FDOT Systemic Safety Analysis

Signalized Intersections on State Highway System

Technical Memorandum

prepared for

Florida Department of Transportation

Traffic Engineering and Operations Office

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Systemic Safety Analysis

Introduction

The underlying principle of the systemic approach to the roadway safety management process is to identify sites with similar characteristics based on their crash potential, rather than only focusing on observed crashes. It is intended to be used for addressing crash types that are widely dispersed across the roadway network (e.g., fatal-and-serious-injury crashes, pedestrian crashes, lane departure crashes), which tend to be overlooked when ranking sites using a crash-history-based or site-specific safety management approach. The key to addressing low crash densities is by implementing low-cost countermeasures to many sites based on roadway features correlated with specific severe crash types. The systemic approach helps agencies broaden their traffic safety efforts and consider crash types, as well as crash history when identifying where to make low-cost safety improvements.

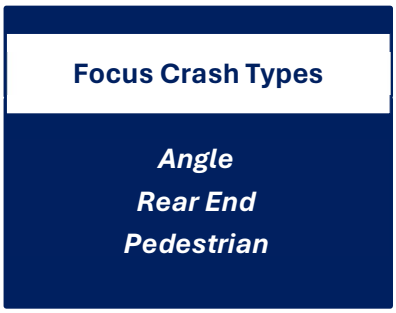
The steps to systemic approach to roadway safety management entails the following:

- Identify focus crash types and focus facility types, which can be done by evaluating historical crash data.
- Look for characteristics (e.g., roadway/roadside geometry, traffic volume, traffic control features, driver characteristics, etc.) frequently associated with focus crash types and focus facilities. These characteristics can be proactively used to identify and prioritize locations with low-cost countermeasures that can be implemented across the network of locations with similar characteristics.
- Select one or more low-cost countermeasures to address the underlying circumstances contributing to focus crash types on the facility types under consideration.
- Identify and prioritize locations or projects across the roadway network for implementation. The prioritization process may take on different forms such as implementing low-cost countermeasures as part of resurfacing, restoration, and rehabilitation (3R) projects or standalone safety projects. In either case, the systemic approach to safety represents one of several mechanisms to implement a State Highway Safety Plan (SHSP) or other local safety plan.

Analysis and Dashboard

The FDOT Traffic Engineering and Operations Office (TEOO) conducted the systemic safety analysis for signalized intersections on the State Highway System (SHS). The analysis entails an investigation of roadway features and fatal-and-serious-injury (F&SI) crash data across the network of signalized

intersections followed by identifying and suggesting a set of countermeasures. A thorough investigation of multiple years of crash data (i.e., 2018-2022) and crash locations on the SHS reveals that a majority of signalized intersection crashes (i.e., crashes that occurred within 250 ft of a signalized intersection) that resulted in fatalities or serious injuries are concentrated on roadways within Suburban Commercial (C3C), Suburban Residential (C3R), and Urban General (C4) context classes. The crash statistics also show that angle, rear-end, and pedestrian crashes are the most common fatal or serious injury crash types at signalized intersections on the SHS. Please see Appendix A for details of crash statistics. Note that the intersection inventory was created from the Exhibit A layer (a GIS layer of traffic control devices maintained by local agencies through Traffic Signal Maintenance and Compensation Agreement (TSMCA) with FDOT Districts) in eTraffic, a web-based GIS data collection and sharing application maintained by FDOT TEOO.



The Power BI dashboard shows the results of the analysis. The dashboard is separated into two parts:

1) Crash Tree Diagram and Summary Data Module, and
2) Suggested Countermeasures Module.

The Crash Tree Diagram and Summary Data Module interact in a one-way relationship with the Suggested Countermeasures Module; i.e., the filtering and selections in the Crash Tree Diagram and Summary Data Module influence the Suggested Countermeasures Module, but not vice versa.

Crash Tree Diagram and Summary Data Module

The top panel includes filters which allow the user to specify which FDOT District, County, Crash Type, or Crash Years they would like to analyze. Following the filtering is the crash tree diagram that shows the number of crash incidents based on the user selection of roadway features (see Figure 1).

A crash tree diagram is a type of event tree diagram which is often used in safety analyses to study crash and built environment characteristics. Like a tree, the diagram starts with a single trunk and expands further into branches. Every point where a branch splits off represents a characteristic and

its distribution of values. If a value is selected, the tree moves on to the next branching event, where a subsequent characteristic's values are branched. This process can go on for as few or as many levels as desired. Microsoft Power BI software calls this type of data visualization a "decomposition tree".

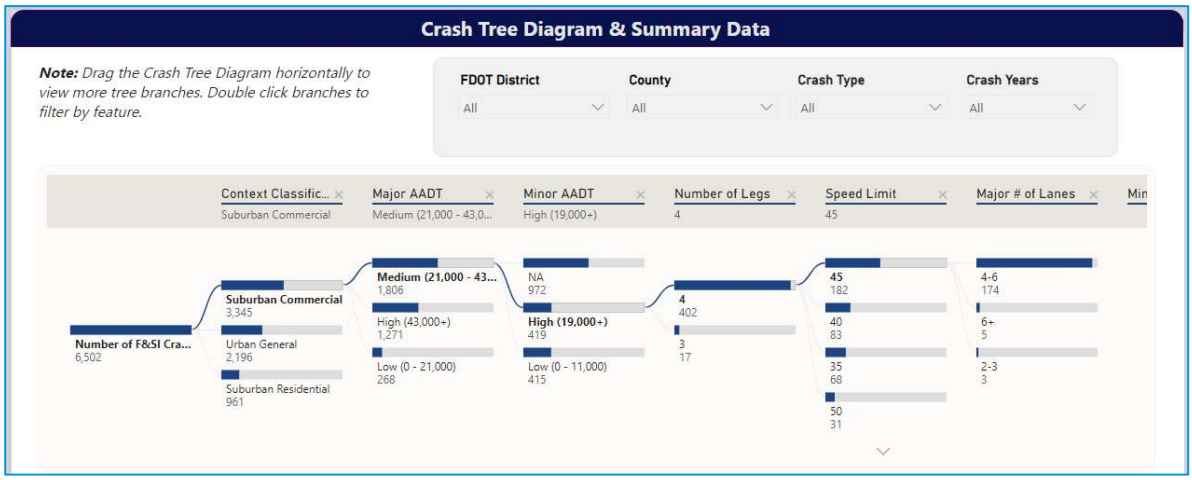


Figure 1 Crash Tree Diagram

The variables used to develop the crash tree diagram for this analysis include:

- Number of Legs: This analysis considers 3-legged and 4-legged signalized intersections only.
- Major AADT: Annual Average Daily Traffic (AADT) volumes on major road, taken as the higher of the AADT values between two major road approaches and then classified into the following categories for analysis using natural breaks:
  - Low: AADT less than 21,000 veh/day
  - Medium: AADT between 21,000 veh/day and 43,000 veh/day
  - High: AADT more than 43,000 veh/day
- Minor AADT: AADT on minor road, classified into the following categories using natural breaks:
  - Low: AADT less than 11,000 veh/day
  - Medium: AADT between 11,000 veh/day and 19,000 veh/day
  - High: AADT more than 19,000 veh/day
- Speed Limit: Posted speed limit on the major road approaches, ranging from 35 MPH to 55 MPH. In cases where there are different speed limits for different sides of the road, e.g. on a divided roadway, the higher of the two speed limits is taken.
- Major Median Type: Median type on the major road approaches, classified with the following precedence if the median type is different between major road approaches:
  - Divided
  - Undivided

  - Unknown (information not available)
- Minor Median Type: Median type on the minor road approaches, classified as follows:
  - Divided
  - Undivided
  - Unknown (information not available)
- Major # of Lanes: The total number of through lanes (including shared lanes) on major road, taken as the higher of the number of lanes between two major road approaches.
- Minor # of Lanes: The total number of through lanes (including shared lanes) on minor road, taken as the higher of the number of lanes between two minor road approaches if present.
- Lighting: Presence of lighting at the intersection, determined based on whether the intersection milepoint of major roadway falls within 250 ft of the RCI Feature 341 that indicates the presence of high mast or standard luminaires.

The Crash Tree Diagram is completely reconfigurable by changing the sequence of the variables (i.e., branches). By default, the branches display the number of crashes which meet the branch criteria. Hovering the cursor over the branches also displays a series of information, including the number of intersection and various crash statistics. Selecting branches by clicking on them serves to filter the dashboard elements which are below the Crash Tree, namely the map, table, and countermeasure summary. The branches can be excluded from the tree by clicking the "x" next to their labels at the top of the visualization. Once branches are excluded, they become an option for addition at the end of the tree, by clicking the "+" symbol which appears when hovering over the last branch of the tree. Similarly, the branches can be rearranged by first excluding them and then adding the particular branch by hovering over the last branch of the tree.

Next, two callout boxes provide a high-level overview of the numbers of intersections reflecting the criteria selected in the initial filters and the Crash Tree Diagram, with separate boxes for signalized intersections which experienced F&SI crashes and signalized intersections with no F&SI crashes (see Figure 2).

A map of signalized intersections represented by points is next down the page (Figure 2), with the colors of the points representing whether F&SI crashes occurred at those intersections. Hovering over the points brings up information about the intersection's specific location and whether F&SI crashes occurred there.

The Table below the map provides additional information on the intersections such as context classification and numbers of F&SI crashes by crash type based on the selection in the top panel (i.e., the filtering and the crash tree diagram), regardless of crash occurrence (see Figure 3). Note that clicking on the intersection in the map also filters the table with information displaying only for the selected intersection. It must be noted that the right-most column, which indicates the total number of F&SI crashes is a total of *all* crash types, and not just the three focus crash types. Thus,

that column may contain a number which is greater than the sum of the three columns containing crash totals of the three crash types.

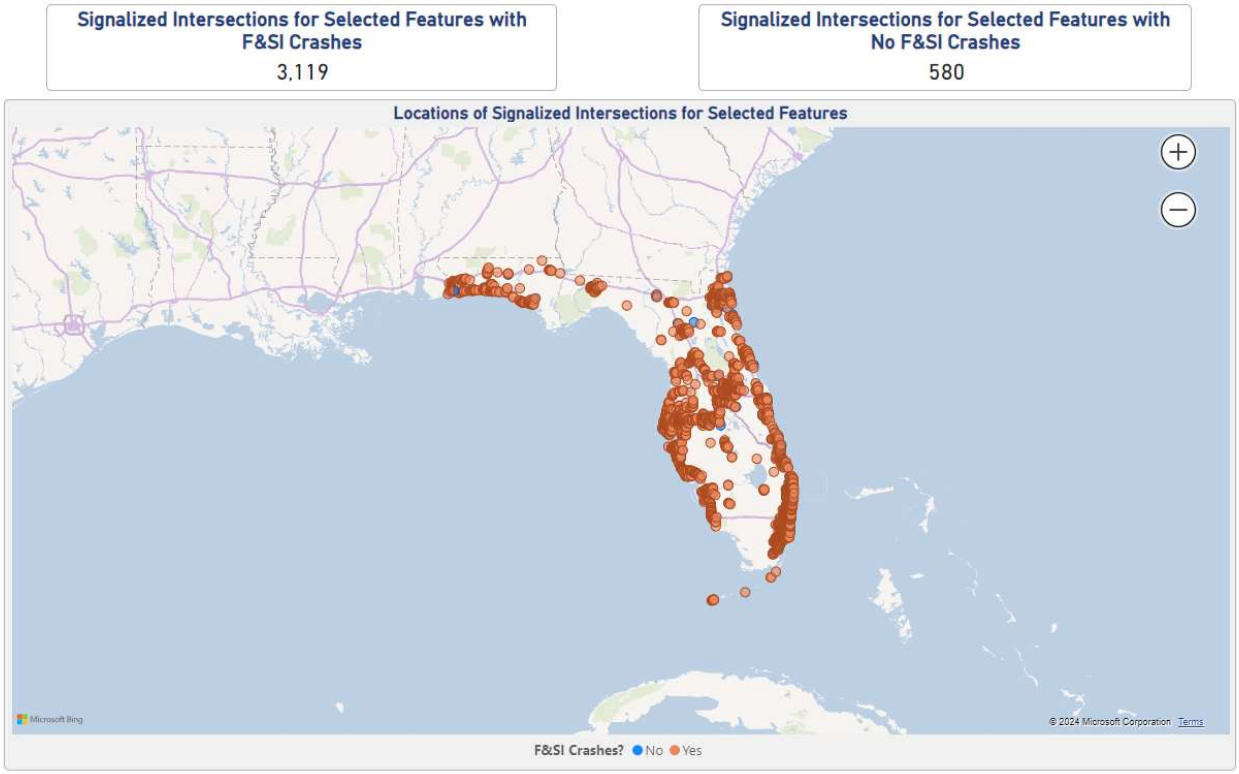


Figure 2 Intersection Map and Callout Boxes

Crash Summary of Signalized Intersections for Selected Features

Roadway ID	Milepost	Context Classification	FDOT District	County	F&SI Crashes?	# of F&SI Angle Crashes	# of F&SI Pedestrian Crashes	# of F&SI Rear End Crashes	# of F&SI Crashes [a]
01010000	20.73	SUBURBAN COMMERCIAL	1	Charlotte	No	0	0	0	0
01040000	3.44	SUBURBAN COMMERCIAL	1	Charlotte	Yes	0	0	0	0
01050000	3.99	SUBURBAN COMMERCIAL	1	Charlotte	No	0	0	0	0
01050000	5.32	SUBURBAN COMMERCIAL	1	Charlotte	No	0	0	0	0
01060000	9.36	SUBURBAN COMMERCIAL	1	Charlotte	No	0	0	0	0
03010000	14.94	SUBURBAN COMMERCIAL	1	Collier	No	0	0	0	0
03010000	3.29	SUBURBAN COMMERCIAL	1	Collier	No	0	0	0	0
03010000	3.79	SUBURBAN COMMERCIAL	1	Collier	No	0	0	0	0
03010000	8.81	SUBURBAN COMMERCIAL	1	Collier	No	0	0	0	0
09030000	3.75	SUBURBAN COMMERCIAL	1	Highlands	No	0	0	0	0
09030000	6.25	SUBURBAN COMMERCIAL	1	Highlands	No	0	0	0	0
10020000	10.17	SUBURBAN COMMERCIAL	7	Hillsborough	No	0	0	0	0
10020000	6.01	SUBURBAN COMMERCIAL	7	Hillsborough	No	0	0	0	0
10020000	6.62	SUBURBAN COMMERCIAL	7	Hillsborough	No	0	0	0	0
Total						**3,216**	**1,283**	**1,968**	**8,341**

[a] # of F&SI Crashes includes crashes of *all* crash types and not just the three focus crash types.

Figure 3 Intersection Summary Table

Suggested Countermeasures Module

The final section of the dashboard is the Suggested Countermeasures summary. The specific countermeasures considered in this analysis are:

- Centerline Hardening
- Extend Yellow Change Interval
- Flashing Yellow Arrow
- High Emphasis Crosswalk
- Intersection Lighting
- Leading Pedestrian Interval
- Pedestrian Refuge Island
- Retroreflective Signal Backplates

For each countermeasure, Crash Modification Factors (CMFs) are selected from either the CMF Clearinghouse or National Cooperative Highway Research Program (NCHRP) research report. When multiple values of CMFs are available for each countermeasure, the most appropriate values are chosen based on available information about facility, crash type, crash severity for which the CMF was developed. For example, the Clearinghouse has two CMF values for the High Emphasis Crosswalk countermeasure, identified by IDs 4123 and 4124. The main difference in these two CMFs is that ID 4123 applies only to "Vehicle/pedestrian" crash types and ID 4124 applies in cases where the crash type is "Angle, Head on, Left turn, Rear end, Rear to rear, Right turn, Sideswipe". To that end, when analyzing pedestrian crashes, this analysis considers CMF ID 4123, which has a value of 0.60. For angle or rear end crashes, the analysis considers CMF ID 4124, with a value of 0.81.

In cases where a countermeasure has various CMFs available by crash severity, this analysis uses the more severe crash severity groupings. For example, if all else being equal, two CMFs exist where one applies to KABCO crashes and another applies to KABC crashes, the analysis uses the CMF that applies to KABC crashes. This is because the Systemic Safety Analysis is a study of fatal and serious injury crashes (KA) and so using CMFs that apply to as-severe as possible crashes is deemed to be more appropriate for investigating the effect of countermeasures. Details of the countermeasures are provided in Appendix B.

The Suggested Countermeasure Module allows the user to see which countermeasures apply to the selected criteria from the Crash Tree Diagram. Clicking on a countermeasure activates the summary box that provides information on the countermeasure's CMF, annual crash reduction, and a unit cost estimate. CMF and annual crash reduction may depend on the crash type which is selected in the initial filtering. The unit cost estimate is derived from the 12-month moving average costs paid by FDOT for the specific pay items comprising the countermeasure construction. These are statewide ranges based on minimum and maximum costs in the fourteen market areas. Hovering over the underlined "Unit Cost Estimate" text brings up a table with a breakdown of the cost estimate by pay item number.

Figure 4 Suggested Countermeasures Module

Appendix A.

Table A.1 Statewide Crash Statistics (2018-2022)

Year	Count of All Crashes	Count of Fatal Crashes	Count of Serious Injury Crashes	Count of Fatalities	Count of Serious Injuries
2018	741,262	2,924	15,170	3,137	19,208
2019	746,153	2,957	14,320	3,192	18,126
2020	589,856	3,109	12,468	3,344	15,618
2021	703,324	3,460	13,449	3,745	16,827
2022	706,267	3,400	12,821	3,637	16,080
Total	**3,486,862**	**15,850**	**68,228**	**17,055**	**85,859**
5-year Average	**697,372**	**3,170**	**13,646**	**3,411**	**17,172**

Table A.2 Crash Statistics at Signalized Intersections (within 250 ft) on State Highway System by Context Classification

Year	Context Classification								
	C1 – Natural	C2 – Rural	C2T – Rural Town	C3C – Suburban Commercial	C3R – Suburban Residential	C4 – Urban General	C5 – Urban Center	C6 – Urban Core	LA – Limited Access
Count of Fatal Crashes (Count of Fatalities)									
2018	2 (4)	9 (10)	1 (1)	121 (124)	35 (37)	101 (105)	12 (12)	4 (4)	1 (1)
2019	2 (2)	7 (9)	3 (4)	126 (132)	25 (25)	87 (90)	6 (7)	6 (6)	4 (5)
2020	2 (2)	25 (15)	0 (0)	136 (152)	28 (29)	91 (102)	8 (9)	2 (2)	1 (3)
2021	1 (1)	11 (14)	2 (2)	138 (147)	32 (35)	123 (128)	7 (7)	2 (2)	3 (4)
2022	0 (0)	17 (19)	3 (3)	116 (121)	31 (32)	98 (104)	4 (4)	7 (7)	3 (3)
5-year Total	**7 (9)**	**59 (67)**	**9 (10)**	**637 (676)**	**151 (158)**	**500 (529)**	**37 (39)**	**21 (21)**	**12 (16)**
5-year Average	**1.4 (1.8)**	**11.8 (13.4)**	**1.8 (2.0)**	**127.4 (135.2)**	**30.2 (31.6)**	**100.0 (105.8)**	**7.4 (7.8)**	**4.2 (4.2)**	**2.4 (3.2)**
Count of Serious Injury Crashes (Count of Serious Injuries)									
2018	2 (4)	57 (81)	6 (8)	724 (923)	170 (237)	473 (566)	48 (51)	22 (23)	14 (25)
2019	2 (2)	53 (81)	17 (18)	668 (841)	160 (210)	455 (542)	58 (63)	13 (13)	17 (23)
2020	2 (2)	48 (61)	13 (15)	561 (682)	152 (210)	392 (457)	51 (44)	15 (16)	16 (19)
2021	3 (3)	49 (64)	14 (16)	571 (714)	136 (170)	412 (483)	57 (65)	24 (28)	15 (23)
2022	2 (2)	55 (82)	18 (22)	584 (725)	138 (194)	440 (534)	51 (60)	22 (24)	12 (16)
5-year Total	**11 (13)**	**262 (369)**	**68 (79)**	**3,108 (3,885)**	**756 (1,021)**	**2,172 (2,582)**	**255 (283)**	**96 (104)**	**74 (106)**
5-year Average	**2.2 (2.6)**	**52.4 (73.8)**	**13.6 (15.8)**	**621.6 (777.0)**	**151.2 (204.2)**	**434.4 (516.4)**	**51.0 (56.6)**	**19.2 (20.8)**	**14.8 (21.2)**

Table A.3 Crash Statistics at Signalized Intersections on State Highway System (within 250 ft) with Roadway Attribute Information by Crash Types

Year	Crash Type							Total
	Angle	Bike	Pedestrian	Head On	Rear End	Sideswipe	Unknown/ Other	
Count of Fatal Crashes (Count of Fatalities)								
2018	113 (120)	18 (18)	94 (96)	8 (8)	26 (28)	10 (10)	59 (64)	328 (344)
2019	115 (126)	8 (8)	102 (102)	13 (14)	28 (31)	5 (5)	41 (43)	312 (329)
2020	105 (117)	15 (15)	89 (90)	14 (19)	27 (30)	9 (11)	63 (73)	322 (355)
2021	114 (126)	14 (14)	112 (112)	11 (13)	32 (36)	3 (3)	74 (79)	360 (383)
2022	107 (112)	20 (20)	90 (92)	14 (15)	38 (41)	5 (5)	67 (71)	341 (356)
5-year Total	**554 (601)**	**75 (75)**	**487 (492)**	**60 (69)**	**151 (166)**	**27 (34)**	**304 (330)**	**1,663 (1,767)**
5-year Average	**110.8 (120.2)**	**15.0 (15.0)**	**97.4 (98.4)**	**12.0 (13.8)**	**30.2 (33.2)**	**5.4 (6.8)**	**60.8 (66.0)**	**332.6 (353.4)**
Count of Serious Injury Crashes (Count of Serious Injuries)								
2018	714 (941)	90 (93)	219 (221)	99 (140)	554 (698)	79 (92)	344 (389)	2,099 (2,574)
2019	698 (908)	91 (94)	228 (230)	102 (135)	499 (602)	70 (80)	277 (318)	1,965 (2,367)
2020	610 (795)	74 (74)	170 (173)	110 (147)	358 (416)	59 (67)	265 (290)	1,646 (1,962)
2021	601 (754)	67 (67)	205 (211)	96 (128)	374 (447)	85 (101)	253 (282)	1,681 (1,990)
2022	619 (823)	93 (93)	210 (216)	92 (131)	352 (422)	78 (88)	270 (312)	1,714 (2,085)
5-year Total	**3,502 (4,221)**	**415 (421)**	**1032 (1,051)**	**499 (681)**	**2137 (2,585)**	**371 (428)**	**1,409 (1,591)**	**9,105 (10,978)**
5-year Average	**648.4 (844.2)**	**83.0 (84.2)**	**206.4 (210.2)**	**99.8 (136.2)**	**427.4 (517.0)**	**74.2 (85.6)**	**281.8 (318.2)**	**1,821.0 (2,195.6)**

Appendix B.

Table B.1 Countermeasure Information

Countermeasure	Crash Type(s)	Crash Severity	Area Type	Roadway Type	Number of Legs	CMF ID(s)	CMF
Centerline Hardening	Pedestrian	KABC	—	—	—	—*	0.540
Extend Yellow Change Interval	Rear End	KABCO	Urban	—	3, 4	4209	0.934
Flashing Yellow Arrow	Angle	KABCO	All	—	3, 4	9669	0.700
High Emphasis Crosswalk	Angle, Rear End	KABCO	Urban	—	3, 4	4124	0.810
	Pedestrian	KABCO	Urban	—	3,4	4123	0.600
Intersection Lighting	Angle, Pedestrian Rear End (nighttime)	ABC	—	—	—	433	0.620
	Pedestrian (nighttime)	ABC	—	—	—	436	0.580
	Angle, Pedestrian, Rear End	ABC	—	—	—	438	0.500
	Pedestrian	ABC	—	—	—	441	0.410
Leading Pedestrian Interval	Pedestrian	KABCO	Urban, Suburban	All	—	9918	0.870
Pedestrian Refuge Island	Pedestrian	KABCO	Urban, Suburban	Minor Arterial	—	8799	0.685
Retroreflective Signal Backplates	Angle, Pedestrian, Rear End	KABCO	Urban	—	—	1410	0.850

* The CMF value for the Centerline Hardening countermeasure is obtained from the NCHRP Guidance to Improve Pedestrian and Bicyclist Safety at Intersections (2020) http://nap.nationalacademies.org/25808.