LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT

Guidelines for Conducting a Crash Data Analysis using Safety Performance Functions and Pattern Recognition Analysis

January 2016

DESTINATION ZERO DEATHS

PREFACE

These guidelines are for use by Louisiana Department of Transportation and Development (LADOTD) employees, consultants, metropolitan planning organizations (MPOs), and local jurisdictions conducting safety studies and preparing reports. This document is not intended to establish standards or requirements.

These guidelines will be available on LADOTD's website at http://www.dotd.la.gov/planning/highway_safety. The Highway Safety Section will maintain and update these guidelines as needed. If you need more information, please contact the Highway Safety Section at DOTD-HighwaySafety@la.gov.

I. INTRODUCTION

These guidelines are intended to aid transportation professionals in the assessment and management of safety performance of their road projects on the state highway system. Understanding safety performance is critical to developing effective projects that provide for safety, mobility, and quality in maintaining, rehabilitating, and rebuilding the state's highways.

One of the key components of understanding safety performance is recognizing any pre-existing safety issues and safety implications of potential construction approaches. To identify any pre-existing safety issues, the LADOTD currently uses a descriptive method that utilizes historical crash data for determining patterns or trends in crashes in order to direct resources to locations that may require mitigation.

The purpose of this document is to describe the steps involved with conducting a crash data analysis using Safety Performance Functions (SPFs) and the Pattern Recognition Analysis (PRA).

II. METHODOLOGY

Analyzing safety on a roadway segment involves a very similar procedure to paying a visit to the doctor. To begin with, the receptionist asks you for basic information about yourself and you need to fill out some paperwork. In other words, they want to know who you are. After some time, a nurse welcomes you into a room to collect minimal measurements of your body including weight and height. This also involves some questions about your general habits such as diet, weight, exercise, stress, sleep, smoking, alcohol use, vaccines, etc., to define your current condition. In other words, they want to know your current lifestyle or operating conditions. Finally, the doctor comes in, analyzes your condition and compares you to the rest of the population to determine if you fall above, within, or below an established baseline.

Falling above or below the baseline will determine the next step. Most likely, it will lead you into further and generally more comprehensive exams, i.e. blood tests, x-rays, cardiogram, etc., depending on what your symptoms are. After receiving the results, the doctor will have a better understanding of possible issues, where they are located and how to deal with them.

Similarly, when analyzing safety on a roadway segment we follow the same steps. First, a location is properly identified. Then, the crash history of the location is reviewed and different analyses are performed to compare to an established baseline. If the location falls above the baseline, further examinations are executed to identify possible issues, their locations and how to deal with them.

A. Know Your Location

It is imperative to have a comprehensive understanding of the study location. When you go to the doctor, no one knows yourself better than you; you should feel similarly about the location you are analyzing. Basic pieces of information required to perform an informative and relevant safety analysis include control section and log-miles, highway classification, whether it is urban or rural, annual average daily traffic (AADT), surroundings (potential to extend your limits), the crash history of the last three years and a map of the location. This resembles you providing your basic information at the doctor's office.

B. Crash History

The crash history of a roadway segment will only provide an overview of the situation. It resembles measuring your height and weight at the doctor's office. All you can tell from those numbers is that you are a certain height and a certain weight. In other words, they are just numbers. To determine your "ideal body weight", several factors should be considered including age, muscle-fat ratio, height, gender, and bone density. Although there are several methods to estimate it, independently of the method you use, there is an established baseline that will determine if you are underweight, ideal, overweight or even obese.

In the case of a roadway segment, looking at the crash history may be useful in the sense of understanding the big picture of the situation. However, all that can be said is that there were a certain number of crashes, of a certain type, at a certain year, and under certain conditions. Without having a baseline it cannot be determined if there is actually an issue with the segment or not.

C. Network Screening

Despite many years of modern road building and until recently, the transportation engineering profession lacked a definite frame of reference on how to assess and describe the magnitude of the safety problem. Since the publication of the HSM in 2010, the science of highway safety has been quickly evolving and states are establishing their own baselines through different methods.

The HSM mentions 13 “performance measures” (methods) used to determine the magnitude of a safety problem on a specific roadway segment. It also suggests that “performance measure selection” (method selection) should be based on data availability, regression to the mean bias, and the establishment of a performance threshold.

The Louisiana Department of Transportation and development (DOTD) has been using “Crash Rate” and “Excess proportion of Specific Crash Types” as methodologies for network screening and analyzing safety on both, roadway segments and intersections. However, since familiarity with the data has grown, data improvements have been made, and new technologies are better understood, the DOTD has decided to incorporate the “Level of Service of Safety” as the methodology for the network screening process of roadway segments. In addition, the DOTD has decided to reevaluate the “Excess proportion of Specific Crash Types” incorporating a more statistically rigorous approach to the safety analysis process. Until more data is available for intersections, they will continue to use the “Crash Rate” and “Excess proportion of Specific Crash Types.”

1. Level of Service of Safety

In simple words, the Level of Service of Safety (LOSS) describes how a specific roadway segment is currently performing (crash count and severity) in reference to what is “average” for a segment with the same basic characteristics (AADT (Annual Average Daily Traffic), length, and highway classification). The “average” values are determined by Safety Performance Functions (SPFs) that statistically fit the crash history of all segments statewide within the same highway classification. Then, the degree of deviation from the respective SPF (difference between current performance and “statewide average”) will place the segment into one of four LOSS classifications:

LOSS 1: Low Potential for Safety Improvement
LOSS 2: Low to Moderate Potential for Safety Improvement
LOSS 3: Moderate to High Potential for Safety Improvement

LOSS 4: High Potential for Safety Improvement

Based on crash history from years 2012-2014, two Louisiana specific SPFs (one for all crashes and one for fatal and serious injury crashes) were developed for 11 different highway classifications as follows:

- Rural two-lane
- Rural two-lane with TWLTL
- Rural four-lane divided
- Rural four-lane undivided
- Rural four-lane with TWLTL
- Urban two-lane
- Urban two-lane with TWLTL
- Urban four-lane divided
- Urban four-lane undivided
- Urban four-lane with TWLTL
- Urban six-lane

The SPFs for total number of crashes were developed using the average number of total crashes from years 2012-2014, while the SPFs for fatal and serious injury (F&SI) crashes were developed using the total count of F&SI crashes of those 3 years. Appendixes A and B provide a list with all the equations of the SPFs with their respective coefficients and over-dispersion parameters. It is anticipated that the DOTD Highway Safety Section will validate or refine the SPFs on a 3 to 5-yr cycle.

Figure 1 presents an example of an urban four-lane undivided roadway segment during the network screening process.

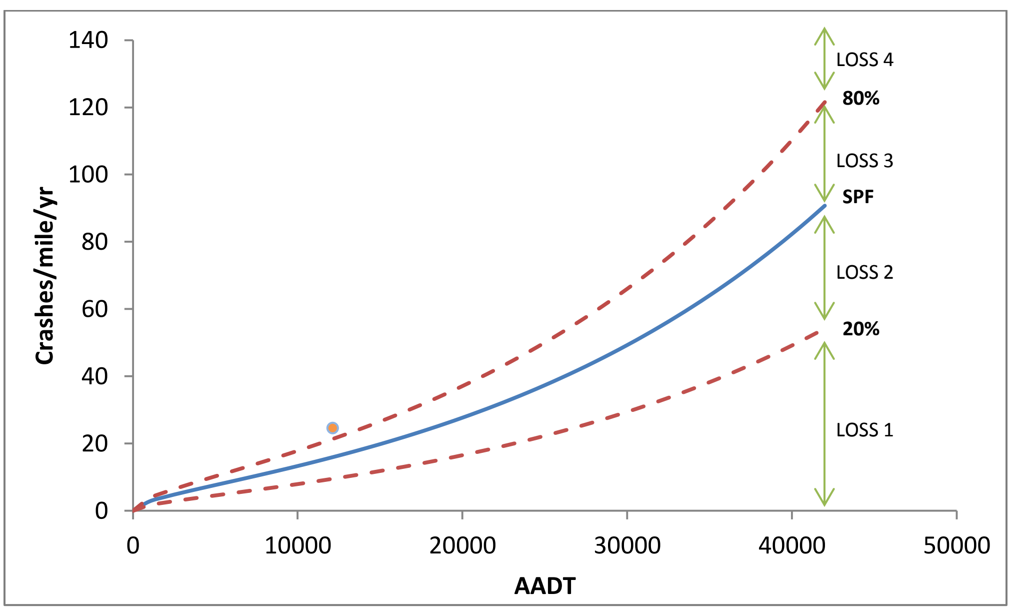


Figure 1 Urban 4-lane Undivided SPF - All Crashes

The orange dot shows where the segment falls compared to the statewide average SPF (blue line). The boundaries dividing LOSS 1 from LOSS 2, and LOSS 3 from LOSS 4 are determined by percentiles (in this case 20% and 80%) of the Gamma distribution of the crash history of all segments within the same highway classification. As it is shown, the segment falls above the 80% line, which represents a LOSS 4.

Although the LOSS provides a comparison of current performance to statewide average, it does not provide any information related to the nature of the safety problem itself. If the safety problem is present, the LOSS will describe only its magnitude. The nature of the problem is determined by pattern recognition techniques.

D. Pattern Recognition Analysis

Going back to the medical analogy, during the screening process the doctor knows that your situation is statistically above an established baseline. This means that more specific analyses have to be done to find the specific location(s) and cause(s) of those issues. In highway safety words, the crash data has to be taken to deeper levels of analysis.

Using the Number-Rate method, the DOTD recommends sorting the crash data by categories (type of collision, time of day, surface condition, etc.) to identify overrepresentation (proportionally greater than statewide average). Statewide averages are percentages of specific crash types based on total number of crashes. However, a known issue with this approach is that there could be “hidden overrepresentation” that may not be recognized when analyzing the segment as a whole. The longer a segment analysis is the greater chances of missing a particular problem area. Also, the method would be more reliable and accurate if it took into account probability and statistics rather than a direct comparison to statewide averages. This will be covered in the Bernoulli Trials section.

1. Hidden Over-representation

Consider a roadway improvement project involving a 5-mile-long segment. Figure 2 illustrates the crash history within the project limits segmented by 1-mile sections. When analyzing the segment as a whole (5 miles), 30% of the crashes (15 out of 50) are roadway departures. If the statewide average for a roadway under this classification is 32%, for example, we would conclude that there is no overrepresentation. However, by considering “mile 3” only, roadway departures would represent 70% of the crashes (7 out of 10), which would trigger overrepresentation. This means that there is a significant yet correctible problem, which is not detected when the segment is analyzed as a whole. A form of continuous test should be used throughout the length of the segment to truly determine overrepresentation. This test is called the pattern recognition analysis.

	mile 1	mile 2	mile 3	mile 4	mile 5
Rwy Departures =	2	2	7	3	1
Other =	8	8	3	7	9
Total =	10	10	10	10	10

Rwy Departures =	15
Other =	35
Total =	50

Figure 2 Crash Data Diagram Segmented by 1-mi Sections

2. Bernoulli Trials

In the theory of probability and statistics, a Bernoulli trial (or binomial trial) is a random experiment with exactly two possible outcomes: "success" or "failure", in which the probability of success is the same every time the experiment is conducted. Assuming that crashes can be analyzed as independent Bernoulli trials, consider the following example:

The crash history of a 1-mile long segment shows that there were 20 total crashes; including 4 rear-end crashes (20% of total crashes). If the statewide average for rear-end crashes is 19%, for example, the statewide average comparative method would indicate that there is over-representation. However, considering that each crash can be viewed as a Bernoulli trial with 19% probability of being a rear-end crash, the probability of having 4 rear-ends out of 20 total crashes can be calculated using the Cumulative Binomial Distribution function within Excel as shown in Figure 3.

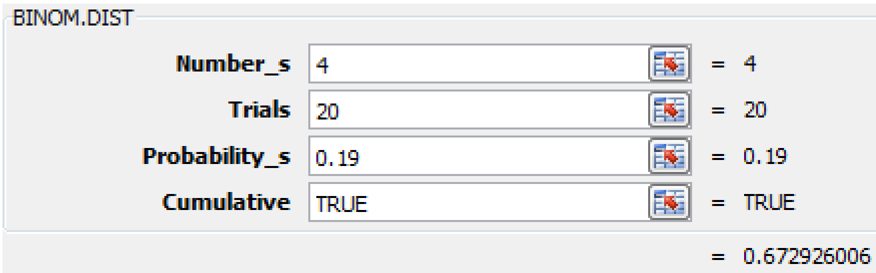


Figure 3 Excel Function - Binomial Distribution

As it is shown, the probability for this event to actually occur is only 67% which may be considered low. Recommended probabilities range from 90 to 99%. Using statistics and probability, we have a better understanding of overrepresentation.

3. Pattern Recognition Analysis

By using SPFs we can determine the magnitude of the safety problem in a segment. In terms of the nature of the problem, it is evident that estimating over-representation by analyzing segment length as a whole is not sufficient in detecting possible issues like "hidden over-representation". Some form of continuous test should be used throughout the length of the segment to truly determine over-representation. The patterns recognition analysis uses a "sliding segment" (scanning interval) of a determined length (Δ), that analyzes one piece of the segment at a time as it is described in Figure 4.

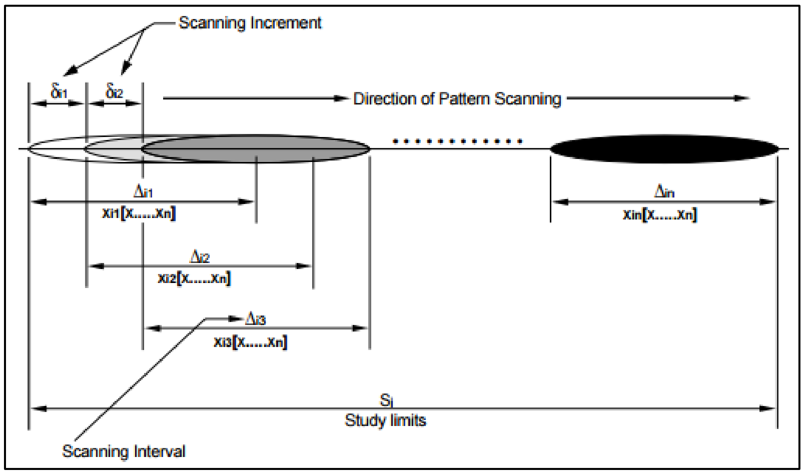


Figure 4 Diagram for Pattern Recognition Analysis

Starting at the beginning of the segment, the first scanning interval is analyzed using Bernoulli trials to determine over-representation of different categories (severity, manner of collision, etc.) rather than direct comparison to statewide averages. Then, the scanning interval slides a distance δ (scanning increment) performing a new analysis. This procedure is repeated until the whole segment length is analyzed determining the over-represented category(ies) of crashes and the location (logmiles) of the over-representation(s). Although this procedure may result in long and tedious calculations, the DOTD offers a tool to perform the analysis automatically.

III. SAFETY ANALYSIS EXAMPLE

A roadway safety improvement project involves a 1.5-mile segment. The segment is located on LA 315 within Control-Section 245-90 and the project limits go from log-mile 4.05 to 5.56 (segment length = 1.51 miles). The segment is classified as rural two-lane. The average AADT for the last three years is 1987 and the crash history notes that there were 14 total non-intersection crashes, including 2 F&SI crashes in the last three years.

A. Know Your Location

In order to start the analysis, it is recommended to have a clear understanding of the location. It is like providing your basic information at the doctor's office. This example provides all the information needed to start the analysis, which is summarized in Figure 5. In addition, analyzing the location on a map could also provide important information about the segment. As it is shown in Figure 6, there is a curve at the beginning of the study segment centered at log-mile 4.25.

Project Name/Number =	Example
Route =	LA 315
Control Section =	245-90
Logmile From =	4.05
Logmile To =	5.56
AADT =	1987
Highway Class =	Rural 2-Lane

Figure 5 Information Summary

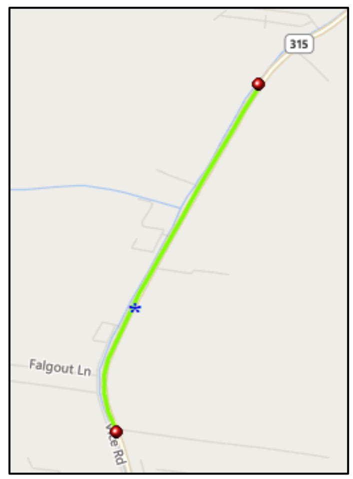


Figure 6 Map of Location

B. Crash History

Resembling the medical analysis, in this step we will measure the "height" and the "weight" of the segment. Figure 7 and Figure 8 display a basic representation of the crash history using the Cat Scan Tool which can be found in the DOTD's website (http://www.dotd.la.gov/planning/highway_safety). Although this information will only provide an overview of the situation, certain speculations about possible issues can be made.

Project Name/Number =	Example		**Analysis Performed by:**	DOTD Highway Safety
Control Section / Route =	245-90		**Date:**	xx/xx/2015
Logmile / Milepoint From =	4.05	(i.e XX.XX)		
Logmile / Milepoint To =	5.56	(i.e XX.XX)		

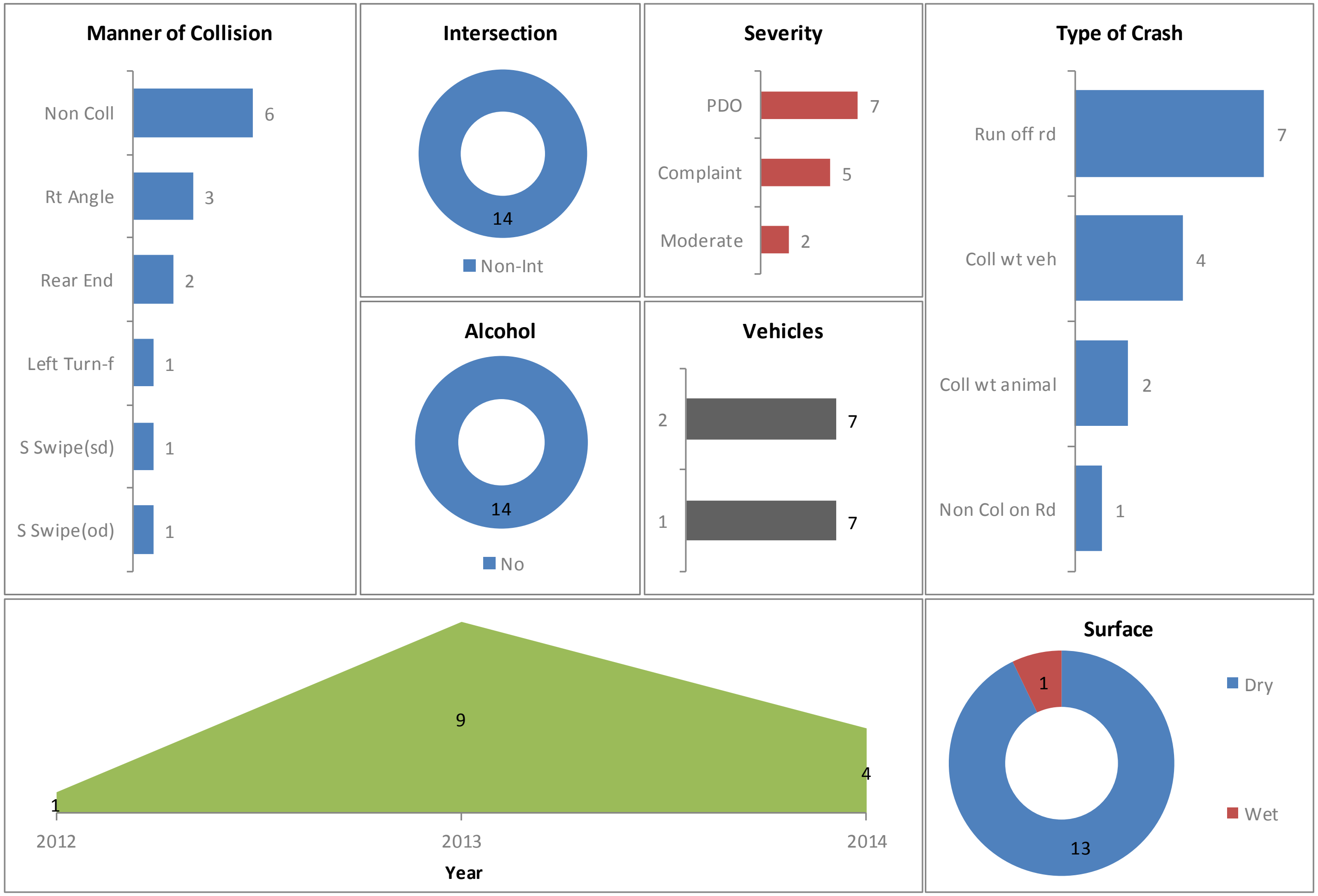


Figure 7 Crash History 1 - Sample

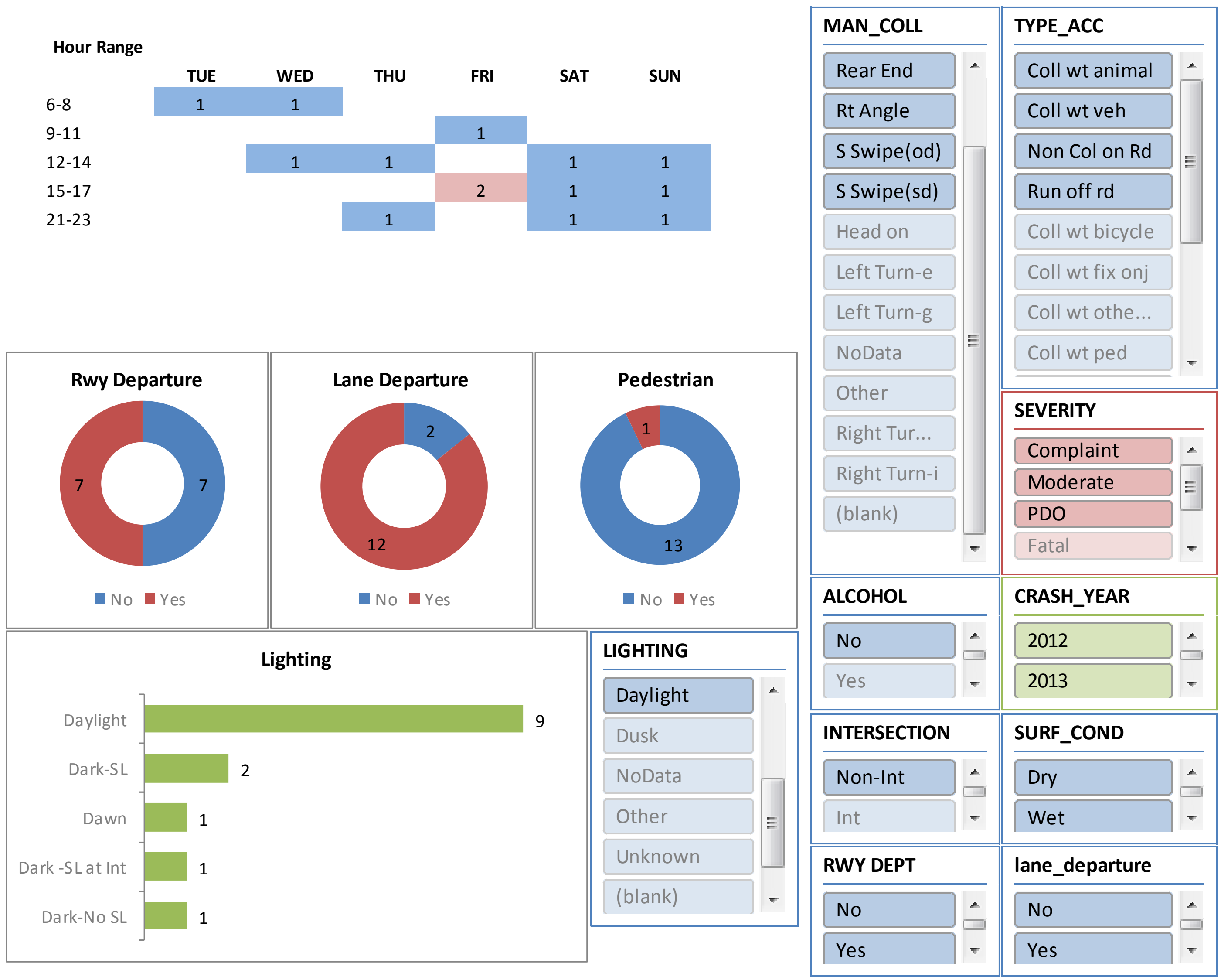


Figure 8 Crash History 2 - Sample

For example, 12 out of 14 crashes involved a lane departure and half of the crashes involved a roadway departure. Only from these two pieces of information we can speculate that there might be a contributing factor for roadway and/or lane departure crashes. Also, seeing that most of the crashes occurred during dry and daylight conditions (13 and 9 out of 14 crashes, respectively), it could also be assumed that the issue may not be related to wet surfaces or dark conditions.

C. Network Screening

As mentioned previously, the network screening process involves the concepts Level of Service of Safety (LOSS) and Safety Performance Functions (SPFs). In this step, we will discover how the segment has performed (crash count and severity) in reference to what it is "average" for a segment with the same length and AADT within the same highway classification (statewide average).

The CAT Scan Tool offers a graphic representation of the level of service of safety and performs all the calculations automatically for both "All crashes" and "F&SI crashes" as it is shown in Figure 13 and Figure 14. On the graphs, the orange dots represent the segment under study, the blue line is the statewide average, and the dashed, red line represents the 80th percentile.

The methodology for all calculations regarding the network screening process for all crashes and F&SI crashes is described below as backup information.

1. All Crashes

Estimating the current performance involves two main parts: the observed number of crashes and the correction for the regression to the mean bias (EB). From the information provided we estimate the observed crashes per year (CY):

$$CY = \frac{Number\ of\ Crashes}{Number\ of\ Years} = \frac{14}{3} = 4.67\frac{Crashes}{yr}$$

Then, the correction for the regression to the mean bias is applied using the predicted crashes per year (PCY), the over-dispersion parameter (OP) and the weighted adjustment (WA), which are calculated from the "All Crashes SPF" and its coefficients (Figure 9):

All Crashes - Rural 2-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$				
β_0	β_1	β_2	β_3	b
0.0028	0.9458	0.7489	NA	2.6400

Figure 9 All Crashes - Rural 2-Lane SPF

Note: SPFs for other rural and urban roadway classifications are listed in Appendix A and B

$$PCY = \beta_0 * L^{\beta_1} * AADT^{\beta_2} = 0.0028 * 1.51^{0.9458} * 1987^{0.7489} = 1.22 \frac{Crashes}{yr}$$

With the segment length (L) and the coefficients "b" and "β_1" from the SPF, OP is estimated:

$$OP = \frac{1}{b * L^{\beta_1}} = \frac{1}{2.64 * 1.51^{0.9458}} = 0.26$$

Then, WA is estimated with OP and PCY:

$$WA = \frac{1}{1 + PCY * OP} = 0.76$$

Finally, the corrected current performance of the segment in terms of All Crashes per mile per year, CMY (EB), is calculated as follows:

$$CMY\ (EB) = \frac{WA * PCY + (1 - WA) * CY}{L^{\beta_1}} = \frac{0.76 * 1.22 + (1 - 0.76) * 4.67}{1.51^{0.9458}} = 1.39 \frac{Crashes}{mi * yr}$$

Once the current performance of the segment is determined, it is compared to statewide average and placed into one of the four LOSS distributions mentioned before (See Figure 1). The statewide average (Predicted Crashes per mile per year, SWA) is calculated as follows:

$$SWA = \frac{PCY}{L^{\beta_1}} = \frac{1.22}{1.51^{0.9458}} = 0.83 \frac{Crashes}{mi * yr}$$

Since the current performance of the segment (1.39 Crashes/mi/y) is greater than the statewide average (0.83 Crashes/mi/y), the segment under study has a LOSS 3 or a LOSS 4. To estimate the limit between LOSS 3 and LOSS 4, the 80th percentile for the gamma distribution of the SPF is determined using the Excel inverse gamma distribution function (Figure 10) with:

Alpha = coefficient "b" from the SPF = 2.64, and

Beta = PCY divided by the coefficient "b" from the SPF = 1.22/2.64 = 0.46

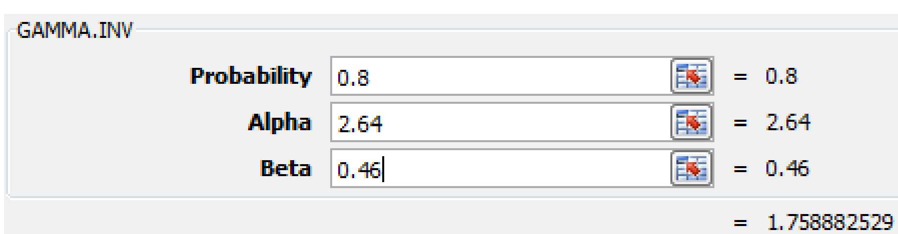


Figure 10 All Crashes - Excel Inverse Gamma Distribution Function

$$80th\ Percentile = \frac{GAMMA.INV(0.80, Alpha, Beta)}{L^{\beta_1}} = \frac{1.76}{1.51^{0.9458}} = 1.20\frac{Crashes}{mi * yr}$$

The current performance of the segment (1.39 Crashes/mi/y) is greater than the 80th percentile, which represents that the segment currently presents a LOSS 4 for All Crashes. In other words, the segment has high potential for safety improvements (high PSI) for all crashes.

2. F&SI Crashes

The procedure to calculate the LOSS for F&SI crashes is similar to the one used for all crashes. The main difference is that the SPFs for total number of crashes were developed using the *average* number of total crashes from years 2012-2014, while the SPFs for fatal and serious injury crashes were developed using the *total count* of fatal and serious injury crashes for those 3 years. Therefore, the F&SI calculations are based on number of crashes in 3 years rather than number of crashes per year.

From the information provided we have:

$$F\&SI = Number\ of\ F\&SI\ Crashes\ in\ 3\ Years = 2.0\frac{Crashes}{3yrs}$$

Then, the correction for the regression to the mean bias is applied using the predicted crashes per 3 years (PF&SI), the over-dispersion parameter (OPF&SI) and the weighted adjustment (WAF&SI), which are calculated from the “F&SI Crashes SPF” and its coefficients (Figure 11):

F&SI Crashes - Rural 2-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * \left(\frac{1}{1 + \beta_2 * AADT^{\beta_3}}\right)$				
β_0	β_1	β_2	β_3	ƀ
1.7824	0.9392	1590.2576	-0.7856	0.7303

Figure 11 F&SI Crashes - Rural 2-Lane SPF

Note: SPFs for other rural and urban roadway classifications are listed in Appendix A and B

$$PF\&SI = \beta_0 * L^{\beta_1} * \left(\frac{1}{1 + \beta_2 * AADT^{\beta_3}}\right) = 1.7824 * 1.51^{0.9392} * \left(\frac{1}{1 + 1590.2 * 1987^{-0.7856}}\right)$$
$$= 0.52\frac{Crashes}{3yrs}$$

With the segment length (L) and the coefficients “ƀ” and “β_1” from the SPF, OPF&SI is estimated:

$$OPF\&SI = \frac{1}{b * L^{\beta_1}} = \frac{1}{0.7303 * 1.51^{0.9392}} = 0.93$$

Then, WAF&SI is calculated with OPF&SI and PF&SI:

$$WAF\&SI = \frac{1}{1 + PF\&SI * OPF\&SI} = 0.68$$

Finally, the corrected current performance of the segment in terms of F&SI Crashes per mile per 3 years is calculated as follows:

$$CMY\ (EB) = \frac{WAF\&SI * PF\&SI + (1 - WAF\&SI) * F\&SI}{L^{\beta_1}} = \frac{0.68 * 0.52 + (1 - 0.68) * 2.0}{1.51^{0.9392}}$$
$$= 0.68 \frac{Crashes}{mi * 3yrs}$$

Now the statewide average for F&SI Crashes per mile per 3 years (Predicted Fatal & Serious Injury Crashes per mile per 3 years, SWA F&SI) is calculated to compare:

$$SWA\ F\&SI = \frac{PF\&SI}{L^{\beta_1}} = \frac{0.52}{1.51^{0.9392}} = 0.35 \frac{Crashes}{mi * 3yrs}$$

Once again, the current performance of the segment (0.68 Crashes/mi/3yrs) is greater than the statewide average (0.35 Crashes/mi/3yrs). This means that the segment under study has either a LOSS 3 or LOSS 4. Again, the 80th percentile for the gamma distribution of the SPF is determined with:

Alpha = coefficient "*b*" from the SPF = 0.7303, and

Beta = PF&SI divided by the coefficient "*b*" from the SPF = 0.52/0.7303 = 0.7120

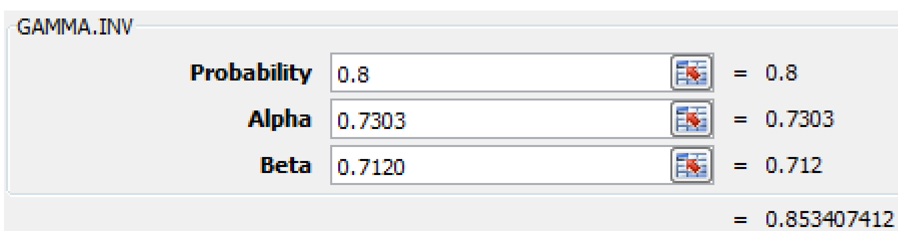


Figure 12 F&SI Crashes - Excel Inverse Gamma Distribution Function

$$80th\ Percentile = \frac{GAMMA.INV(0.80, Alpha, Beta)}{L^{\beta_1}} = \frac{0.85}{1.51^{0.9392}} = 0.58 \frac{Crashes}{mi * 3yrs}$$

As it was for All Crashes, the current performance of the segment (0.68 Crashes/mi/3yrs) is greater than the 80th percentile, which represents that the segment currently presents a LOSS 4 for F&SI Crashes. In other words, the segment has high potential for safety improvements (high PSI) for F&SI crashes.

Network Screening

Project Name/Number =	Example
Route =	LA 315
Control Section =	245-90 (i.e XXX-XX)
Logmile From =	4.05 (i.e XX.XX)
Logmile To =	5.56 (i.e XX.XX)
AADT =	1987 (Average of last 3 yrs)
Highway Class =	Rural 2-Lane

All Crashes - Safety Performance Function (SPF)

All Crashes - Rural 2-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$$

β_0	β_1	β_2	β_3	b
0.0028	0.9458	0.7489	0.0000	2.6400

Observed Crashes =	4.67	Crashes/yr
Predicted Crashes (SPF) =	1.22	Crashes/yr
Overdispersion Parameter =	0.26	
Weighted Adjustment =	0.76	
Segment Length =	1.51	mile
Observed Crashes =	3.09	Crashes/mile/yr
Predicted Crashes (SPF) =	0.83	Crashes/mile/yr
Expected Crashes (SPF + EB) =	1.39	Crashes/mile/yr
Statewide Average =	0.83	Crashes/mile/yr
80th Percentile =	1.20	Crashes/mile/yr
Level of Service of Safety =	**LOSS 4**	

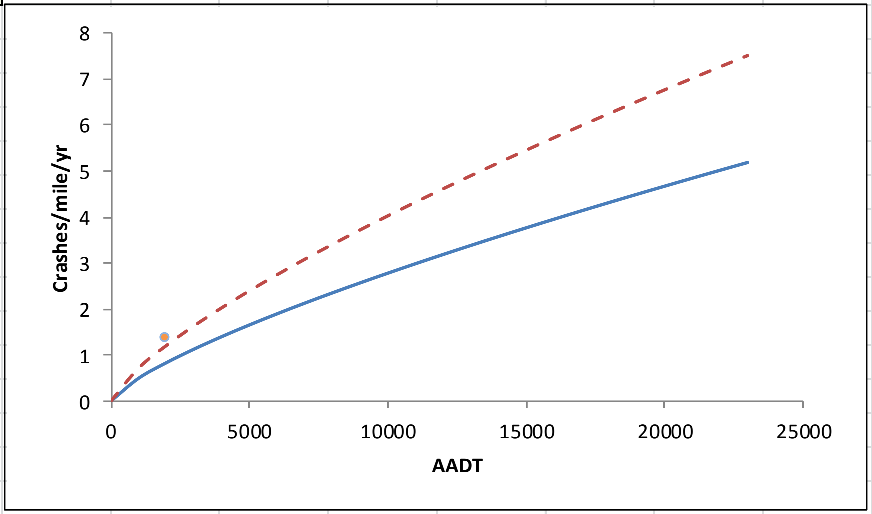


Figure 13 All Crashes - Network Screening - Sample

Fatal and Seriuos Injury Crashes - Safety Performance Function (SPF)

F&SI Crashes - Rural 2-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * \left(\frac{1}{1 + \beta_2 * AADT^{\beta_3}}\right)$$

β_0	β_1	β_2	β_3	b
1.7824	0.9392	1590.2576	-0.7856	0.7303

Observed Crashes =	2.00	Crashes/3yrs
Predicted Crashes (SPF) =	0.52	Crashes/3yrs
Overdispersion Parameter =	0.93	
Weighted Adjustment =	0.68	
Segment Length =	1.51	mile
Observed Crashes =	1.32	Crashes/mile/3yrs
Predicted Crashes (SPF) =	0.35	Crashes/mile/3yrs
Expected Crashes (SPF + EB) =	0.68	Crashes/mile/3yrs
Statewide Average =	0.35	Crashes/mile/3yrs
80th Percentile =	0.58	Crashes/mile/3yrs
Level of Service of Safety =	**LOSS 4**	

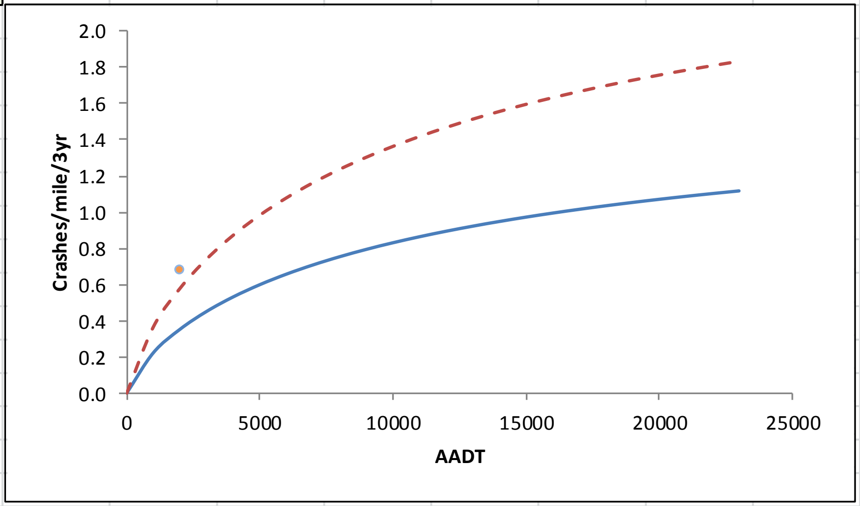


Figure 14 F&SI Crashes - Network Screening - Sample

D. Pattern Recognition Analysis

Since the pattern recognition analysis is a procedure that may result in long and tedious calculations, the DOTD offers the CAT Scan Tool to perform the analysis automatically. Once the crash history is added into the tool, the user has to press two buttons ("Run Deltas" and "Run Pattern Recognition Analysis") to perform the calculations as it is presented in **Figure 15**.

Highlighted cells (in red) represent the categories where at least one "sliding segment" had a greater probability of occurrence than the probability set as limit (cutoff probability). In this case, "Moderate", "Complaint", "Coll wt veh", "Coll wt animal", "Non Coll", "Rt Angle", "Roadway dept.", and "Lane Dept." crashes were overrepresented.

The number within each highlighted cell represents the number of "sliding segments" with greater probability of occurrence than the probability set as limit (95% in this case). In this case, "moderate injury", "complaint injury", "collision with vehicle", "collision with animal", "non-collision with vehicle", "right angle", "roadway departure", and "lane departure" crashes were overrepresented.

The pattern recognition analysis identifies the type(s) of potential issues (over-representation) within the segment. From the initial review of the crash history (Section 5.2), for example, it was noted that 12 out of 14 crashes involved a lane departure and half of the crashes involved a roadway departure. Based on this information it was speculated that there was a possible issue with lane and roadway departure crashes. This speculation was confirmed when the pattern recognition analysis showed over-representation of those types of crashes. Also, seeing that most of the crashes occurred during dry and daylight conditions (13 and 9 out of 14 crashes, respectively), it was expected that the issue might not have a relationship with wet surfaces or dark conditions. This was also confirmed through the pattern recognition analysis (no over-representation for dark or wet conditions).

At this point, there is only one question left: where do we need to perform surgery? Or in other words, where are those issues located? The CAT Scan Tool offers a graphic representation of the pattern recognition analysis by log-mile. **Figure 15** shows a check box located next to each crash category. Once a box is checked, a graphic representation of that specific category of crashes is displayed. In this case, the box for roadway departure crashes with 7 over-represented "sliding segments" is checked as it was shown in **Figure 15**. Figure 16 shows the graphic representation of the pattern recognition analysis for roadway departure crashes. In the graph, the solid line represents the probabilities of every "sliding segment" and the dashed line represents the probability set as limit (cutoff probability, 95% in this case). Then, if the solid line crosses the dashed line, there is an over-representation of that specific category of crashes at that specific location.

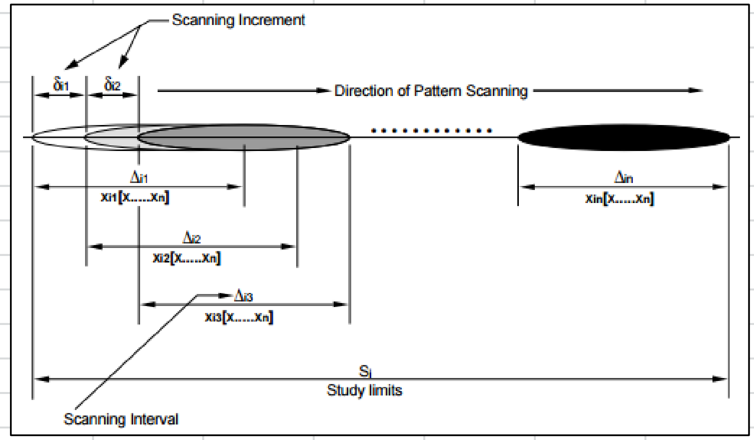
Pattern Recognition Analysis

Control Section =	245-90	(i.e XXX-XX)
Logmile From =	4.05	(i.e XX.XX)
Logmile To =	5.56	(i.e XX.XX)
AADT =	1987	(Average of last 3 yrs)
Highway Class =	Rural 2-Lane	

Δ =	0.50	miles
δ =	0.02	miles
Percent Cutoff =	95%	%
Possible Δs =	54	
AADT Group =	Low	

Run Deltas

Run Patter Recognition Analysis



Code	Category	Obs %	State %	Δs > Cutoff	
A	Fatal	0.00%	1.99%	0	☐
B	Severe	0.00%	1.02%	0	☐
C	Moderate	14.29%	10.48%	3	☐
D	Complaint	35.71%	28.03%	5	☐
E	None	50.00%	58.47%	0	☐
A	Run off rd	50.00%	56.33%	0	☐
B	Overturn on rd	0.00%	0.64%	0	☐
C	Coll wt ped	0.00%	0.46%	0	☐
D	Coll wt veh	28.57%	24.62%	13	☐
E	Coll wt pk car	0.00%	0.32%	0	☐
F	Coll wt train	0.00%	0.06%	0	☐
G	Coll wt bicycle	0.00%	0.06%	0	☐
H	Coll wt animal	14.29%	10.29%	12	☐
I	Coll wt fix obj	0.00%	3.08%	0	☐
J	Coll wt other obj	0.00%	1.80%	0	☐
K	Non Col on Rd	7.14%	2.34%	0	☐

Code	Category	Obs %	State %	Δs > Cutoff	
A	Non Coll	42.86%	67.33%	7	☐
B	Rear End	14.29%	11.32%	0	☐
C	Head On	0.00%	1.62%	0	☐
D	Rt Angle	21.43%	3.36%	2	☐
E	Left Turn-e	0.00%	2.62%	0	☐
F	Left Turn-f	7.14%	1.36%	0	☐
G	Left Turn-g	0.00%	0.65%	0	☐
H	Right Turn-h	0.00%	0.27%	0	☐
I	Right Turn-i	0.00%	0.23%	0	☐
J	S Swipe(sd)	7.14%	2.49%	0	☐
K	S Swipe(od)	7.14%	3.77%	0	☐
Z	Other	0.00%	4.94%	0	☐
1	Roadway dept.	50.00%	71.78%	7	☑
1	Lane Dept.	85.71%	79.28%	10	☐
B	Night (Dark-B)	14.29%	37.60%	0	☐
1	Alcohol	0.00%	11.36%	0	☐
B	Wet surface	7.14%	18.23%	0	☐

Figure 15 Pattern Recognition Analysis - Sample

As it is shown in the graph, roadway departure crashes are overrepresented approximately from log-mile 4.3 to 4.5. The over-represented roadway departure crashes occurred within the limits of the curve that was noticed in Figure 6. In the same way, every overrepresented category of crashes can be graphed and analyzed.

This safety analysis provides a deeper understanding of what the problems are and where are they located, leading the analyst to make a better selection of possible countermeasures improving safety in an easy, proactive and more informed manner.

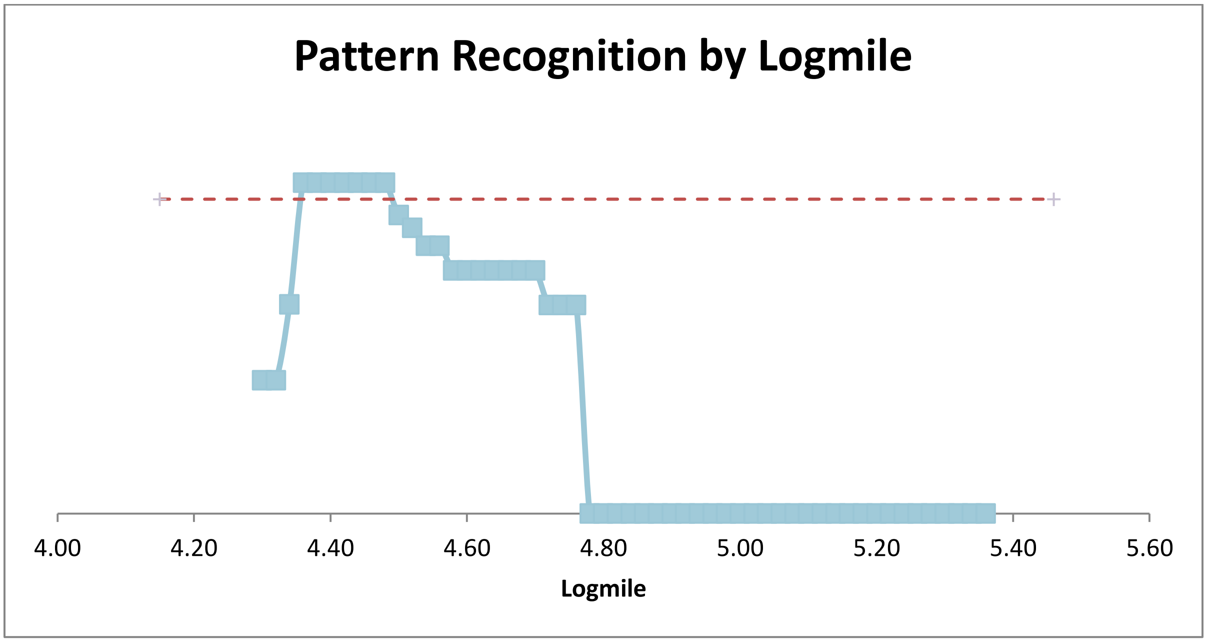


Figure 16 Pattern Recognition Analysis by Logmile - Sample

IV. INDICATIONS AND COUNTERMEASURES

The crash data analysis is intended to be a resource during plan development. Engineering judgment should be used and all factors should be considered when selecting an alternative.

The crash data analysis may provide insight to driver behavior and may consideration of additional countermeasures. The following table provides possible causes and countermeasures related to certain crash types.

Table 1: Possible Causes and Countermeasures by Crash Type

Crash Type	Possible Cause	Countermeasure
Access-related	Left-turning vehicles	Install median
		Install/lengthen left turn lanes
	Improperly located driveway	Move driveway to side street

		Install channelizing islands to define driveway location
		Consolidate adjacent driveways
	Right-turning vehicles	Provide right turn lanes
		Increase width of driveways
		Widen through lanes
		Increase curb radii
	Large volume of through traffic	Move driveway to side street
		Construct a local service road
	Large volume of driveway traffic	Signalize driveway
		Provide accel/decel lanes
		Channelize driveway
	Restricted sight distance	Remove obstruction
	Inadequate lighting	Install lighting
Bridges	Alignment	Realign bridge/roadway
		Install advance warning signs
		Improve delineation
	Narrow roadway	Widen structure
		Improve delineation
		Install signing/signals
	Visibility	Remove obstruction
		Install advance warning signs
		Improve delineation
	Vertical clearance	Rebuild structure/adjust roadway grade
		Install advance warning signs
		Improve delineation
		Provide height restriction/warning
	Slippery surface	Resurface deck
		Improve skid resistance
		Improve drainage
		Enhance signing
	Rough surface	Resurface deck
		Rehabilitate joints
		Regrade approaches
	Inadequate barrier system	Upgrade guardrail
		Upgrade approach rail/terminals
		Upgrade bridge - approach rail connections
		Remove hazardous curb
		Improve delineation

Intersection-related	Large volume of left/right turns (from side street)	Widen road
		Channelize intersection
		Install STOP signs
		Install signal/roundabout
		Increase curb radii
	Restricted sight distance	Remove sight obstructions
		Provide adequate channelization
		Provide left/right turn lanes
		Install warning signs
		Install STOP signs
		Install signal/roundabout
		Install advance markings to supplement signs
		Install STOP bars
	Slippery surface	Improve skid resistance
		Improve drainage
	Large volume of turning vehicles	Provide left/right turn lanes
		Increase curb radii
		Install signal/roundabout
	Inadequate lighting	Install lighting
	Lack of adequate gaps	Install signal/roundabout
		Install STOP signs
	Crossing pedestrians	Install/improve ped signing/marking
		Install signal
	Large total intersection volume	Install signal
		Add traffic lane
	Excessive vehicle speed on approaches	Install rumble strips in travel lane
	Inadequate traffic control devices	Upgrade traffic control devices
	Poor visibility of signals	Install/enhance advance warning signs
		Install overhead signals
		Install 12" LED signal lenses
		Install visors/backplates
		Relocate signals to far side of intersection
		Remove sight obstructions
		Add illuminated/retroreflectorized signs
	Unwarranted signals	Remove signals

	Inadequate signal timing	Upgrade signal system timing/phasing
Nighttime	Poor visibility	Install/enhance advance warning signs
		Install/enhance pavement markings
		Install lighting
Overturn	Roadside features	Flatten slopes/ditches
		Relocate drainage facilities
		Extend culverts
		Provide traversable culvert end treatments
		Install/improve traffic barriers
	Inadequate shoulder	Widen shoulder
		Upgrade shoulder surface
		Remove curb/obstruction
	Pavement	Eliminate edge drop-off
		Improve
Pedestrian/Bicycle	Poor visibility	Remove sight obstructions
		Install pedestrian crossing signs and pavement markings
		Install median for refuge
		Add "WALK" phase
		Install lighting
		Install advance warning signs
		Reduce speed limit
		Install/Improve sidewalks/bicycle paths
Railroad	Restricted sight distance	Install/enhance advance warning signs
		Install/enhance pavement markings
		Remove sight obstructions
		Provide preemption
		Install gates
		Install lighting
Rear End	Slippery pavement	Improve pavement condition
		Install high friction surface treatment
	Driver inattention	Provide advance warning signs
		Eliminate unnecessary signing
		Install transverse rumble strips
Right Angle (at Unsignalized Intersection)	Restricted sight distance	Install warning signs
		Install STOP signs

		Install yield signs
		Remove sight obstructions
		Install signal/roundabout
		Install lighting
Right Angle (at Signalized Intersection)	Poor visibility of signals	Install advance warning signs
		Install back plates
		Remove sight obstructions
		Add signal heads
		Upgrade to 12" LED heads
	Inadequate signal timing	Provide protected only left turn phase
		Adjust amber phase
		Provide all-red clearance interval
		Install detection
		Improve coordination
Run off the Road	Slippery pavement/ponded water	Improve pavement condition/skid resistance
		Improve drainage
	Inadequate road design and/or maintenance	Improve superelevation
		Improve shoulders
		Eliminate shoulder drop-off
		Install/improve traffic barriers
		Enhance signing
		Widen lanes
		Flatten slopes/ditches
		Improve alignment/grade
		Remove/Reduce/Delineate roadside hazards
	Poor delineation	Install roadside delineators
		Install advance warning signs
		Improve/install pavement markings
	Poor visibility	Increase sign size
		Install lighting
		Evaluate sight distance
Side Swipe or Head-On	Inadequate road design and/or maintenance	Perform necessary road surface repairs
		Install median or guardrail
		Reevaluate no passing zones
		Provide roadside delineators
		Improve alignment/grade

		Widen lanes
		Provide passing lanes
		Improve shoulders
		Install rumble strips
	Excessive vehicle speed	Set speed limit based on speed study
	Inadequate pavement markings	Install/improve centerlines, lane lanes, edge lines
		Install reflectorized markers
	Inadequate signing	Provide advance direction and warning signs
		Add illuminated street name signs
	Superfluous signing	Limit signs to meet standards
Wet Weather	Slippery pavement	Improve pavement condition
		Install high friction surface treatment
		Improve drainage
	Poor visibility	Install raised pavement markers

V. CRASH DATA QUALITY

Crash data is traffic incident information recorded by various police agencies throughout the State and uploaded to a statewide database, which is maintained by the Louisiana Department of Transportation and Development in conjunction with the Louisiana State University Highway Safety Research Group (LSU HSRG). Crash data listings are available through Crash 1, a user interface developed for easier access of the crash database. In most cases, a crash listing will provide sufficient information to complete a crash data analysis. However, in some cases it may be necessary to review each individual crash report. LADOTD has been using GPS coordinates to locate crashes to our base map. Before 2008, LADOTD used the control section log mile referencing system.

The crash data file for a given year is open to change until it is officially closed by the LADOTD Highway Safety Section, which is typically one year later. For example, the crash data file for 2008 was not closed until December 31, 2009. This timeframe allows for quality control measures and to allow law enforcement agencies to submit any outstanding crash reports. It is important to note that not all crashes that occur are reported and the crashes that are reported may be reported inadequately. Communication with law enforcement can help identify apparent safety concerns that are not indicated by the crash data. If a project is located within city limits, the local law enforcement agency should be contacted to gather input and support. The Highway Safety Section at LADOTD can assist in contacting the appropriate law enforcement personnel.

A. Data Sampling Size

Because less severe crashes are less likely to appear in crash databases, there is a potential problem of underreporting. Data generated from a small sampling can be misleading because they can be significantly influenced by small variances. A limited amount of data makes this descriptive method of analysis difficult. It is important to exercise engineering judgment when identifying crash patterns. Consultation of a statistician may be beneficial.

B. Confounding Effects

When evaluating the effectiveness of implemented countermeasures, it is often tempting to develop a simplified model with few explanatory variables (for example, using traffic flow as the only explanatory variable in the model). However, as with all traditional statistical estimation methods, leaving out important explanatory variables results in biased parameter estimates that can produce erroneous inferences. This would especially be the case if the omitted variable is correlated with variables included in the specification, which is often the case. For example, if multiple countermeasures were implemented it would be difficult to isolate the effectiveness of one of those countermeasures due to interaction with others.

C. Behavior Elements

Data elements associated with fatal motor vehicle crash reports are usually of very high quality with relatively few missing values. Fatal crashes require investigation of behavioral elements, including but not limited to seatbelt use, speeding, distractions, impairments, etc.

Data elements associated with non-fatal motor vehicle crash reports are usually of lesser quality and behavioral elements are often omitted from the crash report. This leads to underreporting of contributing factors.

D. Intersection Crashes

Law enforcement officers are continuously trained on how to properly fill out a crash report according to their investigation. The level of training for law enforcement personnel varies throughout the state so the interpretation of the uniform crash report may differ across jurisdictions. It is important to note that not all crashes that occur as a result of the intersection will be included within the ”Intersection (from report)” option and not all crashes within this option occurred as a result of the intersection. However, for consistency purposes it is recommended to use the “Intersection (from report)” option.

APPENDIX A: SPFs FOR RURAL ROADWAY SEGMENTS

All Crashes - Rural 2-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$				
β_0	β_1	β_2	β_3	ƀ
0.0028	0.9458	0.7489	NA	2.6400

F&SI Crashes - Rural 2-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * \left(\frac{1}{1 + \beta_2 * AADT^{\beta_3}}\right)$				
β_0	β_1	β_2	β_3	ƀ
1.7824	0.9392	1590.2576	-0.7856	0.7303

All Crashes - Rural 3-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$				
β_0	β_1	β_2	β_3	ƀ
3.12E-06	0.7857	1.5694	NA	1.0000

F&SI Crashes - Rural 3-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$				
β_0	β_1	β_2	β_3	ƀ
6.05E-07	1.0775	1.6822	NA	1.9408

All Crashes - Rural 4-Lane Divided SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$				
β_0	β_1	β_2	β_3	ƀ
0.0022	0.7350	0.7314	2.18E-05	2.9468

F&SI Crashes - Rural 4-Lane Divided SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$				
β_0	β_1	β_2	β_3	ƀ
1.45E-05	0.8425	1.2063	-2.31E-05	1.4528

All Crashes - Rural 4-Lane Undivided SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$				
β_0	β_1	β_2	β_3	ƀ
0.0013	0.6425	0.7781	2.61E-05	36.3982

F&SI Crashes - Rural 4-Lane Undivided SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * (1 + \beta_3 * \mathrm{AADT})$				
β_0	β_1	β_2	β_3	ƀ
0.0011	0.6942	0.6443	0.0001	72.1839

All Crashes - Rural 5-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$				
β_0	β_1	β_2	β_3	ƀ
0.0433	0.8221	0.2751	0.0001	4.6195

F&SI Crashes - Rural 5-Lane SPF				
$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * (1 + \beta_3 * \mathrm{AADT})$				
β_0	β_1	β_2	β_3	ƀ
2.77E-08	1.0150	0.7340	1.3843	13.0709

APPENDIX B: SPFs FOR URBAN ROADWAY SEGMENTS

All Crashes - Urban 2-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.0362	0.7370	0.5388	3.88E-05	2.9330

F&SI Crashes - Urban 2-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.0656	0.8338	0.3093	3.02E-05	1.9513

All Crashes - Urban 3-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.0651	1.1359	0.5390	3.58E-05	5.1708

F&SI Crashes - Urban 3-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$$

β_0	β_1	β_2	β_3	k
1.11E-05	1.2129	1.3300	NA	1.2645

All Crashes - Urban 4-Lane Divided SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
2.38E-05	0.6276	1.3364	2.24E-06	2.7348

F&SI Crashes - Urban 4-Lane Divided SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
3.03E-05	0.7409	1.1855	-1.33E-05	2.7932

All Crashes - Urban 4-Lane Undivided SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.0816	0.8866	0.5171	3.28E-05	4.4919

F&SI Crashes - Urban 4-Lane Undivided SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$$

β_0	β_1	β_2	β_3	k
0.0030	0.8898	0.7387	NA	3.8246

All Crashes - Urban 5-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.0001	0.8906	1.2904	1.35E-05	3.4567

F&SI Crashes - Urban 5-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.0171	0.9805	0.5352	1.62E-05	2.9371

All Crashes - Urban 6-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2} * e^{\beta_3 * AADT}$$

β_0	β_1	β_2	β_3	k
0.1138	0.9508	0.5162	1.81E-05	6.2046

F&SI Crashes - Urban 6-Lane SPF

$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$$

β_0	β_1	β_2	β_3	k
0.0127	1.1710	0.6075	NA	3.8905

APPENDIX C: THINKSTREAM USER'S MANUAL

APPENDIX D: CONTENT MANAGER USER'S MANUAL