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Interchange Crash Analysis by Type on Florida Highways

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Abstract:- For the past decades many studies have focused on the operations and safety of limited access roadways. Most studies conducted were concerned with the general performance of the roadway segments and using interchanges as variables within the analysis. However, interchanges are significant elements with independent functionalities which are different from the basic segments of limited access roadways. There are different types of interchanges and in Florida these interchanges have been classified into nine types. The objective of this paper was to make an observation on the crash distributions for the different types of interchanges in Florida, compare the distributions among themselves and compare them with the total crashes that occurred from all interchanges. Another objective was to observe different variables that could affect crashes on the interchanges and perform a regression analysis to infer their effects on crashes. The comparison of the distributions showed that there are slight differences in the distributions and the regression analysis showed the effects of some the variables affect interchanges different from how they affect basic limited access segments.

I. INTRODUCTION

For the past decades many studies have focuses on the operation and safety of limited access roadways. Most studies conducted are concerned with the general performance of the limited access roadway to satisfy the general operation of traffic in order to have efficient and safe roadways. There is often a tendency of researchers producing contradicting results between operations and safety of the highways since some of the traffic characteristics produce different results when analyzing safety and operation of the highways. One example is the influence of trucks on limited access highways. Researchers have reported that the presence of a high percentage of trucks on limited access highways reduces the roadway operations by reducing the speed which in turn increase travel time (*1, 2, 3*). However, some studies show that since there is a reduction in speed then there is a potential for increased safety when considering speed as a measure of safety (4, *5, 6*).

Accessibility of limited access highways are made possible by interchanges which are systems of interconnecting roadways with one or more grade separations which provide movement of traffic between two or more roadways of similar or different characteristics such as speed, traffic and roadway class. Interchanges are significant elements on the limited access highways and they are potential conflict locations. There are nine types of interchanges in Florida as per the Roadway Characteristics Inventory (*7*) handbook and some are more dominant than others depending on the location and the roads they serve as shown on the photographs in Figure 1. These interchanges are named according to the shape of the ramps which are a link between the main roadway and the crossing roadway.

In the Florida Department of Transportation Strategic plan there were four goals for reducing the rate of fatalities and serious injuries. The areas of concentration were aggressive driving, intersection crashes, vulnerable road users and lane departure crashes. The lane departure strategic plan involved interchanges where the goal was to improve public education, engineering, and law enforcement practices to reduce lane departure crashes on limited access and rural two lane roadways (8).

TRB and AASHTO are in the process of producing a Highway Safety Manual (HSM) and their focus is on producing quantitative formulae that can be used to produce the safety effects of the different roadway segments. However, they reported on their 2006 report that the publication that is expected to be produced in 2008 did not contain freeway and interchange analysis for the HSM. Their objective was to produce methodologies to predict highway safety performance for freeways and interchanges for both rural and urban conditions. This paper provides preliminary information on the safety characteristics of interchanges which can assist in the developing the quantitative evaluations of interchanges.

Figure 1: Types of Interchanges in Florida

II. PROBLEM STATEMENT

Most studies have concentrated on the freeway main line and used interchanges as one of the variables in the analysis (3, 6); however freeway interchanges are the most critical points on the limited access highways (*9*). Since there are a number of interchange types, there also is a need to solely analyze the safety characteristics of the different interchange types and be able to report the conditions in which individual types of interchanges operate safely and point out what characteristics have most influence on their safety. A few studies have been done on interchanges where consistency on design of interchanges was found to be important (*10*). The study showed that there were more crashes on a study segment which lacked consistency i.e. having different design approach to the interchange compared to the rest of the interchanges that were on the study corridor. This study was done on Highway 417 where one of the interchanges had the exit after the interchange and this segment resulted in the highest frequency of PDO crashes as compared to the whole corridor of study. These types of design interfere with driver expectancy especially those who are not regular commuters on that particular roadway.

Another study done (*9, 11*) suggested that since turbulence on the roadways represents potential safety hazards to the motorists, it would be safe to use the conflict rates as an indicator of ramp safety. Further, in terms of operations freeway weaving sections, conflict rates were better measures of effectiveness than the present average running weaving and non weaving speed measures of effectiveness and shown to be adequate microscopic measure of turbulence. Rear end conflict rates were highly sensitive to change in volume capacity ratio where as lane change conflict rates were highly sensitive to change in the weaving volume to total volume ratio.

Chatterjee et.al (*12*) conducted a study with the goal of developing practical tools for assessing safety consequences of freeway in the context of long-range urban transportation plans. The crash data used were obtained from the North Carolina Department of Transportation and Tennessee Department of Transportation. The authors pointed out that several studies have investigated the effects of roadway geometrics, driver and environmental factors on the number and severity of crashes. However these models are difficult to use for long-range planning involving future highway networks because planners usually make forecasts of the values of many of the explanatory variables used for these models. In their study they noticed the weakness from previous studies where although there was evidence that crash risks between two types of freeway segments, segments near interchanges and segments located away from interchanges, none of the studies treated these segments separately. With that they suggested developing separate models for non interchange and interchange segments being a reasonable approach considering the traffic flow characteristics in those two areas being different. The conclusion made from their study was that there was a pattern of increase of crashes with the increase traffic volume as being predicted from the two models from the Tennessee crash data and North Carolina data. They further found out that interchange segments with four lanes were most crash prone when AADT exceeded 50,000 and 60,000 for North Carolina and Tennessee respectively. In this study only AADT and segment length were used in the models.

The amalgamation of these studies shows how interchanges should analyzed as be a function of their own when analyzing limited access roadways as it pertains to traffic operations as well as traffic safety. As mentioned earlier there are is a spectrum of types of interchanges which are of different geometric, traffic and environmental characteristics. It is imperative that researcher and practitioners understand their operations and safety characteristics in order to have efficient and safer roadways.

A number of methods have been used to analyze crashes on roadways. The most common methods are the before and after method which are used to monitor improvements or modifications done towards a certain road and another method is prediction using different distributions. The most common distributions used are the Poisson and Negative Binomial distributions. These two distributions have proven to provide close predictions on crashes when observing the effects of a number of factors that may be assumed to affect the roadway crash occurrence. However, it may be important to study different distributions from the data available in order to produce better prediction models for a particular roadway facility. Probability Distribution Functions (PDF) which are derived from the Cumulative Distribution Functions (CDF) may be a useful tool to produce a better prediction model for these crash occurrences.

III. OBJECTIVE AND SCOPE

The hypothesis is that different types of interchanges have different safety characteristics depending on the type of traffic they serve and their configuration. In addition to that, different types of interchanges would have different crash distributions which is also a function of the interchange configuration and the traffic it serves. Moreover, it is hypothesized that the different crash severity levels have different distributions on interchanges which could also impact the severity levels of crashes on limited access roadways. The main objective of this paper is to assess the different types of interchanges in Florida and observe their crash distribution (PDFs) and compare them with the Poisson distribution and depict how well the distributions match and determine if the Poisson distribution can be used for these types of interchanges. The analysis of this study was done using parametric and non parametric statistics where five year crash data was collected from 2003 to 2007 from interchanges on selected limited access roadways in Florida.

IV. OVERVIEW

Previously herein nine types of interchanges were introduced and figure 1 showed the types of interchanges that are found across the state of Florida. However, of those nine interchange types mentioned, only eight of them had definite shapes to describe their types where as the ninth type was given a name "other" which suggested that anything that does not conform with the other eight was put in this classification. For the purpose of this analysis this interchange type, "other" was not considered since interchanges in this category did not have common characteristics. The types of interchanges then considered in this study were the diamond, partial diamond, trumpet, Y- interchange, partial cloverleaf and cloverleaf. For database purposes interchange types were numbered from 1 to 9 (where type 9 is the others category which was not considered in the analysis) as shown in table 1 below.

Table 1:Types of interchange and numerical configuration

Interchange type	Numeric Configuration	Quantity
Diamond	Type 1	441
Partial Diamond	Type 2	177
Trumpet	Type 3	65
Y intersection	Type 4	30
2 Quadrant Cloverleaf or Partial Cloverleaf	Type 5	306
4 Quadrant Cloverleaf with Collector Road	Type 6	8
4 Quadrant Cloverleaf	Type 7	13
Direct Connection Design	Type 8	61
Other	Type 9	17

For interchanges type 1 through type 8, an observation was made on the number of crashes that occurred in these particular types of interchanges. This assisted in accounting for the types of interchanges that have a potential to have more crashes than others and make inferences on some parameters that may cause this behavior. However, since exposure is a factor for crash occurrence, along with the total number of crashes, crash rates were also taken into consideration and this was used a measure of safety of the different types of interchanges.

The data collected stratified that three type of interchange were dominant in the state and these were the diamond interchange (type 1), partial diamond interchange (type 2) and the partial cloverleaf interchange (type 5). With the total number of interchanges in the state being 1118, 40 % of the interchanges were diamond, 16% were partial diamond and 27% of the interchanges were partial cloverleaf. The rest of the interchanges were less than 10% as shown in Table 1. These results also were reflected on the contribution that these types of interchanges have on the total number of crashes yearly and the crash rates as shown in Table 2 and Table 3 respectively.

Table 2: Number of Crashes on Different types of Interchanges.

Interchange type	Crash Frequency				
	2003	2004	2005	2006	2007
Diamond	635	267	247	214	130
Partial Diamond	308	113	158	102	104
Trumpet	49	24	24	28	17
Y intersection	25	23	26	24	20
2 Quadrant Cloverleaf or Partial Cloverleaf	471	222	241	169	142
4 Quadrant Cloverleaf with Collector Road	4	2	1	0	0
4 Quadrant Cloverleaf	10	2	4	5	0
Direct Connection Design	83	56	62	52	34
Other	5	7	10	9	3

Table 3: Crash rate in crashes per number of interchanges

Interchange type	**Crash rates (crashes/ number of interchanges)**				
	2003	**2004**	**2005**	**2006**	**2007**
Diamond	1.44	0.61	0.56	0.49	0.29
Partial Diamond	1.74	0.64	0.89	0.58	0.59
Trumpet	0.75	0.37	0.37	0.43	0.26
Y intersection	0.83	0.77	0.87	0.80	0.67
2 Quadrant Cloverleaf or Partial Cloverleaf	1.54	0.73	0.79	0.55	0.46

4 Quadrant Cloverleaf with Collector Road	0.50	0.25	0.13	0.00	0.00
4 Quadrant Cloverleaf	0.77	0.15	0.31	0.38	0.00
Direct Connection Design	1.36	0.92	1.02	0.85	0.56
Other	0.29	0.41	0.59	0.53	0.18

Analysis

As mentioned earlier herein, the dominant types of interchanges were diamond, partial diamond and partial cloverleaf interchanges. This information was also reflected to the number of crashes. Since there was more crash data available from these types of interchanges, the analysis only focused on them. The rest of the interchanges did not have enough data point to be considered in this analysis.

The analysis of the three interchanges mentioned was done by comparing the total crash distributions and the individual interchange type distribution and by comparing their distribution with the Poisson distribution. Further analysis was done to determine the parameters that contribute to the occurrence of crashes on these interchanges and make inferences on what type of interchange is more prone to crashes that the other.

V. DIAMOND INTERCHANGE CRASHES

The distribution of crashes for the diamond interchanges was plot for the five years of analysis to obtain the histograms which produced the CDFs used to produce PDFs for the particular years. As mentioned in the earlier the Inverse Transformation (IT) method was used to produce the estimated distribution functions each particular year. Figure 2 shows a comparison between the total crash distribution and the diamond interchange crashes for the year 2007.

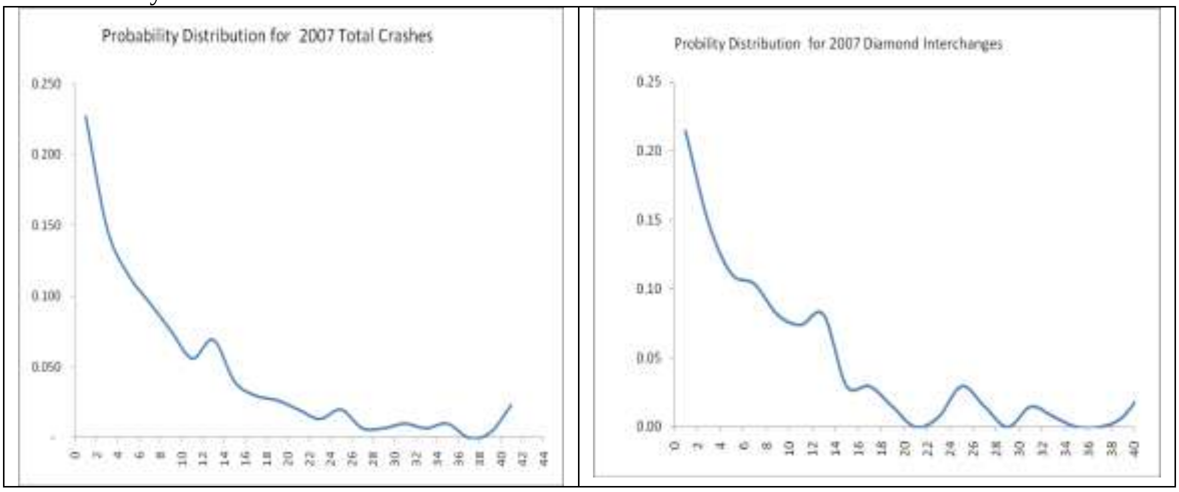

Figure 2: Comparison between Total Crashes and Diamond Interchanges

A comparison of the two distributions shows that there is a slight similarity among the two distributions however, using the IT method, actual distributions were produced for the total crashes and the diamond interchange crashes and these distributions are represented in Table 4.

Table 4: Distribution Equations for Comparison of Total Crashes and Diamond Interchange Crashes

Year	Total Crash Functions	Diamond interchange Functions
2003	$x = \begin{cases} e^{25\ln(0.1778r+1)} \ldots 0 \le r \le 0.73 \\ 65.92 - 86.55\sqrt{(1-r)} \ldots\ldots 0.73 \le r \le 1 \end{cases}$	$x = \begin{cases} e^{-3.268\ln(1-0.718r)} \ldots 0 \le r \le 0.796 \\ 20 - 21.5\sqrt{(1-r)} \ldots\ldots 0.796 \le r \le 1 \end{cases}$
2004	$x = \begin{cases} e^{-4.76\ln(1-0.561r)} \ldots 0 \le r \le 0.86 \\ 56.198 - 90.9\sqrt{(1-r)} \ldots\ldots 0.86 \le r \le 1 \end{cases}$	$x = \begin{cases} e^{-2.23\ln(1-0.813r)} \ldots 0 \le r \le 0.934 \\ 19 - 34.3\sqrt{(1-r)} \ldots\ldots 0.934 \le r \le 1 \end{cases}$
2005	$x = \begin{cases} e^{-9.708\ln(1-0.0.311r)} \ldots 0 \le r \le 0.89 \\ 43 - 63.25\sqrt{(1-r)} \ldots\ldots 0.89 \le r \le 1 \end{cases}$	$x = \begin{cases} -6.329\ln(0.854-0.88r) \ldots 0 \le r \le 0.904 \\ 19 - 34.3\sqrt{(1-r)} \ldots 0.904 \le r \le 1 \end{cases}$

2006	$x = \begin{cases} e^{9.43\ln(0.487r+1)} \ldots 0 \le r \le 0.81 \\ 52 - 66.67\sqrt{(1-r)} \ldots\ldots 0.81 \le r \le 1 \end{cases}$	$x = \begin{cases} -9.8\ln(0.903 - 0.889r) \ldots 0 \le r \le 0.993 \\ 27 - 34.25\sqrt{(1-r)} \ldots 0.993 \le r \le 1 \end{cases}$
2007	$x = \begin{cases} e^{10.12\ln(0.417r+1)} \ldots 0 \le r \le 0.87 \\ 42 - 52.128\sqrt{(1-r)} \ldots\ldots 0.87 \le r \le 1 \end{cases}$	$x = \begin{cases} -7.692\ln(0.878 - 0.946r) \ldots 0 \le r \le 0.85 \\ 21 - 20\sqrt{(1-r)} \ldots 0.85 \le r \le 1 \end{cases}$

The distributions in Table 4. show that the crashes for the year 2003 and 2004 were both power distributions however from the year 2004 to 2007 the best fitting distribution was the exponential distributions. To test the statistical significance of the two distributions and Pearson's Chi square test was performed which is shown in table 7 will be discussed in the results discussion section.

VI. PARTIAL DIAMOND INTERCHANGE CRASHES

Similar to the diamond interchanges, the comparison of the partial diamond interchange crashes was done with the total crash distributions. However, there were fewer crashes from the partial diamond interchange with approximately equal average number of crashes over the five years as shown in table 2. Figure 3 shows the comparison of the total crashes and the partial diamond crashes for the year 2007.

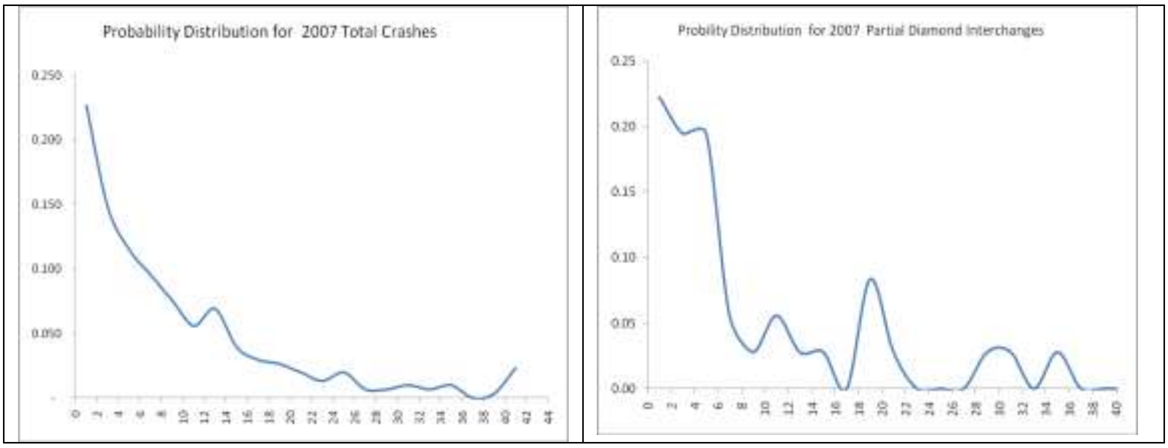

Figure 3: Comparison between Total Crashes and Partial Diamond Interchanges

The distribution of the partial diamond interchange crashes has a slight similarity with the total crash distribution for this particular year and it shows that the maximum probabilities for the lower level interval crashes are approximately between 0.2 and 0.25 for both distributions. However Table 5 shows the actual distributions for the years of analysis.

Table 5: Distribution Equations for Comparison of Total Crashes and Partial Diamond Interchange Crashes

Year	Total Crash Functions	Partial Diamond interchange Functions
2003	$x = \begin{cases} e^{25\ln(0.1778r+1)} \ldots 0 \le r \le 0.73 \\ 65.92 - 86.55\sqrt{(1-r)} \ldots\ldots 0.73 \le r \le 1 \end{cases}$	$x = \begin{cases} e^{-3\ln(1-0.794r)} \ldots 0 \le r \le 0.712 \\ 20 - 21.5\sqrt{(1-r)} \ldots\ldots 0.99 \le r \le 1 \end{cases}$
2004	$x = \begin{cases} e^{-4.76\ln(1-0.561r)} \ldots 0 \le r \le 0.86 \\ 56.198 - 90.9\sqrt{(1-r)} \ldots\ldots 0.86 \le r \le 1 \end{cases}$	$x = \begin{cases} e^{-7.812\ln(1-0.346r)} \ldots 0 \le r \le 0.787 \\ 19 - 34.3\sqrt{(1-r)} \ldots\ldots 0.99 \le r \le 1 \end{cases}$
2005	$x = \begin{cases} e^{-9.708\ln(1-0.0.311r)} \ldots 0 \le r \le 0.89 \\ 43 - 63.25\sqrt{(1-r)} \ldots\ldots 0.89 \le r \le 1 \end{cases}$	$x = \begin{cases} e^{7\ln(0.827r+1)} \ldots 0 \le r \le 0.419 \\ 19 - 34.3\sqrt{(1-r)} \ldots\ldots 0.99 \le r \le 1 \end{cases}$

2006	$x=\begin{cases} e^{9.43\ln(0.487r+1)}\text{....}0\le r\le 0.81 \\ 52-66.67\sqrt{(1-r)}\text{.....}0.81\le r\le 1 \end{cases}$	$x=\begin{cases} e^{-100\ln(1-0.032r)}\text{....}0\le r\le 0.974 \\ 19-34.3\sqrt{(1-r)}\text{.....}0.99\le r\le 1 \end{cases}$
2007	$x=\begin{cases} e^{10.12\ln(0.417r+1)}\text{....}0\le r\le 0.87 \\ 42-52.128\sqrt{(1-r)}\text{.....}0.87\le r\le 1 \end{cases}$	$x=\begin{cases} -5.58\ln(0.823-1.125r)\text{ ....}0\le r\le 0.692 \\ 19-34.3\sqrt{(1-r)}\text{.....}0.99\le r\le 1 \end{cases}$

The distributions shown in table 5 shows that all diamond interchange follow a power distribution except for the 2007 distribution which has an exponential distribution. The significance difference between these distributions was tested again by the Pearson Chi square test with which the summary is provided on table 7 in the summary section.

VII. PARTIAL CLOVERLEAF INTERCHANGE CRASHES

The partial cloverleaf interchanges were the second highest in the number of this type of interchange. This type of interchange was also expected to have similar distribution characteristics to the total crash distribution. Similar to the previous types, a comparison of the total crash distributions was done with the partial cloverleaf interchange and Figure 4 shows an example of the comparison for the distributions for 2007.

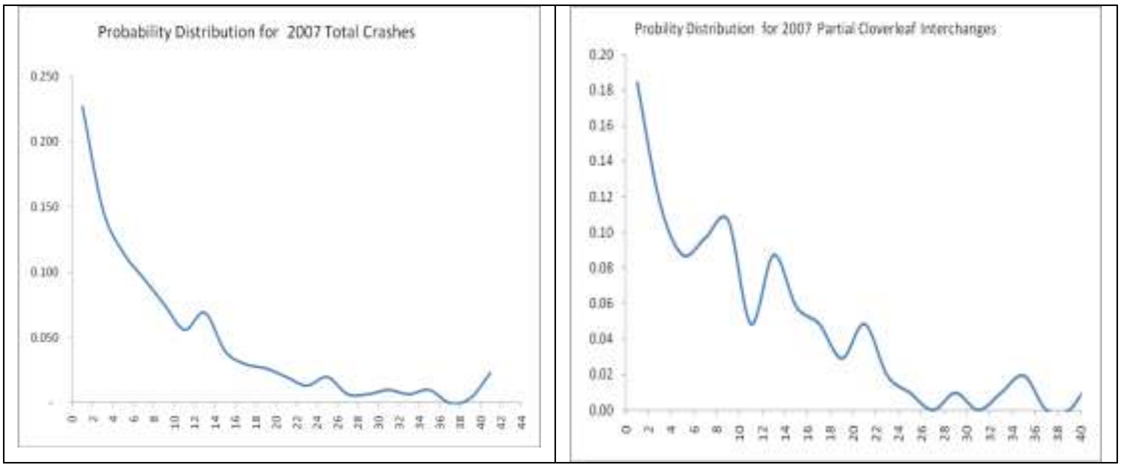

Figure 4: Comparison between Total Crashes and Partial cloverleaf Interchanges

The partial cloverleaf distributions had a lower highest probability for the lower crash intervals. The partial cloverleaf interchanges had its highest probability between 0.18 and 0.2 where as that for the total crash distributions has its highest probability above 0.2. Table 6 shows the actual distribution for the total crashes and the partial cloverleaf crashes.

Table 6: Distribution Equations for Comparison of Total Crashes and Partial Cloverleaf Interchange Crashes

Year	Total Crash Functions	Partial Cloverleaf interchange Functions
2003	$x=\begin{cases} e^{25\ln(0.1778r+1)}\text{....}0\le r\le 0.73 \\ 65.92-86.55\sqrt{(1-r)}\text{.....}0.73\le r\le 1 \end{cases}$	$x=\begin{cases} e^{-3.65\ln(1-0.66r)}\text{....}0\le r\le 0.865 \\ 20-21.5\sqrt{(1-r)}\text{.....}0.99\le r\le 1 \end{cases}$
2004	$x=\begin{cases} e^{-4.76\ln(1-0.561r)}\text{....}0\le r\le 0.86 \\ 56.198-90.9\sqrt{(1-r)}\text{.....}0.86\le r\le 1 \end{cases}$	$x=\begin{cases} -4.46\ln(0.799-0.87r)\text{ ....}0\le r\le 0.888 \\ 19-34.3\sqrt{(1-r)}\text{.....}0.99\le r\le 1 \end{cases}$
2005	$x=\begin{cases} e^{-9.708\ln(1-0.0.311r)}\text{....}0\le r\le 0.89 \\ 43-63.25\sqrt{(1-r)}\text{.....}0.89\le r\le 1 \end{cases}$	$x=\begin{cases} -5.747\ln(0.84-0.876r)\ldots 0\le r\le 0.909 \\ 19-34.3\sqrt{(1-r)}\ldots .0.99\le r\le 1 \end{cases}$

2006	$x = \begin{cases} e^{9.43\ln(0.487r+1)} \ldots 0 \le r \le 0.81 \\ 52 - 66.67\sqrt{(1-r)} \ldots\ldots 0.81 \le r \le 1 \end{cases}$	$x = \begin{cases} -9\ln(0.895 - 0.904r) \ldots 0 \le r \le 0.94 \\ 19 - 34.3\sqrt{(1-r)} \ldots 0.99 \le r \le 1 \end{cases}$
2007	$x = \begin{cases} e^{10.12\ln(0.417r+1)} \ldots 0 \le r \le 0.87 \\ 42 - 52.128\sqrt{(1-r)} \ldots\ldots 0.87 \le r \le 1 \end{cases}$	$x = \begin{cases} -10.75\ln(0.911 - 0.875r) \ldots 0 \le r \le 0.94 \\ 19 - 34.3\sqrt{(1-r)} \ldots\ldots 0.99 \le r \le 1 \end{cases}$

The distributions for the partial cloverleaf were all exponential except for the 2003 crashes which followed a power distribution. The results for the significant difference test are presented in Table 7and discussed in detail.

VIII. SIGNIFICANT TEST FOR THE DISTRIBUTIONS

Most distributions were similar to the total crashes distributions however there was a need to have a quantitative test to confirm the hypothesis made by the graphs that were presented. Since the number of data points was unequal for the interchanges, the distributions were used to simulate the crash distributions and the results were used for the Pearson Chi square test analysis. For the simulation, 100 data points were produced. Table 7 shows the summary of the results.

Table 7: Comparison of the Interchange type distributions with total crash distribution

Type of Interchange	Year				
	2003	**2004**	**2005**	**2006**	**2007**
Diamond	1.000	0.207	1.000	1.000	1.000
Partial Diamond	1.000	1.000	1.000	1.000	1.000
Partial Cloverleaf	1.000	0.000	1.000	1.000	1.000

The results from table 7 provide the probability for accepting the null hypothesis for the Pearson's Chi square distribution that the observed distribution is similar to the expected distribution. From the table, all probabilities are greater than the alpha value of 0.05 suggesting that the null hypothesis is accepted therefore it shows that there needs to be more statistical evidence to show the differences in these distributions. However, for the purposes of analysis this analysis can be used as guide to accept that the distributions for the interchange types are equal to the distribution of the total crashes. However, a closer observation of the table shows that the probability for the 2004 crash distribution test was lower than 0.5 suggesting that the uncertainty on the difference for this year's crashes was more than the rest of the years.

In addition to the comparison with the total crash distribution, the type of interchange distributions were also compared to the Poisson distribution as shown in table 8 the Poisson distribution is always used for count data such as crash data. Since this distribution is one of the popular distributions used for crash analysis there was a need to compare the types of interchanges crash distribution.

Table 8: Comparison of the Interchange type distributions and the Poisson distributions

Type of Interchange	Year				
	2003	**2004**	**2005**	**2006**	**2007**
Diamond	0.998	0.001	1.000	1.000	1.000
Partial Diamond	1.000	1.000	1.000	1.000	0.720
Partial Cloverleaf	1.000	0.000	1.000	1.000	1.000

The results in table 8 shows that most of the types of interchange distributions may follow Poisson distribution. The 2003 diamond interchange distribution and 2007 partial diamond distributions were the two that did not have a probability of 1 however their probabilities were above 0.5 therefore a higher probability suggests that there are more prospects to the similarity of the distributions to Poisson distribution.

IX. REGRESSION ANALYSIS

The regression was performed on the interchange crashes in order to observe the variables that influence the occurrence of crashes on these interchange. However, one of the objectives of this research was to observe the behavior of the types of interchanges with the crashes occurrence. The variables that were considered for this analysis were the AADT, operating speed, location (urban/rural), truck percentage and the type of interchange. The first three years of analysis were used for this analysis. The previous section showed that there was a statistical similarity among the actual interchange distributions and the Poisson distribution, the Poisson distributions was used. The result of the analysis is shown in table 9.

Table 9: Regression Results

Variables	Coefficient	Std. Error	Z Value	Pr(>|z|)
(Intercept)	7.23	1.687	4.286	0.00
AADT	-0.00000044	0.00000	-2.193	0.03
Interchange type	0.01	0.050	0.162	0.87
Speed	-0.06	0.022	-2.594	0.01
Truck	-9.67	2.777	-3.483	0.00
Location	-0.22	0.262	-0.839	0.40

Table 9 shows that all variables have negative effect on the occurrence of crashes, except the interchange type which has a positive coefficient. In addition to this all variables are significant at 0.05 alpha value except the location variable and interchange type. However, unimodels were run for these regressor variables to observe their behavior on crashes. The results from the unimodals showed that AADT, interchange type and location produced positive coefficients suggesting an increase in crashes with the increase in these variables. Speed and truck percent produced negative coefficients similar to the multimodel results.

X. DISCUSSION OF RESULTS

There were two types of analysis considered the first dealt with the determination of the interchange crash distribution and the second part was the observation of the effects of a number of variables on the occurrence of these interchanges crashes. From the first the distributions were found to be either negative exponential or power distributions (with negative powers). These results are similar to other studies that have been done for years (*3*,*6*). However the actual distributions for the particular roads and types of interchanges clearly showed that there was a difference in the mathematical expressions even though the statistical analysis showed that there was no statistical significance in the distributions using the Pearson's chi square test. The difference in the actual distributions therefore shows that there are different characteristics that cause the variation on the occurrence of these crashes from one location to the other. The difference may be due to the different traffic patterns, geometric arrangement, driver characteristics or environmental characteristics.

The second analysis used regression models to explain the effect of variables on the occurrence of these interchange crashes. The variables that were used were, traffic characteristics, geometric characteristics and location characteristics. The traffic characteristics used were the AADT and operating speed, geometric characteristics was the type of interchange and the location was either urban or rural. The geometric and location characteristics were categorical variables where as the rest were continuous variables. The Poisson distribution was used again for this since statistically there was no significant difference to the above produced distributions from the first section. The results again contradict some other studies that have been done on crashes. Most studies consider AADT as a variable that increases the number of crashes on the roadways since it is an exposure variable. However in this study this variable produced opposite results such that with the increase in AADT there is a decrease in crashes on the interchanges. This again is another proof of the difference in characteristics from different roadway elements. An observation of the characteristics of the interchange operation shows that with the increase in AADT most drivers will be more careful and there will be less speeds experienced hence reducing the number of crashes. This phenomenon can also be supported by the results of the effects of the speed on the occurrence of the interchange crashes since the increase in the speed reduces the number of crashes suggesting that there would be less exposed vehicles attributing to high speeds.

XI. CONCLUSION AND RECOMMENDATION

Since the nineteen fifties when the interstate system was introduced there has been research on the major highways with limited access to increase their operation and safety. However, interchanges have been an entity as a variable rather than an independent function. The complexity of interchanges calls for more in depth observation in order to improve their operation and safety too. The objective of this paper was to produce a preliminary analysis of interchanges in Florida by considering the types and study crash distributions. With the observation of the crash distribution, a comparison of the total crashes that occur was compared with the different interchange type distributions. From the PDFs it was clearly seen that there are slight differences among the distributions when comparing them among different types interchanges and with the total crashes. With that phenomenon there is a need to analyze interchanges separately and bearing in mind the operations on different types of interchanges are different therefore they can not be treated in the same manner. The second objective was to observe the effect of different variables pertaining the interchanges. The results from this analysis has also shown different results from studies done on the freeways especially when looking at the variables as discussed in the result discussion. Again these results show that interchanges should not be analyzed similar to the freeway segments.

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