DOTD
LOUISIANA DEPARTMENT OF
TRANSPORTATION & DEVELOPMENT

Crash Data Analysis Guidelines

2023 April

DESTINATION ZERO DEATHS

Preface

The following guidelines are intended for Louisiana Department of Transportation and Development (DOTD) employees, consultants, metropolitan planning organizations (MPO), and local municipalities conducting safety studies. This document is not intended to establish standards or requirements.

These guidelines are available at: <http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Multimodal/Highway_Safety/Pages/Highway_Safety_Analysis_Toolbox.aspx>. The DOTD Highway Safety Section maintains and updates guidelines as needed. Contact the DOTD Highway Safety Section at <DOTDHighwaySafety@la.gov> if you need more information.

Introduction

The purpose of this document is to describe the guidelines for conducting a crash data analysis. The guidelines are intended to aid transportation professionals in the assessment of road safety performance for projects on public roads.

Understanding road safety performance is critical to developing effective projects that provide safety, mobility, and quality in maintaining, rehabilitating, and rebuilding our public roads. One of the key components of understanding road safety performance is identifying potential pre-existing safety concerns and potential implications of construction approaches.

Select Crash Data Elements

Crash data comprises the same set of crash data elements collected from the Louisiana Uniform Motor Vehicle Crash Report and assigned to specific types of roadway facilities. These elements include, but are not limited to, Intersection (demarked as True or False), Highway Classification (including Rural vs. Urban distinction), and Intersection ID (uniquely named or Null). The correct differentiation of these roadway data elements ensures the appropriate crash data analysis classification.

Existing Crash Data Analysis Classification

An analyst should know that the road system is divided into parts: segments, intersections, and interchanges – collectively known as "facilities".

Crash data analyses differ considerably depending upon how data is classified, which is by the dominant structural function of the road system. For the purposes of this document, classification categories include segment crash data analysis and intersection crash data analysis. Interchange crash data analysis is not yet available and therefore, segment and intersection analyses should be used as appropriate.

While these divisions may overlap geographically, they are more clearly defined operationally, but still can be tricky to parse. Intersection crashes are those that could not have occurred if the intersection was not there. An example would be a vehicle running a red-indication and crashing perpendicularly with another vehicle that proceeded after seeing the intersection was clear. Segment crashes are those not at an intersection or ambivalent to its existence. An example would be a driver drifts off the road after a 12-hour shift and strikes the traffic-signal pole. Interchange crashes are a group of ramp-segments in a relatively small geographic area.

Segment Crash Data Analysis

To analyze existing crash data specific to a road segment, it is imperative that road segment crash data be clearly separate from other data sets, specifically intersection data. Otherwise, crash data analysis results and conclusions will not be highly valid or reliable.

To analyze road segment crash data, include crashes where Intersection is False. For segment data, the Intersection Identification is irrelevant.

Intersection Crash Data Analysis

Crash counts for intersection safety analysis changes depending on the Rural/Urban classification of the intersection. Rural intersections include crashes with the same intersection ID and where the intersection crash flag is marked 'TRUE' by the investigating officer. Urban intersections include all crashes with the same intersection ID regardless of the value of the intersection crash flag.

Since there is a difference in how the data element "Intersection" is used by Law-Enforcement Officers (LEO) and DOTD, it is recommended to use a point (latitude and longitude coordinates) and radius to search for crashes that have geographically occurred at an intersection.

Crash Analysis Preparation

Before crash data analysis can begin, an analyst must be familiar with the location under consideration, as well as how DOTD delineates the location.

Location Appraisal

High-quality location appraisal will lead to sound analysis. While this mostly applies to segments, this is applicable to intersections, too. To complete a location appraisal, the analyst should gather the necessary components and evaluate the potential for adjoining road inclusion. This includes location attributes (route and mile-point, control-section and log-mile, or latitude and longitude for intersections), highway classification, annual average daily traffic (AADT), crash data, and a map of the location.

Road segments should be sufficiently long – at minimum 0.4 miles for urban areas and 0.6 miles for rural areas. Segments that are too short may not produce valid and reliable crash data analysis. Segments that are too long will trend towards average and thus not produce meaningful results either. Urban segments should not be longer than 2 miles, while Rural segments may be up to 8 miles.

Evaluation of Potential for Adjoining Road Inclusion

The adjoining road’s potential for inclusion is a stand-alone, informal evaluation best performed and may involve engineering judgment. This evaluation involves considering the location attributes, highway classification, and the AADT, to determine which adjoining roads, if any, should be included in the crash data analysis.

When evaluating the potential for including adjoining intersections, the intersection’s turn-lanes should automatically be included in the crash data analysis. Since not all intersections have turn-lanes and the intersection’s functional area varies with traffic, determining the extents of an intersection may involve judgment and multiple queries.

When evaluating the potential for including adjoining segments, judgement should be exercised. If the segment’s Highway Classification differs at all from the adjoining segment’s Highway Classification, or if the segment’s AADT differs greatly from the adjoining segment’s AADT, then do not include that adjoining segment.

For a Traffic Management Plan (TMP), the adjoining segment where construction signs are placed should be included in the analysis. If lane closures are anticipated on the segment, then the 95th percentile queue on the adjoining segment should be included in the crash data analysis.

Safety Performance Methodology

Road safety performance methodology comprises three components. First is crash history, followed by safety evaluation, and completed with pattern recognition analysis. For TMP only, there is a fourth component – Cumulative Crashes by Time of Day. DOTD Highway Safety Section has some tools available to expedite calculations and provide consistency.

Crash History

A site’s crash history will provide a glimpse into the road’s existing safety characteristics, but only so much information can be gleaned. The crash history presents statistics to show the percentage of Collision Manner types, Crash Type options, Severity types, etc. The crash history is limited as it is does not compare the statistics to similar facilities, nor does it delve deeply into the data. Without having a valid and reliable comparison, it cannot be determined if there is actually a safety concern based on safety performance, hence its limitations.

Safety Comparison

In safety comparison, analysts compare their facility's crash rate to a statistical model for that facility type to determine safety performance. For most facilities, DOTD has a nonlinear statistical model, Safety Performance Function (SPF), which can be used as the comparison statistical model. DOTD has developed many SPFs for segment highway classifications and intersection classifications based on crash data and traffic exposure. For the remaining facilities: interchanges, ramps, and one-way roads, DOTD has yet to develop a SPF. In these instances, where DOTD agrees that no SPF could be used, then the number-rate (discussed later) should be used as the comparison model or an SPF of a facility most similar.

The "All Severity" SPF is the model derived from using all crashes for a given highway classification, while the "Injury Severity" SPF is the model using crashes where Severity is not "E" (Property Damage Only). The equations for each SPF with their respective coefficients and over-dispersion parameters are readily available in DOTD's CAT-Scans.

Safety Service Level

This is a categorical classification used to help understand the relative safety performance. The Safety Service Level is described in terms of LOSS (Level of Service of Safety). The degree of deviation from the respective SPF will place the segment or intersection into one of four LOSS classifications:

- LOSS 1: Negligible Potential for Safety Improvement
- LOSS 2: Low Potential for Safety Improvement
- LOSS 3: Moderate Potential for Safety Improvement
- LOSS 4: High Potential for Safety Improvement

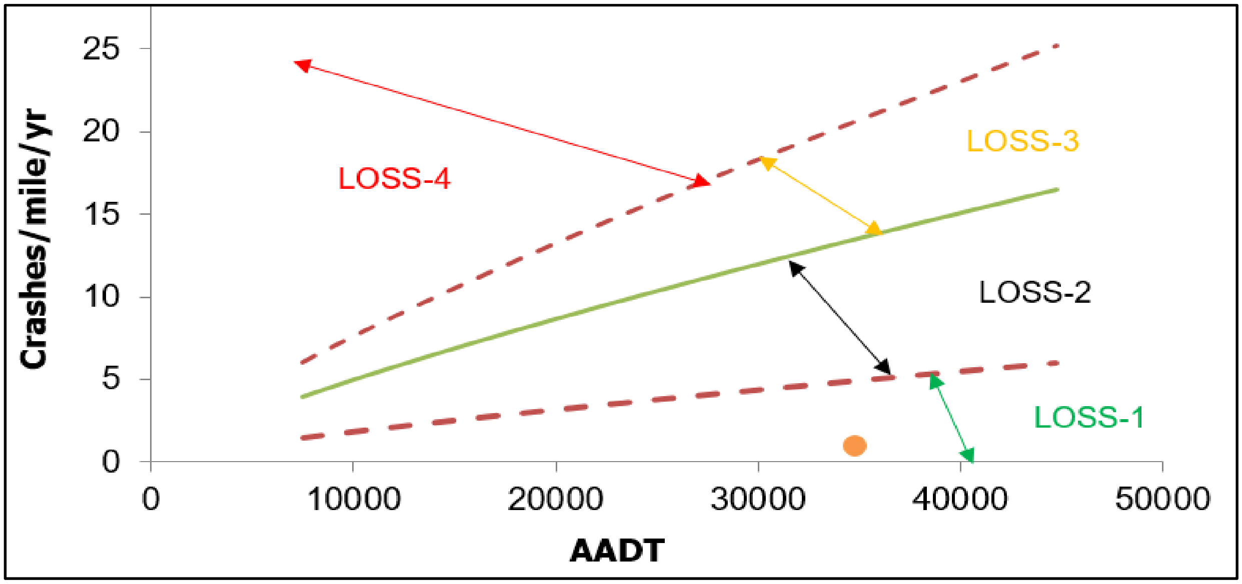


Figure-1 Urban 5-lane SPF - Injury Crashes

Figure-1 presents an example of an urban five-lane roadway segment comparison. The orange dot shows where the segment falls compared to the relevant SPF (green 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 for all crashes within the same highway classification. As it is shown, the segment falls below the 20the percentile line, which means the segment is LOSS-1.

Although the Safety Service Level provides a comparison of current performance to the statistical model, it does not provide any information related to the nature of the potential safety concern itself. If a potential safety concern is present, the Safety Service Level will describe only its magnitude in the form of safety performance. The nature of the problem is determined by pattern recognition.

Number-Rate

For some facilities where DOTD has yet to develop a SPF and agrees than no SPF could be used, then the number-rate could be used instead. The method is slightly different for segments than for intersections. It is preferable to use whole years of data.

For roadway segments use the following formula:

$$R_S = (C \times 10^6) / (L \times AADT \times D)$$

Where: R_S = segment crash rate

C = crash count (crashes)

D = analysis days (days)

L = segment length (miles)

AADT = annual average daily traffic (vehicles/day)

For intersections use the following formula:

$$R_i = (C \times 10^6) / (EV \times D)$$

Where: R_i = intersection crash rate

C = crash count (crashes)

D = analysis days (days)

EV (Entering Vehicles) = average vehicles entering intersection each day from all approaches (vehicles/day)

Pattern Recognition Analysis

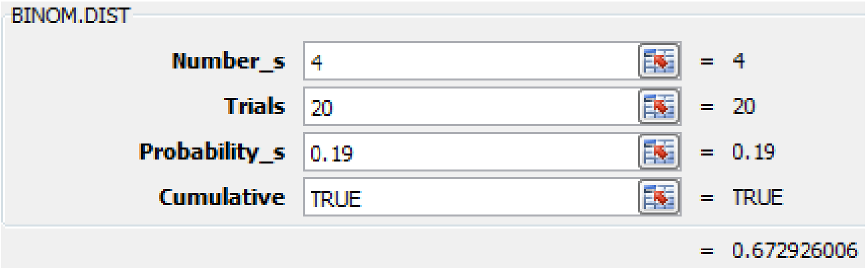
Pattern Recognition Analysis (PRA) compares the site's category percentages to its comparison group's average. These categories are Collison Manner, Crash Type, Lighting, Surface Condition, Location Type, etc. For intersections the site is compared once, while for segments the sliding window technique is used.

Issues may arise if unsophisticated PRA are used. Direct comparisons between statistics fail to inform users as to whether the differences are significant. Segments pose additional challenges over intersections. Longer segment's lend themselves to categorize closer to the average percentages, potentially missing over-representations within the segment. Therefore, analysts should be careful to ensure that segments are not too long. See "Location Appraisal" for guidelines on length of segments to analyze.

Bernoulli Trials

Bernoulli Trials are used to determine significance. 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, a direct comparison 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-end crashes out of 20 total crashes can be calculated using the Cumulative Binomial Distribution function within Excel as shown in Figure-2.


BINOM.DIST

Number_s: 4 = 4
Trials: 20 = 20
Probability_s: 0.19 = 0.19
Cumulative: TRUE = TRUE
= 0.672926006

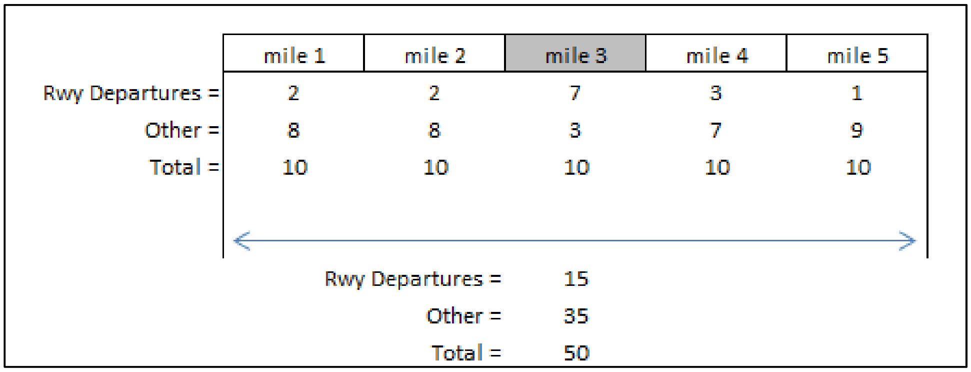
Figure-2 Excel Function - Binomial Distribution

As it is shown, the probability for this event to actually occur is only 67% which may be considered low. DOTD Highway Safety Section recommends using probabilities over 90% to be significant.

Hidden Over-Representation

To find hidden over-representation within a segment, the segment is divided into pieces. Assuming that the crashes are located properly, consider the following example:

A roadway improvement project involves a 5-mile long segment. Figure-3 illustrates the crash history within the project limits divided into 1-mile buckets. 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 over-representation. However, by considering “mile 3” only, roadway departures would represent 70% of the crashes (7 out of 10), which would trigger over-representation. Therefore, a significant yet correctible problem is revealed, which is otherwise not detected when the segment is analyzed as a whole.



	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-3 Crash Data Diagram Segmented by 1-mi Sections

Sliding Window

The Sliding Window technique is better at finding hidden over-representation. This process determines a scanning window's (scanning interval) length and its δ (scanning increment). Figure-4 illustrates the process.

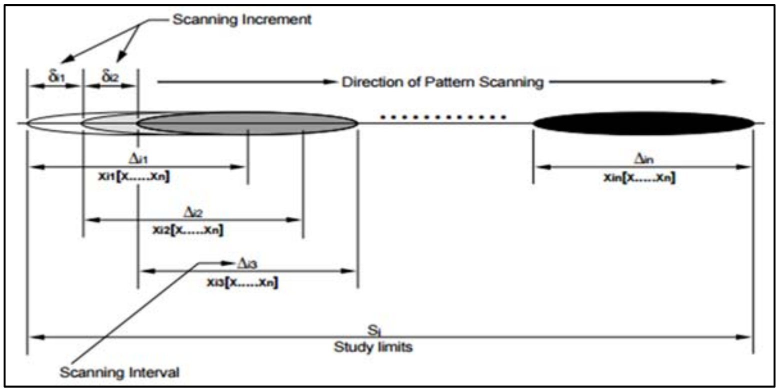


Figure-4 Sliding Window Technique

Starting at the beginning of the segment, the first scanning window is analyzed using Bernoulli Trials to determine over-representation. Then, the scanning interval slides a distance δ (scanning increment) and the process loops until all scanning windows have been analyzed. Although this procedure could be a long and tedious process if manually calculated, DOTD offers a tool to perform the analysis quickly.

Traffic Management Plans (TMPs)

Some additional analysis may be needed to perform TMPs. To inform lane closure determination, it is helpful to know when existing crashes occur on a specific corridor. This can be accomplished by plotting crash times of day by days of the week. Since most traffic patterns are specific to weekdays or weekends, the crash data should be divided this way as well. Example graphs depicting crashes by time and day are shown in Figure-5.

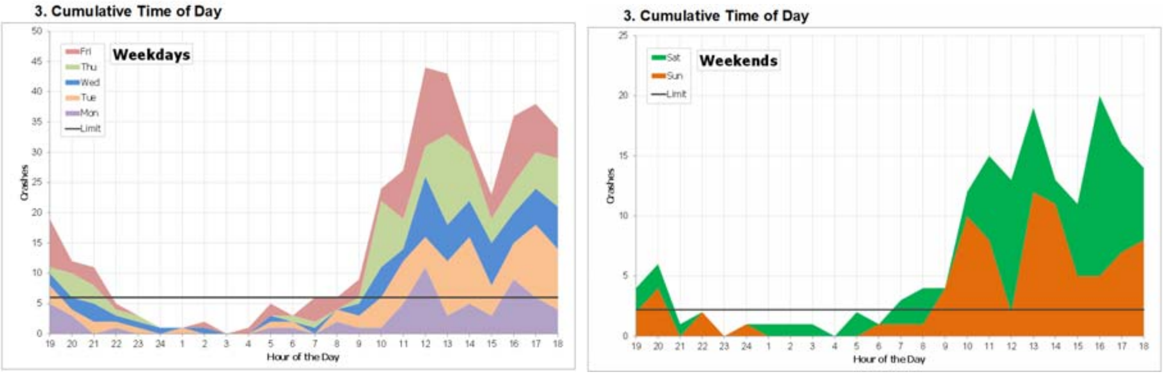


Figure-5 Cumulative Time of Day graphs

CRASH DATA QUALITY

Crash data quality assurance is the process of reviewing critical elements from select crash reports, and ensuring that the data elements are properly coded. Typically, a crash data listing will provide sufficient information to complete a preliminary project level crash data analysis. However, in some cases, it is necessary to review critical individual crash reports to gain a better understanding of the safety concerns and to correct inconsistent crash data.

There are many reasons why reviewing crash reports may improve the crash data analysis. Not all crashes that occur are reported and the crashes that are reported may have elements that are not coded correctly. The level and quality of formal and on-job training for LEOs varies throughout the state and the interpretation of the elements contained in the uniform crash report may differ across jurisdictions. Also, LEOs may not be aware all of the data elements they are capturing or how some element pairs function together. Crash data inaccuracies and incompleteness may also be due to missing information for vehicles and/or drivers, and drivers who are not truthful or not aware of the circumstances of the crash. LEOs may be tasked with other duties, like securing a crash scene and issuing citations, before completing the crash report.

Patterns at intersections are easily understood when there are no other access conections (driveways, median crossovers, etc.) within the intersection. Those are rarely cases, more often access connections exist within the functional area of the intersection and determining where the patterns exist requires some investigation. Quality assurance is easily done alongside this investigation.

Data Sampling Size

Data generated from a small sample can be misleading because they can be significantly influenced by small variances. It is important to exercise engineering judgment when identifying crash patterns for segments or intersections with a small sample size of crashes.

There are some ways to overcome small sample sizes. One way is toadding an additional year, beyond the usual three, up to five years, until a reasonable sample size is achieved. This can be done so long as consistent operations have occurred at the site during the duration queried. For segments there is the potential option of extending the limits.

Behavior Elements

It is noted that data elements associated with fatal motor vehicle crash reports are usually of 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 occasionally omitted from the crash report.

Accessing Crash Data

Crash data is traffic incident information recorded by various police agencies and uploaded to a state database, which is maintained by Louisiana State University's Center for Analytics Research and Transportation Safety (CARTS). Contact DOTD Highway Safety Section to gain access to our current crash data system.

The crash data file for a given year is preliminary until quality reviews are conducted for the entire year and the year is officially closed by the DOTD Highway Safety Section. This typically occurs eight months after the previous year's end. This timeframe allows a few weeks for law enforcement agencies to submit any outstanding crash reports and several more weeks for map-spotting efforts to confirm location and roadway attributes, as well as select quality assurance activities for other critical data fields.

Considering Potential Countermeasures

Countermeasures are crash mitigation strategies. There are two main groups – behavioral and infrastructure and operations. Engineering judgment should be used and all factors should be considered when selecting crash mitigation strategies. The crash data analysis may provide insight into driver behavior. Behavioral countermeasures are best explored with your Regional Safety Coalition. Contact DOTD Highway Safety Section to get in contact with your Regional Safety Coalition. The following table focuses on Infrastructure and Operational strategies. It groups the countermeasures by crash groups (Crash Types, not to be confused with the DOTD crash data element "Crash Type") and then by possible cause.

Table 1: Countermeasures Grouped by Crash Type

Crash Type	Possible Cause	Potential 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
		Add/Improve delineation
	Narrow roadway	Widen structure
		Add/Improve delineation
		Install signing/signals
	Visibility	Remove obstruction

		Install advance warning signs
		Add/Improve delineation
	Vertical clearance	Rebuild structure/adjust roadway grade
		Install advance warning signs
		Add/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

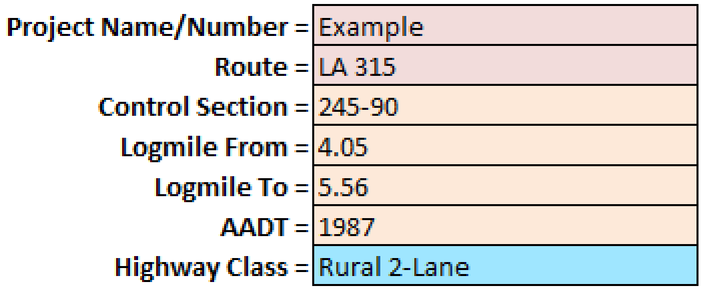
APPENDIX A: Segment Example

I. 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. This example provides all the information needed to start the analysis, which is summarized in Figure-6. In addition, analyzing the location on a map could also provide important information about the segment. As it is shown in Figure-7, 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 6 Information Summary

Figure 7 Map of Location

B. Crash History

Figure-8 and Figure-9 display a basic representation of the crash history using the Cat Scan Tool which can be found in the DOTD's website <http://wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Multimodal/Highway_Safety/Pages/Highway_Safety_Analysis_Toolbox.aspx>. Although this information will only provide an overview of the situation, certain speculations about possible issues can be made.

Project Name/Number = Example
Control Section / Route = 245-90
Logmile / Milepoint From = 4.05 (i.e XX.XX)
Logmile / Milepoint To = 5.56 (i.e XX.XX)

Analysis Performed by: DOTD Highway Safety
Date: xx/xx/2015

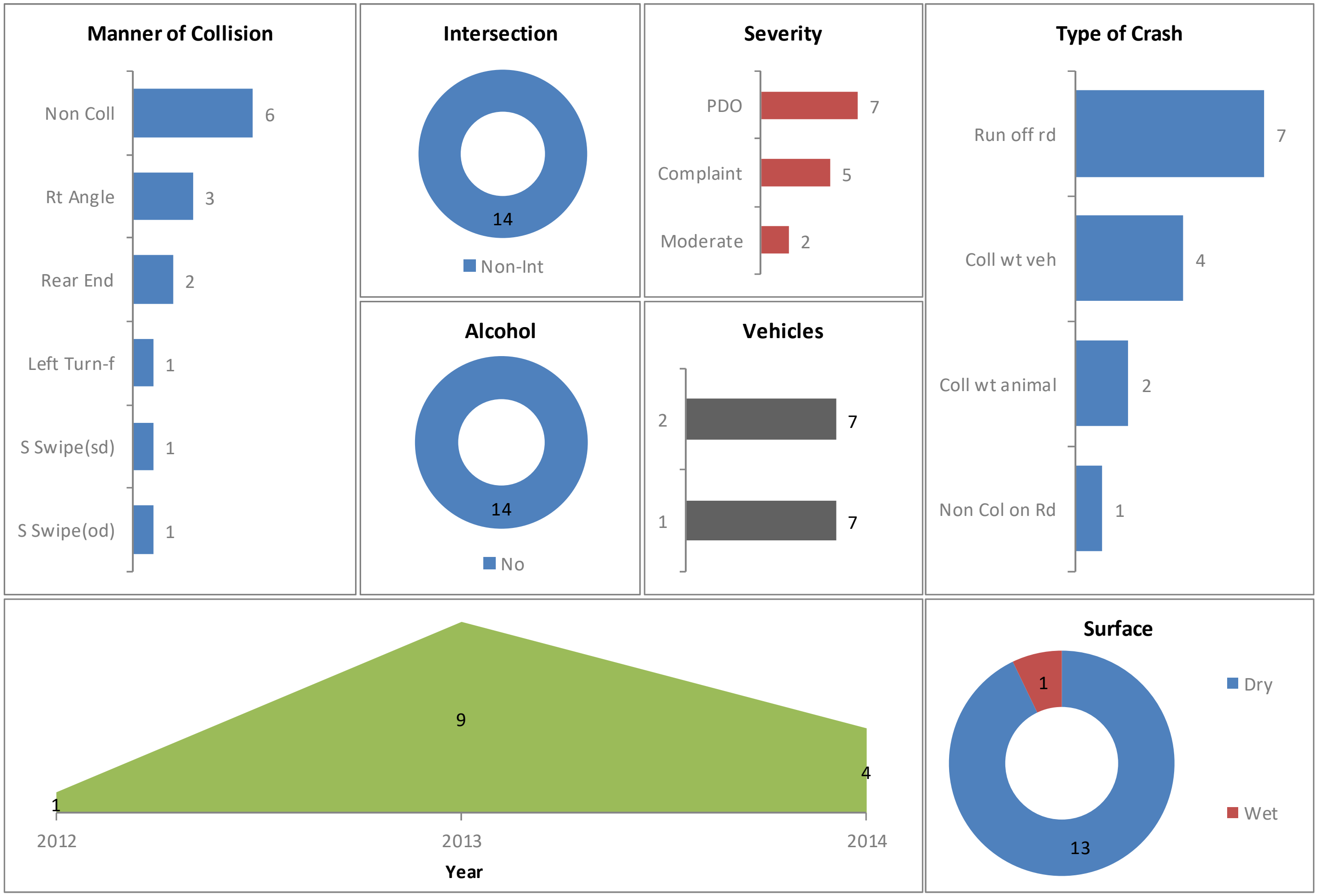
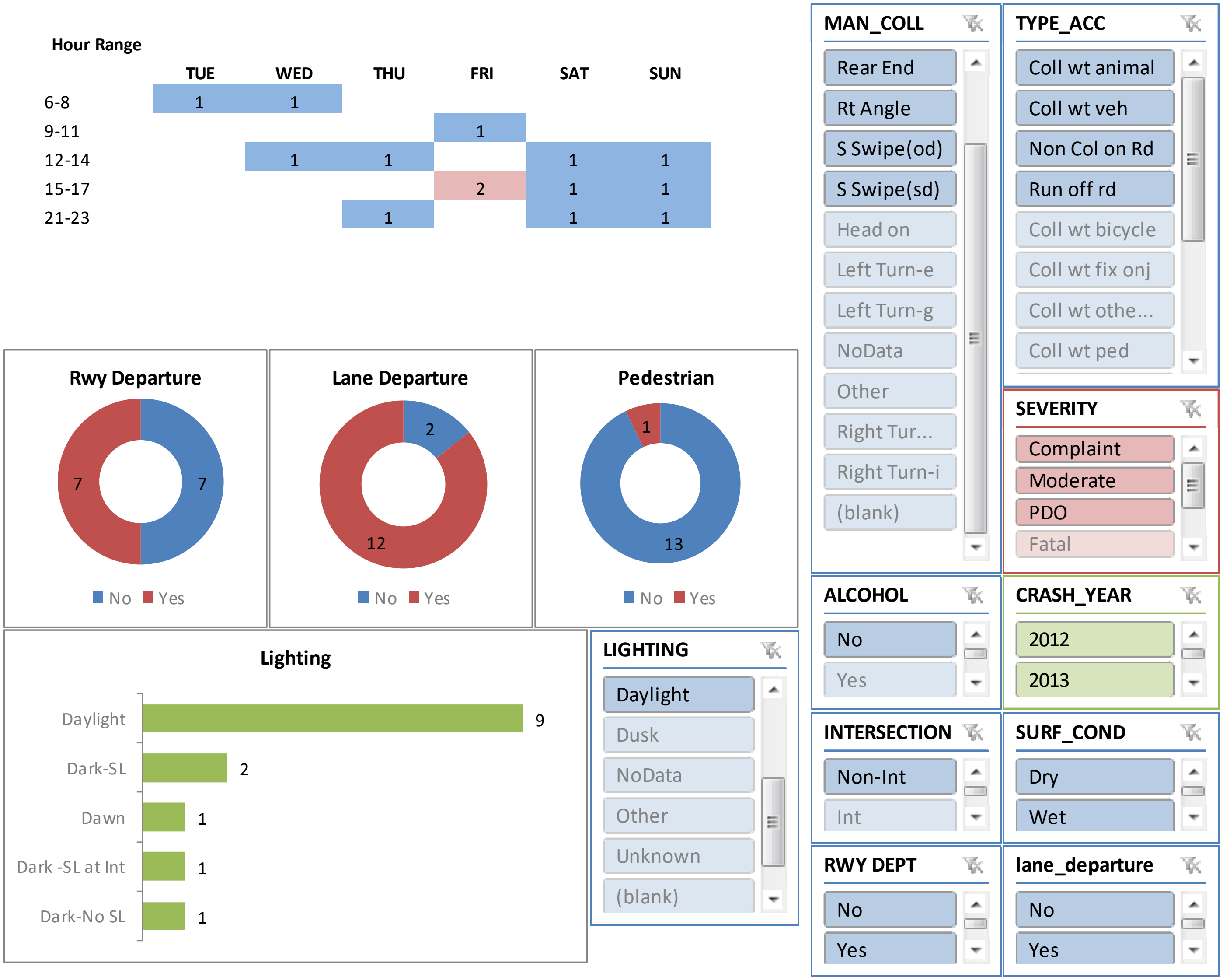


Figure-8 Crash History 1 - Sample



Hour Range

	TUE	WED	THU	FRI	SAT	SUN
6-8	1	1				
9-11				1		
12-14		1	1		1	1
15-17				2	1	1
21-23			1		1	1

Figure-9 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. LOSS Calculation

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 **Error! Reference source not found.**-4 and **Error! Reference source not found.**-5. 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.

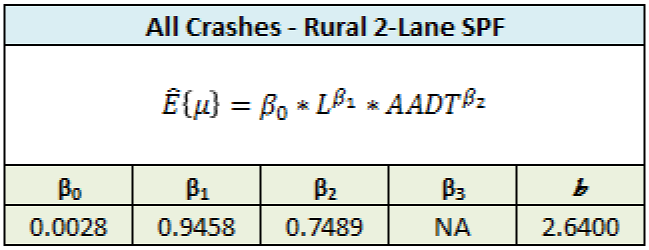
The methodology for all calculations regarding the network screening process for all crashes and F&SI crashes is described below as backup information.

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 (**Error! Reference source not found.**10):



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

Figure-10 All Crashes - Rural 2-Lane SPF

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

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:

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

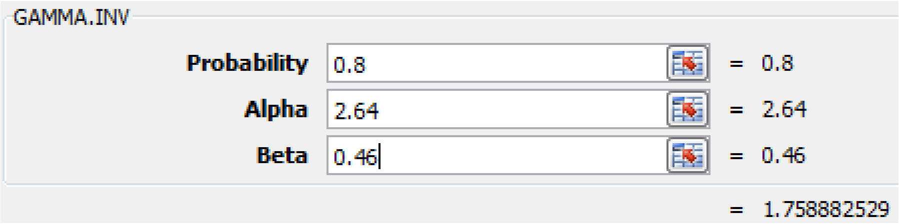
Once the current performance of the segment is determined, it is compared to statewide average and placed into one of the four LOSS distributions mentioned before (See Figure-1). The statewide average (Predicted Crashes per mile per year, SWA) is calculated as follows:

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

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-11) 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



GAMMA.INV

Probability 0.8 = 0.8

Alpha 2.64 = 2.64

Beta 0.46 = 0.46

= 1.758882529

Figure-11 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.

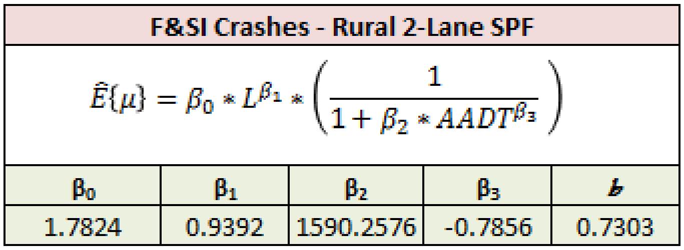
2. F&SI Crashes

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-12):



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

Figure-12 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 "b" 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:

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

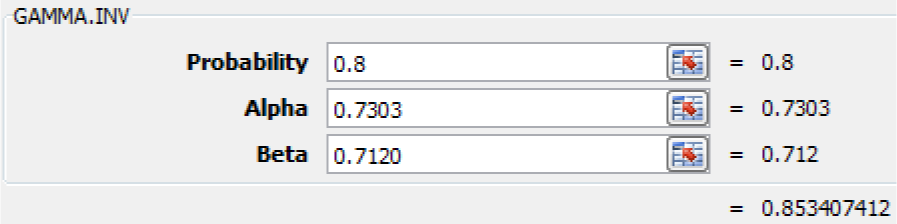
Now the statewide average for F&SI Crashes per mile per 3 years (Predicted Fatal & Serious Injury Crashes per mile per 3 years, SWA F&SI) is calculated to compare:

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

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 (Figure-13) 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



GAMMA.INV

Probability 0.8 = 0.8

Alpha 0.7303 = 0.7303

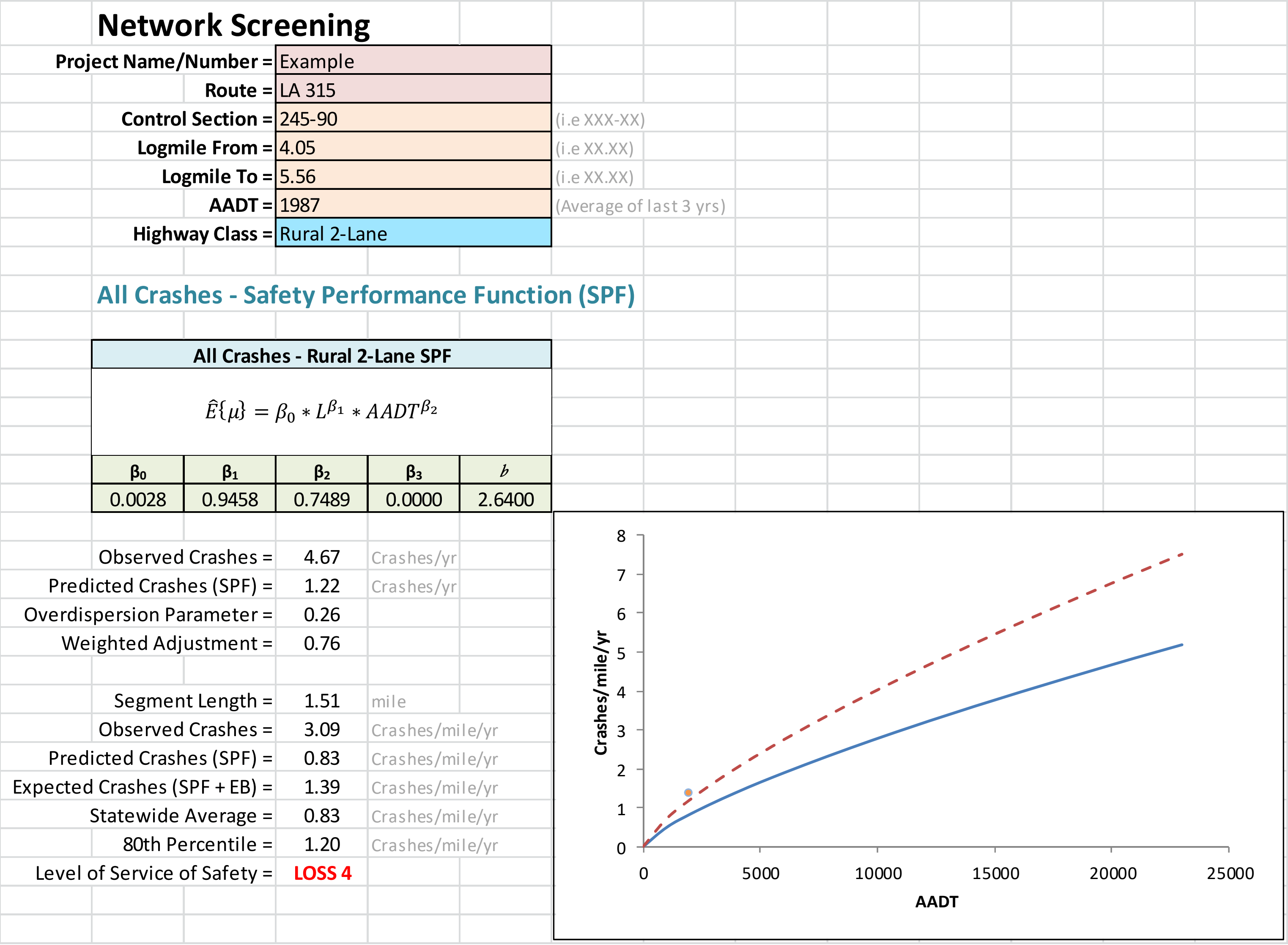
Beta 0.7120 = 0.712

= 0.853407412

Figure-13 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

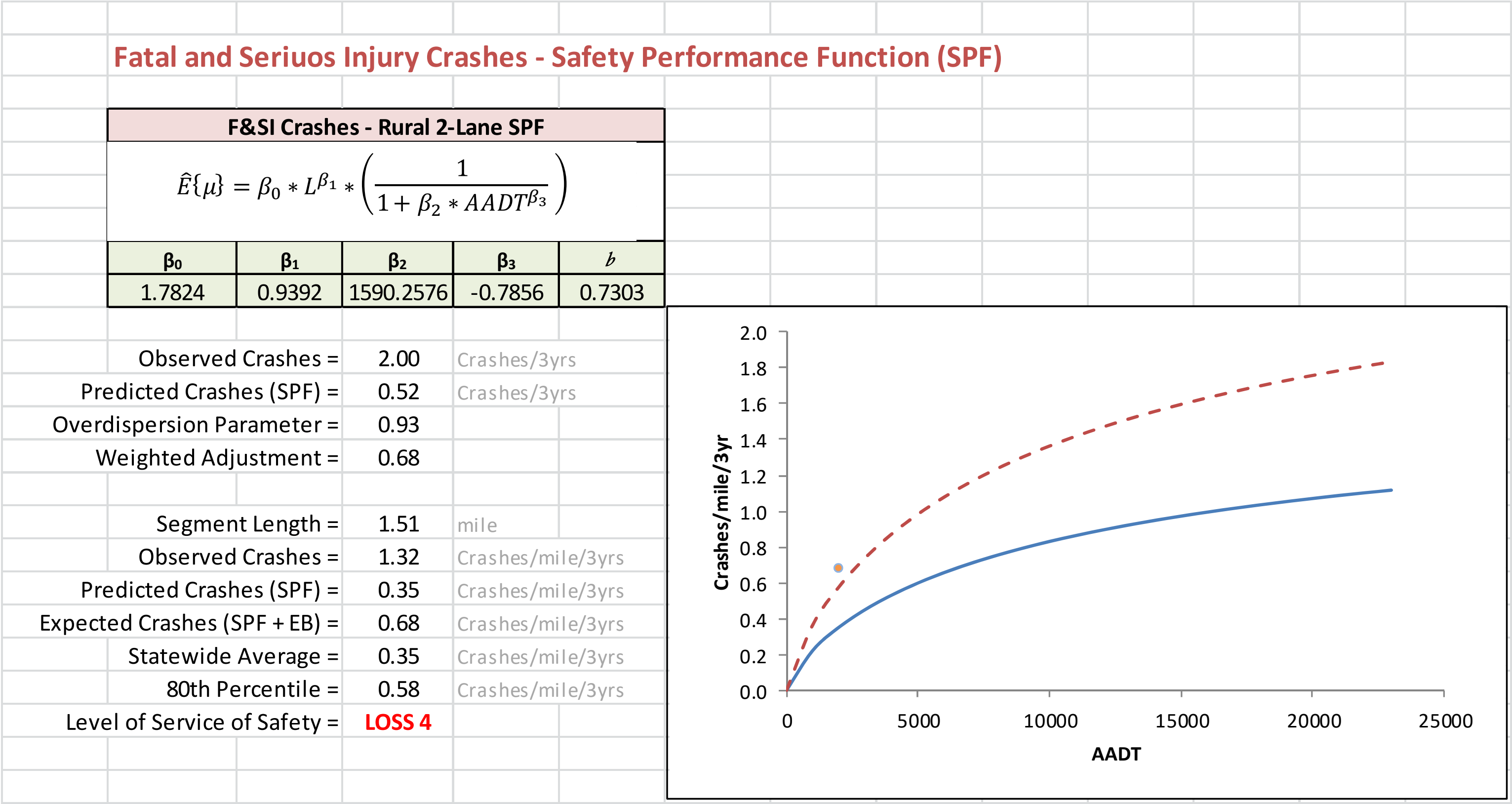
$$\hat{E}\{\mu\} = \beta_0 * L^{\beta_1} * AADT^{\beta_2}$$

β₀	**β₁**	**β₂**	**β₃**	***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-14 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-15 F&SI Crashes - Network Screening - Sample

D. Pattern Recognition Analysis

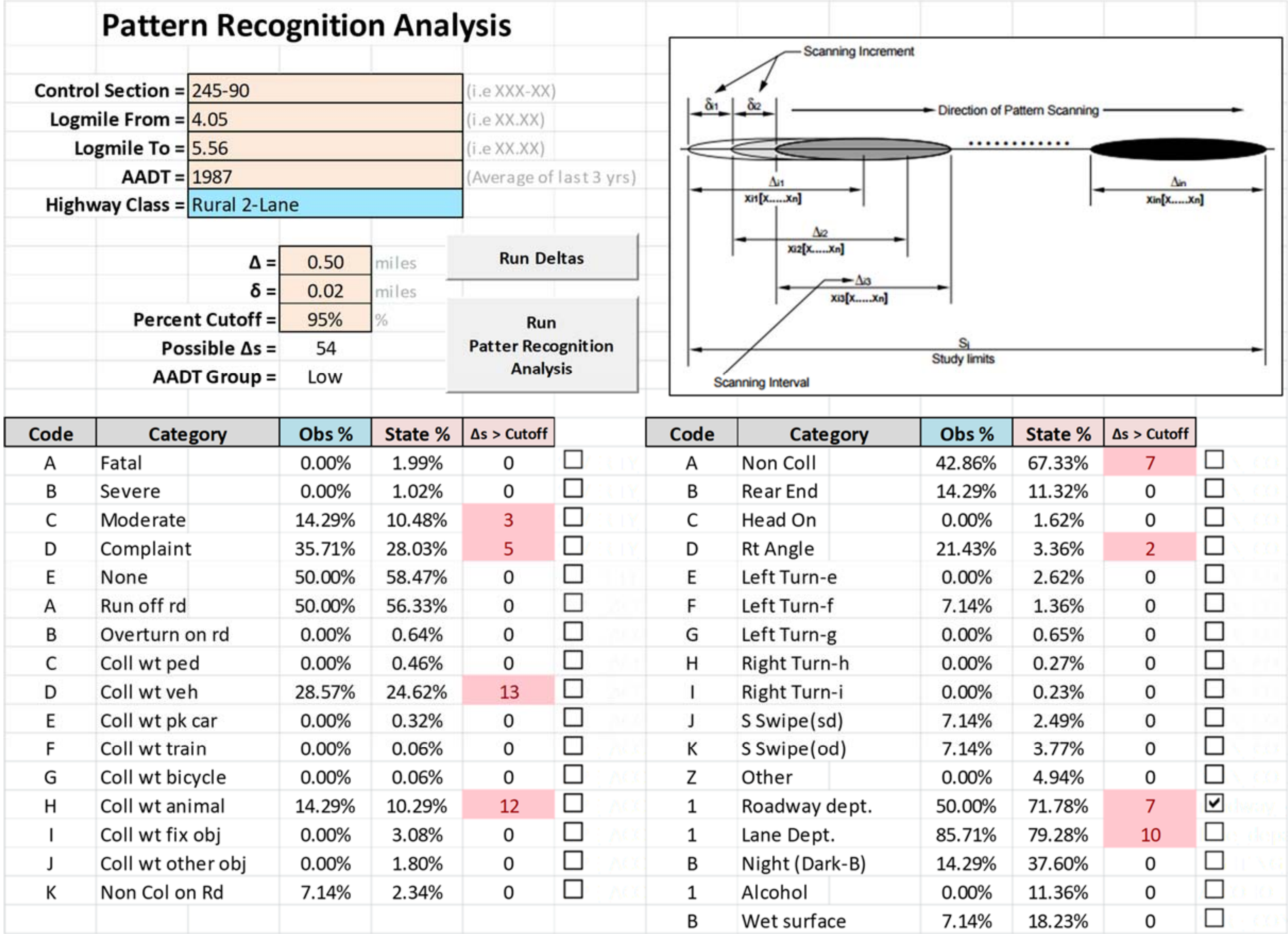
Since the pattern recognition analysis is a procedure that may result in long and tedious calculations, the DOTD offers the CAT Scan Tool to perform the analysis automatically. Once the crash history is added into the tool, the user has to press two buttons ("Run Deltas" and "Run Pattern Recognition Analysis") to perform the calculations as it is presented in Figure-16.

Highlighted cells (in pink) 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).

So where are those issues located? The CAT Scan Tool offers a graphic representation of the pattern recognition analysis by log-mile. Figure-16 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-16. Figure-17 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

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-16 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.

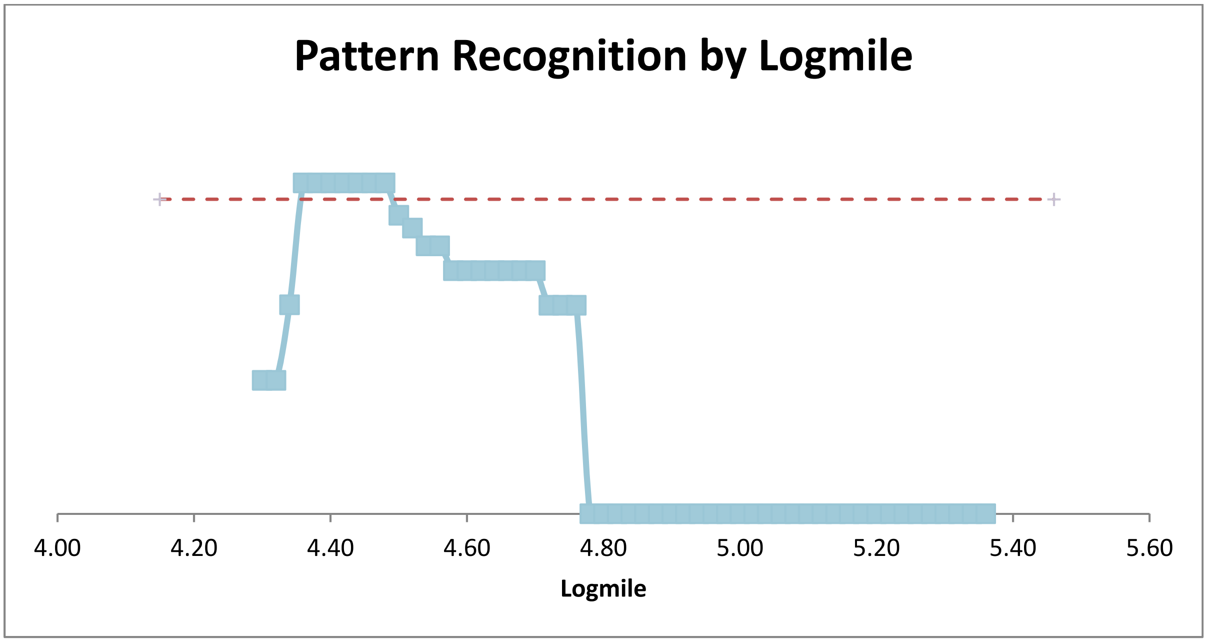


Figure-17 Pattern Recognition Analysis by Log-mile - Sample