Guidelines for Installing Pedestrian Treatments at Midblock Locations

Final Report

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

METRIC CONVERSION TABLE

U.S. UNITS TO SI* (MODERN METRIC) UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.400	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.610	kilometers	km
mm	millimeters	0.039	inches	in
m	meters	3.280	feet	ft
m	meters	1.090	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
in^2	square inches	645.200	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.470	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		VOLUME		
fl oz	fluid ounces	29.570	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
NOTE: volumes greater than 1,000 L shall be shown in m^3.				

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16. Abstract

This study explored pedestrian safety treatments used at midblock locations to assist the Florida Department of Transportation (FDOT) in developing guidelines to improve pedestrian safety. The specific objectives included (a) identifying arterial corridors that are prone to pedestrian crashes, (b) recommending pedestrian treatments to be installed at these locations, and (c) developing guidelines to assist in selecting the midblock locations and pedestrian treatments for improving pedestrian safety. The research identified the top 20 pedestrian crash hotspots in FDOT District Four. A detailed analysis was then conducted to determine the geometric, traffic, land-use, and census variables that could potentially influence pedestrian safety at midblock locations and to develop crash modification factors (CMFs). The modeling results identified the following variables whose increase resulted in a higher frequency of pedestrian crashes and were significant at a 90% credible interval: natural logarithm of average annual daily traffic (AADT), proportion of the low-income population, density of bus stops, density of bars and food joints, and density of shopping centers. A lower proportion of senior population and logarithm of the total population showed a reduction in the frequency of pedestrian crashes and were significant at a 90% credible interval.

The research developed a set of guidelines to follow when considering a midblock location for installing pedestrian crossing treatments. The assessment procedure was presented in the form of flow charts that covered the following criteria: the distance of the potential location from established crossing points, AADT, pedestrian activities, posted speed limit, roadway configuration, pedestrian crash hotspots, and income level. The developed guidelines are expected to help practitioners make decisions about pedestrian safety in identifying and prioritizing midblock locations to install pedestrian crossing treatments.

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EXECUTIVE SUMMARY

Pedestrian safety is a serious concern. In recent years, the number of pedestrian fatalities in the United States (U.S.) has grown substantially. During the most recent ten-year period for which crash data are available, the Governors Highway Safety Association (GHSA) reported that the number of pedestrian fatalities increased by 53% (from 4,109 deaths in 2009 to 6,283 deaths in 2018) compared to the combined number of all other traffic fatalities, which increased by 2%. Moreover, Florida was ranked among the top three states in the U.S. for pedestrian fatalities in 2019 (Retting, 2020).

The pedestrian crashes occur at both midblock locations as well as at signalized intersections. Because people prefer to walk the shortest distance to access their destinations, they are more likely to cross at midblock locations even when there are no designated pedestrian crossings. Therefore, this study explores pedestrian crossing treatments at midblock locations to assist the Florida Department of Transportation (FDOT) in developing guidelines to improve pedestrian safety in the state. The specific objectives included (a) identifying specific arterial corridors that are prone to pedestrian crashes, (b) recommending pedestrian treatments to be installed at these locations, and (c) developing guidelines to assist in selecting the corridors and the pedestrian treatments for improving pedestrian safety.

A thorough review of the existing national, state, and local warrants and guidelines on installing pedestrian safety treatments at midblock locations was conducted. The variables that could potentially influence pedestrian crashes at midblock locations were then identified. These included socioeconomic, land-use, demographic, roadway geometric characteristics, traffic, and pedestrian infrastructure variables. A total of 20 pedestrian crash hotspots in FDOT District Four were identified and ranked. The supplemental .kmz file, submitted as part of this report, includes the spatial locations of these hotspots. The supplemental Excel file, also submitted as part of this report, includes the list of state roads within each of the 20 hotspots. The Excel file also includes the location and type of crosswalks and other pedestrian infrastructure (e.g., pedestrian signals, RRFBs, etc.) within each hotspot.

Statistical analysis was conducted to evaluate the safety of midblock segments and develop the crash modification factors for different geometric, traffic, land-use, and census variables. The modeling results identified several variables that impact pedestrian crash occurrence at midblock locations. The increase in the following variables showed an escalation in the frequency of pedestrian crashes, and the variables were significant at a 90% credible interval:

- natural logarithm of AADT,
- proportion of the low-income population,
- density of bus stops,
- density of bars and food joints, and
- density of shopping centers.

The increase in the following variables showed a reduction in pedestrian crashes, and the variables were significant at a 90% credible interval:

- proportion of senior population, and

- logarithm of the total population.

Based on the different factors influencing the safety of pedestrians at midblock locations coupled with considerations from different guidelines nationwide, a set of specific guidelines was developed to assist transportation agencies in identifying corridors for installing midblock pedestrian treatments and selecting the most appropriate pedestrian safety treatment at midblock locations. The developed guidelines will enable the practitioners to identify corridors for installing pedestrian treatments based on the roadway characteristics, traffic volume, land-use characteristics, and the built environment. The assessment procedure was presented in the form of a flow chart and covered the following criteria:

- the distance of the potential location from established crossing points,
- AADT,
- pedestrian activities,
- posted speed limit,
- configuration of the roadway,
- pedestrian crash hotspots, and
- income level.

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ACRONYMS AND ABBREVIATIONS

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ACS	American Community Survey
ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
CCD	City and County of Denver
CRFB	Circular Rapid Flashing Beacons
DOT	Department of Transportation
EPDO	Equivalent Property Damage Only
FARS	Fatality Analysis Reporting System
FDOT	Florida Department of Transportation
FGDL	Florida Geographic Data Library
FHWA	Federal Highway Administration
FTDE	Florida Transit Data Exchange
GHSA	Governors Highway Safety Association
GIS	Geographic Information System
GLM	Generalized Linear Model
GTFS	General Transit Feed Specification
HAWK	High-intensity Activated crossWalK
HCM	Highway Capacity Manual
ITE	Institute of Transportation Engineers
LOS	Level of Service
MnDOT	Minnesota Department of Transportation
MUTCD	Manual on Uniform Traffic Control Devices
MUTS	Manual on Uniform Traffic Studies
NASEM	National Academies of Sciences, Engineering, and Medicine
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
O-D	Origin-Destination
PBSSP	Pedestrian and Bicycle Strategic Safety Plan
PDI	Pedestrian Danger Index
PDO	Property Damage Only
PedSD	Pedestrian Sight distance
PHB	Pedestrian Hybrid Beacons
PSM	Propensity Score Matching
RCI	Roadway Characteristics Inventory
RRFB	Rectangular Rapid Flashing Beacon
SGA	Smart Growth America
SHS	State Highway System
SHSP	Strategic Highway Safety Plan
SIS	Strategic Intermodal System
SSD	Stopping Sight Distance
TEM	Traffic Engineering Manual
TRCP	Transit Cooperative Research Program
TWLTL	Two-Way Left Turn Lane
UBR	Unified Basemap Repository
UCONN	University of Connecticut
USDOT	United States Department of Transportation

VDOT	Virginia Department of Transportation
VRU	Vulnerable Road User
ZINB	Zero Inflated Negative Binomial

CHAPTER 1
INTRODUCTION

1.1 Background

Over the past decade, pedestrian injuries and fatalities have increased in the United States (U.S.). The Fatality Analysis Reporting System (FARS), a data resource maintained by the National Highway Traffic Safety Administration (NHTSA), indicates that pedestrian deaths increased by 35.4% between 2008 and 2017, for a total of 49,340 fatalities (NHTSA, 2019). The Governors Highway Safety Association (GHSA) reports that the number of pedestrian fatalities continued to increase by 53% (from 4,109 deaths in 2009 to 6,283 deaths in 2018) during the ten years from 2009 to 2018 compared to the combined number of all other traffic fatalities which increased by 2% (Retting, 2020). A recent study by the National Complete Streets Coalition, a program of Smart Growth America (SGA), examined pedestrian deaths that occurred in the U.S. from 2008 to 2017 and developed a pedestrian danger index (PDI) to measure the degree of danger for pedestrians while walking along or crossing roadways (SGA, 2019). Based on area and state population, and the share of people that may walk to work, SGA determined the 20 most dangerous metropolitan areas for pedestrians, shown in Figure 1-1. The following eight Florida metropolitan areas were ranked in the top 10 most dangerous metropolitan areas for pedestrians:

- Orlando-Kissimmee-Sanford (Rank: 1)
- Deltona-Daytona Beach-Ormond Beach (Rank: 2)
- Palm Bay-Melbourne-Titusville (Rank: 3)
- North Port-Sarasota-Bradenton (Rank: 4)
- Lakeland-Winter Haven (Rank: 5)
- Jacksonville (Rank: 6)
- Cape Coral-Fort Myers (Rank: 8)
- Tampa-St. Petersburg-Clearwater (Rank: 9)

Statewide, 5,433 pedestrian fatalities occurred in Florida from 2008-2017 (SGA, 2019). Based on state population, Florida was ranked third in the U.S. for pedestrian fatalities in 2017 and second in the nation in the four preceding years (NHTSA, 2019). Given these statistics, pedestrian safety is a serious concern in Florida.

To improve safety and reduce crashes involving vulnerable road users (VRUs), such as pedestrians and bicyclists, the Florida Department of Transportation (FDOT) has identified VRU safety as one of the 13 emphasis areas in the 2016 Florida Strategic Highway Safety Plan (SHSP), which includes strategies that follow the four E's: Engineering, Education, Enforcement, and Emergency Services (FDOT, 2016a). The SHSP also serves as a framework for Florida's Pedestrian and Bicycle Strategic Safety Plan (PBSSP), an implementation guide for Florida's Pedestrian and Bicycle Safety Coalition (FDOT, 2019).

Crashes involving pedestrians can occur at any point along a roadway corridor. However, intersection and midblock crossings are the primary sites for pedestrian incidents. People are more likely to take the most direct route to get to their destination, and as a result, they often cross roadway facilities at midblock locations (Federal Highway Administration [FHWA], 2006). This study focuses on exploring pedestrian safety treatments used at midblock locations to assist FDOT in developing guidelines and strategies to improve pedestrian safety in the state.

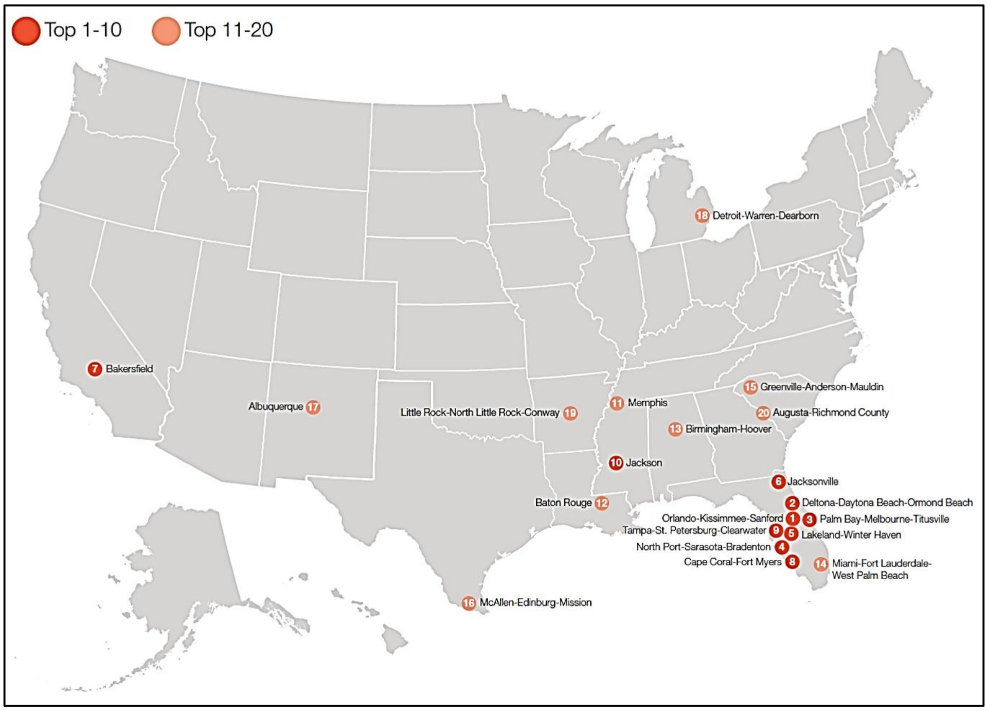


Figure 1-1: Top 20 Most Dangerous Metropolitan Areas for Pedestrians (2008–2017)
(Source: Smart Growth America, 2019)

1.2 Report Organization

This project aims to assist the Department in reducing pedestrian crashes at midblock locations in Florida. This project conducted a spatial analysis to identify arterial corridors that are prone to pedestrian crashes and developed guidelines to assist in selecting the corridors and treatments for improving pedestrian safety. The rest of the report is organized as follows:

- Chapter 2 provides a review of the literature on the existing national, state, and local warrants and guidelines for installing pedestrian safety treatments at midblock locations.
- Chapter 3 identifies demographic, socioeconomic, land-use, and roadway geometric variables that affect pedestrian safety through an extensive literature search and provides the data sources for all the variables.
- Chapter 4 presents spatial analysis in ArcGIS to identify pedestrian crash hotspots.
- Chapter 5 discusses the developed Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) for several variables relating to pedestrian crashes.
- Chapter 6 presents the guidelines for (a) identifying corridors for installing pedestrian treatments, and (b) selecting the most appropriate pedestrian safety treatment.
- Chapter 7 summarizes the research efforts and findings.

CHAPTER 2
LITERATURE REVIEW

This chapter focuses on existing national, state, and local warrants and guidelines on installing pedestrian safety treatments at midblock locations. An extensive review was conducted to explore guidelines developed and used by transportation agencies to evaluate potential midblock crossing locations and appropriate pedestrian crossing treatments. The chapter is organized as follows:

- Section 2.1 provides a brief introduction and background information about midblock crossings.
- Section 2.2 describes factors influencing midblock crossings.
- Section 2.3 discusses various pedestrian crossing treatments at midblock locations.
- Section 2.4 presents general guidelines recommended at the national level to evaluate crosswalk locations and specific treatments.
- Section 2.5 presents guidelines used in Florida and by other state agencies.
- Section 2.6 provides the chapter summary.

2.1 Midblock Crossings

Although midblock pedestrian crosswalks have been implemented throughout the U.S. for many years, available literature on the topic is somewhat limited. The majority of published information at the national level focuses on recommended pedestrian treatments (National Academies of Sciences, Engineering, and Medicine [NASEM], 2006; FHWA, 2018), specific pedestrian treatments (FHWA, 2015b), or treatment application information and guidelines (FHWA, 2006; FHWA, 2008; FHWA, 2012). Moreover, many state and local agencies have developed crosswalk treatment guidelines for their jurisdictions, based primarily on FHWA guidelines and recommendations (Ashur and Alhassan, 2015).

Several studies have been conducted with a focus on midblock crosswalks. Zegeer et al. (2005) studied the safety effects of marked versus unmarked crosswalks at uncontrolled locations in terms of crash rates. Chu and Baltes (2001) examined pedestrian midblock crossing difficulties to develop a level of service methodology at midblock locations, and Dougald (2010) studied the effectiveness of zigzag approach markings at midblock crosswalks.

Marked crosswalks are considered by many to enhance pedestrian safety; however, they may not improve pedestrian crash rates at some locations. Zegeer et al. (2005) compared the safety effects of marked versus unmarked crosswalks at uncontrolled crossings, both at intersections and midblock locations. The study examined 2,000 crossing sites on two-lane and multilane roadways in eight states, with most sites located on roadways with speeds of 35 mph or less. Findings revealed no significant differences in pedestrian crash rates between marked and unmarked crosswalks on two-lane roadways or multilane roadways with average daily traffic (ADT) volumes of 12,000 vehicles/day or less (Zegeer et al., 2005).

Pedestrians instinctively prefer to take the shortest route to arrive at their destinations. Crossing a roadway at non-designated crossing points can be dangerous for both pedestrians and drivers (University of Connecticut [UCONN], 2014). Providing midblock crosswalks offer a safer, more visible, and more direct route for pedestrians to cross and reduces the potential for crossing at random points along a roadway segment (UCONN, 2014). However, drivers are less conditioned to expect pedestrian crosswalks at midblock locations. While marked crosswalks may increase pedestrian safety, they may potentially decrease driver safety. Therefore, the needs of all road users must be considered when implementing a marked midblock crosswalk, and all pedestrian crosswalks must comply with standards required by the Americans with Disabilities Act of 1990 (ADA).

Midblock crosswalks are location-based and designed for the distinctive safety needs of the location. Designated crossing locations may occur along a roadway section between two consecutive signalized or non-signalized intersections (Chu and Baltes, 2001), and they may be controlled or uncontrolled, depending on the treatments deemed necessary for the crossing location. The *Manual on Uniform Traffic Control Devices* (MUTCD) defines uncontrolled crosswalks as locations that are "not controlled by traffic control signals or STOP or YIELD signs" (FHWA, 2012). Designated midblock crossing locations generally have crosswalk pavement markings that legally establish the crosswalk (FHWA, 2012). However, the MUTCD states that "crosswalk lines should not be used indiscriminately" and recommends an engineering study be performed before installing crosswalk markings at either uncontrolled or sign-controlled locations (FHWA, 2012). Extensive guidelines pertaining to crosswalk markings, location restrictions, signing, and various signal treatments are provided in the MUTCD.

The strategy of channelizing pedestrians to marked midblock crosswalks to prevent dash-dart and other conflicts with motorists has been used in the U.S. for many years. However, determining the appropriate location and treatment option can be challenging for transportation designers and engineers. Based on the available literature, installing a midblock crosswalk can be categorized into two primary decision-making processes: (1) evaluate potential crosswalk locations, and (2) determine appropriate crosswalk treatments.

With respect to these two decision-making processes, examples and guidelines for evaluating potential midblock crosswalk locations were found only at the state and local levels. Procedures to determine appropriate crosswalk treatments at midblock locations were found at both the national and state levels. Deciding where to install midblock crosswalks requires considerable evaluation, and several factors can influence not only the site but also the selection of pedestrian treatments. The following section discusses various factors that should be considered when evaluating potential crosswalk locations.

2.2 Factors Influencing Midblock Crossings

Chu and Baltes (2001) examined pedestrian midblock crossing difficulties at several sites in Hillsborough and Pinellas Counties in Florida. Pedestrian crossing behavior was deduced as primarily governed by three components: the availability of gaps, crossing time, and perceived safety margin. The availability of gaps was determined by traffic volume and traffic patterns, which indicate the spatial and temporal distributions of traffic (Chu and Baltes, 2001). Crossing time was based on pedestrian walking speed, distance to be crossed, and whether a median exists to allow for two-stage crossings, with walking speed mostly dependent on age and/or physical ability. Age and gender, traffic speed at midblock locations, sight distance, lighting conditions, and the volume of large vehicles are factors that may affect the safety margin perceived by pedestrians (Chu and Baltes, 2001). The authors used the following explanatory variables to analyze the crossing difficulty and level of service of midblock crossing locations:

- pedestrian age (proportion of population 65 years or older),
- total traffic volume – near side and far side (vehicles/hour),
- turning movements – near side and far side (vehicles/hour),
- average speed (miles/hour),
- crossing width – near side and far side (feet),
- width of the restricted median (feet),
- width of the painted median (feet), and
- signal spacing (feet).

Additional factors that may affect a pedestrian's perception of safety at a midblock crosswalk include (Chu and Baltes, 2001):

- traffic speed,
- presence of large vehicles in traffic,
- pedestrian sight distance, and
- lighting conditions.

The study found that each characteristic variable was statistically significant in determining midblock crossing difficulty, except for non-restrictive medians (i.e., painted medians or Two-Way Left-Turn Lanes (TWLTLs)) and vehicle travel speeds (i.e., average speed). The developed model revealed that the far side traffic volume and share of pedestrians age 65+ increased the level of crossing difficulty. Factors considered by Zegeer et al. (2005) to determine the effects of marked and unmarked crosswalks on pedestrian safety that were found to significantly affect pedestrian crash rates include:

- pedestrian volume (demand),
- ADT,
- number of lanes,
- existence of median,
- median type (TWLTLs were considered as travel lanes, not medians), and
- region of the country

Zegeer et al. (2005) also found that the following factors had no significant effect on pedestrian crash rates:

- land-use (e.g., residential, central business district (CBD)),
- location (i.e., intersection versus midblock),
- speed limit,
- traffic operation (one-way or two-way),
- condition of the crosswalk (excellent, good, fair, or poor), and
- crosswalk pattern (e.g., parallel lines, ladder-type).

Other factors to consider for midblock crossing locations include (FDOT, 2020):

- pedestrian attractors: an end destination for pedestrian trips (e.g., residential, commercial, office, recreational, transit stops, or other land-use types),
- pedestrian generators: the starting point for a pedestrian trip (e.g., residential, commercial, office, recreational, transit stops, or other land-use types),
- the proximity of the proposed crosswalk to significant generators,
- pedestrian-vehicle crash history, and
- distance between crossing locations.

2.3 Midblock Crossing Treatments

In addition to crosswalk markings, various treatments can be implemented at designated crossing locations to improve safety for pedestrians and other road users. Depending on the crosswalk location site, one or more treatment options may be installed. The following sections briefly discuss different types of treatments that can be used at midblock crosswalks.

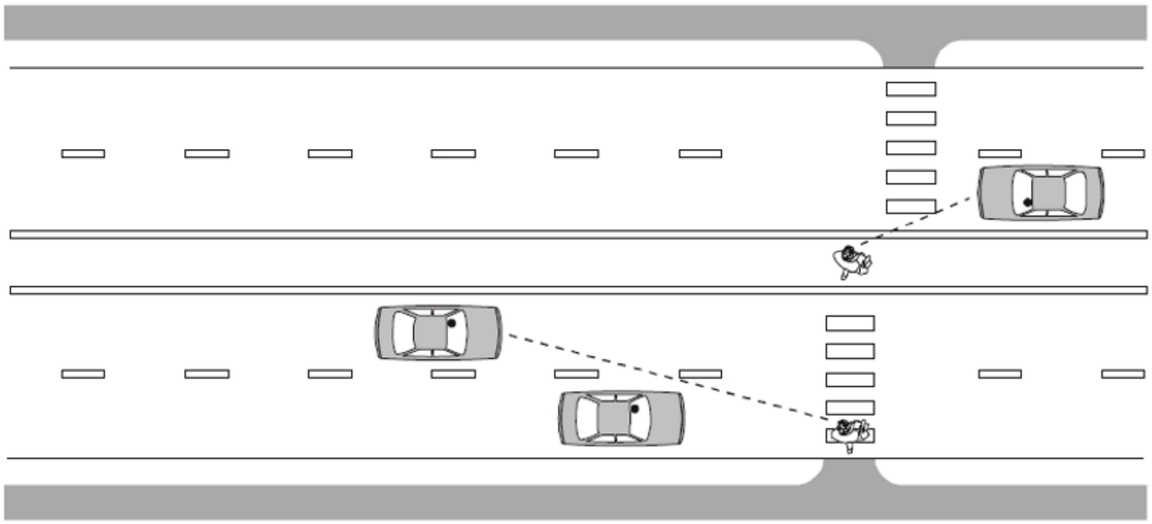
2.3.1 Medians and Refuge Islands

Medians separate the directional flow of traffic and provide additional safety to the traveling public and channelize pedestrians to a crossing point where motorists can more easily detect a crossing pedestrian (FHWA, 2006). Refuge islands are located in the median and provide pedestrians with a safe location to wait for an acceptable gap to continue crossing. A median refuge allows pedestrians to concentrate on one direction of traffic at a time before crossing, as shown in Figure 2-1 (a), rather than scanning both directions of traffic at crossings without a median refuge, as shown in Figure 2-1 (b) (FHWA, 2006). Moreover, finding acceptable gaps to traverse both directional lanes of traffic is more difficult and may take longer than crossing each direction of traffic separately. Advantages of medians with refuge islands include (FHWA, 2006):

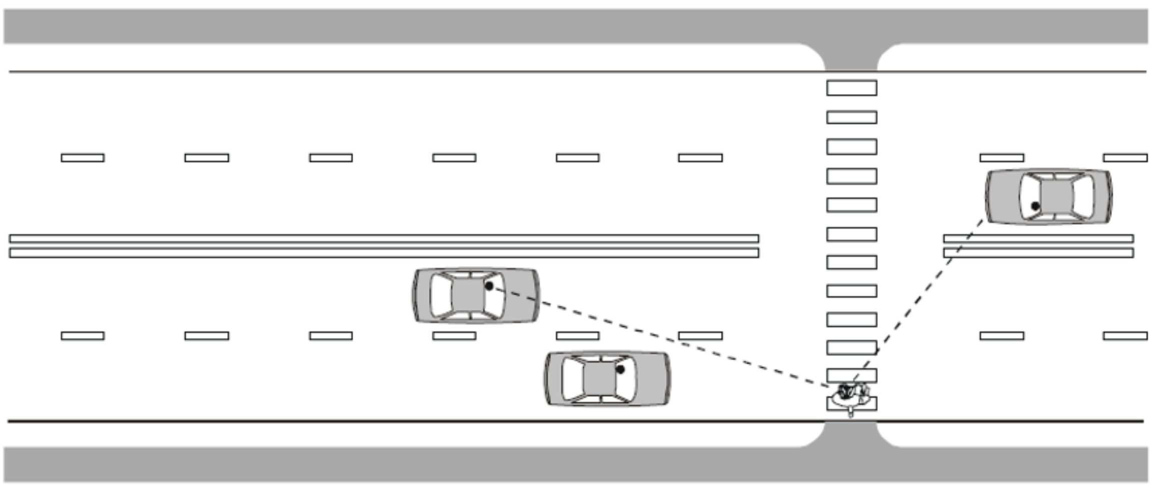
- potential conflicts are separated,
- greater potential for acceptable gaps to cross shorter distances,
- greater safety for pedestrians with reduced gap acceptance skills (e.g., younger and older pedestrians),
- increased safety at night to assess gaps, and
- reduced time to fully complete the crossing.

Staggered crosswalks, also called Z-crossings, are a variation of midblock crossings that utilize refuge islands. The FDOT *Traffic E01*

ngineering Manual (TEM) refers to this type of crosswalk as a “two-staged marked crosswalk” (FDOT, 2020). As shown in Figure 2-2, staggered crosswalks are split by a median and offset on either side of the median (FHWA, 2006). This type of crossing treatment requires a pedestrian to turn slightly towards traffic in the median before turning again to follow the crosswalk path to the other side. This shift in the walking path may challenge visually impaired pedestrians to discern, where the second stage crossing path is located, as shown in Figure 2-2 (a) (FHWA, 2006). To address this potential issue, detectable warnings and railings can be placed to realign visually impaired pedestrians perpendicularly to the roadway (Figure 2-2 (b)). Median landscaping or fencing may also be necessary to delineate the desired walking path for other pedestrians to prevent walking off-path or shortcutting.

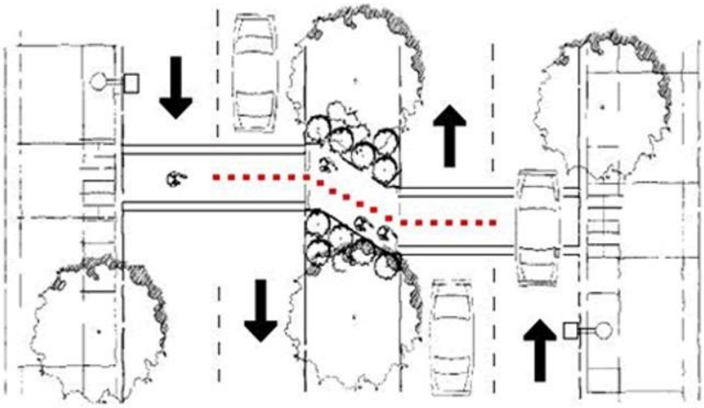


(a) Midblock crossing with median refuge



(b) Midblock crossing without median refuge

Figure 2-1: Midblock Crossings with and without Median Refuge
(Source: FHWA, 2006)



(a) A Staggered Midblock Crossing

(b) Street View of a Staggered Midblock Crosswalk

Figure 2-2: Staggered Midblock Crossings
(Source: (a) FHWA, 2006; (b) Fitzpatrick, 2016)

2.3.2 Curb Extensions

Curb extensions, also called bulb-outs, essentially reduce the roadway width by extending the sidewalk out into the parking lane, as shown in Figure 2-3. Bulb-outs offer pedestrians a safer space to wait while allowing motorists to see them more easily and can be implemented at intersections or midblock crossings. The perceived narrowing of the roadway by drivers results in slower speeds through areas with bulb-outs, thus promoting traffic calming (FHWA, 2013). Bulb-outs have the following advantages (FHWA, 2013):

- shorten the pedestrian crossing distance,
- improve the ability of pedestrians and motorists to see each other,
- reduce the time that pedestrians are in the street, and
- encourage pedestrians to cross at designated locations.

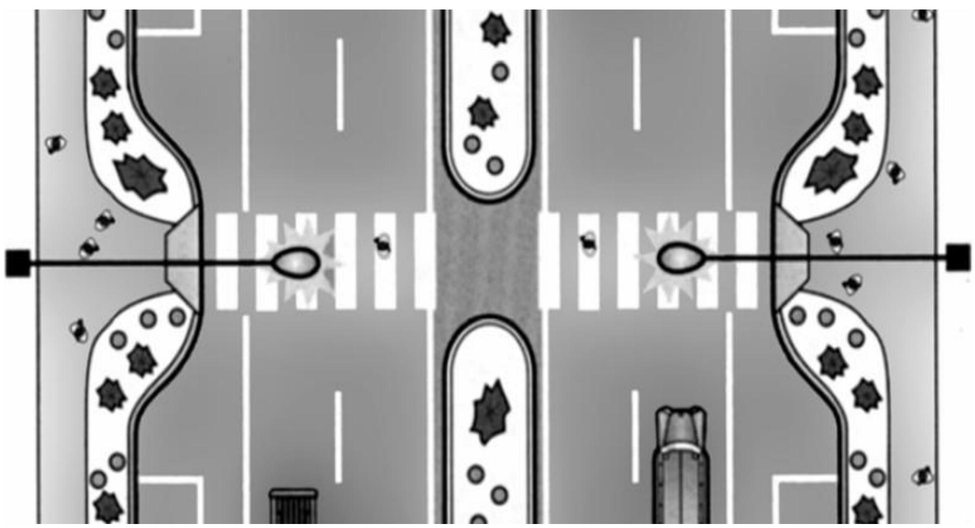


Figure 2-3: Curb Extensions (Bulb-outs)
(Source: FHWA, 2006)

2.3.3 Pavement Markings

Similar to crosswalks at signalized intersections, marked midblock crosswalks that delineate the crossing path generally follow the guidelines outlined in the MUTCD (FHWA, 2012). Motorists are conditioned to expect pedestrian crosswalks when approaching intersections, especially signalized intersections. Since midblock crossings may occur at any point along a roadway segment, motorists are less conditioned to the potential of crossing pedestrians.

To better inform drivers of an upstream pedestrian crosswalk, approach pavement markings placed at midblock crossings, such as zigzag striping, may increase awareness and slow travel speeds. Zigzag pavement markings may vary in design, as shown in Figure 2-4, and offer a low initial installation and maintenance cost option to reduce vehicle-pedestrian conflicts at midblock crossings. A pilot study conducted by Dougald (2010) analyzed the benefits of zigzag pavement markings at two study sites in Iowa. The study sites consisted of a rural two-lane facility, shown in Figure 2-4 (a), and a suburban four-lane divided facility, shown in Figure 2-4 (b).

A 500 ft longitudinal length of zigzag striping was used at both sites to provide a visual cue to motorists before the crosswalk was visible. Findings revealed a positive effect in lowering mean speeds approaching the crosswalk at the suburban study site (Figure 2-4 (b)), with a reduction of 85th percentile speeds by up to 1.3 miles/hour (FHWA, 2015a; Dougald, 2010). While used extensively in several other countries and in the State of Hawaii, zigzag striping is still not common in most U.S states. To date, no safety evaluations have been conducted on the use of zigzag pavement markings, and they are currently not included in the MUTCD as a safety countermeasure at midblock crossings (FHWA, 2015a; Dougald, 2010).

(a) Rural two-lane facility

(b) Suburban four-lane divided facility

Figure 2-4: Zigzag Pavement Markings
(Source: Dougald, 2010)

Yield lines, constructed as a line of solid white isosceles triangles, as shown in Figure 2-5, may be placed across the full width of a travel lane approaching a midblock crosswalk. Pedestrian crossing signs typically accompany yield line pavement markings, as directed by the MUTCD, and inform motorists to yield to crossing pedestrians at a specified point near the crosswalk (FHWA, 2012).

Figure 2-5: Yield Line Pavement Markings
(Source: FHWA, 2015b)

2.3.4 Enhanced Treatments

Enhanced treatments, such as signals and warning lights, may be used to increase motorist yield rates and require motorists to stop at a crosswalk approach. These treatments also increase driver visibility and encourage slower traffic speeds. Commonly used enhanced treatments include the following:

- Rectangular rapid flashing beacons (RRFBs)
- Pedestrian hybrid beacons (PHBs)
- Flashing signal beacons
- In-road flashing warning lights

Active or passive sensors may be installed to activate warning lights or signals to inform drivers of crossing pedestrians. If active sensors are installed, a pedestrian must push a button to activate the crossing signal (UCONN, 2014). Active sensors are more effective when the sensors are "hot," i.e., there is little to no delay in changing the signal (UCONN, 2014). Long delays in signal change may encourage pedestrians not to wait and simply cross during an acceptable gap. Drivers may also become frustrated if stopped by a pedestrian signal with no pedestrians (UCONN, 2014).

Alternatively, passive sensors do not require the pedestrian to push a button to activate the crosswalk signal or warning lights. Passive sensors use infrared detectors, placed either in the curbside area or on the crosswalk, to determine the presence of a pedestrian (UCONN, 2014). One advantage of passive activation is that all pedestrians are detected, even those who are unable or unwilling to push a signal activation button (UCONN, 2014). Another advantage of passive sensors is extending the signal for a pedestrian detected in the crosswalk to allow more time to cross (UCONN, 2014).

a) Rectangular Rapid Flashing Beacon (RRFB)

Rectangular Rapid Flashing Beacons (RRFBs) are traffic control devices with two rapidly flashing alternating yellow rectangular indications that serve as a warning beacon (FDOT, 2020). Figure 2-6 shows two examples of RRFBs: (a) a median installation and (b) a curbside installation. The median installation consists of a double-sided sign with RRFBs directed toward both directions of traffic, as shown in Figure 2-6 (a).

RRFBs are generally more effective at crosswalks spanning short distances and mounted above the pedestrian crossing sign (FHWA, 2015b). RRFBs also have higher-yielding rates than sign treatments alone and cost less than Pedestrian Hybrid Beacon (PHB) installations (FDOT, 2020). Similar to PHBs, RRFBs can also be mounted above a crosswalk on mast-arm poles.

Guidelines related to the use and design of RRFBs are not included in the current edition of the MUTCD (FHWA, 2012). However, the FHWA issued Interim Approval 21, *Rectangular Rapid Flashing Beacons at Crosswalks (IA-21)* on March 20, 2018, which specifies the intended use and design requirements for RRFB devices. All local agencies must currently obtain approval from FHWA to use RRFB pedestrian treatments (FDOT, 2020).

(a) Median Installation (b) Curbside

Figure 2-6: Rectangular Rapid Flashing Beacon (RRFB) Examples
(Source: MnDOT, 2014)

b) Pedestrian Hybrid Beacon (PHB)

Pedestrian Hybrid Beacons (PHBs), also known as High-intensity Activated crossWalK (HAWK) signals, are used to warn and control traffic at unsignalized marked crosswalks (FDOT, 2020). As shown in Figure 2-7 (a), PHBs are a special type of hybrid beacons, similar to traditional traffic signals that require drivers to stop when the red signal light is activated. Additional overhead signs are required, such as "STOP ON RED" and "CROSSWALK," and the PHBs require either active or passive pedestrian activation (UCONN, 2014). Implementation criteria for the use and design of PHBs are included in the MUTCD, and installation must be warranted per the MUTCD guidelines (FHWA, 2012).

c) Flashing Beacon

Pedestal mounted flashing signal beacons, shown in Figure 2-7 (b), can be used to increase driver awareness at midblock crosswalks. The beacon requires active or passive pedestrian activation and is often used at low-speed school crossings and midblock crossing locations (MnDOT, 2014). Design and operation guidelines are included in the MUTCD (FHWA, 2012).

(a) Pedestrian Hybrid Beacon (PHB) (b) Pedestal Beacon

Figure 2-7: Pedestrian Hybrid Beacon (PHB) and Pedestal Mounted Flashing Beacon
(Source: (a) WSDOT, 2013; (b) MnDOT, 2014)

d) In-Roadway Warning Light

As shown in Figure 2-8, in-roadway warning lights are amber lights embedded in the roadway surface on each side of a crosswalk and directed towards oncoming traffic (UCONN, 2014). In-roadway lights intend to warn motorists of an approaching situation that may require them to slow down or yield or come to a stop (FHWA, 2012). Active or passive sensors may also be used to activate the lights. Implementation criteria for the use and design of in-roadway warning lights are included in the MUTCD (FHWA, 2012).

Figure 2-8: In-Roadway Warning Lights
(Source: TAPCO, Inc., 2020)

2.3.5 Special Emphasis Treatments

Special emphasis crosswalk pavement markings consist of white 24-inch stripes installed perpendicular to the standard longitudinal lines delineating the walking path. The "ladder" pattern shown in Figure 2-9 is one style of a special emphasis crosswalk. This type of crosswalk treatment is preferred for uncontrolled midblock crossings (Koos, 2012). Brick pavers of various colors may also be used for special emphasis when aesthetics is a factor (e.g., shopping malls).

Figure 2-9: Midblock Special Emphasis Marking
(Source: Koos, 2012)

Raised crossings, also known as speed tables, shown in Figure 2-10, not only serve as traffic calming measures but also can include a marked crosswalk, providing additional emphasis to the presence of pedestrians.

Figure 2-10: Midblock Speed Table with Crosswalk
(Source: FHWA, 2020)

2.3.6 Overhead Lighting

Adequate overhead lighting is essential at midblock crosswalks to help drivers see pedestrians crossing and waiting to cross and light the crosswalk for pedestrians crossing at night. Overhead lighting can also be activated using active or passive sensors to be used only when needed (UCONN, 2014). Available street lighting should be assessed when evaluating potential locations for installing overhead lighting (FHWA, 2012). Additionally, careful consideration of adequate lighting is needed for a grade-separated crossing to reduce potential crime (FHWA, 2006).

2.3.7 Grade-Separated Crossings

Grade-separated crossings can be constructed as an underpass (Figure 2-11 (a)) or an overpass (Figure 2-11 (b)). Generally, these pedestrian crossings are only considered when warranted, and the crossing meets a barrier, such as a multitrack railroad, a stream, or a freeway (FHWA, 2006). Constructing these structures can be expensive and difficult; therefore, advanced planning, funding resources, and a compelling purpose and need are required (FHWA, 2006).

(a) Underpass (b) Overpass

Figure 2-11: Grade-Separated Crossing Examples
(Source: (a) FHWA, 2006; (b) MnDOT, 2014)

2.4 General Guidelines

Reports and guidelines published at the national level were reviewed for information on midblock pedestrian treatments. The following sections discuss general guidelines used by transportation agencies to evaluate potential midblock crosswalk locations and pedestrian treatments.

2.4.1 Crosswalk Locations

The majority of literature and guidelines reviewed focus on the design and placement criteria of selected treatment options at the national level. The decision-making process to evaluate potential midblock crossing locations is not addressed. However, the MUTCD states that "crosswalk lines should not be used indiscriminately" and recommends an engineering study be performed before installing marked crosswalks at uncontrolled locations (FHWA, 2012). The following factors should be considered in the engineering study (FHWA, 2012):

- number of lanes,
- presence of a median,
- distance from adjacent signalized intersections,
- pedestrian volumes and delays,
- traffic volume,
- posted or statutory speed limit or 85th percentile speed,
- roadway geometry,
- possible consolidation of multiple crossing points,
- availability of street lighting, and
- other appropriate factors.

2.4.2 Specific Pedestrian Treatments

The Transit Cooperative Research Program (TCRP) and the National Cooperative Highway Research Program (NCHRP) conducted a joint study on improving pedestrian safety at unsignalized intersections. This 2006 report (TRCP 112/ NCHRP 562) presented recommendations for pedestrian crossings, including midblock crossings, on high-volume, high-speed roadways, with an emphasis on roadways used by public transportation agencies (National Academies of Sciences, Engineering, and Medicine [NASEM], 2006).

Guidelines for selecting treatments at unsignalized intersections and midblock crossings were developed for two roadway scenarios: peak hour traffic volumes on roadways with speeds of 35 mph (55km/h) or less, and peak hour traffic volumes for roadways with speeds greater than 35 mph (55 km/h). The evaluation process uses a quantitative procedure consisting of key input variables such as pedestrian volume, crossing width, and traffic volume, and a five-step evaluation process to determine one of the following four possible crossing treatments (NASEM, 2006):

- marked crosswalks,
- enhanced, high-visibility, or "active when present" traffic control devices,
- red signal or beacon device, or
- conventional traffic control signal.

The TCRP/NCHRP report also recommended using a 3.5 ft/s (1.1 m/s) as a walking speed for the general population and a 3.0 ft/s (0.9 m/s) walking speed for the older or less able population when calculating pedestrian clearance intervals (NASEM, 2006). The procedural flowchart, roadway scenario worksheets, and description of input variables are provided in Appendix A.

A recent FHWA (2018) report helps select appropriate countermeasures at uncontrolled pedestrian crossings to improve pedestrian safety. The report offers a quick reference guide of various pedestrian crosswalk treatments based on roadway configuration, posted speed, and average annual daily traffic (AADT) volumes. In Appendix B, Figure B-1 shows a sample inventory form used in the decision-making process. Figure B-2 shows a countermeasure decision matrix, and Figure B-3 describes various safety issues addressed by each countermeasure (FHWA, 2018). A useful resource to explore potential pedestrian crosswalk treatments is the Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE), an online resource tool provided by FHWA, consisting of treatment information and interactive selection matrices (FHWA, n.d.). The matrices suggest applicable countermeasures at crossing locations related to crash type and performance measures.

a) Medians and Refuge Islands

FHWA (2006) suggests that medians should be at least 8 ft wide to allow pedestrians a comfortable space in the center to wait, 4 ft from moving traffic. However, a minimum median width of 4 ft is acceptable if wider medians cannot be achieved from the existing roadway geometry (FHWA, 2006). Refuge islands may be the width of the crosswalk or wider, if needed, for adequate visibility by motorists.

Medians and refuge islands are rarely necessary for low-volume and low-speed (25-30 mph) roadways, such as local roads (FHWA, 2006). Midblock crossings with medians and refuge islands may be useful on two-lane collector roads with 30-40 mph speeds, depending on adjacent land-use. However, the median refuge is often essential for multilane minor and major arterial roadways, and the location of midblock crossings should be considered carefully for corridors with speeds exceeding 40 mph (FHWA, 2006).

b) Curb Extensions

While curb extensions (bulb-outs) improve pedestrian safety significantly, they typically should only be considered for roadways with on-street parking (parking lane) and areas where cyclists and transit vehicles travel outside the curb edge for the length of the roadway (FHWA, 2013). Bulb-outs must not extend into travel lanes, bicycle lanes, or shoulders, and enhancements to the bulb-out, such as furniture and landscaping, should not obstruct a driver's view of pedestrians. Additionally, facilities where bulb-outs are constructed should have low-speeds (FHWA, 2013).

c) Signalization

For four-lane arterial highways, signalization may be required under the following conditions (FHWA, 2006):

- on higher volume roadways,
- where gaps are infrequent,
- in school zones,
- where elderly or disabled pedestrians' cross,
- where speeds are high, or
- when a combination of the above factors is present.

On multilane arterial highways with six or more lanes, where vehicle speeds are high, signalization of a midblock crossing location may be the only practical method to reduce the potential risk to crossing pedestrians (FHWA, 2006).

d) Warning Devices

Midblock crossings on multilane arterial highways with six or more lanes require more devices to alert motorists. For highways with speeds 40 mph or greater, FHWA (2006) suggests the following devices should be considered:

- 36 x 24 inch advanced crossing symbol signs
- 36 x 24 inch pedestrian crossing signs
- pavement word symbols
- zebra- or ladder-style enhanced crosswalk markings
- large overhead signs
- flashing beacons
- curb extensions (bulb-outs)
- flashing overhead signs

e) Grade-separated Crossings

Since pedestrian overpasses or underpasses can be expensive and difficult to implement, certain criteria must be met to warrant these structures. For a grade-separated crossing to be warranted, FHWA suggests the following circumstances should be present (FHWA, 2006):

- high pedestrian volumes at the location and high demand to cross,
- a large number of young children who must regularly cross (particularly at locations near schools),
- high volumes of motor vehicles traveling at high speeds along the roadway,
- no convenient alternative crossing places nearby,
- funding and a specific need for the overpass/underpass, or
- an extreme hazard for pedestrians.

2.5 State and Local Guidelines

Ashur and Alhassan (2015) recently conducted a comprehensive review of guidelines used by state DOTs in the selection of treatments to improve safety at controlled and uncontrolled pedestrian crossings. Based on state reports, guidelines, design manuals, policies, and information gathered from a statewide questionnaire, findings revealed that all state DOTs refer to the MUTCD, Part 3, for standards and guidelines on pedestrian crossing treatments; although, some agencies have developed independent manuals for their jurisdictions (Ashur and Alhassan, 2015). Additionally, most state DOTs have developed selection guidelines based on studies and reports by FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE) (Ashur and Alhassan, 2015).

The following sections discuss available guidelines on the evaluation processes for determining midblock crosswalk locations and appropriate treatments at the state and local levels. Evaluation criteria for implementing midblock crosswalks are numerous, both at the state and national levels; therefore, only summaries are presented in this report. Designers and engineers should refer to the guideline resources for different jurisdictions mentioned in this report to gain the full scope of crosswalk and treatment requirements.

2.5.1 Florida

FDOT refers to the following guidelines for the design and implementation of pedestrian crosswalks with uncontrolled approaches:

- MUTCD (FHWA, 2012),
- FDOT TEM (FDOT, 2020),
- FDOT Manual on Uniform Traffic Studies (MUTS) (FDOT, 2016b),
- FDOT Plans Preparation Manual (PPM), Volume 1 (FDOT, 2017),
- FDOT Florida Greenbook (FDOT, 2016c), and
- FDOT Standard Plans for Road and Bridge Construction Manual.

To evaluate potential midblock crosswalk locations, FDOT follows the procedure outlined in TEM, Section 5.2, to determine if a marked crosswalk is warranted. The *FDOT Manual on Uniform Traffic Studies* (MUTS) provides additional guidelines to assist with the engineering study. Steps involved in the determination process include:

Step 1: An engineering study of the proposed crosswalk location is conducted by the District Traffic Operations Engineer. Criteria listed in the TEM, Section 5.2.6, must be met and documented for a marked crosswalk to be approved (FDOT, 2020). A summary of the information required in the engineering study includes:

- field data to demonstrate need based on pedestrian volumes,
- availability of alternative crossing locations that meet TEM criteria,
- pedestrian Origin-Destination (O-D) assessments,
- safety consideration (e.g., stopping sight distance (SSD), lighting, and proximity to intersection conflict areas),
- proposed location plan, including signing, marking, and signal treatments (if applicable),
- number and nature of pedestrian-vehicle conflicts, based on field observations,
- three-year minimum pedestrian-vehicle crash history, and
- transit stop activity and location within the vicinity of the proposed crosswalk.

Step 2: The District Traffic Operations Engineer must coordinate with local agencies to determine maintenance responsibilities for any proposed traffic control devices.

Step 3: Decide to approve or not consider the installation, based on evaluation results and engineering judgment.

Section 5.2 of the TEM describes the criteria that must be met when considering a new marked crosswalk at midblock and uncontrolled approach locations. Briefly summarized, some of these criteria include (FDOT, 2020):

- the location must meet minimum levels of pedestrian demand,
- multi-use trail crossings must be considered,
- minimum location characteristics must be met, and
- safety considerations must be met.

Midblock crosswalk location criteria are also addressed in the PPM, Volume 1 (FDOT, 2017). The PPM also provides midblock crosswalk lighting requirements and appropriate use of midblock crossings on Strategic Intermodal System (SIS) (limited and controlled access) corridors and State Highway System (SHS) (urban and rural) corridors (FDOT, 2017).

Once a new marked crosswalk is approved, appropriate treatments are considered. FDOT uses guidelines from the MUTCD for pedestrian signal warrants, traffic control signals, PHBs, and flashing yellow warning beacons. Illustrated treatment charts reflecting the MUTCD guidelines for low-speed roadways (speeds of 35 mph or less) and high-speed roadways (speeds greater than 35 mph), and a matrix of selection criteria, are shown in Figures C-1, C-2, and C-3 of Appendix

C, respectively (FDOT, 2020). The use of RRFBs is also considered; however, approval for use must be granted by FHWA.

Crosswalk pavement markings and curb ramp details are provided in the *FDOT Standard Plans for Road and Bridge Construction* manual, and the MUTCD also serves as guidance for signing and markings. Also known as the "Florida Greenbook," the *FDOT Manual of Uniform Minimum Standards for Design, Construction, and Maintenance for Streets and Highways* provides additional guidance on marked crosswalks, lighting, and refuge islands (FDOT, 2016c). The *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities* is used for guidance when considering grade-separated crossings.

Another resource available to FDOT designers and engineers to explore potential pedestrian crosswalk treatments is FHWA's PEDSAFE online resource tool (FHWA, n.d.). A link to the PEDSAFE online resource tool is provided on FDOT's Pedestrian and Bicycle Safety webpage (FDOT, 2019).

2.5.2 Other States and Municipalities

Available literature and guidelines from agencies outside of Florida were reviewed for information pertaining to midblock crossing location evaluations and treatment practices. The following sections present the findings.

a) City and County of Denver, Colorado

Since evaluating a potential midblock crosswalk location can be difficult, the City and County of Denver (CCD) has developed a flowchart to assist in the determination process. As shown in Figure D-1, in Appendix D, each step identifies the criteria that must be met before advancing to subsequent steps to determine if a location is suitable for installing a marked crosswalk. Criteria are based on guidelines contained in the MUTCD, the 2010 Highway Capacity Manual (HCM), and AASHTO's *A Policy on Geometric Design for Highways and Streets* (CCD, 2016).

Similar to the treatment matrix provided by Zegeer et al. (2005), shown in Table B-1, Appendix B, CCD categorizes recommended treatment options into "Levels": Level A indicates markings and signing should be used; Level B indicates RRFBs should be used; Level C indicates the need for PHBs or pedestrian signals (see Table D-1, Appendix D). CCD refers to the MUTCD for guidance with PHB applications for low-speed (35 mph or less) and high-speed (greater than 35 mph) roadways, as well as signing, marking and warrants for the installation of pedestrian signals (CCD, 2016).

b) Minnesota

Minnesota DOT has developed an evaluation procedure for pedestrian crossings at uncontrolled locations. The goal is to provide safe crosswalks at appropriate locations that minimize pedestrian delay (MnDOT, 2014). The eleven-step procedure was based on safety guidance provided by FHWA and pedestrian delay procedures outlined in the HCM. A flowchart of the evaluation methodology is provided in Appendix E. The evaluation process includes the following steps (MnDOT, 2014):

1. Conduct a field data review to determine roadway and crossing geometrics, such as crossing distance, median width, crosswalk width, and curb ramps.
2. Conduct a safety review to evaluate crash data at the crossing site.
3. Calculate stopping sight distance (SSD) to determine if adequate SSD exists. A location may not be suitable for a pedestrian crossing if adequate SSD cannot be provided.
4. Determine the average pedestrian delay and Level of Service (LOS) of the crosswalk using the procedure outlined in the HCM. Pedestrian routing to another location or high-level treatments, such as PHBs, traffic signals, overpass, or underpass treatments, should be considered if an acceptable service level cannot be achieved.
5. Determine pedestrian sight distance (PedSD).
6. Review pedestrian origin-destination (O-D) movements. Also, determine potential alternative routes that may serve the same routes while providing less delay.
7. Determine the functional classification and access control of the roadway. Marked uncontrolled crosswalks should only be considered on signalized roadway corridors with less than 12,000 vehicles/day usage, where the spacing between signals is inadequate to serve the pedestrian traffic.
8. Determine traffic and pedestrian volumes at the crossing site.
9. Review FHWA safety guidelines for uncontrolled crossings reported by Zegeer et al. (2005) (see Appendix B).
10. Determine if a school crossing is needed.
11. Consider appropriate treatment options.

Careful consideration should be given when considering treatment options for uncontrolled crosswalks, including midblock crossings. In some cases, treatments may increase the crash potential at the location or may not noticeably affect motorist yielding and service levels (MnDOT, 2014). Therefore, MnDOT requires crossing treatments to be justified through an engineering study. Tables E-1 and E-2 in Appendix E, list signing and marking treatments and uncontrolled crossing treatment guidelines used by MnDOT.

c) North Carolina

North Carolina Department of Transportation (NCDOT) has developed a four-step assessment flowchart outlining the process applied to midblock locations (NCDOT, 2015). The process consists of the following steps:

Step 1: Existing characteristics / signalized crossing assessment.
Step 2: Unsignalized or midblock crossing assessment (see Figure F-1, Appendix F).
Step 3: Additional/alternative treatments assessment.
Step 4: PHB assessment.

d) Virginia

Similar to other state agencies, the Virginia Department of Transportation (VDOT) follows FHWA recommendations in requiring an engineering study before crosswalk markings are installed at midblock locations and uncontrolled intersection approaches (VDOT, 2016). Figure G-1 in Appendix G displays a flowchart of the decision-making process to determine whether a potential crossing location meets the criteria for a marked crosswalk. If criteria are met for a marked crosswalk, the flowchart directs the engineer to the next step in the process, to determine if the crosswalk location meets the requirements for an uncontrolled or a stop/yield controlled crosswalk. Figure G-2 illustrates the evaluation process for a marked crosswalk with uncontrolled approaches, and Figure G-3 illustrates the evaluation process for a stop or yield controlled crosswalk.

Following the location evaluation process, appropriate treatments are selected using the decision matrix shown in Table G-1, Appendix G. A flowchart illustrating the use of the treatment decision matrix is shown in Figure G-4. VDOT also provides worksheets to assist in the evaluation processes, shown in Figures G-5 through G-7 (VDOT, 2016).

2.6 Summary

This chapter presented findings from a literature review of the existing national, state, and local warrants and guidelines on installing pedestrian safety treatments at midblock locations. Based on the available literature, installing marked midblock crosswalks is essentially a two-part process. First, candidate locations must be evaluated to determine if a midblock crosswalk is warranted. The evaluation process involves several steps, with pedestrian volume, traffic volume, posted speed, crash history, and the distance from other established crossing points used as the primary factors. However, other factors must also be considered, such as pedestrian generators and attractors, pedestrian age and ability, roadway geometrics, etc.

Following the identification of a suitable location, the type and scope of pedestrian treatments must then be determined. There are several treatment options for both controlled and uncontrolled crosswalks, and most state and local transportation agencies refer to national guidelines.

In summary, midblock crosswalks could improve pedestrian safety by directing pedestrians to a designated crossing point, thus reducing random crossings that increase the crash risks to both pedestrians and motorists. The challenge for many agencies is where to place marked midblock crosswalks to effectively improve pedestrian safety. The existing national, state, and local warrants and guidelines provide guidance pertaining to installing pedestrian safety treatments at midblock locations.

CHAPTER 3
IDENTIFY INFLUENTIAL VARIABLES

This chapter identifies socioeconomic, land-use, demographic, roadway geometric characteristics, and pedestrian infrastructure variables that could potentially affect pedestrian crashes. The analysis was based on pedestrian crashes from 2012–2016 in the Florida Department of Transportation (FDOT) District Four. The pedestrian crash data were extracted from the FDOT's Unified Basemap Repository (UBR). Information on roadway geometric characteristics and pedestrian facilities were extracted from the FDOT's Roadway Characteristics Inventory (RCI) and the FDOT's Geographic Information System (GIS) Shapefiles. The demographic and socioeconomic variables were obtained from the United States Census Bureau. The land-use variables were extracted from the Florida Geographic Data Library (FGDL), and the information on transit stops was collected from the Florida Transit Data Exchange (FTDE). This chapter is organized as follows:

- Section 3.1 discusses the pedestrian crash data,
- Section 3.2 provides other potential variables that could influence pedestrian safety, and
- Section 3.3 presents the summary.

3.1 Pedestrian Crash Data

Pedestrian crashes on both on-system and off-system roadways in FDOT District Four during the years 2012 through 2016 were included in the descriptive statistics analysis. Table 3-1 summarizes these crashes by year and crash severity. The frequency of pedestrian crashes since 2014 was higher than the pedestrian crash frequency in 2012 and 2013. Although the frequency of crashes seemed to be on an increasing trend, the proportion of fatal crashes remained unchanged and the proportion of injury crashes decreased. Overall, 90% of all pedestrian crashes resulted in either an injury or a fatality; fatal crashes constituted 8% of all pedestrian crashes. Figure 3-1 shows the spatial distribution of pedestrian crashes in District Four. Figure 3-2 shows the density map of pedestrian crashes in District Four. Since this project focuses on non-limited access facilities, a total of 74 pedestrian crashes that occurred on freeways during the analysis period were excluded from the analysis. Descriptive statistics of pedestrian crashes are provided in the following sections.

Table 3-1: Distribution of Pedestrian Crashes by Year and Severity

Year	Fatal		Injury		PDO		Total
	Frequency	%	Frequency	%	Frequency	%	
2012	94	8	974	83	111	9	1,179
2013	90	8	999	83	109	9	1,198
2014	98	8	1,068	83	124	10	1,290
2015	101	8	988	81	134	11	1,223
2016	99	8	980	81	129	11	1,208
Total							**6,098**

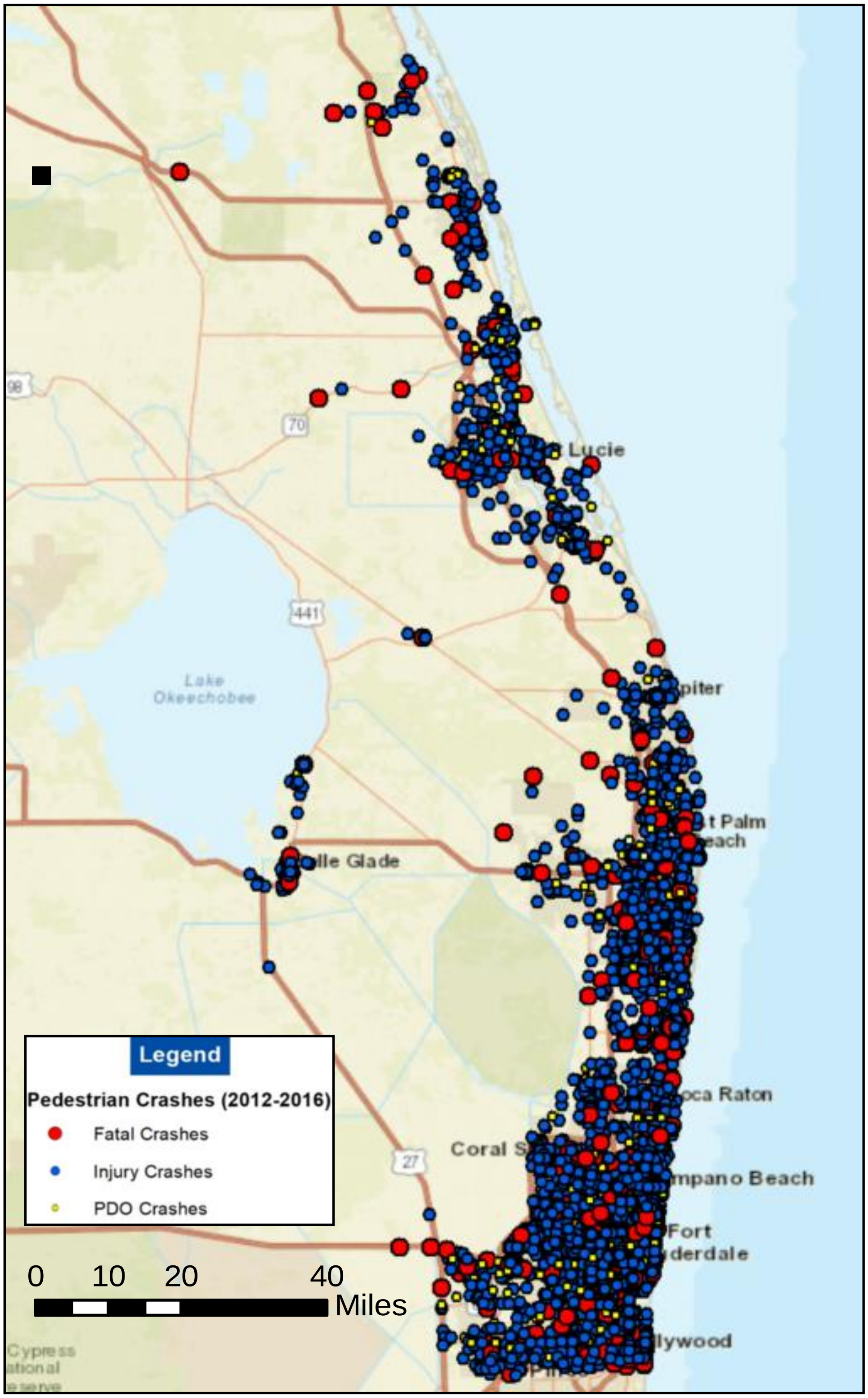


Figure 3-1: Pedestrian Crashes on Non-limited Access Facilities in FDOT District Four

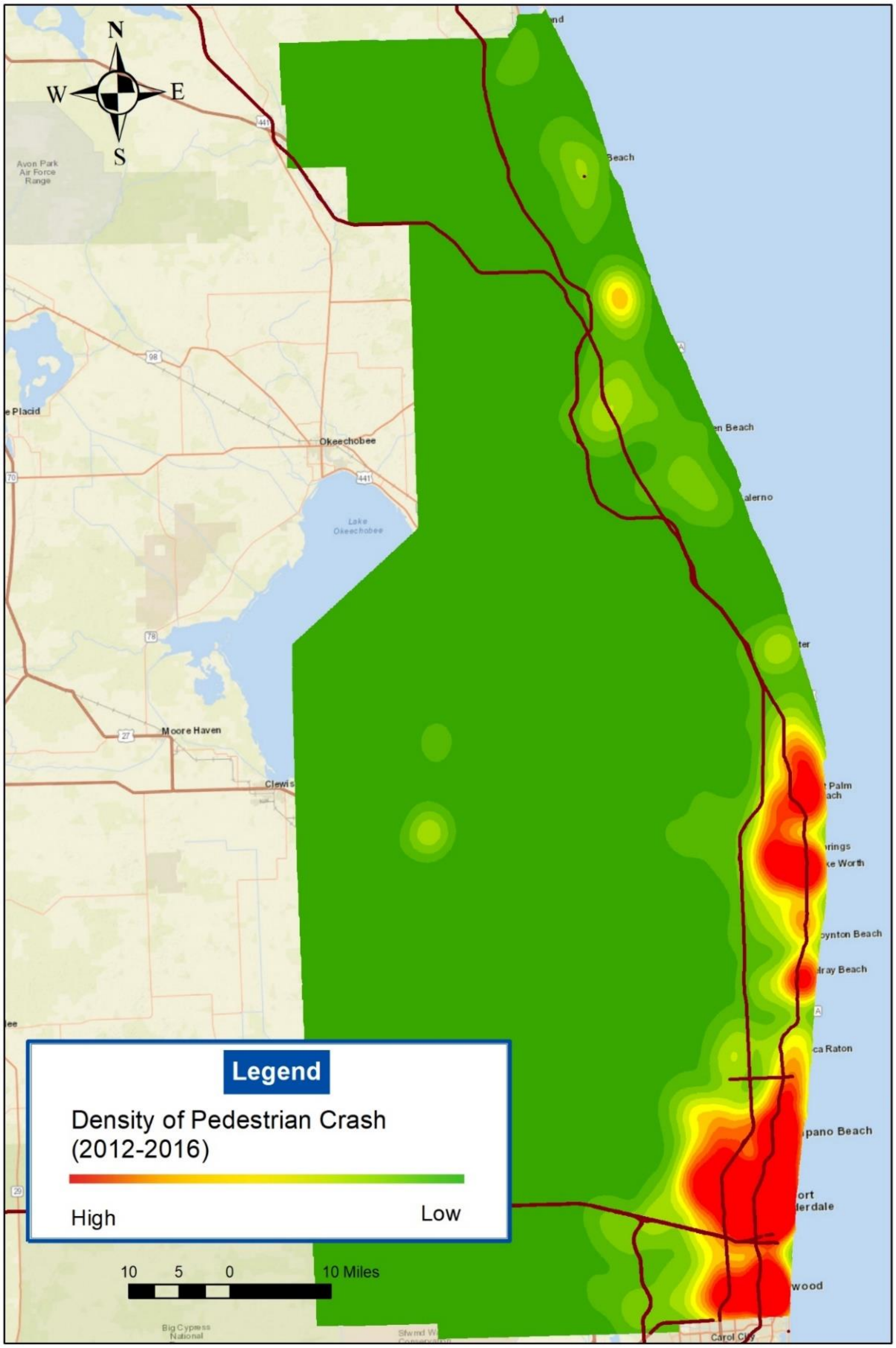


Figure 3-2: Density Map of Pedestrian Crashes in District Four

Crash Time

Table 3-2 provides the distribution of pedestrian crashes by crash severity and crash occurrence time. The crash occurrence time was divided into three groups: morning peak hours (6 am – 10 am), evening peak hours (3 pm – 7 pm), and off-peak hours (10 am – 3 pm and 7 pm – 6 am). Off-peak hours resulted in more severe crashes compared to peak hours. Within the morning and evening peak hours, evening peak hours experienced a higher frequency of pedestrian crashes than morning peak hours.

Table 3-2: Pedestrian Crashes by Time of Day and Crash Severity

Time	Fatal		Injury		PDO		Total
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	
Morning Peak	40	4%	854	85%	111	11%	1,005
Evening Peak	68	4%	1,305	85%	155	10%	1,528
Daytime Off-peak	45	4%	1,042	86%	122	10%	1,209
Nighttime Off-peak	329	14%	1,808	77%	219	9%	2,356
Total							**6,098**

Crash Month

Table 3-3 provides the distribution of pedestrian crashes by crash severity and crash month. Pedestrian crash frequency from October to December was higher than the rest of the year. December was associated with the most pedestrian crashes, while October was associated with the highest percentage of fatal crashes compared to the rest of the year.

Table 3-3: Pedestrian Crashes by Month and Crash Severity

Month	Fatal		Injury		PDO		Total
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	
January	42	8	438	82	56	10	536
February	42	8	417	82	50	10	509
March	42	8	447	82	53	10	542
April	30	6	423	83	55	11	508
May	28	6	369	83	46	10	443
June	34	8	337	79	54	13	425
July	29	8	289	79	48	13	366
August	31	7	368	83	44	10	443
September	44	9	404	82	42	9	490
October	55	10	477	83	46	8	578
November	50	9	475	82	54	9	579
December	55	8	565	83	59	9	679
Total							**6,098**

Day of the Week

Table 3-4 provides the distribution of pedestrian crashes by crash severity and day of the week. Pedestrian crash frequency was highest on Friday compared to the other days of the week. Saturday and Sunday had the highest percentage of fatal pedestrian crashes.

Table 3-4: Pedestrian Crashes by Day of Week and Crash Severity

Day	Fatal		Injury		PDO		Total
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	
Sunday	65	10	496	78	71	11	632
Monday	58	7	714	84	73	9	845
Tuesday	49	6	729	83	96	11	874
Wednesday	70	8	775	84	83	9	928
Thursday	55	6	724	84	78	9	857
Friday	87	9	825	81	107	11	1,019
Saturday	98	10	746	79	99	10	943
Total							**6,098**

Lighting Condition

Table 3-5 provides the distribution of pedestrian crashes by crash severity and lighting condition. Pedestrian crashes were found to be more severe during dark conditions (both lighted and not lighted) than during daytime. Fatal crashes comprised 15% of the crashes that occurred during dark-not lighted conditions and 14% of the crashes that occurred during dark-lighted conditions, while a relatively low 3% of the crashes that occurred during daytime were fatal.

Table 3-5: Pedestrian Crashes by Lighting Condition and Crash Severity

Lighting Condition	Fatal		Injury		PDO		Total
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	
Dark-Lighted	275	14	1,537	78	152	8	1,964
Dark-Not Lighted	79	15	398	76	49	9	526
Dark-Unknown Lighting	1	4	18	75	5	21	24
Dawn	11	9	110	86	7	5	128
Daylight	102	3	2,777	86	366	11	3,245
Dusk	11	6	145	81	22	12	178
Other	3	9	24	73	6	18	33
Total							**6,098**

A little over 40% of the crashes were found to occur during dark conditions. Figure 3-3 provides the hourly crash frequencies of total and fatal pedestrian crashes. As expected, morning and evening peak hours experienced a relatively higher number of total and fatal crashes. Especially during nighttime, the time periods from 8 pm to 1 am experienced relatively more pedestrian crashes compared to the rest of the night.

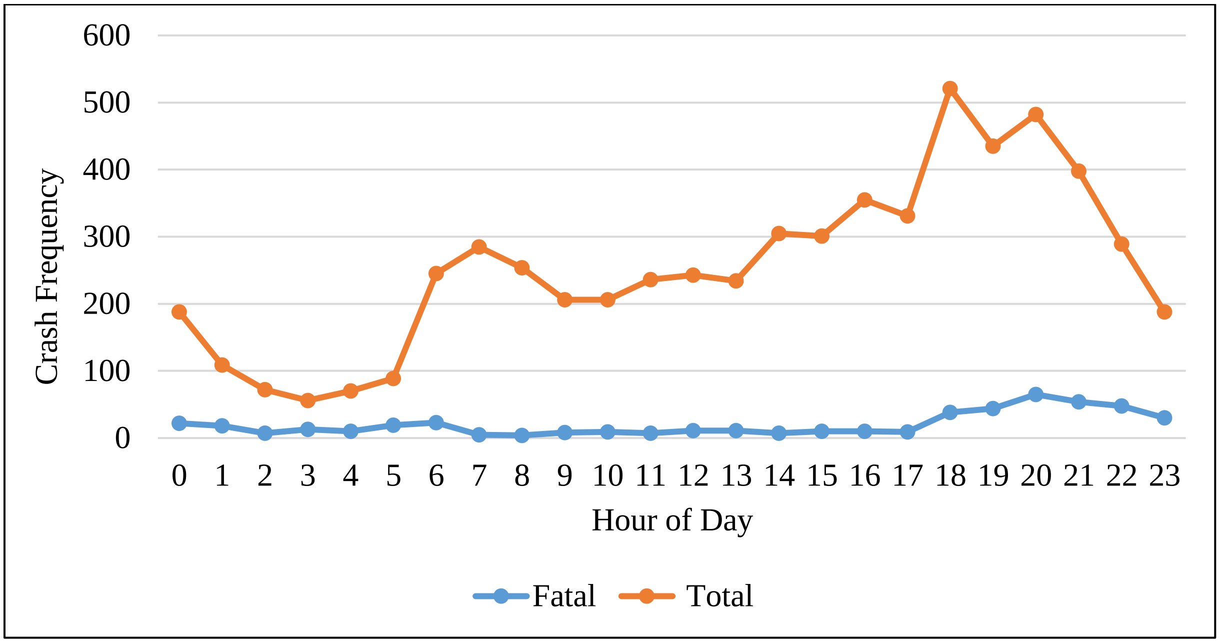


Figure 3-3: Total and Fatal Pedestrian Crashes by Hour of Day

Alcohol or Drug Involvement

Table 3-6 provides the distribution of pedestrian crashes by crash severity and alcohol and/or drug involvement. About 11.3% of pedestrian crashes involved alcohol and/or drugs. Pedestrian crashes involving alcohol and/or drugs had a higher percentage of fatal crashes (22%) compared to those that did not involve alcohol and/or drugs.

Table 3-6: Pedestrian Crashes by Alcohol or Drug Involvement and Crash Severity

Alcohol or Drug Involvement	Fatal		Injury		PDO		Total
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	
Alcohol or Drugs	149	22	496	72	44	6	689
None	333	6	4,513	83	563	10	5,409
Total							**6,098**

Crash Location

Table 3-7 provides the distribution of pedestrian crashes by crash severity and crash location (i.e., intersection or midblock). Almost 64% of the pedestrian crashes occurred at midblock locations. Pedestrian crashes at midblock locations were slightly more severe compared to those that occurred at intersections. Approximately 9% of the pedestrian crashes at midblock locations were fatal, while a relatively low 6% of the crashes at intersections were fatal.

Table 3-7: Pedestrian Crashes by Crash Location and Crash Severity

Location	Fatal		Injury		PDO		Total
	Frequency	%	Frequency	%	Frequency	%	
Intersection	125	6	1,860	85	212	10	2,197
Midblock	357	9	3,149	81	395	10	3,901
Total							6,098

3.2 Influential Variables

Existing literature has shown that several roadway geometric, demographic, socioeconomic, and land-use factors influence pedestrian safety. Table 3-8 presents the predominant factors associated with pedestrian crashes, such as densely populated regions, low-income neighborhoods, low educational level areas, senior population, alcohol intoxication, a high number of bus stops, and vehicle ownership. The following subsections discuss the various roadway characteristics, land-use, census, pedestrian infrastructure, and pedestrian exposure data that could potentially influence pedestrian crashes.

3.2.1 Roadway Characteristics Data

Data on roadway characteristics, including annual average daily traffic (AADT), number of lanes, median type, median width, surface width, presence of signalized intersections, etc., were extracted from the 2016 Roadway Characteristics Inventory (RCI). FDOT also has been maintaining a NavStreets Basemap Shapefile from HERE (formerly NAVTEQ). NavStreets provides the most detailed street network with the highest level of coverage within Florida. The 2015 NavStreets Shapefile for FDOT District Four includes 270,343 street segments. This research conducted a GIS-based spatial clustering analysis based on the 2015 NavStreets Shapefile to identify the top hotspots for pedestrian crashes. Chapter 4 of this report provides more details about this analysis. Figure 3-4 shows a sample of the detailed street network in the NavStreets Basemap in the Fort Lauderdale Beach area.

Figure 3-4: Sample NavStreets Basemap in Fort Lauderdale Beach Area

Table 3-8: Demographic, Socioeconomic, and Land Use Factors Affecting Pedestrian Crashes

Demographic, Socioeconomic, and Land Use Factors	Study Period	Location	Method	Reference
Low-income, low education level, densely populated areas; high presence of bus stops; roads with higher speed limits; drinking establishments.	2011-2014	Florida	Logistic Regression	Lin et al. (2017)
Percentage distribution of population by race; age; mean household income; percentage in the labor force; vehicle ownership; poverty level	2003-2009	Tennessee	Negative Binomial Regression	Chimba et al. (2014)
Race; alcohol intoxication; areas with high number of alcohol sale establishments; gender; proportion of senior population	1997-2006	Nationwide	Descriptive Statistics	Chang (2008)
Race; transit access; commercial access; population density	2000-2002	Maryland	Ordinary Least Squares (OLS) Linear Regression	Clifton and Kreamer-Fults. (2007)
Gender; low transit access areas	2000-2004	Maryland	Descriptive Statistics and Ordered Probit	Clifton et al. (2009)
Population; income; transit	2005	Illinois	Poisson Model	Cottrill et al. (2010)
Population density; age; unemployment; gender; education level; alcohol intoxication; areas with high number of alcohol sale establishments	1990	California	Ordinary Least Squares (OLS) Linear Regression	LaScala, et al. (2000)
Population density; low-income areas; transit stops; linguistically isolated households; commercial land-use; areas with high number of alcohol sale establishments	2000-2007	Georgia	Bivariate Correlation and Negative Binomial	Dai and Jaworski (2016)
Age; alcohol intoxication; senior population; children	2000-2007	Georgia	Logistic Regression	Dai (2012)
Alcohol intoxication; pedestrian behavior: consequence of demographic and socioeconomic characteristics	2000	Florida	Descriptive Statistics	Spainhour et al. (2006)

3.2.2 Land Use Data

The 2015 Florida Land Use layer includes a total of 9,117,116 parcels in the entire state. Figure 3-5 shows the 2015 Florida Parcel Land Use map. This dataset contains parcel boundaries with each parcel's associated tax information from the Florida Department of Revenue's tax database. This feature class contains parcel polygons and associated parcel attribute information. Attributes include Parcel ID, Alt Key, Section, Township, Range, Owner Name, Owner Mailing Address, Site Address, Most Recent Sales Information, Valuation, Land Use Codes, Building Details, Legal Description, etc. It includes the original 99 land-use classes and 15 generalized classes.

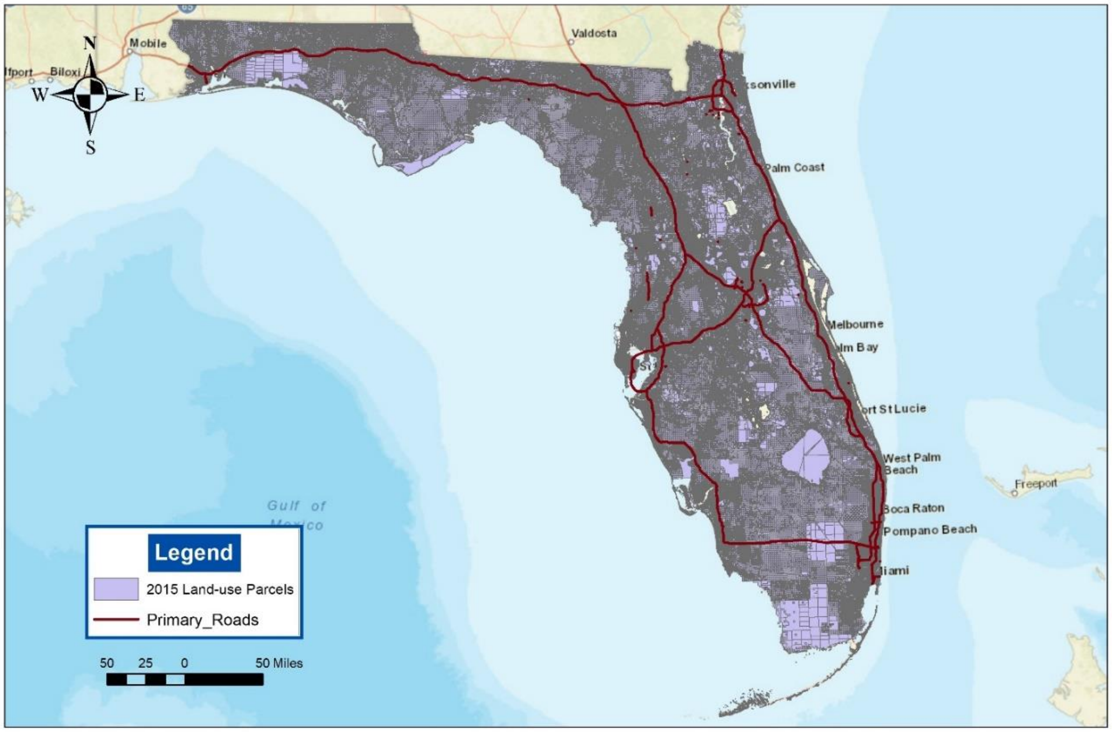


Figure 3-5: 2015 Florida Parcel Land Use Map

Table 3-9 provides more details about the following four groups of attributes considered in the 2015 Florida Parcel Land Use dataset analyzing pedestrian crashes: shopping centers, hotels, recreation facilities, and restaurants/bars in FDOT District Four. Figures 3-6 through 3-9 show the density maps of these four groups in FDOT District Four.

Table 3-9: Key Attributes Associated with Pedestrian Crashes in 2015 Florida Parcel Land Use Dataset

Group	Attribute	Number
Shopping Centers	Supermarket	224
	Regional shopping malls	96
	Community shopping centers	907
Hotels	Hotels and motels	879
Recreation Facilities	Tourist attractions	22
	Camps	3
	Park and recreational areas	1,574
	Outdoor recreational facilities	1,064
Restaurants/Bars	Restaurants, cafeterias	989
	Fast food restaurants	761
	Night clubs, bars, and cocktail lounges	209

Note: The numbers presented in this table are for FDOT District Four.

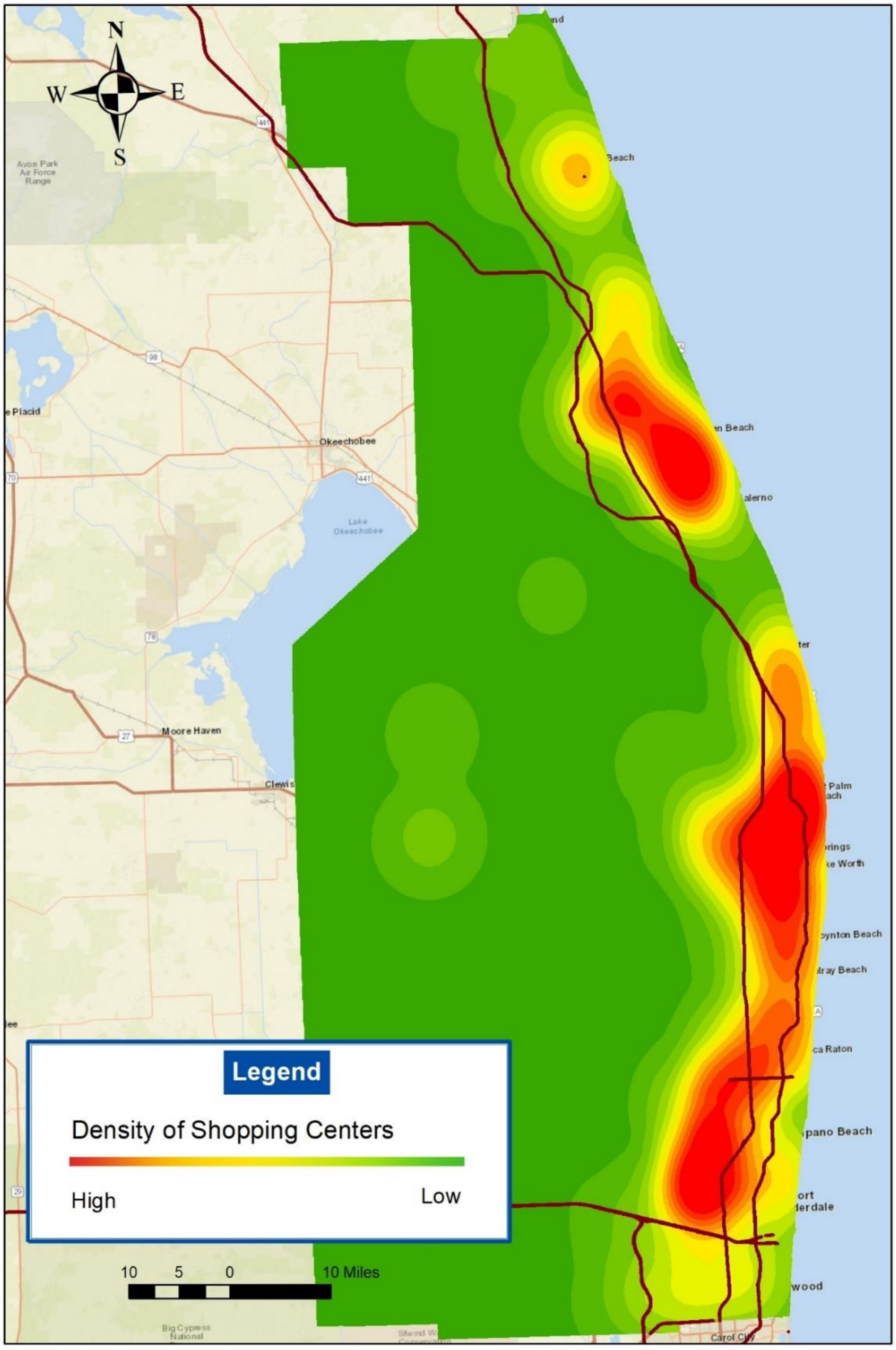


Figure 3-6: Density Map of Shopping Centers in FDOT District Four

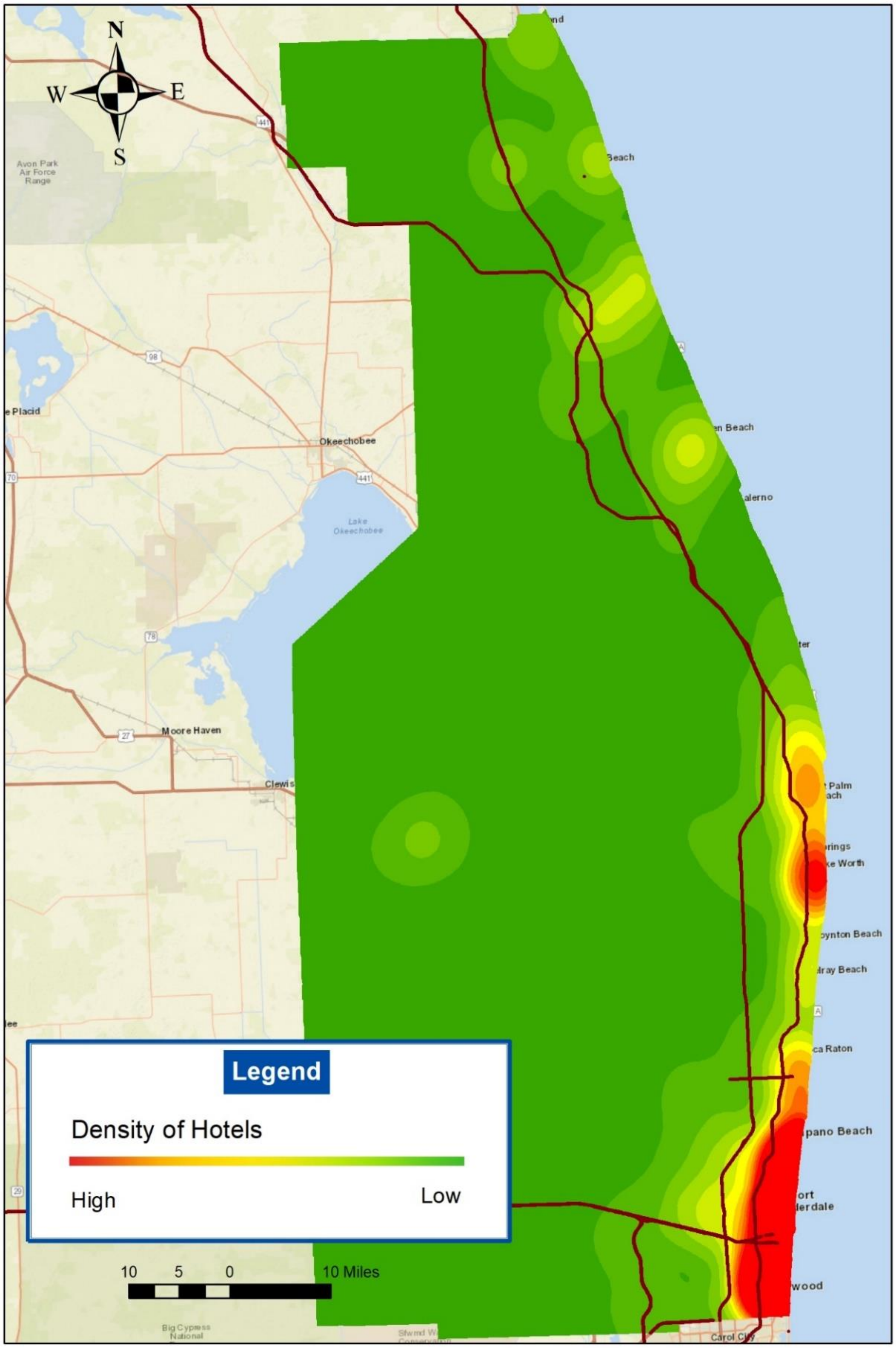


Figure 3-7: Density Map of Hotels in FDOT District Four

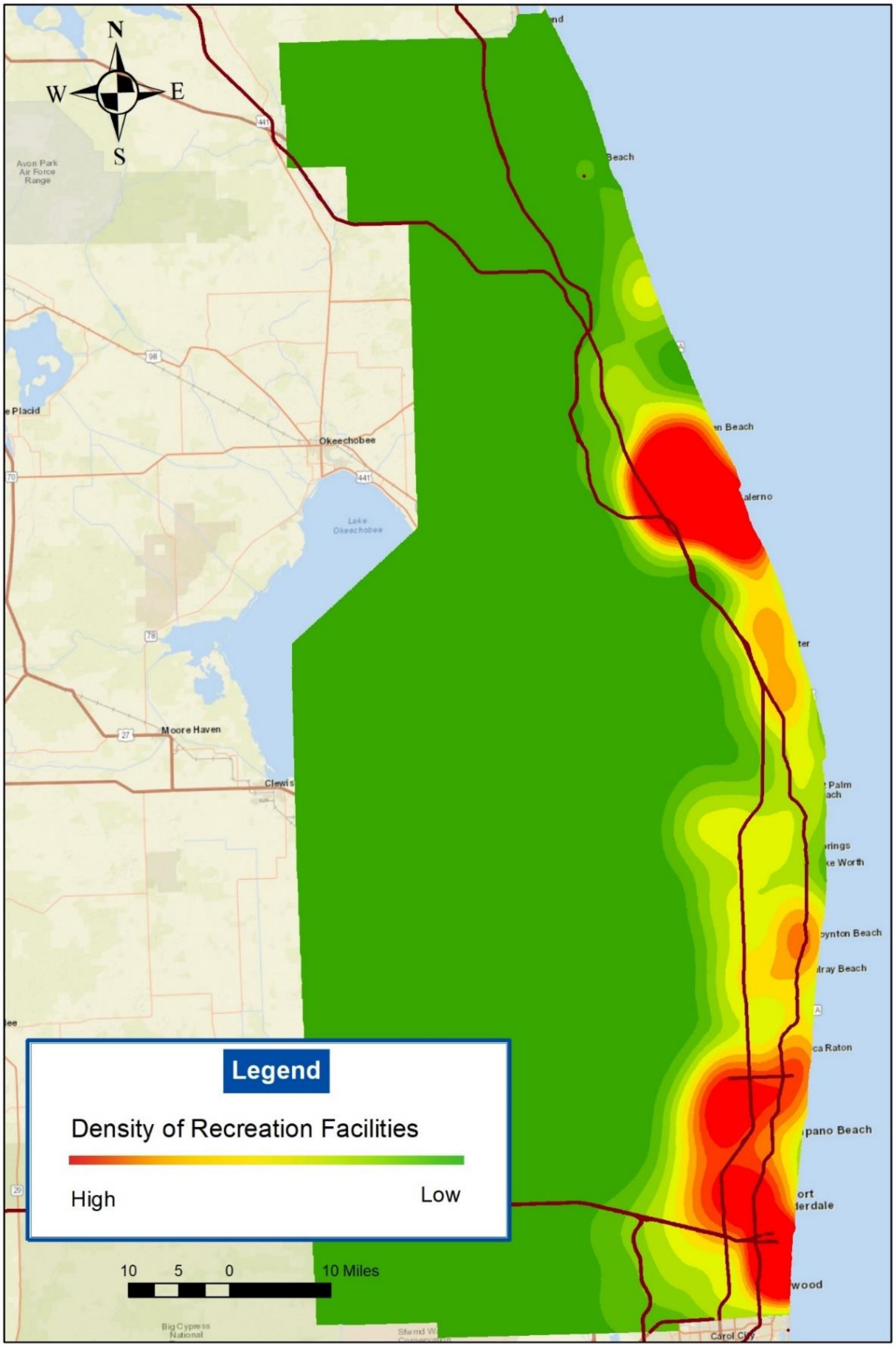


Figure 3-8: Density Map of Recreation Facilities in FDOT District Four

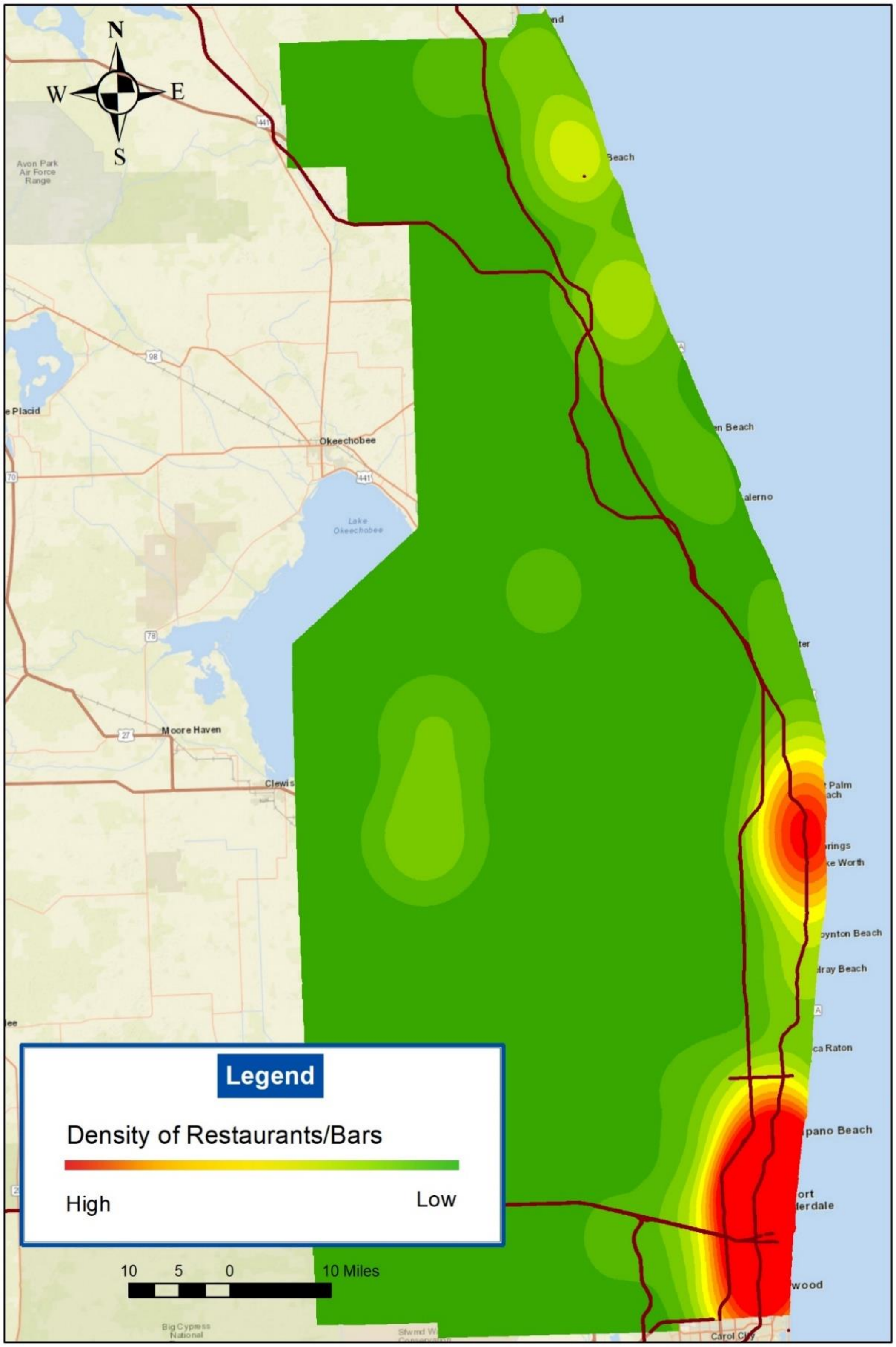


Figure 3-9: Density Map of Restaurants/Bars in FDOT District Four

3.2.3 Census Data

The census data were primarily extracted from the 2015 United States Census Bureau, with selected fields extracted from the 2011-2015 American Community Survey (ACS). The Census Block Group is the smallest geographical unit for which the Bureau publishes sample data. The 2015 FDOT District Four Census Block Groups GIS layer includes a total of 2,154 Census Block Groups. The fields included in this dataset are *Total Population*, *Education*, *Housing*, and *Economic Characteristics*. Although the ACS data provides survey estimates for one, three, and five-year time periods, only the five-year estimates provide data at the block group level. The following six groups of attributes are considered in the 2015 Florida Census Block Groups data: *population*, *gender*, *age*, *income*, *total households*, and *transportation*. Table 3-10 lists the detailed attributes extracted from the 2015 FDOT District Four Census Block Groups dataset. Figure 3-10 shows the 2015 Census Block Groups in FDOT District Four. As an example, Figure 3-11 shows the distribution of the total population within the 2015 Census Block Groups in District Four.

Table 3-10: Key Attributes in 2015 Census Block Groups Dataset

Group	Attribute	Definition
Population	TOTALPOP	Total Population
Gender	MALE	Population Male
	FEMALE	Population Female
Age	AGE_UNDER5	Population Under 5 years
	AGE_5_17	Population 5 to 17 years
	AGE_18_21	Population 18 to 21 years
	AGE_22_29	Population 22 to 29 years
	AGE_30_39	Population 30 to 39 years
	AGE_40_49	Population 40 to 49 years
	AGE_50_64	Population 50 to 64 years
	AGE_65_UP	Population 65 years and up
Income	LESS_10K	# of Households (HH*) with HH Income in The Past 12 Months < $10,000
	I10K_14K	# of HH with HH Income in The Past 12 Months $10,000 to $14,999
	I15K_19K	# of HH with HH Income in The Past 12 Months $15,000 to $19,999
	I20K_24K	# of HH with HH Income in The Past 12 Months $20,000 to $24,999
	I25K_29K	# of HH with HH Income in The Past 12 Months $25,000 to $29,999
	I30K_34K	# of HH with HH Income in The Past 12 Months $30,000 to $34,999
	I35K_39K	# of HH with HH Income in The Past 12 Months $35,000 to $39,999
	I40K_44K	# of HH with HH Income in The Past 12 Months $40,000 to $44,999
	I45K_49K	# of HH with HH Income in The Past 12 Months $45,000 to $49,999
	I50K_59K	# of HH with HH Income in The Past 12 Months $50,000 to $59,999
	I60K_74K	# of HH with HH Income in The Past 12 Months $60,000 to $74,999
	I75K_99K	# of HH with HH Income in The Past 12 Months $75,000 to $99,999
	I100K_124K	# of HH with HH Income in The Past 12 Months $100,000 to $124,999
	I125K_149K	# of HH with HH Income in The Past 12 Months $125,000 to $149,999
	I150K_199K	# of HH with HH Income in The Past 12 Months $150,000 to $199,999
	I200KMORE	# of HH with HH Income in The Past 12 Months $200,000 or more
Household	HOUSEHOLDS	Total Households
Transportation	TRAN_WALK	# of HH with Transportation to Work Walked

* HH is households.

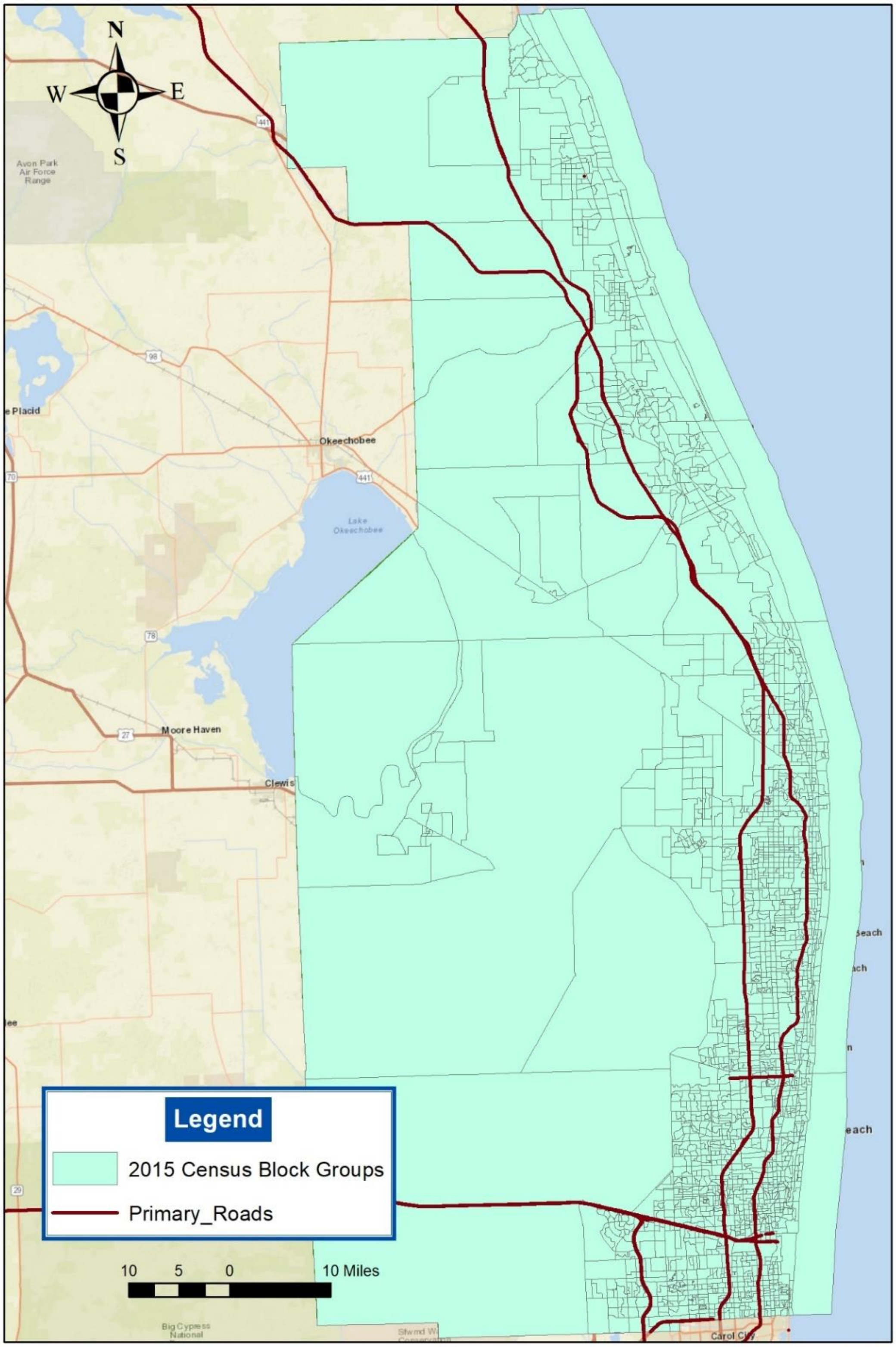


Figure 3-10: 2015 Census Block Groups Map in District Four

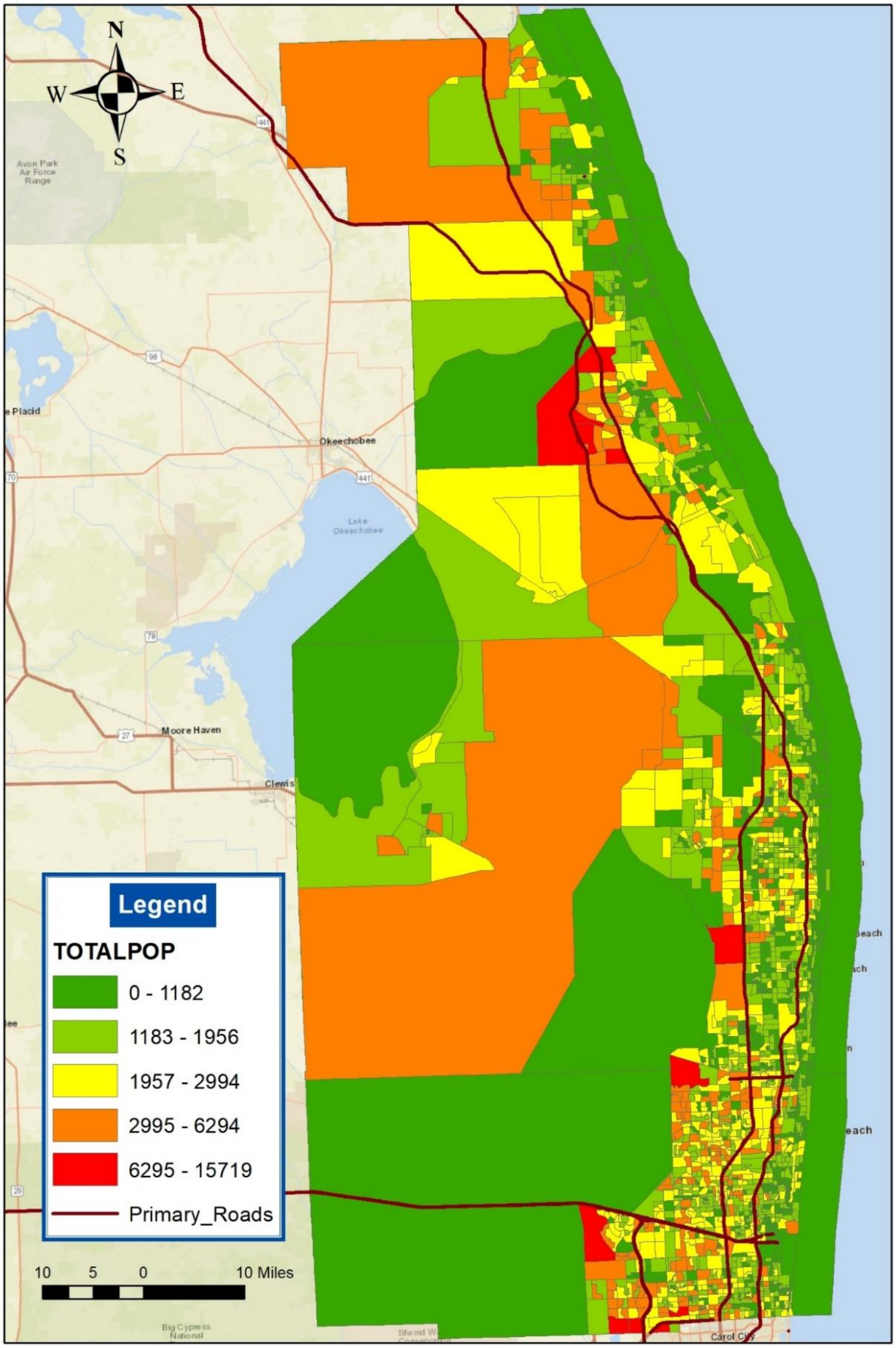


Figure 3-11: Distribution of Total Population in District Four

3.2.4 Pedestrian Infrastructure Data

Data on pedestrian infrastructure, including the presence of a shared path, sidewalk barrier, sidewalk width, etc., were obtained from the FDOT GIS layers. These GIS layers are for the year 2019. Information on the location of transit stops in FDOT District Four was extracted from the Florida Transit Data Exchange (FTDE). FTDE is a Web-based system used to share planning-related spatial data of the Florida fixed-route transit agencies. These include General Transit Feed Specification (GTFS) and GIS data. Note that the extracted transit stop data were in different formats, and the data had to be combined to generate a single shapefile. This shapefile included a total of 8,178 transit stops within FDOT District Four. Table 3-11 summarizes the number of transit stops within each of the five counties in District Four. Figure 3-12 shows the spatial distribution of these transit stops.

Table 3-11: Transit Stops in FDOT District Four

County	Number of Transit Stops	Year Data was Updated
Broward	4,576	2019
Indian River	262	2017
Martin	42	2014
Palm Beach	2,986	2019
St. Lucie	312	2015
Total	**8,178**	

3.2.5 Pedestrian Volume Data

With the advent of smartphone technology, researchers have begun to use innovative means to extract pedestrian and bicycle exposure data. The use of crowdsourced data is one such approach. *Strava* is a smartphone application that facilitates pedestrians and bicyclists keeping track of their walking and biking trips and providing means for athletes to monitor their activity. However, by delving deeper into this dataset, the research team realized that the *Strava* smartphone application users are mostly athletes and bicyclists. This sample size does not reflect the walking patterns of the general public. As such, the *Strava* dataset, although initially considered, was not included in the analysis.

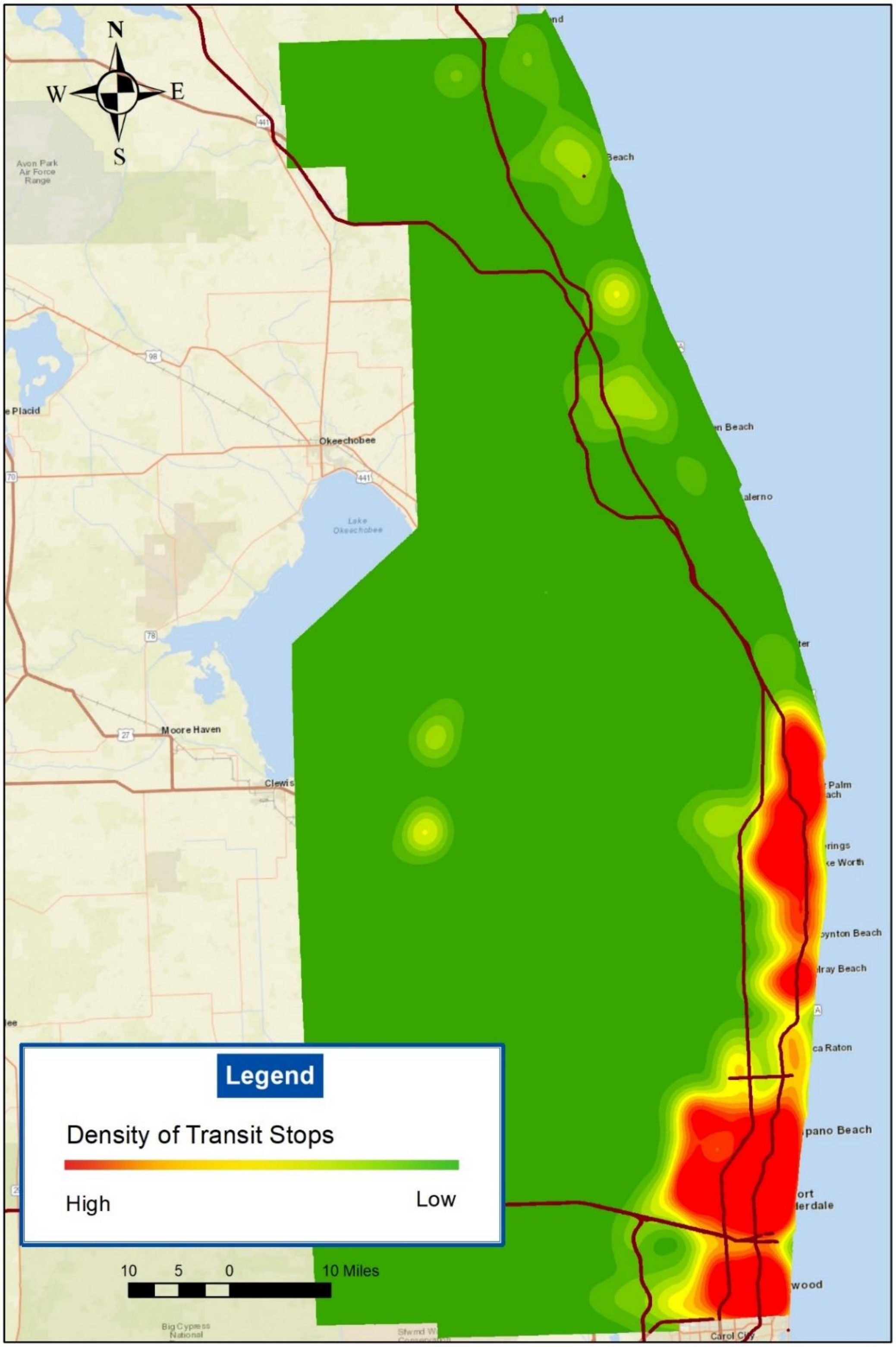


Figure 3-12: Distribution of Transit Stops in District Four

3.3 Summary

This chapter focused on describing socioeconomic, land-use, demographic, roadway geometric characteristics, and pedestrian infrastructure variables that could potentially affect pedestrian crashes. Table 3-12 provides the list of variables and the respective data sources considered in this research.

Table 3-12: List of Potential Influential Variables and Their Data Sources

Data Variables		Data Source
Pedestrian Crash Data	• Crash severity • Crash time • Crash month • Day of the week • Crash location • Influence of alcohol/drugs • Lighting condition	• FDOT's Unified Basemap Repository (UBR)
Roadway Geometric Characteristics	• Traffic volume • Number of lanes • Median type and width • Surface width • Signalized intersections	• 2016 FDOT's Roadway Characteristics Inventory (RCI) • 2015 NavStreets Shapefile
Land Use Variables	• Shopping centers • Hotels • Recreation facilities • Restaurants and bars	• 2015 Florida Parcel Land use Dataset
Socioeconomic and Demographic Variables	• Population • Gender • Age • Income level • Total households • Transportation mode	• 2015 Census Block Groups
Pedestrian Exposure*	• Pedestrian volume	• Strava Database
Pedestrian Facilities	• Presence of a shared path • Presence of a sidewalk barrier • Sidewalk width	• 2016 FDOT's Roadway Characteristics Inventory (RCI) • FDOT's Geographic Information System (GIS) Shapefiles
Transit Stops	• Number and location of transit stops	• Florida Transit Data Exchange (FTDE) Portal of Florida Transit Information System (FTIS)

*Strava data was not incorporated in further analysis. Please refer to Section 3.2.5 for more details.

CHAPTER 4
PEDESTRIAN CRASH HOTSPOTS

Chapter Four focuses on identifying the pedestrian crash hotspots in FDOT District Four. The analysis was based on five years of pedestrian crashes that occurred on non-limited access facilities from 2012-2016. GIS-based spatial clustering analysis was used to identify the top 20 pedestrian crash hotspots in FDOT District Four. The chapter is organized into the following sections:

- Section 4.1 discusses the pedestrian crash data,
- Section 4.2 explains the analysis framework to identify pedestrian crash hotspots,
- Section 4.3 presents the top 20 pedestrian crash hotspots in FDOT District Four, and
- Section 4.4 provides the chapter summary.

4.1 Pedestrian Crash Data

4.1.1 Pedestrian Crash Frequency

The analysis was based on five years of pedestrian crash data from 2012-2016. The crash data shapefiles for the years 2012-2016 were downloaded from the FDOT UBR. Since the scope of this research project is limited to non-limited access facilities, the analysis did not include pedestrian crashes that occurred on freeways. The variable FL_VRU_PED, a yes/no flag that indicates a crash involving a pedestrian, was used to identify pedestrian crashes.

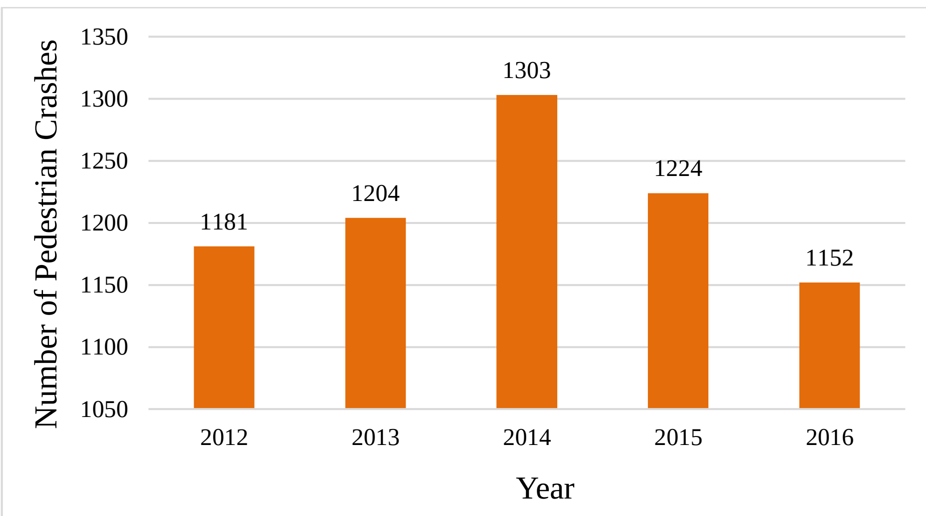


Figure 4-1: Pedestrian Crashes on Non-limited Access Facilities from 2012–2016

Figure 4-1 provides the pedestrian crash frequency on non-limited access facilities during the years 2012 through 2016. A total of 6,098 pedestrian crashes were found to have occurred during the five-year analysis period. Of these, 34 pedestrian crashes with unknown injury severity were excluded from the analysis. As can be inferred from Figure 4-1, pedestrian crashes on arterials increased from 2012 through 2014, and then slightly reduced in 2015 and 2016. The year 2014 experienced the highest number of pedestrian crashes (1,303), while 2016 experienced the lowest pedestrian crash frequency (1,152).

4.1.2 Pedestrian Crash Density

Figure 4-2 shows the spatial distribution of pedestrian crashes on non-limited access roadways in FDOT District Four. Note that the purple lines in the figure are the state roads. As expected, the crashes are not evenly distributed. They are clustered more in urban areas along the beach, particularly in the West Palm Beach and Fort Lauderdale regions. Pompano Beach and Hollywood areas also experienced a higher density of pedestrian crashes. Within the rest of District Four, the density of pedestrian crashes was found to be relatively low.

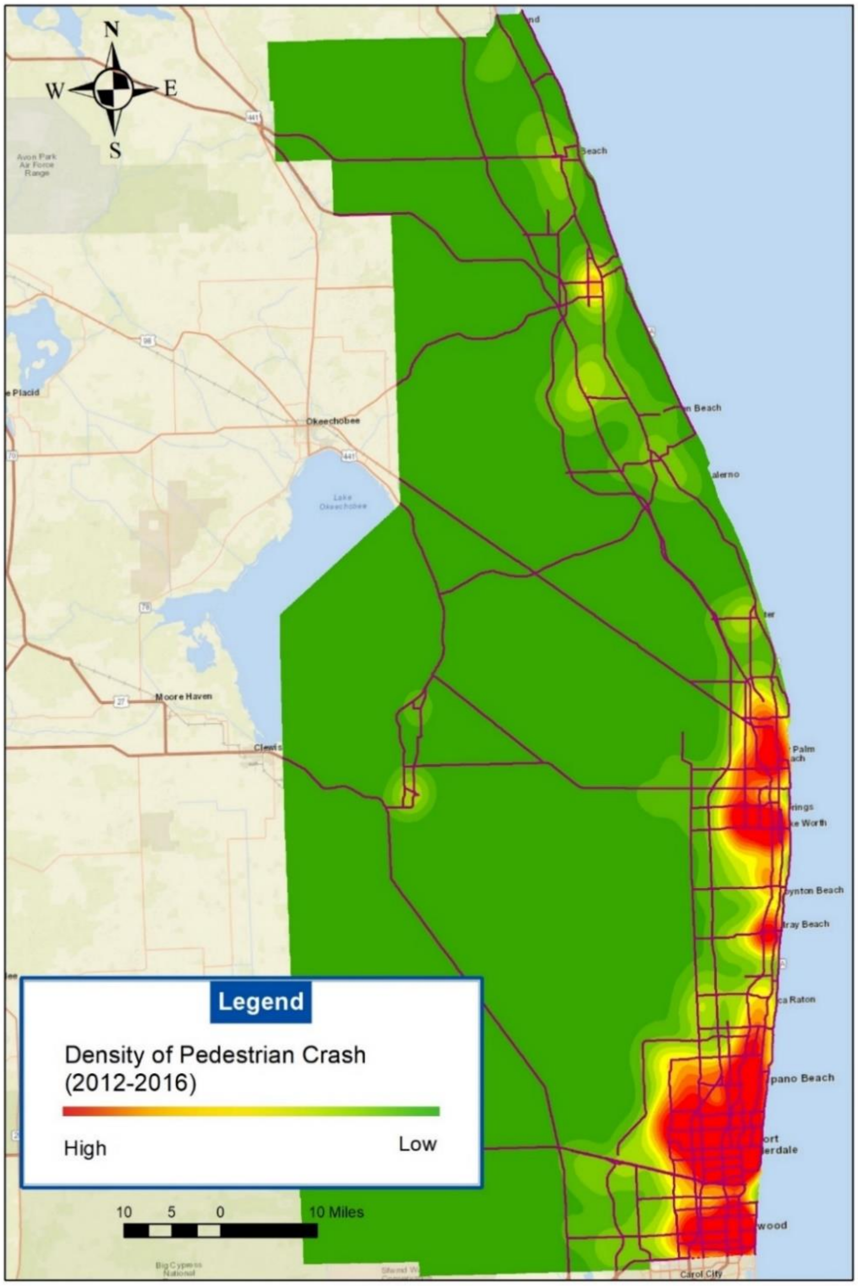


Figure 4-2: Density Map of Pedestrian Crashes in FDOT District Four (2012-2016)

4.2 Analysis Framework to Identify Pedestrian Crash Hotspots

GIS-based spatial clustering analysis was used to identify pedestrian crash hotspots in FDOT District Four. Figure 4-3 illustrates the concept. The *X* and *Y*-axis in the conceptual figure represent the spatial terrain of the region. The *Z*-axis represents the number of pedestrian crashes. The approach creates a service area (along the road network) for each pedestrian crash and then merges the overlapping service areas. Depending on the density of the pedestrian crashes, each of the overlapping service areas will cover a varying number of pedestrian crashes. The nearby service areas within a certain step length (i.e., within a certain distance) are then identified and grouped. These grouped service areas are then ranked based on the total number of pedestrian crashes identified within these areas and their Equivalent Property Damage Only (EPDO) scores.

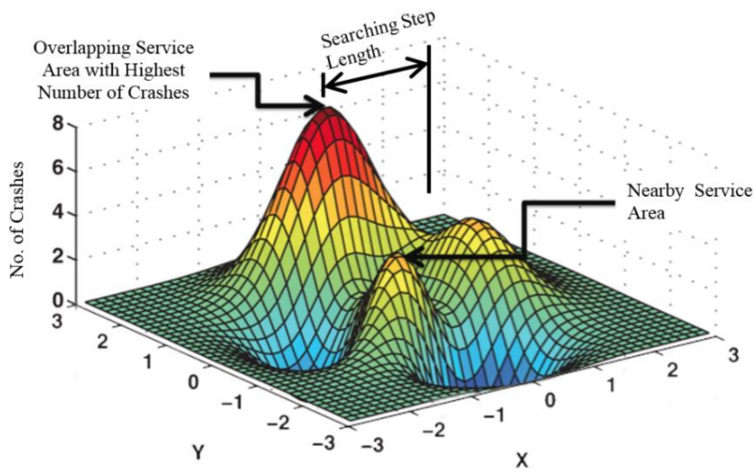


Figure 4-3: Concept to Identify Hotspots

The following steps constitute the framework adopted to identify pedestrian crash hotspots in FDOT District Four:

1. Develop an arterial road network
2. Set parameters
3. Identify the service area for each crash
4. Merge overlapping service areas
5. Group nearby service areas
6. Identify candidate hotspots
7. Emphasize pedestrian crashes at midblock locations on state roads

Step 1: Develop Arterial Road Network

The network dataset was developed based on the 2015 Florida Street Network extracted from NAVTEQ NAVSTREETS layer. The 2015 Florida Street Network includes 18,053,775 street records, which cover the entire public road network in Florida. Since this project focuses only on pedestrian crashes on non-limited access facilities, all limited-access facilities were excluded from the network dataset. As an example, Figure 4-4 shows the service areas of pedestrian crashes that occurred near I-95 in Fort Lauderdale. Note that the streets included within the service areas did not constitute freeways.

Figure 4-4: Non-limited Access Roadways within Pedestrian Crash Service Areas

Step 2: Set Parameters

The algorithm requires the following two parameters:

1. The radius of the pedestrian crash service area
2. Searching step length

The radius of the pedestrian crash service area helps determine the total number of pedestrian crashes that occurred within the core area (i.e., the height of the mountain in Figure 4-3). The larger the radius, the greater the number of crashes, and the larger the area (i.e., the mountain in Figure 4-3) in general. The other parameter, searching step length, helps determine the distance between the core crash area and the nearby area with fewer (or no) crashes.

A pedestrian trip is usually considered to be shorter than a quarter-mile. The probability of pedestrians walking more than a quarter-mile is close to 0. Therefore, this research used 0.1-mile as the radius of the pedestrian crash service area, implying that the closest distance between two nearby service areas is 0.2 miles. This limit means the distance between two pedestrian crashes is still under the acceptable walking distance of 0.25 miles. The searching step length is set at 250 ft (i.e., 0.05 miles) to ensure that the distance between the nearby service areas, when grouped, is still less than 0.25 miles.

Step 3: Identify the Service Area for Each Crash

To identify the service area of a pedestrian crash, the most common and easiest way is to create a straight-line buffer around the crash (shown as the pink circle in Figure 4-5). This method assumes that the service area surrounding the pedestrian crash (i.e., the potential walking distance) is the Euclidian distance (i.e., a straight-line distance). The actual walking distance depends on the real-world street configuration, as shown by the blue line in Figure 4-5. The purple polyline, therefore, shows the actual service area of the crash.

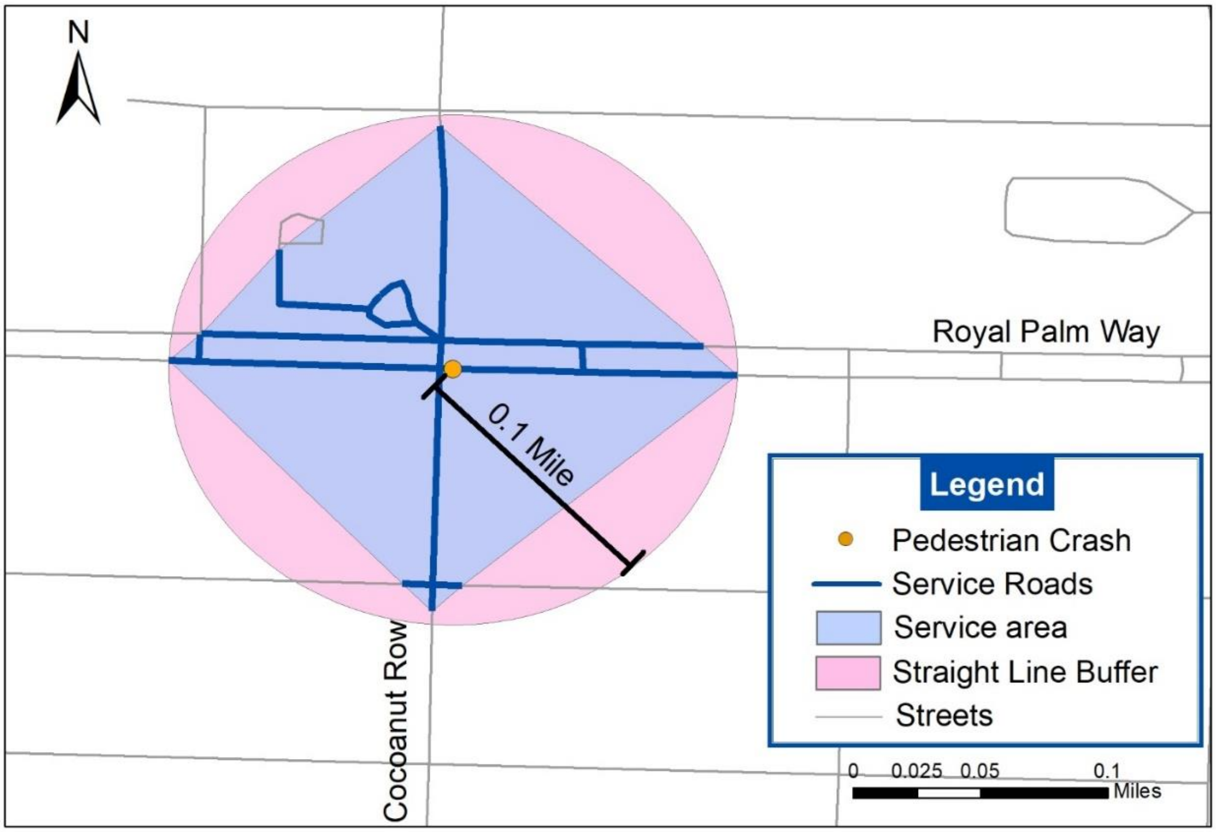


Figure 4-5: Service Area for a Crash

Service areas were identified for each of the 6,064 pedestrian crashes using the 0.1-mile radius. This step helps determine the impact area of each pedestrian crash. Figure 4-6 shows an example of service areas for each of the eight pedestrian crashes that occurred near Lake Worth in Palm Beach County. Note that the service area of each crash was identified using a different color.

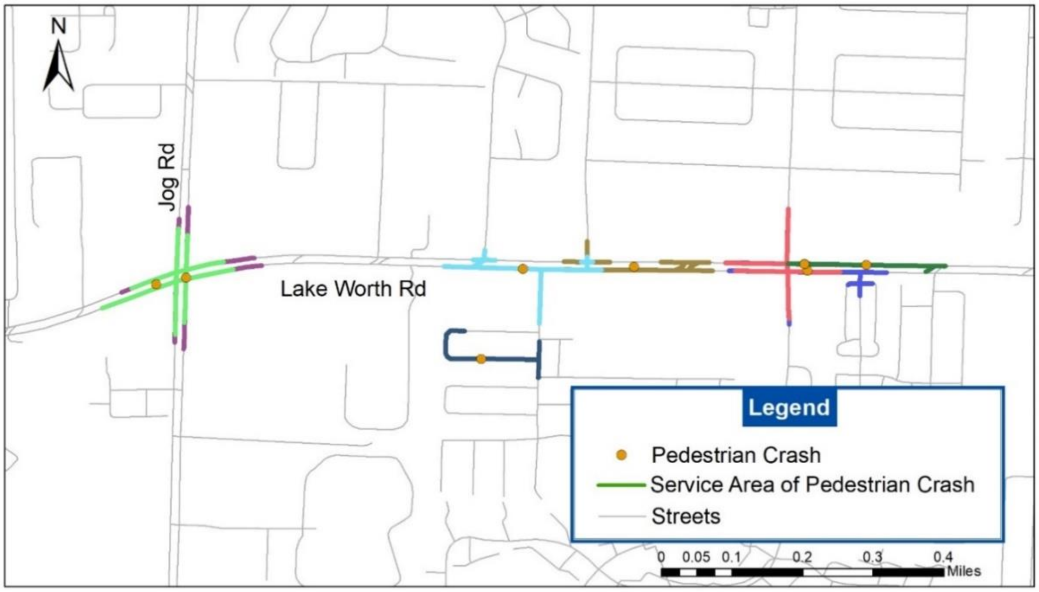


Figure 4-6: Preliminary Service Areas of Each Pedestrian Crash

Step 4: Merge Overlapping Service Areas

Once the service area for each pedestrian crash was identified, the next step was to merge the overlapping service areas and determine the total number of pedestrian crashes that occurred within the core area. As can be observed from Figure 4-7, the overlapped service areas of the eight pedestrian crashes (i.e., eight independent service areas) near Lake Worth in Palm Beach County were merged, and these eight areas were aggregated into four areas, as shown in Figure 4-7.

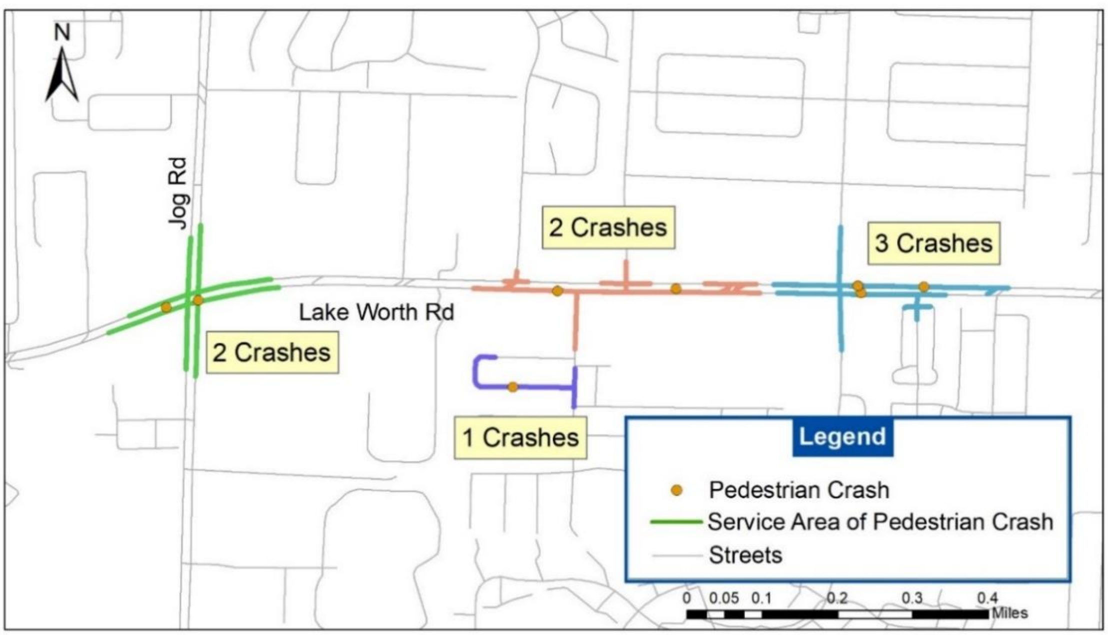


Figure 4-7: Merging Overlapped Service Areas

Step 5: Group Nearby Service Areas

Once the overlapping service areas were merged, the next step was to identify nearby service areas that could be grouped. All the service areas within 250 ft (0.05 miles) of each other, known as the step length, were grouped.

For example, as can be observed from Figure 4-8, a total of three service areas are within 250 of each other. These three service areas, identified in green color in Figure 4-8, are grouped into one large service area. Note that the service area shown in purple is not grouped with the rest since it is farther than 250 ft (i.e., searching step length) from the other service areas.

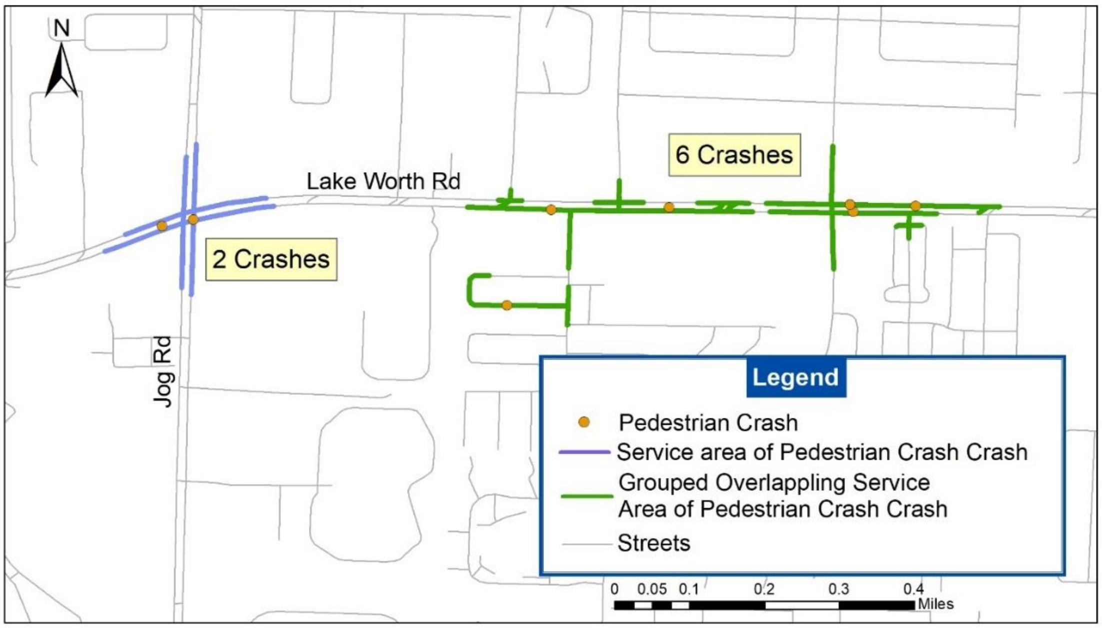


Figure 4-8: Grouping Nearby Service Areas

Step 6: Identify Candidate Hotspots

This step focused on selecting pedestrian crash hotspots in FDOT District Four based on the total number of pedestrian crashes and the EPDO scores. The EPDO weighting method was used to calculate the EPDO score of candidate crash hotspots based on injury weighting. Note that the EPDO score considers the severity breakdown of crashes, providing greater weight to fatal and injury crashes over PDO crashes. Table 4-1 provides the EPDO weighting scores for different injury severity levels based on the High Crash Analysis Report Section of CAR 2011 through 2014 as presented in Volume 1 of the 2017 Plans Preparation Manual. Fatal crashes are assigned an EPDO weight of 1346.05. This is calculated as the ratio of fatal crash cost to the PDO crash cost. Similarly, other injury crashes are assigned different EPDO weights, as shown in Table 4-1. A total of 40 candidate pedestrian hotspots were selected based on EPDO scores, as shown in Figure 4-9.

Table 4-1: EPDO Weighting Scores for Different Injury Severity Levels

Injury Severity	Code	Comprehensive Cost Per Crash	Weight
Property Damage Only (PDO)	O	$7,600	1
Minor Injury	C	$97,650	12.84
Moderate Injury	B	$157,170	20.68
Severe Injury	A	$580,320	76.35
Fatal	K	$10,230,000	1,346.05

* Based on 2010 through 2014 CAR system analysis years.

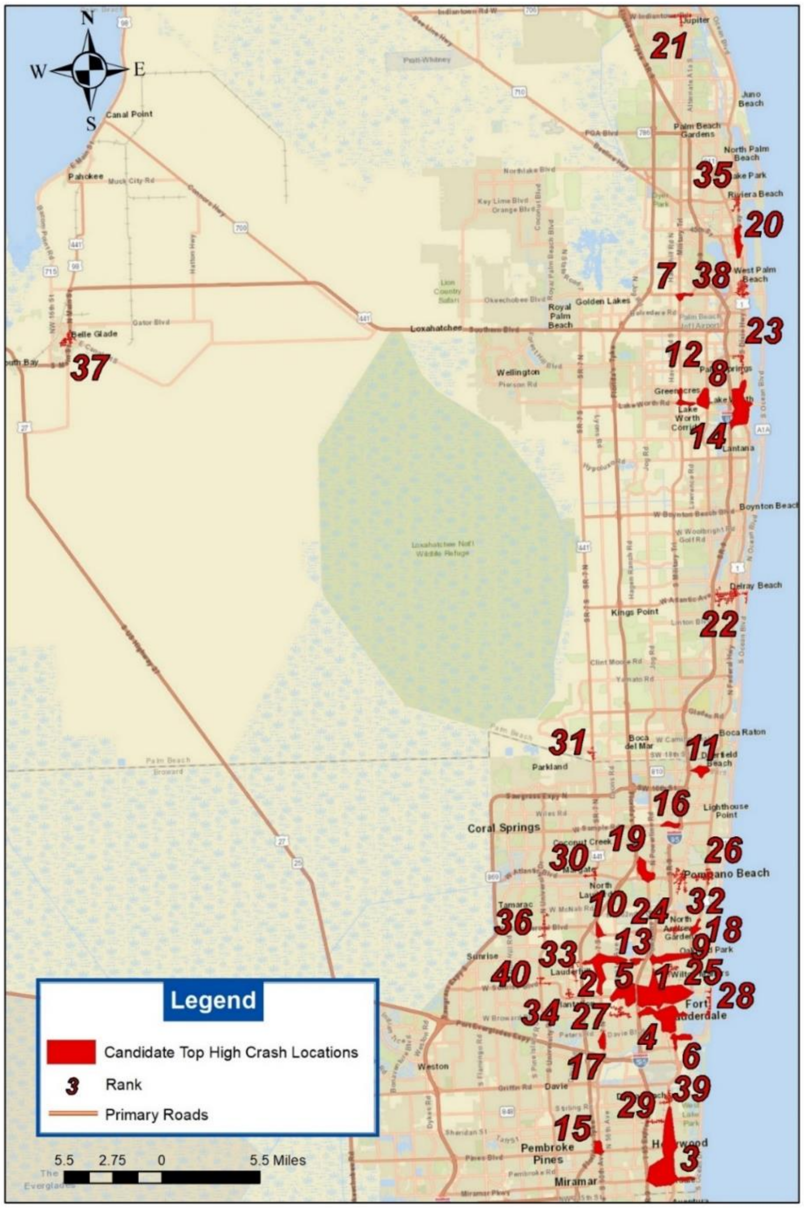


Figure 4-9: Top 40 Candidate Pedestrian Crash Hotspots in FDOT District Four

Step 7: Emphasize on Pedestrian Crashes at Midblock Locations on State Roads

The scope of this research project is limited to pedestrian crashes on state-maintained non-limited access facilities at midblock locations. The research team, therefore, reviewed the pedestrian crashes within all the 40 candidate pedestrian crash hotspots to identify pedestrian crashes at midblock locations on state roads. The crash hotspots where pedestrian crashes occurred only at intersections were excluded. Those hotspots that did not have any state roads were also excluded. Figure 4-10 shows the state roads and pedestrian crashes at midblock locations within the crash hotspots. The purple nodes in the figure represent the pedestrian crashes at intersections and the green nodes represent the pedestrian crashes at midblock locations.

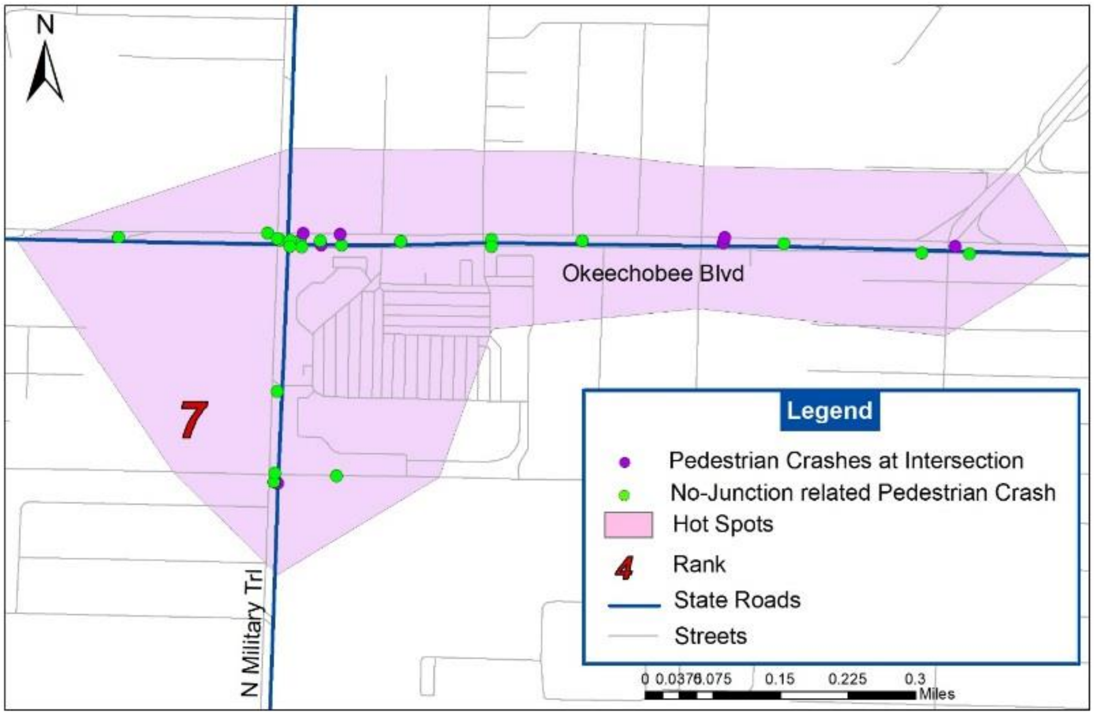


Figure 4-10: Pedestrian Crashes on State Roads within Crash Hotspots

4.3 Pedestrian Crash Hotspots

Table 4-2 lists the final top 20 pedestrian crash hotspots in FDOT District Four based on the EPDO scores. The table also includes the number of pedestrian crashes on state roads within each hotspot. Figure 4-11 gives the map of these 20 hotspots in FDOT District Four. The supplemental .kmz file includes the spatial locations of these hotspots. The supplemental excel file includes the list of state roads within each of these 20 hotspots.

Table 4-2: Top 20 Pedestrian Crash Hotspots in FDOT District Four

Rank	Location	Total Crashes	Fatal Crashes	Severe Injury Crashes	Moderate Injury Crashes	Minor Injury Crashes	PDO Crashes	EPDO Score
1	Sunrise	190	13	39	75	48	15	22,659.49
2	Lauderdale Lakes	125	6	17	48	42	12	10,918.76
3	Hollywood	206	4	32	74	67	29	10,247.99
4	Fort Lauderdale	167	4	26	67	49	21	9,405.77
5	Fort. Lauderdale	67	5	8	29	20	5	8,202.85
6	Fort. Lauderdale	52	5	6	20	12	9	7,765.21
7	Westgate	32	5	8	7	10	2	7,616.39
8	Lake Worth Corridor	31	5	7	11	6	2	7,571.35
9	Oakland Park	74	4	17	28	18	7	7,499.66
10	Tamerac	24	5	7	8	4	0	7,481.61
11	Deerfield Beach	28	5	6	8	7	2	7,445.80
12	Greenacres	25	5	6	8	3	3	7,395.40
13	Oakland Park	18	5	4	3	4	2	7,151.13
14	Lake Worth	109	3	22	50	21	13	7,034.92
15	Hollywood	30	4	7	10	7	2	6,217.47
16	Pompano Beach	21	4	7	6	3	1	6,082.35
17	Plantation	26	4	4	10	5	3	5,963.69
18	Knoll Ridge	20	4	2	7	6	1	5,759.78
19	Pompano Beach	41	3	13	17	8	0	5,485.19
20	West Palm Beach	50	3	8	17	19	3	5,247.74

Table 4-3: Number of Pedestrian Crashes at Midblock Locations

Rank	Location	Total Crashes	Total Pedestrian Crashes at Midblock Locations	Percentage of Pedestrian Crashes at Midblock Locations	Length of State Roads (Miles)
1	Sunrise	190	154	81%	6.93
2	Lauderdale Lakes	125	117	94%	4.94
3	Hollywood	206	157	76%	9.75
4	Fort Lauderdale	167	130	78%	4.24
5	Fort. Lauderdale	67	65	97%	1.43
6	Fort. Lauderdale	52	43	83%	2.13
7	Westgate	32	23	72%	1.51
8	Lake Worth Corridor	31	23	74%	1.59
9	Oakland Park	74	64	86%	4.13
10	Tamerac	24	22	92%	1.39
11	Deerfield Beach	28	23	82%	1.34
12	Greenacres	25	20	80%	1.98
13	Oakland Park	18	15	83%	0.87
14	Lake Worth	109	78	72%	5.69
15	Hollywood	30	18	60%	2.08
16	Pompano Beach	21	21	100%	1.15
17	Plantation	26	22	85%	1.18
18	Knoll Ridge	20	17	85%	1.72
19	Pompano Beach	41	40	98%	1.92
20	West Palm Beach	50	36	72%	1.94

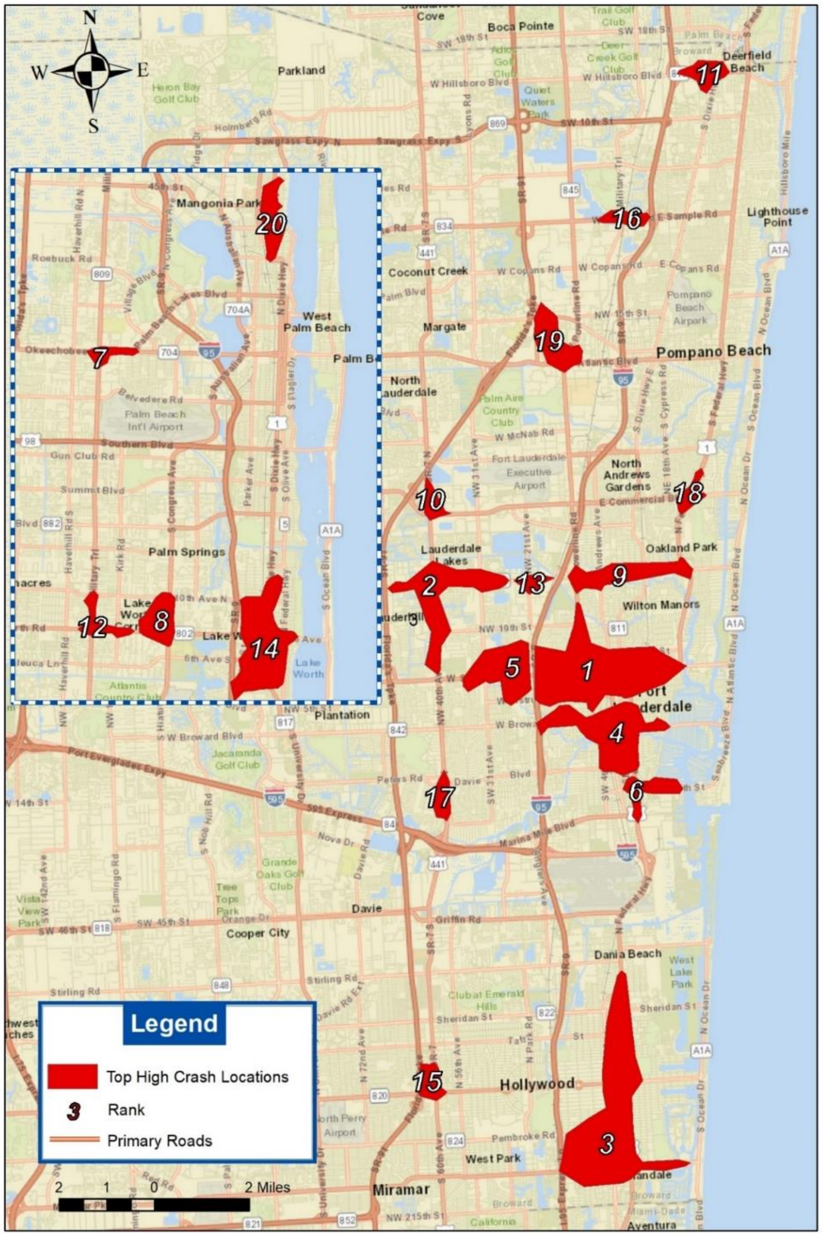


Figure 4-11: Top 20 Pedestrian Crash Hotspots in FDOT District Four

4.4 Summary

This chapter focused on identifying 20 pedestrian crash hotspots in FDOT District Four. The supplemental .kmz file, submitted as part of this report, includes the spatial locations of these hotspots. The supplemental Excel file, also submitted as part of this report, includes the list of state roads within each of these 20 hotspots. The Excel file also includes the location and type of crosswalks and other pedestrian infrastructure (e.g., pedestrian signals, RRFBs, etc.) within each hotspot.

CHAPTER 5
ANALYSIS OF PEDESTRIAN CRASHES AT MIDBLOCK LOCATIONS

This chapter explores the roadway, socioeconomic, demographic, and land-use variables that affect pedestrian safety at midblock locations. The chapter describes the pedestrian crashes at hotspot locations in District Four and presents the statistical analysis conducted to develop safety performance functions (SPFs) and crash modification factors (CMFs). Below is the outline of the major sections:

- Section 5.1 presents the variables of interest in the analysis.
- Section 5.2 provides the descriptive statistics of crashes that occurred within the hotspots.
- Section 5.3 documents the data collection and processing efforts along with a description of the study corridors.
- Section 5.4 discusses the research approach adopted to develop the SPFs and CMFs for midblock locations.
- Section 5.5 presents the results of the developed SPFs and CMFs.
- Section 5.6 summarizes the key findings.

5.1 Variables of Interest

The crash, census, land-use, and roadway variables are considered in the analysis. These variables were selected based on an extensive literature review and preliminary analysis of pedestrian crashes in FDOT District Four. Table 5-1 lists all the variables considered in the analysis. The table also includes the specific attributes of interest and their corresponding data sources, attribute units, and attribute feature types. The crash data shapefiles for the years 2012-2016 were downloaded from the FDOT UBR. All the land-use attributes were extracted from the 2015 Florida Parcel Land Use dataset of the FGDL: their standard unit is square miles, and the features are polygons. Census data were obtained from the 2015 Census Block Groups dataset: the standard unit is population, and the features are polygons as well. Roadway characteristics data, including roadway type, speed limit, and number of lanes, were extracted from the FDOT's RCI database, and information on bus stops was extracted from the FTDE platform.

5.2 Analysis of Pedestrian Crashes in Hotspots

This section provides descriptive statistics of the pedestrian crashes at midblock locations within the top 20 hotspots identified in Chapter 4. Note that the pedestrian crash data includes crashes that occurred on both state and non-state roads within the hotspots. The 20 hotspots within District Four experienced 1,088 crashes during the five-year analysis period from 2012 through 2016.

Table 5-1: Variables of Interest

<table>
<tr><th>Categ.</th><th>Variable</th><th>Attribute</th><th>Source</th><th>Unit</th><th>Feature Type</th></tr>
<tr><td rowspan="6">Crash Data</td><td>Crash ID</td><td>CRASHNUM</td><td rowspan="6">2012-2016 FDOT UBR</td><td></td><td rowspan="6">Point</td></tr>
<tr><td>Hour of crash</td><td>CRASHTIME</td><td>Number</td></tr>
<tr><td>Day of crash</td><td>DAYOFWEEK</td><td>Number</td></tr>
<tr><td>Lighting condition</td><td>LIGHTCOND</td><td>Category</td></tr>
<tr><td>Weather condition</td><td>WEATHCOND</td><td>Category</td></tr>
<tr><td>Crash location</td><td>RELATOJUNC</td><td>Category</td></tr>
<tr><td rowspan="4">Census Data</td><td>Senior population</td><td>AGE_65_UP</td><td rowspan="4">2015 Census Block Groups</td><td rowspan="3">Population</td><td rowspan="4">Polygon</td></tr>
<tr><td>Total population</td><td>TOTALPOP</td></tr>
<tr><td>The population with annual income < 10K</td><td>LESS_10K</td></tr>
<tr><td>The population who “walk” to work</td><td>TRAN_WALK</td><td>Households</td></tr>
<tr><td rowspan="18">Land use Variables</td><td rowspan="3">Alcohol sales establishments</td><td>Night clubs</td><td rowspan="18">2015 Florida Parcel Land Use</td><td rowspan="18">Number</td><td rowspan="18">Polygon</td></tr>
<tr><td>Bars</td></tr>
<tr><td>Cocktail lounges</td></tr>
<tr><td rowspan="2">Restaurants and cafeterias</td><td>Restaurants, cafeterias</td></tr>
<tr><td>Drive-in restaurants</td></tr>
<tr><td rowspan="2">Schools</td><td>Private schools</td></tr>
<tr><td>Public schools</td></tr>
<tr><td rowspan="2">Hotels</td><td>Hotels</td></tr>
<tr><td>Motels</td></tr>
<tr><td rowspan="3">Shopping center</td><td>Supermarket</td></tr>
<tr><td>Regional shopping malls</td></tr>
<tr><td>Community shopping centers</td></tr>
<tr><td rowspan="2">Theaters, auditoriums, and sport arenas</td><td>Enclosed theaters, auditoriums</td></tr>
<tr><td>Arenas</td></tr>
<tr><td rowspan="4">Recreational facilities</td><td>Forest, park, and recreational areas</td></tr>
<tr><td>Outdoor recreational</td></tr>
<tr><td>Camps</td></tr>
<tr><td>Tourist attractions</td></tr>
<tr><td rowspan="4">Roadway Characteristics</td><td>Bus stops</td><td>STOP</td><td>FTDE</td><td>Number</td><td>Point</td></tr>
<tr><td>State roads</td><td>ROADWAY</td><td>FDOT GIS layers</td><td>Miles</td><td>Line</td></tr>
<tr><td>Speed limits</td><td>SPDLIMITS</td><td rowspan="2">FDOT RCI</td><td>Category</td><td>Line</td></tr>
<tr><td>Number of lanes</td><td>LANES</td><td>Number</td><td>Line</td></tr>
</table>

Note: Categ. = Category.

5.2.1 Crash Time

Table 5-2 presents the pedestrian crash statistics by crash time within the hotspots. The crash time was divided into four categories: 6 am – noon; noon – 6 pm; 6 pm – midnight; and midnight – 6 am. In terms of crash frequency, the most critical time was found to be from 6 pm to midnight, approximately 38% of all pedestrian crashes were found to occur during this time period. During the daytime, the morning (i.e., 6 am to Noon) period had fewer crashes compared to the afternoon period. Also, most nighttime crashes were found to result in fatalities.

Table 5-2: Pedestrian Crash Statistics by Crash Time

Hour	No Injury	Possible Injury	Non-incapacitating Injury	Incapacitating Injury	Fatal Injury	Total Crashes	%
Midnight – 6 am	11	19	42	26	13	111	21.3
6 am – Noon	35	73	87	31	6	232	30.0
Noon – 6 pm	29	105	141	43	8	326	38.5
6 pm – Midnight	34	89	142	108	46	419	10.2
Total	**109**	**286**	**412**	**208**	**73**	**1,088**	**100**

Figure 5-1 presents the hourly distribution of pedestrian crashes at the hotspots. The graph shows that pedestrian crashes peaked between 7 am and 9 am during the morning rush hour and again between 7 pm and 9 pm during the evening rush hour. As expected, the pedestrian crash frequency during daytime is much lower compared to nighttime.

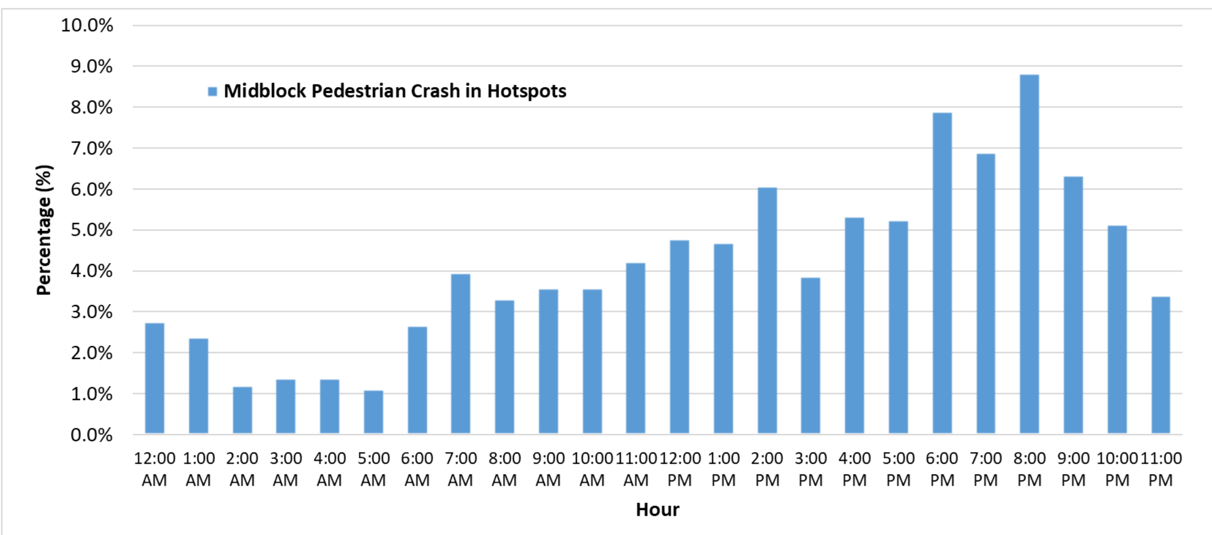


Figure 5-1: Hourly Distribution of Pedestrian Crashes at Hotspot Locations

5.2.2 Day of the Week

Table 5-3 shows the trend of pedestrian crashes by day of the week. The proportion of pedestrian crashes within hotspots was higher on Fridays and Saturdays, constituting 17.2% and 15.4%, respectively. It could be inferred from these statistics that a relatively higher proportion of pedestrian crashes involved after-work trips. More fatal crashes were also observed to occur on Fridays and Saturdays. Overall, most crashes resulted in non-incapacitating injuries (i.e., 412 crashes), accounting for 38% of total crashes.

Table 5-3: Pedestrian Crash Statistics by Day of Week

Day of Week	No Injury	Possible Injury	Non-incapacitating Injury	Incapacitating Injury	Fatal Injury	Total Crashes	%
Monday	14	38	65	21	6	144	13.2
Tuesday	18	41	59	26	5	149	13.7
Wednesday	13	43	58	32	10	156	14.3
Thursday	12	44	58	28	11	153	14.1
Friday	19	38	76	38	16	187	17.2
Saturday	21	49	50	33	15	168	15.4
Sunday	12	33	46	30	10	131	12.0
Total	**109**	**286**	**412**	**208**	**73**	**1,088**	**100**

5.2.3 Lighting Condition

Table 5-4 provides pedestrian crash statistics based on the lighting condition. As expected, a slightly higher proportion of pedestrian crashes occurred during the daytime. The pedestrian crashes at midblock locations within hotspots have a higher proportion during dark-lighted conditions. Dark-lighted conditions resulted in relatively more incapacitating and fatal pedestrian crashes (i.e., 102 and 51 crashes, respectively).

Table 5-4: Pedestrian Crash Statistics by Light Condition

Lighting Condition	No Injury	Possible Injury	Non-incapacitating Injury	Incapacitating Injury	Fatal Injury	Total Crashes	%
Daylight	68	184	223	77	13	565	51.9
Dark-lighted	31	75	149	102	51	408	37.5
Poor light/Other	10	27	40	29	9	115	10.6
Total	**109**	**286**	**412**	**208**	**73**	**1,088**	**100**

5.2.4 Weather Condition

Table 5-5 provides pedestrian crash statistics by weather condition. Most pedestrian crashes occurred during clear weather. This is expected because pedestrians do not normally walk during adverse weather conditions.

Table 5-5: Pedestrian Crash Statistics by Weather Condition

Weather Condition	No Injury	Possible Injury	Non-incapacitating Injury	Incapacitating Injury	Fatal Injury	Total Crashes	%
Good	103	268	386	192	68	1,017	93.5
Adverse Weather	6	18	26	16	5	71	6.5
Total	**109**	**286**	**412**	**208**	**73**	**1,088**	**100**

5.2.5 Speed Limits

Table 5-6 shows the pedestrian crash statistics by speed limits. A higher proportion of pedestrian crashes at midblock locations with higher speeds, i.e., ≥ 40 mph. The lower the speed limits, the higher the chance of pedestrians to safely cross the roads at midblock locations. The corridors with speed limits lower than 30 mph mostly belong to minor/local roads with relatively low traffic and narrower lanes. The chance of having a crash at these locations is, therefore, lower. As such, the proportion of pedestrian crashes at corridors with lower speed limits is lower.

Table 5-6: Pedestrian Crash Statistics by Speed Limits

Speed Limit	Crash Frequency	%
≤ 30 mph	239	22.0
35 mph	335	30.8
≥ 40 mph	494	45.4
Unknown	20	1.8
Total	**1,088**	**100**

5.2.6 Number of Lanes

Table 5-7 provides pedestrian crash statistics by the number of lanes. Note that the number of lanes is the total number of lanes in both directions. Most crashes occurred on facilities with 3 to 6 lanes. To an extent, this is expected since most non-limited access facilities have 3-6 lanes.

Table 5-7: Pedestrian Crash Statistics by Number of Lanes

No. of Lanes	Crash Frequency	%
≤ 2	386	35.5
3-6	683	62.8
> 6	19	1.7
Total	**1,088**	**100**

5.2.7 Review of Pedestrian Crash at Midblock Location along the State Roads

For statistical analysis purposes, data integration and summary are based on 1,088 pedestrian crashes at midblock within the top 20 hotspots. These crashes include the pedestrian crashes at midblock locations on both state-maintained and non-state-maintained roadways (Table 5-8).

Table 5-8: Summary of All Variables within Pedestrian Crash Hotspots

Rank	Area	Midblock Pedestrian Crashes	Population Variables				Land use Variables							Roadway	
			Senior	Total	Income < 10 K	Travel with Transit	Bar	Restaurant	Hotel	School	Shopping Center	Theater	Recreation	Bus Stop	State Roads
	Sq. Miles	Crashes/ Sq. Mile	Population/Sq. Mile				Number/Sq. Mile								Miles
1	3.37	45.7	627.4	7,395.2	391.7	64.8	0.9	5	1.5	4.2	1.2	0.3	3.6	38.6	7.08
2	1.6	72.9	980.5	8,852.0	288.6	23.6	0	8.1	0	7.5	1.9	0	1.2	44.9	4.96
3	3.93	39.9	913.9	7,664.3	452.8	157	3.1	18.3	16.5	5.6	1.5	0.3	1.3	38.4	9.83
4	1.87	69.5	815	6,829.6	368.7	156.5	5.9	11.2	2.1	10.7	1.1	0.5	9.1	47.1	4.30
5	1.21	53.7	706	5,653.5	177.2	34.8	1.7	5	1.7	5	0	0.8	3.3	41.3	1.45
6	0.96	81.1	670.9	5,267.5	255.8	131.8	8.3	23.9	4.2	3.1	1	0	1	59.3	5.66
7	0.47	134.8	689.9	3,326.5	84.2	104.4	2.1	21.1	27.4	4.2	4.2	0	6.3	54.8	4.09
8	0.24	179.3	405.4	5,110.7	352.3	119.5	0	37.5	0	0	29.2	0	0	58.4	2.14
9	1.94	7.7	717.3	8,320.8	329.7	40	3.1	10.3	11.4	3.1	3.6	0.5	0	33.6	0.78
10	0.61	37.7	404.7	5,415.7	114.3	21.1	3.3	16.4	0	3.3	4.9	1.6	0	41	1.53
11	0.25	93.2	261.5	4,750.1	154.2	42.6	4.1	12.2	12.2	12.2	4.1	0	0	73	1.60
12	0.41	53.8	733.3	4,201.5	265.7	27	0	9.8	4.9	0	2.4	0	4.9	34.3	1.39
13	0.35	66.2	492.8	5,766.3	124.8	244.5	0	25.9	0	0	14.4	0	2.9	72	1.37
14	0.19	103.2	425.1	3,101.6	115.8	20.1	0	20.6	0	10.3	0	0	0	77.4	1.94
15	0.34	52.7	1081.4	8,923.0	286.4	3.2	2.9	20.5	11.7	2.9	0	0	0	67.4	2.07
16	0.27	77.1	295.2	5,864.4	149.3	61.7	0	18.3	0	3.7	0	0	0	25.7	1.13
17	0.31	71.6	374.5	6,317.3	83.6	35.3	0	13	6.5	0	0	0	3.3	58.6	1.18
18	0.77	22	624.1	4,215.1	181.4	17.5	1.3	11.6	1.3	6.5	0	0	1.3	36.2	1.69
19	0.26	151.7	924.3	4,619.6	158.5	74.4	0	30.3	3.8	7.6	0	0	0	87.2	1.90
20	0.58	61.7	719	6,620.1	492.8	165.6	3.4	1.7	8.6	3.4	3.4	0	0	42.9	1.91

Note: Sq. = Square.

The 1,088 pedestrian crashes were then reviewed on Google Earth to exclude non-state roads. A total of 405 midblock road locations was reviewed in detail to determine if the following roadway characteristics (which serves as an indicator of pedestrian activity) exist:

- Sidewalk
- Crosswalk
- Street lighting
- Median
- Pedestrian signals
- Bus stop

Table 5-9 summarizes the roadway characteristics at the identified 405 midblock locations along the state roads within the top 20 hotspots. As can be inferred from Table 5-9, most midblock locations where pedestrian crashes occurred had sidewalks (99.5%) and street lighting (91.4%). On the other hand, pedestrian crossing facilities were relatively rare; only 9.1% of locations had crosswalks, and 10.1% of locations had traffic signals for pedestrians. Around 80% of the locations had raised medians. Note that around 30% of the 405 locations had bus stops.

Table 5-9: Roadway Characteristics at Midblock Locations along the State Roads

	Sidewalk		Crosswalk		Lighting		Median		Pedestrian Signal		Bus Stop	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Presence	403	99.5	37	9.1	370	91.4	321	79.3	41	10.1	129	31.9
Absence	2	0.5	368	90.9	35	8.6	84	20.7	362	89.4	276	68.1
Total	**405**	**100**	**405**	**100**	**405**	**100**	**405**	**100**	**405**	**100**	**405**	**100**

Note: No. = Number.

5.2.8 Summary

The analysis of pedestrian crashes within the top 20 hotspots led to the following conclusions:

- Pedestrian crashes peaked between 7 pm and 9 pm. Overall, the most critical time was found to be from 6 pm to midnight.

- The proportion of pedestrian crashes on Fridays and Saturdays was relatively higher than the other days of the week.

- Even though more pedestrian crashes occurred during daylight conditions, more severe crashes occurred during dark-lighted conditions.

- Most pedestrian crashes (93.5%) occurred during good weather conditions.

- A higher proportion of pedestrian crashes occurred on corridors with speed limits ranging from 35-40 mph.

- Based on the roadway characteristics review of midblock locations along the state roads within the hotspots, most midblock locations where the pedestrian crashes occurred were found to have sidewalks (99.5%) and street lighting (91.4%). On the other hand, the pedestrian crossing facilities were found to be rare; only 9.1% of locations had crosswalks, and 10.1% had pedestrian signals.

5.3 Development of CMFs

Safety analysis of midblock locations focused on developing SPFs and estimating CMFs. This section describes the data, the methods used, and the model results. The descriptive statistics in the previous sections focused on the top 20 crash hotspots identified in Chapter 4. This section focuses on the midblock locations in the entire District Four. The midblock pedestrian countermeasures and all relevant data for analysis were collected. Note that the analysis focused only on state-maintained, non-limited access roadways as indicated in the scope of this research.

An SPF is a regression equation that is developed to determine the predicted crash frequency at a location usually as a function of AADT with segment length, and in some cases, AADT with other roadway geometric or intersection characteristics such as lane width, shoulder width, presence and degree of horizontal curve, or any other specific conditions (Srinivasan et al., 2015). This research utilized the Generalized Linear Model (GLM) approach with Zero Inflated Negative Binomial (ZINB) to develop the SPFs for pedestrian crashes at midblock locations.

A CMF is a multiplicative factor that is used to compute the expected number of crashes when a specific countermeasure is implemented at a site. When a countermeasure is implemented, a CMF of less than 1 indicates a reduction in the crash frequency while a CMF of greater than 1 indicates an increase in the frequency of crashes. The preferred methods for developing CMFs can be classified into two broad categories: before-and-after studies and cross-sectional studies. The cross-sectional analysis is usually applied as an alternative method to estimate the CMFs when before-and-after studies are impractical to apply, e.g., due to lack of data from the period after implementing treatments, unavailability of the actual dates that the pedestrian countermeasures were implemented, etc. In a cross-sectional analysis, crash frequencies for locations with and without pedestrian countermeasures (i.e., treatment and comparison sites, respectively) are analyzed. The difference in the crash frequency is then attributed to the presence of the installed countermeasure(s). In this research, a cross-sectional analysis of the treatment and comparison sites was conducted to estimate the CMFs for midblock pedestrian treatments. The CMFs were derived from the regression models (i.e., SPFs).

5.3.1 Study Corridors

The first step in the analysis was to identify midblock segments. Each midblock segment was identified as a section of the roadway between two signalized intersections. The locations of signalized intersections were obtained from the FDOT shapefiles. The treatment segments had at least one midblock pedestrian crosswalk while the comparison segments did not have any crosswalks. The beginning and end mileposts of the segments were then used to match different variables to their respective segments during data processing. Segments longer than 2 miles and shorter than 200 ft were not considered in the analysis.

The preliminary data on the location of midblock crosswalks were obtained from the FDOT GIS Web application (FDOT, n.d.). The study locations included the midblock pedestrian countermeasures with Traffic Signals (TS), Rectangular Rapid Flashing Beacons (RRFBs), and Pedestrian Flashing Beacons (PFB). Additional midblock locations with crosswalks were manually identified from the Google Earth Street View. Geometric data on the identified pedestrian crossings were obtained from the Google Earth Street View and FDOT shapefiles. The data included the number of lanes, presence of bicycle lanes, speed limit, type of control at the crosswalk, presence and type of pedestrian crossing, and presence of median.

The types of pedestrian countermeasures installed at midblock locations were classified based on three features: signals, pavement markings, and pedestrian crossing signs. The signals included Circular Rapid Flashing Beacons (CRFBs), Rectangular Rapid Flashing Beacons (RRFBs), and Traffic Signals (TS) that control vehicles at midblock crossings. The pavement markings comprised two parallel lines, parallel lines with red bricks layout, and High Visibility Crosswalk Markings (HVCMs). The pedestrian signs at crosswalks were categorized into two categories: in-street pedestrian signs and overhead pedestrian signs. Some sites had a combination of these two signs.

5.3.2 Data Collection

The following data were used to develop the SPFs and CMFs:

a) Crash Data

The crash data shapefiles for the years 2012-2016 were downloaded from the FDOT UBR. The data were processed to remove all intersection-related crashes. A total of 967 pedestrian crashes were found to occur on state-maintained non-access-controlled roadways in District Four for years 2012-2016.

Since traffic crashes are usually dispersed along the road network, it is rare for crashes to be concentrated only at one location, particularly at a midblock crosswalk. Therefore, this analysis considered crashes that occurred on midblock segments (instead of just those that occurred at the midblock crossing). Since the crash data were geo-referenced, ArcGIS was used to assign crashes to the treatment and comparison segments. The crash data were merged with the midblock segments to obtain the total number of crashes for each segment. Close observation of the crash data indicated that several segments did not experience pedestrian crashes during the five-year analysis period.

b) Roadway Characteristics Data

Roadway geometric and traffic data for the study segments were extracted from the FDOT shapefiles. The data included AADT, roadway functional classification, number of lanes, presence of bicycle lanes, posted speed limit, presence of median, and presence of sidewalks. Data on bus stop locations were extracted from the FTDE. These data were matched with the study segments based on Roadway ID and mileposts using ArcGIS tools and Microsoft Excel functions. Table 5-

10 describes these geometric and traffic characteristics for the treatment and the comparison segments.

c) Surrogate Measures of Pedestrian Volume

Ideally, pedestrian volumes provide a good estimation of pedestrian exposure. However, pedestrian volumes were not available for the study locations. Land use and census data were, therefore, utilized as surrogate measures for pedestrian volumes. The census data included the percentage of the senior population, total population, population with annual household income less than 10K, and population who “walk” to work. The census blocks from the 2015 census block group data were merged with the roadway segments. The roadway and census blocks were intersected in ArcGIS to obtain the census data for the blocks that the roadway passed through. The data were then normalized by segment length. Since all these variables were polygon layers, the effort to integrate these data with the study segments was rather complex due to differences in polygon shapes between the census block groups and the line shape of the study segments.

Surrounding land use data and pedestrian traffic generators/activity areas were used to determine the level of pedestrian activity and are considered as a proxy for pedestrian volume. These data were identified within a 0.25-mile radius (Monsere et al. 2016). The following land use variables were extracted: alcohol sales establishments; restaurants and cafeterias; hotels; schools; shopping centers; theaters, auditoriums, and sports arenas; and recreational facilities. Note that all these land-use variables are polygon layers. To be consistent with the bus stops’ point layer, all polygon layers of land use data were converted into point layers based on the geometric center of each polygon.

5.4 Research Approach

5.4.1 Propensity Score Matching

The comparison sites for the cross-sectional analysis should have similar characteristics to the identified treatment sites except for the presence of pedestrian crosswalks. To identify the comparison sites for this study, propensity score matching (PSM) was used. This is a statistical method that involves a regression model for estimating the conditional probability of a site, e.g., intersection, segment, or corridor, being selected to apply a treatment, given a vector of observed variables. This approach has been reported to reduce selection bias while selecting comparison sites (Song and Noyce, 2019).

A set of comparison sites with different characteristics were identified alongside the treatment sites (i.e., sites with at least one pedestrian treatment). For each treatment segment, comparison segments having the smallest difference in propensity score from the treatment sites were matched (Song and Noyce, 2019). Matching the segments using the PSM method helps strengthen causal arguments in observational studies by reducing selection bias.

A propensity score representing the conditional probability of a facility receiving a countermeasure given the variables and the outcomes are established. The score shows the relationship between treatment status (1 – treated; 0 – control) and covariates, i.e., variables that completely or partially account for the apparent association between an outcome and risk factor. The potential comparison segments were matched with the treatment segments at a ratio of 1 to 5 (i.e., each treatment segment was matched with five comparison segments). The following variables were used to establish the matching between comparison and treatment segments:

- AADT
- Presence of median
- Presence of sidewalks
- Maximum posted speed
- Number of lanes
- Presence of bicycle lanes
- Bars and food joints
- Schools
- Shopping centers
- Bus stops

5.4.2 Descriptive Statistics

Table 5-10 summarizes the descriptive statistics of the collected data. The table includes geometric variables, AADT, land use, and census data. Note that some of the variables (e.g., population-related) were normalized by segment length to obtain a uniform reference for all the study sites. The analysis was based on 245 midblock segments, of which 41 were treatment segments and the remaining 204 were comparison segments. The treatment segments had at least one midblock pedestrian crosswalk. The treatment and comparison segments had similar land use characteristics, as reflected in the propensity score matching variables.

Table 5-10: Descriptive Statistics

Categorical Variables			
Variable	**Category**	**Frequency**	**Percentage (%)**
Segment	Treatment	41	17
	Comparison	204	83
Functional Class	Arterial	228	93
	Collector	17	7
Median	No	45	18
	Yes	200	82
Sidewalk	No	4	2
	One Side	59	24
	Both Sides	182	74
Surface Width	≤ 30 ft	46	19
	31 ft to 50 ft	85	34
	> 50 ft	114	47
Speed Limit	≤ 30 mph	42	17
	>35 mph	203	83
Number of Lanes	≤ 2	47	19
	2 to 4	86	35
	> 4	112	46
Bicycle Lane	No	92	38
	One Side	37	15
	Both Sides	116	47
Proportion of Senior Population	0 to 0.2	127	52
	0.2 to 0.6	118	48
Proportion of People Who Walk to Work	0 to 0.01	169	69
	0.01 to 0.09	76	31
Proportion of Population with Annual Income < 10 K	0 to 0.03	103	42
	0.03 to 0.1	142	58

Continuous Variables				
Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Bus Stops Density (Number/mile)	9.38	8.1	0	40.82
Bars & Food Joints Density (Number/mile)	3.93	6.79	0	44.78
Schools Density (Number/mile)	1.67	3.73	0	30.61
Shopping Centers Density (Number/mile)	0.99	2.86	0	24.63
Natural Logarithm of Total Population	12.64	1.17	9.44	16.08
Natural Logarithm of AADT	10.19	0.64	8.15	15

Note: total number of segments is 245.

5.4.3 Regression Model Development

A cross-sectional analysis using the GLM approach with ZINB distribution was adopted to develop the relevant SPFs for pedestrian crashes. A regression model was developed for both the treatment and comparison segments. The model had the crash frequency on the midblock segments as the dependent variable and the roadway geometric characteristics, land use, and census data as explanatory variables. The objective was to develop a regression function that identifies factors influencing the occurrence of pedestrian crashes at midblock locations. The negative binomial models take care of the overdispersion in the crash data, while the zero-inflated model was used because the dataset had a multitude of zero crashes at most of the study segments.

Zero Inflated Negative Binomial (ZINB) Model

The Zero-inflated distributions are two regime models: predicting the zero-inflation probability and predicting a constant zero-inflation probability across observations. The first part (i.e., the zero-inflation probability model) governs whether the given frequency is a zero or a positive number. The second part of the distribution then takes care of the positive frequency. Both parts of the model are used to make full use of the data with excess zeros. The model was computed using the ***brms*** package on the open-source program "**R**".

The probability distribution of the ZINB random variable y_i (NCSS, 2018) is:

$$Pr(y_i = j) = \begin{cases} \pi_i + (1-\pi_i)\, g(y_i = 0), & if\ j = 0 \\ (1-\pi_i)\, g(y_i), & if\ j > 0 \end{cases} \tag{1}$$

where π_i is the proportion of true zeros that cannot be explained by the NB model, and $g(y_i)$ follows the negative binomial distribution as:

$$g(y_i) = Pr\big(Y = y_i \mid \mu_{i,}\, \alpha\big) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(\alpha^{-1})\,\Gamma(y_i + 1)} \left(\frac{1}{1+\alpha\mu_i}\right)^{\alpha^{-1}} \left(\frac{\alpha\mu_i}{1+\alpha\mu_i}\right)^{y_i} \tag{2}$$

where μ_i is the mean crash frequency, and α is the over-dispersion parameter. The basic form of the NB regression model used in this study is:

$$\mu_i = exp\left(\beta_0 + \beta_1 \times ln\, AADT_i + \ldots + \beta_k \times X_{ik} + OFFSET\right) \tag{3}$$

where,

μ_i	=	crash frequency on a road section *i*,
$AADT_i$	=	average annual daily traffic on a road section *i* (vehicle/day),
X_{ik}	=	roadway characteristic *k* of road section *i*,
β_0	=	model intercept/constant,
$\beta_1, \beta_2\ldots, \beta_k$	=	model coefficients, and
$OFFSET_i$	=	ln (5× (segment length)) for segments to predict crash frequency in crashes per mile. The number 5 was used since the analysis period was five years.

Variable Correlation

Correlation among model variables leads to inaccurate estimates of the coefficients for the highly correlated variables. Correlation analysis is a statistical method used to evaluate the strength of the relationship among the variables. A high correlation means that two or more variables have a strong relationship with each other, while a weak correlation means that the variables are hardly related. The equation of the correlation coefficient between two variables is as shown below:

$$\rho_{XY} = \frac{\mathrm{cov}(X,Y)}{\sqrt{Var(X)\cdot Var(Y)}} \tag{4}$$

where,

ρ_{XY}	= correlation coefficient between two datasets X and Y,
$\text{cov}(X,Y)$	= covariance of two dataset X and Y,
$Var(X)$	= variance of X, and
$Var(Y)$	= variance of Y.

Prior to developing the ZINB regression models, all the variables were checked for correlation. Figure 5-2 presents the results of the correlation analysis. Highly correlated variables were not included in the final model. The cut-off for correlation was 0.5 (Dissanayake and Roy, 2014; Kitali et al., 2018). The presence of median, surface width, functional class, and number of lanes were highly correlated with AADT, and hence AADT was retained in the final model to account for all these variables. The final model was then developed using the remaining 13 variables.

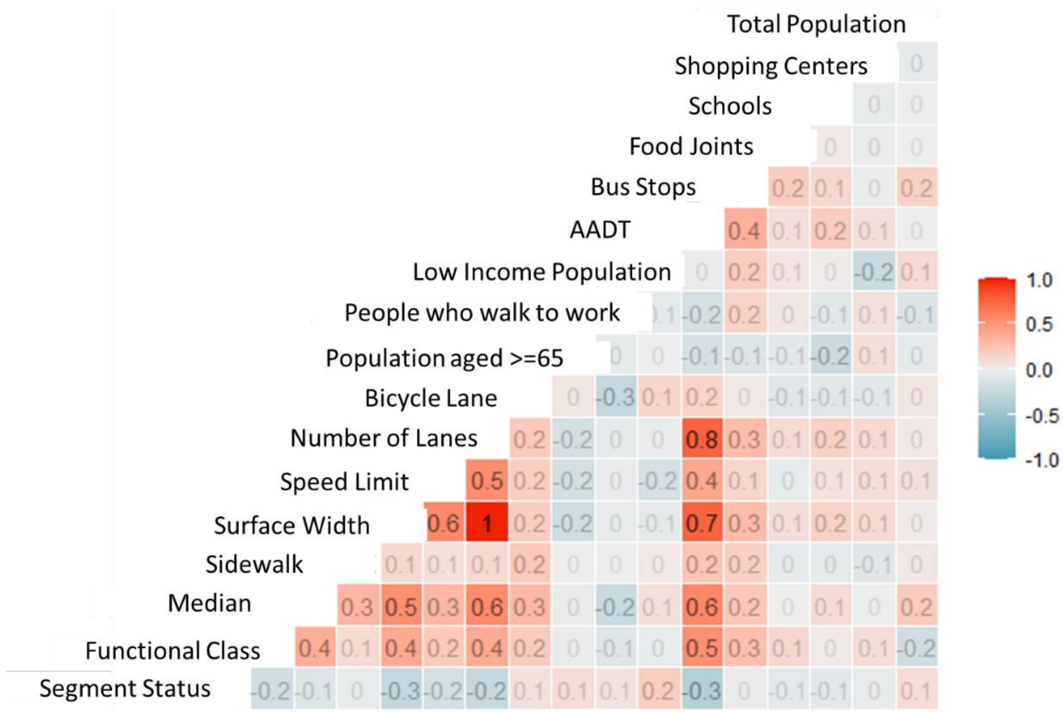


Figure 5-2: Correlation Matrix

5.5 Results

5.5.1 SPFs

The model results indicate that the natural logarithm of AADT; proportion of low-income population; proportion of seniors; density of bus stops, density of bars and food joints; density of shopping centers; and the natural logarithm of the total population were significant at 90% credible interval. Table 5-11 summarizes the coefficients, estimate errors, and credible intervals for all variables in the ZINB model. Base categories are shown in bold font. The model coefficients indicate the change in the frequency of pedestrian crashes as a result of a unit change in the variables. The variables with positive coefficients are associated with an increase in pedestrian crash frequency while negative coefficients indicate a reduction in pedestrian crash frequency.

Table 5-11: ZINB Model Results

Variable	Category	Coefficient	Estimate Error	90% CI Lower Limit	90% CI Upper Limit
Intercept		-14.31	4.00	-20.9	-7.88
Segment*	**Comparison**				
	Treatment	-0.2	0.36	-0.77	0.39
Sidewalk*	No	0.97	1.14	-0.92	2.78
	One Side	-0.08	0.38	-0.7	0.55
	Both Sides				
Speed Limit*	≤ 30 mph	0.07	0.51	-0.77	0.9
	35 mph				
	≥ 40 mph	-0.67	1.77	-3.17	2.36
Presence of Bicycle Lane*	No	-0.21	0.32	-0.73	0.3
	One Side	0.11	0.47	-0.65	0.89
	Both Sides				
Proportion of Senior Population	**0 to 0.2**				
	0.2 to 0.6	-0.61	0.29	-1.09	-0.15
Proportion of People Who Walk to Work*	**0 to 0.01**				
	0.01 to 0.09	0.15	0.33	-0.38	0.68
Proportion of Population with Annual Income < 10 K	**0 to 0.03**				
	0.03 to 0.1	0.78	0.30	0.28	1.27
Natural Logarithm of AADT		1.44	0.39	0.81	2.09
Bus Stops Density		0.09	0.02	0.06	0.13
Bars & Food Joints Density		0.03	0.02	0	0.06
Schools Density*		-0.05	0.04	-0.12	0.02
Shopping Centers Density		0.12	0.05	0.04	0.19
Natural Logarithm of Total Population		-0.31	0.14	-0.54	-0.09

Note: CI – Credible Interval; *Variable is not significant at 90% credible interval. Bold categories indicate base variables.

The pedestrian crash frequency at midblock segments seemed to increase with a higher density of bus stops shown by a positive coefficient in Table 5-11. Bus stops were used in the analysis as a proxy for pedestrian activities. The presence of bus stops shows that people walk to and from the bus stops to access transit services. This increases the exposure of pedestrians to traffic and hence the probability of occurrence of pedestrian crashes. Similarly, the density of bars and food joints, as well as shopping centers, increased the frequency of pedestrian crashes on the analyzed segments. Previous research also found similar patterns in terms of bus stop density and land-use variables (Xie et al., 2017). Of the three variables, shopping centers had the highest positive influence on pedestrian crashes.

Higher traffic volume also indicated a higher frequency of pedestrian crashes in District Four. AADT was positively correlated with the number of lanes, the presence of median, surface width, and the roadway functional classification. All these geometric variables indicate increased exposure and hence an increased risk of pedestrian crashes.

The larger the proportion of the low-income population (i.e., annual household income less than 10K) the greater the frequency of pedestrian crashes. This implies that in low-income neighborhoods, more people tend to walk increasing the chances of being hit by a motor vehicle. Areas with a higher proportion of seniors (aged 65 and above) indicated lower frequencies of pedestrian crashes. Also, the results show that more pedestrian crashes tend to happen in areas with relatively low population density. However, this surprising trend could be attributed to the fact that the study region (District Four) is along the eastern coast of Florida. This location is a tourist destination hence the pedestrian activities do not necessarily reflect the population of the residents.

5.5.2 CMFs

CMFs from the cross-sectional analysis are calculated by taking the exponent of the coefficient of the variables of interest in the regression models (Lee et al., 2020; Raihan et al., 2019). Table 5-12 gives the results for CMFs of the significant variables for the pedestrian crashes based on the SPFs presented in Table 5-11. A CMF value of 1.0 represents no effect on the pedestrian crashes, while CMF above 1.0 indicates an increase in the frequency of crashes and a CMF below 1.0 indicates that the variable reduces the pedestrian crash frequency. Of the seven variables that were significant at 90% credible interval, the higher proportion of seniors and the total population were found to reduce pedestrian crash frequency by 46% and 27%, respectively. The rest of the variables with positive coefficients increased the chances of pedestrian crashes.

The focus of this research was to investigate whether the presence of a pedestrian crosswalk (and /or other pedestrian treatments) at midblock locations improved pedestrian safety. The variable ‘segment’ was used to characterize the study corridors. The midblock locations with crosswalks were identified as “treatment” sites while those without any midblock pedestrian treatments were identified as “comparison” sites. Although not significant at 90% credible interval, the status of the segment (i.e., with treatment or without treatment) had a negative coefficient and a median value for the CMF of 0.82 indicating an 18% reduction in pedestrian crashes. The probability of having the CMF for pedestrian midblock crosswalk less than 1.0 is 71%, as shown in Figure 5-3. This implies that having a crosswalk at the midblock location has a 71% probability of reducing crashes.

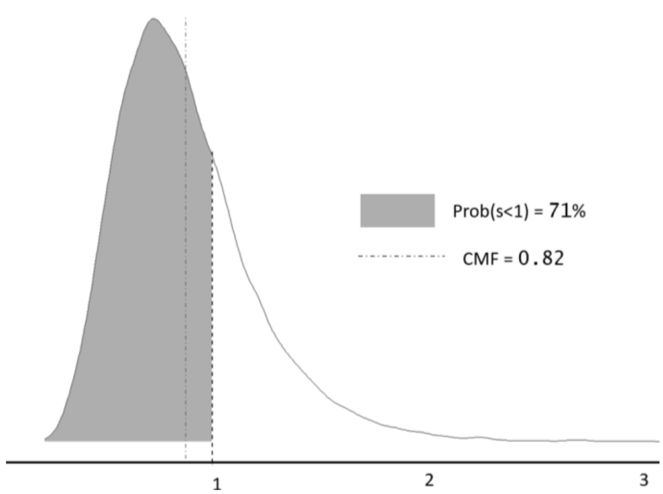


Figure 5-3: Probability Plot for Segment Treatment CMF

Table 5-12: Crash Modification Factors (CMFs)

Variable	Category	Coefficient	CMF
Segment*	Comparison		
	Treatment	-0.2	0.82
Proportion of Senior Population	**0 to 0.2**		
	0.2 to 0.6	-0.61	0.54
Proportion of Population with Annual Income < $10 K	**0 to 0.03**		
	0.03 to 0.1	0.78	2.18
Natural Logarithm of AADT		1.44	4.22
Bus Stops Density		0.09	1.09
Bars & Food Joints Density		0.03	1.03
Shopping Centers Density		0.12	1.13
Natural Logarithm of Total Population		-0.31	0.73

*Variable is not significant at 90% credible interval.

5.6 Summary

This chapter analyzed the safety of midblock segments and developed the CMFs for different geometric, land use, and census variables. The modeling results identified several variables that impact pedestrian crash occurrence at midblock locations.

The following variables were found to increase the frequency of pedestrian crashes and were significant at a 90% credible interval:

- natural logarithm of AADT,
- proportion of the low-income population,
- density of bus stops,
- density of bars and food joints,
- density of shopping centers, and

The following variables were found to reduce the frequency of pedestrian crashes and were significant at a 90% credible interval:

- proportion of senior population, and
- logarithm of the total population.

CHAPTER 6
GUIDELINES FOR INSTALLING PEDESTRIAN TREATMENTS AT MIDBLOCK LOCATIONS

This chapter focuses on developing guidelines for identifying corridors to install pedestrian treatments and selecting the most appropriate pedestrian safety treatment at midblock locations. In this chapter, the guidelines were developed based on (a) the extensive review of the existing national, state, and local warrants and guidelines pertaining to installing pedestrian safety treatments at midblock locations; and (b) the results for the different factors influencing the safety of pedestrians at midblock locations. Note that Chapter 2 focused on the review of existing guidelines, while Chapter 5 discussed the factors affecting pedestrian crashes at midblock locations in FDOT District Four. This chapter presents the criteria and discusses the proposed guidelines to consider when assessing whether a location is appropriate for installing midblock pedestrian treatments. The chapter is divided into the following sections:

- Section 6.1 provides a brief background of the general guidelines.
- Section 6.2 discusses the factors influencing pedestrian safety at midblock locations.
- Section 6.3 describes the criteria and considerations for installing pedestrian treatments.
- Section 6.4 presents the steps to follow based on the developed guidelines and the analysis of sample midblock locations.
- Section 6.5 gives the chapter summary.

6.1 General Guidelines

Midblock pedestrian crossings provide a safe passage for pedestrians crossing from one side of the roadway to another. Locations with significant pedestrian activity and no pedestrian treatments may be subjected to jaywalking, resulting in pedestrian safety issues. Therefore, a careful assessment is necessary to identify midblock locations that are critical and require pedestrian treatments to be installed to improve pedestrian safety.

Several states and local jurisdictions, including the City and County of Denver, Colorado; Minnesota; Florida; North Carolina; and Virginia, have developed guidelines to determine if a midblock location is suitable for installing a marked crosswalk. Criteria are based on guidelines contained in the manuals, including the local design manuals, the MUTCD, the HCM, and the AASHTO's A Policy on Geometric Design for Highways and Streets (CCD, 2016; MnDOT, 2014; FDOT, 2020; NCDOT, 2015; VDOT, 2016).

The MUTCD states that an engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign. The engineering study should consider the number of lanes, the presence of a median, the distance from adjacent signalized intersections, the pedestrian volumes and delays, the average daily traffic (ADT), the posted or statutory speed limit or 85^{th} percentile speed, the geometry of the location, the possible consolidation of multiple crossing points, the availability of street lighting, and other appropriate factors (FHWA, 2012).

To evaluate potential midblock crosswalk locations and determine if a marked crosswalk is warranted, FDOT follows the procedure outlined in the FDOT Traffic Engineering Manual (TEM), Section 5.2. The goal can be to improve either the safety or mobility (e.g., reduce pedestrian crashes, reduce delay) of pedestrians. The FDOT TEM Section 5.2: '*Marked pedestrian crosswalks at midblock and uncontrolled approach locations'* provides the criteria for installing marked pedestrian crosswalks for midblock locations and unsignalized intersections. The manual identifies the documented pedestrian demand and distance to the nearest intersection to be among the general considerations for installing the crosswalks (FDOT, 2020).

6.2 Factors Influencing Pedestrian Safety

The factors are based on the safety analysis results for the midblock locations in FDOT District Four. The increase in the following variables showed an increase in the pedestrian crash frequency, and the variables were significant at a 90% credible interval:

- natural logarithm of AADT,
- proportion of the low household income population,
- density of bus stops,
- density of bars and food joints, and
- density of shopping centers.

The increase in the *proportion of senior population* and *logarithm of the total population* showed a reduction in pedestrian crashes, and were significant at a 90% credible interval.

6.3 Criteria for Developing the Guidelines

Determining whether a location qualifies for installing a midblock pedestrian treatment requires considerable evaluation. Several factors may influence not only the location but also the selection of pedestrian treatments. This section discusses various factors that should be considered when evaluating potential midblock pedestrian treatment locations. The goal of this research was to develop guidelines for:

- identifying corridors for installing midblock pedestrian treatments and
- selecting the most appropriate pedestrian safety treatment at midblock locations.

FDOT District Four is located on the east coast of Florida. This geographical location is characterized by tourist activities attracting a relatively high pedestrian population. Assessment for installing pedestrian countermeasures should therefore consider the different attractors and generators of pedestrians along the corridors. The process of identifying corridors for installing pedestrian treatments involved a review of various local and state guidelines as well as a safety analysis to determine factors influencing pedestrian crashes at midblock locations in District Four. After determining that a location is eligible for installing pedestrian treatments, the second step was to identify the type of countermeasure to be installed. Pedestrian treatments with high visibility crosswalk markings and pedestrian signage may be enhanced to involve CRFBs, RRFBs, PHBs, and TS that control vehicles at midblock crossings. The choice of which enhancement to incorporate is governed by several factors, including geometric features, traffic characteristics, safety considerations, etc.

There was not enough sample size to analyze all the different types of pedestrian treatments in District Four. As a result, no specific factors influencing different types of pedestrian countermeasures were identified. However, the MUTCD could be referred to for the guidelines for installing pedestrian signals and pedestrian hybrid beacons. The MUTCD provides guidance on the installation of pedestrian hybrid beacons for major streets and warrants for the installation of pedestrian signals. The TEM Section 5.2.5 provides guidance on the selection of traffic control signals and PHBs in addition to a marked pedestrian crosswalk at midblock locations. Engineering judgment should be exercised to determine the location of the crosswalk on midblock segments. These may include locations connecting the pedestrian generators and attractors (e.g., bus stops, restaurants, shops, etc.) so that people do not have to walk long distances to their destinations after crossing. This may reduce the tendency of jaywalking.

6.4 Guidelines for Installing Midblock Pedestrian Treatments

Locations within the identified pedestrian crash hotspot locations may require immediate safety intervention to improve pedestrian safety. From an inventory of midblock locations within the study area or along a specific corridor, the analyst can select a potential location for installing a pedestrian crosswalk. The following criteria were developed to assess if a location qualifies for the installation of a pedestrian crosswalk:

- the distance of the potential midblock location from established crossing points such as a signalized intersection,
- traffic volume, i.e., AADT,
- pedestrian activities or pedestrian counts (i.e., facilities directly serving schools, hospitals, parks, bus stops, large apartment complexes, commercial areas, etc.)
- posted speed limits,
- configuration of the roadway (e.g., number of lanes and presence of median),
- pedestrian crash hotspots, and
- level of household income of the population.

6.4.1 Discussion on the Guidelines

Figures 6-1 (a) through 6-1 (c) present flowcharts to guide the assessment of a potential location for installing a pedestrian crossing treatment at a midblock location. The proposed assessment should be done by following the flowcharts starting with Chart #1. For each midblock location, the developed guidelines could be used to reach one of the following conclusions:

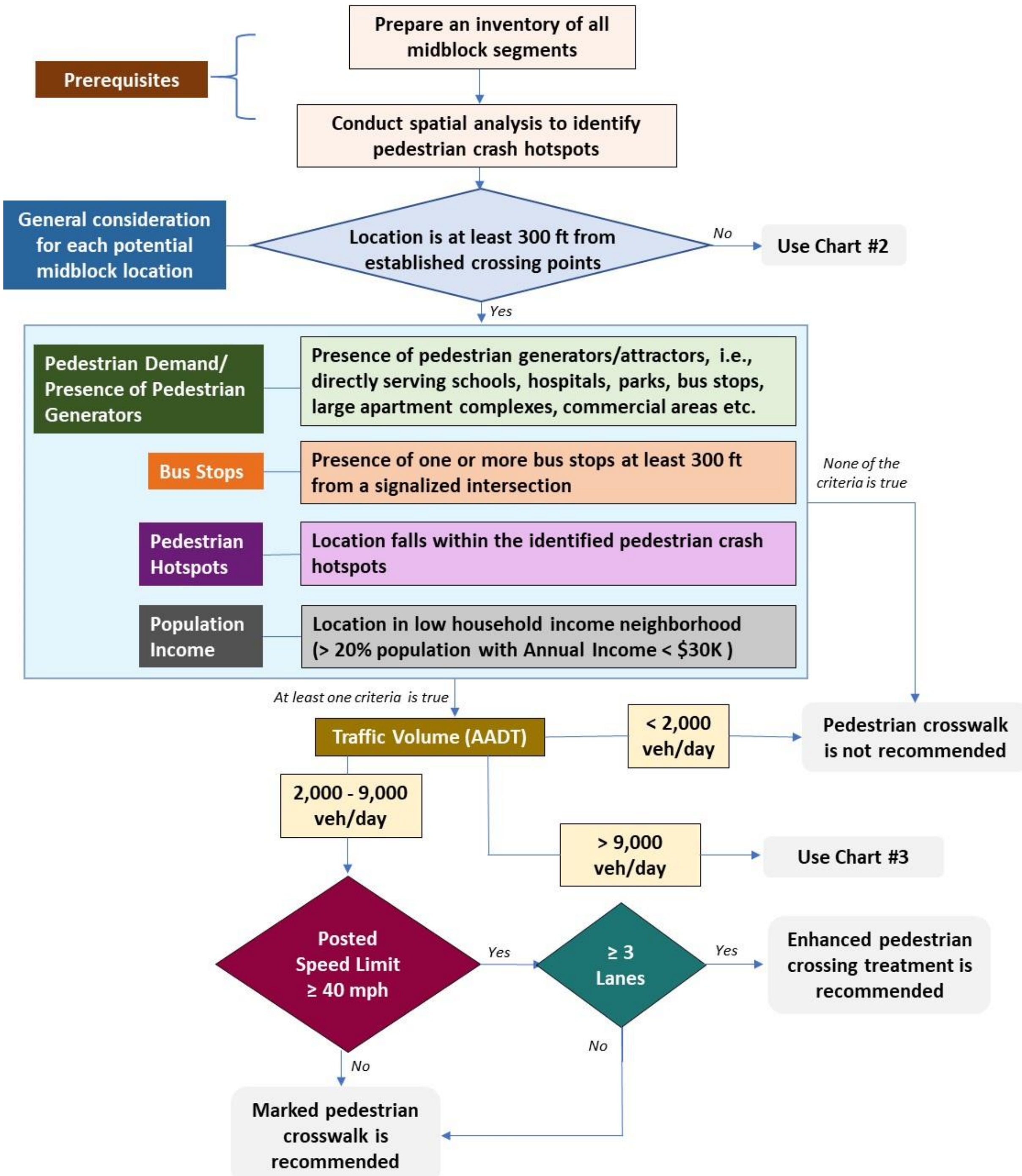
a) *No pedestrian crossing treatment is recommended.*

b) *No pedestrian crossing treatment is recommended, but longitudinal pedestrian barriers may be needed.* Longitudinal pedestrian barriers may be considered to prevent people from jaywalking and guiding them to a nearby crosswalk.

c) *A pedestrian marked pedestrian crosswalk is recommended.* In this context, a marked pedestrian crosswalk is any pedestrian crossing by pavement marking lines on the surface, which might be supplemented by contrasting pavement structure, style, or color (FDOT, 2020). The marked pedestrian crosswalk may be accompanied by the overhead pedestrian signs, in-street pedestrian signs, or flashing beacons to provide additional emphasis on the marked crosswalk and the presence of pedestrians.

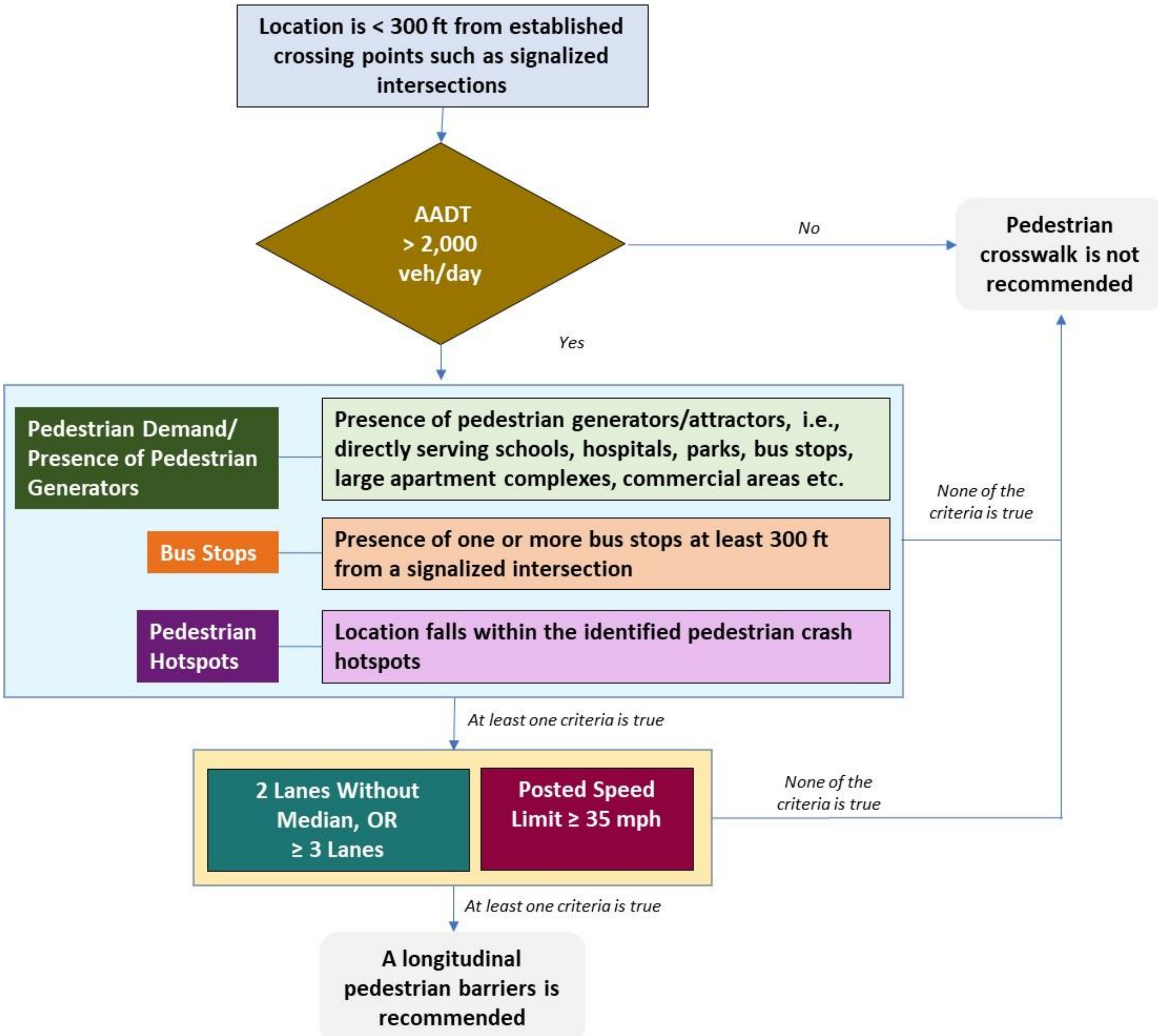
d) *An enhanced pedestrian crossing treatment is recommended.* Enhanced pedestrian crosswalks include RRFBs, PHBs, flashing signal beacons, or traffic signals. These enhanced treatments are explained in detail in Section 2.3.4 of this report.

The choice to enhance the pedestrian crosswalk may also be determined based on the crash history of the location and if the given enhancements will not interfere with traffic flow or result in more safety issues as determined by the conducted studies. The decisions reached by following the proposed guidelines should not be final. Depending on other considerations, including the availability of funds, locations may be prioritized. Before installing the midblock pedestrian crossing treatments, an engineering study and benefit-to-cost analysis are recommended to determine the impact of these installations.

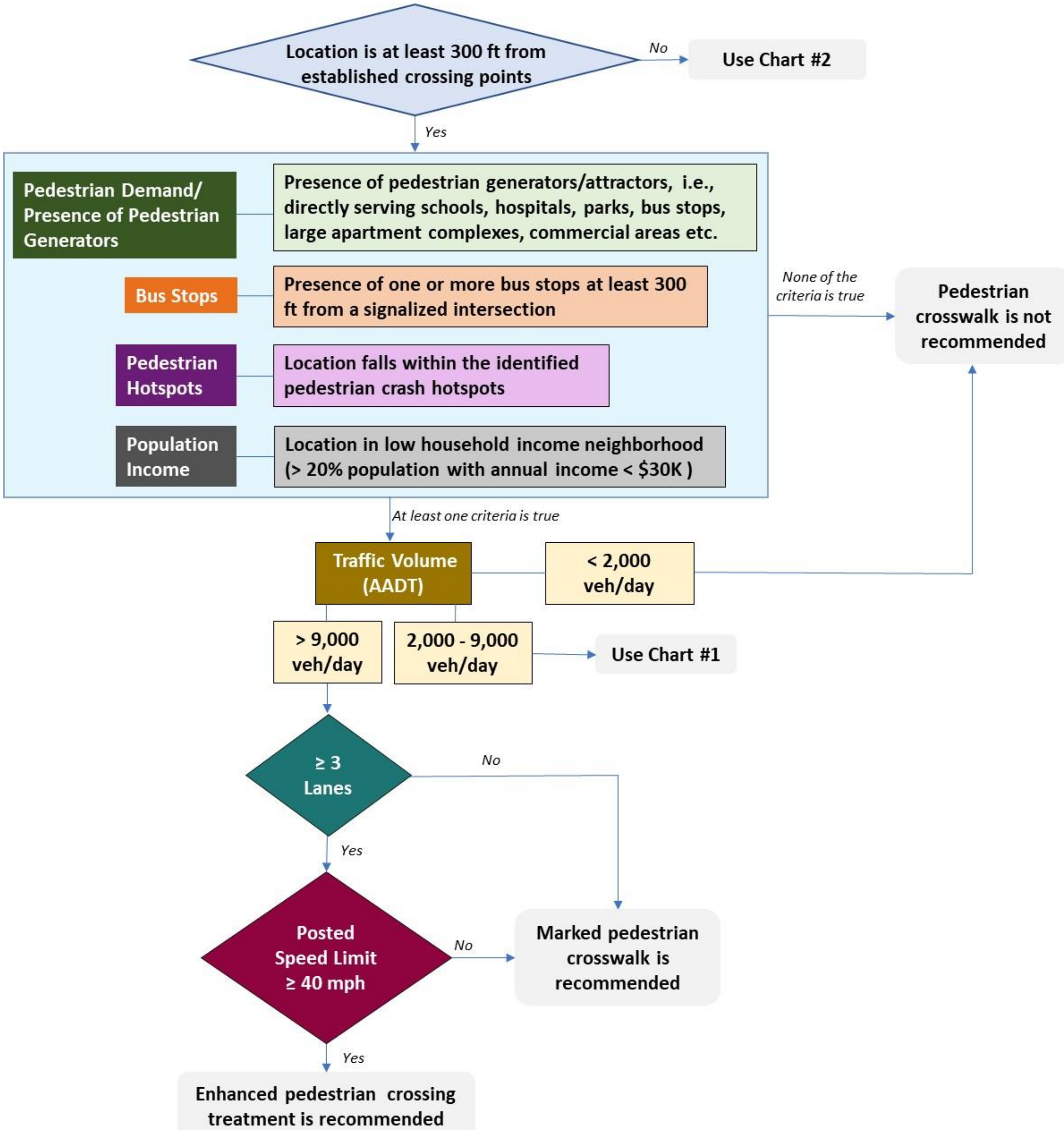


Prerequisites
Prepare an inventory of all midblock segments
Conduct spatial analysis to identify pedestrian crash hotspots
General consideration for each potential midblock location
Location is at least 300 ft from established crossing points
No
Use Chart #2
Yes
Pedestrian Demand/ Presence of Pedestrian Generators
Presence of pedestrian generators/attractors, i.e., directly serving schools, hospitals, parks, bus stops, large apartment complexes, commercial areas etc.
Bus Stops
Presence of one or more bus stops at least 300 ft from a signalized intersection
Pedestrian Hotspots
Location falls within the identified pedestrian crash hotspots
Population Income
Location in low household income neighborhood (> 20% population with Annual Income < $30K)
None of the criteria is true
At least one criteria is true
Traffic Volume (AADT)
< 2,000 veh/day
Pedestrian crosswalk is not recommended
2,000 - 9,000 veh/day
> 9,000 veh/day
Use Chart #3
Posted Speed Limit ≥ 40 mph
Yes
≥ 3 Lanes
Yes
Enhanced pedestrian crossing treatment is recommended
No
No
Marked pedestrian crosswalk is recommended

(a) Chart #1


Location is < 300 ft from established crossing points such as signalized intersections
AADT
> 2,000
veh/day
No
Pedestrian crosswalk is not recommended
Yes
Pedestrian Demand/ Presence of Pedestrian Generators
Presence of pedestrian generators/attractors, i.e., directly serving schools, hospitals, parks, bus stops, large apartment complexes, commercial areas etc.
Bus Stops
Presence of one or more bus stops at least 300 ft from a signalized intersection
Pedestrian Hotspots
Location falls within the identified pedestrian crash hotspots
None of the criteria is true
At least one criteria is true
2 Lanes Without Median, OR ≥ 3 Lanes
Posted Speed Limit ≥ 35 mph
None of the criteria is true
At least one criteria is true
A longitudinal pedestrian barriers is recommended

(b) Chart #2



(c) Chart #3

Figure 6-1: Flowcharts of the Developed Guidelines

6.4.2 Analysis of Sample Locations

The developed guidelines were used to determine the need for pedestrian treatments at a sample of 202 midblock locations in FDOT District Four using the proposed criteria. Table 6-1 provides the descriptive statistics of the number of locations for each criterion. An Excel file of the locations with their decisions is submitted as part of this report.

Table 6-1: Frequency Distribution of the locations for Each Criterion

Criteria		Frequency	%
Location	< 300 ft from a signalized intersection	27	13
	≥ 300 ft from a signalized intersection	175	87
AADT	≤ 2,000 veh/day	0	0
	2,000 – 9,000 veh/day	5	2
	≥ 9,000 veh/day	197	98
Pedestrian Activities	No pedestrian generators and attractors	37	18
	Presence of pedestrian generators and attractors	165	82
Bus Stops	No bus stop	54	27
	One bus stop	34	17
	More than one bus stop	114	56
Posted Speed Limit	≤ 35 mph	130	64
	≥ 40 mph	72	36
Roadway Configuration	2 lanes with a median	23	11
	2 lanes without median	42	21
	3 or more lanes with or without median	137	68
Pedestrian Crash Hotspots	Outside top-ranked hotspots	171	85
	Within top-ranked hotspots	31	15
Low-Income Neighborhood	< 20% population with Annual Household Income < $ 30K	197	98
	> 20% population with Annual Household Income < $ 30K	5	2

Each of the 202 midblock segments was located between two signalized intersections. The assessment was conducted with an assumption that did not consider other crosswalks on stop signs or driveways along the segments. In the event that there is another crosswalk other than the ones at the signalized intersections, then the results from this analysis may be used to confirm the presence and type of pedestrian crossing treatment installed. The assumption was that the pedestrian crosswalk would be installed to allow at least 300 ft from either of the two signalized intersections. When conducting an assessment, the analyst is expected to have a specific potential location for installing the pedestrian crossing treatment. A proposed crossing location that falls between 100 and 300 feet from other established crossing points is further evaluated using Chart # 2 to determine if the longitudinal pedestrian barriers are recommended.

The FDOT TEM (FDOT, 2020) suggests installing marked pedestrian crosswalks to midblock segments with a minimum vehicular volume of 2,000 veh/day ADT. In the proposed guidelines, the assumption was that the seasonal correction factor is 1, i.e., the AADT is 2,000 veh/day. No pedestrian crosswalk was proposed for segments with less than 2,000 veh/day. Segments with AADT 2,000 – 9,000 veh/day are analyzed based on the criteria presented in Chart #1, while those with AADT >9,000 veh/day are analyzed based on the criteria presented in Chart #3. Segments with low traffic volumes are expected to have more gaps for pedestrians to cross the roadways safely.

Surrounding land-use data and pedestrian traffic generators/activity areas were used to determine the level of pedestrian activity, and as a proxy for pedestrian volume. These data were identified within a 0.25-mile radius. The information included the presence of bars, food joints, schools, and shopping centers. The pedestrian demand may also be generated when the roadway is directly serving these locations. For example, if there is an apartment complex on one street and a restaurant across the street, it is safe to assume that pedestrians will cross the street to access the services. On the other hand, a shopping mall may not be directly serving pedestrian traffic to the state road. Pedestrian counts at the potential location, when available, may provide the basis for decisions following the guidelines in FDOT TEM Section 5.2.

The presence of bus stops was among the criteria considered. People access transit services by walking, so it is critical to provide pedestrian facilities in the vicinity of bus stops. The assessment was conducted to determine if there was a bus stop(s) along the segments. Some segments had more than one bus stop indicating more pedestrian activities. When analyzing a potential location, it is recommended to determine if there is any crosswalk within 300 ft of the bus stop. Some bus stops are located in the immediate vicinity of signalized intersections; in such situations, other countermeasures such as physical barriers may be deployed if there is a pedestrian safety problem.

Higher posted speed limits indicate a possible increase in pedestrian crash risk. Based on the reviewed existing guidelines, the posted speed limit was grouped into two categories: ≤ 35 mph and ≥ 40 mph. Since the analyzed segments were on non-limited access facilities on the state highway system, the posted speed limits were ≤ 55 mph.

Another criterion was the roadway geometric configuration, and it includes the following four categories: two-lane divided roadways, two-lane undivided roadways, divided roadways with ≥ 3 lanes, and undivided roadways with ≥ 3 lanes. The presence of a median provides a refuge for pedestrians to cross the roadway in stages. The greater the number of lanes, the more difficult it becomes to find gaps, especially for high-speed roadways with high AADT.

The analyzed locations were grouped on whether or not they fall within the top 20 hotspot locations (identified in Chapter 4). Only 15% of the midblock segments were found within the top 20 hotspots. Locations in low-income neighborhoods are associated with a high risk of pedestrian crashes. The annual household income of below $ 30K was used to define the low-income population.

Table 6-2 provides a summary of results for the 202 midblock locations that were analyzed. No crosswalk was recommended at 55 locations; the pedestrian barriers were recommended at 17 of these 54 locations. Crosswalks were recommended at the remaining 148 locations; enhanced pedestrian crossings treatment was recommended at 48 of these 148 locations. Further studies may be conducted to account for other factors that may affect the installation of recommended pedestrian crossing for the identified candidate locations.

Table 6-2: Recommended Decisions for the Sample Analyzed Locations

Decision	Count of Locations	%
No pedestrian crosswalk (Barrier recommended for 17 locations)	54	27%
Install pedestrian crosswalk	100	50%
Install an enhanced pedestrian crosswalk	48	23%

6.5 Summary

This chapter presented a set of guidelines to follow when considering a midblock location for installing a pedestrian crosswalk. Based on the results presented in Chapter 5 for the different factors influencing the safety of pedestrians at midblock locations coupled with considerations from different guidelines nationwide, several guidelines were developed.

The assessment procedure was presented in the form of a flow chart and covered the following criteria:

- the distance of the potential location from established crossing points,
- AADT,
- pedestrian activities,
- posted speed limit,
- configuration of the roadway,
- pedestrian crash hotspots, and
- low-income neighborhood.

The developed guidelines will enable the practitioners to identify corridors for installing pedestrian treatments based on the roadway characteristics, traffic volume, land use characteristics, and the built environment.

CHAPTER 7
SUMMARY AND CONCLUSIONS

Pedestrian-vehicle crashes have continued to impact several states in the U.S., including Florida. Florida was ranked among the top three states in the U.S. for pedestrian fatalities in 2019 (Retting, 2020). Crashes involving pedestrians can occur at any point along a roadway corridor. However, intersection and midblock crossings are the primary sites for pedestrian incidents. People are more likely to take the most direct route to get to their destination, and as a result, they often cross roadway facilities at midblock locations. The goal of this study was to improve pedestrian safety at midblock locations. The specific objectives included (a) identifying arterial corridors that are prone to pedestrian crashes, (b) recommending pedestrian treatments to be installed at these locations, and (c) developing guidelines to assist in selecting the midblock locations and pedestrian treatments for improving pedestrian safety.

To achieve the research goal and objectives, an extensive review of the literature on the existing national, state, and local warrants and guidelines pertaining to installing pedestrian safety treatments at midblock locations was first conducted. The demographic, socioeconomic, land-use, traffic, and roadway geometric variables that affect pedestrian safety were next identified. Spatial analysis was performed in ArcGIS to identify pedestrian crash hotspots in FDOT District Four. ZINB models were then developed and CMFs were estimated to quantify the impact of several roadway geometric, land use, and socioeconomic variables on pedestrian crashes at midblock locations. Finally, based on the available guidelines at the national and state levels, the pedestrian crash hotspots, and the estimated CMFs, guidelines for developed for: (a) identifying corridors for installing pedestrian treatments, and (b) selecting the most appropriate pedestrian safety treatment.

7.1 Existing Guidelines

Installing marked midblock crosswalks is essentially a two-part process. First, candidate locations must be evaluated to determine if a midblock crosswalk is warranted. The evaluation process involves several steps, with pedestrian volume, traffic volume, posted speed, crash history, and the distance from other established crossing points used as the primary factors. However, other factors must also be considered, such as pedestrian generators and attractors, pedestrian age and ability, roadway geometrics, etc. Following the identification of a suitable location, the type and scope of pedestrian treatments must then be determined. There are several treatment options for both controlled and uncontrolled crosswalks, and most state and local transportation agencies refer to national guidelines.

7.2 Factors Influencing Pedestrian Safety at Midblock Locations

The following variables were considered to influence pedestrian crashes at midblock locations and were included in the analysis:

- Pedestrian Crash Data
  - Crash severity
  - Crash time
  - Crash month

- Day of the week
  - Crash location
  - Influence of alcohol/drugs
  - Lighting condition

- Roadway Geometric Characteristics
  - Traffic volume
  - Number of lanes
  - Median
  - Signalized intersections

- Land use Variables
  - Shopping centers
  - Hotels
  - Recreation facilities
  - Restaurants and bars

- Socioeconomic and Demographic Variables
  - Population
  - Income level
  - Transportation mode

- Pedestrian Facilities
  - Presence of sidewalk

- Bus Stops
  - Number of bus stops

7.3 Pedestrian Crash Hotspots

GIS-based spatial clustering analysis was used to identify pedestrian crash hotspots in FDOT District Four. The EPDO weighting method was used to calculate the EPDO score of candidate crash hotspots based on injury severity weighting. The analysis was based on five years of pedestrian crash data from 2012-2016 downloaded from the FDOT UBR. Since the scope of this research project is limited to non-limited access facilities, the analysis did not include pedestrian crashes that occurred on freeways. The analysis of pedestrian crashes within the 20 hotspots led to the following conclusions:

- Pedestrian crashes peaked between 7 pm and 9 pm. Overall, the most critical time was found to be from 6 pm to midnight.
- The proportion of pedestrian crashes on Fridays and Saturdays was relatively higher than the other days of the week.
- Even though more pedestrian crashes occurred during daylight conditions, more severe crashes occurred during dark-lighted conditions.
- A majority of pedestrian crashes (93.5%) occurred during good weather conditions.

- A higher proportion of pedestrian crashes occurred at corridors with speed limits ranging from 35-40 mph.
- A majority of midblock locations where the pedestrian crashes occurred were found to have sidewalks (99.5%) and street lighting (91.4%). On the other hand, the pedestrian crossing facilities were found to be rare; only 9.1% of locations had crosswalks, and 10.1% had pedestrian signals.

7.4 CMFs

The analysis was conducted to evaluate the safety of midblock segments and develop the crash modification factors for different geometric, land use, and census variables. The modeling results identified several variables that impact pedestrian crash occurrence at midblock locations. The increase in the following variables showed an increase in the pedestrian crash frequency and were significant at a 90% credible interval:

- natural logarithm of AADT,
- proportion of the low-income population,
- density of bus stops,
- density of bars and food joints, and
- density of shopping centers.

The increase in the following variables showed a reduction in pedestrian crashes and were significant at a 90% credible interval:

- proportion of senior population, and
- logarithm of the total population.

7.5 Guidelines

Based on the different factors influencing the safety of pedestrians at midblock locations coupled with considerations from various guidelines nationwide, a set of guidelines were developed to assist transportation agencies in identifying corridors for installing midblock pedestrian treatments and selecting the most appropriate pedestrian safety treatment at midblock locations. The developed guidelines will enable the practitioners to identify corridors for installing pedestrian treatments based on the roadway characteristics, traffic volume, land use characteristics, and the built environment. The assessment procedure was presented in the form of flowcharts and covered the following criteria:

- the distance of the potential location from established crossing points,
- AADT,
- pedestrian activities,
- posted speed limit,
- configuration of the roadway,
- pedestrian crash hotspots, and
- low-income neighborhood.

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APPENDIX A: TCRP and NCHRP Report Guidelines

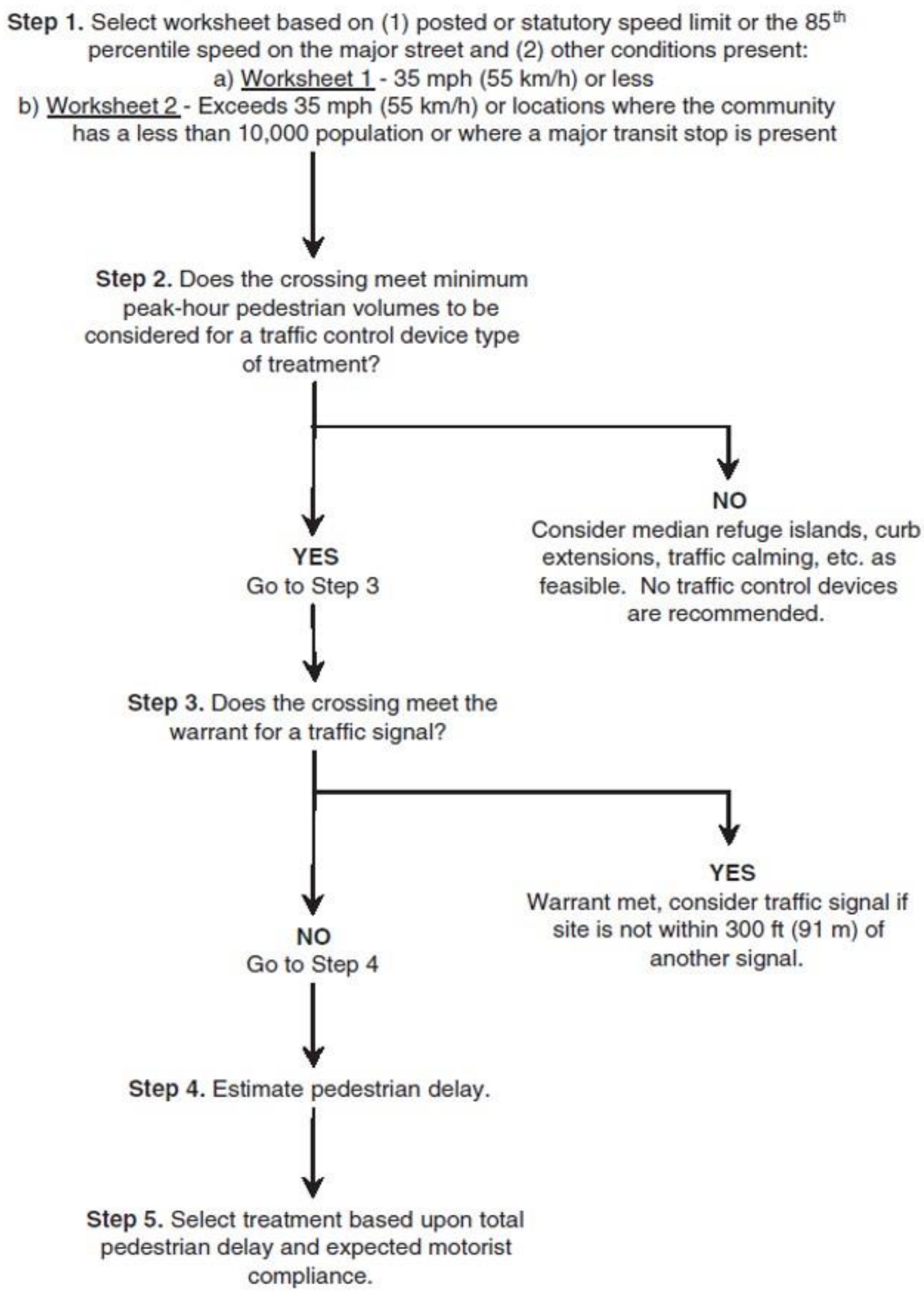


Figure A-1: TCRP and NCHRP Report Guidelines Flowchart for Pedestrian Treatments
(Source: NASEM, 2006)

WORKSHEET 1: PEAK-HOUR, 35 MPH (55 KM/H) OR LESS

Analyst and Site Information	
Analyst: Analysis Date: Data Collection Date:	Major Street: Minor Street or Location: Peak Hour:

Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85th percentile speed on the major street): a) Worksheet 1 – 35 mph (55 km/h) or less b) Worksheet 2 – exceeds 35 mph (55 km/h), communities with less than 10,000, or where major transit stop exists		
Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a TCD type of treatment?		
Peak-hour pedestrian volume (ped/h), V_p	*2a*	
If *2a* ≥ 20 ped/h, then go to Step 3.		
If *2a* < 20 ped/h, then consider median refuge islands, curb extensions, traffic calming, etc. as feasible.		
Step 3: Does the crossing meet the pedestrian volume warrant for a traffic signal?		
Major road volume, total of both approaches during peak hour (veh/h), $V_{maj\text{-}s}$	*3a*	
Minimum signal warrant volume for peak hour (use *3a* for $V_{maj\text{-}s}$), SC $SC = (0.00021\ V_{maj\text{-}s}^2 - 0.74072\ V_{maj\text{-}s} + 734.125)/0.75$ OR $[(0.00021\ 3a^2 - 0.74072\ 3a + 734.125)/0.75]$	*3b*	
If *3b* < 133, then enter 133. If *3b* ≥ 133, then enter *3b*.	*3c*	
If 15th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce *3c* by up to 50 percent; otherwise enter *3c*.	*3d*	
If *2a* ≥ *3d*, then the warrant has been met and a traffic signal should be considered if not within 300 ft (91 m) of another traffic signal. Otherwise, the warrant has not been met. Go to Step 4.		
Step 4: Estimate pedestrian delay.		
Pedestrian crossing distance, curb to curb (ft), L	*4a*	
Pedestrian walking speed (ft/s), S_p	*4b*	
Pedestrian start-up time and end clearance time (s), t_s	*4c*	
Critical gap required for crossing pedestrian (s), $t_c = (L/S_p) + t_s$ OR $[(4a/4b) + 4c)]$	*4d*	
Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), $V_{maj\text{-}d}$	*4e*	
Major road flow rate (veh/s), $v = V_{maj\text{-}d}/3600$ OR $[4e/3600]$	*4f*	
Average pedestrian delay (s/person), $d_p = (e^{v\,tc} - v\,t_c - 1)/v$ OR $[(e^{4f \times 4d} - 4f \times 4d - 1)/4f]$	*4g*	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3{,}600$ OR $[(4g \times 2a)/3600]$ (this is estimated delay for all pedestrians crossing the major roadway without a crossing treatment – assumes 0% compliance). This calculated value can be replaced with the actual total pedestrian delay measured at the site.	*4h*	
Step 5: Select treatment based upon total pedestrian delay and expected motorist compliance.		
Expected motorist compliance at pedestrian crossings in region, Comp = high or low	5a	

Total Pedestrian Delay, D_p (from *4h*) and Motorist Compliance, Comp (from *5a*)	**Treatment Category** (see Descriptions of Sample Treatments for examples)
$D_p \geq 21.3$ h (Comp = high or low) OR 5.3 h ≤ D_p < 21.3 h and Comp = low	RED
1.3 h ≤ D_p < 5.3 h (Comp = high or low) OR 5.3 h ≤ D_p < 21.3 h and Comp = high	ACTIVE OR ENHANCED
D_p < 1.3 h (Comp = high or low)	CROSSWALK

Figure A-2: TCRP and NCHRP Report Worksheet (35 mph or less)
(Source: NASEM, 2006)

WORKSHEET 2: PEAK-HOUR, EXCEEDS 35 MPH (55 KM/H)

Analyst and Site Information

Analyst: Analysis Date: Data Collection Date:	Major Street: Minor Street or Location: Peak Hour:

Step 1: Select worksheet (speed reflects posted or statutory speed limit or 85th percentile speed on the major street):
a) Worksheet 1 – 35 mph (55 km/h) or less
b) Worksheet 2 – exceeds 35 mph (55 km/h), communities with less than 10,000, or where major transit stop exists

Step 2: Does the crossing meet minimum pedestrian volumes to be considered for a TCD type of treatment?		
Peak-hour pedestrian volume (ped/h), V_p	*2a*	
If *2a* ≥ 14 ped/h, then go to Step 3.		
If *2a* < 14 ped/h, then consider median refuge islands, curb extensions, traffic calming, etc. as feasible.		
Step 3: Does the crossing meet the pedestrian volume warrant for a traffic signal?		
Major road volume, total of both approaches during peak hour (veh/h), $V_{maj\text{-}s}$	*3a*	
Minimum signal warrant volume for peak hour (use 3*a* for $V_{maj\text{-}s}$), SC $SC = (0.00035\ V_{maj\text{-}s}^2 - 0.80083\ V_{maj\text{-}s} + 529.197)/0.75$ OR $[(0.00035\ 3a^2 - 0.80083\ 3a + 529.197)/0.75]$	*3b*	
If *3b* < 93, then enter 93. If *3b* ≥ 93, then enter *3b*.	*3c*	
If 15th percentile crossing speed of pedestrians is less than 3.5 ft/s (1.1 m/s), then reduce *3c* by up to 50 percent; otherwise enter *3c*.	*3d*	
If *2a* ≥ *3d*, then the warrant has been met and a traffic signal should be considered if not within 300 ft (91 m) of another traffic signal. Otherwise, the warrant has not been met. Go to Step 4.		
Step 4: Estimate pedestrian delay.		
Pedestrian crossing distance, curb to curb (ft), L	*4a*	
Pedestrian walking speed (ft/s), S_p	*4b*	
Pedestrian start-up time and end clearance time (s), t_s	*4c*	
Critical gap required for crossing pedestrian (s), $t_c = (L/S_p) + t_s$ OR $[(4a/4b) + 4c)]$	*4d*	
Major road volume, total both approaches or approach being crossed if median refuge island is present during peak hour (veh/h), $V_{maj\text{-}d}$	*4e*	
Major road flow rate (veh/s), $v = (V_{maj\text{-}d}/0.7)/3600$ OR $[(4e/0.7)/3600]$	*4f*	
Average pedestrian delay (s/person), $d_p = (e^{v\,tc} - v\,t_c - 1)/v$ OR $[(e^{4f \times 4d} - 4f \times 4d - 1)/4f]$	*4g*	
Total pedestrian delay (h), $D_p = (d_p \times V_p)/3{,}600$ OR $[(4g \times 2a)/3600]$ (this is estimated delay for all pedestrians crossing the major roadway without a crossing treatment – assumes 0% compliance). This calculated value can be replaced with the actual total pedestrian delay measured at the site.	*4h*	
Step 5: Select treatment based upon total pedestrian delay and expected motorist compliance.		
Expected motorist compliance at pedestrian crossings in region, Comp = high or low	*5a*	

Total Pedestrian Delay, D_p (from *4h*) and Motorist Compliance, Comp (from *5a*)	Treatment Category (see Descriptions of Sample Treatments for examples)
$D_p \geq 21.3$ h (Comp = high or low) OR $5.3\ h \leq D_p < 21.3$ h and Comp = low	RED
$D_p < 5.3$ h (Comp = high or low) OR $5.3\ h \leq D_p < 21.3$ h and Comp = high	ACTIVE OR ENHANCED

Figure A-3: TCRP and NCHRP Report Worksheet (greater than 35 mph)
(Source: NASEM, 2006)

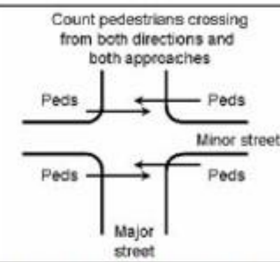
INPUT VARIABLES	TERM	DISCUSSION
ROAD CHARACTERISTICS		
Speed on the major street (mph)	S_{maj}	Use the major road posted or statutory speed limit for the facilities or, if available, the 85th percentile speed to determine which worksheet is applicable. Worksheet 1 is used when the speed is 35 mph (55 km/h) or less, while Worksheet 2 is used when the speed exceeds 35 mph (55 km/h).
Pedestrian **crossing distance** (ft)	L	Pedestrian crossing distance represents the distance that a pedestrian would need to cross before reaching either the far curb or a median refuge island. The distance would be between the near and far curbs if a painted or raised median refuge island is not present, or to the median refuge island if the island is present. Note if a parking stall is present, its width should be included in the crossing distance measurement. Crossing distance rather than number of lanes was selected for the procedure so that the extra time needed by a pedestrian to cross bike lanes, two-way left-turn lanes, wide lanes, etc. could be considered.
COUNTS		
Peak-hour **pedestrian volume** crossing major roadway (ped/h)	V_p	Pedestrian volume is the number of pedestrians crossing the major roadway in a peak hour. The count includes all pedestrian crossings of the major roadway at the location. 
Major road peak hour **vehicle volume** (veh/h)	$V_{maj\text{-}s}$ $V_{maj\text{-}d}$	Vehicle volume represents the number of vehicles and bicycles on both approaches of the major road during a peak hour. If a painted or raised median refuge island is present of sufficient size to store pedestrians (minimum of 6 ft [1.8 m] wide), then consider the volume on each approach individually. In the signal warrant calculations, use the volume on both approaches ($V_{maj\text{-}s}$). For the delay calculations, the volume ($V_{maj\text{-}d}$) would reflect either both approaches if a refuge island is not present or each approach individually if a refuge island is present.
LOCAL PARAMETERS		
Motorist **compliance** for region (high or low)	Comp	Compliance reflects the typical behavior of motorists for the site. If motorists tend to stop for a pedestrian attempting to cross at an uncontrolled location, then compliance is "high." If motorists rarely stop for a crossing pedestrian, then compliance is "low."
Pedestrian **walking speed** (ft/s)	S_p	Walking speed represents the speed of the crossing pedestrians. Recent research has suggested walking speeds of 3.5 ft/s (1.1 m/s) for the general population and 3.0 ft/s (0.9 m/s) for the older population. If calculating for a site, determine the 15th percentile value of those using the crossing.
Pedestrian **start-up** time and end clearance time (s)	t_s	Start-up time is used in the calculation of the critical gap. A value of 3 s is suggested in the *Highway Capacity Manual.*

Figure A-4: TCRP and NCHRP Report Worksheet Variables
(Source: NASEM, 2006)

CALCs	TERM	DISCUSSION
Signal warrant check (ped/h)	SC	Regression equations were determined for the plots shown in the 2003 *MUTCD* Figures 4C-3 and 4C-4. These equations can calculate the minimum number of vehicles that would be needed at the given major road volume to meet the signal warrant. The recommendation made in 2006 to the National Committee on Uniform Traffic Control Devices is that the vehicles signal warrants values for crossing two lanes be used as the pedestrian signal warrant values. Because the pedestrian signal warrant is to reflect total pedestrian crossings rather than just the number of pedestrians on the higher approach, the vehicle signal warrant values should be divided by 0.75 to reflect an assumed directional distribution split of 75/25. Different equations are provided for low-speed and high-speed conditions. The worksheets provide instructions on checking the peak hour. Both the peak vehicle hour and the peak pedestrian hour may need to be checked.
Critical gap (s)	T_c	Critical gap is the time in seconds below which a pedestrian will not attempt to begin crossing the street. For a single pedestrian, critical gap (t_c) can be computed using Equation 18-17 of the *2000 Highway Capacity Manual*. The equation includes consideration of the pedestrian walking speed (S_p), crossing distance (L), and start-up and end clearance times (t_s). $$t_c = (L/S_p) + t_s$$
Major road flow rate (veh/s)	v	Flow rate is a measure of the number of vehicles per second (v). For high-speed conditions, the number of vehicles is adjusted by dividing by 0.7. Flow rate is determined by: Low speed: $v = V_{maj-p}/3600$ high speed: $v = (V_{maj-p}/0.7)/3600$ It is based on the major road volume (V_{maj-d}), which is the total of both approaches (or the approach being crossed if median refuge island is present) during the peak hour (veh/h).
Average pedestrian delay (s/person)	d_p	The *2000 Highway Capacity Manual* includes Equation 18-21 that can be used to determine the average delay per pedestrian at an unsignalized intersection crossing (s/person). $$d_p = \frac{1}{v}\left(e^{vt_c} - vt_c - 1\right)$$ It depends upon critical gap (t_c), the vehicular flow rate of the crossing (*v*), and the mean vehicle headway.
Total pedestrian delay (ped-h)	D_p	Total pedestrian delay (D_p) uses the average pedestrian delay (d_p) and multiplies that value by the number of pedestrians (V_p) to determine the total pedestrian delay for the approach. $$D_p = (d_p \times V_p)/3{,}600$$

Figure A-4: TCRP and NCHRP Report Guidelines Worksheet Variables (continued)
(Source: NASEM, 2006)

APPENDIX B: FHWA Guidelines

Table B-1: FHWA Marked Crosswalk Guidance Matrix

(Source: Zegeer et al., 2005; MnDOT, 2014)

Roadway Type (Number of Travel Lanes and Median Type)	Vehicle ADT ≤ 9,000			Vehicle ADT > 9,000–12,000			Vehicle ADT > 12,000–15,000			Vehicle ADT > 15,000		
	Speed Limit*											
	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)	≤ 48.3 km/h (30 mph)	56.4 km/h (35 mph)	64.4 km/h (40 mph)
Two lanes	C	C	P	C	C	P	C	C	N	C	P	N
Three lanes	C	C	P	C	P	P	P	P	N	P	N	N
Multilane (four or more lanes) with raised median**	C	C	P	C	P	N	P	P	N	N	N	N
Multilane (four or more lanes) without raised median	C	P	N	P	P	N	N	N	N	N	N	N

*Where the speed limit exceeds 64.4 km/h (40 mph), marked crosswalks alone should not be used at unsignalized locations.

**The raised median or crossing island must me at least 1.2 meters (4 feet) wide and 1.8 meters (6 feet) long to serve adequately as a refuge area for pedestrians, in accordance with MUTCD and Amerian Association of State Highway and Transportation Officials (AASHTO) guidelines.

C = Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites. It is recommended that a minimum utilization of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) be confirmed at a location before placing a high priority on the installation of a marked crosswalk alone.

P = Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements. These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.

N = Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased by providing marked crosswalks alone. Consider using other treatments, such as traffic-calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvements, to improve crossing safety for pedestrians.

Roadway Conditions Inventory

Speed Limit

☐ ≤ 30 mph ☐ 35 mph ☐ ≥ 40 mph

Total Vehicles per Day

Annual Average Daily Traffic (AADT): __________

Approximate Vehicles per Hour (VPH): __________

☐ AADT < 9,000
☐ AADT 9,000–15,000
☐ AADT > 15,000

Travel Lane Configuration

☐ 2 lanes without raised median
☐ 3 lanes without raised median
☐ 3 lanes with raised median
☐ 4+ lanes without raised median
☐ 4+ lanes with raised median

Crosswalk Length (feet): ______________

Approximate Total Pedestrians per Hour (PPH) Crossing the Roadway: ______________

Pedestrian Safety Issues Inventory

Noted conflicts at crossing locations ☐ Yes ☐ No

- History of turning movement crashes
- Observed conflicts at permitted crossings

Excessive vehicle speed ☐ Yes ☐ No

- 85th percentile speeds, per speed study
- History of speed-related crashes

Inadequate conspicuity/visibility ☐ Yes ☐ No

- Dim or dark conditions for pedestrians in the crosswalk
- Limited visibility of crosswalk due to roadway curvature or topography
- Obstructions, such as on-street parking, vegetation, and signage

Drivers not yielding to pedestrians in crosswalks ☐ Yes ☐ No

- Crash history in marked crosswalks

Insufficient separation between pedestrians and traffic ☐ Yes ☐ No

- Long crossing distance
- No buffer (e.g., landscape buffer, on-street parking, bike lanes)

Figure B-1: Sample Inventory Form for Countermeasure Selection Process
(Source: FHWA, 2018)

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

*Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.

**It should be noted that the PHB and RRFB are not both installed at the same crossing location.

Figure B-2: Pedestrian Crash Countermeasure Decision Matrix

(Source: FHWA, 2018)

Pedestrian Crash Countermeasure for Uncontrolled Crossings	Safety Issue Addressed: Conflicts at crossing locations	Excessive vehicle speed	Inadequate conspicuity/ visibility	Drivers not yielding to pedestrians in crosswalks	Insufficient separation from traffic
Crosswalk visibility enhancement	✓	✓	✓	✓	✓
High-visibility crosswalk markings*	✓		✓	✓	
Parking restriction on crosswalk approach*	✓		✓	✓	
Improved nighttime lighting*	✓		✓		
Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line*	✓		✓	✓	✓
In-Street Pedestrian Crossing sign*	✓	✓	✓	✓	
Curb extension*	✓	✓	✓		✓
Raised crosswalk	✓	✓	✓	✓	
Pedestrian refuge island	✓	✓	✓		✓
Pedestrian Hybrid Beacon	✓	✓	✓	✓	
Road Diet	✓	✓	✓		✓
Rectangular Rapid-Flashing Beacon	✓		✓	✓	✓

*These countermeasures make up the STEP countermeasure "crosswalk visibility enhancements." Multiple countermeasures may be implemented at a location as part of crosswalk visibility enhancements.

Figure B-3: Safety Issues Addressed per Countermeasure
(Source: FHWA, 2018)

APPENDIX C: FDOT Guidelines

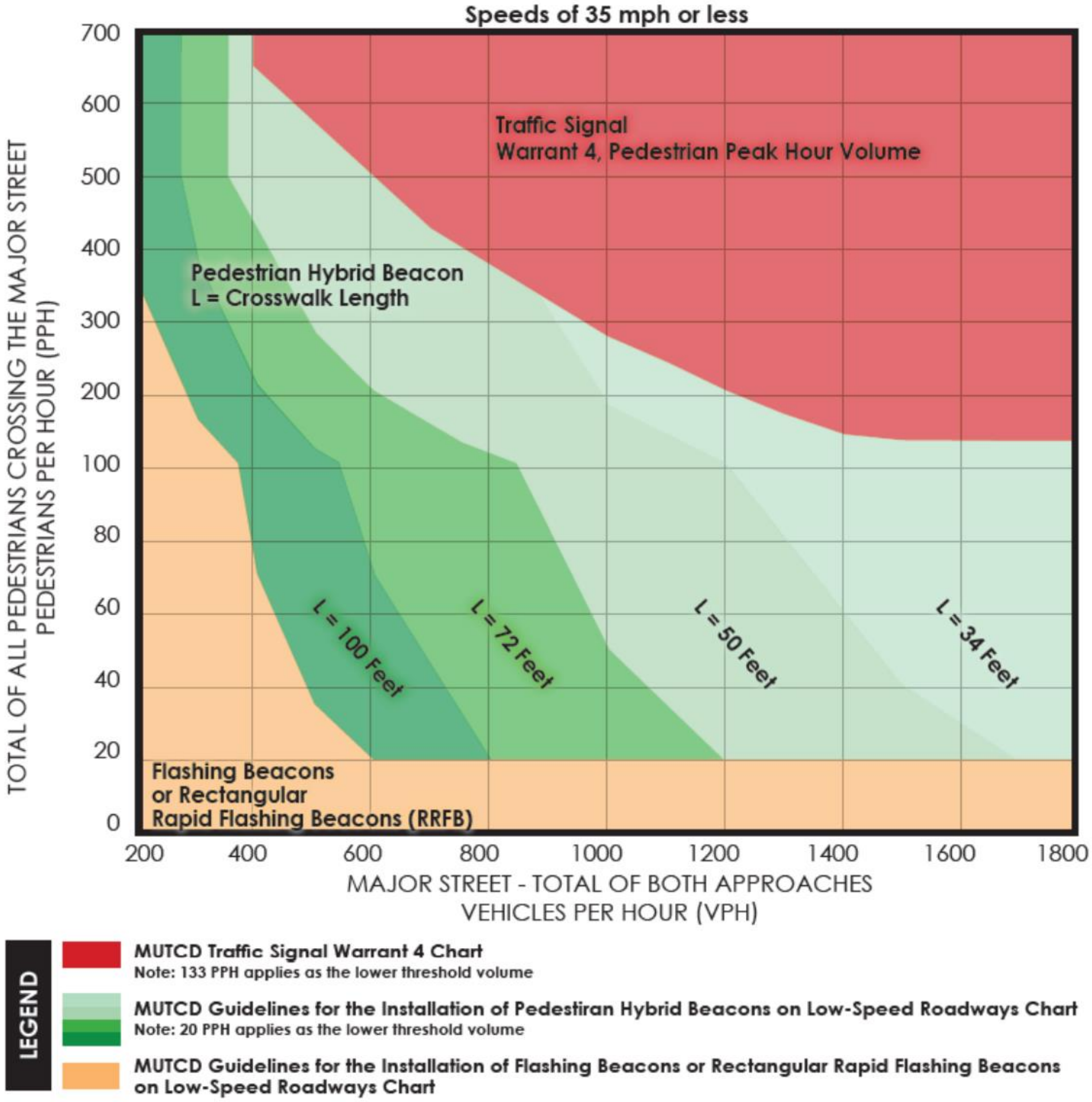


Figure C-1: Pedestrian Treatment Guidelines for Low-Speed Roadways
(Source: FDOT, 2020)

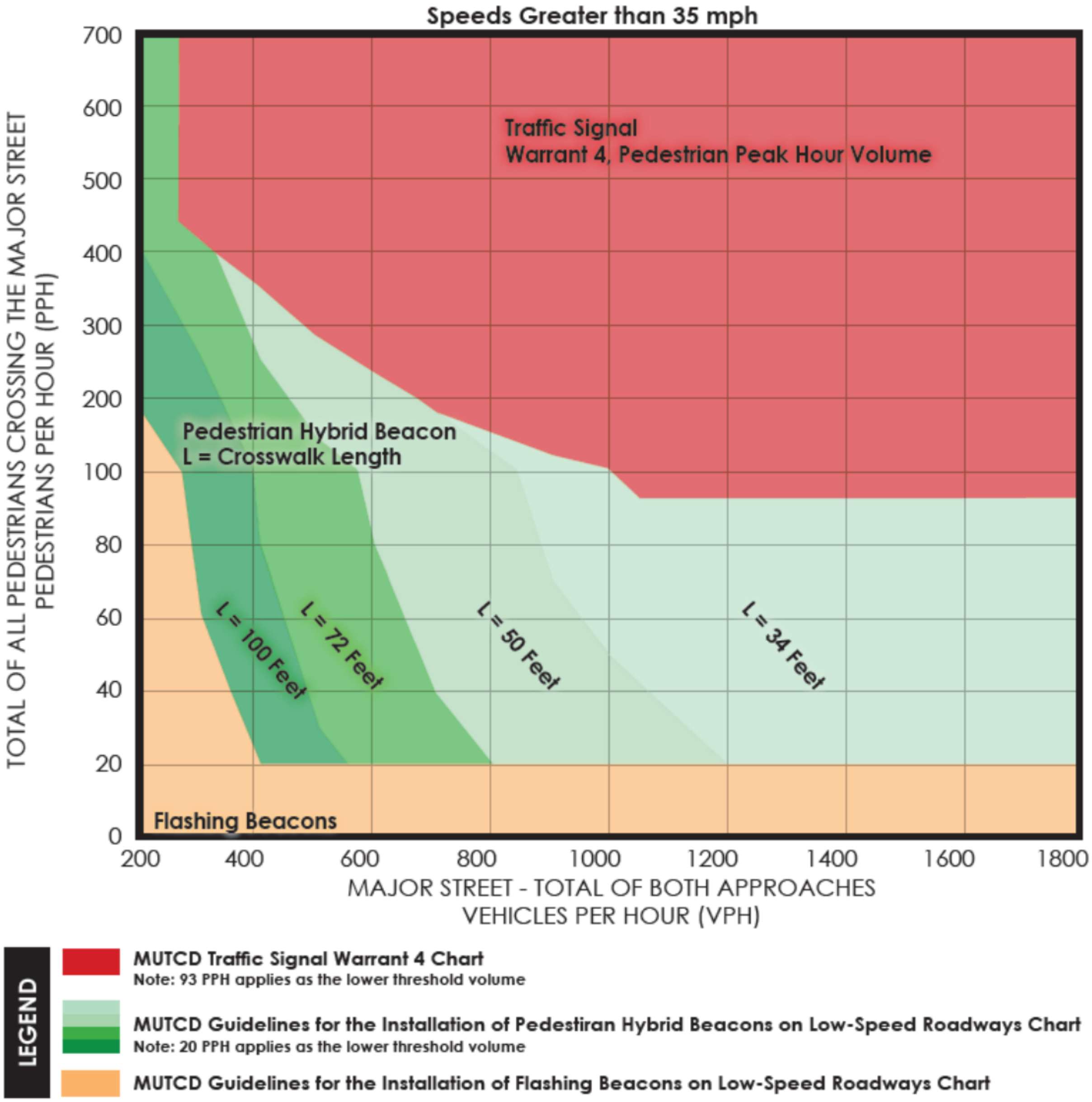


Figure C-2: Pedestrian Treatment Guidelines for High-Speed Roadways
(Source: FDOT, 2020)

TEM 5.2 Midblock Crosswalks and Unsignalized Intersection Selection Guidance Matrix			Midblock and Intersections							Midblock		TEM SECTION
			Pavement Markings				Beacons			Beacons and Signals		
			Special Emphasis Crosswalk			Standard Crosswalk	RRFB		Flashing Beacon	PHB	Traffic Signal	
			20 PPH for 1 Hr or **18 PPH** for 2 Hr or **15 PPH** for 3 Hr ***or*** SHARE USE PATH 50% PPH reduction ***or*** school zones			Stop controlled sidestreets and driveways	2-4 lanes	3-5 lanes With TWTL		Florida warrants must be met		
			***or* C2T, C4, C5 & C6** 0-35 MPH	35-45 MPH	45+ MPH		0-35 MPH					
Pavement Markings	Special emphasis crosswalk	Midblock	M	M	M	N	M	M	M	M	M	
		Intersection	M	M	M	N	M	M	M	N	N	
	Standard crosswalk		N	N	N	M	N	N	N	N	N	
	Other pavement markings		O	O	O	O	O	O	O	O	O	
Signs	R1-5b/R1-5c	Enhance option: highlighted or beacon	O	O	O	O	M	M	O	N	N	5.2.7.2
	W11-2/W16-9P											
	W16-7P/FTP-68C-21		O	O	O	O	M	M	O	O	O	
	R1-9a		O	O	O	O			M	O	O	
	R10-23a		O	O	O	O	O	O	O	M	O	
	Stop for pedestrians in crosswalk		O	O	O	O	O	O	O	O	O	
	In-street sign (R1-6a)	1-4 lanes	R	R	N	O	R	N	O	N	N	
Beacons	Audible message		N/A	N/A	N/A	N/A	M	M	N	N	N	
	In-roadway warning light		N/A	N/A	N/A	N/A	O	O	O	O	N	
Other Treatments	Two-stage pedestrian crossing	Pedestrian refuge islands	O	O	R	O	R	M	O	R	R	5.2.7.5
		Raised median	O	O	R	O	O	R	O	R	R	
	Passive pedestrian and bike detection	SHARED USE PATH	N/A	N/A	N/A	N/A	R	R	R	R	R	
		All others locations	N/A	N/A	N/A	N/A	O	O	O	O	O	
	Curb extensions		O	O	R	O	O	O	O	O	O	
	Transverse rumble strips		O	O	O	O	O	O	O	O	O	
	Raised crosswalks		O	O	R	O	O	O	O	O	O	
	Speed reduction treatments		O	O	R	O	O	O	O	O	O	
	Overhead lighting		M	M	M	O	M	M	M	M	M	
TEM SECTION			5.2.5.1				5.2.5.2					

Legend
- M — Mandatory if applied
- R — Recommend
- O — Available Option
- N — Cannot be Applied
- N/A — Not Available Option*

*Identifies where the treatment cannot be applied because the infrastructure is not there. Ex: Audible Message on a Marked Crosswalk

Figure C-3: Midblock Crosswalk and Unsignalized Intersection Selection Guidance Matrix
(Source: FDOT, 2020)

APPENDIX D: City & County of Denver Guidelines

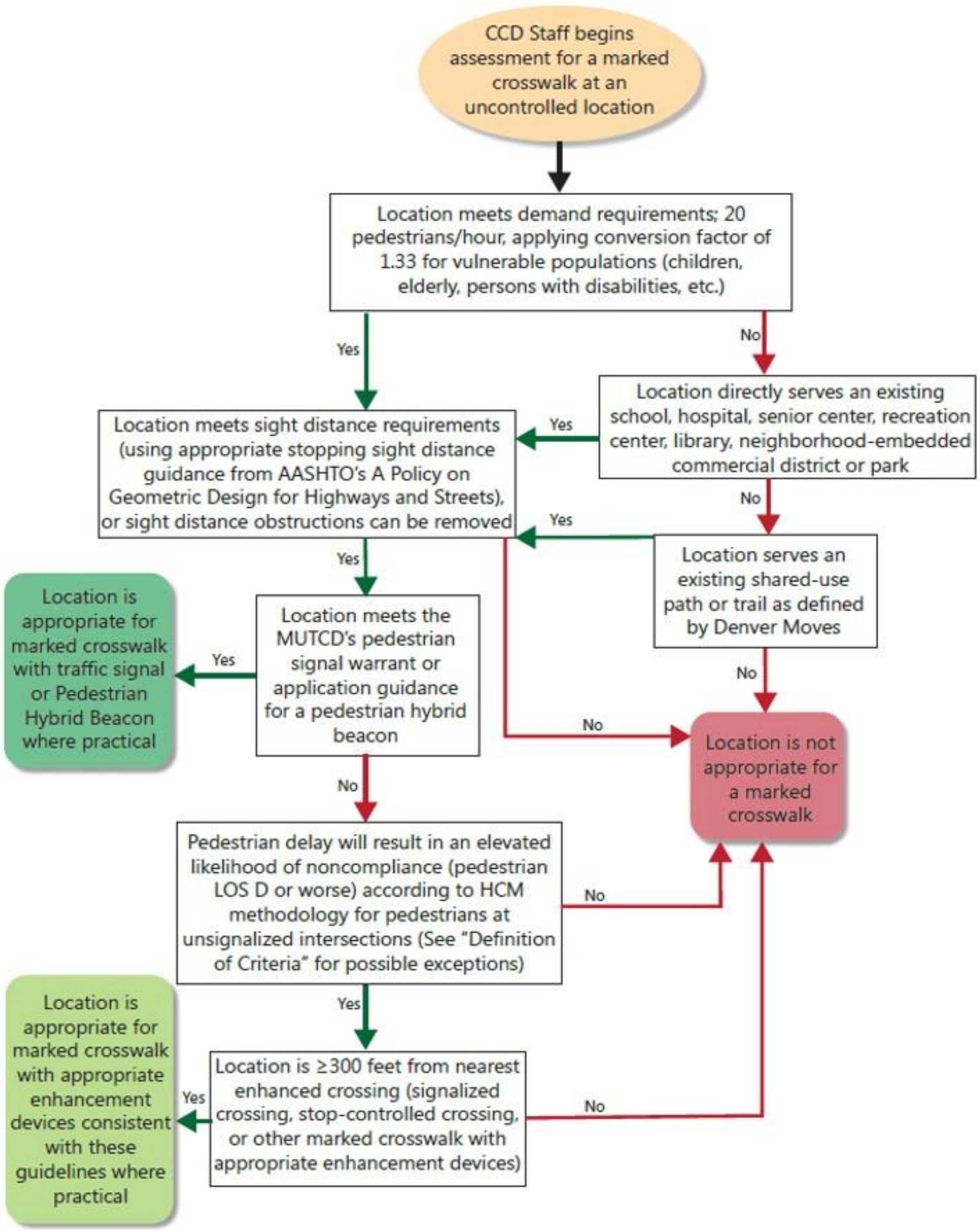


Figure D-1: City and County of Denver Candidate Marked Crosswalk Flowchart
(Source: CCD, 2016)

Table D-1: City and County of Denver Recommended Treatment at Marked Crosswalks
(Source: CCD, 2016)

Roadway Type	Vehicle ADT ≤9,000			Vehicle ADT >9,000 to 12,000			Vehicle ADT >12,000 to 15,000			Vehicle ADT ≥15,000		
	≤30 mph	35 mph	40 mph	≤30 mph	35 mph	40 mph	≤30 mph	35 mph	40 mph	≤30 mph	35 mph	40 mph
Two Lanes	A	A	B	A	A	B	A	A	C	A	B	C
Three lanes	A	A	B	A	B	B	B	B	C	B	C	C
Multilane with raised median	A	A	C	A	B	C	B	B	C	C	C	C
Multilane without raised median	A	B	C	B	B	C	C	C	C	C	C	C

Note: Level – A: Markings and Signing; Level – B: Rapid Rectangular Flashing Beacon (RRFB); Level – C: Pedestrian Hybrid Beacon (PHB) or Signal.

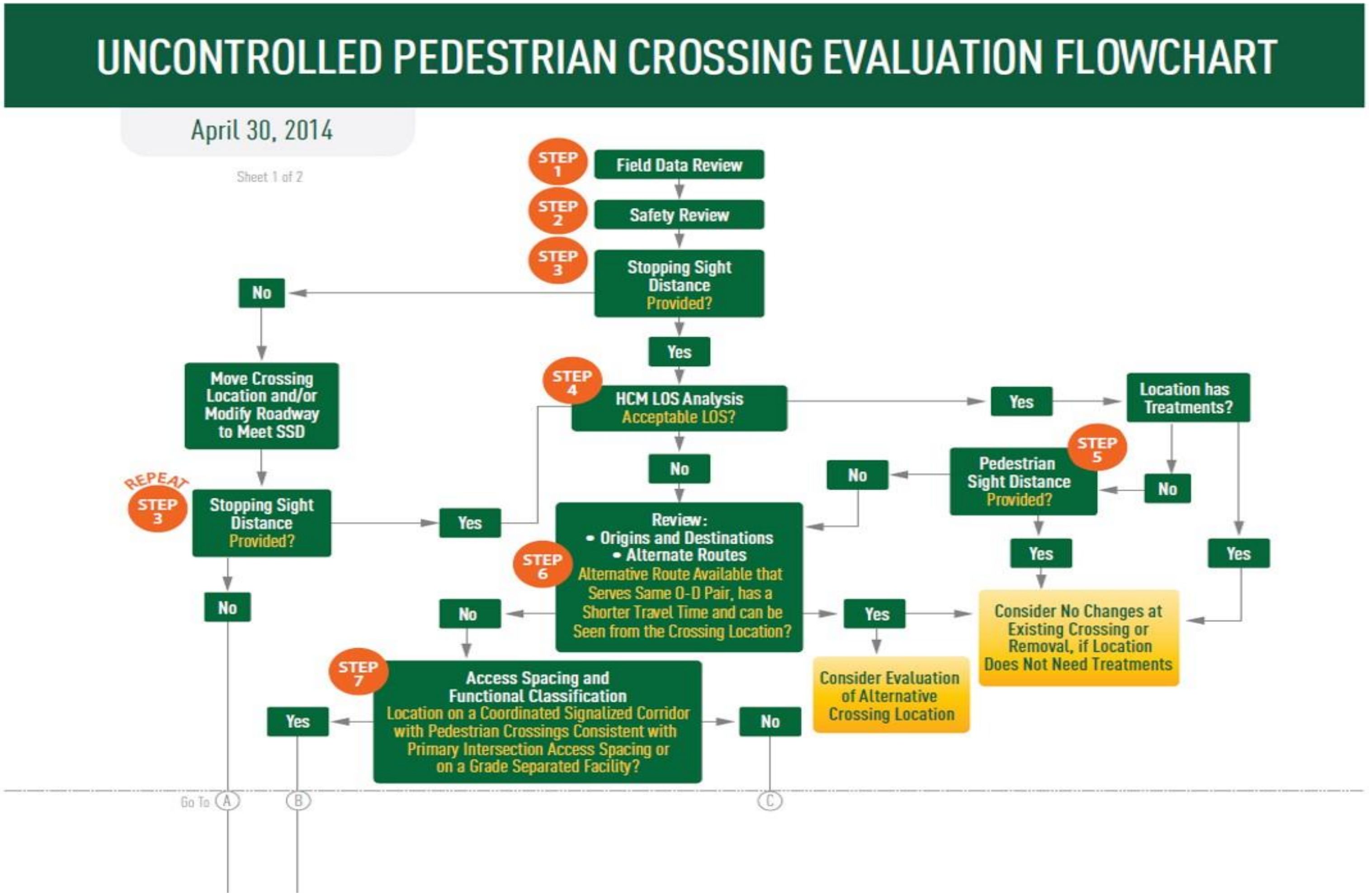


Figure E-1: MnDOT Uncontrolled Pedestrian Crossing Evaluation Flowchart
(Source: MnDOT, 2014)

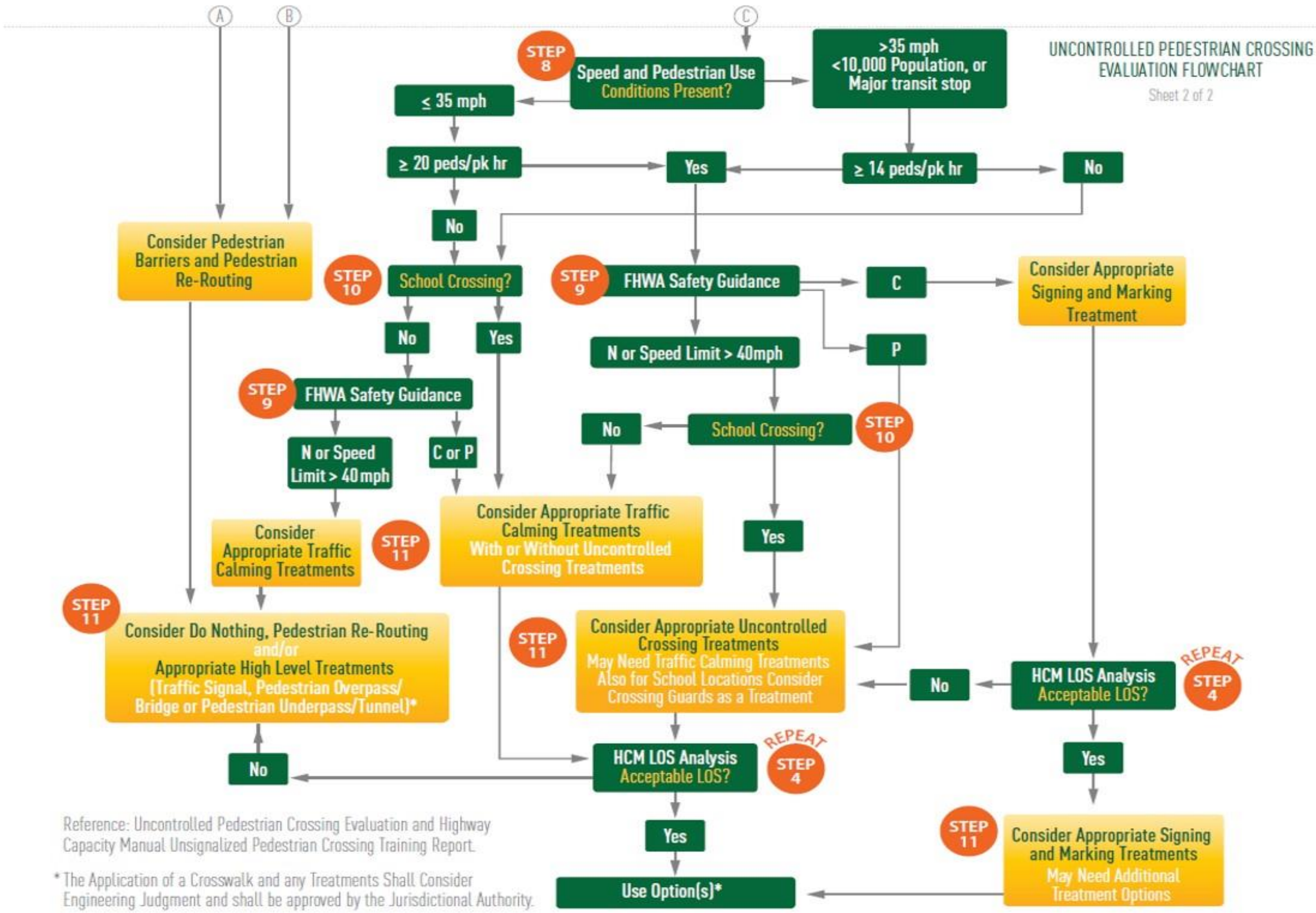


Figure E-1: MnDOT Uncontrolled Pedestrian Crossing Evaluation Flowchart (continued)
(Source: MnDOT, 2014)

Table E-1: MnDOT Signing and Marking Treatments
(Source: MnDOT, 2014)

Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Crosswalk Markings Only	• Inexpensive • Helps define a crossing location • Indicates to drivers that crossing location is present	• Very little effect at night • Speeds increase over time • Not shown to reduce crashes	• Not usually recommended alone • Low-volume and low-speed roadways • Where justified	NR	NR	\$500–\$2,000
Warning Signs	• Inexpensive • Helps define a crossing location • Warning to drivers that crossing location is present	• Tend to be ignored unless pedestrians use the crossing consistently • Proven to be ineffective at reducing crashes at uncontrolled intersections	• Where unexpected entries into the road by pedestrians may occur • At or before the crossing location • With or without a marked crosswalk	NR	NR	\$300–\$1,200
Overhead Warning Signs	• May decrease vehicle speed	• Requires overhead structure • Tend to be ignored unless pedestrians use the crossing consistently	• Multilane roadways • Mid-block crossing locations • Usually coupled with other measures such as RRFBs or beacons	NR	NR	\$60,000–\$75,000
Colored Concrete/Brick Pavers	• Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed	• Can be expensive • Not shown to reduce crashes	• Downtown/urban conditions • Traffic signal locations • In conjunction with pavement markings	NR	NR	\$10,000–\$75,000
Crosswalk Markings and Signs	• Inexpensive • Warning to drivers that crossing location is present • May decrease vehicle speed	• Make snow removal more difficult • Need consistent maintenance and replacement due to vehicle hits	• Where justified	7%	7%	\$800–\$3,200
In-Street Crossing Signs (25–30 mph)	• Inexpensive • Additional warning to drivers that crossing location is present	• Not shown to reduce crashes • Speeds increase over time	• Downtown/urban conditions • Supplement warning signs at high pedestrian volume locations • In conjunction with pavement markings	87%	90%	\$500–\$1,000
High-Visibility Crosswalk Markings	• May decrease vehicle speed	• Not shown to reduce crashes • Speeds increase over time	• Where justified • Urban conditions	61% (25mph) 17% (35mph)	91% (25mph) 20% (35mph)	\$5,000–\$50,000
NR = No research found on effect to yielding rate						

Table E-2: MnDOT Uncontrolled Crossing Treatments (with Markings and Signs)
(Source: MnDOT, 2014)

Treatment	Advantages	Disadvantages	Recommended Locations	Staged Pedestrian Yield Rate	Unstaged Pedestrian Yield Rate	Cost
Center Median with Refuge Island	• Decreases pedestrian crossing distance • Provides higher pedestrian visibility • Reduces vehicle speeds approaching the island • Reduces conflicts • Increases usable gaps • Reduces pedestrian exposure time	• May make snow removal more difficult • May be a hazard for motorists • Small islands not recommended on high-speed roadways (>40 mph)	• Wide, two-lane roads and multilane roads with sufficient right-of-way	34%	29%	Variable depending on length
School Crossing Guards	• Inexpensive • Provides higher pedestrian visibility • Highlights when a pedestrian crossing is being used	• May require trained staff or local law enforcement, especially on high-speed and high-volume roadways	• At school locations	NR	86%	Variable
Pedestrian Crossing Flags	• Inexpensive • Provides higher pedestrian visibility to drivers assuming the flag is held in a noticeable location	• No effect at night • Requires pedestrians to actively use a flag • Can be easily removed/stolen • Shorter crossings are preferred	• Downtown/urban locations • High pedestrian volume locations • Across low-speed (<45mph) roadways	65%	74%	<$500
Warning Sign with Edge Mounted LEDs	• Highlights a crossing both at night and during the day	• Requires pedestrian activation • Minimal to no effect on speed	• In conjunction with in-road warning lights • Downtown/ urban conditions	NR	28%	$3,000–$8,000
In-Road Warning Lights	• Highlights a crossing both at night and during the day • Provides higher driver awareness when a pedestrian is present	• Snowplows can cause maintenance issues • No effect when road surface is snow covered • Requires pedestrian activation	• Downtown/urban conditions	NR	66%	$20,000–$40,000
Pedestal Mounted Pedestrian Flashing Signal Beacons	• Provides higher driver awareness when a pedestrian is present	• Requires pedestrian activation • Not advisable on multilane streets • Not shown to reduce crashes	• Low-speed school crossings • Two-lane roads • Midblock crossing locations	NR	57% (two-lane, 35mph)	$12,000–$18,000
Pedestrian Overhead Flashing Signal Beacons	• Provides higher driver awareness when a pedestrian is present	• Requires pedestrian activation	• Multilane roadways • Mid-block crossing locations • Lower speed roadways	active 47% passive 31%	active 49% passive 67%	$75,000–$150,000
Rectangular Rapid Flash Beacons (RRFBs)	• Provides higher driver awareness when a pedestrian is present • Increases yielding percentage • Increases usable gaps • Reduces probability of pedestrian risk taking • Can be seen from 360 degrees	• Requires pedestrian activation	• Supplement existing pedestrian crossing warning signs • School crossings • Midblock crossing locations • Low- and high-speed roadways	84%	81%	$12,000–$18,000
NR = No research found on effect to yielding rate						

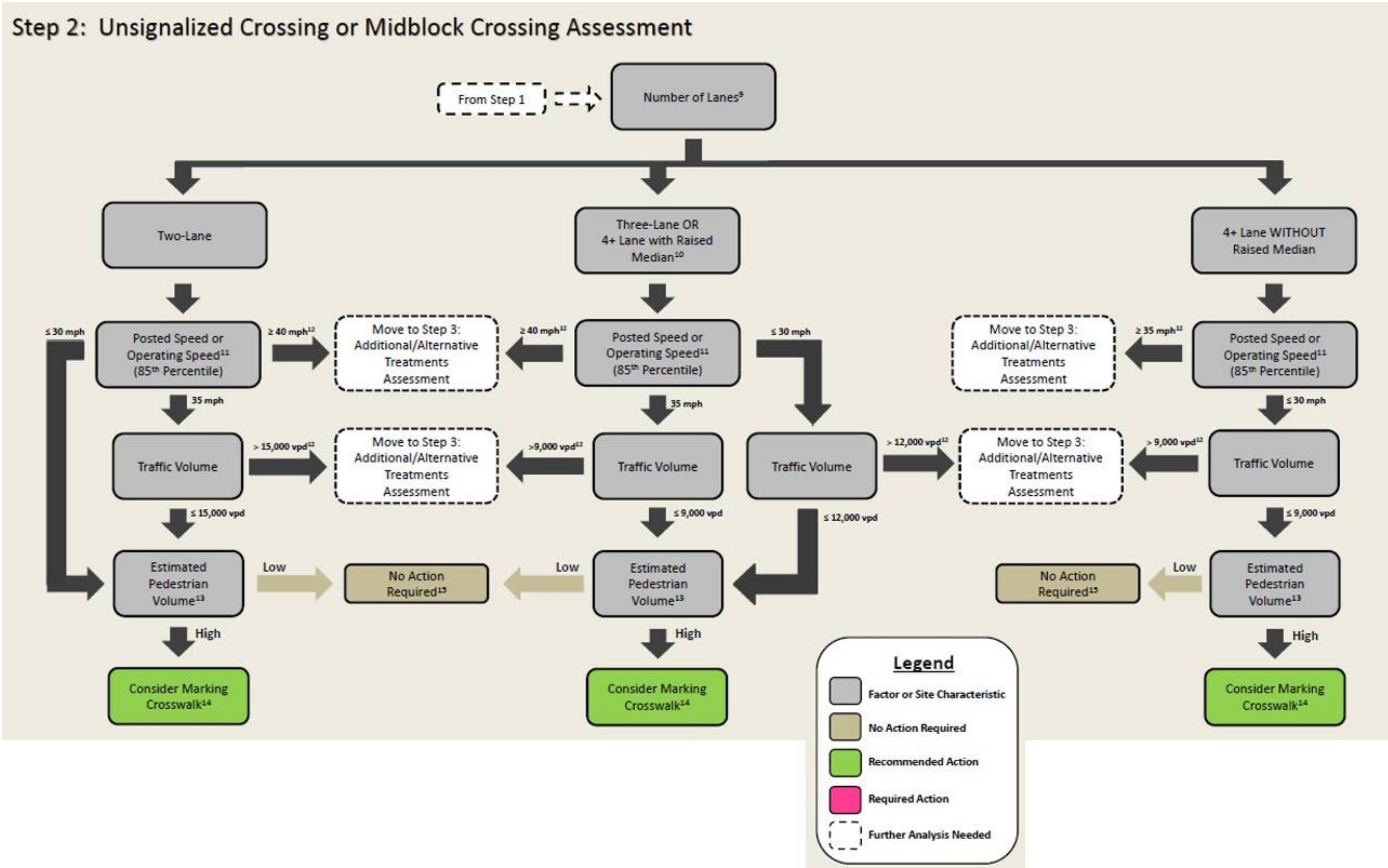


Figure F-1: NCDOT Unsignalized Crossing or Midblock Crossing Assessment
(Source: NCDOT, 2015)

APPENDIX G: VDOT Guidelines

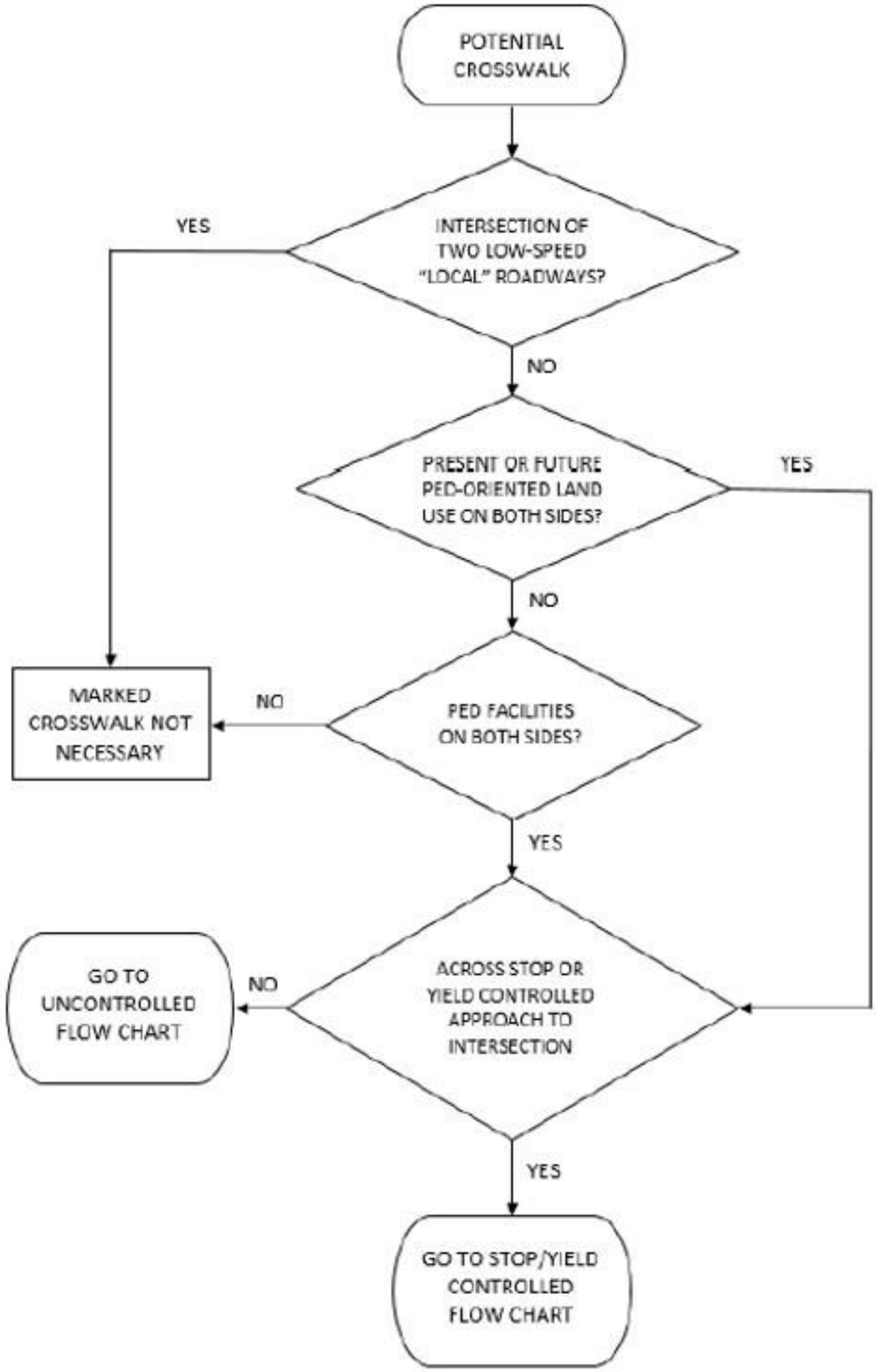


Figure G-1: VDOT Potential Crosswalk Flowchart
(Source: VDOT, 2016)

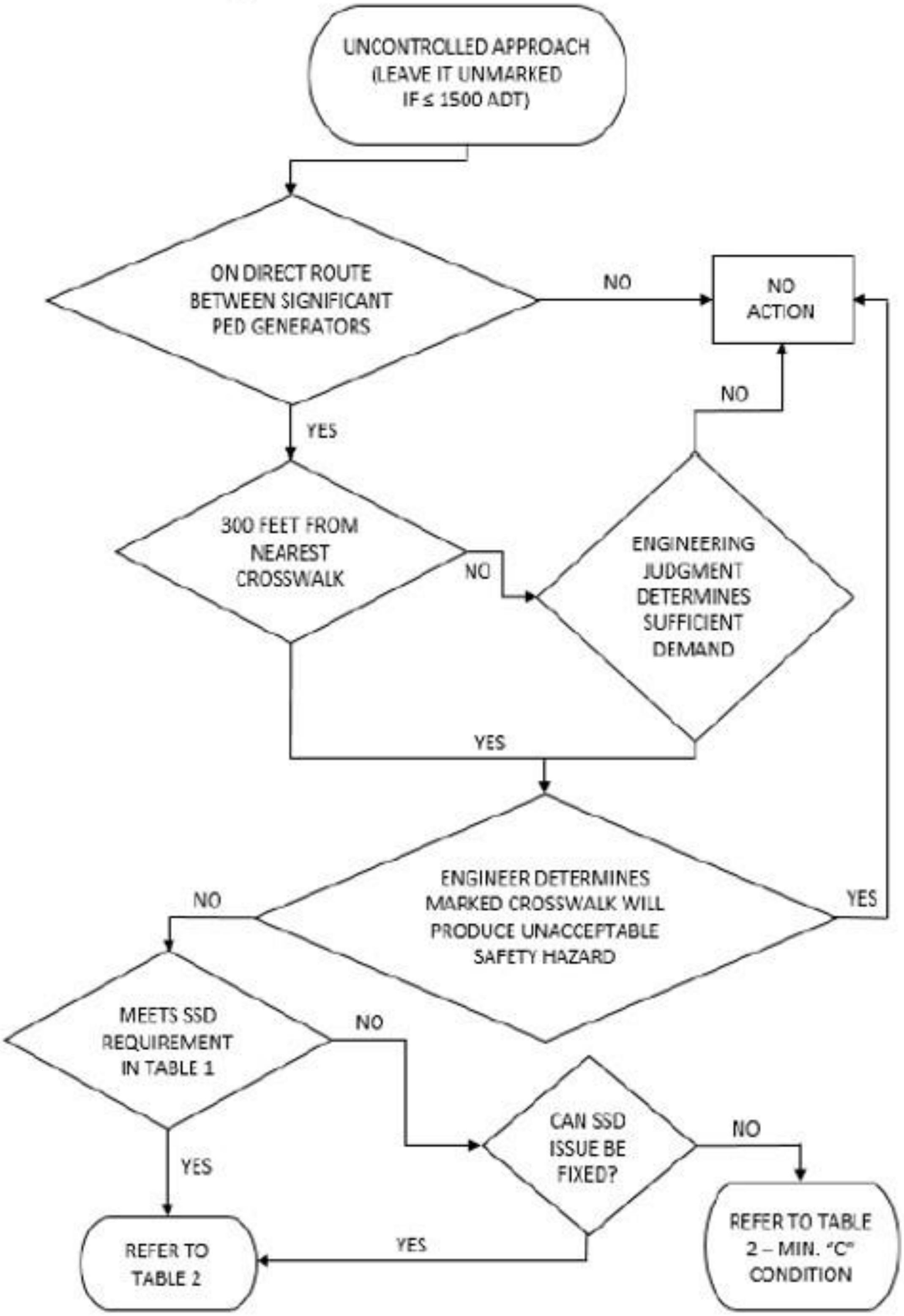


Figure G-2: VDOT Uncontrolled Crosswalk Flowchart
(Source: VDOT, 2016)

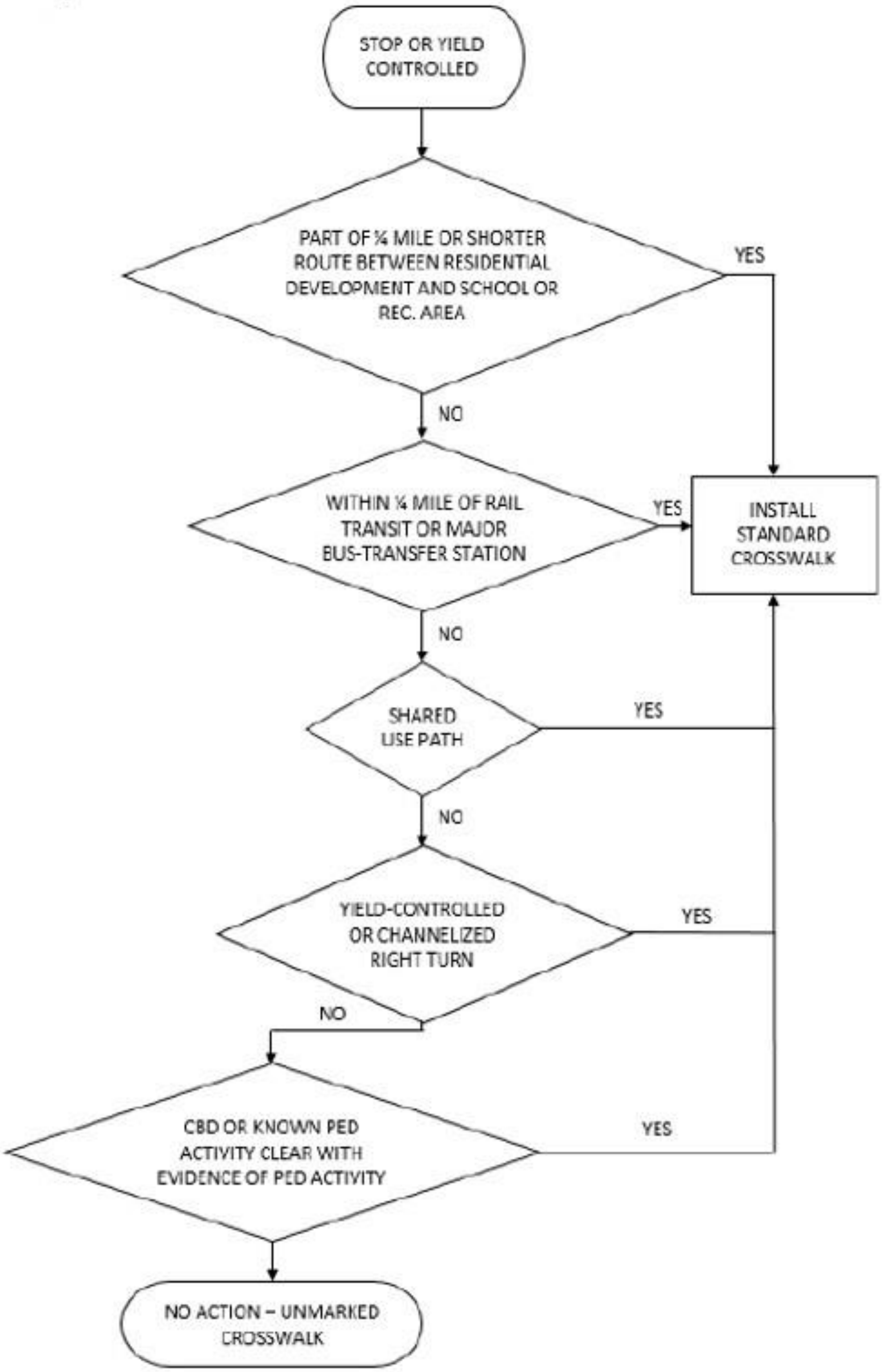


Figure G-3: VDOT Stop or Yield Controlled Crosswalk Flowchart
(Source: VDOT, 2016)

Table G-1: VDOT Marked Crosswalk Treatment Matrix
(Source: VDOT, 2016)

Roadway Configuration	Roadway ADT and Speed Limit															
	1,500 to 9,000 VPD				9,000 to 12,000 VPD				12,000 to 15,000 VPD				More than 15,000 VPD			
	≤ 30 MPH	35 MPH	40 MPH	≥ 45 MPH	≤ 30 MPH	35 MPH	40 MPH	≥ 45 MPH	≤ 30 MPH	35 MPH	40 MPH	≥ 45 MPH	≤ 30 MPH	35 MPH	40 MPH	≥ 45 MPH
2 Lanes (undivided two-way street or two-lane one-way street)	A	A	B	B	A	A	B	B	A	A	B	B	B	B	B	C
3 Lanes with refuge island OR 2 Lanes with raised median*	A	A	B	B	A	B	B	B	A	A	B	B	B	B	B	C
3 Lanes (center turn lane)	A	A	B	B	A	B	B	B	A	B	B	C	B	C	C	C
4 Lanes (two-way street with no median)	A	B	C	C	B	B	C	C	B	C	C	D	C	C	C	D
5 Lanes with refuge island OR 4 lanes with raised median*	A	A	B	B	A	B	B	C	B	B	C	C	B	B	C	D
5 Lanes (center turn lane)	A	B	C	C	B	B	C	C	C	C	C	D	C	C	C	D
6 Lanes (two-way street with* or without median)	A	B	D	D	B	B	D	D	D	D	D	D	D	D	D	D

Source: Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (Michigan Department of Transportation, 2014)

Condition A	**Candidate site for marked crosswalk alone** (standard if speed limit is 30 MPH or less, high-visibility if speed limit is 35 MPH or greater). Evaluate need for advance signing
Condition B	**Potential candidate site for marked crosswalk.** Location should be monitored & consideration given to providing a high-visibility crosswalk and/or warning signs (see Section 7.2)
Condition C	**Marked crosswalks alone are insufficient.** The crosswalk shall use a high-visibility pattern and other improvements (warning signs and/or geometric/ traffic calming improvements) (see Section 7.2) will likely be necessary.
Condition D	**Marked crosswalks shall not be installed**

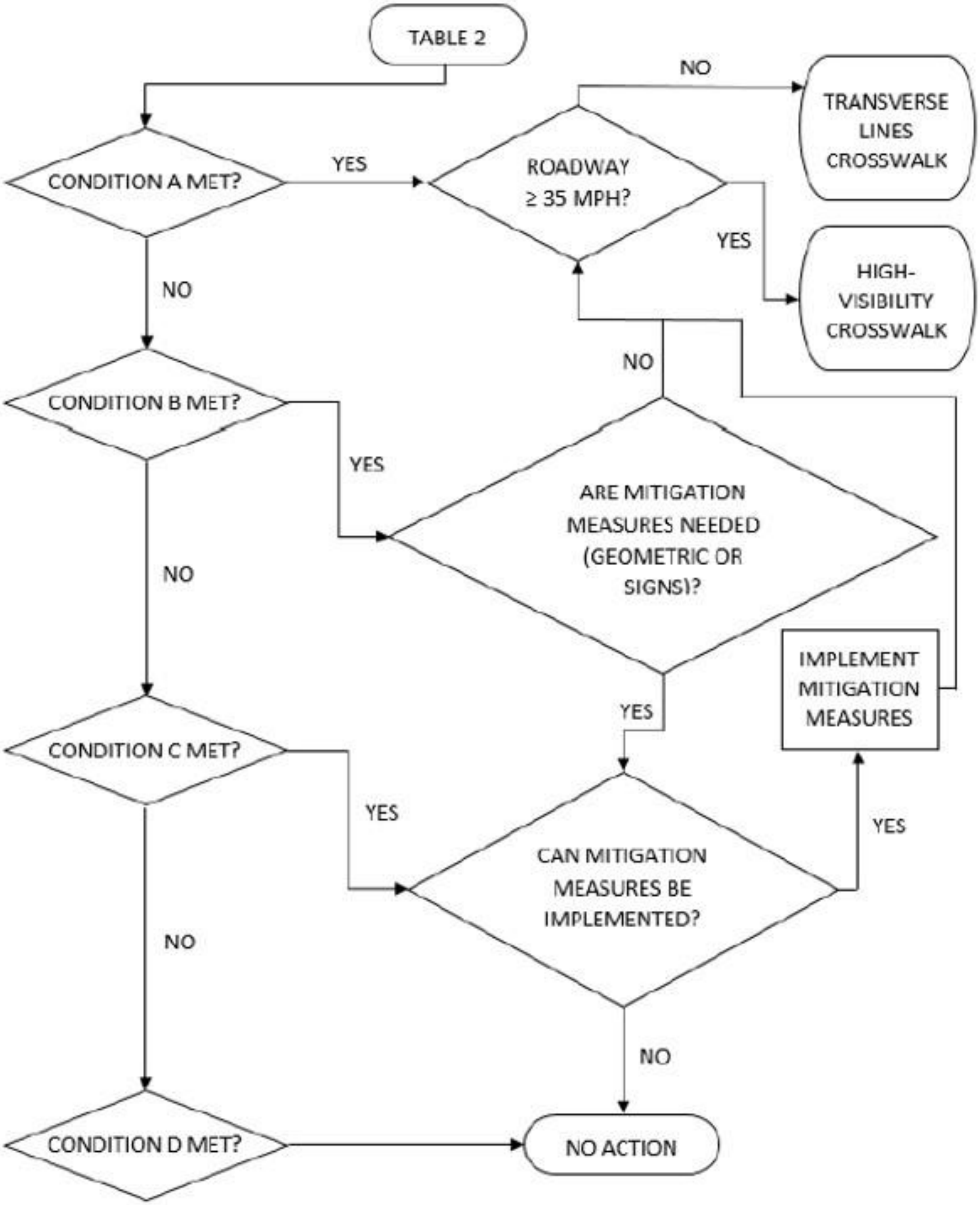


Figure G-4: VDOT "Table 2" Marked Crosswalk Treatment Flowchart
(Source: VDOT, 2016)

LOCATION DESCRIPTION – PART 1

Name of Data Collector: ______________________________

Date of Data Collection: ______________________________

Locality/District of Study Location: ______________________________

1) Crossing Location: □ Unsignalized Intersection □ Mid-block

If crossing is (or will be) at unsignalized intersection location, define intersecting streets:

Major Street	
Name:	Posted Speed Limit: __________ MPH
Functionality: □ Arterial □ Collector □ Local	

Minor Street	
Name:	Posted Speed Limit: __________ MPH
Functionality: □ Arterial □ Collector □ Local	

If crossing is (or will be) at mid-block location, define location on major street:

Major Street	
Name:	Posted Speed Limit: __________ MPH
Functionality: □ Arterial □ Collector □ Local	
Location Description (e.g. 500 ft East of Main St.):	

2) Is this a shared-use path (e.g. bicycles) crossing? □ Yes □ No

3) Existing Nearby Pedestrian Generators and Attractors (e.g. moderate density residential developments, schools, parks, commercial establishments, transit stops):
North/East of crossing: ______________________________

____

South/West of crossing: ______________________________

____

4) Existing Traffic Control: □ Stop/Yield Sign □ Uncontrolled

5) Is there Another Marked Crosswalk across the same roadway within 300 feet of the Crossing Location? □ Yes □ No

6) Existing Crossing Treatments (if any) (e.g. standard crosswalk, curb ramps, and etc.):

____

____

7) *(for stop/yield controlled locations only)* Is the Crossing Location Across a Yield-controlled Approach at an Off-ramp Junction or Channelized Right Turn Lane? □ Yes □ No

Figure G-5: VDOT Sample Data Collection Sheet: Part 1
(Source: VDOT, 2016)

LOCATION DESCRIPTION – PART 2

8) Roadway Configuration:
□ 2-Lanes (one-way street)
□ 2-Lanes (two-way street with no median)
□ 2-Lanes with raised median
□ 3-Lanes with refuge island
□ 3-Lanes (center turn lane)
□ 4-Lanes (two-way street with no median)
□ 4-Lanes with raised median
□ 5-Lanes with refuge island
□ 5-Lanes (center turn lane)
□ 6-Lanes (two-way street with or without median)
□ Other: ____________________________

9) Crossing Distance by Direction:
Total: _______ ft
(if applicable) From one end to the median: _______ ft, Direction: _______
(if applicable) From other end to the median: _______ ft, Direction: _______

10) Nearest Marked or Protected Pedestrian Crossing: __________________ Distance to: _______ ft

11) Could the Crossing Contain a Crosswalk of at Least 6 ft in Width? □ Yes □ No

12) *(for uncontrolled locations only)* Stopping Sight Distance (SSD):
_______ ft, Direction: _______
_______ ft, Direction: _______
Can SSD be improved? □ Yes □ No □ Other: ____________________________

13) Potential Safety Hazard within Crossing Location (if any):

____

14) Sketch/Photo of the Crossing Location:

Figure G-6: VDOT Sample Data Collection Sheet: Part 2
(Source: VDOT, 2016)

STEP 3 – TRAFFIC DATA

What are the peak period(s) for pedestrian activity?
□ AM □ PM □ Midday □ Other: ______________________________

Major Street Vehicular Volume (ADT): _______________ vehicles/day
(if applicable) Minor Street Vehicular Volume (ADT): _______________ vehicles/day

(Complete where appropriate) Pedestrian Crossing Volumes / Bicycle Crossing Volumes:

	AM	Mid-day	PM	Other
Time:	to	to	to	to
Date / Day of Week:	/	/	/	/
Major Street Vehicular Volume (Hourly):				
# of Bicyclists (if known)				
# of Pedestrians (if known)				

Is a significant proportion of the pedestrians at this location expected to be young (middle school students or below), elderly, or disabled?
□ Yes □ No Describe: ____

Figure G-7: VDOT Sample Data Collection Sheet: Traffic Data
(Source: VDOT, 2016