6	30.5	345	0	4	23	112	206	0	29991	81	S-7	090	5.57	090	6.57	14.6	547.8	128.6	204	0	4	18	23	159	0	34028
32	S-107	010	0.00	010	1.00	16.3	868.3	113.3	221	0	1	14	45	161	0	29887	82	S-45	050	2.56	050	3.56	6.6	638.7	54.0	80	0	0	5	25	50	0	12225
33	S-103	000	1.00	000	2.00	6.4	2283.1	34.8	71	0	1	6	24	40	0	7462	83	S-130	060	0.00	060	1.00	6.2	792.3	17.7	54	0	0	3	36	15	0	8987
34	S-365	110	15.35	110	16.35	13.1	880.8	109.0	153	1	2	14	39	97	2	17400	84	S-89	010	16.00	010	17.00	7.5	652.8	32.9	97	0	0	10	19	68	0	13631
35	S-18	040	2.27	040	3.27	14.1	829.4	116.3	170	0	0	14	48	108	0	18956	85	S-112	010	0.37	010	1.37	9.6	612.8	37.7	92	0	4	10	36	42	0	13857
36	S-141	000	2.00	010	0.92	9.9	960.5	55.6	109	1	2	11	30	65	1	10953	86	S-265	020	2.30	020	3.30	11.9	556.9	74.4	129	0	1	15	41	72	0	21357
37	S-89	010	17.00	010	18.00	12.7	871.4	64.3	143	0	1	18	39	85	0	15092	87	S-29	030	15.18	040	0.73	5.3	761.3	20.9	52	0	0	9	18	25	0	6990
38	S-7	140	3.01	140	4.01	12.9	818.7	105.0	175	0	0	18	27	130	0	19615	88	S-5	180	19.14	180	20.14	2.9	1200.7	16.9	35	0	2	3	6	24	0	7877
39	S-18	040	0.27	040	1.27	12.7	800.7	112.0	164	0	3	9	38	114	0	20254	89	S-18	040	1.27	040	2.27	10.8	555.9	76.4	119	0	1	11	40	67	0	19553
40	S-36	030	23.33	040	0.43	11.6	892.5	52.4	95	0	0	14	59	22	0	9782	90	S-18	060	16.06	070	0.42	5.8	704.7	25.4	52	2	0	4	25	21	2	7360
41	S-7	090	11.57	090	12.57	8.1	996.2	45.8	98	1	1	7	24	65	1	8991	91	S-22	030	11.21	030	12.21	4.7	862.9	15.4	49	0	1	7	15	26	0	5190
42	S-7	130	13.73	130	14.73	7.4	1043.6	38.1	87	0	1	6	26	54	0	7745	92	S-284	010	15.44	020	0.19	4.6	805.0	18.5	36	0	0	5	25	6	0	5325
43	S-22	010	1.00	010	2.00	16.1	754.3	113.9	197	0	1	14	55	127	0	24477	93	S-102	030	2.86	030	3.86	11.1	549.0	57.4	124	1	1	14	34	74	1	20677
44	S-16	020	12.85	030	0.57	16.9	732.8	116.7	178	0	4	17	63	94	0	24349	94	S-190	050	0.52	050	1.52	2.9	1301.0	14.6	31	0	0	2	13	16	0	3542
45	S-365	110	14.35	110	15.35	8.9	833.3	76.5	109	0	2	6	30	71	0	12433	95	S-180	000	1.00	020	0.35	11.4	577.4	29.5	120	2	1	12	39	66	2	20605
46	S-16	130	14.66	130	15.66	10.4	854.5	49.6	92	0	0	15	45	32	0	9853	96	S-107	010	4.00	010	5.00	11.5	542.0	59.0	143	0	0	12	36	95	0	24738
47	S-321	010	3.00	010	4.00	8.8	811.1	73.0	105	0	4	11	19	71	0	12560	97	S-21	060	0.35	060	1.35	5.0	704.9	23.0	42	0	0	4	28	10	0	5457
48	S-5	080	2.48	080	3.48	13.3	739.6	80.1	117	0	0	7	77	33	0	14862	98	S-107	010	1.00	010	2.00	9.2	547.1	61.7	142	0	0	8	18	116	0	23765
49	S-331	000	4.00	010	0.23	7.3	799.5	66.6	113	0	2	4	13	94	0	13961	99	S-190	050	7.52	050	8.52	10.5	624.4	19.1	89	0	1	12	51	25	0	13598
50	S-107	010	3.00	010	4.00	14.8	690.0	96.3	179	1	0	20	40	118	1	23827	100	S-69	020	0.23	020	1.23	4.7	733.6	19.2	53	0	0	6	16	31	0	7170

Table 12. Summary of high crash locations on State highways in Top 500 ranked segments

State Routes	Number of High Crash Segments	Segment Ranked Highest (Rank)	Number of Fatalities in Top 500 (3 year data)	Total Number of Fatalities by route (3 year data)
1	10	170(64)	1	15
5	**25**	**80(48)**	**12**	**36**
7	**34**	**90(1)**	**11**	**46**
8	**6**	**130(430)**	**6**	**11**
10	**14**	**80(10)**	**5**	**20**
12	*7*	*30(243)*	*2*	*11*
16	**14**	**20(44)**	**3**	**19**
18	*9*	*70(29)*	*2*	*9*
22	**11**	**10(6)**	**3**	**13**
36	4	30(24)	0	1
51	2	10(63)	0	3
59	**9**	**50(18)**	**4**	**17**
60	2	0(109)	2	6
69	**9**	**20(5)**	**4**	**13**
88	6	40(10)	0	5
102	7	30(25)	1	4
107	5	10 (32)	1	5
112	10	0(13)	0	0
133	6	0(138)	2	4
141	2	0(30)	2	7
161	6	30(30)	0	5
180	3	0(31)	2	2
255	2	30(23)	2	4
265	*8*	*20(107)*	*3*	*7*
321	2	10(47)	0	2
338	5	10(47)	0	4
365	*12*	*110(45)*	*2*	*9*
367	**13**	**140(60)**	**4**	**11**

From Table 13 it can be inferred that the high crash segments are located in particular regions of each route of the state highway network system. The listed segments are in the top 500 ranked segments. These segments should be given more importance in improving traffic safety. From Table 13, the segment 1.6(90) to 12.6(90) was identified as the longest continuous high crash segment on route S-7. Hence, more safety measures must be provided to improve this section.

Table 13. Summary of High Crash Segments on State Highways

State Routes	Begin LM (Section Start)-End LM (Section End)	S1 Crashes, HCS (3 year data)	S2 Crashes, HCS (3 year data)
1	11.0(110)-1.9(120) 4.9(130)-6.9(130) 0.7(170)-3.7(170)	0	4
5	1.5(80)4.5(80) 1.0(90)-5.0(90) 6(90)-0.4(120) 4.4(120)-6.4(120) 2.6(170)-4.6(170) 18.1(180)-1.0(190)	**9**	**35**
7	1.6(90)-12.6(90) 5.4(100)-8.4(100) 13.7(130)-4.0(140) 0.0(150)-3.0(150) 3.1(200)-7.1(200) 8.1(200)-10.1(200)	**4**	**25**
8	18.4(70)-0.8(80) 7.9(130)-0.5(140)	**6**	**0**
10	1.0(0)-3.0(0)	**5**	**14**
12	*1.2(30)-3.2(30)*	*0*	*6*
16	0.9(20)-2.9(20) 9.9(20)-3.6(20) 13.7(130)-15.7(130)	**1**	**10**
18	0.3(40)-5.3(40) 16.1(60)-3.4(70)	*2*	*11*
22	0.0(10)-6.0(10) 7.0(10)-9.0(10) 10.21(30)-12.21(30)	**3**	**8**
36	19.3(30)-22.3(30)	0	3
51	29.8(10)-31.8(10)	0	3
59	23.50(50)-1.2(60)	**2**	**4**
60	0.0(0)-2.0(0)	2	4
69	0.2(20)-20(2.2) 18.2(20)-2.8(30) 5.3(60)-1.7(70)	**4**	**3**
88	0.4(40)-0.5(50)	0	10
102	3.0(20)-5.0(20) 1.9(30)-5.9(30)	1	12
107	0.0(10)-2.0(10) 3.0(10)-6.0(10)	1	3

Table 13. Continued

State Routes	Begin LM (Section Start)-End LM (Section End)	S1 Crashes, HCS (3 year data)	S2 Crashes, HCS (3 year data)
112	1.0(0)-3.4(10) 0.0(30)-2.0(30)	0	8
133	0.0(0)-2.0(0) 0.4(10)-2.4(10)	1	5
141	7.9(10)-8.9(10)	1	0
161	0.0(30)-3.0(30)	0	3
180	0.0(0)-0.4(20)	2	5
255	4.5(30)-0.3(40)	1	3
265	6.0(10)-8.0(10) 1.3(20)-3.3(20) 5.3(20)-9.3(20)	*3*	*10*
321	3.0(10)-4.0(10)	0	4
338	2.0(10)-6.0(10)	2	7
365	13.4(110)-1.0(120) 18.5(140)-20.5(140)	*3*	*7*
367	1.0(120)-0.7(130) 9.7(130)-1.0(140) 2.0(140)-4.0(140) 3.1(150)-5.1(150)	**3**	**7**

To evaluate if the top 500 high crash segments included significant number of high severity crashes the results were compared with the total number of crashes for the state routes. To show the difference between the top 100 and the top 500 high crash segments, frequency of crashes by type was also compared. Figure 8 presents the results of the comparison for the three years of crash data. The comparison shows that the severity including property damage only, S5 has the highest frequency than any other crash severity for the top 100, top 500, and all segments data. The severity including fatalities has higher rate of frequency for all the segments than the top 500 crash segments. The total frequency of crashes for all segments for S1 is 5.67 times (613/106) the total frequency of crashes in top 500 segments, showing that the crash severity including fatalities is spread randomly over the highway network. The frequency of crashes in top 100 crash segments constitutes 29.5% (14,598/49,454), and the frequency of crashes in top 500 crash segments constitutes 54.5% (26,959/49,454) of the total frequency of crashes for the three year crash data.

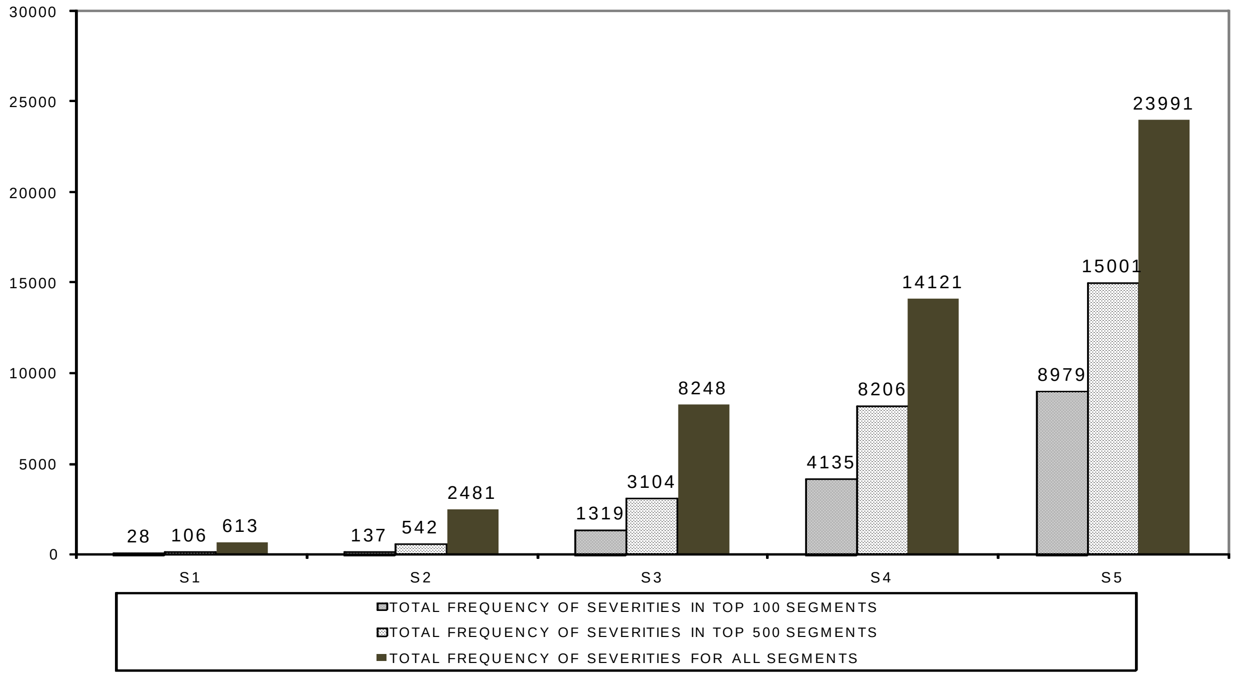


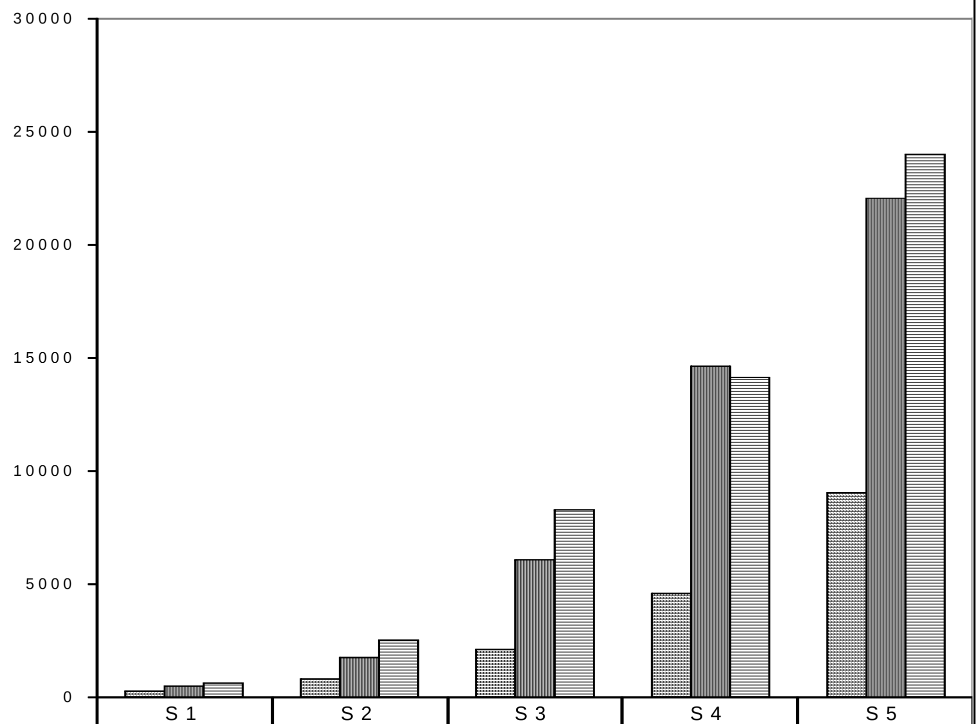
Figure 8. Comparison of total frequency of severities on State Highway by Top 100, Top 500 ranked segments and all segments for 3 years of crash data.

VII.4. Summary and Analysis of Interstate, US and State Highways using Crash Severity and AADT

The three highway networks were also compared in terms of frequency of crashes by severity. The comparison was not performed to evaluate their performance and compare them but to analyze and indicate which highway networks are most vulnerable to high severity and high frequency of crashes. Only in this manner can a safety engineer propose remedial measures and allocate resources. Figure 9 shows an analysis and comparison of the three highway networks.

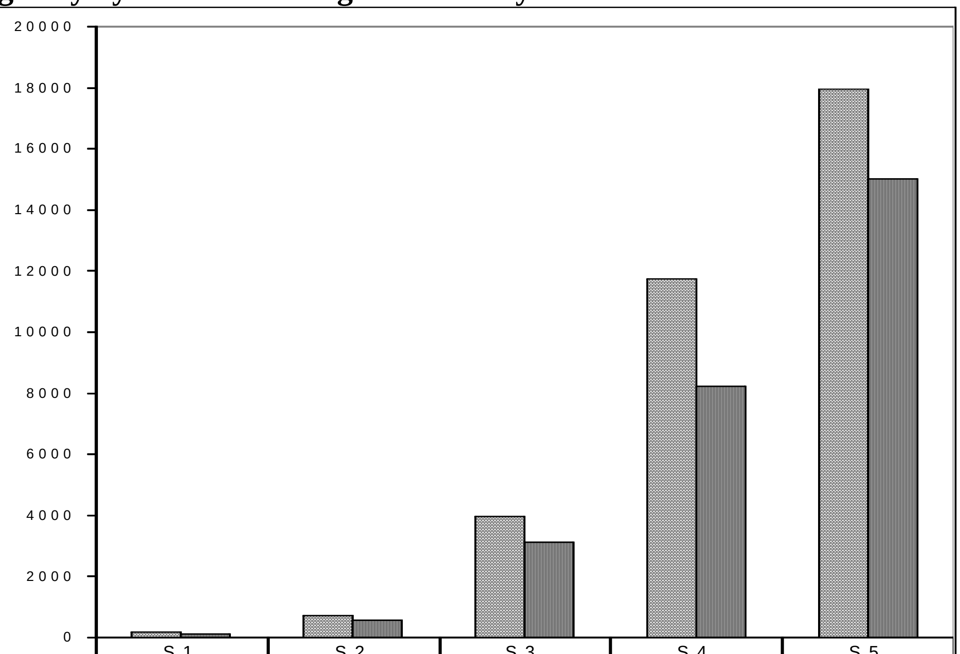
From Figure 9, it can be inferred that the frequencies of crashes were higher on State highway network when compared to other highway networks. The severity including fatalities was also at a higher frequency for the State highway network system when compared to other highway networks. This can also be seen for S2, S3 and S5 crashes. Only for S4, the US network indicates a slightly higher frequency of crashes. This indicates that State highways are more prone to crashes including crashes that include loss of life.

Figure 10 compares the frequency of crashes by type for the US and State highway routes for the top 500 high crash segments. It can be observed that the frequency of crashes for all severities is higher for the US routes compared to the State routes. This indicates that the top 500 high crash segments capture higher number of crashes for US highways compared to State highways. Additionally, the top 500 high crash segments are more effective for US highways as the crashes are more concentrated on the 18 US highways compared to 138 State highways.



	S1	S2	S3	S4	S5
INTERSTATES	224	793	2083	4551	9049
US HIGHWAYS	473	1723	6073	14623	22053
STATE HIGHWAYS	613	2481	8248	14121	23991

Figure 9. Summary of Frequency of Crashes by Severity on Interstates, US and State Highway Systems for All segments for 3 years of crash data



	S1	S2	S3	S4	S5
US HIGHWAYS	168	700	3936	11732	17937
STATE HIGHWAYS	106	542	3104	8206	15001

Figure 10. Summary of Frequency of Crashes by Severity on US and State Highway Systems for Top 500 High Crash Segments

Figure 12 shows the summary of the three highway systems in terms of frequency of crashes for the top 100 segments with the three year average AADT. It illustrates that the total number of crashes is highest for the US highway system when crashes from the top 100 segments are summed up. Also, when the ratio of number of crashes to the three year average AADT is analyzed, the ratio is highest for the State highway system indicating that the State highways were more prone to crashes which may lead to unsafe zones of driving. The Interstate highways were much safer compared to other highway systems as the average AADT for interstate highways is much higher, 2.6 times higher compared to the US highway system and almost 3.7 times higher compared to the State highway system. In general, it needs to be kept in perspective that the Interstate highways are divided and the US and State highway routes comprise of divided and undivided sections which leads to more frequency of crashes on US and State highway routes. From Figure 10 it can be inferred that though the AADT is higher for the Interstates, the frequency of crashes are relatively low when compared to the US and State routes.

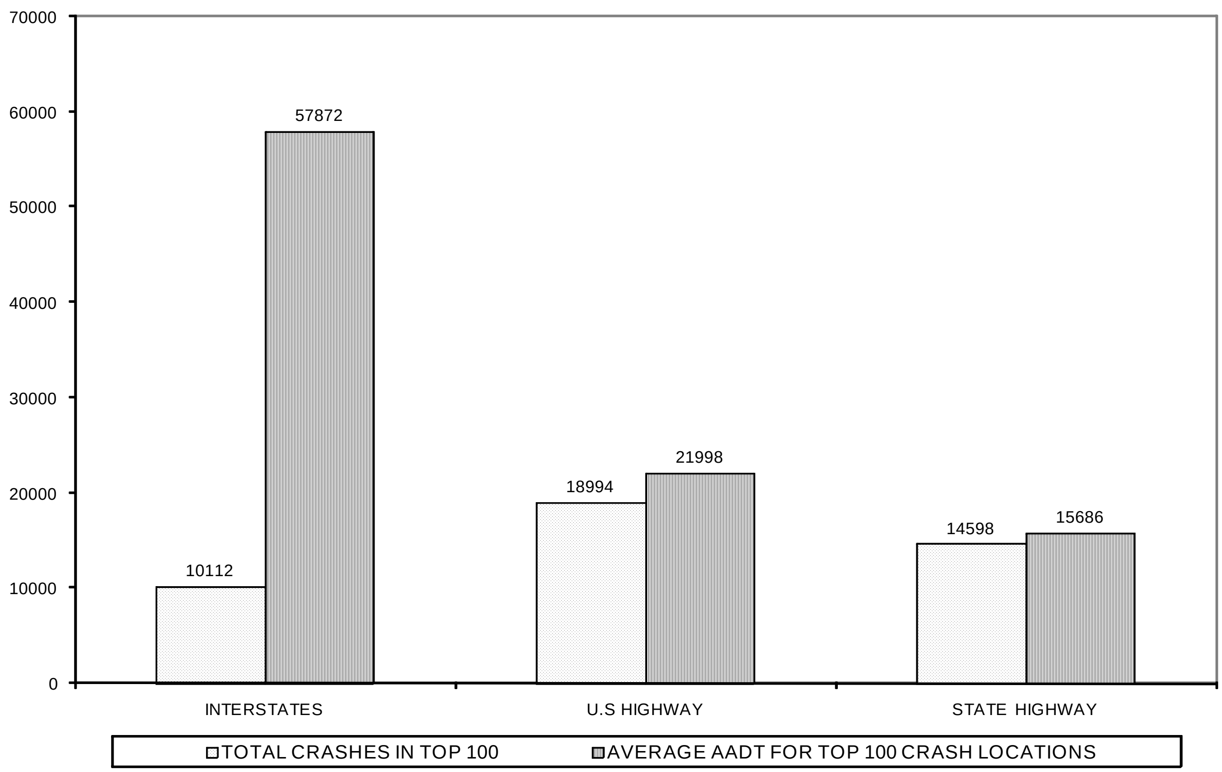


Figure 12. Summary of three highway systems in terms of total crashes in Top 100 segments to the average AADT

VIII. CONCLUSIONS AND RECOMMENDATIONS

This report presents the analysis of three highway networks, the Interstates, US, and State Highways and identifies the segments with the highest crash frequency and severity. The high crash segments were ranked and the ranking depended upon factors such as AADT, weighted severities index, frequency of crashes, etc. The report analyzed highway segments 1 mile in length as this length can be safely assumed to be homogenous with similar traffic, geometric, and control conditions. For interstate highways, top 100 high crash segments were analyzed whereas for US and State highways the top 500 high crash segments were considered. This was considered appropriate for analysis as the top 100/500 represented a reasonable number of crashes over the high crash segments versus the total number of crashes over the network for the three years of crash data by percentage.

Table 14 summarizes the high crash segments for each of the interstate highways which can be considered as hot spots. The frequency of crashes was found to be much higher whenever a route passed through the vicinity of major cities mainly because of higher traffic volumes. This was a common pattern in the analysis of interstate highways. I-30 and I-40 have the highest number of segments among the top 100 interstate highways and the highest frequency of crashes among the interstate highways for the three years of crash data. Hence, I-30 and I-40 are most prone to crashes among interstate highways primarily because of high volume and location in the densely populated city of Little Rock and I-30 is also at the intersection with other Interstate highways. In the top 100 Interstate highway segments, no high crash segments were identified for I-440 and only three segments were identified for I-530 which is not included in Table 14.

Table 14~. Summary of High Crash Segments on Interstate Highways

Interstate Routes	High Crash Segments* (from mile marker to mile marker)	Fatalities, HCS (3 yr data)	Fatalities by route (3 yr data)	Total Crashes, HCS (3 yr data)	Total Crashes on route (3 yr data)
30	114 to 143	26	68	3268	4762
40	126 to 155, 272 to 285	19	97	2387	5502
55	1 to 11	4	42	491	1074
430	1 to 12	2	5	945	1121
540	4 to 10, 62 to 68	9	30	1043	2758
630	1 to 8	3	3	1265	1381
Total	-	63	245	9399	16,598

*High Crash Segments = HCS

~ For details, refer to specific tables by route in the appendix

The frequency of crashes which occurred on US and State highways were found to be more on undivided sections compared to divided sections. The analysis also revealed that for US and State highway systems the major crash locations occurred in and around the city of Little Rock. For US highways, 10 highways were selected as most vulnerable to high frequency and severity of crashes. These 10 highways are identified in Table 15. For State highways, out of the 28 highways selected from the 138 routes which were analyzed from the top 500 high crash segments, 13 highways were categorized into 9

On US highways, US-71 and on State highways, S-7 had high frequency of crashes compared to other US and State highways. For most of the segments which had high frequency of crashes and were identified as high crash locations, continuous segments which can be termed as high crash locations or hot spots were identified and are identified in the tables in this section and the above sections. On the US highway, US-71 had several sections that were identified as high crash locations. On the State highways, route 7 had several sections which were identified as high crash locations. The above sections and the high crash locations are described in detail in the report. In this report, the identification of high crash segments have been carried out and another report aims to find the causes of high frequency of crashes and propose remedial measures.

Table 15^. Summary of High Crash Segments on US Highways

US Routes	Sections	Fatalities, HCS (3 yr data)	Fatalities by route (3 yr data)	Total Crashes, HCS (3 yr data)	Total Crashes on route (3 yr data)
49	10, 20, 30, 80, 90, 100	10	33	1743	2177
62	10, 20, 30, 40, 50, 110, 170, 200	20	46	2688	3601
63	30, 60, 70, 80, 120, 130	20	50	1126	1914
64	10, 20, 30, 40, 50, 60, 80, 90, 150, 160	6	43	2960	3853
65	10, 70, 80, 90, 170, 200, 210	15	48	2438	3316
67	10, 20, 50, 60, 70, 80, 90, 100, 110, 120, 160, 180, 190	21	56	3661	4793
70	10, 80, 90, 120, 130, 170, 180, 190, 200	15	32	3678	4315
71	**20, 30, 40, 60, 70, 100, 130, 140, 150, 160, 180, 190**	**22**	**58**	**7304**	**8463**
270	40, 50, 60, 90, 100	12	24	1722	2223
412	10, 20, 30, 40, 60, 70, 80, 90	17	30	3459	3876

^For complete details, refer to Table 10

Tables 14 to 17 identify the high crash segments on the routes which had higher crash frequency and severity. These high crash segments were determined based on their rank in the top 100/500 ranked segments. These particular sections must be examined carefully and a detailed analysis on these sections is required to reduce the fatalities primarily as it causes loss of life and also to provide remedial measures to reduce the crashes which result in property damage only.

It was found from the analysis of the three major highway systems that similar to Little Rock, the frequency of crashes increased around other major cities such as Fayetteville. Hence, a possible way to reduce the frequency of crashes would be to perform a more detailed study of crashes in and around major cities by which the methods of reducing the frequency and severity of crashes could be identified. This study was carried out at the network level and a more detailed study could be carried out around major cities to get a better understanding of crash patterns which could be used to propose safety measures for the reduction of frequency and severity of crashes.

Table 16*. Summary of High Crash Segments on State Highways

State Routes	Sections	Fatalities, HCS (3 yr data)	Fatalities on route (3 yr data)	Total Crashes, HCS (3 yr data)	Total Crashes on route (3 yr data)
5	80, 90, 120, 170, 180, 190	12	36	1160	2037
7	**90, 100, 130, 140, 150, 200**	**11**	**46**	**3685**	**4725**
8	70, 80, 130, 140	6	11	63	357
10	0	5	20	1564	2012
16	20, 130	3	19	888	1294
22	10, 30	3	13	1932	2175
59	50, 60	2	17	210	1065
69	20, 30, 60, 70		13		
367	120, 130, 140, 150	4	11	490	899

* For complete details, refer to Table 13

The Empirical Bayes', EPDO, and Crash Rate methods yielded similar results for the Interstate, US and State highway networks. The EPDO considers severity into account while calculating the rank of each segment. The EB method takes AADT and the variations in crashes over time into account. The EB method is based on historical data as it takes the variations for traffic volume and frequency of crashes into account. The CR method takes AADT, length of the segment, and number of crashes into account. CR method takes factors in analysis which play a vital role in the location of high crash locations. The analysis revealed that the ranking and identification conducted by the above methods were accurate and each of the methods took important factors into account.

Table 17*. Summary of High Crash Segments on State Highways

State Routes	Sections	Fatalities, HCS (3 yr data)	Fatalities on route (3 yr data)	Total Crashes, HCS (3 yr data)	Total Crashes on route (3 yr data)
12	30	2	11	150	440
18	40, 60, 70	2	9	823	1153
265	10, 20	3	7	521	807
365	110, 120, 140	5	9	791	1244

* For complete details, refer to Table 13

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APPENDIX

Table A1. Top 25 High Crash Locations of Interstate I-30

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	141	43.5	581.1	294.3	452	2	4	24	159	263	2	98845
2	140	46.8	395.7	281.6	470	2	6	40	155	267	2	108779
3	126	18.0	909.1	118.3	171	2	1	22	53	93	2	52698
4	138	22.2	404.3	115.8	218	1	6	19	69	123	2	80046
5	142	22.0	189.9	48.0	217	2	4	15	75	121	3	104441
6	0	9.3	276.9	58.7	89	1	2	7	31	48	1	30594
7	130	12.1	238.7	50.8	122	1	1	15	32	73	1	67185
8	120	10.8	184.5	60.2	135	0	1	7	28	99	0	68702
9	128	14.0	173.5	52.1	143	0	2	8	52	81	0	76342
10	123	18.2	166.7	45.5	143	1	1	11	89	41	1	79227
11	139	16.9	163.3	30.5	168	1	2	18	51	96	1	94393
12	115	7.1	170.7	41.5	78	0	0	9	18	51	0	45827
13	118	8.9	154.4	43.2	99	0	1	10	22	66	0	59126
14	122	11.9	131.9	22.4	103	0	0	10	52	41	0	72359
15	137	11.7	102.0	22.8	100	1	2	15	37	45	1	89834
16	129	9.3	118.1	11.0	95	1	1	10	25	58	2	74126
17	113	6.0	102.5	16.5	44	3	1	8	15	17	3	40993
18	116	5.5	112.3	11.2	54	1	1	8	11	33	1	52791
19	124	6.9	75.2	26.3	62	0	3	7	21	31	0	76674
20	125	7.0	84.9	16.6	69	1	2	3	24	39	1	75370
21	127	6.9	78.7	22.9	65	0	3	10	15	37	0	76468
22	133	5.8	73.0	29.4	62	0	1	7	14	40	0	78023
23	135	6.1	59.5	55.8	56	1	0	4	24	27	1	86270
24	134	6.1	66.6	35.4	57	2	3	4	14	34	2	78530
25	114	4.4	91.4	11.1	36	0	0	5	18	13	0	39444

Table A2. Top 25 High Crash Locations of Interstate I-40

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	152	21.2	98.0	177.9	234	1	3	11	69	150	1	67786
2	277	17.7	254.0	153.6	195	2	8	8	45	132	2	52033
3	154	18.5	257.0	85.7	190	0	5	21	48	119	0	103447
4	151	12.4	207.0	102.2	150	0	2	10	30	108	0	63663
5	153	19.7	94.0	102.8	203	1	3	17	61	121	1	100913
6	128	10.8	90.0	74.1	103	0	5	7	36	55	0	42788
7	147	11.8	216.0	82.8	122	0	3	17	25	77	0	56030
8	150	9.8	251.0	66.0	111	0	3	11	20	77	0	62972
9	278	8.6	187.0	43.6	83	1	6	7	19	50	1	58923
10	142	9.4	120.0	55.3	101	1	1	11	22	66	1	64088
11	279	9.1	18.0	48.7	87	1	8	7	18	53	1	57556
12	280	7.8	103.0	43.7	66	2	9	5	13	37	2	37235
13	148	6.6	204.0	46.7	79	1	0	7	13	58	1	51395
14	271	5.2	118.0	26.9	45	1	6	2	11	25	2	33996
15	133	6.6	47.0	31.1	66	0	0	6	24	36	0	55348
16	125	4.7	41.0	25.2	50	2	4	0	24	20	2	44734
17	276	6.1	203.0	25.6	50	0	7	3	17	23	0	44186
18	199	4.7	132.1	29.7	48	0	3	6	8	31	0	33233
19	146	6.1	73.0	22.0	64	0	2	6	16	40	0	62506
20	284	6.0	97.4	21.9	44	1	12	2	8	21	1	41750
21	149	5.7	45.0	22.8	64	1	3	4	10	46	1	61786
22	135	5.0	171.0	17.1	52	1	3	2	12	34	1	56306
23	282	5.8	97.0	20.9	42	0	9	5	11	17	0	40460
24	242	4.0	1.0	22.0	39	1	1	7	5	25	1	33546
25	84	3.4	78.0	23.2	38	0	2	6	2	28	0	26153

Table A3. Top 25 High Crash Locations of Interstate I-55

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	9	13.8	1722.6	78.2	103	2	11	8	46	36	2	22303
2	8	9.9	812.4	62.4	84	0	8	5	33	38	0	22865
3	10	10.0	795.9	52.2	72	2	1	7	45	17	2	24358
4	3	6.2	145.9	39.4	65	0	4	4	15	42	0	41471
5	7	6.1	165.5	31.2	53	0	6	5	15	27	0	36462
6	67	4.4	220.7	30.9	46	0	0	3	16	27	0	19041
7	2	6.4	106.9	27.3	58	0	8	3	14	33	0	49872
8	0	7.1	103.5	25.6	56	0	9	8	13	26	0	49736
9	63	2.4	218.2	11.6	21	0	1	2	8	10	0	15019
10	4	3.3	80.0	12.2	33	1	1	0	11	20	1	37836
11	23	3.0	90.2	10.8	24	1	4	2	4	13	15	25621
12	1	5.8	72.8	9.9	40	2	3	8	14	13	2	50523
13	66	1.6	75.4	6.7	16	0	1	2	3	10	0	19381
14	20	2.1	62.7	5.5	19	1	1	1	5	11	1	27679
15	13	2.0	57.4	4.1	18	0	2	1	5	10	0	28678
16	33	1.1	382.8	4.1	10	0	2	1	0	7	0	11839
17	64	1.5	61.1	4.2	13	0	1	1	5	6	0	19423
18	25	1.6	54.8	3.1	11	0	5	0	0	6	0	18318
19	40	1.0	76.3	3.1	8	0	0	2	3	3	0	10038
20	56	1.3	54.2	2.8	10	0	0	3	3	4	0	17040
21	26	1.6	49.6	2.2	10	0	2	1	5	2	0	18420
22	41	1.5	51.1	2.0	9	1	1	2	2	3	1	16878
23	36	1.2	56.9	2.0	7	0	1	2	3	1	0	12329
24	11	1.8	34.3	2.4	11	0	2	2	5	2	0	29318
25	43	1.3	47.6	1.9	10	0	0	1	6	3	0	19190

Table A4. Top 13 High Crash Locations of Interstate I-430

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	9	17.2	252.9	106.9	188	0	1	24	40	123	0	68368
2	6	14.9	198.7	69.1	158	0	3	17	38	100	0	73746
3	7	16.0	187.7	62.9	155	1	1	16	53	84	1	75886
4	0	8.2	165.4	33.8	83	0	2	10	21	50	0	45910
5	5	8.5	135.0	19.5	90	0	1	9	24	56	0	61342
6	11	8.7	130.1	15.8	88	0	2	12	21	53	0	62582
7	3	7.1	90.6	10.4	62	1	2	11	16	32	1	62781
8	1	6.2	89.0	10.5	56	0	3	7	17	29	0	58693
9	8	4.1	48.6	47.3	38	0	0	5	14	19	0	71592
10	12	6.1	94.4	5.5	59	2	3	3	15	36	2	57198
11	4	5.2	80.1	16.7	53	1	1	5	13	33	1	60896
12	10	5.9	87.9	15.0	65	0	1	3	20	41	0	67982
13	2	3.1	38.0	45.9	26	0	1	3	11	11	0	62554

Table A5. Top 15 High Crash Locations of Interstate I-440

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	0	4.7	60.0	13.8	43	0	1	7	13	22	0	66456
2	3	4.2	62.9	13.7	41	0	2	5	10	24	0	60015
3	1	4.1	56.5	11.1	40	0	0	6	12	22	0	65190
4	13	2.3	139.4	8.8	21	0	1	1	9	10	0	18024
5	9	2.9	77.5	6.3	30	1	0	2	8	19	1	48763
6	10	1.9	78.6	4.9	19	0	0	4	3	12	0	22321
7	5	3.2	47.0	1.5	27	1	0	6	6	14	1	54433
8	2	3.5	35.1	3.9	25	1	0	7	9	8	2	65548
9	6	3.0	46.4	0.9	26	0	0	4	11	11	0	53246
10	14	1.7	30.2	12.2	14	0	2	2	3	7	0	56843
11	4	3.0	41.4	0.6	26	0	1	6	6	13	0	57792
12	7	1.6	30.5	7.5	18	0	0	1	5	12	0	54611
13	8	1.5	31.8	6.8	18	0	0	2	3	13	0	52283
14	12	1.4	37.0	5.0	9	0	1	3	3	2	0	22433
15	11	1.0	40.5	4.1	9	0	1	0	3	5	0	20300

Table A6. Top 25 High Crash Locations of Interstate I-530

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	0	6.3	113.5	23.8	55	0	1	9	20	25	0	45513
2	33	4.2	233.6	25.1	34	0	1	8	11	14	0	16559
3	3	5.6	95.4	11.0	31	5	2	10	6	8	6	33058
4	9	3.5	95.4	12.4	26	0	2	8	6	10	0	24900
5	2	4.6	87.9	10.3	36	0	3	9	8	16	0	39692
6	37	1.9	526.3	10.7	22	0	2	1	2	17	0	21686
7	29	2.4	89.3	8.8	18	1	1	4	4	8	1	18511
8	36	2.6	80.9	8.3	21	0	3	3	5	10	0	23752
9	10	2.3	84.4	7.2	16	0	1	4	7	4	0	18038
10	42	2.7	71.2	5.8	21	1	1	3	7	9	1	27252
11	31	1.9	107.6	5.2	14	0	1	2	7	4	0	18286
12	8	3.6	65.1	3.5	22	1	3	9	2	7	1	31473
13	1	2.9	51.6	4.0	24	1	1	5	4	13	1	42567
14	5	2.7	42.6	6.5	16	1	3	4	4	4	3	36431
15	26	1.7	69.1	5.0	14	1	1	2	2	8	1	18550
16	6	1.7	41.6	7.2	15	0	0	4	3	8	0	36133
17	4	1.6	36.2	8.4	12	0	0	3	5	4	0	34092
18	27	1.3	60.9	3.4	12	0	1	1	3	7	0	18017
19	7	2.0	45.7	3.4	17	0	0	7	1	9	0	33965
20	25	1.6	56.4	2.5	12	1	1	2	2	6	1	19433
21	43	1.4	58.4	2.6	13	0	0	2	4	7	0	20777
22	34	2.3	51.1	0.4	16	1	1	3	5	6	1	29019
23	40	1.9	46.2	1.5	14	0	1	5	2	6	0	27893
24	39	1.8	47.1	0.8	13	0	3	3	1	6	0	25623
25	35	1.2	54.5	1.7	14	0	1	1	1	11	0	23507

Table A7. Top 25 High Crash Locations of Interstate I-540

Rank	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
		EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1	64	14.8	3660.3	113.0	149	3	5	10	39	92	4	41442
2	62	15.2	1317.3	106.0	129	3	0	16	54	56	3	28161
3	63	8.8	668.0	52.4	79	0	9	8	18	44	0	34757
4	65	8.6	2570.1	51.6	79	0	1	16	20	42	0	35492
5	8	10.5	172.0	47.9	92	1	6	9	30	46	1	48968
6	66	12.0	153.9	39.8	103	0	6	18	29	50	0	61645
7	82	9.7	183.6	36.9	83	0	7	10	26	40	0	50528
8	71	8.5	176.3	45.7	94	1	0	10	20	63	1	51934
9	6	8.8	149.9	36.1	81	0	10	4	21	46	0	49717
10	3	6.5	141.4	30.5	72	0	2	4	19	47	0	47381
11	4	6.2	134.5	27.0	70	0	0	2	24	44	0	48510
12	9	6.9	132.3	26.5	71	0	3	5	20	43	0	49611
13	67	7.6	126.1	22.9	76	1	3	8	17	47	1	55396
14	44	2.9	546.7	21.0	31	0	2	2	6	21	0	16524
15	81	7.6	105.6	10.0	66	0	5	7	22	32	0	57427
16	61	4.8	121.1	19.8	42	0	1	7	14	20	0	31781
17	80	7.1	103.0	8.3	65	1	5	1	24	34	1	57889
18	5	5.5	100.3	10.0	52	0	3	5	15	29	0	48042
19	33	2.7	263.2	9.6	18	0	3	5	4	6	0	16272
20	78	5.6	70.6	16.4	49	0	2	5	20	22	0	63412
21	84	5.9	96.8	7.2	54	2	3	3	15	31	4	51420
22	73	5.2	65.7	21.7	47	0	3	6	13	25	0	65377
23	42	2.4	119.3	13.4	23	0	1	5	3	14	0	17609
24	79	5.1	66.0	18.6	45	0	3	0	22	20	0	62347
25	11	5.0	44.6	53.0	38	0	0	10	16	12	0	77800

Table A8. Top 8 High Crash Locations of Interstate I-630

Rank	#	Mile Marker	Analysis Methods			Number of Crashes						Other Variables	
			EPDO	CR	EB	Total	S1	S2	S3	S4	S5	Fatal	AADT
1		0	31.4	413.5	81.4	312	0	7	38	87	180	0	79287
2		6	20.1	217.1	58.5	223	0	2	20	55	146	0	94152
3		4	19.0	175.3	70.5	202	0	3	11	66	122	0	105527
4		2	17.4	143.0	36.2	166	2	2	21	49	92	2	106201
5		5	14.1	124.0	6.2	141	1	3	16	37	84	1	104147
6		7	9.7	98.9	74.6	99	0	1	10	30	58	0	91572
7		1	10.8	107.4	12.8	122	0	4	8	27	83	0	104162
8		3	11.8	96.0	4.0	116	0	4	13	32	67	0	110523

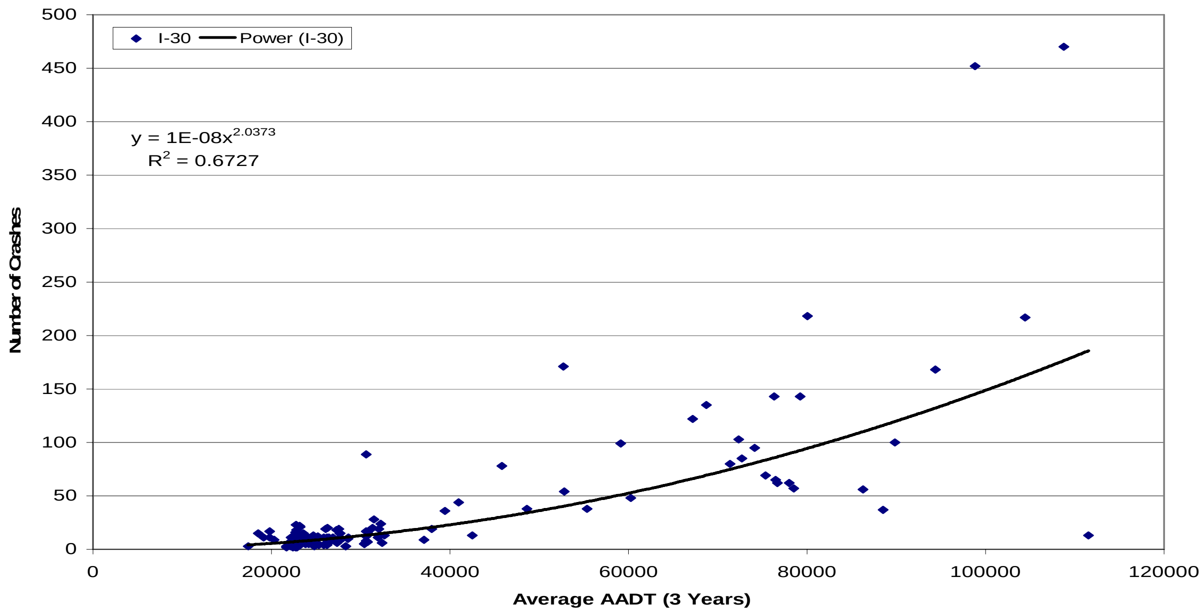

Figure A1. Safety Performance Function for I-30

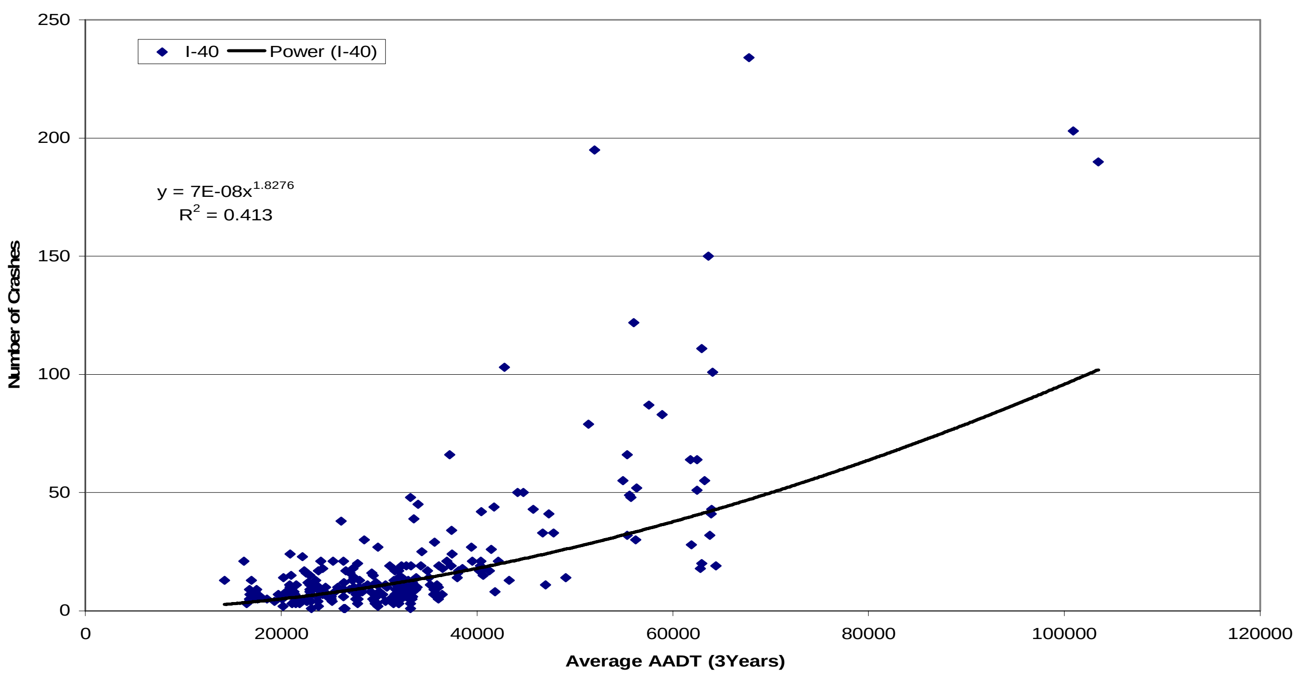

Figure A2 Safety Performance Function for I-40

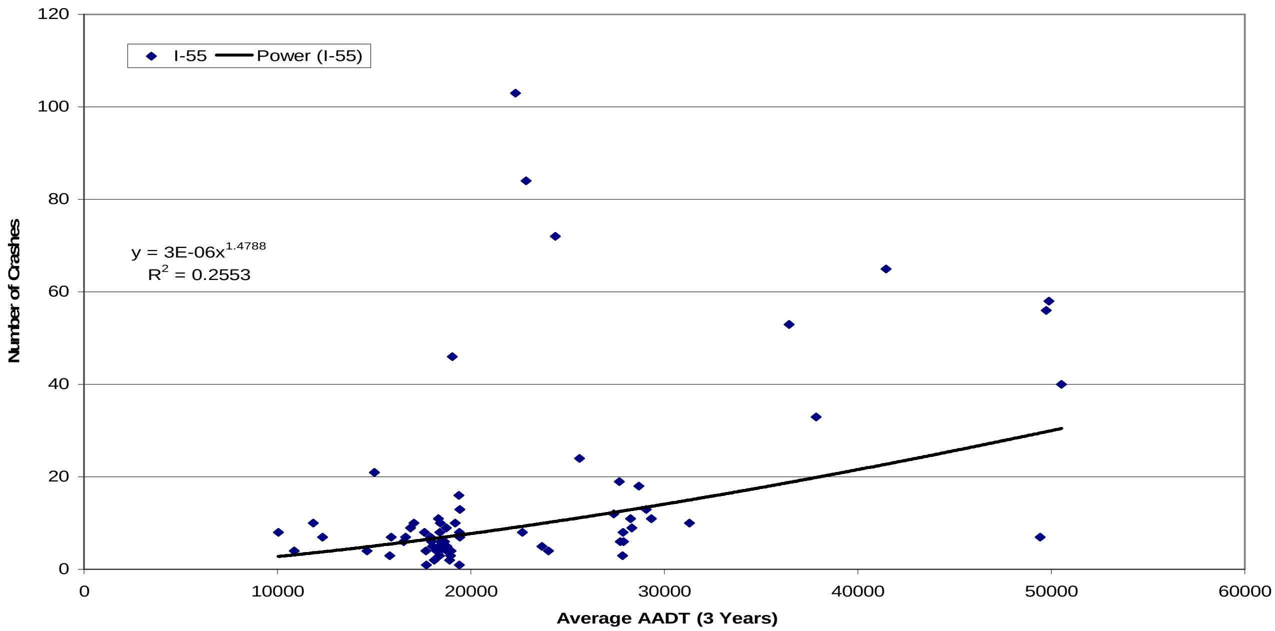

Figure A3 Safety Performance Function for I-55

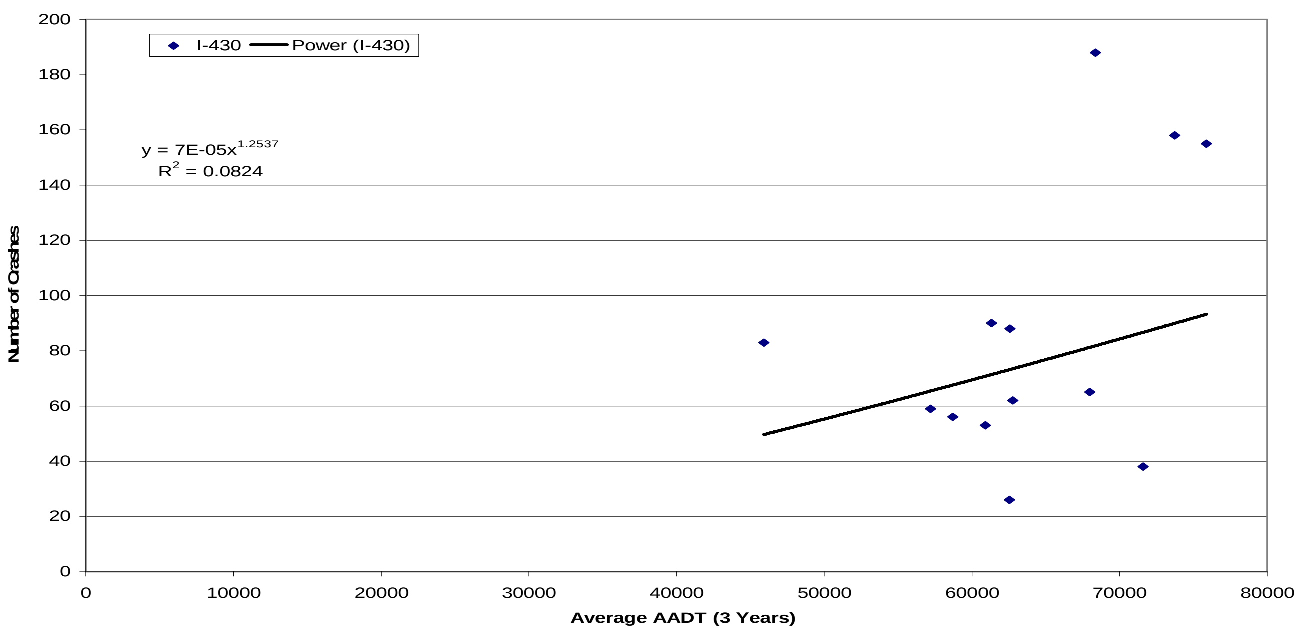

Figure A4 Safety Performance Function for I-430

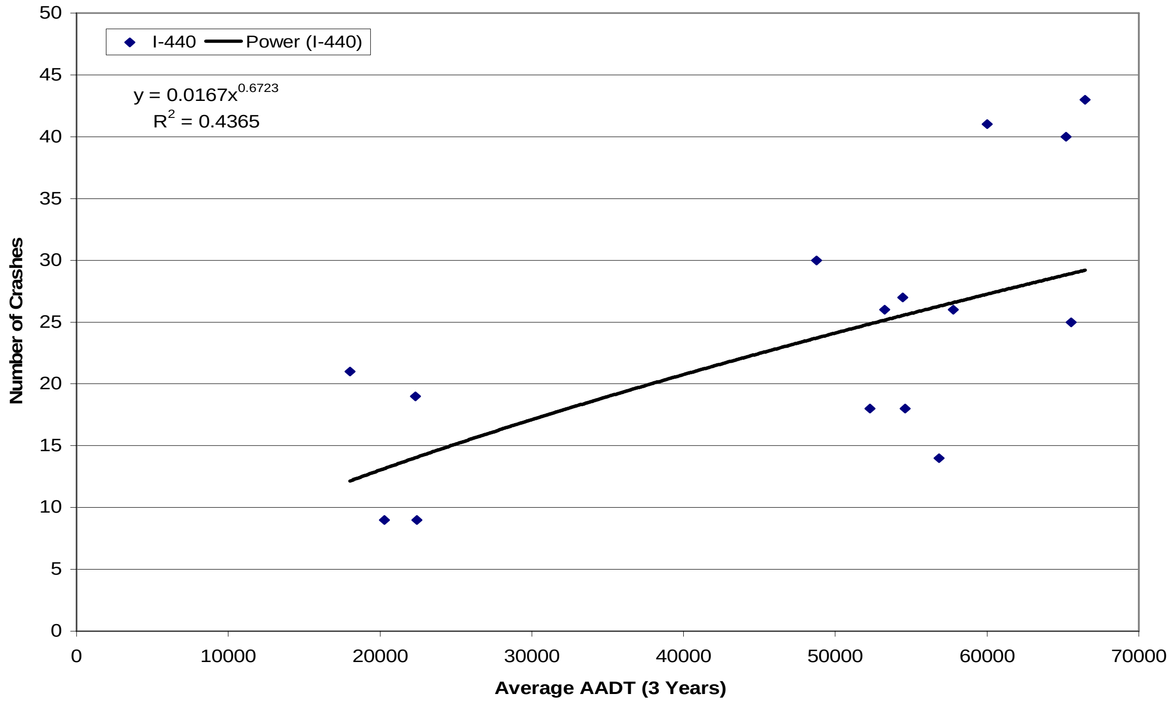

Figure A5 Safety Performance Function for I-440

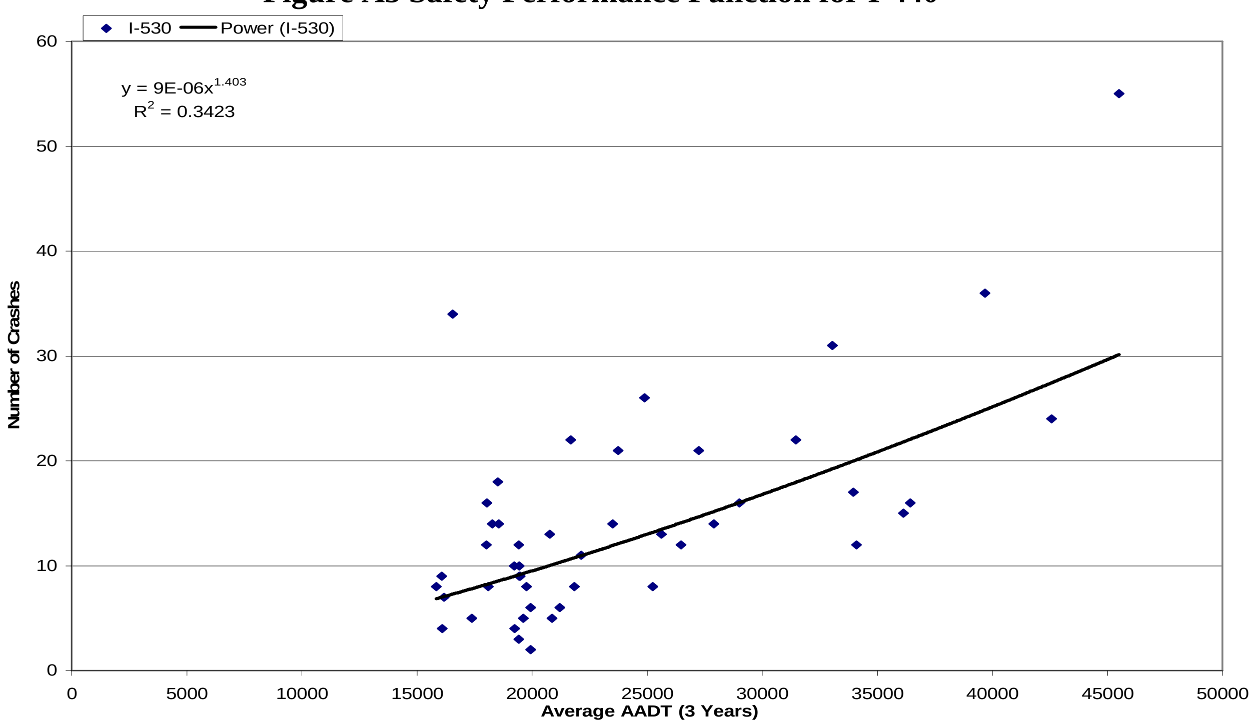

Figure A6 Safety Performance Function for I-530

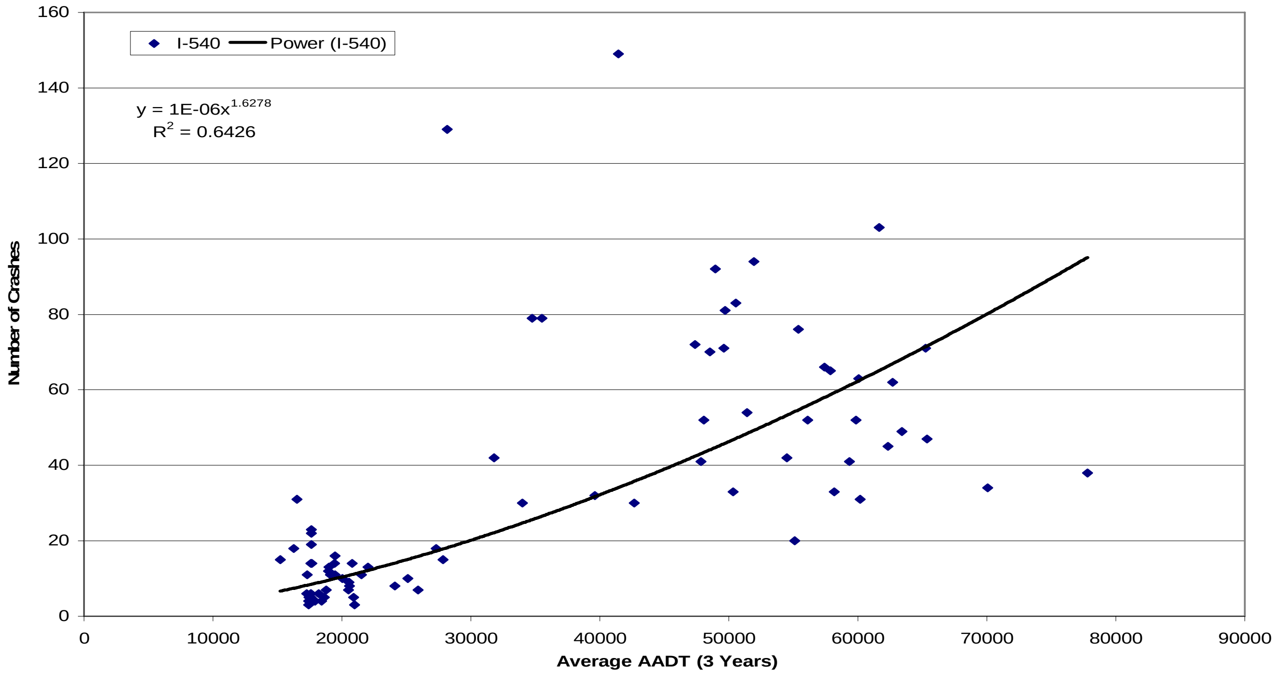

Figure A7 Safety Performance Function for I-540

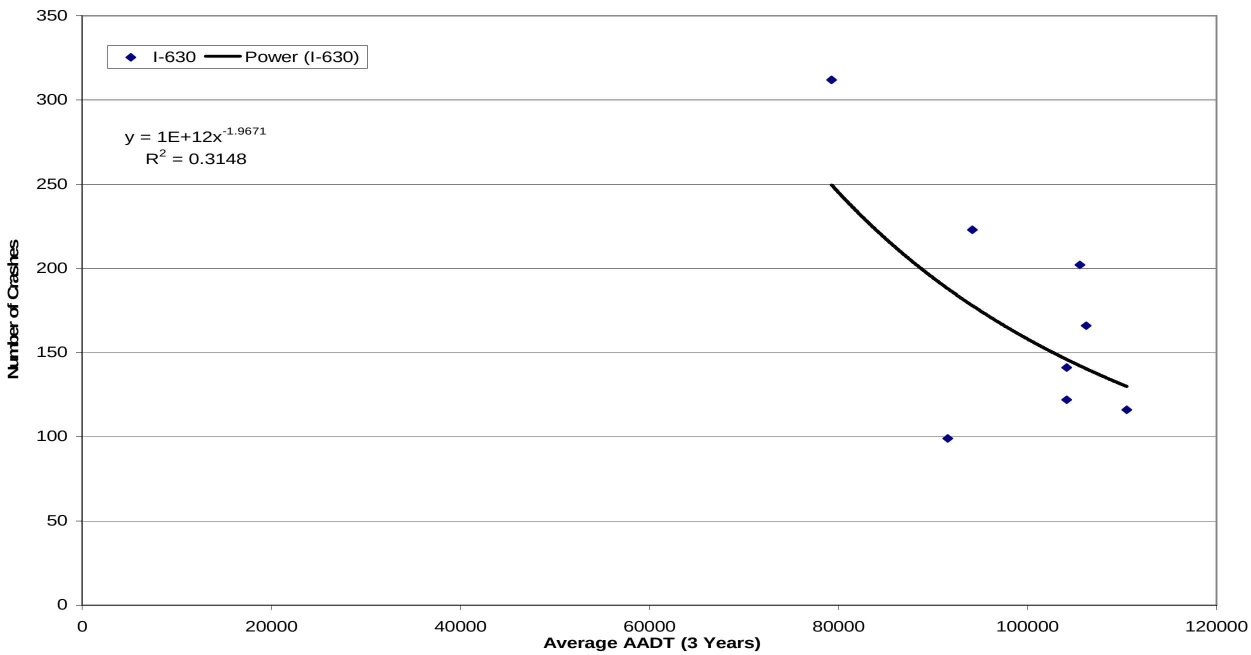

Figure A8 Safety Performance Function for I-630

Table A9. Three Year Crash Data for State Highways of Arkansas

State Routes	Total Crashes	Fatalities	Crash Severity		Severity Rate
			S1	S2	
1	1094	15	13	46	5.6
4	18	1	1	4	27.8
5	2037	36	30	157	9.5
7	4725	46	42	178	4.7
8	357	11	10	17	7.8
9	654	15	12	59	11.3
10	2012	20	16	50	3.5
11	71	2	2	8	14.1
12	440	11	11	44	12.5
13	92	0	0	5	5.4
14	716	27	18	62	12.4
15	141	2	2	18	14.2
16	1294	19	19	102	9.4
17	78	2	2	12	17.9
18	1153	9	7	39	4.2
19	50	2	2	1	6.0
20	5	0	0	1	20.0
21	243	12	10	20	13.2
22	2175	13	13	27	1.8
23	470	16	14	85	21.5
24	87	1	1	14	17.2
25	829	17	17	65	9.9
26	63	3	3	4	11.1
27	495	15	14	29	8.9
28	96	4	4	5	9.4
29	283	5	4	9	4.9
31	226	8	8	19	11.9
32	109	1	1	11	11.0
33	33	1	1	1	6.1
34	27	3	3	3	22.2
35	348	3	3	14	4.9
36	562	1	1	36	6.6
37	48	1	1	5	12.5
38	168	6	6	7	7.7
41	84	3	3	11	16.7
42	38	2	2	7	23.7
43	238	2	2	22	10.1
44	30	0	0	5	16.7
45	606	3	3	41	7.3
46	66	4	3	8	18.2
48	10	1	1	1	20.0
50	26	1	1	7	30.8
5	305	3	3	21	7.9

Table A9. continued					
State Routes	**Total Crashes**	**Fatalities**	**Crash Severity**		**Severity Rate**
			S1	**S2**	
52	43	0	0	1	2.3
53	75	2	2	7	12.0
54	197	1	1	8	4.6
56	37	0	0	7	18.9
57	16	0	0	1	6.3
58	33	0	0	12	36.4
59	1065	17	16	57	6.9
60	370	6	6	8	3.8
66	93	2	2	6	8.6
69	1067	13	12	19	3.0
72	449	9	9	13	4.9
73	44	0	0	1	2.3
74	157	3	3	23	16.6
75	26	1	1	1	7.7
77	325	4	4	15	5.8
80	89	1	1	3	4.5
83	59	4	4	0	6.8
84	85	1	1	9	11.8
87	97	0	0	7	7.2
88	643	5	5	15	3.1
89	823	6	6	16	2.7
90	169	1	1	4	3.0
91	77	1	1	4	6.5
92	77	3	3	10	16.9
94	457	2	2	23	5.5
95	99	2	2	10	12.1
96	78	1	1	6	9.0
98	25	0	0	8	32.0
100	465	4	3	5	1.9
101	33	1	1	9	30.3
102	923	4	4	18	2.4
103	234	1	1	19	8.5
104	23	1	1	2	13.0
105	96	1	1	1	2.1
106	56	2	2	1	5.4
107	1125	5	5	24	2.6
108	23	0	0	1	4.3
109	83	6	3	6	14.5
110	127	1	1	17	14.2
111	16	0	0	1	6.3
112	967	0	0	16	1.7
113	51	3	3	6	17.6
114	43	2	2	5	16.3

Table A9. continued					
State Routes	**Total Crashes**	**Fatalities**	**Crash Severity**		**Severity Rate**
			S1	**S2**	
115	141	6	5	15	14.9
116	11	0	0	0	0.0
117	16	0	0	0	0.0
118	63	1	1	0	1.6
119	36	3	3	0	8.3
121	31	0	0	1	3.2
122	23	0	0	0	0.0
123	95	3	3	13	16.8
124	189	5	5	30	18.5
125	12	1	1	1	16.7
126	45	3	2	6	20.0
127	33	0	0	9	27.3
128	206	0	0	13	6.3
129	22	0	0	4	18.2
130	103	0	0	1	1.0
131	23	0	0	4	17.4
133	358	4	3	16	5.6
134	7	0	0	2	28.6
135	199	3	3	9	6.0
137	39	0	0	2	5.1
138	30	2	2	2	13.3
139	46	1	1	6	15.2
140	163	4	4	7	6.7
141	216	7	6	8	6.9
143	30	0	0	11	36.7
144	28	2	2	1	10.7
145	10	0	0	1	10.0
146	15	0	0	3	20.0
147	42	1	1	8	21.4
148	7	0	0	1	14.3
149	41	1	1	7	19.5
150	26	1	1	0	3.8
151	53	0	0	4	7.5
152	10	0	0	1	10.0
153	9	0	0	0	0.0
154	35	3	3	5	22.9
155	13	0	0	0	0.0
156	14	0	0	0	0.0
157	63	4	4	15	30.2
158	63	3	2	3	9.5
159	38	0	0	2	5.3
160	65	1	1	5	9.2

Table A9. continued					
State Routes	**Total Crashes**	**Fatalities**	**Crash Severity**		**Severity Rate**
			S1	**S2**	
161	477	5	5	15	4.2
162	167	3	3	3	3.6
163	132	2	2	5	5.3
164	53	1	1	7	15.1
166	22	3	2	1	18.2
169	14	0	0	1	7.1
170	66	0	0	2	3.0
171	46	2	2	10	26.1
172	19	0	0	1	5.3
174	29	0	0	1	3.4
175	84	4	3	3	8.3
176	639	1	1	4	0.8
177	39	1	1	12	33.3
178	144	2	2	16	12.5
180	605	2	2	7	1.5
181	35	1	1	0	2.9
182	26	0	0	3	11.5
183	439	1	1	1	0.5
185	10	0	0	0	0.0
186	7	0	0	1	14.3
187	47	2	2	9	23.4
189	25	0	0	3	12.0
190	462	2	2	2	0.9
191	73	0	0	0	0.0
192	79	1	1	5	7.6
193	11	0	0	1	9.1
195	35	0	0	1	2.9
196	133	3	3	4	5.3
197	25	0	0	3	12.0
198	11	0	0	0	0.0
201	188	1	1	29	16.0
202	32	1	1	6	21.9
203	17	0	0	0	0.0
206	29	0	0	4	13.8
212	34	2	2	4	17.6
214	36	1	1	0	2.8
215	29	3	3	4	24.1
217	23	3	2	2	21.7
219	25	0	0	0	0.0
220	31	1	1	3	12.9
221	31	0	0	5	16.1

Table A9. continued					
State Routes	**Total Crashes**	**Fatalities**	**Crash Severity**		**Severity Rate**
			S1	**S2**	
222	10	0	0	2	20.0
224	26	0	0	10	38.5
225	56	0	0	11	19.6
226	69	0	0	3	4.3
227	213	1	1	16	8.0
230	64	2	2	4	9.4
233	29	0	0	1	3.4
235	23	1	1	6	30.4
237	56	2	2	8	17.9
239	36	0	0	0	0.0
242	57	2	2	4	10.5
245	126	4	4	4	6.3
247	56	1	1	4	8.9
248	26	1	1	2	11.5
251	31	2	2	1	9.7
252	19	0	0	1	5.3
253	41	0	0	2	4.9
255	578	4	3	4	1.4
256	43	0	0	2	4.7
261	15	0	0	2	13.3
263	41	2	2	9	26.8
264	308	1	1	13	4.5
265	807	7	7	17	3.0
267	63	5	5	6	17.5
274	38	1	1	1	5.3
275	24	1	1	3	16.7
279	67	1	1	5	9.0
282	80	0	0	6	7.5
284	100	2	2	5	7.0
285	34	0	0	6	17.6
286	103	1	1	12	12.6
287	25	1	1	3	16.0
289	19	0	0	4	21.1
290	55	4	3	8	21.8
294	120	0	0	9	7.5
295	21	0	0	4	19.0
298	57	3	3	5	14.0
300	133	3	3	3	4.5
303	21	0	0	3	14.3
305	24	0	0	6	25.0
306	18	1	1	2	16.7
309	71	2	2	4	8.5
310	18	4	2	2	33.3

Table A9. continued					
State Routes	**Total Crashes**	**Fatalities**	**Crash Severity**		**Severity Rate**
			S1	**S2**	
312	25	0	0	1	4.0
319	51	2	2	7	17.6
321	240	2	2	10	5.0
323	30	0	0	4	13.3
326	150	0	0	2	1.3
331	159	2	2	2	2.5
335	36	1	1	1	5.6
337	40	1	1	7	20.0
338	444	4	3	10	3.2
340	110	1	1	2	2.7
341	26	1	1	10	42.3
348	32	0	0	1	3.1
351	139	1	1	2	2.2
352	23	1	1	3	17.4
355	143	1	1	6	4.9
358	31	0	0	1	3.2
365	1244	9	8	27	2.9
367	899	11	10	28	4.3
369	24	1	1	5	25.0
375	22	0	0	0	0.0
376	30	2	2	1	10.0
384	31	0	0	4	12.9
385	42	1	1	7	19.0
391	21	0	0	0	0.0
392	113	0	0	6	5.3
395	25	0	0	7	28.0
463	106	2	2	5	6.6

Table A10. State Highways, Summary of Crashes by Routes, Divided and Undivided Highways, three year data

Route	Divided	Undivided	Route	Divided	Undivided	Route	Divided	Undivided
1	251	843	50	3	23	111	4	12
4	1	17	51	50	255	112	100	867
5	387	1650	52	5	38	113	6	45
7	395	4330	53	9	66	114	3	40
8	34	323	54	11	186	115	9	132
9	93	561	56	4	33	116	0	11
10	699	2012	57	6	10	117	5	11
11	5	66	58	1	32	118	8	55
12	21	419	59	205	860	119	0	36
13	17	75	60	202	168	121	0	31
14	73	643	66	8	85	122	1	22
15	18	123	69	61	1006	123	18	77
16	49	1245	72	9	440	124	14	175
17	11	67	73	2	42	125	0	12
18	88	1153	74	7	150	126	3	42
19	5	45	75	2	24	127	0	33
20	0	5	77	24	301	128	27	179
21	19	224	80	11	78	129	5	17
22	400	1775	83	12	47	130	14	88
23	95	375	84	16	69	131	3	30
24	10	77	87	5	92	133	48	310
25	81	748	88	38	605	134	0	7
26	10	73	89	112	711	135	14	185
27	92	403	90	31	138	137	3	34
28	11	85	91	7	70	138	5	25
29	14	269	92	3	94	139	1	45
31	33	193	94	21	436	140	24	139
32	5	104	95	13	86	141	18	198
33	5	28	96	14	78	143	2	28
34	2	25	98	2	23	144	4	24
35	21	321	100	350	115	145	1	9
36	34	528	101	1	32	146	0	15
37	0	48	102	19	904	147	8	34
38	18	150	103	61	173	148	1	6
41	2	82	104	0	23	149	2	39
42	6	32	105	18	78	150	3	23
43	4	234	106	3	103	151	8	45
44	9	21	107	261	864	152	1	9
45	34	572	108	1	22	153	0	9
46	2	64	109	11	71	154	3	32
48	1	9	110	25	102	155	0	12

Table A10.continued.

Route	Divided	Undivided	Route	Divided	Undivided	Route	Divided	Undivided
156	1	13	212	3	31	289	1	18
157	4	59	214	3	33	290	6	49
158	9	54	215	1	28	294	8	112
159	7	31	217	5	19	295	0	21
160	2	63	219	7	18	298	9	48
161	65	411	220	4	28	300	60	73
162	17	150	221	4	27	303	0	21
163	5	127	222	2	8	305	0	24
164	5	48	224	0	26	306	2	16
166	0	22	225	5	51	309	5	66
169	0	14	226	9	60	310	0	18
170	11	55	227	18	195	312	2	23
171	7	39	230	5	59	319	3	48
172	1	18	233	1	28	321	37	203
174	1	28	235	1	22	323	4	26
175	29	55	237	4	52	326	3	147
176	86	553	239	1	35	331	6	153
177	3	36	242	16	41	335	3	33
178	8	132	245	59	67	337	3	37
180	21	584	247	9	47	338	143	321
181	4	131	248	3	23	340	55	55
182	3	23	251	2	29	341	1	25
183	167	272	252	3	16	348	6	26
185	1	9	253	5	36	351	3	136
186	2	5	255	87	491	352	7	16
187	1	46	256	3	40	355	6	137
189	3	23	261	0	15	358	3	28
190	28	434	263	5	36	365	226	1018
191	22	51	264	7	301	367	252	648
192	2	77	265	14	793	369	6	18
193	4	7	267	0	63	375	1	21
195	0	35	274	5	33	376	2	28
196	6	27	275	2	22	384	2	29
197	1	24	279	17	50	385	8	34
198	1	10	282	9	71	391	1	20
201	17	171	284	18	82	392	5	108
202	0	32	285	5	29	395	0	25
203	1	17	286	8	95	463	25	81
206	0	29	287	1	24	-	-	-