Appendix C. Expanded Project Development Methodology

The process to assign proven effective safety countermeasures to specific locations involved dataset preparation, researching and documenting assumptions, and developing sound combinations of criteria for each selected countermeasure. The purpose of Appendix C is to expand on the project selection summarized in Section 7 and detail the approach and resources utilized to develop cost estimates for project implementation. The structure for Appendix C is as follows:

- Supplementary Intersection Project Development Information
  - Retroreflective Backplates on Signal Heads & Special Emphasis Crosswalk Markings
  - Leading Pedestrian Intervals, Blank Out Signs & R10-15 Signs
- Supplementary Segment Project Development Information
  - Upgrade Pavement Markings
  - Upgrade Bike Lane Markings
  - Rectangular Rapid Flashing Beacons
  - Refuge Islands
  - Dynamic Speed Feedback Signs
  - Pedestrian Hybrid Beacons
  - Street Lighting
  - Access Management
- Implementation Cost Summary

C.1 Supplementary Intersection Project Development Information

Two independent approaches were used to identify which of the at-risk intersections would receive selected countermeasures. The first approach used a project development guide to identify candidate locations for special emphasis crosswalk marking upgrades and retroreflective backplates. The second approach used a modified countermeasure warrant approach to identify suitable signalized intersections for implementation of LPIs, blank out signs and regulatory yield to pedestrian signs.

C.1.1 Retroreflective Backplates & Special Emphasis Crosswalk Markings

A project development guide was created to provide a step-by-step process to candidate locations for the installation of retroreflective backplates and special emphasis crosswalks based on existing site conditions. This approach required an analyst to review each intersection in Google Earth and determine if the existing signal heads and crosswalks already had the recommended countermeasures installed at the site. The three potential signal head conditions are shown in Figure C-1. Analysts were required to determine which of the three conditions shown in Figure C-1 most closely matched the condition for each signal head at each signalized intersection. Installation of retroreflective backplates was recommended for each signal head with either Condition #1 or Condition #2. The count of each signal head without retroreflective backplates was used to determine the cost to install retroreflective backplates at each at risk intersection. Condition #3 represents the installation of the recommended countermeasure and no further backplate project would be assigned for these signal heads. It's important to note that the installation of retroreflective backplates are specific to each signal head, not just each intersection.

Similarly, for the installation of special emphasis crosswalks, analysts reviewed Google Earth aerial imagery to determine the absence of special emphasis crosswalks, as defined in Figure C-2. For each intersection approach where there was no special emphasis crosswalk markings, the analyst measured the total distances, in feet, requiring the installation of special emphasis crosswalk markings. These distances were used to determine the cost associated with installing special emphasis crosswalk markings at each at risk intersection. The full project development guide can be found in Appendix D.

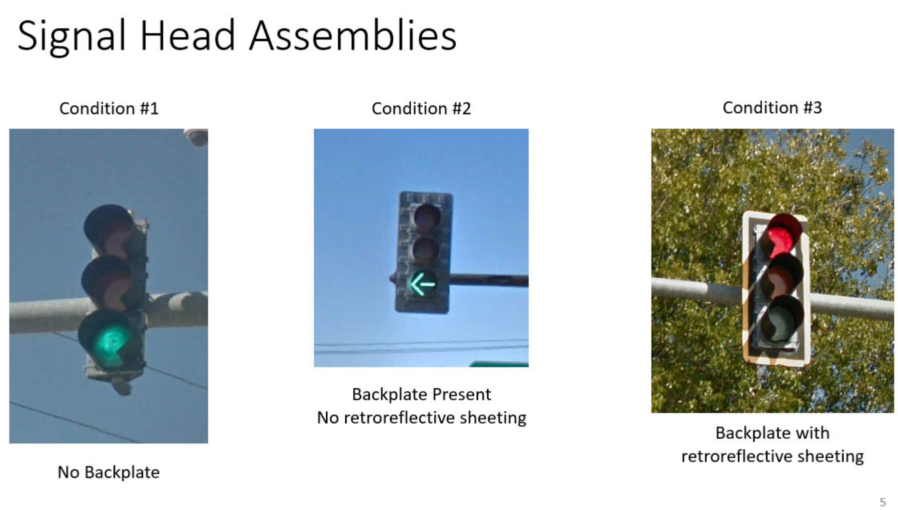

Figure C-1. Signal Head Assembly Slide

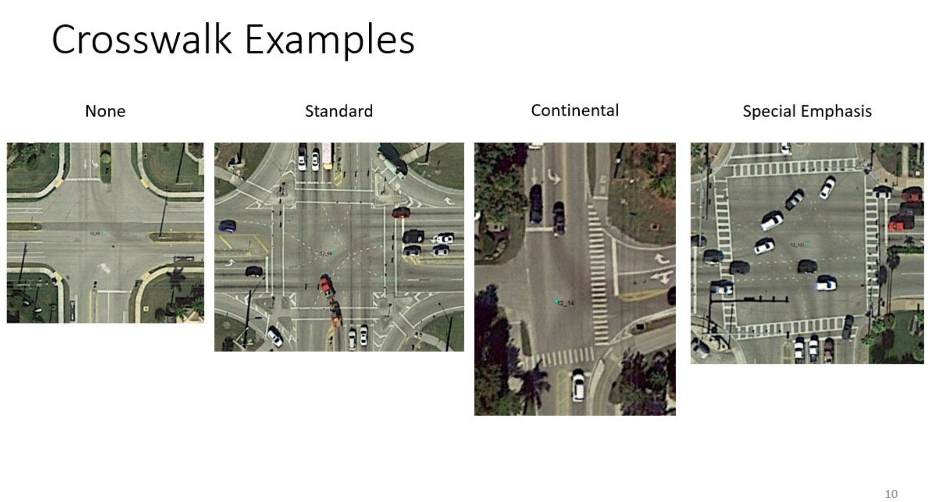

Figure C-2. Crosswalk Example Slide

C.1.2 Leading Pedestrian Intervals, Blank Out Signs & R10-15 Signs

The Lee County-specific methodology used to determine reasonably suitable locations for implementing an LPI, prohibiting right turn on red blank out sign and/or installation of the R10-15 Turning Vehicles Yield to Pedestrian sign is based on recent research establishing warrants for the implementation. The abbreviated methodology assessed the majority of warrants that were established in the CUTR Research report BDV25-977-22 *Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida*. The LPI warrant analysis was performed on 210 signalized intersections that were identified as “at-risk” based on the preceding risk assessment. Since the limiting resources available to completely adhere to CUTR report’s guidelines, the following modified LPI warrants were used to screen the network for reasonably suitable LPI installations.

C.1.2.1 Warrant 1 – Average Crash Frequency

The risk assessment had previously identified intersection related crashes based on a spatial buffer of 350 feet for the three most recent years of the original dataset used (2014-2016). Warrant 1 was satisfied if the intersection had two or more crashes involving a pedestrian or bicycle. Approximately 14 percent (30 of 210) of the intersections had at least two pedestrian or bicycle related crashes. Figure C-3 shows the distribution of intersections and crash density.

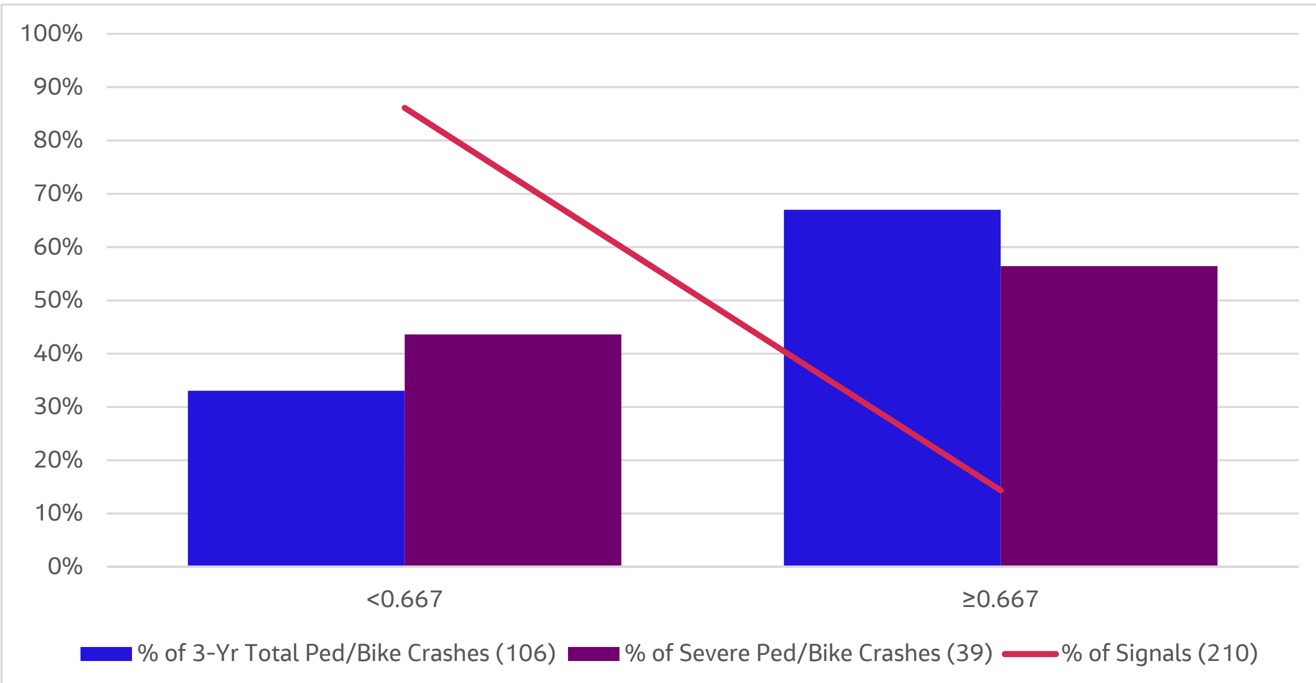

Figure C-3. Crash Frequency (3-Year Crash Density Surrogate)

C.1.2.2 Warrant 2 – Reported Visibility Issues

Collecting intersection specific reported visibility issues at over 200 locations was not considered feasible for this study. As such, a surrogate measure for potential visibility issues was used. The presence of any approach having a skewed alignment (more than 5 degrees) was manually collected. Approximately 30 percent (62 of 210) of the intersections had at least one leg with a skewed approach. Figure C-4 shows the distribution of crashes combined with Warrant 2.

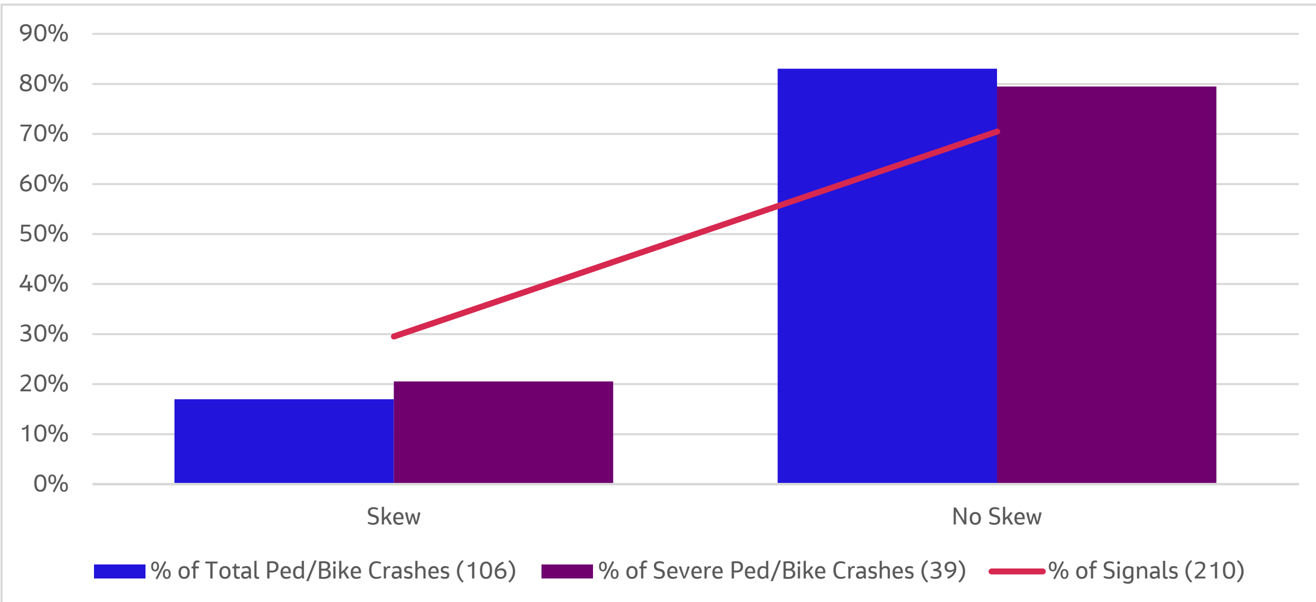

Figure C-4. Approach Skew Angle Present (Reported Visibility Issues Surrogate)

C.1.2.3 Warrant 3 – Vehicle Non-Yielding Behavior

Utilizing the available crash data, three different variables were considered to determine if Warrant 3 is satisfied. Non-yielding behavior is recorded when the reporting officer makes the observational assessment of what occurred at the time of the crash based on physical evidence and/or witness statements. Crash densities associated with attributes from the "Driver Action" and "Crash Lane" fields of the crash report were considered when determining how Warrant 3 would be satisfied and can be found in Table C-1.

Table C-1. Pedestrian Peak Hour Surrogate Data Thresholds

Attribute Field	Attribute Value	Crash Density
Driver 1 Action	FAILED TO YIELD THE RIGHT OF WAY	1.333
	IMPROPER TURN	0.333
Crash Lane	PEDESTRIAN IN CROSSWALK	0.333
	BICYCLE IN A DESIGNATED BICYCLE TRAVEL LANE	

The combination of the two attributes from the "Crash Lane" field acts as a surrogate for the pedestrian or bicyclist having the right-of-way when traversing through an intersection. Keeping consistent with Warrant 1, crash records were reviewed from 2014 to 2016, the most recent 3-year period, which also aligns with the CUTR report.

Intersections were noted as having non-yielding behavior if at least one or more threshold densities were met.. Approximately 60 percent (125 of 210) of intersections satisfy Warrant 3. Figure C-5 shows the distribution of crashes and intersections with respect to Warrant 3

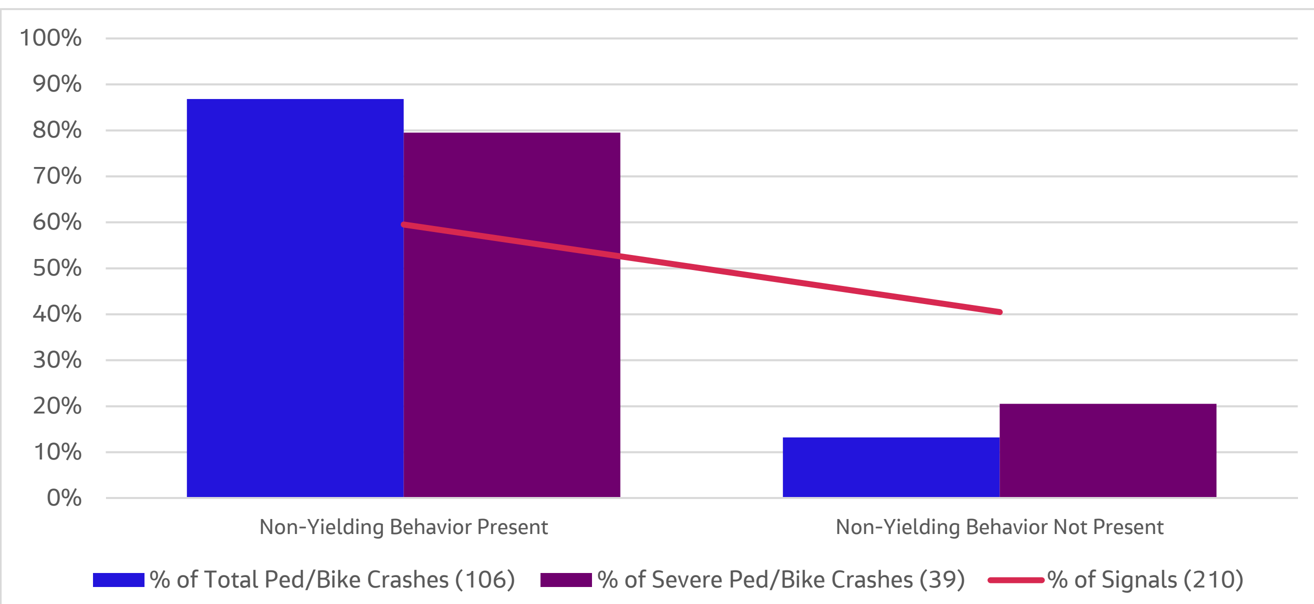

Figure C-5. Crash Attributes Present (Non-Yielding Behavior Surrogate)

C.1.2.4 Warrant 4 – Vehicle Peak Hour

Since turning movement volumes were not available for this exercise, two-way traffic approach volumes were used as a surrogate exposure warrant. The Average Annual Daily Traffic (AADT) shapefile sourced from FDOT's file geodatabase was spatially referenced to the segment and intersection networks. AADTs were assigned to each of the approaching legs of the intersections and where there was missing data, estimated data was applied. Estimated volumes were determined based on countywide averages categorized by context classification. Approximately 90 percent of all exposure data was directly referenced from FDOT's AADT shapefile. Total entering volume was computed in order to determine which of the signalized intersections satisfy Warrant 4. Intersections with 50,000 or more total entering vehicles was the selected threshold due to the proportion of crashes that are overrepresented. Approximately 41 percent (87 of 210) of the intersections satisfy Warrant 4. Figure C-6 shows the distribution of crashes and traffic volume ranges.

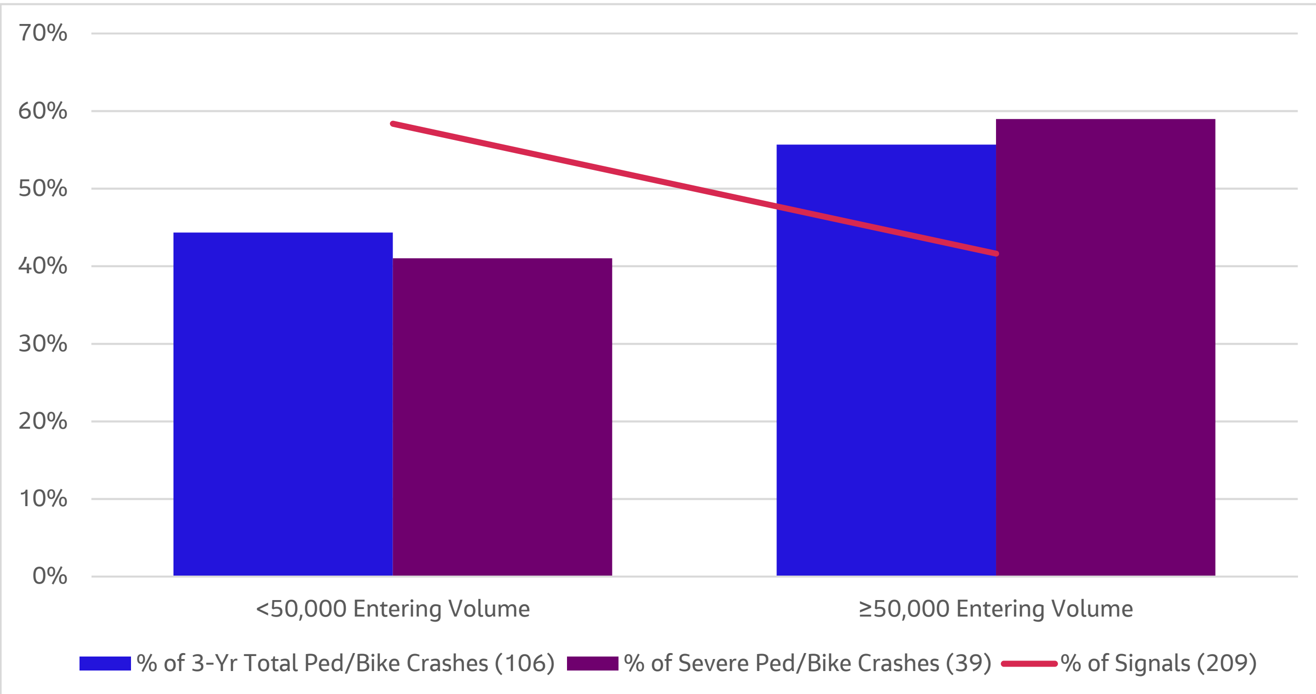

Figure C-6. Entering Traffic Volume (Vehicular Peak Hour Surrogate)

C.1.2.5 Warrant 5 – Pedestrian Peak Hour

Pedestrian peak hour volume was not available for all intersections. As such presence of various pedestrian generator facilities was used as a surrogate measure for this warrant. Table C-2 describes the five types of pedestrian generators and the associated buffer distances used to satisfy Warrant 5.

Table C-2. Pedestrian Peak Hour Surrogate Data Thresholds

Pedestrian Generator Type	Buffer Distance [miles]
Transit Stops	0.25
Points of Interest	0.50
Public Parks	1.00
Off-Street Trails	1.00
Public Libraries	2.00

Warrant 5 is satisfied when an intersection has four or more of the pedestrian generator types present. Approximately 54 percent (114 of 210) of intersections satisfy Warrant 5. Figure C-7 shows the distribution of crashes and proportion of intersections that meet the various buffer distances.

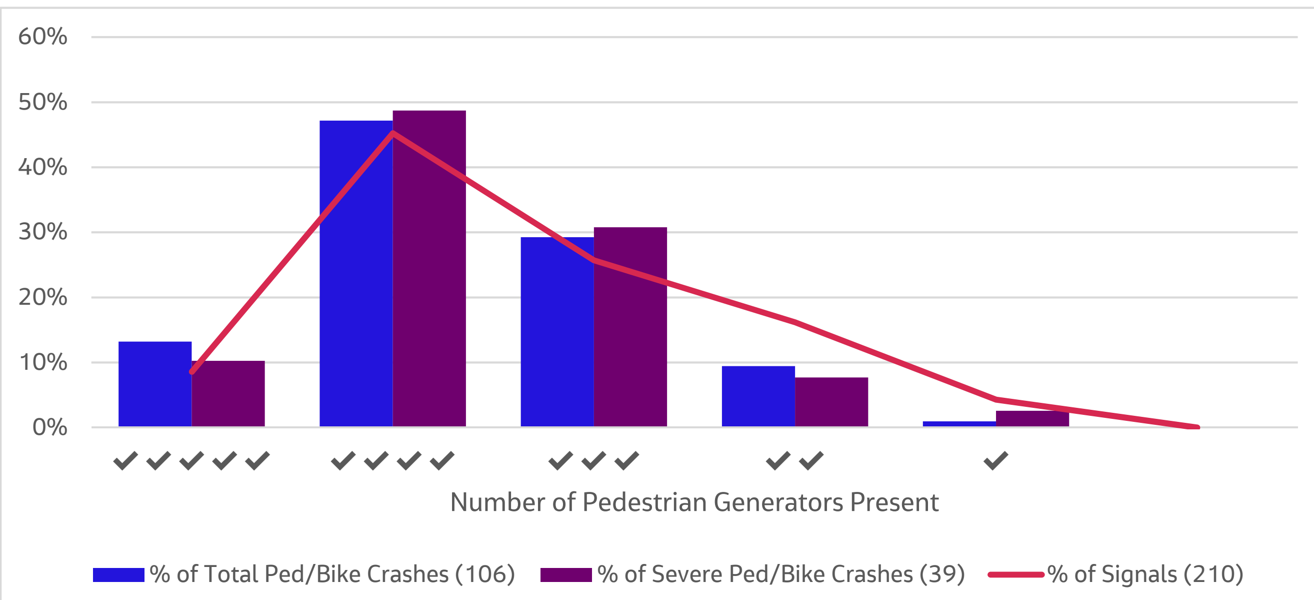

Figure C-7. Presence of Pedestrian Generators Surrogate (Pedestrian Peak Hour)

C.1.2.6 Warrant 8 – School Crossing

The last warrant is based on presence of a school crossing. A Lee County-specific schools shapefile was used to determine which intersections satisfy Warrant 8. The shapefile includes points located in the center of the school's property. Warrant 8 is satisfied when an intersection is within a three-quarter mile radius from the point. Approximately 53 percent (112 of 210) of intersections satisfy Warrant 8. Figure C-8 shows the distribution of crashes and proportion of intersections that satisfy Warrant 8 buffer distance.

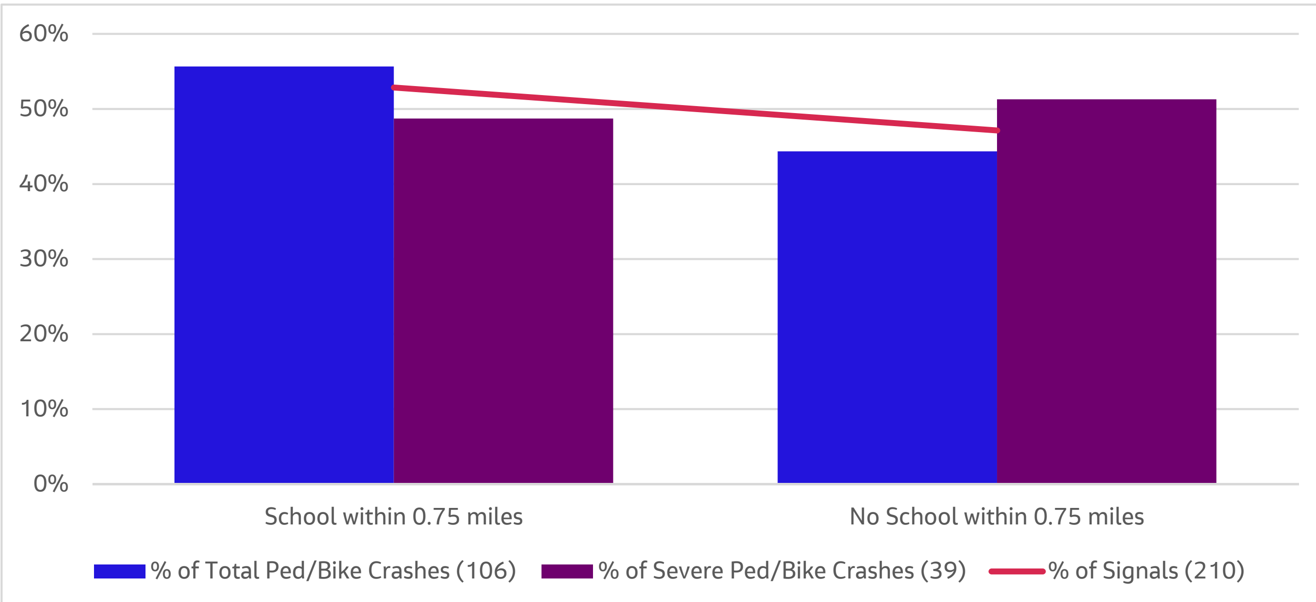

Figure C-8. Proximity to School (School Crossing Presence Surrogate)

C.1.2.7 Application of Warrant Analysis

The last step in determining which at-risk signalized intersections receive the countermeasures was based on the accumulation of warrants. Table C-3 shows the distribution of locations with the assigned projects and Figure C-9 is the corresponding chart that also incorporates the distribution of crashes based on the number of satisfied warrants.

Table C-3. Warrant Analysis Summary

Number of Satisfied Warrants	Number of Intersections	Percent of Intersections	Projects Assigned
6	0	0%	LPI + Blank Out Sign
5	13	6%	
4	40	19%	
3	50	24%	LPI + R10-15 Sign
2	58	28%	R10-15 Sign Only
1	37	17%	
0	12	6%	No Project
Total	210	100%	

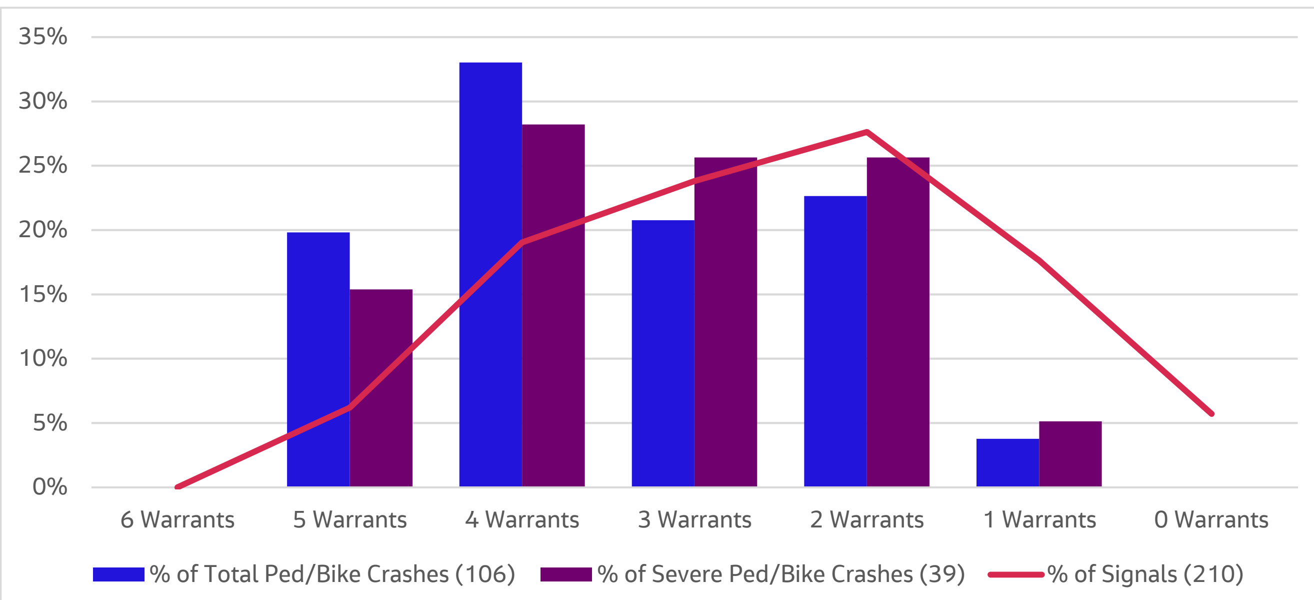

Figure C-9. Distribution of Crashes and Satisfied Warrants

In total, 194 at-risk signalized intersections received at least one improvement specific to this effort. There were 101 intersections that qualified for LPIs. Of those, 51 intersections had a supplemental Blank Out Sign and 50 intersections had supplemental R10-15 signs. There were 94 at-risk signalized intersections that received only the R10-15 sign only assuming two approaches would be sufficient to implement the sign.

Additionally, there were five locations that already had LPIs implemented. Two locations satisfied four warrants, another two locations satisfied two warrants and one location satisfied zero warrants. None of these locations had recommendations applied to them for this effort specifically.

C.2 Supplementary Segment Project Development Information

The following section describes the process and information used to determine which segments receive the previously selected safety countermeasures. Basic logic was applied to various existing and supplemental segment-related data to determine the most suitable project. Table C-4 provides a matrix of which existing or supplemental data was used to determine which countermeasures can be selected. There were six datasets that were already existing from previously gathered information and there were five datasets that had to be manually collected through Google Earth aerial imagery. Specific criteria for each countermeasure is provided below.

Table C-4. Segment Project Development Data Matrix

Data Type	Data Variable	Selected Segment Countermeasures							
		Upgrade Pavement Markings	Upgrade Bike Markings	Rectangular Rapid Flash Beacon	Refuge Island	Dynamic Speed Feedback Sign	Pedestrian Hybrid Beacon	Street Lighting	Access Management
Existing Data	Jurisdiction	✔		✔			✔		
	Speed Limit			✔		✔			✔
	Length	✔			✔				
	Context Classification		✔			✔		✔	✔
	Functional Classification		✔				✔		✔
	Crash Cost	✔							
Supplemental Data	Lane Count			✔	✔		✔		✔
	Cross Section			✔	✔		✔		✔
	Lighting Present					✔		✔	
	Marked Bike Lanes		✔						
	Signal Density								✔

C.2.1 Upgraded Pavement Markings

Upgrading pavement markings provide better longitudinal delineation for drivers. Based on the criteria in Table C-5, 39 segments (16.88 miles) are recommended for upgraded pavement markings. 4 percent (2 of 46) severe crashes occurred along these segments.

Table C-5. Upgraded Pavement Marking Project Criteria

Data Variable	Data Type	Criteria	Justification
Jurisdiction	Existing	FDOT	• The majority of severe crashes occur on state owned highways in Lee County
Segment Length	Existing	≤ 1 mile	• 84% of segments / 70% of miles in the “high-priority” list has a length less than or equal to 1 mile.
FDOT Crash Cost	Existing	< $1,000,000	• Total pedestrian/bicycle crashes used for crash cost calculation • There is a potential to capture at least one A severity crash in the crash costs otherwise higher frequency of less severe crashes will be considered. (22% of severe crashes)

C.2.2 Upgraded Bike Lane Markings

Upgrading bike lane markings provide better visibility for drivers and provide a better dedicated space for bicyclists. Based on the criteria in Table C-6, 41 segments (26.32 miles) are recommended for upgraded bike lane markings. 28 percent (13 of 46) severe crashes occurred along these segments.

Table C-6. Upgraded Bike Lane Marking Project Criteria

Data Variable	Data Type	Criteria	Justification
Context Classification	Existing	C3C – Suburban Commercial	• Greatest proportion of miles for improvement and current risk factor
Functional Classification	Existing	Arterial	• Greatest proportion of miles for improvement and current risk factor
Marked Bike Lanes	Supplemental	No	• Smaller proportion of miles that could use the improvement

C.2.3 Rectangular Rapid Flashing Beacon (RRFB)

Rectangular rapid flashing beacons provide an enhanced crosswalk for pedestrians to more safety cross busy roadways. These devices, when used properly greatly increase driver yielding compliance as well. Based on the criteria in Table C-7, 34 segments (15.43 miles) are recommended for rectangular rapid flashing beacons. 24 percent (11 of 46) severe crashes occurred along these segments.

Table C-7. Rectangular Rapid Flashing Beacon Project Criteria

Data Variable	Data Type	Criteria	Justification
Jurisdiction	Existing	FDOT ***OR*** Lee County	• 83% of severe crashes
Speed Limit	Existing	45	• 80% of severe crashes and current risk factor
Lane Count	Supplemental	4	• 48% of miles • 48% of severe crashes
Cross Section	Supplemental	Divided	• Infrastructure already in place for the potential of a two-phase crossing option

C.2.4 Pedestrian Refuge Island

Refuge islands reduce the crossing distance and allows for two separate times to cross depending on traffic conditions. Based on the criteria in Table C-8, 14 segments (12.17 miles) are recommended for refuge islands. 15 percent (7 of 46) severe crashes occurred along these segments.

Table C-8. Pedestrian Refuge Island Project Criteria

Data Variable	Data Type	Criteria	Justification
Speed Limit	Existing	≤ 45	• 80% of severe crashes and existing risk factor
Lane Count	Supplemental	≤ 4	• 48% of miles and severe crashes
Cross Section	Supplemental	TWLTL	• No current roadway division • Optional consideration for access modifications to accommodate new designated crossings

C.2.5 Dynamic Speed Feedback Sign

Dynamic speed feedback signs help alert drivers of their speed. These devices are intended to be placed in where context classifications change. Based on the criteria in Table C-9, 19 segments (17.01 miles) are recommended for speed feedback signs. 9 percent (4 of 46) severe crashes occurred along these segments.

Table C-9. Dynamic Speed Feedback Sign Project Criteria

Data Variable	Data Type	Criteria	Justification
Speed Limit	Existing	≥ 45	• 91% of severe crashes
Context Classification	Existing	C2T ***OR*** C3R	• 91% of severe crashes and 79% of miles
Lighting Present	Supplemental	No	• No current roadway division • Optional consideration for access modifications to accommodate new designated crossings

C.2.6 Pedestrian Hybrid Beacon (PHB/HAWK)

Pedestrian Hybrid Beacons act as a traffic control device and allows the pedestrian to press a button actuating a traffic signal with a red light for motor-vehicles requiring the vehicle to come to a complete stop and allowing the pedestrian to cross the road. Based on the criteria in Table C-10, 21 segments (10.33 miles) are recommended for pedestrian hybrid beacons. 15 percent (7 of 46) severe crashes occurred along these segments.

Table C-10. Pedestrian Hybrid Beacon Project Criteria

Data Variable	Data Type	Criteria	Justification
Jurisdiction	Existing	FDOT	• 65% of total severe crashes
Functional Classification	Existing	Arterial	• 100% of total severe crashes and current risk factor
Lane Count	Supplemental	6	• 39% of total severe crashes with only 30% of miles
Cross Section	Supplemental	Divided	• 65% of total severe crashes

C.2.7 Street Lighting

Providing street lighting to roadway segments when previous lighting was absent is a proven countermeasure that reduces the prevalence of low light related crashes. Based on the criteria in Table C-11, 52 segments (34.85 centerline miles) are recommended for street lighting. 20 percent (9 of 46) severe crashes occurred along these segments.

Table C-11. Street Lighting Project Criteria

Data Variable	Data Type	Criteria	Justification
Context Classification	Existing	C3C ***OR*** C4	• 65% of total severe crashes
Lighting Present	Supplemental	No	• "Present of Lighting" field was manually collected and assumes no street lighting is present on both sides of the road • Similarly, project suggestions take the form of two sides of road per mile based on Lee LRTP Costing Tool

C.2.8 Access Management

Access management types of projects involve reducing the number of conflict points between turning vehicles at intersections along a corridor. Based on the criteria in Table C-12, 13 segments (10.61 miles) are recommended for access management. 22 percent (10 of 46) severe crashes occurred along these segments.

Table C-12. Access Management Project Criteria

Data Variable	Data Type	Criteria	Justification
Speed Limit	Existing	≥ 35	• 96% of total severe crashes • 99% of segments
Context Classification	Existing	C3C	• 89% of total severe crashes • 76% of segments
Functional Classification	Existing	Arterial	• 100% of total severe crashes • 98% of segments
Lane Count	Supplemental	≥ 4	• 48% of total severe crashes • 48% of segments
Cross Section	Supplemental	TWLTL ***OR*** Undivided	• 35% of total severe crashes • 29% of segments
Signal Density	Supplemental	≥ 1.00	• 93% of total severe crashes • 87% of segments

C.3 Implementation Cost Summary

Figure C-10 provides an overview of how implementation costs were determined. The primary source of this information came from FDOT's Basis of Estimates Manual and statewide average unit costs for the applicable pay items. Another source of cost information was Lee MPO's long range project costing tool.

Treatment Type	Countermeasure	FDOT Average Unit Cost	Unit	%	Inflation	%	MOT	%	Mobilization	%	CEI	%	Design	Subtotal	%	Contingency	Total Estimated Implementation Costs	Construction Estimate	Unit	Notes
Segment	Upgrade Pavement Markings	$ 1,029.27	GM	5%	$ 51	10%	$ 103	10%	$ 103	15%	$ 154	10%	$ 103	$ 1,544	25%	$ 386	$ 1,930	$ 1,930	GM	
Segment	Upgrade Bike Lane Markings	$ 1,029.27	GM	5%	$ 51	10%	$ 103	10%	$ 103	15%	$ 154	10%	$ 103	$ 1,544	30%	$ 463	$ 2,007	$ 2,007	GM	
Spot	Rectangular Rapid Flash Beacon	$ 14,469.00	AS		$ -	10%	$ 1,447	10%	$ 1,447	15%	$ 2,170		$ -	$ 19,533	25%	$ 4,883	$ 24,416	$ 24,416	AS	
Spot	Refuge Islands	$ 28.23	LF	5%	$ 1	15%	$ 4	10%	$ 3	15%	$ 4	15%	$ 4	$ 45	75%	$ 34	$ 79	$ 11,639	LF	Assumed 8 feet wide and 30 feet long
		$ 3.31	SF	5%	$ 0	15%	$ 0	10%	$ 0	15%	$ 0	15%	$ 0	$ 5	75%	$ 4	$ 9		SF	
		$ 71.45	SY	5%	$ 4	15%	$ 11	10%	$ 7	15%	$ 11	15%	$ 11	$ 114	75%	$ 86	$ 200		SY	
Spot	Dynamic Speed Feedback Sign	$ 13,000.00	AS	5%	$ 650	10%	$ 1,300	10%	$ 1,300	15%	$ 1,950	10%	$1,300	$ 19,500	30%	$ 5,850	$ 25,350	$ 25,350	AS	
Spot	Pedestrian Hybrid Beacon	$ 111,681.00	EA		$ -	10%	$11,168	10%	$ 11,168	15%	$16,752		$ -	$150,769	25%	$ 37,692	$ 188,462	$ 188,462	EA	
Segment	Street Lighting	$ 517,989.00	EA		$ -	10%	$51,799	10%	$ 51,799	15%	$77,698		$ -	$699,285	25%	$ 174,821	$ 874,106	$ 874,106	per mile	• Cost for two sides of road • Old cost assumed $6,000 per light pole placed every 200 feet
Segment	Access Management Study	$ -	NA		$ -		$ -		$ -		$ -		$ -	$ -		$ -	$ -	$100,000 - $500,000	NA	• Estimated Cost Range Per Study • Will not be quantified in final project recommendations table
Interseciton	Retroreflective Backplate	$ 248.37	EA	5%	$ 12	10%	$ 25	10%	$ 25	15%	$ 37	10%	$ 25	$ 373	25%	$ 93	$ 466	$ 466	EA	Retrofit existing signal heads
Interseciton	Special Emphasis Crosswalk	$ 17.22	LF	5%	$ 1	10%	$ 2	10%	$ 2	15%	$ 3	10%	$ 2	$ 26	15%	$ 4	$ 30	$ 30	LF	• Assumed crosswalk width of 10' and ladders spaced every 5 feet • Equation derives cost based on total length of crosswalk needed plus milling area
		$ 2.43	SY	5%	$ 0	10%	$ 0	10%	$ 0	15%	$ 0	10%	$ 0	$ 4	15%	$ 1	$ 4	$ 4	SY	
		$ 9.87	LF	5%	$ 0	10%	$ 1	10%	$ 1	15%	$ 1	10%	$ 1	$ 15	15%	$ 2	$ 17	$ 17	LF	
Interseciton	Blank Out Sign	$ 5,169.54	AS	5%	$ 258	10%	$ 517	10%	$ 517	15%	$ 775	10%	$ 517	$ 7,754	25%	$ 1,939	$ 9,693	$ 9,693	AS	
Interseciton	R10-15 YTP Sign	$ 350.08	AS	5%	$ 18	10%	$ 35	10%	$ 35	15%	$ 53	10%	$ 35	$ 525	25%	$ 131	$ 656	$ 656	AS	
Interseciton	Leading Pedestrian Interval	$ -	NA		$ -		$ -		$ -		$ -		$ -	$ -		$ -	$ -	$1,000 - $250,000	NA	• Estimated Cost Range Per Study • Will not be quantified in final project recommendations table

Legend
Jacobs Cost Development
LRTP Costing Tool
Unknown - Provided Range

Figure C-10. Implementation Cost Summary Table