CUTR RESEARCH

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Final Report

Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida

PREPARED FOR
Florida Department of Transportation

FDOT

December 2017

Center for Urban Transportation Research
University of South Florida
4202 E. Fowler Ave., CUT100, Tampa, FL 33620-5375

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December 2017

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.

UNIT CONVERSION TABLE

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
in^2	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	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	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
fl oz	fluid ounces	29.57	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
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

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16. Abstract

Pedestrian safety is an ongoing major concern throughout the United States and is one of the highest priorities for the Florida Department of Transportation (FDOT). Vehicles often fail to yield to pedestrians at intersections, especially when pedestrians enter an intersection with a corresponding green signal in the same direction of vehicle travel. Leading Pedestrian Interval (LPI) has been implemented as a low-cost countermeasure to provide pedestrians an advance start before the concurrent green traffic signal to increase pedestrian visibility and safety in crosswalk. However, the LPI is not universally applied at all intersections since it is dependent on the characteristics of intersection geometry, vehicle and pedestrian traffic conditions, traffic signal timing, etc. This research conducted an integrated study to determine the suitability and effectiveness of LPI implementation at signalized intersections to improve pedestrian safety and to develop statewide guidelines for LPI implementation. A comprehensive and in-depth literature review was conducted regarding successes and lessons learned from LPI implementation. Preliminary LPI implementation guidelines were developed after input was collected among experienced traffic engineers and FDOT District representatives through surveys, interviews, and teleconferences. Then, data collection and analyses were conducted before and after pilot LPI implementation at nine selected intersections that covered a geographically-diverse range of environments. Results from the LPI pilot implementation were used to fine tune the preliminary LPI implementation guidelines. The analysis results show that LPIs were very effective in reducing vehicle-pedestrian conflicts. On the other hand, it showed mixed results of drivers' yielding behaviors in this pilot LPI implementation. To enhance the safety of pedestrians crossing at signalized intersections, it is recommended to implement static or blank-out "NO TURN ON RED" signs or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs along with an LPI implementation. The implementation of LPIs yielded a trivial adverse or even favorable influence of LPI on intersection operation efficiency. Furthermore, proper LPI implementation produced a high utilization efficiency. With results from the pilot LPI implementation and inputs from peer professionals, FDOT project managers, and FDOT District representatives, the proposed statewide LPI implementation guidelines were finalized. The research findings of this project provide clear insight into the suitability of LPI implementation and its effectiveness in increasing pedestrian safety at signalized intersections, and also offer traffic engineers and managers a simple and robust tool for appropriate and effective LPI implementation.

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EXECUTIVE SUMMARY

INTRODUCTION

Pedestrian safety is an ongoing major concern throughout the United States, especially in Florida, which experiences higher crash rates for pedestrians and bicyclists. Pedestrians and bicyclists are commonly referred to as "vulnerable road users" because the lack of a protective structure and differences in mass heighten their injury susceptibility in collisions with motor vehicles. As a general rule, vehicles are legally required to yield to pedestrians when there is a potential conflict between vehicles and pedestrians. However, for many reasons (e.g., driver characteristics, driver distraction, driver impairment, roadway and intersection layouts, surrounding environment), drivers might make risky decisions by accepting short gaps or not yielding to pedestrians, which could threaten pedestrian safety, especially when pedestrians enter an intersection with a corresponding green signal in the same direction of travel of vehicles.

One low-cost technique to separate pedestrians and turning vehicles is the Leading Pedestrian Interval (LPI), a traffic signalization strategy also known as "pedestrian head start" or "delayed vehicle green." LPI gives pedestrians an advance "Walk" signal indication before a concurrent green signal is provided to vehicles, allowing the pedestrians to establish a presence in the crosswalk, thereby increasing the visibility of pedestrians to drivers and potentially reducing conflicts with turning vehicles. However, a traffic agency may not implement LPIs at every intersection since the success of LPI implementation is dependent on the characteristics of the location, traffic conditions, pedestrian activities, number of vehicle and pedestrian conflicts, pedestrians' compliance with traffic signal indications, and signal timing due to the potential adverse effects such as extended travel delay or driver complaints on signal timing. Therefore, there is a need to determine the suitability and effectiveness of LPI implementation at signalized intersections to improve pedestrian safety and also a need to develop statewide guidelines for LPI implementation.

PROJECT OBJECTIVES

The overall objective of this project was to conduct an integrated study to determine the suitability and effectiveness of LPI implementation at signalized intersections to improve pedestrian safety and to develop statewide guidelines for LPI implementation. Specifically, the primary objectives of this study were to:

- Obtain knowledge, experience, and guidance for LPI implementation from literature review, traffic agency interviews, recommendation from field experts, and consultation with FDOT District operations engineers and managers.
- Develop preliminary LPI implementation guidelines based on the knowledge, experience, and guidance from literature reviews, traffic agencies, field experts, and FDOT District operations engineers and managers.
- Conduct before-after data collection, review, and analysis via pilot LPI implementation to evaluate LPI effectiveness in pedestrian safety and traffic operation efficiency.
- Develop simple and robust statewide guidelines for LPI warrants, implementation, and operations in Florida by refining the preliminary guidelines based on data analysis results and findings from pilot LPI implementations.

DEVELOPMENT OF PRELIMINARY LPI IMPLEMENTATION GUIDELINE

Most transportation engineers have a good understanding of how LPIs operate and of the pros and cons of LPI operations. LPIs have been considered or implemented in many cities in the U.S. as well as in other countries. However, the development of simple and robust LPI implementation guidelines was a complex process, and many factors (e.g., crashes, volumes, conflicts, visibility issues, special events, etc.) needed to be considered and examined; also, it was important to balance the needs of pedestrians and drivers.

In this research project, preliminary LPI implementation guidelines for Florida were developed first. To accomplish that, a comprehensive and in-depth literature review regarding LPI was conducted based on agencies that have implemented an LPI or were planning to do so but did not pursue it for various reasons. Consultation was also obtained from CUTR's project consultant (Albeck Gerken, Inc.) to learn LPI implementations in the U.S., where LPIs were successfully implemented or were attempted but not implemented. Furthermore, significant efforts were made to obtain LPI implmentation information via online surveys, phone interviews with experienced traffic engineers and managers within and outside Florida, and detailed discussions with FDOT District traffic operations representatives via teleconferences.

Based on the literature review, surveys and interviews with experienced traffic engineers and managers on LPI, and consultation with FDOT traffic operations representatives, initial statewide LPI implementation guidelines were drafted regarding LPI parameters, warrants, and support. Based on the review comments received on the initial guidelines from the FDOT and Albeck Gerken, Inc. and the guidance from the FDOT project managers, preliminary LPI implementation guidelines, including illustrative examples, were established.

The LPI guidelines developed from this project will provide traffic engineers and managers with a simple and robust tool to:

- Assess the suitability and warrants for LPI implementation
- Determine appropriate LPI duration configurations
- Assess the need for supplemental LPI items

BEFORE-AFTER DATA COLLECTION AND REVIEW PROCESS

A pilot before-after study was conducted to provide measures of effectiveness to evaluate and further refine the preliminary LPI implementation guidelines. To conduct the before-after analysis, the research team coordinated extensively with each FDOT District in the selection process for candidate sites within each District's jurisdiction. The research team selected eleven testing approaches from nine intersection locations statewide that met one or more LPI implementation warrants in the preliminary guidelines and covered a geographically-diverse range of environments (urban/ suburban, high/low speed approaches, north/south/central Florida, inland/coastal, etc.), including:

- East leg (northbound right turn), E Fletcher Ave @ USF Palm Dr, Tampa, FL
- West leg (southbound right turn), E Kennedy Blvd @ N Tampa St, Tampa, FL
- West leg (southbound right turn), E Fletcher Ave @ N Nebraska Ave, Tampa, FL
- South leg (eastbound right turn), W University Ave @ NW 13th St, Gainesville, FL

- South leg (eastbound right turn) and north leg (eastbound left turn), SR A1A @ 178th St, Sunny Isles Beach, FL
- North leg (westbound right turn), US 41 @ Laurel Rd, Nokomis, FL
- West leg (southbound right turn), US 1 @ E Broward Blvd, Fort Lauderdale, FL
- South leg (eastbound right turn) and east leg (northbound right turn), E Tennessee St @ E Monroe St, Tallahassee, FL
- East Leg (northbound right turn), SR 200 @ SW 60th Ave, Ocala, FL

After the LPI approach at each selected intersection was identified, video data of at least eight hours on a weekday before LPI implementation were collected regarding each targeted approach. After an LPI was implemented on the identified approach for each selected intersection, video data of at least eight hours on a weekday, covering peak and non-peak hours, were also collected for the LPI before-after analysis. In the data review process, three pedestrian phases were defined, including LPI phase ("after" data) and the first few seconds of "Walk" signal equal to LPI duration ("before" data), remaining of "Walk" phase (including flashing or count down), and "Do Not Walk" phase. Under different pedestrian signal phases, data were reviewed for pedestrian volume, turning vehicle volume, turning vehicle yielding and non-yielding behavior, vehicle-pedestrian conflict, and pedestrian compliance and non-compliance to pedestrian signal indications. Graduate students were sufficiently trained to review the collected data, and data quality checks were performed to ensure that the reviewed data were accurate for analysis.

ANALYSIS AND FINDINGS ON LPI SAFETY EFFECTIVENESS AND OPERATIONAL IMPACT

Evaluation and comparison analysis were conducted regarding LPI safety effectiveness, LPI influence on traffic operation efficiency in terms of travel delay, and LPI utilization efficiency. The research findings are summarized as follows:

- Proper implementations of LPIs demonstrated promising safety effects in reducing the number of vehicle-pedestrian conflicts at five of the six (83%) testing approaches during the first few seconds equal to LPI length. The percentage of vehicle-pedestrian conflict reduction ranged from 25% to 100%. The implemented LPIs were also able to reduce vehicle-pedestrian conflicts at six of eight (75%) testing approaches during the entire pedestrian walk phase. The percentage of vehicle-pedestrian conflict reduction also ranged from 25% to 100%.
- The implementation of LPIs showed mixed results of drivers' yielding behaviors. A higher percentage of non-yielding vehicles were observed during the first few seconds equal to LPI length, but a lower percentage of drivers' non-yielding vehicles were observed during the entire pedestrian walk phase. Field observations also revealed that drivers continued to make right turns on red if allowed, and tended to turn quickly at the onset of pedestrian walk phase if pedestrians hadn't started to walk. These behaviors induced considerable non-yielding observations and compromised pedestrians.
- Although the risk of drivers' non-yielding behaviors is lower than the conflicts between vehicles and pedestrians, sufficient attention is still needed on this safety issue. It is recommended to implement static or blank-out "NO TURN ON RED" signs or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs along with LPI implementation to enhance the safety of pedestrians crossing at signalized intersections.

- Based on the simulation analyses for the two most congested testing intersections before and after LPI implementation, it was found that the implemented LPI induced a slight increase or decrease in average total delay per vehicle on different approaches, showing a trivial adverse or even favorable influence on intersection operation efficiency.
- In terms of LPI utilization efficiency, it was found that the LPI was effectively used at most tested approaches, including achieving a percentage of utilization above 85% at seven testing intersection approaches; two additional testing approaches achieving above 70%, and one additional achieving above 60%. Overall, the implemented LPI was well recognized and sufficiently used by pedestrians.

REFINEMENT OF LPI IMPLEMENTATION GUIDELINE

Based on data review, analysis, and findings of the collected data before and after LPI implementation at test sites, the preliminary statewide LPI implementation guidelines were refined and finalized. The following summarizes factors considered for the refinement and finalization of LPI implementation guidelines at signalized intersections:

- Crash history between pedestrians and turning vehicles
- Presence of visibility issues blocking driver view of pedestrians
- Citizen complaints about vehicles not yielding to pedestrians, including observed conflicts between pedestrians and turning vehicles and compromised pedestrians at a specific approach
- Land use type that attracts pedestrians near signalized intersections
- T-intersections and intersections with a one-way road
- Risk potential of conflicts at a specific approach based on a combination of the following vehicular and pedestrian volumes during peak hours, four and/or eight hours of a day:
    - turning vehicle volume
    - pedestrian crossing volume
    - through traffic volume of cross street
- Marked school crossings

The results and findings of this project provide clear insight into the suitability of LPI implementation and effectiveness in increasing pedestrian safety at signalized intersections. It also provides traffic engineers and managers with simple and robust LPI implementation guidelines and LPI warrants for appropriate and effective LPI implementation.

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1 INTRODUCTION

1.1 Background

Pedestrian safety is an ongoing major concern throughout the United States, especially in Florida, which experiences higher crash rates for pedestrians and bicyclists [1]. Florida has been ranked among the U.S. states with the highest pedestrian fatalities for many years. From 2008 to 2011, Florida was ranked #1 in pedestrian fatality rates at a pedestrian crash rate double the national average [2]. As a result, the Florida Department of Transportation (FDOT) has made pedestrian safety a top priority. Pedestrians and bicyclists are commonly referred to as "vulnerable road users" because the lack of a protective structure and differences in mass heighten their injury susceptibility in collisions with motor vehicles [3]. As a general rule, vehicles are legally required to yield to pedestrians when there is a potential conflict between vehicles and pedestrians. However, for many reasons (e.g., driver characteristics, driver distraction, driver impairment, road design, surrounding environment), drivers might make risky decisions by accepting short gaps or not yielding to pedestrians, which might threaten pedestrian safety. This is especially true at signalized intersections, where vehicles and pedestrians share the crosswalk during concurrent vehicle and pedestrian phases. Among the many engineering treatments for safety countermeasures, one of the most effective ways to reduce the number of conflicts and crashes involving vehicles and pedestrians is to provide a means of separation by either space or time [4], [5].

One low-cost technique to separate pedestrians and turning vehicles is the Leading Pedestrian Interval (LPI), a traffic signalization strategy also known as "pedestrian head start" or "delayed vehicle green"[5]. LPI, as shown in Figure 1-1, gives pedestrians an advance "Walk" signal before a concurrent green signal is provided to vehicles, allowing the pedestrians to establish a presence in the crosswalk, thereby increasing the visibility of pedestrians to drivers (more yielding to pedestrians) and potentially reducing conflicts with turning vehicles. Typical LPI settings provide three or more seconds of advance walk time. By giving pedestrians a head start, it is less likely that there will be conflict between pedestrians and turning vehicles. LPIs increase the percentage of motorists who yield the right of way to pedestrians because pedestrians are in the crosswalk by the time the traffic signal turns green for parallel vehicle movements.

Figure 1-1 Leading pedestrian interval.

LPIs can be very useful in addressing vehicle-pedestrian conflicts at signalized intersections. However, a traffic agency may not implement them at every intersection since they are dependent on the characteristics of the location, traffic conditions, pedestrian activities, number of vehicle and pedestrian conflicts, and signal timing. For example, if there are no frequent pedestrian crossings, the implementation of an LPI could delay traffic unnecessarily and cause drivers to complain about signal timing when a pedestrian pushes a pedestrian pushbutton and leaves before the display of LPI. Therefore, there is a need to determine the suitability and effectiveness of LPI implementation at signalized intersections to improve pedestrian safety and a need to develop statewide guidelines for LPI implementation.

1.2 Project Objectives

The overall objective of this project was to conduct an integrated study to determine the suitability and effectiveness of LPI implementation at signalized intersections to improve pedestrian safety and to develop statewide guidelines for LPI implementation. Specifically, the primary objectives of this study were to:

- Obtain knowledge, experience, and guidance for LPI implementation from literature review, traffic agency interviews, recommendations from field experts, and consultation with FDOT District operations engineers and managers.
- Develop preliminary LPI implementation guidelines based on the knowledge, experience, and guidance from literature reviews, traffic agencies, field experts, and FDOT District operations engineers and managers.
- Conduct before-after data collection, review, and analysis via pilot LPI implementation to evaluate LPI effectiveness in pedestrian safety and traffic operation efficiency.
- Develop simple and robust statewide guidelines for LPI warrants, implementation, and operations in Florida by refining the preliminary guideline based on data analysis results and findings from pilot LPI implementations.

1.3 Report Organization

This report is organized into seven chapters:

1. Introduction
2. Literature Review on LPI
3. Development of Preliminary LPI Implementation
4. Data Collection Before and After LPI Implementation
5. Before-After Analysis of LPI Safety Effectiveness and Operational Impact
6. Finalization of LPI Implementation Guidelines
7. Conclusions and Recommendations

References and Appendices are provided at the end of this report.

2 LITERATURE REVIEW ON LPI

2.1 Existing LPI Guidelines and Cities with LPI Implementation

Studies in several North American cities, including New York City, San Francisco, and Washington DC, have demonstrated that LPIs reduce conflicts and crashes between vehicles and pedestrians [6]–[8]. Almost all successful implementations were in downtown cores.

Research indicates that the only published scientifically-based document that defines criteria or guidelines for LPI implementation is a Transportation Research Board (TRB) paper from the City of Toronto titled "Leading Pedestrian Interval Assessment and Implementation Guidelines" [8]. The following factors were considered in their LPI suitability assessment:

- Is the pedestrian crossing at a T-intersection and/or parallel to a one-way road?
- Are there issues due to features such as irregular intersection geometry, wide turning radius, crosswalk placement, obstructions such as buildings or the base of a bridge, or blinding sun angle?
- What is the eight-hour volume of pedestrians crossing the leg being considered for LPI? (2 if $p>1000$, 1 if $200<p\leq1000$, or 0 if $p\leq200$)
- What are the impacts of vehicles using the intersection (e.g., delays and v/c ratio)?
- What is the rate of annual pedestrian-turning vehicle collisions per 1,000 eight-hour pedestrian crossings?
- What is the rate of pedestrian-turning vehicle conflicts per 1,000 eight-hour pedestrian observations?
- How far is the location from the nearest elementary school?
- What is the older adult demand score of the area?

The methodology recommends that if the final score exceeds a threshold of 5, the LPI should be considered. Conflict data should be collected only if the score is less than 5 but greater than 3, since collecting conflict data is a resource-intensive exercise. If information related to conflicts would not bring the overall score to 5 or greater, conflict data collection should be omitted [8].

Other cities have published recommendations for LPI location selection (though less comprehensive than Toronto's guidelines), including Boston, Washington DC, and Hamilton, as shown in Table 2-1. Also, the National Association of City Transportation Officials (NACTO), in its *Urban Street Design Guide*, included the following application for LPI: "Use LPIs at intersections where heavy turning traffic comes into conflict with crossing pedestrians during the permissive phase of the signal cycle. LPIs are typically applied where both pedestrian volumes and turning volumes are high enough to warrant an additional dedicated interval for pedestrian-only traffic" (NACTO, 2013). Table 2-1 summarizes cities outside Florida that have implemented LPI and/or evaluated the effectiveness of LPI operations.

Table 2-1 Existing LPI Implementation by Cities outside Florida

City	Implementation Items	Highlights/ Results/Criteria
New York City [6]	• LPIs range from 5–19 secs • List of NYC LPI signals http://www.nyc.gov/html/dot/html/infrastructure/leading-ped-intervals.shtml	10-year before-after crash history study using a control group: • Studied 26 locations with LPIs • 192 vehicle/pedestrian crashes at LPI intersections, 352 crashes at control sites • Change in absolute rate of vehicle-pedestrian crashes= -12% • Change in rate of vehicle-pedestrian crashes factored by severity= -55% • Decided to install more LPIs in NYC
Toronto, Canada [8], [10]	• ~5-sec LPI • 2 LPI intersections	Before-after conflict analysis: • 34% reduction in non-yields at one of two LPI intersections (University and Adelaide) • Significant increase in non-yields at Harbord Street and St. George Street (removed within six weeks of installation)
San Francisco, CA [5]	• 4-sec LPI • 4 LPI intersections	Before-after conflict analysis: • Based on video data collection • 65–76% reductions in number of vehicles turning in front of pedestrians at 3 of 4 LPI intersections • Effectiveness of LPI appeared to vary with intersection characteristics • Impact of LPI could possibly be enhanced with red turn arrow
State College, PA [7]	• 3-sec LPI • Installed at 10 intersections in downtown in 2005	Crash data analysis and empirical Bayes method with control intersections: • Average of 19 vehicle-pedestrian crashes per year in review of 8 years of crash data • 46–71% reduction in crashes, not significantly greater at intersections with larger volumes of pedestrians • Cost savings of $92,130 per intersection per year (0.56 crash reduction) • Estimated benefit-to-cost ratio: 801:1
Philadelphia, PA [11]	• 3-sec LPI • Recommended in city pedestrian and bicyclists plan, and installed at a number of intersections in downtown area	Location selection criteria: • Complex and confusing intersections lacking crosswalks. • Vehicles often fail to yield pedestrian right-of-way • Skewed intersection and wide turning radii.

Table 2-1 Existing LPI Implementation by Cities outside Florida (Continued)

City	Implementation Items	Highlights/ Results/Criteria
Hamilton, Canada [12]	• At least 4-sec LPI • Used in some locations • Routine accommodation and toolbox solutions	Location selection criteria: • Heavy vehicle turning movements, concurrent heavy pedestrian volumes • High crash locations where crashes due to right- and left-turning vehicles • School crossing locations • High use by populations over-represented in crash data (older adults, persons with disabilities) • High levels of citizen complaints about aggressive driving
Boston, MA [13]	• 3–7-sec LPI • the city is looking to expand the use of LPIs with concurrent phasing as alternative to exclusive phases	Complete streets guidelines: • Lagging protected left arrow for vehicles • Should be provided to accommodate LPI • Use of appropriate signage, such as "TURNING VEHICLES YIELD TO PEDESTRIANS" • Use of accessible pedestrian signals, pushbuttons
Phoenix, AZ [14]	• 5-sec LPI • 3 LPI intersections • Time-of-day LPI	Location characteristics: • Heavy left-turn movement conflicts with heavy crossing • Two one-way streets
Washington, DC [14]	• Typically use 3-sec LPI; rare occasions 7–8 sec for unusual geometrics • 162 LPI intersections (~10%) • Mostly have LPI on all four approaches • Implement LPI through central controller	Location selection criteria: • Use of crash data to identify locations with high ratio of crashes involving turning vehicles and pedestrians with signal in crosswalk • High complaint locations • When analyzing count data – DDOT Signal Optimization Project • More effective when "NO RIGHT TURN ON RED" posted

The CUTR research team consulted with Albeck Gerken, Inc. to determine cities in the US that have experience with LPI implementation, as summarized below. The collected information was used when conducting phone interviews with representatives from agencies with LPI implementation experience.

- **Ames, IA** – LPIs installed at many locations
- **Atlanta, GA** – many LPIs in midtown area, but only at two-phase intersections (e.g., no left turning phases)
- **Ann Arbor, MI** – several locations with LPI throughout city
- **Los Angeles, CA** – LPIs implemented on a selective basis at locations with the following characteristics:
    - "Soft" left turn at which drivers can turn at a higher-than-normal turn speed
    - Left turn with a long turning path such that pedestrians might not be readily seen

    - Dual left-turn lanes (or left and left-thru lanes) on a one-way street at which the inside vehicle might block the driver view in the adjacent turn lane
    - Left-turn movement is majority movement on approach and drivers assert themselves without fully recognizing need to yield to pedestrians; being used as interim measure until protected left-turn phasing can be installed
    - LPIs should be reserved for unique situations that truly justify them; should not be applied blindly at conventional four-legged, right-angle intersections
- **Frederick, MD** – LPIs used at intersections with unique crosswalk configurations or limited sight distance from one direction
- **Statesboro, GA** – LPI used at two intersections next to a college campus, both with aggressive drivers on a permissive left who interfere with pedestrians in crosswalk
- **Manhattan Beach, CA** –LPIs used at two intersections near Manhattan Beach Pier due to heavy pedestrian traffic; chose LPI over a scramble because of seasonal nature of pedestrian usage

In reviewing studies on LPI applications in Florida, published documents about LPI operations were found for Orlando, St. Petersburg, and Miami [4], [15], [16]. All were installed in the downtown area. However, LPI applications in St. Petersburg were discontinued when the City updated the timing plans in the central business district and no one complained about not putting LPI into use. In addition, during this study, an LPI phase was implemented at SR 200 @ SW 60th Ave in Ocala, FL to address the visibility issue at this intersection. Table 2-2 summarizes the cities in Florida that have implemented LPI and published their evaluation results of LPI operations.

Table 2-2 Florida Cities with Existing LPIs and Evaluations

City	Implementation Items	Highlights/ Results/Criteria
Orlando [16]	• Primary impetus was highly-publicized accident involving a municipal employee • Location: South Street @ Orange Avenue in downtown (near municipal parking facility) • Cost: hundreds of dollars and two hours to install • 4 seconds LPI • "YIELD TO PEDESTRIANS" sign on green, "NO TURN ON RED" sign on red	• City staff note that, because of reduction in pedestrian/auto conflicts, LPI has improved vehicular level of service despite decrease in green time for vehicles • Both motorists and pedestrians became accustomed to new situation rather quickly • Pedestrians benefit from increased safety and visibility
St. Petersburg [4], [16]	• 3 intersections in downtown (discontinued) • 3-sec LPI • Using modified, solid-state plug-in signal load switch with capability to delay change of traffic signal from red to green	Before-after conflict study: • Odds of conflict for pedestrians leaving curb at beginning of walk period reduced by ~95% • Likelihood that pedestrian would yield to turning vehicle during LPI condition decreased by ~60% • No reduction in intersection effectiveness for motor vehicles was detected LPIs discontinued: • City updated timing plans in central business district, did not re-install LPI, received no complaints
Miami [15]	• 2 intersections in downtown (one 4-leg, one 3-leg) • 4-sec LPI	Before-after conflict study: • 9–18% increase in left-turn yielding to pedestrians • No change in right-turn yielding to pedestrians • 7–15% increase in pedestrians pushing button • 21–31% increase in pedestrians starting their crossing during first 4 secs
Ocala [17]	• 1 skewed intersection with visibility issue • Installed on northbound right-turn approach at SR 200 @ SW 60th Ave • 5-sec LPI	Before-after conflict study: • Visibility issue exists due to the existence of roadside utility cabinet • Pedestrian traffic was low in before and after study. • LPI caused no adverse effect as it was activated when a pedestrian call was placed

The CUTR team also consulted with Albeck Gerken, Inc. to determine cities and counties in Florida that have pursued or implemented LPIs, as summarized in Table 2-3. The collected information was used when conducting phone interviews with representatives from agencies in Florida with LPI implementation experience.

Table 2-3 Florida Cities/Counties That Have Pursued or Implemented LPIs

County or City	Installed (Yes/No)	Notes	Discontinued (Yes/No/ Unknown)
St. Petersburg	Yes	3 locations in downtown	Yes
Gainesville	No *(considered)*	Particularly near University of Florida (UF) campus where pedestrian volumes high	/
Clearwater	No *(discussed)*	Discussed at a few of locations	/
Palm Beach County	Yes	If left turn is permissive or protected/permitted, may implement LPI for both pedestrian movements	No
Orlando	Yes	Implemented at several locations, including one at request of D5; implemented at all locations considered	Unknown
Tallahassee	Yes	At 12 locations	No
Tampa	Yes	At some locations	Unknown
Pinellas County	Yes	At a few locations; most, if not all, at school crossings	No
Melbourne	Yes	One location adjacent to Florida Institute of Technology at request of D5	No
Miami	Yes	2 intersections (one 4-leg and one 3-leg)	Unknown
Lee County	No *(Testing)*	2 intersections will have LPI, 3rd will serve as control	/
Largo	No *(considered)*	Considered LPI, but implemented flashing yellow arrow left turn	/

2.2 Success and Lessons Learned from Pursuit or Trial Implementation of LPI

2.2.1 Successful Applications of LPI

Based on the summary of existing LPI implementations inside and outside Florida, as shown in Section 2.1, a number of successful implementations were identified, including those in New York City, Toronto, San Francisco, State College (PA), Boston, Washington DC, Orlando, St. Petersburg (FL), and Miami. It was found that these successful LPI implementations were effective in reducing vehicle-pedestrian conflict, increasing vehicle yielding behavior to pedestrian right-of-way, increasing pedestrian utilization of pedestrian calls (pushbutton), and the use of the first few seconds of pedestrian signal (LPI). Also, it was concluded that LPI is a very cost-effective countermeasure that achieves a benefit-to-cost ratio as high as 801:1 and reduces the comprehensive cost of approximately $90,000 per intersection per year. LPI implementations in other cities, although lacking sufficient support references to prove its effectiveness, also yielded promising prospects, as they were proposed to address certain intersection pedestrian-safety issues or recommended in regional pedestrian safety plans.

2.2.2 Cities and Counties in Florida That Considered but Did Not Install LPIs

After consultation with engineers, it was determined that several cities and counties in Florida considered but did not implement LPIs as shown below. Some of them provided reasons for their decisions. More investigation was conducted during phone interviews to determine the reasons.

- **Gainesville** – No LPI installations, but has considered them, particularly near the University of Florida campus where pedestrian volumes are high; concerns are possible impacts on progression and making sure they are actuated where they are used.
- **Clearwater** – No LPI installations; discussed for some locations but did not pursue.
- **Pinellas County** – LPI used at a few locations, with most, if not all, at school crossings; popular with crossing guards, but some locations cannot afford lost vehicle time.
- **Largo** – Considered LPI for an intersection on SR 686 @ Central Park Drive; decided to use a flashing yellow arrow left turn that was conditioned by the crosswalk being activated to show a red arrow.

2.2.3 Trial LPI Implementation

Some agencies tried LPI for a period of time but reverted back to regular signals. Table 2-4 shows several trial LPI implementations and the reasons for discontinuing them.

Table 2-4 Trial LPI Implementations in U.S.

City Implemented	Implementation Items	Findings/Reasons
Anaheim, CA [18]	• 3-sec LPI • 1 intersection in suburban area near Convention Center and Disneyland (S Harbor Blvd and W Katella Ave)	Before-and-after conflict analysis: • LPIs did not provide intended benefit of reducing impact of right-turning vehicles on pedestrians trying to get off curb • Advantages of an LPI in downtown environment may not be fully transferable to crosswalks in a suburban environment if no restriction on right turn on red • May be some adjustment in driver behavior as familiarity with LPI operation increases • May be appropriate to use blank-out "NO RIGHT TURN ON RED" sign during LPI
Toronto, Canada [8], [10]	• 1 skewed intersection (Harbord St and St. George St)	Before-and-after conflict analysis: • Removed within six weeks of installation • Skewed intersection geometry; resulting visibility of pedestrian signal heads to vehicular traffic may have contributed to increase in false starts and non-yielding • Possible that operating LPI for additional few weeks and better user education could have addressed issue
Elgin, IL *(Reported by Gerken, Inc.)*	• 1 intersection	• LPI removed because of problems with operation in controller

2.2.4 Summary of LPI Operations Findings

Most transportation engineers have a good understanding of how LPIs operate and of the pros and cons of LPI operations, as summarized in Table 2-5.

Table 2-5 Pros and Cons of LPI Operations

Pros of LPI	Cons of LPI
• LPIs provide increased visibility of crossing pedestrians and give pedestrians priority within intersections. • Both LPIs and all-pedestrian phase can increase pedestrian perception of safety; LPIs have much less delay when compared to exclusive pedestrian phase. • LPIs can reduce vehicle-pedestrian collisions as much as 60% at treated intersections [7]. • LPIs typically require adjustments to existing signal timing that are relatively low cost compared to other countermeasures.	• LPIs tend to increase signal cycle length, thereby potentially increasing vehicular delays. • LPIs may increase delays for pedestrians if driver propensity to yield is low. • Both motorists and pedestrians initially may be confused by the atypical signal operation. • For LPI, there may be no traffic surges to audibly mark the beginning of the crossing interval, so accessible pedestrian signals may have to be installed, thereby increasing the cost. • Drivers may complain about the LPI if pedestrian crossings are infrequent or no pedestrian is present when LPI is on.

Generally, LPIs work well in the following situations:

- In downtown cores with a high volume of pedestrian crossings
- When prevalent throughout an area and pedestrians are familiar with and understand their operations
- When supplementary "RIGHT TURN ON RED" restrictions are provided
- At locations with a high number of vehicle-pedestrian conflicts, or a high number of students or older adults, and at complex intersections with poor sight distance

LPIs may not work well for some locations. The major reasons for not pursuing or avoiding the implementation of LPIs are:

- Concerns about possible negative impacts on vehicular progression
- Concerns about driver complaints if there is no pedestrian when LPI is on
- Concerns that some locations cannot afford lost vehicle time
- Concerns about false starts and non-yielding, especially at skewed intersections
- Concerns about LPI effectiveness if there is no "RIGHT TURN ON RED" restrictions

2.3 Signal Controller Compatibility

2.3.1 Older Signal Controllers

Older signal controllers, such as the TCT8000 and TMP390, may need a new or additional phase for the LPI interval, allowing the "Walk" signal to appear before the green interval and keeping all the other signals red [14]. Also, LPIs typically require a dummy phase to link with the rest of the "Walk" and pedestrian clearance intervals (this can be done with concurrent operating phases or controllers capable of pedestrian overlaps) [14].In addition, it can be more complex to establish left-turn phases with LPI because of the increased number of phases used and limitations of older controllers.

2.3.2 Newer Signal Controllers

The newer signal controllers, such as the ASC/2 or ASC/3, use the delayed green feature, the time that the vehicle green indication is delayed from the start of the "Walk" interval. The delay is ignored if there is no pedestrian service call when the phase is started (actuated mode). If the delay time is greater than the "Walk" time, the "Walk" time is extended to the end of the delayed green [14]. For fixed-time or non-actuated operation, delayed green for LPI is provided for every signal cycle. According to the *ASC/3 Programming Manual*, the delayed green can be set from 0 to 255 seconds as a pushbutton and automated detection of time-of-day.

The cost of implementing LPIs is very low if there is no need for new controllers, requiring only time and effort to implement. The implementation cost could include the implementation of "NO TURN ON RED" signs for which blank-out signs are highly recommended. The cost of accessible pedestrian signal pushbuttons should also be considered in the implementation process, as they are highly recommended for visually-impaired pedestrians.

3 DEVELOPMENT OF PRELIMINARY LPI IMPLEMENTATION GUIDELINES

3.1 Collection of Information and Input for Guideline Development

As mentioned in Chapter 2, an LPI allows pedestrians at signalized intersections to establish a presence in a crosswalk, thereby increasing the visibility of pedestrians to drivers and potentially reducing conflicts with turning vehicles. However, LPI is not suitable for implementation at every intersection. To develop effective and robust guidelines for LPI implementation, it is vital to obtain input from experienced traffic agency engineers/managers, recommendations from field experts, and consultation with state DOT operations representatives.

This chapter documents the efforts of the research team to collect the input information for preliminary LPI implementation guideline development by conducting an LPI online survey, phone interviews with traffic engineers/managers, and GoToMeetings and teleconferences with FDOT District traffic operations representatives.

- **LPI online survey** – The research team developed a survey questionnaire for LPI implementation guidelines based on the knowledge obtained from literature review. The LPI online survey was conducted with experienced traffic agency engineers and/or managers both in and out of Florida.
- **Phone interviews with engineers/managers** – To get more insight, the research team interviewed five engineers and/or managers with LPI experience via teleconferences to follow up with questions regarding the LPI online survey. Three traffic agencies in Florida and two outside Florida were selected for the phone interviews.
- **Discussions with FDOT District traffic operations representatives** – GoToMeetings and teleconferences were held to discuss the development of statewide guidance for LPI implementation with FDOT District traffic operations representatives. For each District, at least one representative attended the GoToMeetings or teleconferences and provided valuable input to the LPI guideline development.

3.1.1 Survey on LPI Implementation

The research team developed a survey questionnaire for experienced traffic engineers/managers to obtain information on their experience and knowledge of LPI implementation in their cities/counties, including:

- Reasons for implementation of LPIs
- Criteria or internal guidelines used to determine implementation of LPIs
- Percentage of pedestrian crash changes after implementation of LPIs
- Percentage of vehicle-pedestrian conflict changes after implementation of LPIs
- Successful experiences or complications with LPI implementation
- Lessons learned from LPI implementation
- Perceptions and reactions from the general public on LPI implementation

The survey questionnaire can be found in Appendix A and the results and findings from the LPI online survey are summarized in Appendix B.

3.1.2 Phone Interviews with Engineers/Managers from Traffic Agencies

The experience gained from traffic agencies on planning, implementation, and operation of LPIs is very helpful for developing LPI implementation guidelines to meet agency needs and expectations. Based on the responses from the LPI online survey, the research team interviewed engineers and/or managers via teleconferences from the following traffic agencies that have LPI experience. The CUTR team coordinated the teleconferences and facilitated and documented discussions with representatives from:

- City of Tampa, FL
- City of Clearwater, FL
- City of Lakeland, FL
- City of Albany, NY
- Washington, DC

The critical input obtained from these teleconferences regarding LPI implementation guideline are summarized in Appendix C.

3.1.3 Discussions with FDOT District Traffic Operations Representatives

The support of FDOT District Traffic Operations for LPI implementation guidelines developed from this research project is essential to the success of future LPI implementation in Florida. GoToMeetings and teleconferences with FDOT District Traffic Operations representatives (Table 3-1) were conducted to obtain input, feedback, and support from engineers and/or managers on LPI implementation, operations, guideline development, and equipment requirements for LPI implementation.

Table 3-1 Attendees at GoToMeetings and Teleconferences

Organization	Attendees*
Central Office	Angela Kristiansen
District 1 (D1)	Renjan Joseph
District 2 (D2)	Sam Middleton, Jerry Ausher
District 3 (D3)	Michael Lewis
District 4 (D4)	Jonathan Overton
District 5 (D5)	Rick Morrow
District 6 (D6)	Evelin Legcevic, Esteban Espinal, Elio Espino
District 7 (D7)	Peter Hsu, Mark Hall, Elizabeth Wehle, Matthew Weaver
Turnpike District	Even Echevarria
CUTR	Pei-Sung Lin, Rui Guo, Kristin Larsson

**Note: Several provided input and feedback through emails*

The feedback from FDOT Central Office managers and FDOT District representatives regarding the development of LPI implementation guideline is summarized in Appendix D.

3.1.4 Summary of Responses from Traffic Agency Engineers/Managers and FDOT District Traffic Operations Representatives

The responses from experienced traffic agency engineers/managers and FDOT District traffic operations representatives provided valuable information and input for the development of guidelines for LPI warrants, implementation, and operations in Florida. In general, it is a complex situation when considering LPI implementation and many factors (e.g., crashes, volumes, conflicts, visibility issues, special events, etc.) need to be considered. It is important to balance the needs of pedestrians and drivers. A summary of the responses is as follows:

a) Consider the following factors for LPI implementation criteria:

- Citizen complaints: It can be used to start looking at LPI and also to meet other criteria for implementation
- Crash history between pedestrians and turning vehicles:
    - During pedestrian signal indications (crash types)
    - At intersection level (difficult to get crash data at approach level)
- Turning vehicle volume at the specific approach:
    - At approach level (e.g., 50 during a peak hour according to criteria in DC)
- Pedestrian volume or activity (in combination with turning vehicle volume):
    - Pre-timed control: specified pedestrian volume threshold
    - Actuated control: perhaps not a specified pedestrian volume threshold
    - Considering adjacent land use types, especially school zones
    - Considering special events with high pedestrian activity
- Conflicts between pedestrians and turning vehicles (not necessarily numerical)
- Irregular intersection features (e.g., visibility issues)
- LPI works mostly with right-turning vehicles, and can be considered with left-turning vehicles at T-intersection and one-way roads.
- Two sets of criteria may be considered for urban areas and suburban areas

b) Consider the following concerns of LPI implementation:

- Various pedestrian compliance/behavior
- Obvious negative impacts on vehicular progression
- Pedestrian behavior of pushing pedestrian button but leaving before LPI starts, leaving LPI unused.

c) Consider the following supplemental needs for LPI implementation:

- "NO TURN ON RED" sign or "NO TURN ON RED" blank-out sign
- Accessible pedestrian signals (APS)
- Education about LPI

3.2 Preliminary LPI Implementation Guidelines

Based on the literature review, surveys and interviews with experienced traffic engineers and managers on LPI, and consultation with FDOT traffic operations representatives, initial statewide LPI implementation guidelines were drafted regarding LPI parameters, warrants, and

support. Based on the review comments received on initial guidelines from FDOT and Albeck Gerken, Inc. and the guidance from the FDOT project managers, preliminary LPI implementation guidelines, including illustrative examples, were established. The full preliminary statewide LPI implementation guidelines are documented in Appendix E.

The LPI guidelines developed from this project will provide traffic engineers and managers with a simple and robust tool to:

- Assess the suitability and warrants for LPI implementation
- Determine appropriate LPI duration configurations
- Assess the need for supplemental LPI items

4 DATA COLLECTION BEFORE AND AFTER LPI IMPLEMENTATION

Statewide LPI implementation guidelines were drafted regarding LPI criteria and parameters. A before-after study was conducted for a pilot implementation of LPIs to evaluate their effectiveness and further refine the preliminary LPI implementation guidelines. This chapter documents the research effort to collect data before and after LPI implementation. Detailed efforts for each of the subtasks are presented in the sections below.

4.1 Establishment of Number and Locations of Test Sites

Based on the research scope, CUTR coordinated extensively with each FDOT District in the selection process for candidate locations within each District's jurisdiction and ensured that there were no objections to implementing LPI on one or more approaches at each of these locations. In response to the research team's request, each FDOT District provided a number of candidate intersection locations that have a potential need for LPI implementation due to vehicle-pedestrian conflicts or crashes, intersection visibility issue, or large vehicle or pedestrian volume that induce a large pedestrian crash risk.

After receiving candidate locations, the research team carefully examined them following the warrants of LPI needs in the preliminary LPI implementation guidelines (Chapter 3). These warrants cover historical vehicle-pedestrian crash or conflict information, visibility issue, land use information, and turning vehicle, pedestrian and intersecting traffic volume information. Eleven testing approaches from nine intersection locations statewide that met one or more LPI implementation warrants in the preliminary guidelines were selected, covering a geographically-diverse range of environments (urban/suburban, high/low speed approaches, north/south/central Florida, inland/coastal, etc.). The approach and location for the LPI implementation at each selected site, along with the geometric information and the reason for choosing it, were provided as follows:

1. East leg (northbound right turn), E Fletcher Ave @ USF Palm Dr, Tampa, FL
2. West leg (southbound right turn), E Kennedy Blvd @ N Tampa St, Tampa, FL
3. West leg (southbound right turn), E Fletcher Ave @ N Nebraska Ave, Tampa, FL
4. South leg (eastbound right turn), W University Ave @ NW 13th St, Gainesville, FL
5. South leg (eastbound right turn) and north leg (eastbound left turn), SR A1A @ 178th St, Sunny Isles Beach, FL
6. North leg (westbound right turn), US 41 @ Laurel Rd, Nokomis, FL
7. West leg (southbound right turn), US 1 @ E Broward Blvd, Fort Lauderdale, FL
8. South leg (eastbound right turn) and east leg (northbound right turn), E Tennessee St @ E Monroe St, Tallahassee, FL
9. East Leg (northbound right turn), SR 200 @ SW 60th Ave, Ocala, FL

Among these, Sites 1, 2, and 3 are in the FDOT District 7 jurisdiction, Site 4 is in District 2, Site 5 is in District 6, Site 6 is in District 1, Site 7 is in District 4, Site 8 is in District 3, and Site 9 is in District 5. The detailed descriptions and justifications of the choice on each intersection and approach are presented below.

4.1.1 E Fletcher Ave @ USF Palm Dr, Tampa, FL

The intersection of E Fletcher Ave @ USF Palm Dr is located on the north of the University of South Florida (USF) main campus. Fletcher Ave, also known as CR 582A, is a major arterial in Tampa that carries eastbound and westbound traffic, and serves as the north boundary of the USF main campus. USF Palm Dr is an in-campus road transferring input and output traffic. The location and vicinity of this intersection are shown in Figure 4-1.

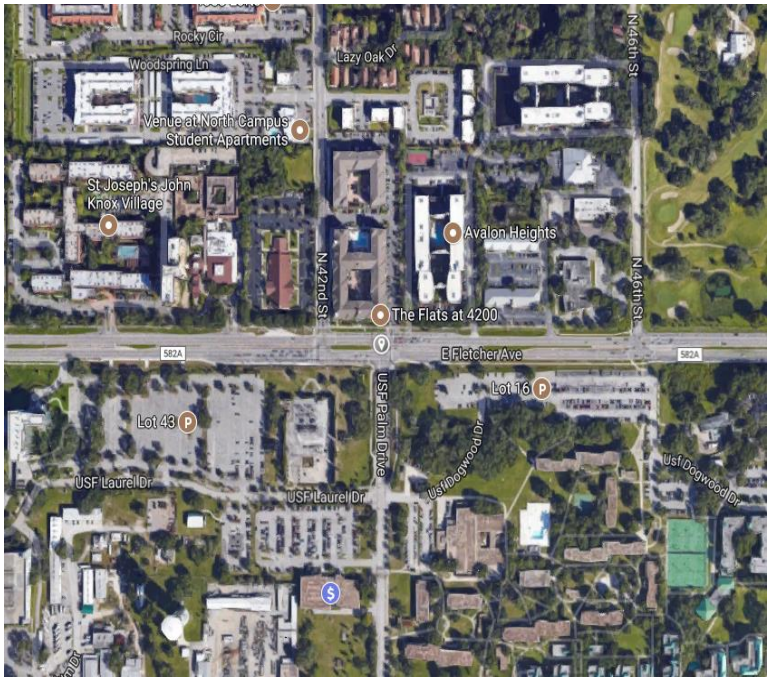


Figure 4-1 Location and vicinity of E Fletcher Ave @ USF Palm Dr, Tampa, FL.

A detailed layout of this intersection is shown in Figure 4-2. The targeted approach for LPI implementation and before-after analysis was the northbound right-turn traffic corresponding to the crosswalk on the east leg of this intersection. The reason for choosing this intersection was that it is close to the USF main campus and there are a number of apartment complexes on the north side, so a significant amount of pedestrian (combined with bicyclists) traffic would be present during the daytime, especially during the AM peak hour, at noon, and during the PM peak hours when vehicle traffic is also high. This intersection was recommended by FDOT District 7 as a candidate for LPI before-after analysis. The pedestrian signal is actuated and is triggered by pushing a button.

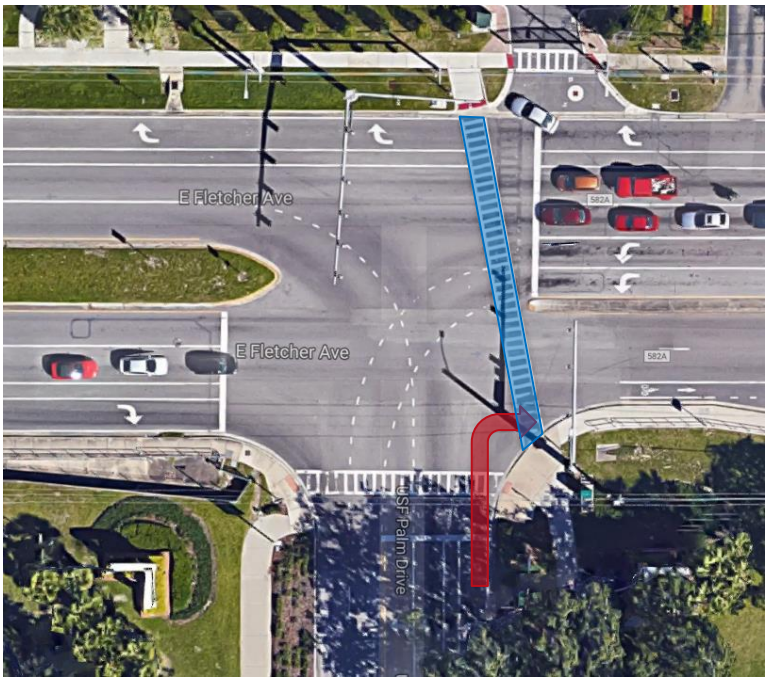


Figure 4-2 Detailed layout of E Fletcher Ave @ USF Palm Dr, Tampa, FL.

4.1.2 West Leg, E Kennedy Blvd @ N Tampa St, Tampa, FL

The intersection of E Kennedy Blvd @ N Tampa St is located in the downtown central business district (CBD) of Tampa. Both of these two intersecting roads are one-way, with N Tampa St carrying southbound traffic and E Kennedy Blvd carrying westbound traffic. The location and vicinity of this intersection are shown in Figure 4-3.

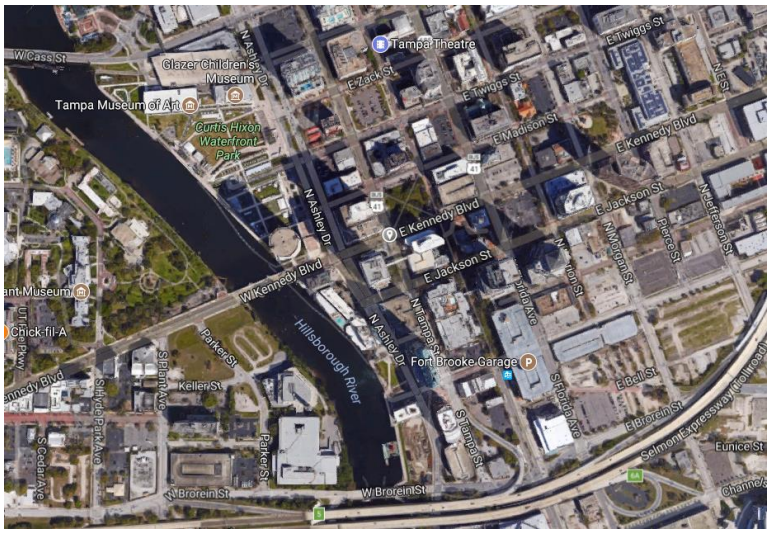


Figure 4-3 Location and vicinity of E Kennedy Blvd @ N Tampa St, Tampa, FL.

A detailed intersection layout is shown in Figure 4-4. The targeted approach for LPI implementation and testing was the southbound right-turn approach, corresponding to the crosswalk on the west leg. The traffic signal control at this intersection is pre-timed, and the pedestrian signal is triggered automatically within in each signal cycle. The reason for choosing this intersection was that it resides in the downtown CBD area where vehicle and pedestrian volumes are both significant and stable. In addition, different from a typical four-way intersection, this intersection is composed of two one-way roads with unique traffic movement patterns, which increases the diversity of candidate sites and provide additional reference to refine the draft LPI implementation guide. This intersection was recommended by FDOT District 7 as a candidate for LPI before-after analysis.

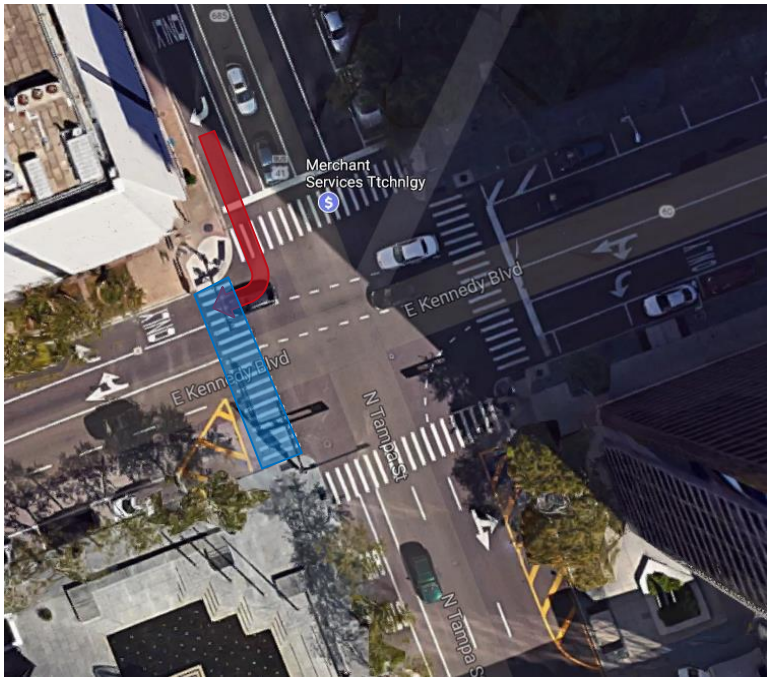


Figure 4-4 Detailed layout of E Kennedy Blvd @ N Tampa St, Tampa, FL.

4.1.3 West Leg, E Fletcher Ave @ N Nebraska Ave, Tampa, FL

This intersection is located in the northern area in Tampa and is formed by two major urban arterials. E Fletcher Ave, also known as CR 582A, is a major arterial carrying eastbound and westbound traffic volumes. N Nebraska Ave is part of US 41 and FL 45 and carries significant northbound and southbound traffic volumes. The location and vicinity of this intersection are shown in Figure 4-5.

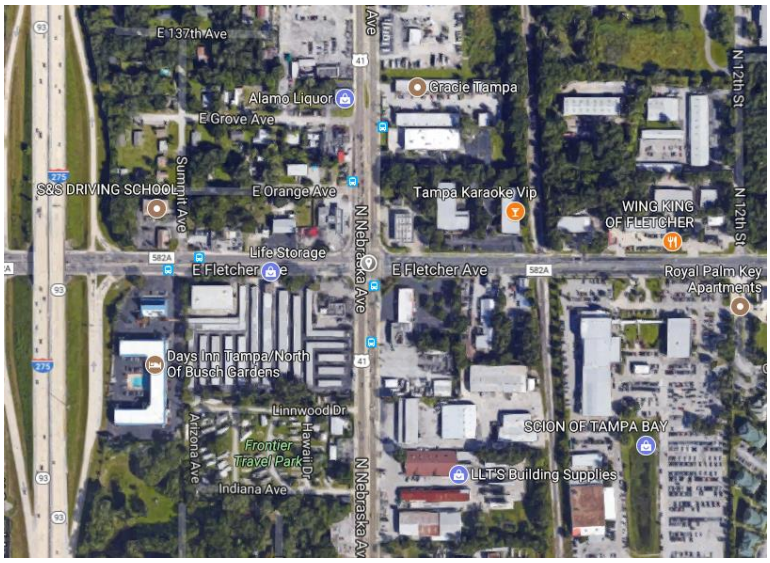


Figure 4-5 Location and vicinity of E Fletcher Ave @ N Nebraska Ave, Tampa, FL.

A detailed intersection layout is shown in Figure 4-6. The targeted approach for LPI implementation and testing was the southbound right-turn approach conflicting with the pedestrian traffic on the crosswalk on the west leg. The reason for choosing this intersection was that it is formed by two major urban arterials, both carrying a significant amount of traffic volume, and historical records indicate that although pedestrian volume is low, there are a considerable number of pedestrians violating the pedestrian signal and crossing the intersection during "Do Not Walk" signal, which causes serious safety issues. This intersection was recommended by FDOT District 7 as a candidate for LPI before-after analysis.

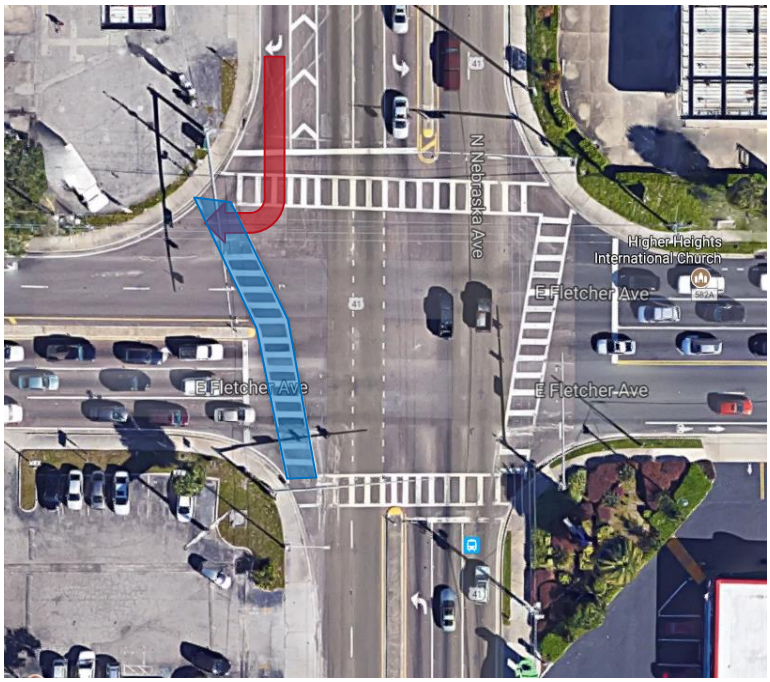


Figure 4-6 Detailed layout of E Fletcher Ave @ N Nebraska Ave, Tampa, FL.

4.1.4 South Leg, W University Ave (SR 26) @ NW 13th St (US 441), Gainesville, FL

This intersection is located in Gainesville on the east of the UF main campus and is formed by two intersecting arterials—SR 26 carrying eastbound and westbound traffic and US 441 carrying northbound and southbound traffic. The location and vicinity of this intersection are shown in Figure 4-7.

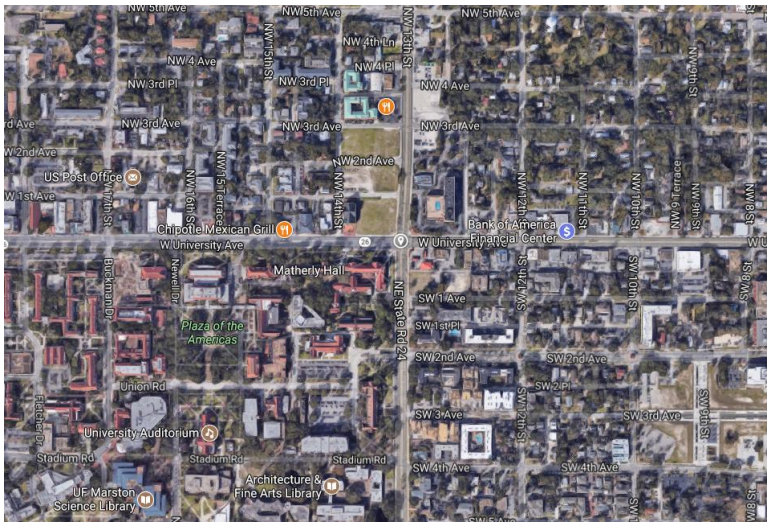


Figure 4-7 Location and vicinity of W University Ave (SR 26) @ NW 13th St (US 441), Gainesville, FL.

A detailed intersection layout is shown in Figure 4-8. The targeted approach for LPI implementation and testing was the eastbound right-turn approach conflicting with the pedestrian traffic on the crosswalk on the south leg. The reason for choosing this intersection was that both of the intersecting roads are major roads carrying a significant amount of traffic volume, and this intersection is close to the UF campus and draws considerable pedestrian volume, making it an ideal location to evaluate LPI effectiveness. This intersection was recommended for LPI before-after study by FDOT District 2.

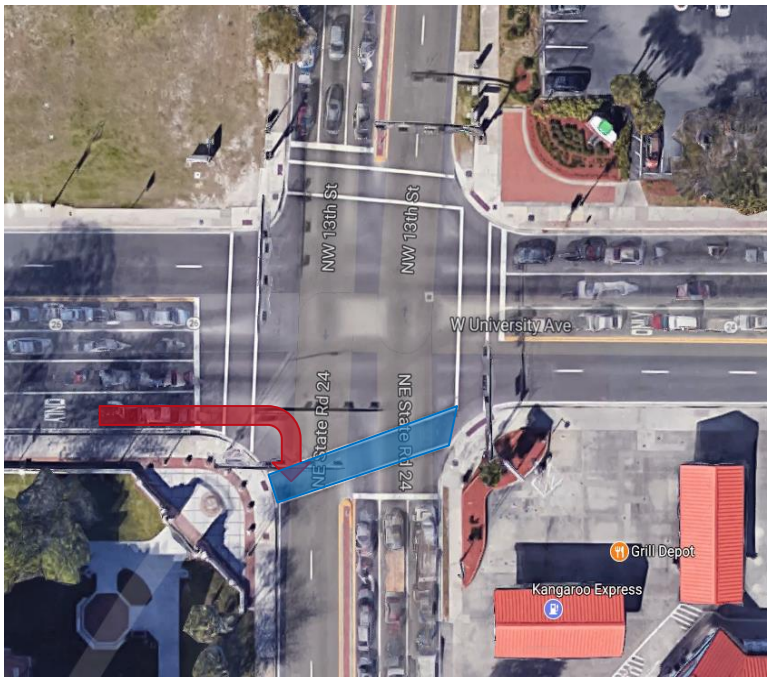


Figure 4-8 Detailed layout of W University Ave (SR 26) @ NW 13th St (US 441), Gainesville, FL.

4.1.5 South and North Legs, SR A1A @ 178th St, Sunny Isles Beach, FL

This intersection is a T-intersection located in Sunny Isles Beach and is formed by two intersecting roads, SR A1A and 178th St. SR A1A is a major urban arterial carrying significant northbound and southbound volume, and 178th St is a minor road carrying eastbound left-turn and right-turn traffic. According to the preliminary LPI implementation guide, for a T-intersection, both left and right turns should be examined for potential implementation. Therefore, both left and right turns on 178th St along with the conflicting crosswalks were considered for the LPI before-after study. The location and vicinity of this location is shown in Figure 4-9.

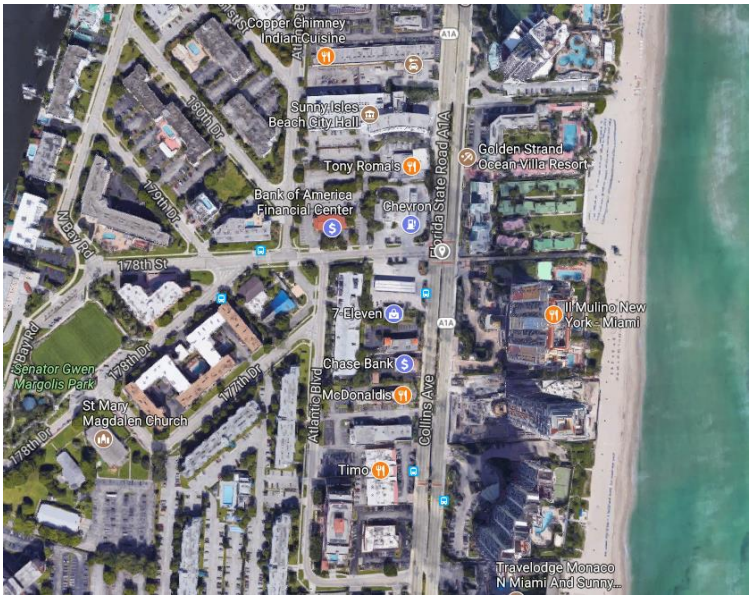


Figure 4-9 Location and vicinity of SR A1A @ 178th St, Sunny Isles Beach, FL.

A detailed layout of this intersection is shown in Figure 4-10. The targeted approaches for LPI implementation and testing were the eastbound right-turn approach conflicting with the pedestrian traffic on the south leg, and the eastbound left-turn approach conflicting with the pedestrian traffic on the north leg. This intersection is located in a tourist area and, therefore, carries significant traffic volume. In addition, it is very close to the beaches on Florida's east coast, and there are a number of luxury hotels along SR A1A, which generate significant pedestrian traffic volume. This intersection was recommended for the LPI before-after study by FDOT District 6.

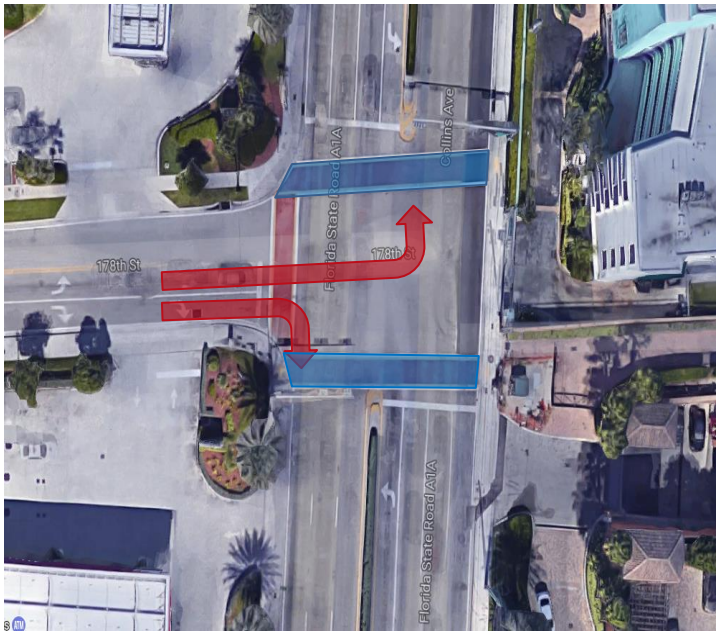


Figure 4-10 Detailed layout of SR A1A @ 178th St, Sunny Isles Beach, FL.

4.1.6 North Leg, US 41 @ Laurel Rd, Nokomis, FL

This intersection is a four-way intersection in Nokomis and is formed by two roads, US 41 (N Tamiami Trail) and Laurel Rd. US 41 is a major urban arterial carrying northbound and southbound traffic, and Laurel Rd is a major urban road carrying eastbound and westbound traffic. The location and vicinity of this location is shown in Figure 4-11.

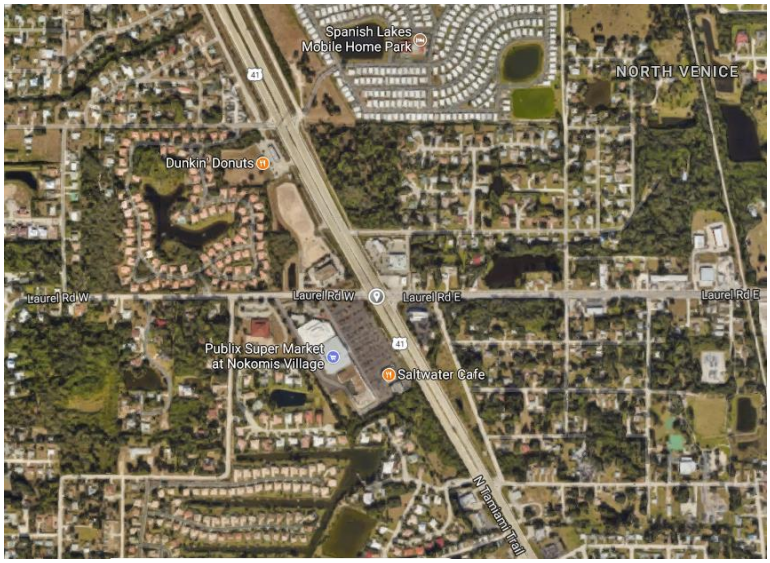


Figure 4-11 Location and vicinity of US 41 @ Laurel Rd, Nokomis, FL.

A detailed layout of this intersection is shown in Figure 4-12. The targeted approach for LPI implementation and testing was the westbound right-turn approach conflicting with the pedestrian traffic on the north leg. This intersection was recommended by FDOT District 1. Due to the skewed design at this intersection, there is large gap distance between the westbound stop line and the north leg crosswalk that leads to a relative high speed when turning vehicles enter the crosswalk. The FDOT received multiple complaints from local residents regarding high turning vehicle speed and failing to yield to pedestrians, especially during peak-hour periods, which made this intersection a good candidate for LPI before-after analysis.

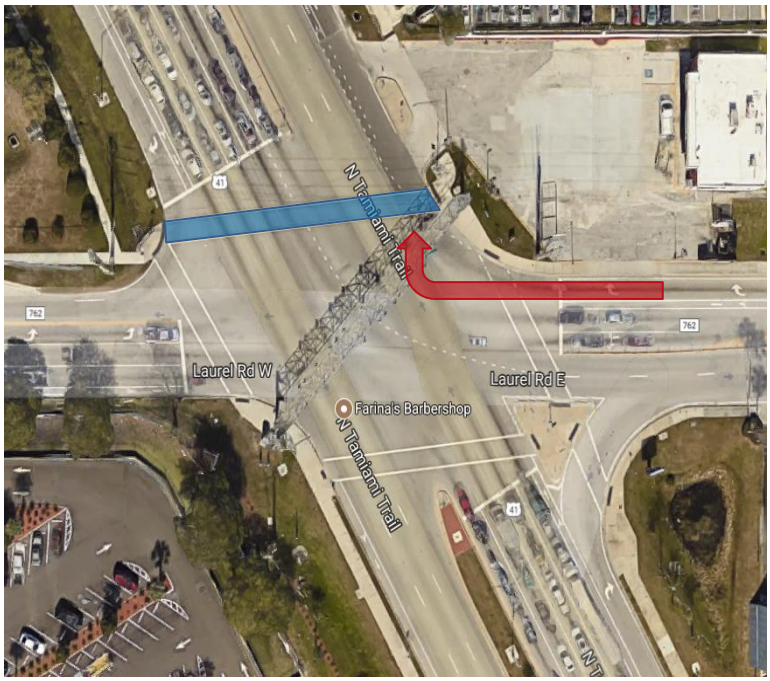


Figure 4-12 Detailed layout of US 41 @ Laurel Rd, Nokomis, FL.

4.1.7 West Leg, US 1 @ E Broward Blvd, Fort Lauderdale, FL

This intersection is located in Fort Lauderdale and is formed by two intersecting roads, US 1 and Broward Blvd. US 1 is a major arterial carrying northbound and southbound traffic, and Broward Blvd is a major arterial carrying eastbound and westbound traffic. The location and vicinity of this location are shown in Figure 4-13.

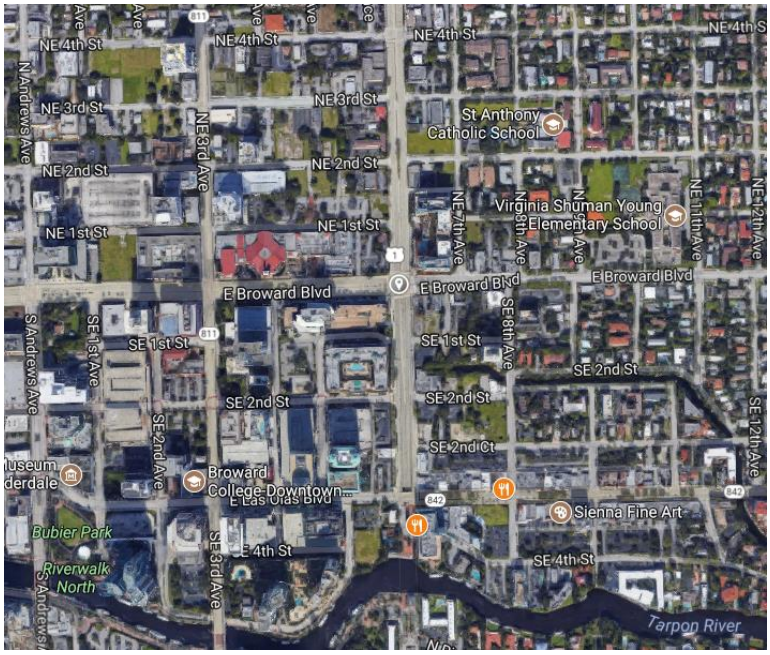


Figure 4-13 Location and vicinity of US 1 @ E Broward Blvd, Fort Lauderdale, FL.

A detailed layout of this intersection is shown in Figure 4-14. The targeted approach for LPI implementation and testing was the southbound right-turn approach conflicting with pedestrian traffic on the west-leg crosswalk. This intersection was recommended for the LPI before-after study by FDOT District 4. A preliminary assessment of this intersection revealed that there are a number of local businesses and bus stops around this intersection that attract a considerable amount of pedestrian traffic. Between 2009 and 2014, there were three bike crashes and one pedestrian crash nearby, according to the Fort Lauderdale Vision Zero Plan. In addition, Broward Blvd and US 1 ranked 2nd highest and 7th highest in the number of pedestrian and bicyclist crashes in the Fort Lauderdale based on 2009–2014 data.

Figure 4-14 Detailed layout of US 1 @ E Broward Blvd, Fort Lauderdale, FL.

4.1.8 South and East Legs, E Tennessee St @ E Monroe St, Tallahassee, FL

This intersection is located in the central area of Tallahassee to the east of Florida State University (FSU) and is formed by two major urban arterials, E Tennessee St and N Monroe St. E Tennessee St is part of US 90 and is a major corridor carrying eastbound and westbound traffic. N Monroe St is part of US 27 and is a major corridor carrying northbound and southbound traffic. The location and vicinity of this location are shown in Figure 4-15.

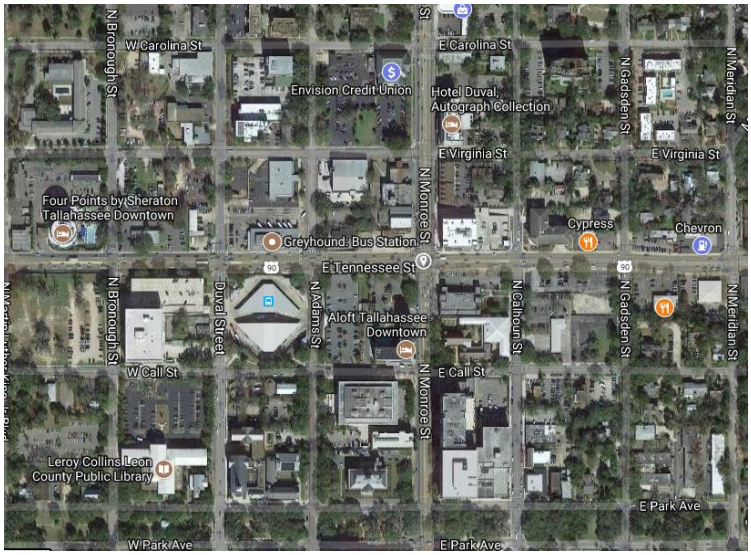


Figure 4-15 Location and vicinity of E Tennessee St @ E Monroe St, Tallahassee, FL.

A detailed layout of this intersection is shown in Figure 4-16. There were two targeted approaches for LPI implementation and testing, the northbound right-turn approach conflicting with pedestrians on east leg crosswalk and the eastbound right-turn approach conflicting with pedestrians on the south leg crosswalk. This intersection was recommended by FDOT District 3. As previously mentioned, this intersection is located in the central area of the city, and there are several hotels and local businesses around the intersection that attract sufficient pedestrian traffic for LPI analysis. It was also noted in the *Tennessee Street/US 90 Traffic Mobility and Alternatives Study* [19] that due to heavy pedestrian traffic at this intersection, "a leading pedestrian interval phasing can be considered for implementation." Field observation also indicated that there is heavy pedestrian traffic on both the east leg and south leg crosswalks. Therefore, these two approaches were chosen for the LPI before-after study.

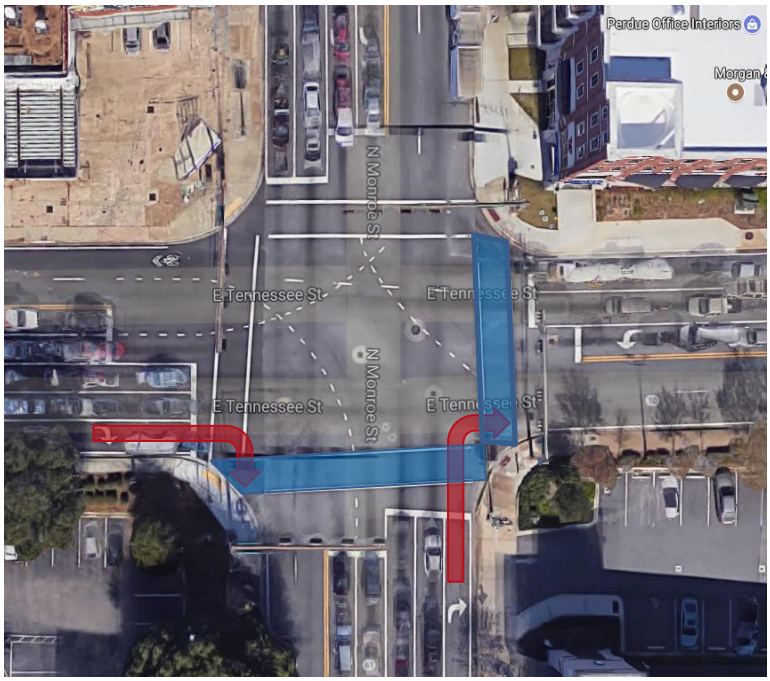


Figure 4-16 Detailed layout of E Tennessee St @ E Monroe St, Tallahassee, FL.

4.1.9 East Leg, SR 200 @ SW 60th Ave, Ocala, FL

This intersection is located on the southwest outskirts of Ocala and is formed by two roads, Florida SR 200 and SW 60th Ave. Florida SR 200 is a major arterial carrying eastbound and westbound traffic, and SW 60th Ave is a minor street carrying northbound and southbound traffic. The location and vicinity of this location are shown in Figure 4-17.

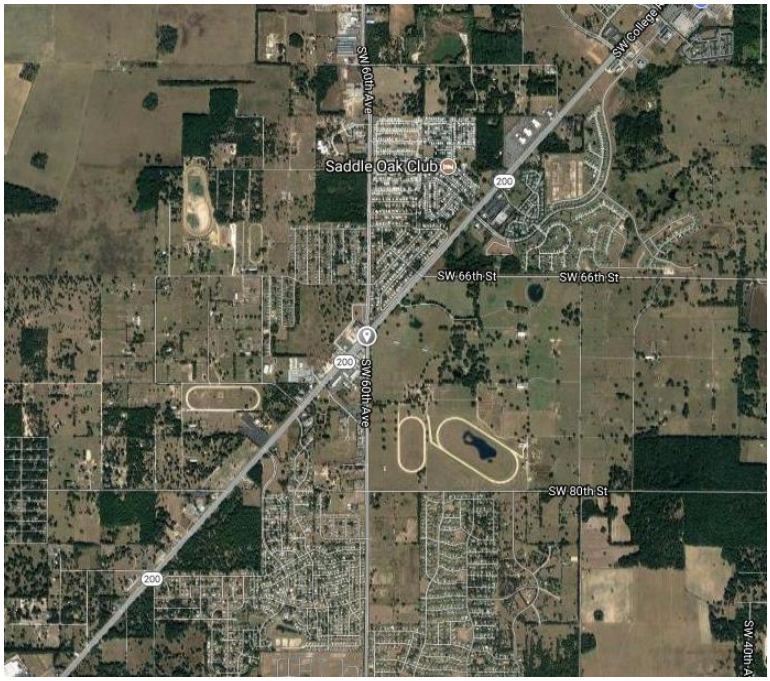


Figure 4-17 Location and vicinity of SR 200 @ SW 60th Ave, Ocala, FL.

A detailed intersection layout is shown in Figure 4-18. The targeted approach for LPI implementation and testing was the northbound right-turn approach conflicting with pedestrian traffic on the east leg crosswalk. This intersection was recommended for LPI implementation by FDOT District 5 after an observational "before" study. Although in the "before" study no pedestrians were observed, it was found that the view of the east leg crosswalk is obscured by a traffic signal support and signal cabinet until a driver is 30–40 feet beyond. Based on the skew intersecting angle, large turning radius, and visibility issues, an LPI was recommended for this approach to enhance pedestrian safety.

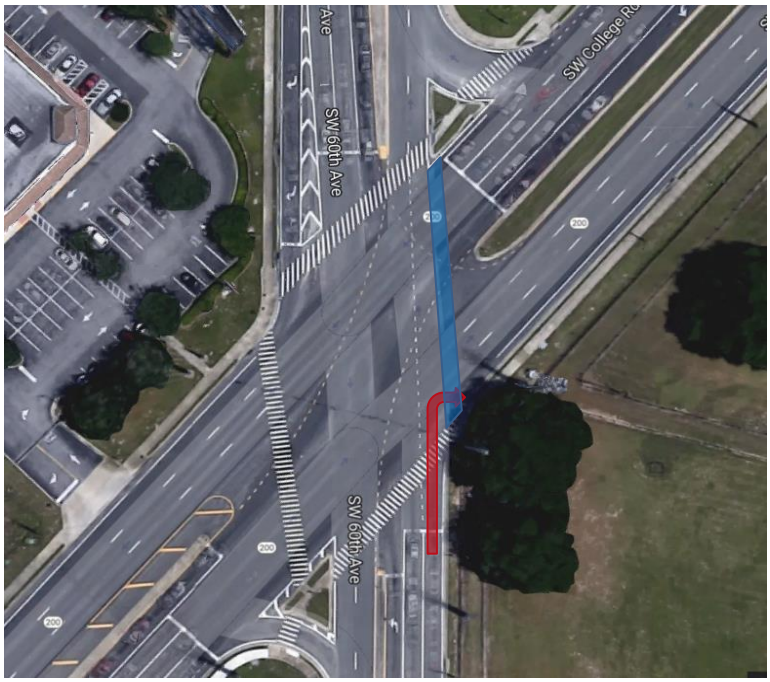


Figure 4-18 Detailed layout of SR 200 @ SW 60th Ave, Ocala, FL.

4.2 Data Collection Before and After LPI Implementation

Video data of at least eight hours on a weekday before LPI implementation were collected on the targeted approach of a selected site. After an LPI was implemented on the same approach on which "before" data were collected following the provided parameter specifications, video data of at least eight hours on a weekday, covering peak and non-peak hours, were collected. The data collected before and after the LPI implementation were used for the LPI before-after data analysis. The "before" data collection included the following data:

1) During first few seconds of walking signal  equal to proposed LPI length for "before" data collection:

    - Number of pedestrians crossing
    - Number of vehicle-pedestrian conflicts
    - Number of vehicles turned
    - Number of vehicles yielding to pedestrians
    - Number of vehicles not yielding to pedestrians

2) During remaining pedestrian "Walk" signal  ,  :

    - Number of pedestrians crossing
    - Number of vehicle-pedestrian conflicts
    - Number of vehicles turned
    - Number of vehicles yielding to pedestrians
    - Number of vehicles not yielding to pedestrians

3) During "Do Not Walk" signal  (for actuated pedestrian signal control):

    - Number of pedestrians pushing button (or seen other pushing) but crossing
    - Number of pedestrians crossing without pushing button
    - Number of pedestrians waiting for the "Walk" signal
    - Number of vehicles turned

4) During "Do Not Walk" signal  (for pre-timed pedestrian signal control):

    - Number of pedestrians waiting for "Walk" signal
    - Number of pedestrians crossing before the "Walk" signal
    - Number of vehicles turned

5) During each hour:

    - Number of pedestrians crossing
    - Number of vehicles turned
    - Number of vehicle-pedestrian conflicts
    - Number of through traffic volume from intersecting approach (at least 8 hours)
    - Number of through traffic volume per lane from intersecting approach (at least 8 hours)

The "after" data collection include the following data:

1) During LPI phase  for "after" data collection:

    - Number of pedestrians crossing
    - Number of vehicle-pedestrian conflicts

- Number of vehicles turned
- Number of vehicles yielding to pedestrians
- Number of vehicles not yielding to pedestrians

2) During remaining pedestrian "Walk" signal  ,  :

    - Number of pedestrians crossing
    - Number of vehicle-pedestrian conflicts
    - Number of vehicles turned
    - Number of vehicles yielding to pedestrians
    - Number of vehicles not yielding to pedestrians

3) During "Do Not Walk" signal  (for actuated pedestrian signal control):

    - Number of pedestrians pushing button (or seen other pushing) but crossing
    - Number of pedestrians crossing without pushing button
    - Number of pedestrians waiting for the "Walk" signal
    - Number of vehicles turned

4) During "Do Not Walk" signal  (for pre-timed pedestrian signal control):

    - Number of pedestrians waiting for "Walk" signal
    - Number of pedestrians crossing before the "Walk" signal
    - Number of vehicles turned

5) During each hour:

    - Number of pedestrians crossing
    - Number of vehicles turned
    - Number of vehicle-pedestrian conflicts

Intersection geographical and traffic sign/signal information of the selected intersections were collected through field observations. Researchers also used field observation to verify the LPI operations (active or inactive) during the data collection period and to record any difference regarding intersection geometrical and traffic sign/signal information before and after LPI implementation.

To retrieve all needed data for detailed analysis, graduate research assistants were fully trained to review the collected data and count the corresponding traffic regarding the above categories. Data quality checks were also performed to ensure that the reviewed data were accurate for analysis.

4.2.1 East Leg (Northbound Right Turn), E Fletcher Ave @ USF Palm Dr, Tampa, FL

4.2.1.1 "Before" Data Collection

Figure 4-19 Field data collection at E Fletcher Ave @ USF Palm Dr, Tampa, FL (GoPro view).

(a) Northbound view **(b) Southbound view**

Figure 4-20 Field observation of targeted approach at E Fletcher Ave @ USF Palm Dr, Tampa, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00-17:00
- Skewed four-way intersection
- Speed limit on E Fletcher Ave is 35 mph, speed limit on USF Palm Dr is 25 mph
- Eastbound: two through lanes, one right-turn lane, one bicycle lane
- Westbound: two left-turn lanes, two through lanes, one right-turn lane
- Northbound: two left-turn lanes, one right-turn lane
- Southbound: lanes connected to apartment complex and for emergency access only
- Intersection works as T-intersection, but no pedestrian crosswalk on west leg
- No visibility issues
- Current pedestrian signal actuated and activated by pushing pedestrian button

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-1 in Appendix F.

4.2.1.2 "After" Data Collection

Figure 4-21 Field data collection after LPI implementation at E Fletcher Ave @ USF Palm Dr, Tampa, FL (GoPro view).

An LPI of 4 seconds was implemented temporarily on the east leg crosswalk corresponding to northbound right-turn traffic at E Fletcher Ave @ USF Palm Dr., Tampa, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI implementation was conducted from 9:00–17:00 on January 11, 2017. Figure 4-21 highlights the

implementation of the LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-2 in Appendix F.

4.2.2 West Leg (Southbound Right Turn), E Kennedy Blvd @ N Tampa St, Tampa, FL

4.2.2.1 "Before" Data Collection

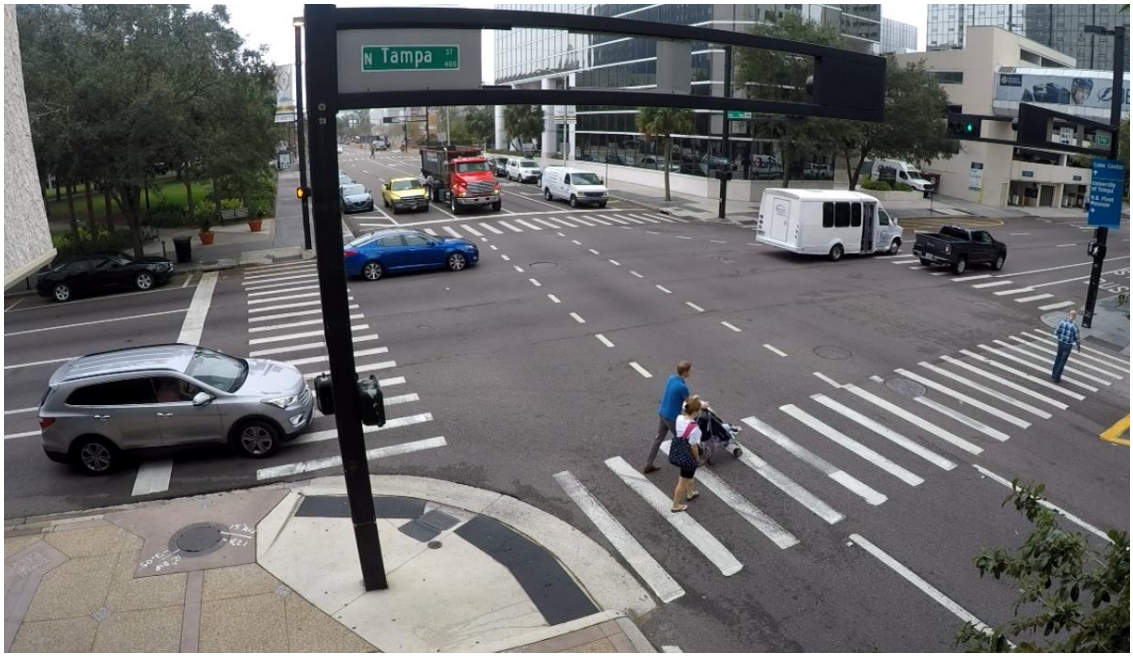


Figure 4-22 Field data collection at E Kennedy Blvd @ N Tampa St, Tampa, FL (GoPro view).

Figure 4-23 Field observation of targeted approach at E Kennedy Blvd @ N Tampa St, Tampa, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 9:00–18:00
- Two-way intersection with two one-way roads in downtown CBD area
- Speed limit on E Kennedy Blvd is 30 mph, speed limit on N Tampa St is 30 mph
- Westbound: one left-turn lane, one shared left-turn/through lane, two through lanes
- Southbound: three through lanes, one bicycle lane, one right-turn lane
- Pedestrian crosswalks available on all intersection legs
- No visibility issues
- Two parking lanes observed along E Kennedy Blvd
- Current pedestrian signal is pre-timed, no pushbutton necessary
- Intersection peak hours with pedestrians going to work 8:00–10:00 and lunch time 13:00–14:00
- During data collection, vehicles turning right often stopped and yielded to pedestrians due to motorcycle police enforcement during morning and early afternoon hours

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-3 in Appendix F.

4.2.2.2 "After" Data Collection

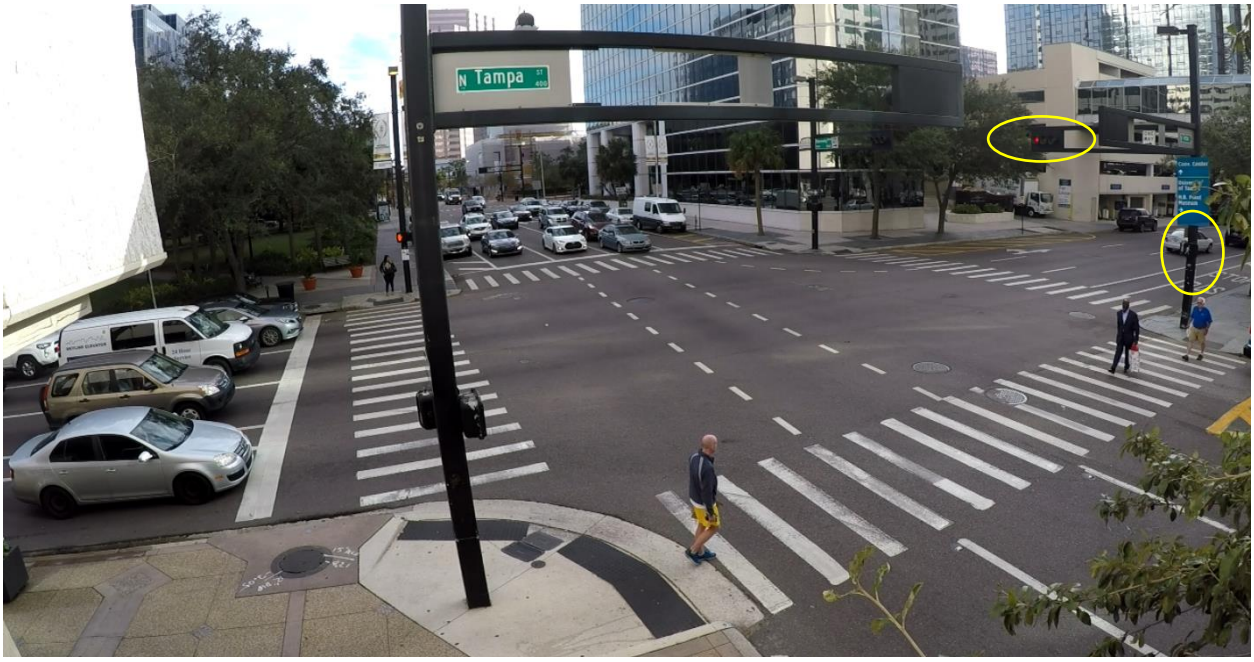


Figure 4-24 Field data collection after LPI implementation at E Kennedy Blvd @ N Tampa St, Tampa, FL (GoPro view).

An LPI of 5 seconds was implemented temporarily on the west leg crosswalk corresponding to the southbound right-turn approach at E Kennedy Blvd @ N Tampa St, Tampa, FL, and the LPI was pre-timed and triggered automatically 4 seconds before onset of the green phase. A one-day data collection after LPI implementation was conducted from 8:00–17:00 on December 15, 2016. Figure 4-24 highlights the implementation of the LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-4 in Appendix F.

4.2.3 West Leg (Southbound right turn), E Fletcher Ave @ N Nebraska Ave, Tampa, FL

4.2.3.1 "Before" Data Collection

Figure 4-25 Field data collection at E Fletcher Ave @ N Nebraska Ave, Tampa, FL (GoPro view).

Figure 4-26 Field observation of targeted approach at E Fletcher Ave @ N Nebraska Ave, Tampa, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00–16:00
- Four-way intersection

- Speed limit on E Fletcher Ave is 35 mph, speed limit on N Nebraska Ave is 45 mph
- Eastbound: one left-turn lane, one through lane, one shared through/right-turn lane
- Westbound: one left-turn lane, one through lane, one shared through/right-turn lane, one bicycle lane
- Northbound: one left-turn lane, one through lane, one shared through/right-turn lane
- Southbound: one left-turn lane, two through lanes, one right-turn lane
- No visibility issues
- Pedestrian crosswalks available on all four legs
- Current pedestrian signal actuated and activated by pushing pedestrian button
- Peak hours difficult to determine based on field observation
- Most pedestrians that waited for signal arrived individually; few groups of 2–3 pedestrians

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-5 in Appendix F.

4.2.3.2 "After" Data Collection

Figure 4-27 Field data collection after LPI implementation at E Fletcher Ave @ N Nebraska Ave, Tampa, FL (GoPro view).

An LPI of 4 seconds was implemented temporarily on the west leg crosswalk corresponding to the southbound right-turn approach at E Fletcher Ave @ N Nebraska Ave, Tampa, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI

implementation was conducted from 8:00–16:00 on December 20, 2016. Figure 4-27 highlights the implementation of LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-6 in Appendix F.

4.2.4 South Leg (Eastbound Right Turn), W University Ave @ NW 13th St, Gainesville, FL

4.2.4.1 "Before" Data Collection

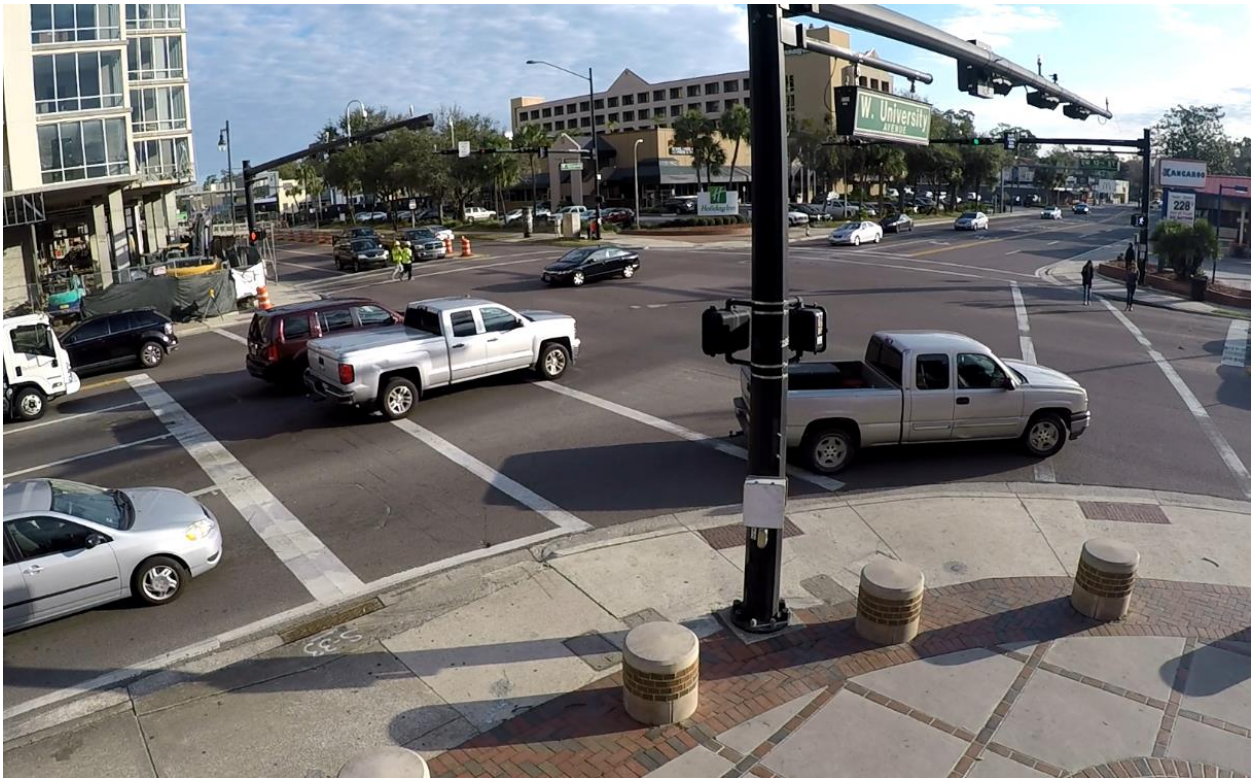


Figure 4-28 Field data collection at W University Ave @ NW 13th St, Gainesville, FL (GoPro view).

(a) Westbound view **(b) Eastbound view**

Figure 4-29 Field observation of targeted approach at W University Ave @ NW 13th St, Gainesville, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00–16:00
- Four-way intersection close to UF main campus
- Eastbound: one left-turn lane, two through lanes, one right-turn lane
- Westbound: one left-turn lane, one through lane, one shared through/right-turn lane
- Northbound: one left-turn lane, one through lane, one shared through/right-turn lane
- Southbound: one left-turn lane, one through lane, one shared through/right-turn lane
- No visibility issues
- Pedestrian crosswalks available on all four legs
- Current pedestrian signal actuated and activated by pushing pedestrian button
- Site under construction at northwest corner

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-7 in Appendix F.

4.2.4.2 "After" Data Collection

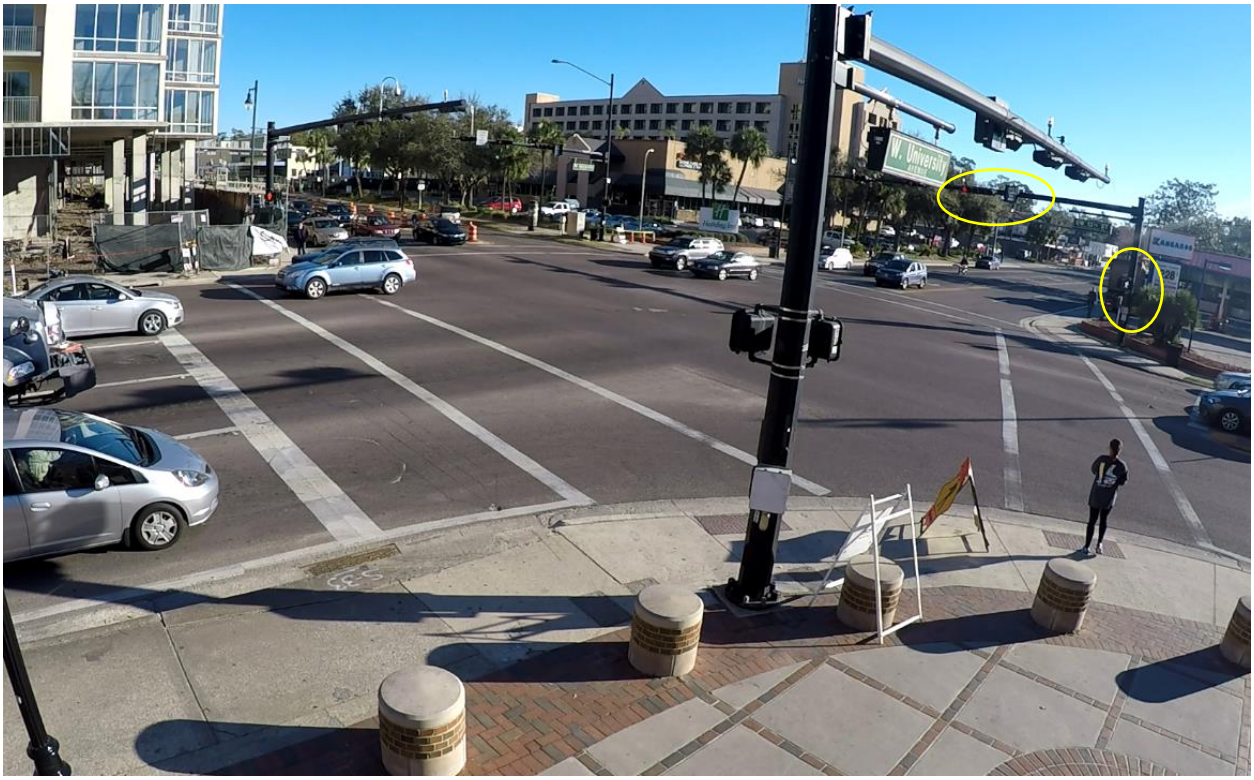


Figure 4-30 Field data collection after LPI implementation at W University Ave @ NW 13th St, Gainesville, FL (GoPro view).

An LPI of 5 seconds was implemented temporarily on the south leg crosswalk corresponding to the eastbound right-turn approach at W University Ave @ NW 13th St, Gainesville, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI implementation was conducted from 9:00–17:00 on January 31, 2017. Figure 4-30 highlights the implementation of LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-8 in Appendix F.

4.2.5 South Leg (Eastbound Right Turn) and North Leg (Eastbound Left Turn), SR A1A @ 178th St, Sunny Isles Beach, FL

4.2.5.1 "Before" Data Collection

Figure 4-31 Field data collection at SR A1A @ 178th St, Sunny Isles Beach, FL (GoPro view).

(a) Right approach view **(b) Left approach view**

Figure 4-32 Field observation of targeted approach at SR A1A @ 178th Street, Sunny Isles Beach, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 9:00–18:00

- Three-way T-intersection near Florida east coast beach in tourism area
- Speed limit on SR A1A is 35 mph, speed limit on 178th St is 20 mph
- Eastbound: one left-turn lane, one right-turn lane
- Westbound is driveway connected to apartment complex, closed most of time
- Northbound: one left-turn lane, three through lanes
- Southbound: one left-turn lane, two through lanes, one shared through/right-turn lane
  Left-turn lane connecting to westbound generally not used
- Westbound is driveway connected to apartment complex, closed most of time
- No visibility issues
- Pedestrian crosswalks available on west, north, and south legs
- Current pedestrian signal actuated and activated by pushing pedestrian button

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Tables F-9 and F-11 in Appendix F.

4.2.5.2 "After" Data Collection

Figure 4-33 Field data collection after LPI implementation at SR A1A @ 178th St, Sunny Isles Beach, FL.

An LPI of 3 seconds was implemented temporarily on the south leg crosswalk corresponding to the eastbound right-turn approach and north leg corresponding to the eastbound left-turn approach at SR A1A @ 178th St, Sunny Isles Beach, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI implementation was conducted from 8:00–18:00 on February 24, 2017. Figure 4-33 highlights the implementation of LPI at the targeted approach.

Field observations and video data review revealed the LPI was triggered simultaneously by pressing the pushbutton on either approach. It was also observed that there were several valet parking staff who did not always use the pedestrian signal. There were peak hours from 8:00–9:30 and 16:00-17:00, during which two traffic staff were stationed to lead people at the intersection, as shown in Figure 4-33.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Tables F-10 and F-12 in Appendix F.

4.2.6 North Leg (Westbound Right Turn), US 41 @ Laurel Rd, Nokomis, FL

4.2.6.1 "Before" Data Collection

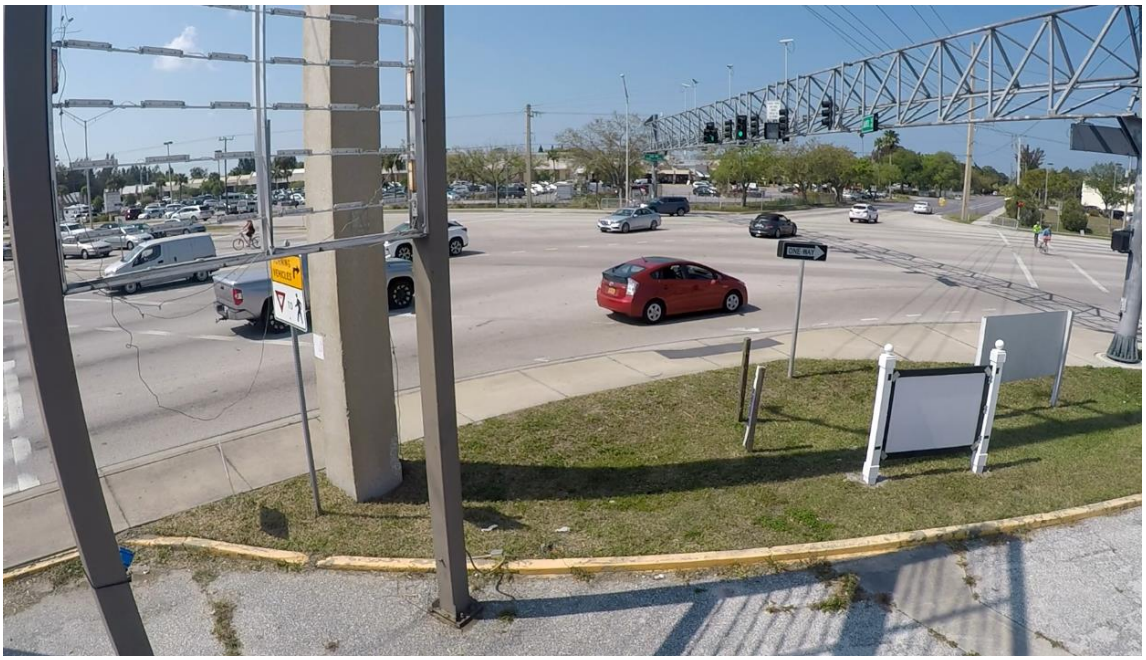


Figure 4-34 Field data collection at US 41 @ Laurel Rd, Nokomis, FL (GoPro view).

(a) "YIELD TO PEDESTRIANS" sign **(b) "NO TURN ON RED" sign**

Figure 4-35 Blank-out "NO TURN ON RED/YIELD TO PEDESTRIANS" sign, Nokomis, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00–18:00
- Skewed four-way intersection
- Speed limit on US 41 is 45 mph, speed limit on Laurel Rd is 30 mph
- Eastbound: one left-turn lane, one through lane, one shared through/right-turn lane, one bicycle lane
- Westbound: one left-turn lane, one through lane, one bicycle lane, one right-turn lane
- Northbound: one left-turn lane, three through lanes, one bicycle lane, one right-turn lane
- Southbound: two left-turn lanes, three through lanes, one bicycle lane, one right-turn lane
- Visibility issue due to wide intersection design on westbound right-turn approach; westbound right-turn vehicles enter north-leg crosswalk at high speed because of long distance between westbound stop line and north-leg crosswalk, posing significant threat to pedestrian safety Complaints from local residents received by FDOT
- Pedestrian crosswalks available on all four legs
- Current pedestrian signal actuated and activated by pushing pedestrian button
- Overhead blank-out "NO TURN ON RED/YIELD TO PEDESTRIANS" sign and "RIGHT TURN ON RED MUST YIELD TO U TURN" sign for targeted approach to regulate right-turn traffic (see Figure 4-35)

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-13 in Appendix F.

4.2.6.2 "After" Data Collection

Figure 4-36 Field data collection after LPI implementation at US 41 @ Laurel Rd, Nokomis, FL (GoPro view).

An LPI of 4 seconds was implemented temporarily on the north leg crosswalk corresponding to the westbound right-turn approach at US 41 @ Laurel Rd, Nokomis, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI implementation was conducted from 8:00–18:00 on April 6, 2017. Figure 4-36 highlights the implementation of LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-14 in Appendix F.

4.2.7 West Leg (Southbound Right Turn), US 1 @ E Broward Blvd, Fort Lauderdale, FL

4.2.7.1 "Before" Data Collection

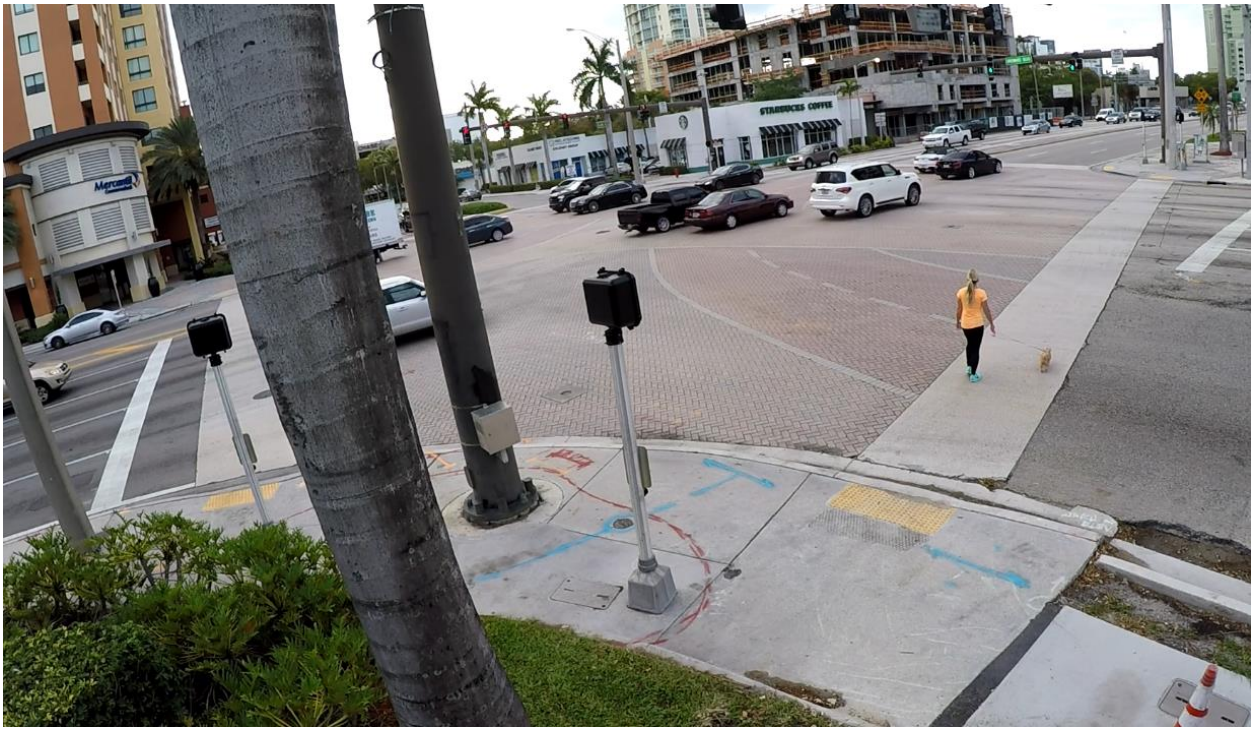


Figure 4-37 Field data collection at US 1 @ E Broward Blvd, Fort Lauderdale, FL (GoPro view).

Figure 4-38 Field observation of targeted approach at US 1 @ E Broward Blvd, Fort Lauderdale, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00–18:00
- Four-way signalized intersection
- Speed limit on US 1 is 35 mph, speed limit on E Broward Blvd is 35 mph
- Eastbound: two left-turn lanes, three through lanes, one bicycle lane, one right-turn lane
- Westbound: two left-turn lanes, one through lane, one shared through/right-turn lane
- Northbound: two left-turn lanes, three through lanes, one right-turn lane
- Southbound: one left-turn lane, three through lanes, one right-turn lane
- No visibility issues
- Pedestrian crosswalks on all four legs
- Current pedestrian signal pre-timed during daytime, actuated by pressing pushbutton for rest of day
- Overhead "No Turn When Pedestrian in Crosswalk" sign for targeted approach to regulate right-turn traffic (see Figure 4-38)

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-15 in Appendix F.

4.2.7.2 "After" Data Collection

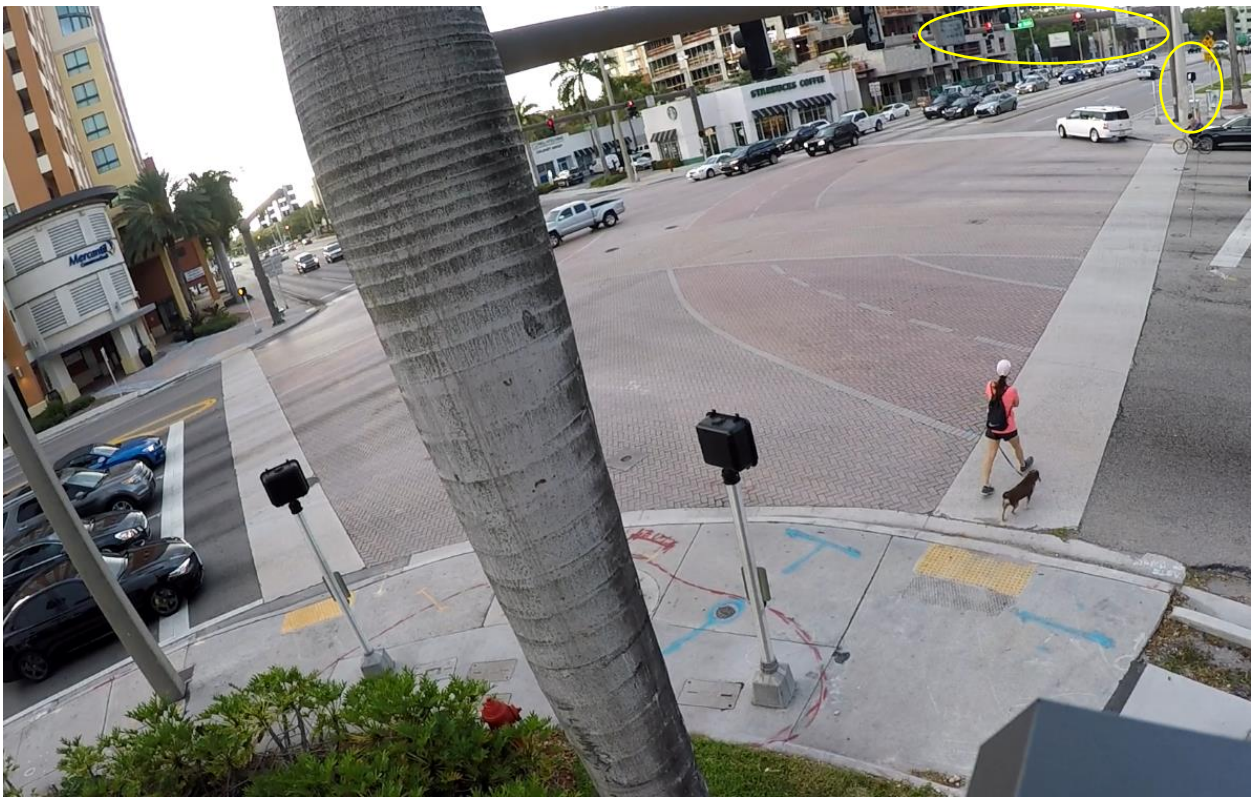


Figure 4-39 Field data collection after LPI implementation at US 1 @ E Broward Blvd, Fort Lauderdale, FL (GoPro view).

An LPI of 4 seconds was implemented temporarily on the west leg crosswalk corresponding to the southbound right-turn approach at US 1 @ E Broward Blvd, Fort Lauderdale, FL, and the LPI was pre-timed during the daytime and was triggered automatically 4 seconds before the onset of the green phase. A one-day data collection after LPI implementation was conducted from 8:00–18:00 on April 20, 2017. Figure 4-39 highlights the implementation of the LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-16 in Appendix F.

4.2.8 South Leg (Eastbound Right Turn) and East Leg (Northbound Right Turn), E Tennessee St @ E Monroe St, Tallahassee, FL

4.2.8.1 "Before" Data Collection

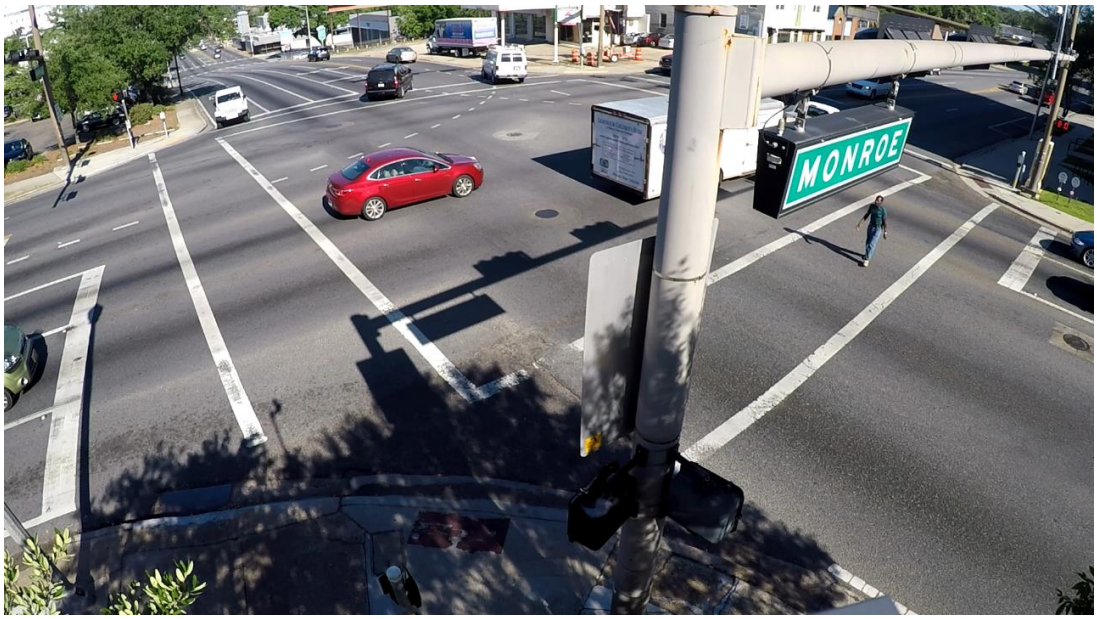
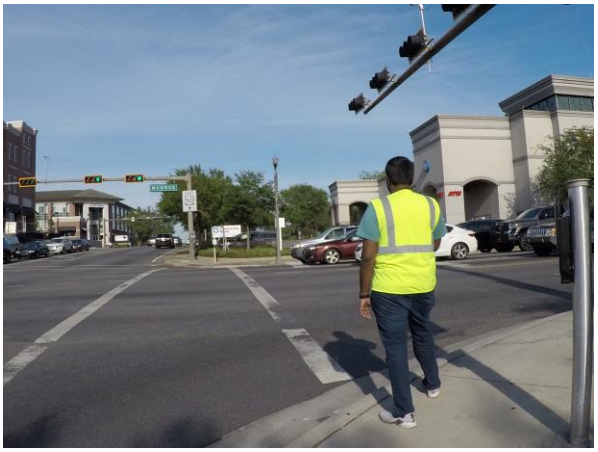


Figure 4-40 Field data collection at E Tennessee St @ E Monroe St, Tallahassee, FL (GoPro view).

(a) East leg crosswalk



(b) South leg crosswalk

Figure 4-41 Field observation of targeted approach at E Tennessee St @ E Monroe St, Tallahassee, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00–18:00
- Four-way signalized intersection close to FSU
- Speed limit on E Tennessee Street is 30 mph, speed limit on N Monroe Street is 35 mph
- Eastbound: two left-turn lanes, two through lanes, one right-turn lane

- Westbound: one left-turn lane, one through lane, one shared through/right-turn lane
- Northbound: two left-turn lanes, two through lanes, one right-turn lane
- Southbound: two left-turn lanes, one through lane, one shared through/right-turn lane
- No visibility issues
- Pedestrian crosswalks on all four legs
- Current pedestrian signal actuated by pressing pushbutton

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Tables F-17 and F-19 in Appendix F.

4.2.8.2 "After" Data Collection

Figure 4-42 Field data collection after LPI implementation on east leg at E Tennessee St @ E Monroe St, Tallahassee, FL (GoPro view).

An LPI of 4 seconds was implemented temporarily on the east leg crosswalk corresponding to the northbound right-turn approach at E Tennessee St @ E Monroe St, Tallahassee, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI implementation was conducted from 8:00–18:00 on May 11, 2017. Figure 4-42 highlights the implementation of the LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-18 in Appendix F.

Figure 4-43 Field data collection after LPI implementation on south leg at E Tennessee St @ E Monroe St, Tallahassee, FL (GoPro view).

An LPI of 4 seconds was implemented temporarily on the south leg crosswalk corresponding to the eastbound right-turn approach at E Tennessee St @ E Monroe St, Tallahassee, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI implementation was conducted from 8:00–18:00 on May 11, 2017. Figure 4-43 highlights the implementation of LPI at the targeted approach. No additional features were observed that were different from those in the data collection before LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-20 in Appendix F.

4.2.9 East Leg (Northbound Right Turn), SR 200 @ SW 60th Ave, Ocala, FL

4.2.9.1 "Before" Data Collection

Figure 4-44 Field data collection at SR 200 @ SW 60th Ave, Ocala, FL (GoPro view).

(a) Red phase (b) Red phase with "NO TURN ON RED" blank-out sign

(c) Green Phase

Figure 4-45 Field observation of targeted approach, SR 200 @ SW 60th Ave, Ocala, FL.

The intersection facts from field observations are summarized below:

- Data collection time: 8:00–18:00
- Skewed four-way signalized intersection
- Speed limit on SR 200 is 50 mph, speed limit on SW 60th Ave is 45 mph
- Eastbound: one left-turn lane, two through lanes, one shared through/right-turn lane
- Westbound: one left-turn lane, two through lanes, one shared through/right-turn lane
- Northbound: one left-turn lane, one through lane, one right-turn lane
- Southbound: one left-turn lane, two through lanes, one right-turn lane
- Visibility issue on northbound right-turn approach, where view of east leg crosswalk obscured by traffic signal support cabinet until driver is 30–40 feet beyond stop line
- Pedestrian crosswalks on all four legs
- Current pedestrian signal actuated by pressing pushbutton
- Overhead "NO TURN ON RED" blank-out, roadside "TURNING VEHICLES YIELD TO PEDESTRIANS," roadside "Stop Here on Red" signs for targeted approach to regulate right-turn traffic

A review summary of the video data collected for the targeted approach at this intersection before LPI implementation is shown in Table F-21 in Appendix F.

4.2.9.2 "After" Data Collection

Figure 4-46 Field data collection after LPI implementation at SR 200 @ SW 60th Ave, Ocala, FL (GoPro view).

An LPI of 5 seconds was implemented temporarily on the east leg crosswalk corresponding to the northbound right-turn approach at SR 200 @ SW 60th Ave, Ocala, FL, and the LPI was triggered by pedestrians pressing the pushbutton. A one-day data collection after LPI

implementation was conducted from 8:00–18:00 on July 6, 2017. Figure 4-46 highlights the implementation of LPI at the targeted approach. Similar to the data collection before LPI implementation, no pedestrians or bicyclists were observed during the data collection after LPI implementation.

A review summary of the video data collected for the targeted approach at this intersection after LPI implementation is shown in Table F-22 in Appendix F.

5 BEFORE-AFTER ANALYSES OF LPI SAFETY EFFECTIVENESS AND OPERATIONAL IMPACT

The before-after data analysis is essential to understand the LPI safety effectiveness and operational impact. After the before and after data collection, it is necessary to conduct before-after comparison analysis to comprehensively evaluate the influence of LPI on traffic safety and operation efficiency. This chapter documents the effort of before-after analysis and research findings on LPI safety effectiveness, LPI influence on traffic operation efficiency in terms of vehicle delay, and LPI utilization efficiency. Detailed analyses results are presented below.

5.1 Before-After Comparison of LPI Safety Effectiveness

To comprehensively evaluate the safety effectiveness of LPI and refine the preliminary statewide LPI implementation guidelines, statistical analyses were conducted to compare safety-related pedestrian and vehicle operations before and after LPI implementation. The factors influencing the effectiveness of LPI implementations, such as turning vehicle volume, pedestrian volume, time of day, regions, intersection characteristics, etc., are addressed. Understanding the impact of these factors on the effectiveness of LPI implementations is important and necessary for refining LPI criteria. In addition, turning vehicle delay due to implementation of LPI were calculated to assess the impact of LPI on intersection operational performance.

LPI is designed to improve pedestrian presence and visibility, thereby reducing the potential for vehicle-pedestrian crashes or conflicts. Therefore, the following measurements are included in the analysis:

- Frequency and percentage of pedestrian compliance with “Walk” indicator
- Frequency and percentage of vehicles yielding and not yielding to pedestrians
- Frequency of vehicle-pedestrian conflicts

Based on the review results of the collected video data before and after LPI implementation, a number of measurements belonging to the above three categories were calculated and are summarized, including:

- Percentage of Veh Non-Yield During LPI – Percentage of vehicles not yielding to pedestrians during LPI (for “after” data) or first few seconds equal to LPI (for “before” data)
- Percentage of Veh Non-Yield Total – Percentage of vehicles not yielding to pedestrians during entire “Walk” phase
- Number of Conflicts During LPI – Total number of vehicle-pedestrian conflicts during LPI (for “after” data) or first few seconds equal to LPI (for “before” data)
- Percentage of Conflict Reduction During LPI – Percentage of vehicle-pedestrian conflict reduction during the first few seconds equal to LPI (before) and LPI (after)
- Number of Conflicts Total – Total number of vehicle-pedestrian conflicts during entire “Walk” phase
- Percentage of Conflict Reduction Total – Percentage of vehicle-pedestrian conflict reduction during entire “Walk” phase before and after LPI implementation

The following terms are defined to calculate the above statistics:

- Vehicle yielding behavior – Driver waits or moves slowly and turns behind a pedestrian even though there is a gap in traffic (turning vehicles are delayed, have altered their travel path, or have altered their travel speed due to concurrent pedestrians).
- Vehicle non-yielding behavior – Driver turns in front of pedestrians with less than one lane of separation, except when "Walk" signal is first shown. In this case, pedestrians are generally delayed walking and have to wait on the sidewalk or the edge of pavement to avoid collision. Due to pedestrians' evasive behavior, vehicle-pedestrian conflict is generally not observed.
- Vehicle-pedestrian conflict: a conflict between crossing pedestrian and turning vehicle is an observable situation in which the crossing pedestrian and the turning vehicle encounter a risk of collision should their movements and speeds remain unchanged. A conflict is generally avoided by the yielding behavior of either the crossing pedestrian or the turning vehicle or both.
- Pedestrian compliance – Pedestrian begins crossing during "Walk" phase.
- Pedestrian non-compliance – Pedestrian begins crossing during "Do Not Walk" phase.
- Percentage of Veh Yield – It is equal to the number of vehicles yielding to pedestrians over total number of vehicles yielding and not yielding to pedestrians.
- Percentage of Veh Non-Yield – It is equal to the number of vehicles not yielding to pedestrians over total number of vehicles yielding and not yielding to pedestrians, Percentage of Veh Non-Yield = 1- Percentage of Veh Yield

Since vehicle-pedestrian crashes are the most direct cause leading to pedestrian injuries and fatalities, the number of vehicle-pedestrian conflicts during data collection before and after LPI implementation was used as the primary index to evaluate LPI safety effects. The percentage of non-yielding vehicles was used as an additional measurement. Based on eight-hour data, the number of conflicts and percentage of non-yielding vehicles before and after LPI implementation for each site is shown in Table 5-1. Note: "N/A" indicates that the corresponding statistics as the denominator for the calculation is 0. For example, given the limited number of pedestrians at the intersection in Ocala in before and after data collection, the number of vehicle-pedestrian conflicts both were 0; therefore, the "Percentage of Conflict Reduction Total" is "N/A."

As shown in Table 5-1, there were six testing intersection approaches where vehicle-pedestrian conflicts were observed during the first few seconds equal to LPI length in the data collection before LPI implementation. LPI was found effective in reducing the number of vehicle-pedestrian conflicts in five testing approaches, with the percentage of conflict reduction ranging from 25% to 100%. In addition, there were eight testing intersection approaches where vehicle-pedestrian conflicts were observed during the entire pedestrian walk phase in the one-day data collection before LPI implementation. LPI was effective in reducing the number of vehicle-pedestrian conflicts in six of the eight testing approaches after implementation, with the percentage of conflict reduction also ranging from 25% to 100%.

At E Fletcher Ave @ USF Palm Dr and E Fletcher Ave @ N Nebraska Ave, neither increase or decrease was observed on the total number of conflicts during the entire pedestrian walk phase based on one-day data collection, which also verifies the safety effects of LPI at these sites. It is also recommended to implement LPI along with a "NO TURN ON RED" or "TURNING

VEHICLES YIELD TO PEDESTRIANS" sign to further regulate turning traffic and increase pedestrian safety. The "Percentage of Conflict Reduction Total" statistic was not available at the last three test approaches, given that no vehicle-pedestrian conflicts were observed during before and after data collection.

Table 5-1 Before-After Statistic Comparison on LPI Safety Effectiveness

Site Information	Percentage of Veh Non-Yield During LPI		Percentage of Veh Non-Yield Total		Number of Conflicts During LPI		Percentage of Conflict Reduction During LPI	Number of Conflicts Total		Percentage of Conflict Reduction Total
	B	***A***	***B***	***A***	***B***	***A***		***B***	***A***	
E Fletcher Ave @ USF Palm Dr	42.9%	33.3%	16.2%	11.1%	4	3	25%	6	6	0%
E Kennedy Blvd @ N Tampa St	40%	14.3%	4.5%	1.9%	4	4	0.0	16	10	37.5%
E Fletcher Ave @ N Nebraska Ave	45.4%	93.7%	53.8%	87.2%	0	1	N/A	3	3	0%
W University Ave @ NW 13th St	50%	N/A	14.3%	0%	1	0	100%	4	3	25%
SR A1A @ 178th St Eastbound Right Turn	22.2%	33.3%	8%	7.3%	6	4	33.3%	22	5	77.3%
SR A1A @ 178th St Eastbound Left Turn	N/A	N/A	0%	0%	0	0	N/A	11	7	36.4%
US 41 @ Laurel Rd	0%	0%	0%	0%	3	0	100%	3	0	100%
US 1 @ E Broward Blvd	20%	37.5%	12%	15.6%	3	0	100%	7	2	71.4%
E Tennessee St @ E Monroe St northbound	N/A	N/A	0%	0%	0	0	N/A	0	0	N/A
E Tennessee St @ E Monroe St eastbound	0%	N/A	0%	0%	0	0	N/A	0	0	N/A
SR 200 @ SW 60th Ave	N/A	N/A	N/A	N/A	0	0	N/A	0	0	N/A

B = Before, A = After

The percentage of non-yielding vehicles was also used as a secondary measurement to assess LPI safety effectiveness. The "Percentage of Veh Non-Yield During LPI" statistic reveals that vehicle non-yielding behavior during the LPI phase varied among different test approaches.

At five approaches (W University Ave @ NW 13th St, SR A1A @ 178th St eastbound left turn, E Tennessee St @ E Monroe St northbound and eastbound, and SR 200 @ SW 60th Ave), vehicle yielding or non-yielding behavior was not observed given the limited LPI length and pedestrian/vehicle volume. At SR A1A @ 178th St eastbound right turn and US 1 @ E Broward Blvd, an increase in the percentage of non-yielding vehicles was observed. A detailed look at these non-yielding behaviors revealed that, at both sites, the number of non-yielding vehicles was increased only by 1. It is likely that the limited amount of vehicle yielding and non-yielding behavior observed during the data collection resulted in the seemly large change in the percentage, even though the actual number of non-yielding vehicles was increased only by 1 at each site.

The "Percentage of Veh Non-Yield Total" statistic reveals that the implemented LPI was effective in reducing vehicle non-yielding behavior at four sites/approaches (E Fletcher Ave @ USF Palm Dr., E Kennedy Blvd @ N Tampa St, W University Ave @ NW 13th St, and SR A1A @ 178th St eastbound left turn). A slight increase in the percentage of non-yielding vehicles was observed at US 1 @ E Broward Blvd from 12% to 15.6%, and a significant increase in the percentage of non-yielding vehicles was observed at E Fletcher Ave @ N Nebraska Ave, from

53.8% to 87.2%. The significant increase could be attributed to the limited pedestrian volume and high vehicle speed at E Fletcher Ave @ N Nebraska Ave.

In summary, the implementation of LPIs showed mixed results of drivers' yielding behaviors. A higher percentage of non-yielding vehicles were observed during the first few seconds equal to LPI length, but a lower percentage of non-yielding vehicles were observed during the entire pedestrian walk phase. Field observations also revealed that drivers continued to make right turns on red if allowed, and tended to turn quickly at the onset of pedestrian walk phase if pedestrians hadn't started to walk. These behaviors induced considerable non-yielding observations and compromised pedestrians. Although the risk of drivers' non-yielding behaviors is lower than the conflicts between vehicles and pedestrians, sufficient attention is still needed. To enhance the safety of pedestrians crossing at signalized intersections, it is recommended to implement static or blank-out "NO TURN ON RED" signs or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs along with LPI implementation.

5.2 Before-After Analysis of LPI Operational Impact

It is expected that the implementation of LPI will increase turning vehicle delay by reducing the green phase of vehicle traffic in order to improve vehicles yielding to pedestrians. An excessive LPI configuration could potentially increase significant travel delay and raise complaints from road users. Therefore, it was necessary to measure turning vehicle delay and assess the impact of LPI on traffic operation efficiency at intersections. Simulation analyses on turning vehicle delay were conducted in Synchro Studio environment at two selected sites:

- West leg (southbound right turn, SBR), E Kennedy Blvd @ N Tampa St, Tampa, FL
- South leg (eastbound right turn, EBR) and north leg (eastbound left turn, EBL), SR A1A @ 178th St, Sunny Isles Beach, FL

Based on field observations and traffic volume from the review of before and after data, these two locations were the two most congested intersections with given existing geometrical layout and lane configurations. In addition, these two locations also have a unique geometric layout and traffic features. Detailed descriptions and results for each test site are provided below. Vehicle Delay Simulation Analysis for E Kennedy Blvd @ N Tampa St, Tampa, FL

E Kennedy Blvd @ N Tampa St (Tampa, FL) is an intersection formed by two one-way roads in the downtown area, and there is constant and considerable vehicular and pedestrian volume in this intersection, based on the data summary in Tables F-3 and F-4 in Appendix F. As shown in Tables F-3 and F-4, the time period 12:00–13:00 is the pedestrian volume peak-hour, and there is also comparable vehicular traffic volume with respect to other hours. Therefore, to compute the vehicle delay due to LPI implementation, the traffic count data between 12:00–13:00 before LPI implementation was used for the simulation analysis. A 5-second LPI was programmed in the simulation process.

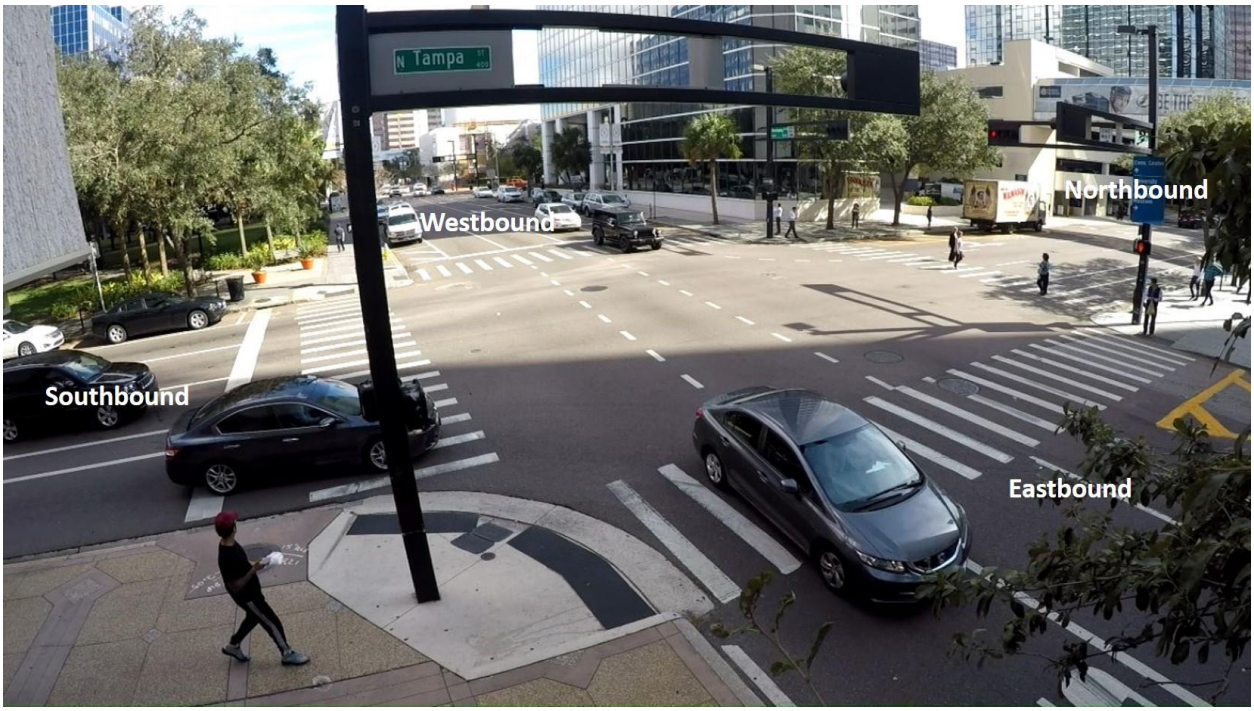


Figure 5-1 E Kennedy Blvd @ N Tampa St (Tampa, FL) intersection layout.

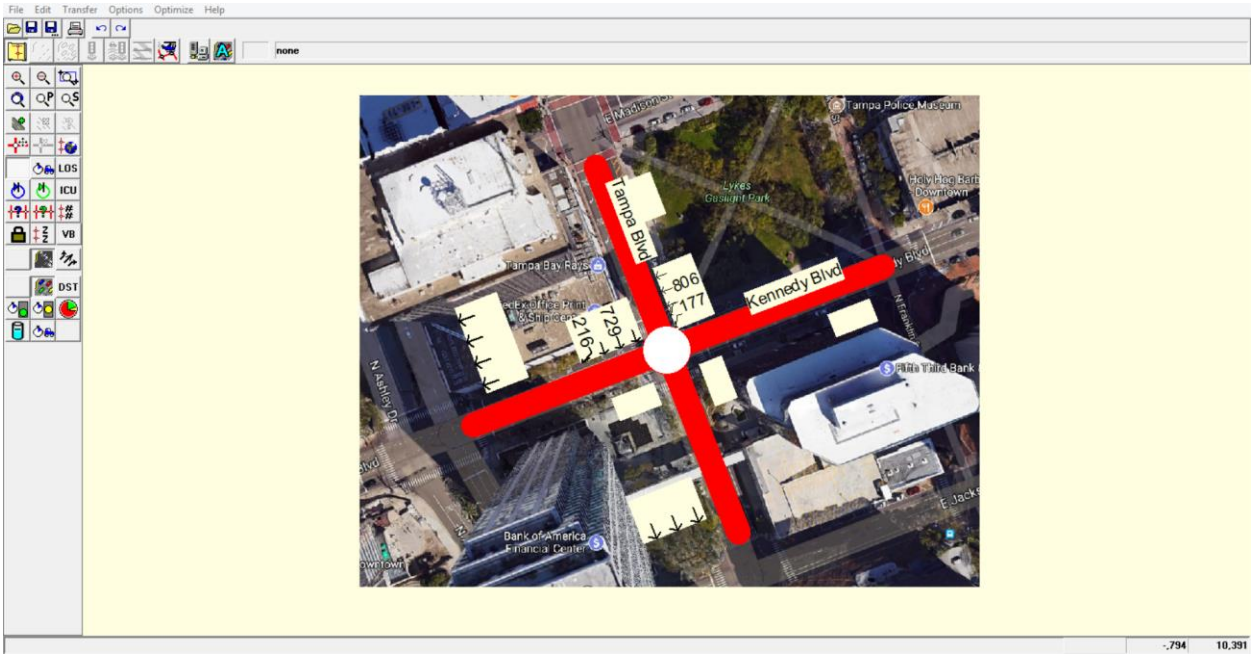


Figure 5-2 Synchro Studio simulation interface for E Kennedy Blvd @ N Tampa St, Tampa, FL.

The traffic delay results before and after LPI implementation from Synchro simulation are summarized in Table 5-2, which shows that the average total delay per vehicle on the southbound right turn (LPI implementation) decreased from 24.9 to 21.0 seconds, the average total delay per vehicle on southbound through traffic increased by 3.7 seconds to 28.0 seconds,

which is trivial and acceptable when compared to the delay before LPI implementation, 24.3 seconds. These results indicate that the implementation of LPI allowed pedestrians to start crossing before the onset of the green phase and cleared the turning approach for southbound right turn traffic, thereby reducing the average waiting time for right-turning vehicles. It allowed vehicles to turn at a faster speed on the cleared path, and facilitate the vehicle turning movement. Implementation of LPI reduced the green phase for southbound through traffic, (the average traffic speed of through traffic was not affected by pedestrian presence on the west leg) and increased the average total delay for southbound through traffic, which was expected to increase. The average total delay for the entire southbound approach increased by 2 seconds to 26.4 seconds, which is also acceptable when compared to the delay before LPI implementation, 24.4 seconds.

Table 5-2 Traffic Delay Simulation Results for E Kennedy Blvd @ N Tampa St (Tampa, FL)

Approach	Total Delay (sec)	
	Before LPI	***After LPI***
Westbound left turn	19.3	19.3
Westbound through	18.6	18.6
Southbound through	24.3	28.0
Southbound right turn	24.9	21.0
Entire westbound	18.7	18.7
Entire southbound	24.4	26.4

5.2.1 Vehicle Travel Delay Simulation Analysis for South Leg (Eastbound Right Turn) and North Leg (Eastbound Left Turn), SR A1A @ 178th St, Sunny Isles Beach, FL

SR A1A @ 178th St (Sunny Isles Beach, FL) is a T-intersection in the beach area. There was constant and considerable vehicular and pedestrian volume in this intersection, based on the data summary in Tables F-9, F-10, F-11, and F-12 in Appendix F. For a T-intersection, both left and right turns should be examined for potential implementation. As shown in Tables F-9, F-10, F-11, and F-12, the time period 15:00–16:00 is the pedestrian volume peak-hour corresponding to eastbound right-turn traffic in the "before" study and east bound left-turn traffic in the "after" study. There is also comparable vehicular traffic volume with respect to other hours. Therefore, to compute the vehicle delay due to LPI implementation, the traffic count data between 15:00–16:00 before LPI implementation was used for the simulation analysis. A 3-second LPI was programmed in the simulation process.

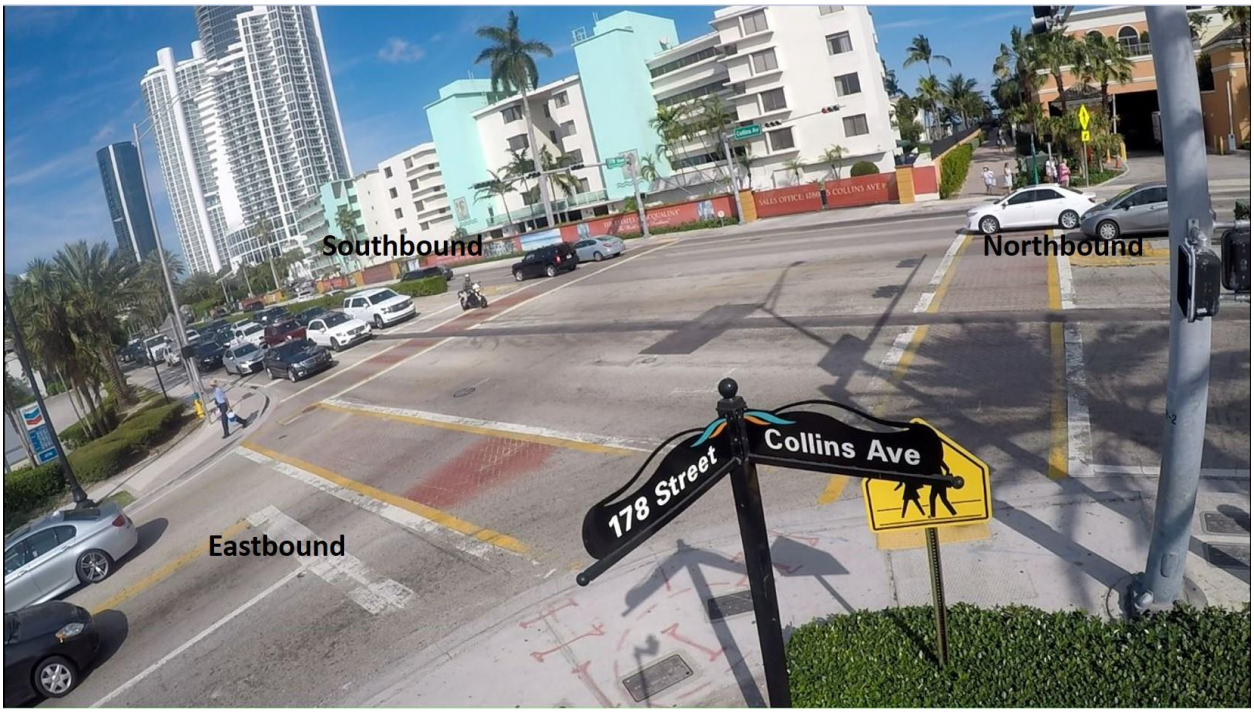


Figure 5-3 SR A1A @ 178th St (Sunny Isles Beach, FL) intersection layout.

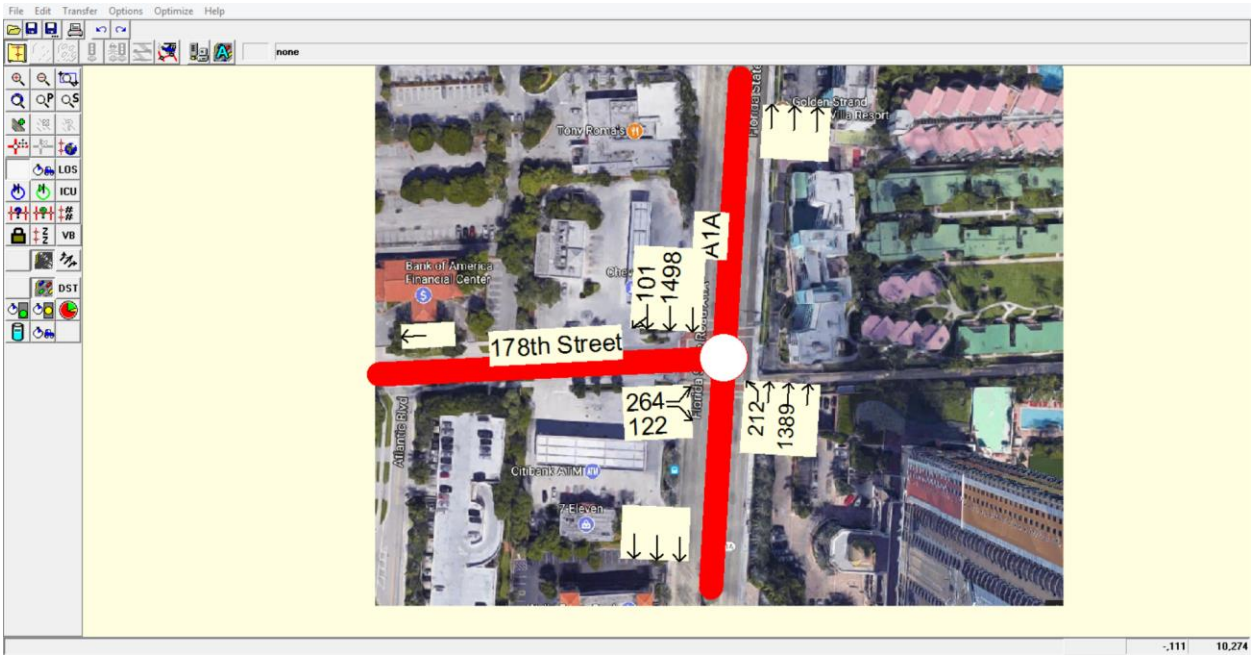


Figure 5-4 Synchro Studio simulation interface for SR A1A @ 178th St, Sunny Isles Beach, FL.

Table 5-3 Traffic Delay Simulation Results for SR A1A @ 178th St, Sunny Isles Beach, FL

Approach	Total Delay (sec)	
	Before LPI	***After LPI***
Eastbound left turn	47.4	50.2
Eastbound right turn	8.5	9.1
Northbound left turn	34.2	32.5
Northbound through	7.4	6.6
Southbound through/right turn	16.5	15.4
Entire eastbound	35.1	37.2
Entire northbound	10.9	10.1
Entire southbound	16.5	15.4

The traffic delay results before and after LPI implementation from the Synchro simulation are summarized in Table 5-3. They show that the average total delay per vehicle on the eastbound left-turn traffic (LPI implementation) increased by 2.8 seconds, from 47.4 to 51.2 seconds, and the average total delay per vehicle on the eastbound right-turn traffic increased by 0.6 seconds, from 8.5 to 9.1 seconds. Both the increases are minimal compared with the corresponding delay before LPI implementation. On the contrary, the average delay of the approaches northbound and southbound decreased. The average total delay for the entire eastbound approach increased by 2.1 seconds to 37.2 seconds, which is also acceptable compared with the delay before LPI implementation, 35.1 seconds. The average delay for the entire northbound approach decreased by 0.8 seconds, from 10.9 to 10.1 seconds, and the average delay for the entire southbound approach decreased by 1.1 seconds, from 16.5 to 15.4 seconds.

From the above two cases, the implementation of LPIs had minor or no impact to traffic operations. It should be noted that the analysis results were based on the simulation process on these two intersections, and may not be always applicable to interpret the operational impact of other LPI implementations. If the implementation of LPI will cause significant vehicle delay and/or adversely affect traffic signal coordination, LPIs will not be recommended for implementation during that period of time.

5.3 LPI Utilization Efficiency

An appropriate LPI phase should be implemented based on vehicle and pedestrian volume and should be coordinated with the existing traffic signal. Pedestrians activate LPI by pressing a pushbutton, but may leave the intersection before the LPI starts (either crossing before the LPI starts or leaving the intersection), which leads to LPI activation, but no pedestrian crossing; this may cause complaints of unnecessary travel delay from drivers. Therefore, it is necessary to examine the utilization efficiency of LPI to ensure that the implemented signal is working effectively. Table 5-4 shows the LPI utilization efficiency for each tested approach based on the collected data after LPI implementation.

Table 5-4 LPI Utilization Efficiency Results

Site Information	LPI Utilization Efficiency			
	Number of Cycles without Pedestrians	Total Number of Cycles	Percentage of Unused Cycles	Percentage of Utilization
E Fletcher Ave @ USF Palm Dr	1	165	0.6%	99.4%
E Kennedy Blvd @ N Tampa St	10	210	4.8%	95.2%
E Fletcher Ave @ N Nebraska Ave	16	57	28.1%	71.9%
W University Ave @ NW 13th St	1	166	0.6%	99.4%
SR A1A @ 178th St Eastbound Right Turn	7	236	3.0%	97.0%
SR A1A @ 178th St Eastbound Left Turn	62	236	26.3%	73.7%
US 41 @ Laurel Rd	0	9	0.0%	100%
US 1 @ E Broward Blvd	79	206	38.3%	61.7%
E Tennessee St @ E Monroe St Northbound	4	27	14.8%	85.2%
E Tennessee St @ E Monroe St Eastbound	3	24	12.5%	87.5%
SR 200 @ SW 60th Ave	0	0	N/A	N/A

The table shows that the LPI was effectively used at most tested approaches with a percentage of utilization above 85%. Several sites had slightly lower utilization as well. At E Fletcher Ave @ N Nebraska Ave, the percentage of LPI utilization was 71.9%. Based on field observation and data review, this was due to the low pedestrian volume on the testing approach and the green phase for the intersecting approach was relatively too long and beyond pedestrian waiting patience.

At the SR A1A @ 178th St eastbound left turn, the percentage of LPI utilization was 73.7%, and the slightly lower utilization was because the LPI was activated on both parallel crosswalks if the pushbutton was pressed by either site. At this intersection, most of the pedestrian volume was on the crosswalk corresponding to right-turning traffic, leaving the LPI on the left approach unused. Therefore, it is recommended that the pedestrian signals on these two approaches be programmed separately.

At the US 1 @ E Broward Blvd, the LPI and pedestrian signal were pre-timed during the daytime, leaving a significant number of LPI phases unused. It is suggested that this pedestrian signal be programmed with actuated control.

5.4 Summary of Data Analysis Results and Findings

This chapter documented the details of the analysis results and research findings based on the collected data before and after LPI implementation at the test sites. Evaluation and comparison analyses were conducted regarding the LPI safety effectiveness, LPI influence on traffic operation efficiency in terms of travel delay, and LPI utilization efficiency. The research findings are summarized below:

- LPI is designed to improve pedestrian visibility and reduce vehicle-pedestrian conflict potential, therefore increasing pedestrian safety. Overall, the implemented LPI demonstrated a promising safety effect in reducing vehicle-pedestrian conflicts and vehicle non-yielding behavior. It was found that:
  - The implemented LPIs demonstrated a promising safety effect in reducing the number of vehicle-pedestrian conflicts at five of the six testing approaches where vehicle-pedestrian conflicts were observed during the first few seconds equal to LPI length before LPI implementation. The percentage of vehicle-pedestrian conflict reduction ranged from 25% to 100%.
  - The implemented LPIs were effective in reducing the number of vehicle-pedestrian conflicts in six of the eight test approaches where vehicle-pedestrian conflicts were observed in the entire pedestrian walk phase before LPI implementation. The percentage of vehicle-pedestrian conflict reduction also ranged from 25% to 100%. In addition, neither increase nor decrease in the total number of vehicle-pedestrian conflicts was observed at two additional testing intersections (E Fletcher Ave @ USF Palm Dr and E Fletcher Ave @ N Nebraska Ave), showing acceptable LPI safety performance.
  - The percentage of non-yielding vehicles during LPI reveals that vehicle non-yielding behavior during the LPI phase varied among different test approaches, including that either yielding or non-yielding vehicles were not observed at five test approaches due to limited pedestrian/vehicle volume.
  - The percentage of non-yielding vehicles during the entire pedestrian walk phase indicates that the implemented LPI was effective in reducing vehicle non-yielding behavior at four sites/approaches. A slight increase in the percentage of non-yielding vehicles was observed at US 1 @ E Broward Blvd from 12% to 15.6%, and a significant increase in the percentage of non-yielding vehicles was observed at E Fletcher Ave @ N Nebraska Ave, from 53.8% to 87.2%. These results indicate that "NO TURN ON RED" or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs should be implemented with the LPI.
- In the analysis of LPI influence on traffic operation efficiency, based on the simulation analyses at the two most congested test intersections, it was found that the implemented LPI induces a slight increase or decrease in average total delay per vehicle on different approaches. It showed a trivial adverse or even favorable influence on intersection operation efficiency. Specifically,
  - At E Kennedy Blvd @ N Tampa St, the implemented LPI with respect to southbound right turn decreased the average total delay per vehicle on the southbound right turn by 3.9 seconds and increased the average total delay per vehicle on southbound through traffic by 3.7 seconds. The average total delay for the entire southbound approach increased by 2 seconds. Both of the increases are acceptable compared with those before LPI application, and the decrease in travel delay on the southbound right turn is favorable.
  - At SR A1A @ 178th St, the implemented LPI with respect to eastbound right turn and eastbound left turn increased the average total delay per vehicle by 0.6 seconds for the eastbound right-turn traffic and 2.8 seconds for eastbound left-turn traffic. The travel delay per vehicle on the entire eastbound approach increased by 2.1 seconds. The three increased delays are trivial compared with existing delay. The implemented

LPI decreased the average delay per vehicle for every movement (turning and through movements) and the entire approach on both southbound and northbound, with the decrease of delay ranging from 0.8 seconds to 1.7 seconds, showing a slight increase in operation efficiency.

- In the analysis of LPI utilization efficiency, it was found that the LPI was effectively used at most tested approaches. Detailed results are summarized as follows:
  - The LPI was effectively used at seven tested approaches with a percentage of utilization above 85%, indicating that the implemented LPI was working efficiently.
  - At E Fletcher Ave @ N Nebraska Ave, the percentage of LPI utilization was 71.9%. This is due to the low pedestrian volume on the tested approach, and the green phase for the intersecting approach was relatively too long and beyond pedestrian waiting patience.
  - At the SR A1A @ 178th St eastbound left turn, the percentage of LPI utilization was 73.7%, and the slightly lower utilization occurred because the LPI was activated simultaneously on both parallel crosswalks if a pedestrian call was placed on either side, and most pedestrians chose to cross the street on the south leg crosswalk.
  - At the US 1 @ E Broward Blvd, the LPI and pedestrian signals were pre-timed during the daytime, leaving a significant number of LPI phases unused. It is recommended to update the pedestrian signal with an actuated control.

6 FINALIZATION OF LPI IMPLEMENTATION GUIDELINES

The development of preliminary statewide LPI implementation guidelines regarding LPI warrants and parameters were described in Chapter 3, with the detailed guidelines included in Appendix E. Based on data review, analysis, and findings of the collected data before and after LPI implementation at test sites, the preliminary guidelines were finalized regarding warrant definition and threshold value fine-tuning to provide traffic engineers and managers in Florida with a simple and robust tool to:

- Assess the suitability and warrants for LPI implementation
- Determine appropriate LPI duration configurations
- Assess the need for supplemental LPI items

The following summarizes factors were considered for the development and refinement of LPI implementation guidelines at signalized intersections:

- Crash history between pedestrians and turning vehicles
- Presence of visibility issues blocking driver view of pedestrians
- Citizen complaints about vehicles not yielding to pedestrians, including observed conflicts between pedestrians and turning vehicles and compromised pedestrians at a specific approach
- Land use type that attracts pedestrians near signalized intersections
- T-intersections and intersections with a one-way road
- Risk potential of conflicts at a specific approach based on a combination of the following vehicular and pedestrian volumes during peak hours, four and/or eight hours of a day:
    - turning vehicle volume
    - pedestrian crossing volume
    - through traffic volume of cross street
- Marked school crossings
- Pedestrian non-compliance behavior and the proportion of pedestrian push-but-leave behavior that leaves LPI phase unused

6.1 Process for Finalization of LPI Implementation Guidelines

Based on data review, analysis and findings documented in Chapters 4 and 5 on the collected data before and after LPI implementation at test sites, several revisions were made to enhance the accuracy and applicability of the statewide LPI implementation guidelines. As shown in Table 5-1, the implemented LPIs were effective in reducing the number of vehicle-pedestrian conflicts and/or vehicle non-yielding behavior at a majority of intersections, although vehicle-pedestrian conflicts or vehicle non-yielding behavior was not observed at several locations. Based on these LPI performance statistics, the LPI warrants were refined, and the threshold values regarding vehicle-pedestrian crashes, vehicle-pedestrian conflicts, and volume of turning vehicles, pedestrians and intersecting traffic were also fine-tuned. These LPI warrants and threshold values are defined in general use based on the data analysis results of the testing locations covering a variety of geographical features; therefore, they are applicable to urban, suburban and rural intersection locations. The primary revisions and the support are documented in Appendix G.

6.2 Refined LPI Implementation Guidelines

Standard:

01 An engineering study of intersection location and physical characteristics, vehicle-pedestrian crash history and conflict frequency, approach traffic conditions, and pedestrian volume and characteristics shall be performed to determine whether implementation of a leading pedestrian interval (LPI) is justified at an intersection approach.

02 Investigation of the need for an LPI shall include analysis of factors related to the existing safety and operations at the study intersection approach, the potential to improve these conditions, and the applicable factors contained in the following LPI warrants:

- Warrant 1, Approach Crash Frequency
- Warrant 2, Reported Visibility Issue
- Warrant 3, Vehicle Non-Yielding Behavior
- Warrant 4, Vehicle Peak Hour
- Warrant 5, Pedestrian Peak Hour
- Warrant 6, Four-Hour Vehicular and Pedestrian Volume
- Warrant 7, Eight-Hour Vehicular and Pedestrian Volume
- Warrant 8, School Crossing

03 The satisfaction of an LPI warrant or warrants should not in itself require the implementation of an LPI.

Guidance:

04 An LPI should not be considered unless one or more of the warrant conditions described are met.

05 An LPI should not be considered unless an engineering study indicates that implementing it will improve the overall pedestrian and vehicle safety and/or operation of the intersection.

06 An LPI should not be implemented if it will significantly increase traffic congestion and travel delay based on engineering judgment.

6.2.1 Warrant 1, Average Crash Frequency

Support:

01 An Average Crash Frequency warrant is intended for application at an approach of intersection at which a vehicle-pedestrian crash is the principal reason to consider implementing an LPI.

Standard:

02 The implementation of an LPI shall be considered at an approach of intersection if an engineering study finds that the following condition is met:

- Average Crash Frequency between turning vehicles on green and pedestrians legally crossing the street on the associated crosswalk with the pedestrian "Walk" signal indication on the approach of the intersection ≥1 per year (in last 3 years).

***Guidance**:*

03 When examining the crash history, the eligible crash type (when pedestrians comply with a signal in a crosswalk) should be considered. It is suggested to review crash data by following these steps:

1. *Screen crashes at signalized intersections that involved pedestrians.*
2. *Review individual reports to determine what occurred.*
3. *Look for vehicles turning on green and striking a pedestrian who is crossing the street at the crosswalk with a pedestrian "Walk" signal indication.*

04 When examining average crash frequency, cyclists should be counted as pedestrians if appropriate for the crossing.

6.2.2 Warrant 2, Reported Visibility Issue

Support:

01 A Reported Visibility Issue Warrant is intended for application at an approach of an intersection at which reported visibility issues for pedestrians on the crosswalk being seen by turning vehicle drivers is the principal reason to consider implementing an LPI.

Standard:

02 The need for an LPI shall be considered if a visibility issue of blocked driver view of pedestrians on the crosswalk due to obstructions or poor sight distance at an approach of an intersection is reported and then verified by an engineering study.

***Guidance**:*

03 Visibility issues could be due to obstructions (e.g., buildings, base of a bridge, trees), blinding sun angle, inferior lighting condition, irregular intersection geometry, etc. Consider removing obstructions as needed before consideration of an LPI.

04 When examining visibility issues, cyclists should be considered as pedestrians if appropriate for the crossing.

6.2.3 Warrant 3, Vehicle Non-Yielding Behavior

Support:

01 A Vehicle Non-Yielding Behavior Warrant is intended for application at an approach of an intersection at which vehicle non-yielding behavior to pedestrians legally in a crosswalk during the "Walk" phase is the principal reason to consider implementing an LPI.

02 Two conditions, Condition A regarding number of vehicle-pedestrian conflicts and Condition B regarding compromised pedestrians due to vehicle non-yielding behavior, are both considered. If either Condition A or Condition B is satisfied, then Warrant 3 is satisfied. If neither Condition A nor Condition B is satisfied, then Warrant 3 is not satisfied.

Standard:

03 The need for an LPI shall be considered if vehicle non-yielding behavior to pedestrians during the "Walk" signal indication at an approach of the intersection is reported and one of the following conditions is satisfied:

A: Average number of conflicts between pedestrians and turning vehicles during the pedestrian "Walk" signal indication ≥3 per day on the studied approach based on field observations of 3 days; or
B: Percentage of compromised pedestrians at onset of the "Walk" signal at the crosswalk of the studied approach≥10%.

***Guidance**:*

04 "Conflicts" between crossing pedestrians and turning vehicles are observable situations in which the crossing pedestrians and the turning vehicles encounter a risk of collision should their movements and speeds remain unchanged. A conflict is generally avoided by the yielding behavior of either the crossing pedestrian or the turning vehicle or both.

05 "Compromised pedestrians" are pedestrians who are delayed or who have altered their travel path or travel speed due to concurrent turning vehicles. (Note: Collecting data about compromised pedestrians is a resource-intensive exercise.)

06 When examining vehicle-pedestrian conflicts or compromised pedestrians, cyclists should be counted as pedestrians if appropriate for the crossing.

Sections 6.2.4 through 6.2.7 document the LPI warrants that are related to vehicular and pedestrian volumes for specific periods of time. The traffic movements examined by these warrants are defined in Figures 6-1 and 6-2.

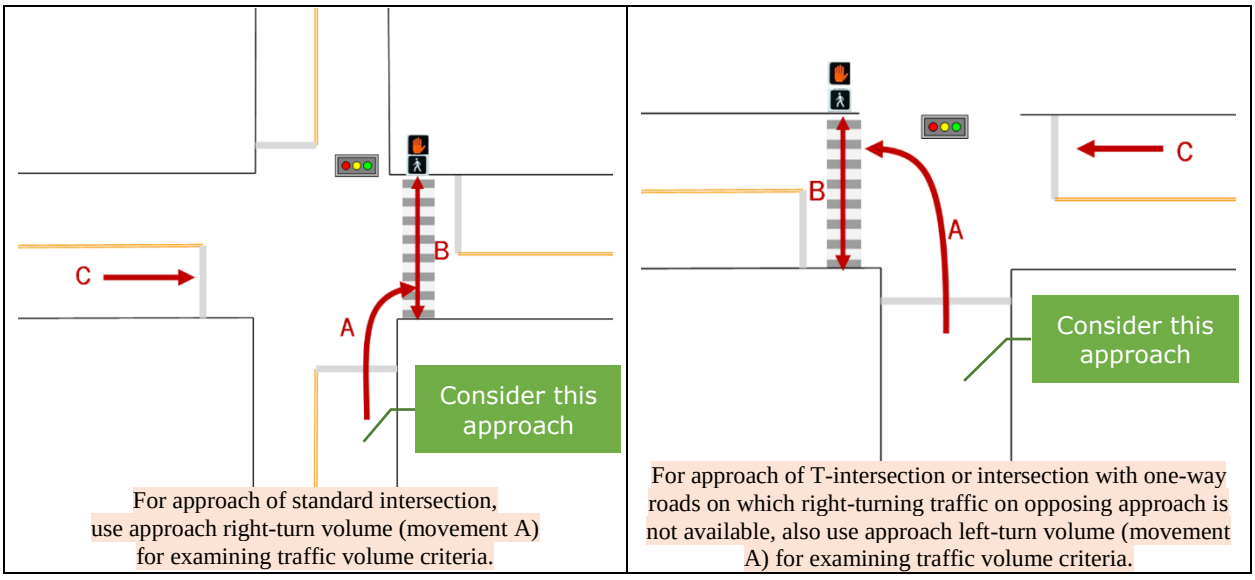


Figure 6-1 Traffic movement on approach for LPI suitability assessment.

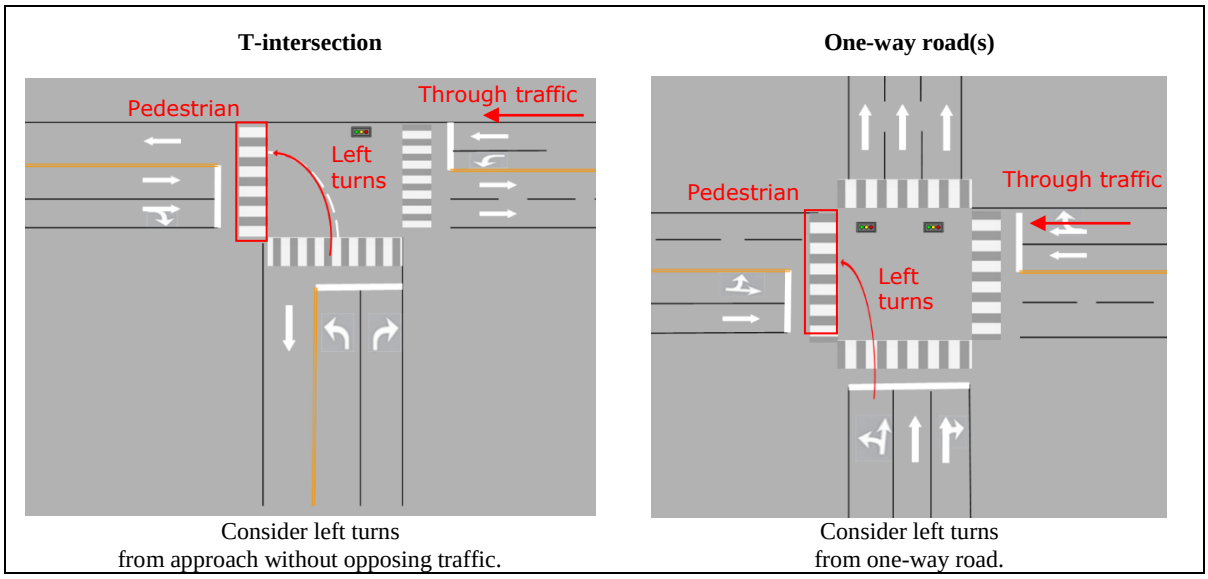


Figure 6-2 Consideration of left turns on approach.

6.2.4 Warrant 4, Vehicle Peak Hour

Support:

01 A Vehicle Peak Hour Warrant is intended for use at an approach of an intersection at which traffic conditions are such that for a minimum of 1 hour of an average day, the high vehicular volume induces potentially significant interactions between vehicles and crossing pedestrians and creates potential risk for pedestrian safety.

Standard:

02 An LPI shall be applied at signalized intersections that attract or discharge large numbers of vehicles over a short time. The need for an LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied (see Figures 6-1 and 6-2 for movement definition):

- For vehicle peak hour of an average day, approach turning vehicle volume (movement A) ≥130/hour, pedestrian volume at crosswalk (movement B) ≥25/hour; or
- If either turning vehicle volume (movement A) ≥130/hour or pedestrian volume at crosswalk (movement B) ≥25/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥500/hour/lane is also satisfied.

***Guidance**:*

03 If the more protective modes (e.g., exclusive pedestrian or protected left-turn phase) are not available or preferred, examine the criteria on the approach for the left turns (as shown in Figure 2) only at T-intersections and intersections with at least a one-way road. Engineering judgment should be used; a 4-leg intersection with a low volume of traffic on the opposing leg can be treated as a T-intersection.

04 *When examining pedestrian volume, count pedestrians in both directions on the examined crosswalk. Cyclists should be counted as pedestrians if appropriate for crossing.*

05 *If both pedestrian and turning movement volumes meet the thresholds for the vehicle volume peak hour, an LPI can be considered on the targeted approach. The vehicle volume peak hours could be identified based on field traffic count and observations.*

***Note:** The through traffic volume of a cross street (movement C) threshold is used as an additional and secondary reference. It is expected that high through traffic volume on a cross street (movement C) will lead to a low possibility of right-turn-on-red movements (when "NO TURN ON RED" sign is not implemented) and will induce fast turning movements at the onset of a pedestrian signal.*

If both pedestrian and turning movement volumes are satisfied during the vehicular volume peak hour, the through traffic volume of the cross street threshold is not needed. If either pedestrian or turning movement volume is satisfied, but not both, and the through traffic volume of the cross street is also satisfied during the vehicular volume peak hour, an LPI should also be considered. If neither pedestrian nor turning movement volume is satisfied during the vehicular volume peak hour, an LPI is not recommended, and the through traffic volume of the cross street threshold is not needed.

6.2.5 Warrant 5, Pedestrian Peak Hour

Support:

01 A Pedestrian Peak Hour Warrant is intended for use at an approach of an intersection at which traffic conditions are such that for a minimum of 1 hour of an average day, the high

pedestrian volume induces significant interactions between vehicles and crossing pedestrians and creates potential risk for pedestrian safety.

Standard:

02 An LPI shall be applied in situations that attract or discharge large numbers of pedestrians over a short time.

The need for an LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied (see Figures 6-1 and 6-2 for movement definition):

- For pedestrian volume peak hour of an average day, approach turning vehicle volume (movement A) ≥100/hour, pedestrian volume at crosswalk (movement B) ≥50/hour; or
- If either turning vehicle volume (movement A) ≥100/hour or pedestrian volume at crosswalk (movement B) ≥50/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥400/hour/lane is also satisfied.

Guidance*:*

03 If the more protective modes (e.g., exclusive pedestrian or protected left-turn phase) are not available or preferred, examine the criteria on the approach for left turns (as shown in Figure 2) only at T-intersections and intersections with at least a one-way road. Engineering judgment should be used; a 4-leg intersection with a low volume of traffic on the opposing leg can be treated as a T-intersection.

04 When examining pedestrian volume, count pedestrians in both directions on the examined crosswalk. Cyclists should be counted as pedestrians if appropriate for crossing.

05 If both pedestrian and turning movement volumes meet the thresholds for the pedestrian volume peak hour, an LPI can be considered on the targeted approach. The pedestrian volume peak hours could be identified based on field traffic count and observations.

Note: *The through traffic volume of a cross street (movement C) threshold is used as an additional and secondary reference. It is expected that high through traffic volume on a cross street (movement C) can lead to a low possibility of right-turn-on-red movements (when "NO TURN ON RED" sign is not implemented) and can induce fast turning movements at the onset of a pedestrian signal.*

If both pedestrian and turning movement volumes are satisfied during the pedestrian volume peak hour, the through traffic volume of the cross street threshold is not needed. If either pedestrian or turning movement volume is satisfied, but not both, and through traffic volume of the cross street is also satisfied during the pedestrian volume peak hour, an LPI should also be considered. If neither pedestrian nor turning movement volume is satisfied during the pedestrian volume peak hour, an LPI is not recommended, and the through traffic volume of the cross street threshold is not needed.

6.2.6 Warrant 6, Four-Hour Vehicular and Pedestrian Volume

Support:

01 Four-Hour Vehicular and Pedestrian Volume Warrant conditions are intended to be applied in situations in which large volumes of vehicles and pedestrians over any 4 hours of a day are the principal reason to consider implementing an LPI.

Standard:

02 The need for an LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied for each of any 4 hours of an average day (see Figures 6-1 and 6-2 for movement definition):

- Approach turning vehicle volume (movement A) ≥105/hour, pedestrian volume at crosswalk (movement B) ≥30/hour; or
- If either turning vehicle volume (movement A) ≥105/hour or pedestrian volume at crosswalk (movement B) ≥30/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥400/hour/lane is also satisfied.

***Guidance**:*

03 If the more protective modes (e.g., exclusive pedestrian or protected left-turn phase) are not available or preferred, examine the criteria on the approach for left turns (as shown in Figure 2) only at T-intersections and intersections with at least a one-way road. Engineering judgment should be used; a 4-leg intersection with a low volume of traffic on the opposing leg can be treated as a T-intersection.

04 When examining pedestrian volume, count pedestrians in both directions on the examined crosswalk. Cyclists should be counted as pedestrians if appropriate for crossing.

05 If both pedestrian and turning movement volumes meet the thresholds for each of any 4 hours of an average day, an LPI can be considered on the targeted approach.

***Note:** The through traffic volume of a cross street (movement C) threshold is used as an additional and secondary reference. It is expected that high through traffic volume on a cross street (movement C) can lead to a low possibility of right-turn-on-red movements (when "NO TURN ON RED" sign is not implemented) and can induce fast turning movements at the onset of a pedestrian signal.*

If both pedestrian and turning movement volumes are satisfied during each of the 4 hours, the through traffic volume of the cross street threshold is not needed. If either pedestrian or turning movement volume is satisfied, but not both, and through traffic volume of the cross street is also satisfied during each of the 4 hours, an LPI should also be considered. If neither pedestrian nor turning movement volume is satisfied during each of the 4 hours, an LPI is not recommended, and the through traffic volume of the cross street threshold is not needed.

6.2.7 Warrant 7, Eight-Hour Vehicular and Pedestrian Volume

Support:

01 Eight-Hour Vehicular and Pedestrian Volume Warrant conditions are intended to be applied in situations in which large and consistent volume of vehicles and pedestrians is the principal reason to consider implementing an LPI.

Standard:

02 The need for an LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied for each of any eight hours of an average day (See Figures 6-1 and 6-2 for movement definition):

- Approach turning vehicle volume (movement A) ≥100/hour, pedestrian volume at crosswalk (movement B) ≥25/hour; or
- If either turning vehicle volume (movement A) ≥100/hour or pedestrian volume at crosswalk (movement B) ≥25/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥400/hour/lane is also satisfied.

***Guidance**:*

03 If the more protective modes (e.g., exclusive pedestrian or protected left-turn phase) are not available or preferred, examine the criteria on the approach for the left turns (as shown in Figure 2) only at T-intersections and intersections with at least a one-way road. Engineering judgment should be used; if a 4-leg intersection with a low volume of traffic on the opposing leg, it can be treated as a T-intersection.

04 When examining pedestrian volume, count pedestrians in both directions on the examined crosswalk. Cyclists should be counted as pedestrians if appropriate for crossing.

05 If both pedestrian and turning movement volumes meet the thresholds for each of any 8 hours of an average day, an LPI can be considered on the targeted approach.

***Note:** The through traffic volume of a cross street (movement C) threshold is used as an additional and secondary reference. It is expected that high through traffic volume on a cross street (movement C) can lead to a low possibility of right-turn-on-red movements (when "NO TURN ON RED" sign is not implemented) and can induce fast turning movements at the onset of a pedestrian signal.*

If both pedestrian and turning movement volumes are satisfied during each of the 8 hours, the through traffic volume of the cross street threshold is not needed. If either pedestrian or turning movement volume is satisfied, but not both, and through traffic volume of the cross street is also satisfied during each of the 8 hours, an LPI should also be considered. If neither pedestrian nor turning movement volume is satisfied during each of the 8 hours, an LPI is not recommended, and the through traffic volume of the cross street threshold is not needed.

6.2.8 Warrant 8, School Crossing

Support:

01 A School Crossing Warrant is intended for application at locations at which school students crossing a street is the principal reason to consider implementing an LPI. For the purpose of this warrant, "school students" include elementary school through university students.

Standard:

02 The need for an LPI shall be considered at the studied approach of an intersection when an engineering study finds that the following condition is satisfied at an intersection with a school crossing (see Figures 6-1 and 6-2 for movement definition):

- Approach turning vehicle volume (movement A) ≥50/hour (consider LPI for the period 1 hour before and 30 minutes after school start time, and the period 30 minutes before and 1 hour after school end time).

6.2.9 LPI Implementation

Standard:

01 An LPI should be minimum of 3 seconds in duration.

02 LPI timing should allow pedestrians to clear the width of one lane in the direction of moving traffic (and the width of a parking lane, if any) to increase the visibility of pedestrians to turning traffic.

***Guidance**:*

03 A minimum of 3-second LPI duration is required. The following formula may be used to design LPI duration:

$$LPI = (ML + PL)/W$$

where:

LPI = number of seconds (rounded value) between onset of "Walk" signal for pedestrians and green indication for vehicles
ML = distance on crosswalk to clear width of one moving lane, in ft
PL = width of parking lane, if any, in ft
W = walking speed (3.5 ft/s for pedestrian clearance calculation suggested by MUTCD, or 3.0 ft/s for aging population suggested by FHWA)

Options:

04 Transportation engineers should determine whether to implement an LPI for a whole day or on a time-of-day basis.

05 An electronic blank-out "NO TURN ON RED" sign should be considered to enhance LPI implementation.

06 Extended LPI should be considered at approaches with large portions of users with slower crossing speeds (children, older adults, persons with physical disabilities), or at approaches where the pedestrian detector location is not immediately adjacent to the curb (or, if no pedestrian detector is present, a location 6 feet from the face of the curb or from the edge of the pavement may be considered for calculating extended LPI).

07 The use of an Accessible Pedestrian Signal (APS) (MUTCD Sections 4E.09–4E.13) should be considered if an LPI is used, as vision-impaired pedestrians use the sound of moving traffic to start crossing.

08 Education about LPI operation should be considered—for example, using a different background color (other than white) for a pushbutton sign plate with a short message such as "Ped Head Start" for crosswalks with the LPI feature.

09 Conducting field observations and safety improvement evaluations after LPI implementation should be considered, and potential further adjustments in signal timing and coordination could be applied based on engineering judgment.

10 Lengthy traffic signal cycles should be avoided to reduce pedestrian wait time and increase pedestrian compliance behavior with pedestrian signals.

6.3 Example Demonstration for the Use of Guidelines

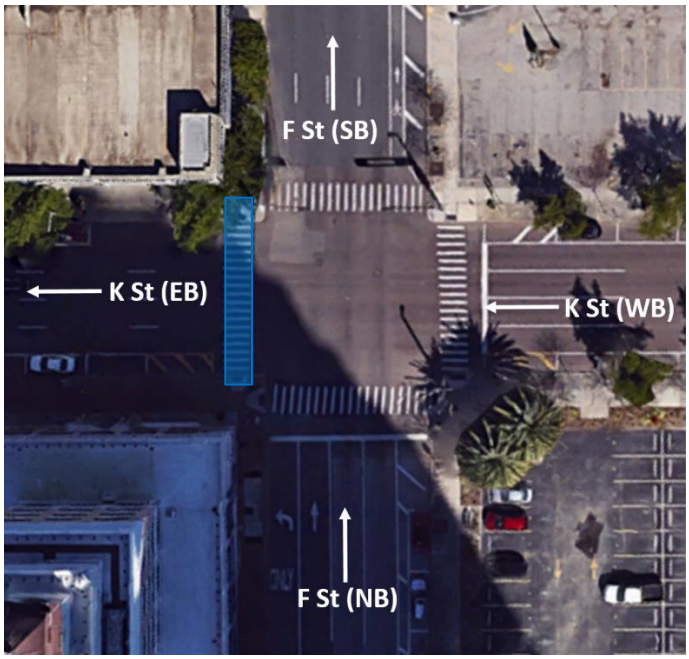
In this section, two examples are presented to demonstrate the use of the developed statewide LPI implementation guidelines.

6.3.1 Example One

Intersection – The intersection of K St (eastbound/westbound) and F St (northbound/southbound) is a junction of two <u>one-way roads</u> in a downtown area.

LPI Eligibility: *Consider if an LPI is needed on the west leg crosswalk (northbound left turn, see highlighted below)*

Intersection Geometry



Fact Summary

- In a downtown CBD
- K St is 4-lane one-way road (WB only)
- 10 ft travel lane width for all approaches
- An 8 ft parking lane on the right side of F street
- No visibility issue reported
- Field observations of vehicle-pedestrian conflicts were conducted on three weekdays, including one weekday for traffic and pedestrian volume data collection of 8 hours.
- No pedestrian crash in last 3 years
- F St is a 4-lane one-way road (northbound only)
- An 8 ft parking lane on both sides of K street
- Pre-timed traffic and pedestrian signals in all approaches, and permissive left turn on northbound
- Vehicle Non-yielding behavior reported by local citizens on northbound left turn.

Approach Traffic Volume and Conflicts (Related to LPI Warrant Analysis)

Weekdays	Day 1	Day 2	Day 3
Number of Observed Conflicts	2	6	5

Time Period	Left Turn Volume (NB)	Ped Volume*	Ped-veh Conflicts	Intersect Traffic Volume (WB)	Intersect Traffic Per Lane (WB)
8:00-9:00	161	109	2	1157	289
9:00-10:00	101	72	0	1049	262
11:00-12:00	134	212	1	848	212
12:00-13:00	141	456	2	731	183
13:00-14:00	105	312	1	872	218
15:00-16:00	75	102	0	853	213
16:00-17:00	54	120	0	949	237
17:00-18:00	112	113	0	923	231

**Count bicyclists as pedestrians*

LPI Warrant Analysis

- ***Warrant 1 Average Crash Frequency***

Since there were no crashes occurred between turning vehicles on green and pedestrian legally crossing the street during "Walk" signal in the past three years, Warrant 1 Average Crash Frequency is NOT MET.

- ***Warrant 2 Reported Visibility Issue***

Since there is no reported visibility issue at the target approach, Warrant 2 Reported Visibility Issue is NOT MET.

- ***Warrant 3 Vehicle Non-Yielding Behavior***

Vehicle non-yielding behavior was reported by local citizens, and the number of conflicts between pedestrians and turning vehicles during pedestrian "Walk" signal are as follows, based on three-day field observation:

Weekdays	Day 1	Day 2	Day 3
Number of Conflicts	3	7	5

The average number of conflicts between pedestrian and turning vehicles during pedestrian "Walk" signal is 4.3 per day. Therefore, Warrant 3 Vehicle Non-Yielding Behavior is MET.

- ***Warrant 4 Vehicle Peak Hour***

Based on the traffic and pedestrian volume criteria in Warrant 4, the warrant analysis results are shown below:

Time Period	Left Turn Volume (NB)	Ped Volume*	Intersect Traffic Volume (WB)	Intersect Traffic Per Lane (WB)	Criteria Met? (Yes/No)
8:00-9:00	161	109	1157	289	Yes
9:00-10:00	101	72	1049	262	No
11:00-12:00	134	212	848	212	Yes
12:00-13:00	141	456	731	183	Yes
13:00-14:00	105	312	872	218	No
15:00-16:00	75	102	853	213	No
16:00-17:00	54	120	949	237	No
17:00-18:00	112	113	923	231	No

**Count bicyclists as pedestrians*

There are a total of 3 one-hour periods meeting Warrant 4 criteria. Therefore, Warrant 4 Vehicle Peak Hour is MET.

- ***Warrant 5 Pedestrian Peak Hour***

Based on the traffic and pedestrian volume criteria in Warrant 5, the warrant analysis for each hour is shown below:

Time Period	Left Turn Volume (NB)	Ped Volume*	Intersect Traffic Volume (WB)	Intersect Traffic Per Lane (WB)	Criteria Met? (Yes/No)
8:00-9:00	161	109	1157	289	Yes
9:00-10:00	101	72	1049	262	Yes
11:00-12:00	134	212	848	212	Yes
12:00-13:00	141	456	731	183	Yes
13:00-14:00	105	312	872	218	Yes
15:00-16:00	75	102	853	213	No
16:00-17:00	54	120	949	237	No
17:00-18:00	112	113	923	231	Yes

**Count bicyclists as pedestrians*

There are a total of 6 one-hour periods meeting Warrant 5 criteria. Therefore, Warrant 5 Pedestrian Peak Hour is MET.

- ***Warrant 6, Four-Hour Vehicular and Pedestrian Volume***

Based on the traffic and pedestrian volume criteria in Warrant 6, the warrant analysis results are shown below:

Time Period	Left Turn Volume (NB)	Ped Volume*	Intersect Traffic Volume (WB)	Intersect Traffic Per Lane (WB)	Criteria Met? (Yes/No)
8:00-9:00	161	109	1157	289	Yes
9:00-10:00	101	72	1049	262	No
11:00-12:00	134	212	848	212	Yes
12:00-13:00	141	456	731	183	Yes
13:00-14:00	105	312	872	218	Yes
15:00-16:00	75	102	853	213	No
16:00-17:00	54	120	949	237	No
17:00-18:00	112	113	923	231	Yes

**Count bicyclists as pedestrians*

There are a total of 5 one-hour periods meeting Warrant 6 criteria. Therefore, Warrant 6 Four-Hour Vehicular and Pedestrian Volume is MET**.**

- ***Warrant 7, Eight-Hour Vehicular and Pedestrian Volume***

Based on the traffic and pedestrian volume criteria in Warrant 7, the warrant analysis results are shown below:

Time Period	Left Turn Volume (NB)	Ped Volume*	Intersect Traffic Volume (WB)	Intersect Traffic Per Lane (WB)	Criteria Met? (Yes/No)
8:00-9:00	161	109	1157	289	Yes
9:00-10:00	101	72	1049	262	Yes
11:00-12:00	134	212	848	212	Yes
12:00-13:00	141	456	731	183	Yes
13:00-14:00	105	312	872	218	Yes
15:00-16:00	75	102	853	213	No
16:00-17:00	54	120	949	237	No
17:00-18:00	112	113	923	231	Yes

**Count bicyclists as pedestrians*

There are a total of 6 one-hour periods meeting Warrant 7 criteria. Therefore, Warrant 7 Eight-Hour Vehicular and Pedestrian Volume is NOT MET.

- ***Warrant 8, School Crossing***

Since this intersection is not within a school zone, Warrant 8 School Crossing is NOT MET.

Overall, the summary of warrant analysis is shown below.

Warrant	Warrant Met? (Yes/No)	Warrant	Warrant Met? (Yes/No)
Warrant 1	No	Warrant 5	Yes
Warrant 2	No	Warrant 6	Yes
Warrant 3	Yes	Warrant 7	No
Warrant 4	Yes	Warrant 8	No

Based on the above results, an LPI is recommended at the target approach.

LPI Implementation Recommendation

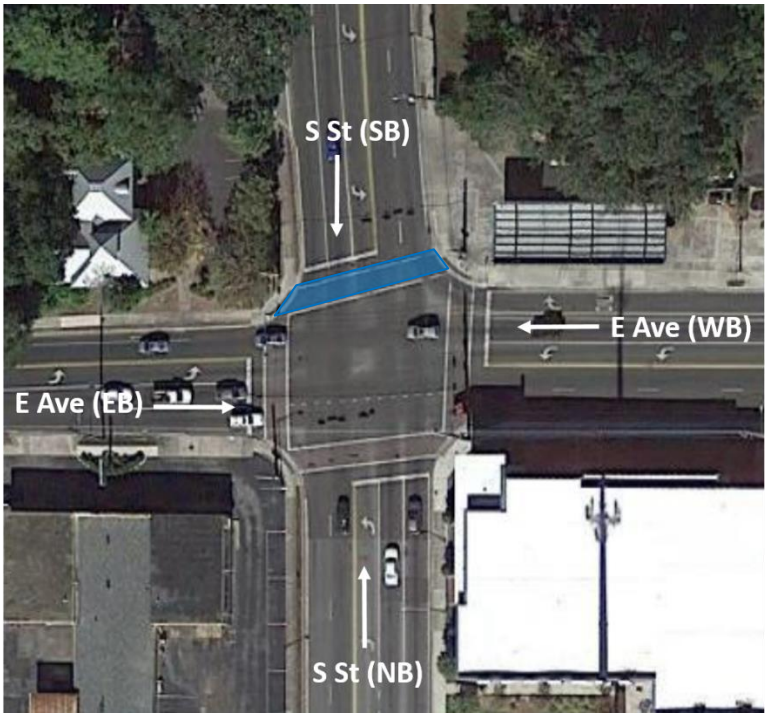
- The suggested LPI duration is: LPI= (ML+PL)/W = (10+8)/3.5=5.1 seconds. Considering the pedestrians with lower crossing speeds and the distance between the curb and pedestrian waiting locations, an LPI of 6 seconds is recommended.
- An Accessible Pedestrian Signal (APS) (MUTCD Sections 4E.09–4E.13) should be considered for LPI implementation.
- Traffic engineers should conduct field observations and safety improvement evaluations after LPI implementation, and provide potential further adjustments in signal timing and coordination as needed.
- Consider implementing static or blank-out “NO TURN ON RED” signs or “TURNING VEHICLES YIELD TO PEDESTRIANS” signs to enhance LPI safety performance.

6.3.2 Example Two

Intersection — The intersection of E Ave (eastbound/westbound) and S St (northbound/southbound) is an intersection within a residential area with various local small businesses.

LPI Eligibility: *Consider if an LPI is needed on the north leg crosswalk (westbound right turn, see highlighted below)*

Intersection Geometry



Fact Summary

- In a residential area with various local small businesses
- E Ave westbound approaching intersection is with a dedicated right-turn lane and a left-turn lane
- 12 ft travel lane width for all approaches
- Actuated traffic signals protected left-turn on all approaches
- No visibility issue reported
- A high school is on the northeast corner of the intersection, school time: 8:00-15:30
- One vehicle-pedestrian crash on target approach in past three years.
- F St is a 4-lane one-way road (northbound only)
- A 4 ft bike lane is on E Ave westbound
- Pedestrian signals are activated by pushbuttons on all approaches
- Vehicle Non-yielding behavior on westbound right-turn was reported.
- Field observations of vehicle-pedestrian conflicts were conducted on three weekdays, including one weekday for traffic and pedestrian volume data collection of 8 hours.

Approach Traffic Volume and Conflicts (Related to LPI Warrant Analysis)

Weekdays	Day 1	Day 2	Day 3
Number of Observed Conflicts	2	1	1

Time Period	Right Turn Volume (WB)	Ped Volume*	Ped-veh Conflicts	Intersect Traffic Volume (NB)	Intersect Traffic Per Lane (NB)
7:00-8:00	80	35	0	590	295
8:00-9:00	97	65	1	746	373
11:00-12:00	52	18	0	310	155
12:00-13:00	66	28	1	295	148
13:00-14:00	68	22	0	465	233
14:00-15:00	79	20	0	538	269
15:00-16:00	102	71	0	658	329
16:00-17:00	110	19	0	808	454

**Count bicyclists as pedestrians*

LPI Warrant Analysis

- ***Warrant 1 Average Crash Frequency***

Since there was one crash occurred between turning vehicles on green and pedestrian legally crossing the street during "Walk" signal in the past three years, Warrant 1 Average Crash Frequency is NOT MET.

- ***Warrant 2 Reported Visibility Issue***

Since there is no reported visibility issue at the target approach, Warrant 2 Reported Visibility Issue is NOT MET.

- ***Warrant 3 Vehicle Non-Yielding Behavior***

Vehicle non-yielding behavior was reported by local citizens, and the number of conflicts between pedestrians and turning vehicles during pedestrian "Walk" signal are as follows, based on three-day field observation:

Weekdays	Day 1	Day 2	Day 3
Number of Observed Conflicts	2	1	1

The average number of conflicts between pedestrian and turning vehicles during pedestrian "Walk" signal is 1.3 per day. Therefore, Warrant 3 Vehicle Non-Yielding Behavior is NOT MET.

- ***Warrant 4 Vehicle Peak Hour***

Based on the traffic and pedestrian volume criteria in Warrant 4, the warrant analysis results are shown below:

Time Period	Right Turn Volume (WB)	Ped Volume*	Intersect Traffic Volume (NB)	Intersect Traffic Per Lane (NB)	Criteria Met? (Yes/No)
7:00-8:00	80	35	590	295	No
8:00-9:00	97	65	746	373	No
11:00-12:00	52	18	310	155	No
12:00-13:00	66	28	295	148	No
13:00-14:00	68	22	465	233	No
14:00-15:00	79	20	538	269	No
15:00-16:00	102	71	658	329	No
16:00-17:00	110	19	808	454	No

**Count bicyclists as pedestrians*

There is none of the one-hour periods meeting Warrant 4 criteria. Therefore, Warrant 4 Vehicle Peak Hour is NOT MET.

- ***Warrant 5 Pedestrian Peak Hour***

Based on the traffic and pedestrian volume criteria in Warrant 5, the warrant analysis results are shown below:

Time Period	Right Turn Volume (WB)	Ped Volume*	Intersect Traffic Volume (NB)	Intersect Traffic Per Lane (NB)	Criteria Met? (Yes/No)
7:00-8:00	80	35	590	295	No
8:00-9:00	97	65	746	373	No
11:00-12:00	52	18	310	155	No
12:00-13:00	66	28	295	148	No
13:00-14:00	68	22	465	233	No
14:00-15:00	79	20	538	269	No
15:00-16:00	102	71	658	329	Yes
16:00-17:00	110	19	808	454	Yes

**Count bicyclists as pedestrians*

There are a total of 2 one-hour periods meeting Warrant 5 criteria. Therefore, Warrant 5 Pedestrian Peak Hour is MET.

- ***Warrant 6, Four-Hour Vehicular and Pedestrian Volume***

Based on the traffic and pedestrian volume criteria in Warrant 6, the warrant analysis results are shown below:

Time Period	Right Turn Volume (WB)	Ped Volume*	Intersect Traffic Volume (NB)	Intersect Traffic Per Lane (NB)	Criteria Met? (Yes/No)
7:00-8:00	80	35	590	295	No
8:00-9:00	97	65	746	373	No
11:00-12:00	52	18	310	155	No
12:00-13:00	66	28	295	148	No
13:00-14:00	68	22	465	233	No
14:00-15:00	79	20	538	269	No
15:00-16:00	102	71	658	329	No
16:00-17:00	110	19	808	454	Yes

**Count bicyclists as pedestrians*

There is only 1 one-hour period meeting Warrant 6 criteria. Therefore, Warrant 6 Four-Hour Vehicular and Pedestrian Volume is NOT MET.

- ***Warrant 7, Eight-Hour Vehicular and Pedestrian Volume***

Based on the traffic and pedestrian volume criteria in Warrant **7**, the warrant analysis results are shown below:

Time Period	Right Turn Volume (WB)	Ped Volume*	Intersect Traffic Volume (NB)	Intersect Traffic Per Lane (NB)	Criteria Met? (Yes/No)
7:00-8:00	80	35	590	295	No
8:00-9:00	97	65	746	373	No
11:00-12:00	52	18	310	155	No
12:00-13:00	66	28	295	148	No
13:00-14:00	68	22	465	233	No
14:00-15:00	79	20	538	269	No
15:00-16:00	102	71	658	329	Yes
16:00-17:00	110	19	808	454	Yes

**Count bicyclists as pedestrians*

There are a total of 2 one-hour periods meeting Warrant 7 criteria. Therefore, Warrant 7 Eight-Hour Vehicular and Pedestrian Volume is NOT MET.

- ***Warrant 8, School Crossing***

There is a high school near this intersection, and the school time is 8:00-15:30. LPI could be considered for the period 7:00-8:30 (1 hour before and 30 minutes after school start time) and the period 15:00-16:30 (30 minutes before and 1 hour after school end time). Therefore, the following 1-hour periods have been examined for warrant analysis.

Time Period	Right Turn Volume (WB)	Ped Volume*	Intersect Traffic Volume (NB)	Intersect Traffic Per Lane (NB)	Criteria Met? (Yes/No)
7:00-8:00	80	35	590	295	Yes
8:00-9:00	97	65	746	373	Yes
15:00-16:00	102	71	658	329	Yes
16:00-17:00	110	19	808	454	Yes

**Count bicyclists as pedestrians*

Therefore, Warrant 8 School Crossing is MET.

Overall, the summary of warrant analysis is shown below**.**

Warrant	Warrant Met? (Yes/No)	Warrant	Warrant Met? (Yes/No)
Warrant 1	No	Warrant 5	Yes
Warrant 2	No	Warrant 6	No
Warrant 3	No	Warrant 7	No
Warrant 4	No	Warrant 8	Yes

Based on the above results, an LPI is recommended at the target approach.

LPI Implementation Recommendation

- Given the warrant analysis results for Warrants 5 and 8, an LPI might be considered between 7:00-8:30 and 15:00-17:00 at the traffic engineers' discretion.
- The suggested LPI duration is: LPI= (ML+PL)/W = (12+0)/3.5=3.4 seconds. Considering the pedestrians with lower crossing speeds and the distance between the curb and pedestrian waiting locations, a LPI of 4 seconds is recommended.
- An Accessible Pedestrian Signal (APS) (MUTCD Sections 4E.09–4E.13) should be considered for LPI implementation.
- Traffic engineers should conduct field observations and safety improvement evaluations after LPI implementation, and provide potential further adjustments in signal timing and coordination as needed.
- Consider implementing static or blank-out "NO TURN ON RED" signs or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs to enhance LPI safety performance.

7 CONCLUSIONS AND RECOMMENDATIONS

This research has successfully conducted an integrated study to determine the suitability and effectiveness of LPI implementation at signalized intersections to improve pedestrian safety and to develop statewide guidelines for LPI implementation. Comprehensive surveys and interviews were conducted among experienced traffic engineers and managers, and intensive discussions and consultation with FDOT district representatives were carried out to develop the preliminary statewide LPI implementation guidelines. Extensive data collections and analyses before and after pilot LPI implementation at the selected intersection approaches within each FDOT District were conducted to refine and finalize the statewide LPI implementation guidelines. By assessing the suitability and warrants for LPI implementation, determining appropriate LPI duration configurations, and evaluating the need for supplemental LPI terms, the finalized guidelines provide a simple and robust tool to increase pedestrian visibility safety at signalized intersections. The conclusions and recommendation from this research project are provided in the following two sections.

7.1 Conclusions

The major conclusions and research findings of this project are provided in three parts—a summary of findings based on literature review and guideline input from experience traffic engineers and managers; a summary of data analysis findings regarding LPI performance; and a summary of findings regarding appropriate LPI implementations and further amendment.

7.1.1 Input Summary for LPI Guideline Development

The responses from experienced traffic agency engineers/managers and FDOT District traffic operations representatives provided valuable information and input for the development of guidelines for LPI warrants, implementation, and operations in Florida. A summary of major factors, concerns and supplemental needs for LPI guideline development is as follows.

- The following factors could be considered for LPI warrant development:
    - Crash history between pedestrians and turning vehicles during pedestrian signal indications at intersection and approach levels
    - Conflicts between pedestrians and turning vehicles at approach level
    - Citizen complaints regarding vehicle-pedestrian conflicts or vehicle non-yielding behavior
    - Pedestrian volume, turning vehicle volume, crossing street volume, and/or activity features under pre-timed and actuated signal timing
    - Irregular intersection features (e.g., visibility issues)
    - Consideration of LPI implementation with left-turning vehicles at T-intersections or one-way roads
    - Different land use types (e.g., school zones) and special events that attract high pedestrian activities
- The following concerns could be considered for LPI implementation:
    - Pedestrian compliance rate to pedestrian signal indications and behavior variation
    - Obvious negative impacts on vehicular progression (e.g., significant delay)
- The following supplemental needs were suggested for LPI implementation:
    - “NO TURN ON RED” sign or blank-out “NO TURN ON RED” sign

- Accessible pedestrian signals (APS)
- Education about LPI for all road users

7.1.2 Data Analysis Findings

In order to evaluate the safety effectiveness and operational impact of LPI, and to refine the preliminary LPI implementation guidelines, before-after comparison analyses were conducted based on the data collected at the selected 11 approaches. It should be noted that these 11 approaches had already met certain criteria or considerations in the preliminary guidelines. The summary of data analysis findings regarding LPI performance in this pilot implementation is presented below.

- Proper implementations of LPIs demonstrated promising safety effects in reducing the number of vehicle-pedestrian conflicts at five of the six (83%) testing approaches during the first few seconds equal to LPI length. The percentage of vehicle-pedestrian conflict reduction ranged from 25% to 100%. The implemented LPIs were also able to reduce vehicle-pedestrian conflicts at six of eight (75%) testing approaches during the entire pedestrian walk phase. The percentage of vehicle-pedestrian conflict reduction also ranged from 25% to 100%.
- The implementation of LPIs showed mixed results of drivers' yielding behaviors. A higher percentage of non-yielding vehicles were observed during the first few seconds equal to LPI length, but a lower percentage of drivers' non-yielding vehicles were observed during the entire pedestrian walk phase. Field observations also revealed that drivers continued to make right turns on red if allowed, and tended to turn quickly at the onset of pedestrian walk phase if pedestrians hadn't started to walk. These behaviors induced considerable non-yielding observations and compromised pedestrians.
- Although the risk of drivers' non-yielding behaviors is lower than the conflicts between vehicles and pedestrians, sufficient attention is still needed on this safety issue. It is recommended to implement static or blank-out "NO TURN ON RED" signs or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs along with LPI implementation to enhance the safety of pedestrians crossing at signalized intersections.
- Based on the simulation analyses for the two most congested testing intersections before and after LPI implementation, it is found that the implemented LPI induced a slight increase or decrease in average total delay per vehicle on different approaches, showing a trivial adverse or even favorable influence of LPI on intersection operation efficiency.
- In terms of LPI utilization efficiency, it was found that the LPI was effectively used at most testing approaches, including achieving a percentage of utilization above 85% at seven testing intersection approaches, two additional testing approaches achieving above 70%, and one additional achieving above 60%. Overall, the implemented LPI has been well recognized and sufficiently utilized by pedestrians.

7.1.3 LPI Implementations

In addition to LPI warrant examination and duration calculation, supplemental implementation measures and further amendment are necessary to enhance LPI safety effectiveness. The summary of findings regarding appropriate LPI implementations and further amendment is as follows.

- For approaches of a T-intersection or intersection with one-way roads on which right-turning traffic on opposing approach is not available, the left-turn traffic volume should be used for traffic volume warrant analysis.
- LPI could be implemented with the company of static or blank-out "NO TURN ON RED" or "TURNING VEHICLES YIELD TO PEDESTRIANS" signs, as shown in Figures 7-1 and 7-2.
- Extended LPI should be considered at approaches with large portions of users with slower crossing speeds (children, older adults, persons with physical disabilities), or at approaches where the pedestrian detector location is not immediately adjacent to the curb, or use a fixed distance of 6 feet if pedestrian detector is not available.
- The use of an Accessible Pedestrian Signal (APS) (MUTCD Sections 4E.09–4E.13) should be considered if an LPI is used.

Figure 7-1 Blank-out "NO TURN ON RED" sign.

Figure 7-2 Dual blank-out "NO TURN ON RED"/"YIELD TO PEDESTRIANS" sign.

7.2 Recommendations

The ultimate goal of this research was to transform LPI knowledge, experience, and research to general standards and implementation instructions to improve pedestrian visibility and safety at signalized intersections. The major recommendations before, during, and after LPI implementation are summarized as follows:

- Four different safety-related aspects should be examined when considering the implementation of LPI, including historical vehicle-pedestrian crash records, reported visibility issue, reported vehicle non-yielding behavior, and traffic and pedestrian volume (peak hour, 4-hour and 8-hour). Historical vehicle-pedestrian crash records, reported visibility issue, reported vehicle non-yielding behavior are given higher priority than traffic and pedestrian volume in consideration of LPI.
- The potential increase in travel delay caused by LPI implementation should be evaluated based on engineering experience. An LPI should not be implemented if significant delay or congestion will be introduced.
- At the locations where LPI is considered, field observations are recommended to evaluate the approximate proportion of pedestrians with slower crossing speeds. The distance between pedestrian detector and the edge of pavement/curb should also be considered for extended LPI.
- Transportation engineers should determine whether to implement an LPI for the whole day or on a time-of-day basis.
- The implementation of LPI should consider installing both static and blank-out "NO TURN ON RED" signs or TURNING VEHICLES YIELD TO PEDESTRIANS signs to enhance the effectiveness of the implementation.
- Education and outreach activities should also be considered to let local residents be familiarized with and get used to new LPI implementations.
- Field observations and evaluations are necessary after LPI implementation, and adjustments should be applied to maximize LPI safety effectiveness and utilization.

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APPENDIX A LEADING PEDESTRIAN INTERVAL IMPLEMENTATION SURVEY

Introduction

This survey is being conducted by Center for Urban Transportation Research (CUTR) for the FDOT Project BDV25 TWO 977-22, "Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida." Your responses will provide valuable information and input for the development of guidelines for LPI warrants, implementation, and operations in Florida. Obtaining feedback from you is important in making signalized intersections much safer and friendlier for pedestrians.

We appreciate your valuable input and will acknowledge your contribution in the final project report. Your privacy and project records will be kept confidential if requested. Thank you in advance for taking the time to complete our survey. If you have questions, please contact Pei-Sung Lin at lin@cutr.usf.edu, (813) 974-5168, or Pete Yauch at pyauch@albeckgerken.com, (813) 319-3790.

Guidance

Please answer the survey questions to the best of your ability and submit the survey by **March 18, 2016.**

Completing the Survey – The survey will take approximately 15 to 20 minutes to complete depending upon your responses and will be available online from **March 2–18, 2016.** Progression through the survey will be tracked by a bar at the bottom of the screen indicating percent complete.

Required Responses – All items with an asterisk require a response.

Moving Within the Survey – You will be able to move back and forth within the survey. Please use the "Back" and "Next" buttons within the survey itself. Use of the browser "back" and "forward" arrows will result in lost responses.

Saving the Survey – The survey will automatically save any responses you have made. When you reach the last page of the survey, do not click "Submit" until you are completely finished. Once you click the "Submit" button on the last page, you will be unable to change your responses or regain access to the electronic survey. After submitting, you will have the option to download a pdf file of your responses.

Forwarding the Survey – This survey link is unique to you. Please do not forward it except as noted. (NOTE: If you determine that another person within your agency or organization has the information necessary for completing some or all of the survey, you may forward your survey link to that individual who can complete some or all of it and submit it directly on your behalf or forward it back to you for submission.)

1. Please provide your contact information, so that we may follow up if necessary. (NOTE: * is required)

Name: _____
Title: _____
Organization*:_____
City*:_____
State*:_____
Email: _____
Phone*:_____

2. What are **the reasons for the consideration or implementation of LPI** in your city/county? Please select all that apply. Alternatively, answer it in your own words in the text box.

   ☐ High pedestrian activity (near school zones, parking facilities, senior centers, theme parks etc.)
   ☐ Citizen complaints/feedback about vehicles non-yielding to pedestrians
   ☐ Crashes involving pedestrians and turning vehicle
   ☐ High percentage of left and/or right turns (e.g., T intersection, one-way road, 4-leg intersection with low volume of traffic on the 4th leg)
   ☐ High benefit-cost ratio of LPI to improve pedestrian safety (cost-effective)
   ☐ Issues due to features such as irregular intersection geometry, wide turning radius, crosswalk placement, obstructions such as buildings or trees, or blinding sun angle. If selected, please indicate the feature: _____
   ☐ Marked school crossing
   ☐ Other (If selected, please specify in the following text box)

   Text box for your answers, comments or explanations:

3. Do you have certain **criteria or internal guidelines** used to determine the implementation of LPIs **with right turning vehicles at a specific crosswalk?** Please select all that apply, and write in your answer in the given space. Alternatively, answer it in your own words in the text box.

   Note: if specific thresholds/numbers are unavailable, please use other words such as high, heavy, relatively high, evident, or repeated etc.

   ☐ Average annual crashes between right-turn vehicles and pedestrians (during pedestrian signal indications) at the specific crosswalk is (larger than): _____
   ☐ Pedestrian volume at the specific crosswalk is (larger than): _____

☐ Right-turning vehicle volume at the specific approach is (larger than): _____

☐ Number of conflicts between right-turn vehicles and pedestrians at the specific crosswalk is (larger than): _____

☐ Issues due to features such as _____

☐ Adjacent land use type (e.g., near school zones, campus, or parking garage) is _____

☐ At the specific approach with "NO TURN ON RED" control _____

☐ Other (If selected, please specify in the following text box)

Text box for your answers, comments or explanations:

4. Do you have certain **criteria or internal guidelines** used to determine the implementation of LPIs **with left turning vehicles at a specific crosswalk?** Please select all that apply, and write in your answer in the given space. Alternatively, answer it in your own words in the textbox.

Note: if specific thresholds/numbers are unavailable, please use other words such as high, heavy, relatively high, evident, or repeated etc.

☐ Average annual crashes between left-turn vehicles and pedestrians (during pedestrian signal indications) at the specific crosswalk is (larger than): _____

☐ Pedestrian volume at the specific crosswalk is (larger than): _____

☐ Left-turning vehicle volume at the specific approach is (larger than): _____

☐ There is a "soft" left turn at which drivers can turn at a higher-than-normal turn speed

☐ There is a left turn with a long turning path such that pedestrians might not be readily seen

☐ There are dual left-turn lanes (or left and left-thru lanes) on a one-way street at which the inside vehicle might block the driver's view in the adjacent turn lane

☐ Where the left-turn movement is the majority movement on approach and drivers assert themselves without fully recognizing the need to yield to pedestrians

☐ It is used as an interim measure until protected left-turn phasing can be installed

☐ At the specific approach with "protected + permissive" left turn phase

☐ At the specific approach with "permissive + protected" left turn phase
☐ Others (If selected, please specify in the following text box)

Text box for your answers, comments or explanations:

5. Based on your engineering judgment, what is the reasonable criterion of **minimum pedestrian volume thresholds on a crosswalk** when considering a LPI implementation for an approach at a signalized intersection?

☐ Typical Minimum Pedestrian Volume Thresholds [(1)]
☐ 2x (twice) the Minimum Pedestrian Volume Thresholds [(1)]
☐ 3x (three times) the Minimum Pedestrian Volume Thresholds [(1)]
☐ 4x (four times) the Minimum Pedestrian Volume Thresholds [(1)]
☐ 5x (five times) the Minimum Pedestrian Volume Thresholds [(1)]
☐ Others (If selected, please specify in the following text box)

[(1)]Minimum Pedestrian Volume Thresholds[*]:

- 20 pedestrians per hour in any one hour, or
- 18 pedestrians per hour in any two hours, or
- 15 pedestrians per hour in any three hours

*Count bicyclist as pedestrian if appropriate for the crossing; users with slower crossing speeds can be weighted twice (children, older adults, physically disabled)

6. In your city/county, which **control mode** is more often used for **a pedestrian phase** at signalized intersections?

☐ All pre-timed control (e.g., time-of-day signal timing plan)
☐ All actuated control (pedestrians need to push the button to activate it)
☐ Mostly pre-timed control for downtown area, actuated control for suburban area
☐ Mostly actuated control
☐ Half pre-timed control, half actuated control

☐ Varies (If selected, please explain in the following text box)

7. Has there been any **change of crash numbers** involving pedestrians and turning vehicles when the pedestrian has the right-of-way after the implementation of LPIs?

   ☐ Crash reduction
   ☐ Unchanged
   ☐ Crash increase
   ☐ Unknown

   Please indicate before-after crashes if available:

8. Has there been any **change of conflict numbers** between pedestrians and turning vehicles when the pedestrian has the right-of-way after the implementation of LPIs?

   ☐ Conflict reduction
   ☐ Unchanged
   ☐ Conflict increase
   ☐ Unknown

   Please indicate before-after conflicts if available:

9. Briefly describe your **successful experiences** with LPI implementation. Please select all that apply. Alternatively, answer it in your own words in the text box.

   ☐ Less conflicts between pedestrians and turning vehicles

☐ No obvious negative impacts on vehicular progression
☐ High driver compliance of yielding to pedestrians
☐ More effective when there is "NO TURN ON RED" sign
☐ More effective when there is blank-out "NO TURN ON RED" sign
☐ More effective when it is used with "protected + permissive" left turn phase
☐ No driver complaint that there is no pedestrian when LPI is on
☐ Other (If selected, please specify in the following text box)

Text box for your answers, comments or explanations:

10. Briefly describe the **lessons learned** from LPI implementation. Please select all that apply. Alternatively, answer it in your own words in the text box.

☐ Obvious negative impacts on vehicular progression
☐ Less effective in suburban areas when compared to downtown areas
☐ Drivers' complaint/feedback that there is no pedestrian when LPI is on
☐ An increase in false-starts (when it's easier for drivers to see the signal head of the perpendicular direction and drivers use the signal changes of pedestrians to anticipate the start of their green signal and made a false start)
☐ Low driver compliance to yield to a pedestrian's right-of-way (If selected, indicate the possible reasons in the text box)
☐ Not effective when there is no "NO TURN ON RED" sign
☐ Not effective because drivers will get used to the LPI and even if they see the red signal the drivers will begin to go
☐ Problems with operation in signal controller (If selected, explain in the text box)
☐ Other (If selected, please specify in the following text box)

Text box for your answers, comments or explanations:

11. What are the **perceptions and reactions from the general public** on LPI implementation? Alternatively, answer it in your own words in the text box.

☐ LPI is intuitive, no education needed
☐ Certain educational campaign needed
☐ Initially confused about LPI
☐ Well-accepted when prevalent throughout an area
☐ Well-accepted when pedestrians are familiar with LPI and understand its operations
☐ Well-accepted when drivers are familiar with LPI and understand its operations
☐ Positive pedestrians' feedback (e.g., feeling safer, less conflicts with turning vehicles)
☐ Negative drivers' feedback (e.g., confusion of signal timing, additional delay)
☐ Other (If selected, please specify in the following text box)

Text box for your answers, comments or explanations:

12. Can you provide **basic information** about the intersections with LPI implementation in your county/city?

	Intersection Name (e.g., 3rd St @ Ctr Ave)	Crosswalk(s) with LPI (e.g., South or North)	LPI Duration, with Left/ Right Turns (e.g., 3 sec, Right)	Period of LPI in Service (e.g., 01/01/2011 – present)
Site #1				
Site #2				
Site #3				
Site #4				
Site #5				
Site #6				
Site #7				
Site #8				
Site #9				
Site #10				

13. Can you provide the following documents for the intersections with LPI implementation? Please select all that apply.

☐ Signal timing sheets or signal retiming report (fixed-time or actuated, splits, phase etc.)
☐ AM and PM peak hour turning movement counts (TMCs) for each approach
☐ Pedestrian volume for each crosswalk
☐ Before-after study results of LPI assessment (e.g., changes in yielding rates or delays)
☐ Adjacent land use (e.g., near parking facility, school, campus, mall, residential etc.)
☐ Other

Please send the relevant documents to rui@cutr.usf.edu if available.

14. Please provide any additional information you feel may be useful to this project, such as suggestions for LPI guidelines, field observation of LPI operation, reasons for considering but not implementing LPI or discontinuing LPI operation.

Text box for your answers, comments or explanations:

15. The project research team may contact the following individual(s) for more information about LPI:

	Name	**Email**	**Phone**
Contact #1			
Contact #2			
Contact #3			

Thank you for taking the time to complete our survey. Click the "Back" button within the survey instrument to review or revise your responses. If you are satisfied with your responses click the "Submit" button. Once you click the "Submit" button, you will be unable to change your responses or regain access to the electronic survey.

APPENDIX B RESPONSE SUMMARY OF LEADING PEDESTRIAN INTERVAL IMPLEMENTATION SURVEY

Q.1 Basic information of respondents from agencies with LPI experience

Table B-1 Respondents and Agencies that Completed LPI Online Survey

#	State	City	Title of Respondent*	Organization	LPI in Service (Yes/No)
1	Alberta, Canada	Lethbridge	Traffic Signal Engineer	City of Lethbridge	Yes
2	CA	Manhattan Beach	City Traffic Engineer	City of Manhattan Beach	Yes
3	CO	Lakewood	Traffic Engineering Manager	City of Lakewood	Yes
4	DC	Washington, DC	Pedestrian Program Coordinator	DC Dept. of Transportation	Yes
5	FL	Clearwater	Signal System Supervisor	City of Clearwater	No (discussed)
6	FL	Clearwater	Signal System Supervisor	Pinellas County Government	Yes
7	FL	Gainesville	Assistant Public Works Director	City of Gainesville	No (considering)
8	FL	Gainesville	Traffic Operations Manager	City of Gainesville	No (considering)
9	FL	Lakeland	Manager of Traffic Operations	City of Lakeland	Yes
10	FL	Melbourne	Traffic Engineering Operations Manager	City of Melbourne	Yes
11	FL	Miami	Bicycle/Pedestrian Administrator	Miami-Dade MPO	Yes
12	FL	St. Petersburg	Transportation Manager	City of St. Petersburg	No (removed)
13	FL	Tampa	TMC Operations Manager	City of Tampa	Yes
14	FL	Tallahassee	Signal System Engineer	City of Tallahassee	Yes
15	GA	Atlanta	Traffic Engineer	Jacobs	Yes
16	GA	Statesboro	City Engineer	City of Statesboro	Yes
17	MI	Ann Arbor	Traffic Engineer	City of Ann Arbor	Yes
18	MI	Kalamazoo	Professor	Western Michigan University	Yes
19	NY	Albany	Traffic Signal Coordinator	NYSDOT	Yes
20	SC	Beaufort	Transportation Engineering Director	Beaufort County Traffic Engineering	Yes

**Note: number of respondents for each question varies*

Q.2 What are the reasons for consideration or implementation of LPI in your city? *(multiple choice)*

Table B-2 Reasons for Consideration of LPI

Answers	Count	%
Heavy pedestrian activity (near school zones, parking facilities, senior centers, theme parks etc.)	15	79%
Citizen feedback about vehicles non-yielding to pedestrians	14	74%
Crashes involving pedestrians and turning vehicles	10	53%
High percentage of left and/or right turns (e.g., T intersection, one-way road, four-leg intersection with low volume of traffic on the 4th leg)	8	42%
Issues due to features such as irregular intersection geometry, wide turning radius or obstructions	6	32%
High benefit-cost ratio of LPI to improve pedestrian safety (cost-effective)	4	21%
Marked school crossing	2	11%
Total number of respondents	**19**	

Q.3 Do you have certain criteria or internal guidelines used to determine the implementation of LPIs with right-turning vehicles at a specific crosswalk? *(multiple choice)*

Table B-3 Criteria to Determine LPI Implementation with Right Turns

Answers	Count	%
Right-turning vehicle volume at the specific approach is relatively high	5	31%
Average annual crashes between right-turn vehicles and pedestrians (during pedestrian signal indications) is relatively high	5	31%
Number of conflicts between right-turning vehicles and pedestrians at the specific crosswalk is relatively high	4	25%
Pedestrian volume at the specific crosswalk is heavy/relatively high	4	25%
Adjacent land use type (e.g., downtown, near school zone, campus, or parking garage)	4	25%
Issues due to features such as one way street, difficult sight distance, or unusual situation where pedestrian waiting area/crosswalk is partially obscured	3	19%
Total number of respondents	**16**	

Comments:

- ***Atlanta:*** We applied LPIs in Midtown Atlanta at all intersections that are 2-phase without any left-turn phasing. These minor intersections have moderate pedestrian volume and additional time to provide to the all-red phase. We plan to implement more LPIs after looking at the effectiveness of LPI at current locations.
- ***Manhattan Beach:*** The decision was based on general benefits to be gained, not specific thresholds.

Q.4 Do you have certain criteria or internal guidelines used to determine the implementation of LPIs with left-turning vehicles at a specific crosswalk? (multiple choice)

Table B-4 Criteria to Determine LPI Implementation with Left Turns

Answers	Count	%
Where the left-turn movement is the majority movement on approach and drivers assert themselves without fully recognizing the need to yield to pedestrians	7	44%
There is a Left turn with a long turning path such that pedestrians might not be readily seen	4	25%
Average annual crashes between left-turning vehicles and pedestrians(during pedestrian signal indications) is relatively high	4	25%
Pedestrian volume at the specific crosswalk is relatively high	4	25%
Left-turning vehicle volume at the specific approach is relatively high	4	25%
There is a "Soft" left turn at which drivers can turn at a higher-than-normal turn speed	3	19%
There are dual left-turn lanes (or left and left-thru lanes) on a one-way street at which the inside vehicle might block the driver's view in the adjacent turn lane	3	19%
Sight issues based on time of day/season or geometrics of the intersection (e.g., building shadow or street trees)	2	13%
At the specific approach with "permissive + protected" left turn phase	1	6%
Total number of respondents	**16**	

Comments:

- ***Atlanta:*** We are currently not using them at intersections with left turn phases.

Q.5 Based on your engineering judgment, what is a reasonable criterion for minimum pedestrian volume thresholds at a crosswalk when considering LPI implementation for an approach at a signalized intersection?

Table B-5 Reasonable Pedestrian Volume Thresholds for LPI Implementation

Answer	Count	%
Typical Minimum Pedestrian Volume Thresholds [(1)]	6	33%
2x (twice) the Minimum Pedestrian Volume Thresholds	2	11%
3x (three times) the Minimum Pedestrian Volume Thresholds	1	6%
5x (five times) the Minimum Pedestrian Volume Thresholds	1	6%
4x (four times) the Minimum Pedestrian Volume Thresholds	0	0%
Total number of respondents	**18**	

[(1)] Minimum Pedestrian Volume Thresholds*:

- 20 pedestrians per hour in any one hour, or
- 18 pedestrians per hour in any two hours, or
- 15 pedestrians per hour in any three hours

*Count bicyclist as pedestrian if appropriate for crossing; users with slower crossing speeds can be weighted twice (children, older adults, physically disabled).

Comments:

- *Ann Arbor*: We rely more heavily on the conflicts than the volumes. Sometimes intersections with fewer pedestrians have a greater need for LPI. Low volume LPI is typically installed where there is pedestrian detection.
- *Lakewood*: We find the problem often occurs at locations with fewer pedestrians—the drivers do not expect them.
- *Manhattan Beach:* 90% or more cycles in which pedestrian pushbuttons are activated.

Q.6 In your city/county, which control mode is more often used for a pedestrian phase at signalized intersections?

Table B-6 Control Mode for a Pedestrian Phase

Answer	Count	%
Mostly pre-timed control for downtown area, actuated control for suburban area	8	42%
All actuated control (pedestrians need to push the button to activate it)	4	21%
Mostly actuated control	3	16%
Total number of respondents	**19**	

Comments:

- *Lakewood*: Most signals are semi-actuated, with main street rest in walk. Previously, it was mostly actuated.
- *Ann Arbor*: We have LPI installed in areas that are fully actuated, SCOOT-controlled, and time-based coordinated.
- *Clearwater:* Mostly actuated. Where time-based coordination is used, the pedestrian phase is usually automatically recalled with the main street. However, where adaptive control has been implemented, the pedestrian recalls have typically been removed from all approaches in an attempt to facilitate greater adaptability.

Q.7 Has there been any change of crash numbers involving pedestrians and turning vehicles when the pedestrian has the right-of-way after the implementation of LPIs?

Of 18 total respondents, only 3 agencies (DC Department of Transportation, Miami-Dade MPO, and City of Lakeland) selected the option of "crash reduction":

- *DC:* We have not done an in-depth analysis, but spot-checking a sample of locations shows a reduction in turning vehicle-pedestrian in crosswalk with signal crashes.
- *Lakeland:* We are finalizing a study on the effectiveness of LPI for 26 intersections in the central business district (CBD) (pre-timed). Preliminary findings indicate that crashes are down 8–33%. Also, there is a significant shift from injury to PDO crashes. There appear to be minimal adverse effects on capacity.

The other 15 agencies selected the option of "unknown":

- *Lakewood:* Crashes are so rare that we need multiple years under the operation to be statistically valid.

Q.8 Has there been any change of conflict numbers between pedestrians and turning vehicles when the pedestrian has the right-of-way after the implementation of LPIs?

- Of the 18 total respondents, 8 selected the option of "conflict reduction" (44%).
- 1 agency (Miami-Dade MPO) selected "unchanged" (6%).
- 9 agencies selected "unknown" (50%).

Q.9 Briefly describe your successful experiences with LPI implementation. *(multiple choice)*

Table B-7 Successful Experiences with LPI Implementation

Answers	Count	%
Less conflicts between pedestrians and turning vehicles	14	74%
High driver compliance of yielding to pedestrians	8	42%
No obvious negative impacts on vehicular progression	7	37%
More effective when there is blank-out "No Turn on Red" sign	4	21%
More effective when there is "No Turn on Red" sign	4	21%
No driver's complaint that there is no pedestrian when LPI is on	2	11%
More effective when it is used with "protected + permissive" left turn phase	1	5%
Total number of respondents	**19**	

Q.10 Briefly describe the lessons learned from LPI implementation. *(multiple choice)*

Table B-8 Lessons Learned from LPI Implementation

Answers	Count	%
Obvious negative impacts on vehicular progression	4	36%
An increase in false-starts (when it's easier for drivers to see the signal head of the perpendicular direction and drivers use the signal changes of pedestrians to anticipate the start of their green signal and made a false start)	2	18%
Not as effective when there is no "No Turn on Red" sign	2	18%
Less effective in suburban areas when compared to downtown areas	1	9%
Drivers' feedback that there is no pedestrian when LPI is on	1	9%
Low driver compliance of yielding to a pedestrian's right-of-way	1	9%
Problems with operation in signal controller (some older controllers not working)	1	9%
Total number of respondents	**11**	

Comments:

- *Ann Arbor*: We have not experienced any locations with major negative impacts from LPI installation. We have one location where we still receive complaints about drivers not yielding, but they are greatly reduced.
- *Gainesville:* My selections are based upon the criteria the City is considering and the impacts from implementation of LPI.
- *Lethbridge:* Some older controllers cannot do it. LPI increased pedestrian safety with small loss of traffic efficiency, as fewer left-turn drivers can sneak through before pedestrians get to the conflicting point. Initial implementations were experimental for safety concerns where dual left lanes exist or left-turning vehicles competing with pedestrians. We did it due to new technical features with newer controllers. For the next widely implementation, we will inform upper management, City Council, and the public, as the City is promoting pedestrian-friendly streets.
- *Manhattan Beach:* No negative observable effects. No signal progression/ coordination at the downtown signals, so only minor vehicle delay.

Q.11 What are the perceptions and reactions from the general public on LPI implementation? *(multiple choice)*

Table B-9 Perceptions and Reactions from the General Public

Answers	Count	%
LPI is intuitive, no education needed	9	47%
Positive pedestrians' feedback (e.g., feeling safer, less conflicts with turning vehicles)	8	42%
Well-accepted when prevalent throughout an area	3	16%
Well-accepted when pedestrians are familiar with LPI and understand its operations	3	16%
Well-accepted when drivers are familiar with LPI and understand its operations	3	16%
Initially confused about LPI	2	11%
Certain educational campaign needed	1	5%
Negative drivers' feedback (e.g., confusion of signal timing, additional delay)	1	5%
Total number of respondents	**19**	

Comments:

- *Beaufort County:* Pedestrians would prefer a pedestrian scramble phase and do not feel the LPI is offering any significant benefit to them.
- *Ann Arbor:* We have not received many reactions to the installation of LPI. One location is adjacent to a school and the SRTS committee chair reports it is successful.
- *Pinellas County:* Most drivers and pedestrians would not notice a change has been made.

- *Lethbridge:* We are planning to implement it at additional 10 locations. We plan to let public know about it.

Q.12 Can you provide basic information about the intersections with LPI implementation in your county/city?

The minimum LPI duration is 3 seconds (e.g., in Atlanta and Washington, DC). For agencies that used longer LPI duration (e.g., 7-sec LPI in Melbourne), "obvious negative impacts on vehicular progression" was selected in Q.10. Details can be found below.

Basic Information about Intersections with LPI

1) **City of Statesboro (GA)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Chandler Rd @ Georgia Ave	Both crosswalks crossing Chandler	5 sec for both	2011–present
#2	Chandler Rd @ Harvey St	Both crosswalks crossing Chandler	5 sec for both	2011–present

2) **Beaufort County (SC)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Bay at Carteret	east, west	5 sec	since 2009
#2	Ribaut at Allison	east, west	6 sec	since 2009
#3	Buckwalter Pkwy @ McCracken Cir	north, south, east, west	5 sec	since 2011
#4	Bay at Charles	north, south, east, west	5 sec	since 2013
#5	Charles at Craven	north, south, east, west	5 sec	since 2013

3) **City of Lakewood (CO)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Alameda @Oak	west and east	4 sec, L/R	10/8/2015
#2	Wadsworth @ Utah PL	north and south	6 sec, L/R	
#3	Wadsworth @ Mansfield	west and east	5 sec, L/R	10/6/2015
#4	Colfax @ Nelson	west and east	5 sec, L/R	
#5	6th @Arbutus	west and east	7 sec, Left	9/15/2014

4) **City of Ann Arbor (MI)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Fourth	Huron	right	
#2	Barton	Pontiac Trail	left/right	2015

5) **Pinellas County (FL)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Gulf Blvd @ Dolphin Village	north and south	4 sec	
#2	113th St @ 74th Ave	south	6 sec	
#3	Oakhurst @ 86th	north	6 sec	

6) **City of Atlanta (GA)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Peachtree St @ 3rd St	All 4	3 sec, right	12/11/2015
#2	Peachtree St @ 4th St	All 4	3 sec, right	12/11/2015
#3	Peachtree St @ 5th St	All 4	3 sec, right	12/11/2015
#4	Peachtree St @ 6th St	All 4	3 sec, right	12/11/2015
#5	Peachtree St @ 7th St	All 4	3 sec, right	12/11/2015
#6	Peachtree St @ 8th St	All 4	3 sec, right	12/11/2015
#7	Peachtree St @ Peachtree Pl	All 4	3 sec, right	12/11/2015
#8	Peachtree St @ 11th St	All 4	3 sec, right	12/11/2015
#9	Peachtree St @ 12th St	All 4	3 sec, right	12/11/2015
#10	Peachtree St @ 16th St	All 4	3 sec, right	12/11/2015

7) **City of Lethbridge (Alberta, Canada)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Mayor Magrath @ 20 Ave S	south	6 sec, left	2014
#2	Scenic Dr at 5 Ave S	north, south	4 sec, left	2015
#3	13 St S at 2A Ave N	north, south	5 sec left	2016
#4	Mayor Magrath @ 3 Ave S	north	5 sec left	2016
#5	Scenic Dr @ 28 St S	west, left	6 sec left	2016

8) **City of Manhattan Beach (CA)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Manhattan Beach Blvd @ Highland Ave	All	5 sec	4/2015–present
#2	Manhattan Beach Blvd @ Manhattan Ave	All	5 sec	4/2015–present

9) **City of Tampa (FL)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Ashley @ Kennedy	West	5 sec, right	2002

10) **City of Melbourne (FL)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Babcock St & University Blvd	Babcock South	7 sec	7/14/2014

11) **City of Albany (NY)**

Site	Intersection Name	Crosswalk(s) with LPI	LPI Duration, with Left/ Right Turns	Period of LPI in Service
#1	Wolf Rd @ Colonie Center B North	South	10 sec	
#2	Wolf Rd @ Sand Creek	N S E W	7 sec	
#3	Rte 5 @ Vly @ Kohl	N	7 sec	
#4	Rte 5 @ Colonie Plaza	N	5 sec	
#5	Rte 5 @ Nicholas Dr	S	7 sec	
#6	Rte 5 @ Balltown Rd	Phase 8	7 sec	
#7	Rte 20 @ Fuller Rd	Phases 4 & 6	7 sec	
#8	Rte 31 @ Rte 370 @ Rte 48	Phases 2, 4, 6, 8	6 sec	
#9	Rte 298 @ Windham	Phase 4	7 sec	
#10	Rte 298 @ Teal	Phase 4	7 sec	

Q.13 Can you provide the following documents for intersections with LPI implementation? *(multiple choice)*

Table B-10 Documents for Intersections with LPI Implementation

Answers	Count	%
Signal timing sheets or signal retiming report(fixed-time or actuated, splits, phase etc.)	7	78%
AM and PM Peak Hour Turning Movement Counts (TMCs) for each approach	4	44%
Pedestrian volume for each crosswalk	3	33%
Adjacent land use (e.g., near parking facility, school, campus, mall, residential etc.)	3	33%
Before-after study results of LPI assessment (e.g., changes in yielding rates or delays)	0	0%
Total number of respondents	**9**	

Q.14 Please provide any additional information you feel may be useful to this project.

Comments:

- *Manhattan Beach:* Signal controller PROM module had to be upgraded to enable LPI.

- *Statesboro:* Based on observations, the LPI has been effective at the two intersections at which we have implemented them. Both locations have relatively heavy pedestrian counts (approximately 100–150 per hour from 9:00 AM to 4:00 PM). Before implementation of LPI, both locations had very poor yielding compliance by turning vehicles for pedestrians. The City was getting complaints from pedestrians prior to LPI being implemented. Observations indicate that this has drastically improved after implementing LPI, and pedestrian complaints have gone away. No complaints have been received from drivers.
- *Western Michigan University:* My experience was as a researcher. The LPI was effective but removed when a leading left protected phase was introduced. No research is available on how well it works if there is a leading protected left followed by a permissive left. Lagging left is not a factor. Most important effect is on crashes with higher energy of left turning vehicles.
- *St. Petersburg:* More education is needed for practitioners and the public before considering LPI.
- *Lakewood:* Previously, I worked at Bellevue, WA, where we implemented several LPIs. They have more accident history data after LPI implementation.
- *Gainesville:* The City does not have any specific intersections or data to provide as we have not implemented LPI. We are in the study phase. We are considering its use along the West University Avenue (SR 26) corridor, NW/SW 13th Street corridor (US 441), and the Archer Road corridor (SR 24) adjacent to the University of Florida campus.
- *Pinellas County:* Our major concern is when accommodating school crossing guards, the word gets out that we provided LPI at one intersection, then they all want it. Some intersections cannot afford the lost vehicle time out of the cycle, especially if not really needed. Therefore, a lot of time is needed to explain or justify not installing LPI.

APPENDIX C SUMMARY OF PHONE INTERVIEWS WITH ENGINEERS/MANAGERS FROM TRAFFIC AGENCIES

City of Tampa, FL

Brian Gentry, TMC Operations Manager for the City of Tampa, completed the LPI online survey. Julie Scanlon sent the CUTR team the signal timing sheets for the intersection of Ashley Dr @ Kennedy Blvd, the only location with LPI operation for nearly 15 years in Tampa. For this intersection, there is a 5–6 sec LPI with right-turning vehicles on the east crosswalk (north-south direction), installed in 2002. Mr. Gentry mentioned that the City has recently developed criteria for LPI implementation and plan to add other good candidate locations for LPI.

The CUTR team then held a phone interview with Vik Bhide, Chief Traffic Management Engineer for the City of Tampa, to follow up the online survey.

Reasons for consideration or implementation of LPI in Tampa include heavy pedestrian activity and crashes involving pedestrians and turning vehicles.

Two criteria recently were developed to determine the implementation of LPIs:

- Average annual crashes between turning vehicles and pedestrians at the specific crosswalk is high—not only number of crashes, but also type of crashes. More important to analyze particular type of crash than total number of crashes. More than 2/3 of vehicle-pedestrian crashes are pedestrian's fault.
- Pedestrian volume at the specific crosswalk is heavy; 1 crash per year with the combination of 100 pedestrians per day could be a criterion for LPI implementation.

Other criteria being considered or recommended:

- Event patterns (e.g., events at Amalie Arena, Starz Center lead to high pedestrian volumes).
- Heavy turning vehicle volume.
- State of infrastructure (e.g., visibility issues).
- Land-use type (for candidate locations): university area, special event locations, downtown area, shopping centers, and school zones.
- Two-stage crosswalks.

Reasonable pedestrian volume thresholds when considering LPI implementation:

- At any given intersection, if pedestrian volume equal or higher than 100 pedestrians per day, LPI needed. Most downtown locations have more than that; many pedestrians cross intersections during lunch time, etc.
- LPI for many intersections needed only during particular period of time.
- In Tampa, all downtown intersections are pre-timed control for a pedestrian phase and mostly actuated control for pedestrian phase in suburban areas.

Successful experiences with LPI implementation:

- Fewer conflicts between pedestrians and turning vehicles.
- From past experience, many engineers have concerns about vehicle progression, but Tampa has not observed any issues.
- High driver compliance of yielding to pedestrians.

Perceptions and reactions from the general public:

- Education and outreach needed.

Concerns about LPI implementation:

- People with disabilities – LPI might affect their usual behavior.

Locations recommended for field observation (high pedestrian and vehicle volumes):

- Channelside Dr – S Meridian Ave
- N Ashley Dr – W Kennedy Blvd
- S Franklin St – Channelside Dr
- N Ashley Dr – E Polk St (T-intersection)
- N Ashley Dr – E Zack St (T-intersection)

City of Clearwater, FL

The City of Clearwater considered LPI but did not implement LPI. Cory Martens, Signal System Supervisor for the City of Clearwater, completed LPI online survey. To get more insight, the CUTR team called him to follow up and ask questions regarding to the survey.

There is no LPI installation in Clearwater; it has been discussed for some locations but never pursued. Instead, the City implemented exclusive pedestrian phases for two locations that had been discussed, mainly because that is what users were requesting.

Reasons for the consideration of LPI in Clearwater include heavy pedestrian activity and citizen complaints/feedback about vehicles not yielding to pedestrians.

No **criteria** are used to determine implementation of LPIs in Clearwater. However, evaluation is on a case-by-case basis and must also take into consideration of political implications.

Two cases for implementing **exclusive pedestrian phases**:

- *Pinellas Trail* crossing with a fair amount of bicycle traffic— City was getting complaints from bicyclists who were having to wait and did not have enough room to queue on one of the corners. From a group prospective, they want to ride in a big groups, but sometimes do not have enough room at another corner to cross the intersection in one step, preferably diagonally. It was decided to provide an exclusive wave.
- *A library* at SW corner and employee parking at the SE corner—library patrons were complaining that drivers were not yielding to them and they almost were hit on a

crosswalk. They did not want cars turning across them. An exclusive pedestrian phase was provided as requested.

Instead of using **pedestrian volume thresholds** on a crosswalk when considering LPI implementation, intersection operation needs to be evaluated holistically.

Clearwater uses mostly **actuated control** for pedestrian signals. Where time-based coordination used, pedestrian phase usually automatically recalled.

Experiences with exclusive pedestrian phase:

- For the two cases with an exclusive pedestrian phase, motorist compliance has been high, perhaps due to few or no other choices.
- Pedestrian compliance varies; many still press the button and then proceed to cross whenever comfortable doing so, often leaving exclusive pedestrian phase to come up with nobody there to use it. For the Pinellas Trail crossing, bicyclists occasionally press the button and wait to make the marked diagonal crossing; however, many press the button and then proceed to cross when they see fit and, in some cases, will not slow to actuate the pedestrian phase, choosing instead to cross in an available gap.
- Exclusive pedestrian phase implementations seem to work reasonably well when all parties use them as intended. However, when they are used incorrectly by pedestrians or bicyclists, they typically result in considerable unnecessary delay to motorists. When and where right turns on red are possible, they tend to function the same as any other signalized intersection as far as pedestrian and motorist interaction is concerned.
- Implementation of an exclusive pedestrian phase was generally well-received by the user group that requested it as pedestrians or bicyclists. Interestingly, however, in one case, when conditions changed and the requesting group was the motorists, they were less accepting. Motorists generally seem to accept the change with few complaints. Occasionally, a motorist will observe the signal not cycling, not perceive any cause, and report it as a malfunctioning signal.

Concerns of LPI implementation:

- Developing LPI implementation guidelines is a challenge. In Mr. Martens' opinion, whereas LPI sounds good in theory, given the complexity of information and activity at most intersections, the predictable, reliable, and consistent application, interpretation, and use seem unlikely to be practical.
- Concerns about driver attention—drivers making turns are less concerned about the signal indication; rather, if they see a gap, they make a right turn.
- Concerns about people not paying attention to "NO TURN ON RED" sign or blank-out "NO TURN ON RED" sign; there are many violations and people ignore different technologies (e.g., part-time signs, electronic signs etc.).
- Concern that perhaps too much has been done to protect people, who are forgetting that they need to look out for themselves.

City of Lakeland, FL

Angelo Rao, Manager of Traffic Operations for the City of Lakeland, completed the LPI online survey and provided 10 intersections with LPIs, which were installed on 03/01/2015. The City is completing a draft report on 26 intersections in downtown Lakeland at which they have installed an LPI phase of 5 secs; the typical cycle length for those intersections is 130 secs. Preliminary data from 2011 to 2014 indicate that, overall, crashes are down by 8–33%, depending on location and traffic volumes. There is also a significant shift from injury to property-damage-only crashes. There appear to be virtually no adverse effects on the level of service (minimal adverse effects on capacity).

Reasons for consideration or implementation of LPI in Lakeland include:

- Heavy pedestrian activity (near school zones, older adult zones, etc.).
- Crashes involving pedestrians and turning vehicles.
- High percentage of turning vehicles (e.g., T intersection, one-way road, etc.).
- High benefit-cost ratio of LPI to improve pedestrian safety (cost-effective).

Although Lakeland does not have specific criteria or internal guidelines for the establishment of LPI phases for turning movements, they do apply such features at intersections in consideration of:

- Continuous pedestrian use, such as downtown locations.
- School student use.
- Commentary from residents, motorists, and pedestrians.
- Intersection design, such as separated right-turn-only lanes and number of lanes to cross (observations indicate the wider the road, the less effective the LPI may be for the particular intersection).
- Right-turning and left-turning volumes (permissive turns only) could be a factor, particularly where there is a propensity for pedestrian use – they do not have a specific guideline number established.
- Establishment of pedestrian zone corridors – encouraging the channelization of pedestrian traffic to signal crossing locations:
    - Instead of looking at a single intersection, it will benefit pedestrians by linking several intersections as a system/corridor.
    - One example being considered is Memorial Blvd, which is a challenging road (similar to Fletcher Ave in Tampa).
    - Florida Ave currently has 6 locations with LPI, which could be an example of a continuous pedestrian zone. If pedestrians become more aware about LPI at all 6 locations, they may use the crosswalk rather than cross the road somewhere else outside the crosswalk.

Typical minimum **pedestrian volume thresholds** would generally apply when considering LPI implementation. Judgment is reserved regarding applying LPI for specific users that frequent a particular location, regardless of pedestrian volume. For example, at one intersection at which 1–2 persons with disabilities cross every day, they think they should respect that and consider LPI based on needs. Each particular intersection should be looked at case by case.

In Lakeland, all **actuated control** for a pedestrian signal is the most common; however, the majority of locations in the CBD are pre-timed control. In their study on the effectiveness of LPI at the 26 intersections in the CBD, there are two locations with actuated control for pedestrian signals.

Successful experiences with LPI implementation:

- Fewer conflicts between pedestrians and turning vehicles.
- No obvious negative impacts on vehicular progression.
- High driver compliance of yielding to pedestrians.
- More effective when there is a blank-out "NO TURN ON RED" sign.
    - Planning a dual use sign: "NO TURN ON RED" during LPI phase and "YIELD TO PEDESTRIANS" during remainder of pedestrian clearance time.

Lessons learned from LPI implementation:

- Increase in false-starts – typically, drivers in downtown areas where intersections generally are pre-timed do not expect pedestrian features such as LPI and proceed earlier intuitively.
- Less reduction in crashes when activation is required by pedestrians, e.g., when LPI is not in effect as in a pre-timed intersection.

Perceptions and reactions from the general public:

- LPI is intuitive, no education needed.
- Well-accepted when prevalent throughout an area.
- Well-accepted when pedestrians are familiar with LPI and understand its operations.
- Well-accepted when drivers are familiar with LPI and understand its operations.
- Anecdotal commentary from citizens and other partners such as the Police Department have indicated a "feeling" of safer crossing opportunities.

LPI evaluation report will be finalized in mid-May 2016. Upon completion, CUTR will be provided with the results, including timing sheets and other data that are readily available.

City of Albany, NY

John Litteer, Traffic Signal Coordinator for the New York State Department of Transportation (NYSDOT), completed the LPI online survey and provided 10 locations with LPI operation in Albany. For those 10 locations, LPI duration varies from 5–10 sec, mostly 6–7 sec to match the pedestrian "WALK" time.

Reasons for consideration or implementation of LPI in Albany include:

- Heavy pedestrian activity.
- Citizen complaints about vehicles non-yielding to pedestrians (drivers in New York have a reputation for being very aggressive).
- Crashes involving pedestrians and turning vehicles.

- Geometric characteristics and visibility issues (e.g., sight distance restriction or the proximity of the crosswalk).
- Marked school crossing.

Criteria or internal guidelines used to determine the implementation of LPIs with right-turning vehicles at a specific crosswalk:

- No specific criteria, deployment based on engineering judgement:
    - significant number of vehicle-pedestrian conflicts (first factor when considering LPI implementation)
    - areas near school or facilities for older adults
    - heavy right-turning vehicle volume and adjacent pedestrian movement at right-turn direction
    - LPI implemented only for crosswalks with right-turning vehicles (more likely to have conflict with pedestrians because they might not see them; left-turning vehicles have a much better view on a crosswalk and typically see pedestrians more clearly)

In Albany, all are **actuated control** for pedestrian signals (pedestrians need to push the button to activate it). Many LPIs are implemented on uncoordinated intersections.

In Albany, the **maximum cycle length** is 210 secs and minimum is 60 secs. Generally speaking, 120 secs is an average cycle length. For successful LPI implementation, they consider cycle length and other factors: How many times will the pedestrian phase be actuated during an hour? Can it still accommodate reasonable vehicle traffic? Should it be a 15 sec split and a 6 sec LPI?

Successful experiences with LPI implementation:

- Fewer conflicts between pedestrians and turning vehicles.
- More effective when there is "NO TURN ON RED" sign:
    - comes up after pedestrian push the button (dynamic sign)
    - reduces number of conflicts and increases effectiveness of LPI
    - prefer sign everywhere with LPI, but dependent on existing facilities

Lessons learned from LPI implementation:

- Increased vehicular delay and driver frustration, particularly when pedestrians push the button but disappear before the "Walk" signal or pedestrians sometimes push both buttons and make drivers wait for no reason.
- Pedestrian compliance rate dependent on traffic conditions:
    - Most pedestrians do not want to walk through heavy traffic, so compliance rates are very high in urban areas.
    - In rural areas or villages, pedestrian compliance rate is low, with ~60% waiting after pushing the button.
    - In college areas, compliance rate is worst—pedestrians tend to be less patient, so they push the button but do not wait.
    - Not as effective when there is "NO TURN ON RED" sign.

Perceptions and reactions from the general public:

- LPI is intuitive, no education needed.
- Well-accepted when pedestrians are familiar with LPI and understand its operations.

Washington, DC

George Branyan, Pedestrian Program Coordinator for the District of Columbia Department of Transpiration (DDOT), completed the LPI online survey. DC currently has 155 intersections with LPI signal timing, and 20 more will be added in 2016. They use 3-sec LPI timing, unless it is a special situation. LPIs are mostly implemented with pre-timed control all the time in the DC downtown area. To get more insight, the CUTR team called Mr. Branyan to follow up and ask questions regarding to the survey.

Some LPIs are **initiated** by complaints, others by signal optimization studies.

Reasons for the consideration or implementation of LPI in DC include:

- Citizen complaints/feedback about vehicles non-yielding to pedestrians
  - If they get complains, they start looking at volumes, etc., based on the complaints, but also to meet other criteria for implementation
- Crashes involving pedestrians and turning vehicles:
  - initial 20 locations were considered based on tuning volume and vehicle-pedestrian crashes
- High percentage of left and/or right turns (e.g., T intersection).
- Issues due to features such as irregular intersection geometry, wide turning radius, obstructions such as buildings or trees, or blinding sun angle.

Criteria or internal guidelines used to determine the implementation of LPIs with right/left turning vehicles:

- Number of pedestrian crashes occurring on crosswalks during displays of pedestrian signal indications is more than half of the total pedestrian crashes:
  - At intersection level
  - Usually using 3 years of crash data
- Right- or left-turning vehicle volume is larger than 50 in a peak hour:
  - At approach level
  - Analyzing count data in 2013–2014 from DDOT signal optimization project
  - Mostly for right turns
  - LPI may not help that much for left turns because they often have to wait for the initial conflicting traffic. But LPI will work for left turns at the T-intersection with high volume of left turning vehicle–pedestrian conflicts.

In DC, they do not use minimum **pedestrian thresholds**, but for heavy or moderate pedestrian volume, they will consider LPI.

- DC is a dense jurisdiction. Many intersections had low pedestrian volume, but now it is much higher, and so LPI is considered.
- LPIs are concentrated in the downtown area and some of the other corridors such as commercial corridors.

Crash reduction analysis has not been conducted in-depth, but spot-checking a sample of locations shows a reduction in turning vehicle-pedestrian in crosswalk with signal crashes.

Successful experiences with LPI implementation:

- Fewer conflicts between pedestrians and turning vehicles.
- No obvious negative impacts on vehicular progression.
- More effective when there is "NO TURN ON RED" sign.
- No driver complaints that there is no pedestrian when LPI is on.
- Perception is that LPIs are very popular; local newspaper rated LPI as "The Best DC New Transportation Policy" in 2011 when they started with the first 40 or 50 locations for LPI implementation.

Perceptions and reactions from the general public:

- LPI is intuitive, no education needed.
- Well-accepted when prevalent throughout an area.
- Positive pedestrians' feedback (e.g., feeling safer, fewer conflicts with turning vehicles).

APPENDIX D SUMMARY OF INPUTS FROM FDOT DISTRICT TRAFFIC OPERATIONS REPRESENTATIVES

Feedback from FDOT Central Office:

- In terms of criteria for LPI implementation, in addition to crashes and vehicle volumes, we also need to consider pedestrian volume.
- When we were trying to calculate the LPI duration, we have used walking speed. How far do we want pedestrian to get—do we want them to cross one lane? Are we using LPI from the button to the edge or to the half of the way? These types of questions will be important when we come up with the guidance for the duration. (CUTR noted that it is very important part of the design and indicated it will consider the proper duration of the LPI.)
- After the pilot project, we must be able to evaluate quantitatively the actual and potential negative impacts from LPI on vehicle progression. There are serious concerns, but we have not seen the numbers, so it will be a very helpful outcome from Stage 3 of the project.
- We are trying to balance with pros and cons to make sure that people in cars will be able to go quickly and safely, but we also want pedestrians to do the same.
- In the downtown area, drivers know that pedestrians might be in a crosswalk; however, in suburban areas, drivers typically do not expect pedestrians. A challenge is to create guidelines for urban and suburban areas with different criteria. It would be good to have two sets with different criteria: one for downtown areas and one for suburban areas. I would also like to see the criteria for some small city areas.
- LPI and "NO TURN ON RED" signs should be considered on an approach-by-approach basis.

Feedback from FDOT District 1:

- We consider using public information for implementing LPI. Currently, we do not have particular criteria, except regarding public complaints.
- The intersection is already large. LPI may impact signal operation. The main thing is to make sure that LPI implementation will not cause vehicle progression problems.
- Situations in which pedestrians push the button and do not wait are always a concern. Bicyclists also push the button, then see the gap and do not wait for the signal.
- We have received good feedback on blank-out signs.

Feedback from FDOT District 2:

- In D2, we started installing LPIs in the top 10 pedestrian crash locations, based on crash history.
- We have not implemented LPI much in D2 yet, except that we have had issues with vehicle-pedestrian conflicts.
- It will not be necessarily a crash problem—it could be just a conflict issue. It might not be necessarily a problem with the high pedestrian volume.
- We also take into account pedestrian complaints. It is normally cases when permissive left-turning vehicles are looking for the gap, but not necessarily are looking or seeing pedestrians. We installed LPI at these locations.
- LPIs were rejected to be put in some high-crash locations in Gainesville because it would affect vehicle progression. If the research team has criteria that are stricter, maybe they would do it.
- We normally put LPIs at locations other than the intersections of two State roads. We should avoid taking the time from State Highway System roads.
- D2 is using 5–7 secs for LPI.

- D2 does use blank out signs.
- We get complaints about pedestrian-actuated lights and time-of-day-activated "NO TURN ON RED" signs, especially around the University of Florida area.
- It's a good idea to have two sets with different criteria, one for downtown areas and one for suburban areas. The situation is different in suburban areas, where we have sometimes very small pedestrian volume.
- When we looked at LPIs, we started thinking from locations with high crashes and high pedestrian volume. When the pedestrian volume is low, it will be just several times per day when pedestrians push the button and activate LPI. So it does not negatively affect vehicle progression. Why not put LPI at the intersections with low pedestrian volume? This is kind of things with which we were struggling.

Feedback from FDOT District 3:

- For criteria, do you mean "and" (meeting all the criteria), or do you mean "or" (one criterion)? (CUTR noted that the tendency is toward "and" but is still open to discussion.)
- We have a lot of locations with parking on one side and offices on the other side in smaller town areas.
- We would like to have one set for urban area and one for smaller town area.

Feedback from FDOT District 4:

- D4 has several locations with exclusive pedestrian phase near the beach area:
  - D4 uses 300 pedestrian volumes per hour at the intersection as the pedestrian volume threshold when considering exclusive pedestrian phase.
  - Since exclusive pedestrian phase is the most protective mode for pedestrians, when considering LPI implementation, the threshold for pedestrian volumes would be lower than 300 per hour.
  - D4 also evaluated the operation of exclusive pedestrian phase and monitored city websites to check if they get complains from citizens.
- Issue/concern about pedestrian behavior because some pedestrians do not follow the rules.
- Concern about the right-turn restrictions:
  - Drivers are looking to the left (the conflicting traffic) to find a gap instead of looking at pedestrians.
  - Good idea to have the blank-out "NO TURN ON RED" sign
  - As a pedestrian, I try to make eye contacts with drivers. If I cannot see drivers, I may just wait.
- Agree to consider the criteria of crashes, turning volumes, and pedestrian volumes together.
- Concern about situation in which pedestrians do not take the opportunity through LPI to start before drivers.
  - Good idea to educate people about LPI, perhaps put small messages or signs near intersections to provide instructions about LPI for pedestrians.
- Popular complaint from pedestrians complaining about drivers not yielding to pedestrians, especially for permissive left turns.

Feedback from FDOT District 5:

- Be careful about pedestrian volume, because when it is really high, drivers are more respectful of pedestrians—not always, but in some cases it works. Drivers are more respectful when they see a group of people at the corner. So we might not need a high pedestrian volume as a requirement for the implementation of LPI.
- Crash history makes sense.
- Turning volume makes sense.
- Always necessary to look at observed conflicts, but not strictly as a numerical product, because it might be a result from different combinations of conditions such as radius, pattern of intersection, etc. For example, we have one location near a school area, and school buses cannot turn on red, which leads to queueing. Pedestrians are trying to cross the street and school buses are trying to turn on green, so there is an issue. LPI works very well in that location, but it works 24 hours when actually it is needed only a couple of hours per day.
- Intersection saturation needs to be considered but it is not necessarily a failure point for LPI.
- Our typical problem is at the intersections near school zones; need to make sure the research team looks specifically on that particular problem.
- D2 uses more than 4 secs, and D5 uses 5–7 seconds—we are less concerned with vehicle delay compared to pedestrian safety.
- Regarding "NO TURN ON RED" blank-out sign, not a good idea to have the sign only for a few seconds, as it would be unfair to drivers. It should be on for the entire phase and then go off when the signal turns.

Feedback from FDOT District 6:

- T-intersections show high benefit with LPI (many T-intersections at locations along beach in D6).
- From our experience, at T-intersections, for the most cases, our recommendation is that the green time allocated for the LPI should be taken from the main time; splits on the main movements (coordinated) can absorb LPI durations.
- Basically, the pedestrian movement coincides with the permissive left turn, which has to be a gap at the same time, when the pedestrians are trying to cross.
- The main concern is that with left-turn movements, we should be very careful with the recommendations. Permissive left-turn vehicles are more likely to find a gap at the end of the green interval than at the beginning.
- With the permissive left turn, LPI should be implemented at the beginning of the green interval. With LPI, a left-turning vehicle does not have permission to make a left turn at the beginning when the pedestrians start walking.
- Central Office: the idea about features of LPI implementation on T-intersections is a very good point.

Feedback from FDOT District 7:

- LPI criteria from NATCO: average 1 pedestrian crash per year and 100 turning vehicle movements.

- Need to find a balance between vehicles and pedestrians/bicyclists.
- Concern about negative impact on capacity.
- Concern about LPI duration—maybe 2–3 secs duration would not cause obvious vehicular delay, but 2 secs may not give any benefit to pedestrians; support 3–4 sec LPI.
- Most complaints from drivers are in suburban areas because there are not many pedestrians there.
- Need to consider how to accommodate needs for 1–2 pedestrians that cross streets at peak hours every day (e.g., to get coffee every morning).
- Good idea to have dual blank-out signs ("NO TURN ON RED," "YIELD TO PEDESTRIANS").

Feedback from Turnpike District:

- At certain times, LPI is OK.
- Consideration on school zones only.
- We used a blank-out sign near a school and experienced many calls to the Public Information Office because people could not understand why the sign is actuated at a particular time. Maybe it varies case-by-case. We may need to educate people about it, especially people driving many years in the same area where new signs can be very unfamiliar. Will take a while for people to use it.

Other Feedback from Emails

District 1 – Renjan Joseph (AMS Engineer)

Currently, we are implementing LPI at three intersections in Lee County on a test basis with before and after studies. Below are a few of my concerns and suggestions with LPI implementation:

1) *The false sense of security pedestrians may develop at intersections/approaches with no LPI, when they are used with LPI at a nearby intersection/approach with LPI.*
   Using a different background color (other than white) for the pushbutton sign plate with or without a short message such as "Ped Head Start" for crosswalks with LPI feature (analogous to using different-colored tickets for different classes of seats in shows). Eventually, pedestrians will figure out the difference in signal operation on seeing the color difference and hopefully be more alert at crosswalks without LPI.
2) *Impact to the efficiency of signal operation at oversaturated intersections when the existing (required) green split is greater than the pedestrian intervals.*
   Try not to use LPI feature at oversaturated intersections where the vehicular green split demand is more than the pedestrian intervals (Walk + FDW).
3) *Conflict with right turns on red may be more severe as drivers may be looking more to the left, watching for conflicting vehicles while turning right.*
   Using electronic blank out signs to restrict right turns during "Walk" interval along with LPI implementation.

District 1 – Mark Every (FMS/AMS Specialist)

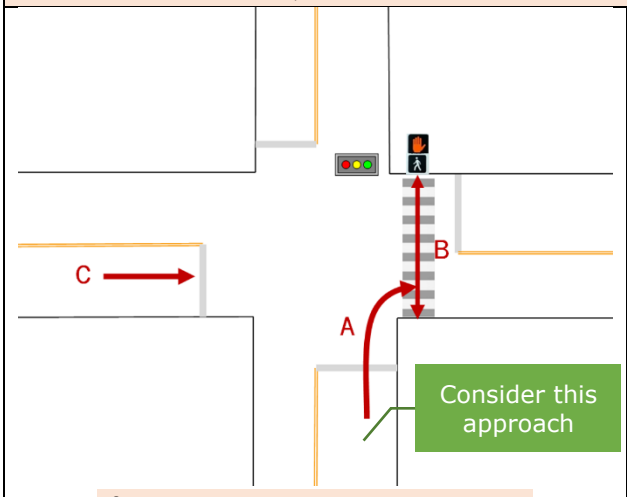
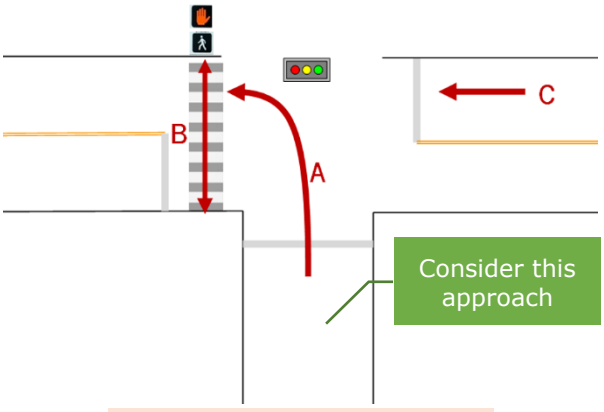
On April 8, 2016, the City of Bradenton finished the installation of a blank-out sign for "NO TURN ON RED"/"YIELD TO PEDESTRIANS" at Manatee Ave and 10th St, as shown in Figure D-1. The LPI and sign are working fine; first of its kind in D1 with a dual display blank-out sign.

Figure D-1 LPI with dual blank-out sign in Bradenton.

APPENDIX E PRELIMINARY LPI IMPLEMENTATION GUIDELINES

Preliminary LPI Implementation Guidelines

Information needed: *a)* intersection location and geometry information, *b)* turning movement counts including pedestrian volume, and *c)* others (optional). Explanations for each item are included at the end of the guidelines table.

Step I. Suitability Assessment at Intersection Level *(If signalized intersection meets at least one of criteria 01–05, go to Step II; otherwise, discontinue and do not consider LPI at this intersection.)*	
01 ☐	**Average crash frequency** between turning vehicles on green and pedestrians legally crossing street on crosswalk with pedestrian "Walk" signal indication >=1 per year (in last 3 years).
02 ☐	**Reported visibility issue** blocking drivers' view of pedestrians due to obstructions or poor sight distance.
03 ☐	**Citizen complaints** about turning vehicles not yielding to pedestrians.
04 ☐	**Land use type** that attracts pedestrians (e.g., downtown core, marked school crossings) near intersection, but avoiding ineligible wide busy intersections.
05 ☐	**Intersection type** is T-intersection or intersection with one-way road (*see figure in Step II*).
Step II. Suitability Assessment at Approach Level *(If approach meets one of criteria 06–10, LPI criteria are met for approach, go to Steps III and IV for recommended LPI duration and supplemental design for implementation; otherwise, discontinue and LPI is not recommended for this approach.)*	
 If 05 ***is not*** selected, use approach right-turn volume (movement A) for examining criteria 06–10	 If 05 ***is*** selected, use approach left-turn volume (movement A) for examining criteria 06–10

06 ☐	***In 1 hour***, approach turning vehicle volume (movement A) >=100/hour, pedestrian volume at crosswalk (movement B) >=80/hour*, and through traffic volume of cross street (movement C) >=400/hour/lane (consider LPI for that one hour).
07 ☐	***In 4 consecutive hours***, approach turning vehicle volume (movement A) >=120/hour, pedestrian volume at crosswalk (movement B) >=70/hour*, and through traffic volume of cross street (movement C) >=400/hour/lane (consider LPI for those four hours).
08 ☐	***In 8 consecutive hours***, approach turning vehicle volume (movement A) >=125/hour, pedestrian volume at crosswalk (movement B) >=60/hour*, and through traffic volume of cross street (movement C) >=400/hour/lane (consider LPI for those eight hours).
09 ☐	***For marked school crossings***, approach turning vehicle volumes (movement A) >=50/hour (consider LPI for AM peak period -1 hour before and 30 mins after school start time, and PM peak period – 30 mins before and 1 hour after school end time).
10 ☐	Percentage of compromised pedestrians at onset of "Walk" signal at specific crosswalk >= 10% (usually for special needs; expensive to collect).
Step III. LPI Duration Recommendations	
11a	Interval should be minimum of 3 seconds in duration.
11b	Timing should allow pedestrians to clear half width of one lane in direction of moving traffic to increase visibility of pedestrians to turning traffic.
Step IV. Supplemental Design Recommendations for LPI Implementation	
12	Right-turn-on-red prohibitions – ""NO TURN ON RED"" sign or blank-out "NO TURN ON RED" sign.
13	Accessible pedestrian signals (APS).
14	Education about LPI.
Note: Count bicyclists as pedestrians if appropriate for crossing; users with slower crossing speeds can be weighted twice (children, older adults, persons with physical disabilities).	

Explanations and Supporting Information by Item Number:

01 When examining the crash history, the ***eligible crash type*** (e.g., when pedestrians complying with the signal in crosswalk) needs to be considered. It is suggested to review crash data by following these steps:

- Screening crashes at signalized intersections that involved pedestrians
- Reading individual reports to determine what happened
- Looking for vehicles turning on green/yellow and striking a pedestrian crossing with signal in crosswalk

02 The ***visibility issue*** could be due to obstructions (e.g., buildings, base of a bridge or trees), blinding sun angle, irregular intersection geometry, etc. It is suggested to consider removing obstructions or using more restrictive modes before the consideration of LPI.

03 ***Citizen complaints*** can be used to start looking at LPI, and the intersection approach should meet other criteria (e.g., pedestrian and vehicle volume) for LPI consideration.

04 The following examples should be considered for the eligible land use type using engineering judgment:

- Urban: Central Business District (CBD)
- Schools: marked school crossings, near campus (within 0.5 miles)
- Residential area: senior centers (or with high older-adult demand)
- Commercial area: parking on one side, shops on another
- Small towns or employment center: parking on one side, offices on another
- Tourist attractions: beaches, theme parks
- Special events/occasions or seasonal patterns

The following examples should be considered ***ineligible wide busy intersection*** using engineering judgment:

- Intersections of two State roads
- At least one road with two-way 6+ through lanes
- Longer cycle length (e.g., longer than 180 seconds)
- Optional: LPI would introduce >=10% increase of delay or >= 0.9 v/c ratio according to quantitative analysis by Synchro modeling

05 If the more protective modes (e.g., exclusive pedestrian or protected left-turn phase) are not available or preferred, examine the criteria on the approach for the ***left turns*** (as shown in Figure E-1) only at T-intersections and intersections with at least a one-way road. Engineering judgment should be used if a 4-leg intersection with a low volume of traffic on the opposing leg can be treated as the T-intersection.

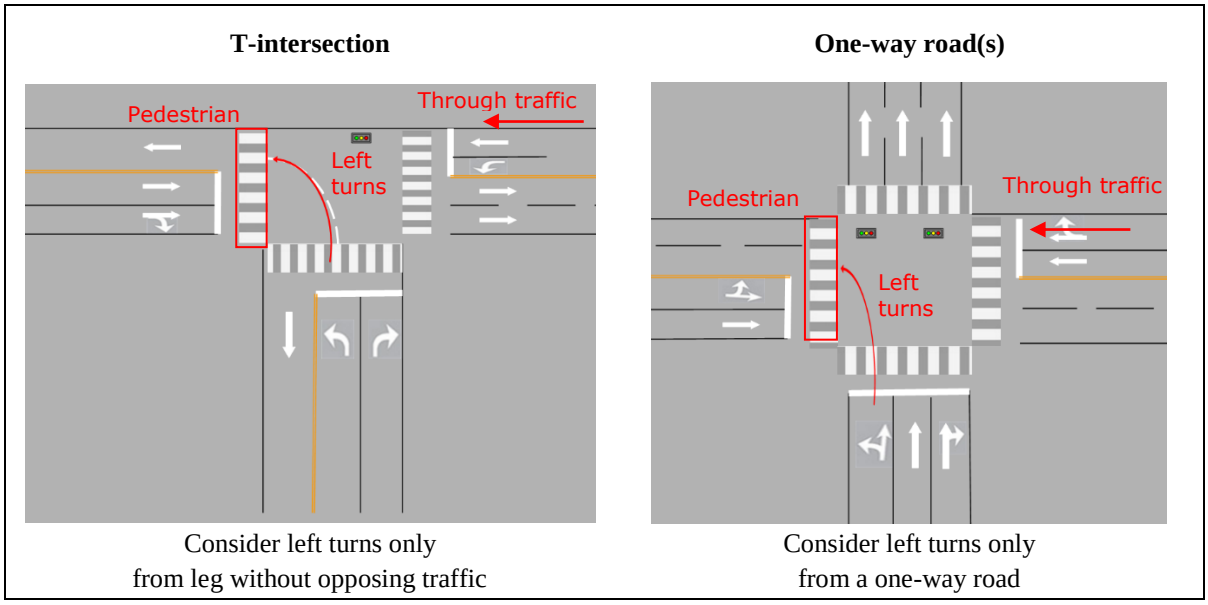


Figure E-2 Consideration of left turns on approach.

06 If both pedestrian and turning movement volumes meet the thresholds ***for 1 hour***, LPI can be considered for that hour with a time-of-day signal timing plan.

07 If both pedestrian and turning movement volumes meet the thresholds ***for 4 consecutive hours***, LPI can be considered for those 4 consecutive hours.

08 If both pedestrian and turning movement volumes meet the thresholds ***for 8 consecutive hours***, LPI can be considered for those 8 consecutive hours.

09 For ***marked school crossings***, consider LPI during the AM peak period (1 hour before and 30 minutes after school start time) and PM peak period (30 minutes before and 1 hour after school end time) to meet the demand for children crossing.

10 ***Compromised pedestrian*** means pedestrians are delayed, have altered their travel path, or have altered their travel speed due to concurrent turning vehicles. (*Note*: Collecting conflict data about compromised pedestrians is a resource-intensive exercise.)

11 A minimum of 3-second LPI duration is required. The following formula can be used to design LPI duration: LPI= (ML/2+PL)/W, where:

LPI = number of seconds (rounded value) between onset of "Walk" signal for pedestrians and green indication for vehicles
ML= distance on crosswalk to clear width of one moving lane, in ft
PL = width of parking lane, if any, in ft
W = walking speed (3.5 ft/s for pedestrian clearance calculation suggested by MUTCD, or 3.0 ft/s for aging population suggested by FHWA)

12 It is suggested to consider using an electronic blank-out "NO TURN ON RED" sign to restrict concurrent right turns during "Walk" intervals along with LPI implementation. A good example is the LPI operation with a dual blank-out sign in Bradenton.

13 The use of an Accessible Pedestrian Signal (APS) (MUTCD Sections 4E.09 through 4E.13) should be considered if an LPI is used, because vision-impaired pedestrians use the sound of moving traffic to start crossing.

14 It is suggested to consider education about LPI operation – for example, using a different background color (other than white) for the pushbutton sign plate with a short message such as "Ped Head Start" for crosswalks with the LPI feature.

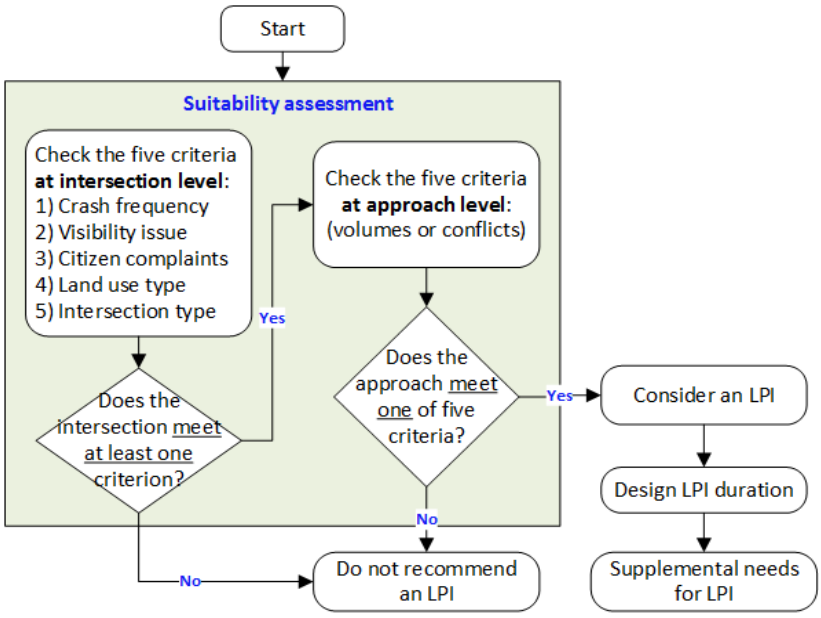


Figure E-3 Flow chart for LPI suitability assessment and design recommendation.

Illustrative Examples

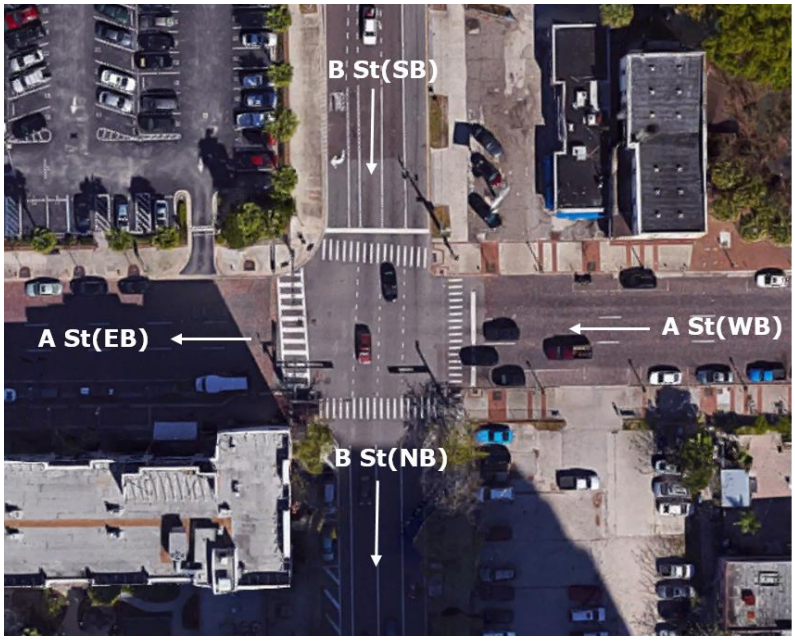
Example 1

Intersection – intersection of A St (EB/WB) and B St (NB/SB) is a junction of two one-way roads in downtown area.

Facts

- Analysis time period: 7:45-8:45 am
- A St is 3-lane one-way road (WB only)
- 10ft lane widths for all approaches
- No pedestrian crash in last 3 years
- No visibility issue
- In downtown CBD, not a wide busy intersection
- B St is a 3-lane one-way road (SB only)
- 8 ft parking lane widths for A St and B St (NB)
- One citizen complaint about driver non-yielding
- Pre-timed control, permissive left turn (WB)

Intersection Geometry



Turning Movement Peak Hour Data (7:45 am)

Start Time (AM)	A St (EB)	A St (WB)			B St (NB)	B St (SB)		
	Peds	*Left*	*Thru*	*Peds*	*Peds*	*Thru*	*Right*	*Peds*
7:45	27	20	284	51	22	516	40	3
8:00	12	36	306	36	26	472	16	3
8:15	57	30	304	33	24	544	24	0
8:30	27	37	314	30	30	449	25	5
Car	-	113	1182	-	-	1953	104	-
Truck		10	26	-	-	28	1	-
Car+Truck		123	**1208**			**1981**	105	
*Pedestrian	**123**	-	-	**150**	**102**	-	-	**11**

** Count bicyclist as pedestrian for crossing*

Steps

<table>
<tr><th>Step I.</th><th colspan="3">Four Criteria/Factors (Yes/No)</th><th>Intersection Eligibility</th><th>Results</th></tr>
<tr><td rowspan="5">Suitability Assessment at Intersection Level</td><td colspan="2">1) Crash frequency</td><td>No</td><td rowspan="5">Yes (meet 3 criteria)</td><td rowspan="5">Consider LPI at this intersection; go to Step II</td></tr>
<tr><td colspan="2">2) Visibility issue</td><td>No</td></tr>
<tr><td colspan="2">3) Citizen complaints</td><td>Yes (1)</td></tr>
<tr><td colspan="2">4) Land use type</td><td>Yes (CBD)</td></tr>
<tr><td colspan="2">5) Intersection type</td><td>Yes (one-way roads)</td></tr>
<tr><th>Step II.</th><th>Approach</th><th colspan="3">Traffic Volume</th><th>Approach Criteria</th><th>Results</th></tr>
<tr><td rowspan="6">Suitability Assessment at Approach Level</td><td rowspan="3">SB</td><td colspan="3">SB approach right turns: 105 (>100)</td><td rowspan="3">Yes (with right turns)</td><td rowspan="6">Consider LPI for SB approach and WB approach; go to Steps III and IV</td></tr>
<tr><td colspan="3">Crosswalk pedestrian volume on A St (EB): 123 (>80)</td></tr>
<tr><td colspan="3">WB through traffic: 1208/3=403/lane (>400/lane)</td></tr>
<tr><td>NB</td><td colspan="3">No approaching traffic (one-way)</td><td>No</td></tr>
<tr><td rowspan="3">WB</td><td colspan="3">WB approach left turns: 123 (>100)</td><td rowspan="3">Yes (with left turns)</td></tr>
<tr><td colspan="3">Crosswalk pedestrian volume on B St (NB): 102 (>80)</td></tr>
<tr><td colspan="3">SB through traffic: 1981/3=660/lane (>400/lane)</td></tr>
<tr><td>EB</td><td colspan="3">No approaching traffic (one-way)</td><td>No.</td></tr>
<tr><th>Step III.</th><th>Crosswalk</th><th>ML</th><th>PL</th><th>W</th><th>LPI= (ML+PL)/W</th><th>Results</th></tr>
<tr><td rowspan="2">LPI Duration</td><td>A St (EB)</td><td>10 ft</td><td>8 ft</td><td>3.5 ft/s</td><td>5 sec (rounded)</td><td rowspan="2">SB: 5-sec LPI
WB: 5-sec LPI</td></tr>
<tr><td>B St (NB)</td><td>10 ft</td><td>8 ft</td><td>3.5 ft/s</td><td>5 sec (rounded)</td></tr>
<tr><th>Step IV.</th><th>Approach</th><th colspan="5">Recommendations (Optional)</th></tr>
<tr><td rowspan="2">Supplemental Needs</td><td>SB</td><td colspan="5" rowspan="2">Consider restrictions of concurrent right turns during “WALK” interval along with LPI, using APS and education about LPI</td></tr>
<tr><td>WB</td></tr>
</table>

Recommendations

- 5-sec LPI for B St (SB) approach with right turns
- 5 sec LPI for A St (WB) approach with permissive left turns
- 7:45–8:45 AM time period at this intersection

Example 2

Intersection **–** junction of O St (NB/SB) and P Dr (EB/WB) is near employment center.

Facts

- Actuated control for pedestrian signal
- O St is two-way 4-lane street
- 12ft lane widths for all approaches
- No citizen complaint
- Parking one side, offices another side
- P Dr is two-way 4-lane road
- No parking lane for all approaches
- No visibility issue
- 3 crashes of vehicles turning and striking pedestrians legally in crosswalk in last 3 years

Traffic Volumes

4:30–5:30 pm	**P Dr (EB)**			**P Dr (WB)**			**O St (NB)**			**O St (SB)**		
	Left	***Thru***	***Right***	***Left***	***Thru***	***Right***	***Left***	***Thru***	***Right***	***Left***	***Thru***	***Right***
No. of lanes	1	**2**	1	1	2	1	1	2	1	1	2	1
Vehicle volume	60	**1280**	90	100	840	55	120	270	**116**	175	510	114
Pedestrian	12			**110**			5			0		

Steps

Step I.	**Four Criteria/Factors (Yes/No)**		**Intersection Eligibility**	**Results**
Suitability Assessment at Intersection Level	1) Crash frequency	Yes (1)	Yes (meet 2 criteria)	Consider LPI at this intersection; go to Step II
	2) Visibility issue	No		
	3) Citizen complaints	No		
	4) Land use type	Yes		
	5) Intersection type	No		

Step II.	**Approach**	**Traffic volume**	**Approach criteria**	**Results**
Suitability Assessment at Approach Level	SB	Crosswalk pedestrian volume on P Dr (EB): 12 *(<80)*	No.	Consider LPI for WB approach only; go to Steps III and IV
	NB	NB approach right turns: **116** *(>100)*	Yes (with right turns)	
		Crosswalk pedestrian volume on P Dr (WB): **110** *(>80)*		
		EB through traffic: 1280/2 = **640**/lane *(>400/lane)*		
	EB	Crosswalk pedestrian volume on O St (NB): 5 *(<80)*	No	
	WB	Crosswalk pedestrian volume on O St (SB): 0 *(<80)*	No	

Step III.	**Crosswalk**	**ML**	**PL**	**W**	**(ML+PL)/W**	**Results**
LPI Duration	P Dr (WB)	12 ft	0	3.5 ft/s	3 sec	NB: 3 sec LPI

Step IV.	**Approach**	**Recommendations (Optional)**
Supplemental Needs	NB	Considering restrictions of concurrent right turns during ““WALK”” interval along with LPI, using APS and education about LPI

Recommendations

- 3 sec LPI for O St (NB) with right turns
- 4:30–5:30 PM time period at this intersection

Example 3

Intersection – intersection of ABC Ave (EB/WB) and Fifty St (NB/SB) is a major junction of two urban roads (1 mile away from a university campus).

Facts

- Semi-actuated
- 12ft lane widths for all approaches
- Analysis time period: 8:00–9:00 am
- No visibility issue
- 160 sec cycle length
- ABC Ave is a 6-lane road
- Fifty St is a 4-lane street
- No citizen complaints about drivers non-yielding

Crash Frequency* *(using 2012–2014 FDOT GIS Crash Database)*

Year	**Filtering Crash Data** based on all following conditions					**Results at This Intersection**
	FL_VRU_PED	*FLAG_INT*	*VEHICLEMOV*	*V1TRAFCTL/V2TRAFCTL*	*DRVACTION1~4*	
2012	Y	Y	03 or 05	05	03	**0**
2013	Y	Y	03 or 05	05	03	**0**
2014	Y	Y	03 or 05	05	03	**0**

FL_VRU_PED: Y/N flag that indicates if there was one or more pedestrians involved in crash
FLAG_INT: Y/N flag that indicates intersection involvement for crash
*VEHICLEMOV (*Vehicle Maneuver Action): 03–Turning left, 05–Turning right
V1TRAFCTL/V2TRAFCTL (Traffic Control Device for Vehicle 1 or Vehicle 2): 05–Traffic control signal
DRVACTION1~4 (Drivers Actions at Time of Crash 1st to 4th entry): 03–Failed to yield right-of-way

**Note: if using FDOT GIS crash data to check crash history, consider eligible crashes that meet all following conditions based on three years of crash data:*

- *Between pedestrian and turning vehicle at signalized intersection (in FDOT GIS crash data, FL_VRU_PED = Y, and FLAG_INT = Y, and VEHICLEMOV = 03–Turning left or 05–Turning right, and V1TRAFCTL/V2TRAFCTL= 05–Traffic control signal)*
- *When pedestrians have right-of-way (in FDOT GIS crash data, DRVACTION1~4=03–Failed to yield right-of-way)*

Steps

Step I.	**Four Criteria/Factors (Yes/No)**		**Intersection Eligibility**	**Results**
Suitability Assessment at Intersection Level	1) Crash frequency	No (0)	No (meet 0 criterion)	Do not recommend LPI
	2) Visibility issue	No		
	3) Citizen complaints	No (0)		
	4) Land use type (wide busy intersection)	No		

Results – Do not recommend LPI at this intersection

APPENDIX F BEFORE-AFTER DATA SUMMARY OF EACH SITE/APPROACH

Table F-1 Data Summary for Fletcher Ave at Palm Dr (Tampa, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
9:00-10:00	110	5	0	3	1	0	67	0	14	7	0	14	17	117	41	58	208	0	979	490
10:00-11:00	129	5	0	5	0	0	80	1	23	5	0	1	4	165	52	80	214	1	929	465
11:00-12:00	92	4	0	1	2	1	62	1	44	5	1	4	6	99	67	112	164	1	1011	506
12:00-13:00	121	4	2	3	1	2	111	0	47	6	0	6	2	172	74	124	240	2	966	483
13:00-14:00	107	7	0	1	3	0	83	0	51	8	0	2	0	159	54	106	192	0	975	488
14:00-15:00	90	7	1	2	3	1	63	0	45	4	0	3	0	114	65	112	156	1	1118	559
15:00-16:00	103	10	0	7	1	2	94	0	70	6	1	4	0	151	110	187	201	0	1233	617
16:00-17:00	126	12	1	2	1	3	127	0	77	9	1	8	1	187	96	175	262	1	992	496

Table F-2 Data Summary for Fletcher Ave at USF Palm Dr (Tampa, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal 					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
9:00-10:00	122	6	0	3	0	0	134	0	21	3	0	1	0	165	66	90	258	0
10:00-11:00	102	3	0	2	0	0	128	0	10	4	0	1	3	160	46	58	234	0
11:00-12:00	94	4	0	3	0	1	89	1	38	2	1	7	3	117	58	99	193	1
12:00-13:00	128	12	1	5	1	0	133	1	43	6	0	2	4	178	93	141	267	2
13:00-14:00	101	5	1	3	1	1	94	0	35	3	0	0	15	145	69	107	210	1
14:00-15:00	88	9	0	1	0	1	82	0	37	6	0	0	1	125	78	116	171	0
15:00-16:00	129	12	1	1	4	1	155	0	53	3	0	17	0	191	147	201	301	1
16:00-17:00	112	16	0	2	2	0	111	1	67	5	0	2	0	200	145	214	225	1

Table F-3 Data Summary for E Kennedy Blvd at N Tampa St (Tampa, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 			Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Waited for Green	Peds Left before Green	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
9:00-10:00	34	14	0	13	0	0	26	0	113	4	0	28	6	20	146	66	0	958	319
10:00-11:00	59	18	0	6	2	0	31	1	131	4	0	52	10	29	166	100	1	893	298
11:00-12:00	106	25	0	10	0	0	80	4	149	1	0	87	25	34	193	211	4	784	261
12:00-13:00	215	22	3	3	0	1	179	1	133	10	0	239	26	35	171	420	4	712	237
13:00-14:00	195	22	1	5	1	0	114	3	142	10	0	150	52	25	172	361	4	800	267
14:00-15:00	74	13	0	8	0	0	68	2	141	5	0	56	33	23	172	175	2	818	273
15:00-16:00	28	7	0	6	0	0	37	1	74	1	0	21	18	22	102	83	1	793	264
16:00-17:00	35	9	0	7	0	1	56	0	104	4	0	21	23	38	149	114	0	853	284

Table F-4 Data Summary for E Kennedy Blvd at N Tampa St (Tampa, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal 					During "DON'T WALK" Signal (Steady) 			Hourly Statistics		
Time Period	**Peds Crossed**	**Vehs Arrived (Stop Line)**	**Ped-veh Conflicts**	**Vehs Turned**	**Vehs Yielded**	**Vehs Not Yielded**	**Peds Crossed**	**Ped-veh Conflicts**	**Vehs Turned**	**Vehs Yielded**	**Vehs Not Yielded**	**Peds Waited for Green**	**Peds Left before Green**	**Vehs Turned**	**Right Turn Volume**	**Ped Volume**	**Ped-veh Conflicts**
8:00-9:00	42	21	0	8	1	0	44	1	183	4	0	23	18	25	216	104	1
9:00-10:00	40	18	0	8	0	0	29	2	126	6	0	35	6	23	157	75	2
10:00-11:00	59	19	0	3	0	0	45	0	128	6	0	48	7	30	161	111	0
11:00-12:00	125	25	2	2	2	0	68	0	153	6	0	91	20	40	195	213	2
12:00-13:00	231	28	1	5	1	1	177	3	156	17	0	163	66	55	216	474	4
13:00-14:00	148	21	0	0	1	0	121	0	132	8	0	128	18	29	161	287	0
14:00-15:00	48	15	1	2	2	0	54	0	127	2	0	35	22	33	162	124	1
15:00-16:00	48	8	0	2	0	0	46	1	123	2	0	30	17	27	152	111	1
16:00-17:00	75	6	0	3	0	0	24	0	63	0	0	39	24	30	96	123	0

Table F-5 Data Summary for E Fletcher Ave at N Nebraska Ave (Tampa, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
8:00-9:00	3	0	0	0	0	2	5	0	16	0	3	7	8	3	162	178	23	0	767	384
9:00-10:00	4	0	0	1	0	0	0	0	6	0	0	2	1	3	155	162	7	0	773	387
10:00-11:00	3	2	0	3	0	1	2	0	10	0	0	1	5	3	181	194	11	0	801	401
11:00-12:00	21	2	0	11	2	1	0	1	33	2	1	6	5	12	211	255	32	1	857	429
12:00-13:00	6	2	0	4	0	0	3	1	23	1	1	5	5	6	176	203	19	1	802	401
13:00-14:00	11	1	0	1	0	0	3	1	14	1	2	5	3	8	230	245	22	1	931	466
14:00-15:00	5	2	0	6	1	0	2	0	23	1	0	3	3	7	189	218	13	0	923	462
15:00-16:00	12	3	0	1	1	0	0	0	19	0	0	1	1	8	201	222	15	0	958	479

Table F-6 Data Summary for E Fletcher Ave at N Nebraska Ave (Tampa, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	7	1	0	3	0	0	1	0	17	0	0	6	4	2	123	143	18	0
9:00-10:00	0	0	0	1	0	1	2	0	9	0	0	3	3	3	162	172	8	0
10:00-11:00	5	2	0	7	1	3	2	1	21	1	0	3	6	4	186	214	16	1
11:00-12:00	5	1	0	4	0	2	3	0	17	1	0	2	10	9	183	204	20	0
12:00-13:00	3	0	0	5	0	1	1	0	12	0	1	2	3	2	186	203	9	0
13:00-14:00	9	3	0	8	0	4	4	0	32	0	0	3	8	8	200	240	24	0
14:00-15:00	5	4	0	2	0	1	3	1	32	0	3	5	4	5	182	216	17	1
15:00-16:00	6	1	1	6	0	3	4	0	31	0	1	3	1	4	207	244	15	1

Table F-7 Data Summary for W University Ave at NW 13th St (Gainesville, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
9:00-10:00	57	2	0	2	1	0	30	0	16	0	0	2	3	68	115	133	92	0	576	288
10:00-11:00	49	6	0	6	1	1	55	0	33	6	0	0	0	68	121	160	104	0	511	256
11:00-12:00	104	13	0	2	2	0	88	0	42	6	0	7	2	176	166	210	201	0	521	261
12:00-13:00	107	14	1	1	1	1	135	1	25	10	1	1	1	188	163	189	244	2	572	286
13:00-14:00	122	14	0	2	0	2	105	0	21	7	0	0	9	173	236	259	236	0	570	285
14:00-15:00	87	14	0	1	1	1	73	1	39	3	0	1	11	123	240	280	172	1	577	289
15:00-16:00	52	16	0	2	0	1	54	1	38	6	0	0	6	92	273	313	112	1	610	305
16:00-17:00	60	12	0	0	0	0	63	1	42	9	0	1	13	98	206	248	137	1	594	297

Table F-8 Data Summary for W University Ave at NW 13th St (Gainesville, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
9:00-10:00	57	12	0	0	0	0	44	0	34	6	0	1	3	78	119	153	105	0
10:00-11:00	44	12	0	2	0	0	52	1	30	5	0	0	1	80	126	158	97	1
11:00-12:00	112	17	0	0	0	0	84	0	42	6	0	5	17	179	169	211	218	0
12:00-13:00	99	17	0	0	0	0	98	0	25	9	0	7	4	157	159	184	208	0
13:00-14:00	111	21	0	0	0	0	71	0	27	3	0	10	7	139	195	222	199	0
14:00-15:00	74	18	0	0	0	0	86	1	49	7	0	2	5	128	170	219	167	1
15:00-16:00	59	14	0	0	0	0	66	1	33	3	0	7	17	100	216	249	149	1
16:00-17:00	20	20	0	0	0	0	67	0	33	0	0	0	0	47	260	293	87	0

Table F-9 Data Summary for SR A1A at 178th St (Sunny Isles Beach, FL) Eastbound Right Turn before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
9:00-10:00	67	21	1	0	1	0	55	8	63	8	0	11	4	91	47	110	137	9	1590	530
10:00-11:00	62	26	1	1	1	0	75	1	68	1	0	3	6	96	46	115	146	2	1498	499
11:00-12:00	41	19	1	2	4	0	60	3	57	2	1	0	12	72	46	105	113	4	1493	498
12:00-13:00	54	18	1	2	1	0	37	3	61	7	0	10	13	72	50	113	114	4	1366	455
13:00-14:00	35	20	1	1	0	0	56	1	77	5	1	3	5	72	53	131	99	2	1347	449
14:00-15:00	79	21	0	2	0	1	61	0	58	4	0	7	18	94	71	131	165	0	1413	471
15:00-16:00	88	20	0	2	0	0	49	0	37	6	0	17	6	105	83	122	160	0	1498	499
16:00-17:00	73	14	1	9	0	1	48	0	55	6	0	9	11	79	68	132	141	1	1573	524
17:00-18:00	100	14	0	3	0	0	48	2	33	8	0	8	15	110	86	122	171	2	1344	448

Table F-10 Data Summary for SR A1A at 178th St (Sunny Isles Beach, FL) Eastbound Right Turn after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal 					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	75	25	0	0	0	0	85	0	65	0	0	3	5	108	80	145	168	0
9:00-10:00	63	22	1	3	1	1	62	0	72	3	0	7	7	81	47	122	139	1
10:00-11:00	65	14	1	1	2	0	74	0	57	3	0	10	11	89	44	102	160	1
11:00-12:00	67	26	0	4	2	0	64	0	55	4	0	10	4	103	63	122	145	0
12:00-13:00	82	17	0	0	0	0	64	0	53	7	0	13	20	94	66	119	179	0
13:00-14:00	47	16	0	1	1	0	61	0	37	5	0	2	4	93	69	107	114	0
14:00-15:00	76	18	2	2	0	2	94	1	30	10	0	7	2	121	73	105	179	3
15:00-16:00	82	13	0	2	0	0	87	0	24	8	1	11	19	104	86	112	199	0
16:00-17:00	86	14	0	0	0	0	66	0	30	5	0	6	6	111	70	100	164	0
17:00-18:00	57	13	0	3	0	0	44	0	32	4	0	8	14	67	82	117	123	0

Table F-11 Data Summary for SR A1A at 178th St (Sunny Isles Beach, FL) Eastbound Left Turn before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
9:00-10:00	16	23	0	0	0	0	18	1	186	4	0	3	4	24	6	192	41	1	1045	348
10:00-11:00	19	27	0	0	0	0	23	1	180	9	0	2	2	33	14	194	46	1	1102	367
11:00-12:00	26	20	0	0	0	0	15	1	131	8	0	1	1	33	16	147	43	1	1368	456
12:00-13:00	24	21	0	0	0	0	27	0	151	10	0	4	3	38	14	165	58	0	1272	424
13:00-14:00	19	23	0	0	0	0	36	2	171	11	0	1	1	44	18	189	57	2	1292	431
14:00-15:00	15	26	0	0	0	0	26	2	204	13	0	1	5	26	23	227	47	2	1324	441
15:00-16:00	27	27	0	0	0	0	41	2	247	9	0	3	2	59	17	264	73	2	1389	463
16:00-17:00	24	21	0	0	0	0	31	2	168	8	0	1	2	42	10	178	58	2	1377	459
17:00-18:00	34	21	0	0	0	0	22	1	199	7	0	2	6	44	26	225	64	1	948	316

Table F-12 Data Summary for SR A1A at 178th St (Sunny Isles Beach, FL) Eastbound Left Turn after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	13	28	0	0	0	0	28	0	263	5	0	0	0	28	23	285	40	0
9:00-10:00	31	25	0	0	0	0	19	0	171	4	0	2	2	32	11	182	54	0
10:00-11:00	40	27	0	0	0	0	16	0	187	10	0	1	1	53	14	201	58	0
11:00-12:00	26	24	0	0	0	0	24	0	183	10	0	8	0	38	8	191	58	0
12:00-13:00	23	21	0	0	0	0	29	1	145	7	0	3	4	30	31	176	59	1
13:00-14:00	37	23	0	0	0	0	22	0	184	9	0	1	1	53	37	221	61	0
14:00-15:00	17	25	0	0	0	0	30	6	204	9	0	5	2	28	20	224	54	6
15:00-16:00	26	25	0	0	0	0	22	0	246	5	0	3	3	44	25	271	54	0
16:00-17:00	40	18	0	0	0	0	20	0	157	1	0	3	2	43	13	170	65	0
17:00-18:00	34	18	0	0	0	0	18	0	154	7	0	3	1	39	37	191	56	0

Table F-13 Data Summary for US 41 at Laurel Rd (Nokomis, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 			Hourly Statistics						
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Right Turn Volume on Red	Right Turn Volume on Green	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
8:00-9:00	1	1	0	0	0	0	0	0	10	1	0	0	0	0	244	274	518	1	0	1260	420
9:00-10:00	3	1	1	0	1	0	0	0	15	1	0	0	0	0	165	247	412	3	1	1048	349
10:00-11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	184	209	393	0	0		
11:00-12:00	2	1	0	1	0	0	0	0	15	1	0	0	0	0	213	204	417	2	0	1222	407
12:00-13:00	5	4	2	1	2	0	3	0	45	0	0	0	0	0	214	199	413	8	2	1377	459
13:00-14:00	5	1	0	0	0	0	1	0	18	1	0	0	0	0	210	194	404	6	0	1279	426
14:00-15:00	1	1	0	1	1	0	0	0	8	0	0	0	0	0	209	138	347	1	0		
15:00-16:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	217	476	0	0	1542	514
16:00-17:00	2	2	0	2	0	0	0	0	30	1	0	0	0	0	176	193	369	2	0	1337	446
17:00-18:00	1	1	0	1	1	0	0	0	12	0	0	1	0	0	243	184	427	2	0	1759	586

Table F-14 Data Summary for US 41 at Laurel Rd (Nokomis, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady 			Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Right Turn Volume on Red	Right Turn Volume on Green	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	1	0	0	0	0	0	0	0	8	0	0	0	0	0	263	306	569	1	0
9:00-10:00	1	0	0	0	0	0	0	0	7	0	0	0	0	0	144	193	337	1	0
10:00-11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159	203	362	0	0
11:00-12:00	1	1	0	0	0	0	0	0	22	0	0	0	0	0	152	208	360	1	0
12:00-13:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	167	209	376	0	0
13:00-14:00	1	1	0	1	1	0	0	0	17	0	0	1	0	0	175	226	401	2	0
14:00-15:00	1	1	0	0	0	0	0	0	7	1	0	0	0	0	143	211	354	1	0
15:00-16:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	212	234	446	0	0
16:00-17:00	3	2	0	2	0	0	0	0	33	1	0	0	0	0	180	222	402	3	0
17:00-18:00	2	2	0	0	0	0	0	0	33	1	0	0	0	0	172	220	392	2	0

Table F-15 Data Summary for US 1 at E Broward Blvd (Fort. Lauderdale, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
8:00-9:00	12	8	1	2	0	0	7	1	100	0	0	1	3	11	132	234	23	2	506	169
9:00-10:00	3	7	0	5	0	0	10	0	109	0	0	1	0	2	101	215	14	0	515	172
10:00-11:00	13	11	0	6	0	0	13	0	87	4	0	1	0	23	112	205	27	0	529	176
11:00-12:00	7	13	0	8	1	0	13	0	97	2	0	0	1	15	110	215	21	0	494	165
12:00-13:00	11	17	2	11	2	0	28	0	122	2	0	1	0	21	125	258	40	2	499	166
13:00-14:00	22	20	0	12	0	1	28	1	144	5	1	4	2	40	128	284	56	1	525	175
14:00-15:00	11	12	0	9	1	0	13	1	107	3	0	2	2	12	120	236	28	1	540	180
15:00-16:00	11	12	0	9	1	0	11	2	71	1	1	2	0	15	97	177	24	2	546	182
16:00-17:00	7	15	0	14	0	0	6	0	122	3	0	3	2	15	76	212	18	0	636	212
17:00-18:00	10	15	0	9	0	0	25	0	126	5	0	0	1	17	82	217	36	0	570	190

Table F-16 Data Summary for US 1 at E Broward Blvd (Fort. Lauderdale, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	13	9	0	6	0	1	7	0	115	1	0	0	0	15	97	218	20	0
9:00-10:00	8	6	0	3	0	0	10	0	78	2	0	3	0	10	95	176	21	0
10:00-11:00	2	7	0	6	0	0	6	0	53	2	0	1	0	2	65	124	9	0
11:00-12:00	8	10	0	6	1	0	11	0	97	2	0	0	0	14	113	216	19	0
12:00-13:00	22	11	0	7	1	0	20	0	100	4	1	0	1	34	114	221	43	0
13:00-14:00	25	14	0	6	1	1	33	1	147	6	0	2	1	43	161	314	61	1
14:00-15:00	15	12	0	13	0	0	23	0	108	2	0	2	0	27	137	258	40	0
15:00-16:00	12	11	0	5	1	0	21	0	95	1	0	0	1	19	95	195	34	0
16:00-17:00	3	12	0	8	0	0	11	0	105	3	0	1	0	4	88	201	15	0
17:00-18:00	15	12	0	6	1	1	15	1	105	3	1	0	1	20	117	228	31	1

Table F-17 Data Summary for E Tennessee St at E Monroe St (Tallahassee, FL) Northbound Right Turn before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
8:00-9:00	2	1	0	2	0	0	0	0	0	0	0	1	1	3	43	45	4	0	771	386
9:00-10:00	7	0	0	0	0	0	3	0	2	2	0	0	0	10	50	52	10	0	635	318
10:00-11:00	4	0	0	0	0	0	2	0	1	0	0	0	0	5	62	63	6	0	622	311
11:00-12:00	7	0	0	0	0	0	1	0	1	0	0	0	1	7	44	45	9	0	725	363
12:00-13:00	6	2	0	0	0	0	4	0	5	0	0	0	3	9	62	67	13	0	686	343
13:00-14:00	6	1	0	0	0	0	1	0	1	0	0	1	6	6	66	67	14	0	845	423
14:00-15:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97	97	0	0	952	476
15:00-16:00	3	2	0	1	0	0	0	0	4	0	0	0	3	5	66	71	6	0	955	478
16:00-17:00	7	1	0	0	0	0	1	0	5	0	0	0	0	5	47	52	8	0	1085	543
17:00-18:00	3	0	0	0	0	0	0	0	0	0	0	0	0	2	89	89	3	0	987	494

Table F-18 Data Summary for E Tennessee St at E Monroe St (Tallahassee, FL) Northbound Right Turn after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	1	0	0	0	0	0	0	0	0	0	0	0	2	0	48	48	3	0
9:00-10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	38	0	0
10:00-11:00	3	0	0	0	0	0	0	0	1	0	0	1	2	2	34	35	6	0
11:00-12:00	5	1	0	1	0	0	0	0	1	0	0	0	2	6	53	55	7	0
12:00-13:00	7	1	0	2	0	0	0	0	1	0	0	0	1	7	63	66	8	0
13:00-14:00	4	1	0	0	0	0	1	0	3	1	0	0	8	4	65	68	13	0
14:00-15:00	2	0	0	0	0	0	0	0	1	0	0	0	2	1	69	70	4	0
15:00-16:00	3	0	0	0	0	0	1	0	0	0	0	0	0	4	55	55	4	0
16:00-17:00	3	0	0	0	0	0	1	0	1	0	0	0	0	2	72	73	4	0
17:00-18:00	1	0	0	0	0	0	0	0	0	0	0	0	1	0	83	83	2	0

Table F-19 Data Summary for E Tennessee St at E Monroe St (Tallahassee, FL) Eastbound Right Turn before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
8:00-9:00	8	0	0	0	0	0	2	0	29	1	0	2	1	8	223	252	13	0	630	315
9:00-10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	197	0	0	574	287
10:00-11:00	3	3	0	2	0	0	0	0	20	1	0	0	0	3	165	187	3	0	550	275
11:00-12:00	2	2	0	2	0	0	0	0	5	1	0	0	4	1	178	185	6	0	645	323
12:00-13:00	5	2	0	1	0	0	2	0	12	3	0	0	1	5	120	133	8	0	561	281
13:00-14:00	19	2	0	1	0	0	4	0	15	2	0	0	5	18	249	265	28	0	625	313
14:00-15:00	2	1	0	1	0	0	2	0	3	1	0	0	0	2	230	234	4	0	572	286
15:00-16:00	4	1	0	1	0	0	1	0	10	0	0	0	2	5	258	269	7	0	648	324
16:00-17:00	5	1	0	0	1	0	2	0	10	1	0	0	3	4	221	231	10	0	706	353
17:00-18:00	1	1	0	0	0	0	1	0	3	0	0	0	0	0	229	232	2	0	608	304

Table F-20 Data Summary for E Tennessee St at E Monroe St (Tallahassee, FL) Eastbound Right Turn after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady) 				Hourly Statistics		
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Vehs Turned	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	3	2	0	2	0	0	1	0	12	2	0	0	6	5	196	210	10	0
9:00-10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	77	0	0
10:00-11:00	4	3	0	2	0	0	0	0	9	0	0	0	0	3	111	122	4	0
11:00-12:00	1	0	0	0	0	0	0	0	2	0	0	0	0	2	200	202	1	0
12:00-13:00	3	0	0	0	0	0	0	0	4	2	0	0	2	3	228	232	5	0
13:00-14:00	17	1	0	0	0	0	2	0	1	2	0	4	0	14	223	224	23	0
14:00-15:00	5	3	0	2	0	0	1	0	8	3	0	1	1	4	199	209	8	0
15:00-16:00	2	0	0	0	0	0	2	0	6	1	0	1	2	5	245	251	7	0
16:00-17:00	2	0	0	0	0	0	0	0	1	0	0	0	0	1	230	231	2	0
17:00-18:00	0	0	0	1	0	0	1	0	8	1	0	0	0	0	229	238	1	0

Table F-21 Data Summary for SR 200 at SW 60th Ave (Ocala, FL) before LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI						During Remainder of "WALK" Signal					During "DON'T WALK" Signal (Steady)			Hourly Statistics						
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Right Turn Volume on Red	Right Turn Volume on Green	Right Turn Volume	Ped Volume	Ped-veh Conflicts	Intersect Traffic Volume	Intersect Traffic Per Lane
8:00-9:00	1	4	0	4	0	0	1	0	62	1	0	0	0	0	158	195	353	2	0	868	289
9:00-10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	217	149	366	0	0	965	322
10:00-11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	247	119	366	0	0		
11:00-12:00	0	1	0	2	0	0	0	0	3	0	0	0	0	0	197	83	280	0	0	1026	342
12:00-13:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	133	377	0	0	1063	354
13:00-14:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	222	96	318	0	0	1006	335
14:00-15:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	216	115	331	0	0		
15:00-16:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	76	198	0	0	817	272
16:00-17:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183	122	305	0	0	820	273
17:00-18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	186	124	310	0	0	807	269

Table F-22 Data Summary for SR 200 at SW 60th Ave (Ocala, FL) after LPI Implementation

	During First Few Seconds of "WALK" Signal Equal to LPI 						During Remainder of "WALK" Signal  					During "DON'T WALK" Signal (Steady` 			Hourly Statistics				
Time Period	Peds Crossed	Vehs Arrived (Stop Line)	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Peds Crossed	Ped-veh Conflicts	Vehs Turned	Vehs Yielded	Vehs Not Yielded	Pushed But Crossed	Crossed without Push	Peds Waited	Right Turn Volume on Red	Right Turn Volume on Green	Right Turn Volume	Ped Volume	Ped-veh Conflicts
8:00-9:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	266	463	0	0
9:00-10:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	188	234	422	0	0
10:00-11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	241	106	347	0	0
11:00-12:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250	127	377	0	0
12:00-13:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	213	99	312	0	0
14:00-15:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	99	291	0	0
15:00-16:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	184	122	306	0	0
16:00-17:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183	154	337	0	0
17:00-18:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	199	120	319	0	0
18:00-19:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	161	102	263	0	0
19:00-20:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	47	177	0	0

APPENDIX G SUPPORT FOR FINALIZATION IN LPI IMPLEMENTATION GUIDELINES

Based on data review and analysis of and findings on the collected data before and after LPI implementation at test sites in Chapters 4 and 5, several changes regarding warrant definition and threshold value fine-tuning were made to refine the accuracy and applicability of the LPI implementation guidelines. The major revisions and the support for these changes are presented.

G-1 Changes in Organization of LPI Implementation Guidelines

To assist transportation practitioners with becoming familiar with LPI warrants quickly and easily, the revised format for the refined guidelines follows the format of "Traffic Signal Warrant Analysis" in the MUTCD and present a detailed definition and evaluation process for each LPI warrant, LPI duration configuration, and supplemental suggestions on LPI implementation.

G-2 Changes in Average Crash Frequency Warrant

Preliminary Guidelines
In Step I, Suitability Assessment at Intersection Level, if "Average crash frequency between turning vehicles on green and pedestrians legally crossing street on crosswalk with pedestrian "Walk" signal indication ≥1 per year (in last 3 years)" is met, then in Step II, Suitability Assessment at Approach Level, it is necessary to check all traffic volume criteria (Criteria 6–10 in Appendix E) to determine if an LPI is needed.

Refined Guidelines
An Average Crash Frequency Warrant is treated as a single warrant and not related to traffic volume criteria. This warrant is met if the average crash frequency between turning vehicles on green and pedestrians legally crossing a street at a crosswalk with a pedestrian "Walk" signal at an approach of an intersection is ≥1 per year in the past 3 years, regardless of the traffic volume information at the approach.

Support for Changes
Because these LPI implementation guidelines aim to provide maximum safety benefits to pedestrians, the safety-related approach regarding vehicle-pedestrian crash frequency during a pedestrian "Walk" signal indication is given a higher priority and is treated as a single warrant. Therefore, an LPI should be considered if the average crash frequency criteria are met.

G-3 Changes in Reported Visibility Issue Warrant

Preliminary Guidelines
In Step I, Suitability Assessment at Intersection Level, if "visibility issue of blocked driver view of pedestrians due to obstructions or poor sight distance" is reported, then in Step II, Suitability Assessment at Approach Level, it is necessary to check all traffic volume criteria (Criteria 6–10 in Appendix E) to determine if an LPI is needed.

Refined Guidelines
Similar to an Average Crash Frequency Warrant, a reported visibility issue is treated as a single warrant and not related to traffic volume. If the "a visibility issue of blocked driver view of pedestrians on the crosswalk due to obstructions or poor sight distance at an approach of an intersection is reported and then verified by an engineering study," this warrant is met regardless of traffic volume information at the studied approach of intersection.

Support for Changes
Similar to an Average Crash Frequency Warrant, a Reported Visibility Issue Warrant is also directly related to pedestrian safety and, therefore, is given a higher priority and treated as a single warrant. An LPI should be considered if the Reported Visibility Issue criteria are met.

G-4 Changes in Vehicle Non-Yielding Behavior (Citizen Complaint) Warrant

Preliminary Guidelines
In Step I, Suitability Assessment at Intersection Level, if "Citizen complaints about turning vehicles not yielding to pedestrians" is reported, then in Step II, Suitability Assessment at Approach Level, it is necessary to check all traffic volume criteria (Criteria 6–10 in Appendix E) to determine if an LPI is needed.

Refined Guidelines
A Vehicle Non-Yielding Behavior (Citizen Complaint) Warrant is related to the number of conflicts between pedestrians and turning vehicles during a pedestrian "Walk" phase. If either Condition A (vehicle-pedestrian conflicts) or Condition B (compromised pedestrians due to vehicle non-yielding behavior) is met, this warrant is met. Specifically, detailed vehicle-pedestrian conflict criteria are proposed as Condition A that "The number of conflicts between pedestrians and turning vehicles during the pedestrian "Walk" phase ≥3 per day on the studied approach based on field observations of 3 days," and the criteria for Condition B are used as a single condition for a Vehicle Non-Yielding Behavior (Citizen Complaint) warrant rather than as general criteria that serve all warrants in the preliminary guidelines.

Support for Changes
A new criterion regarding the number of vehicle-pedestrian conflicts at the targeted approach per day (≥3 per day based on 3-day observation data) is proposed. The reason is that during the before-after study in Chapters 4 and 5, full-day data of at least 8 hours were collected and reviewed, and the minimum number of vehicle-pedestrian conflicts was 3 among all the testing approaches where LPI was found effective; this was observed at the North Leg, US 41 @ Laurel Rd in Nokomis, FL. In addition, given the consideration that 1-day observation might be unstable and subject to a number of external factors (e.g., weather, temperature), a 3-day average is necessary to justify the need for LPI implementation.

In addition, the criterion regarding compromised pedestrians is used as a unique condition for Vehicle Non-Yielding Behavior because "compromised pedestrian" is defined as "pedestrians who are delayed or who have altered their travel path travel speed due to concurrent turning vehicles," which is directly related to vehicle non-yielding behavior.

G-5 Changes in Land-Use Type and Intersection Type Warrants

Preliminary Guidelines
Land-use types that attract large numbers of pedestrians and special intersection types including T-intersections and intersection with one-way roads are used as individual criteria for LPI suitability assessments at intersection levels that call for special attention.

Refined Guidelines
In the refined guidelines, these two criteria are not listed as LPI warrants to be examined.

Support for Changes
In the refined guidelines, the definitions for traffic signal warrants, vehicular peak hour, pedestrian peak hour, 4-hour traffic and pedestrian volume, and 8-hour traffic and pedestrian volume are listed as individual warrants to be examined for LPI installation (see Sections 6.1.4–6.1.7 for warrant details and Sections G-6 to G-8 for support of these changes), regardless of special land-use types or intersection layouts. In the before-after study, a variety of intersections covering different land-use types were used as LPI testing sites, such as school zones, central business areas, downtown cores, etc., and the traffic volume thresholds were revised based on the data review and analysis results on these testing sites. Therefore, there is no need for any special considerations on certain land-use types or intersection layouts, and traffic and pedestrian volumes are the only criteria needed to evaluate LPI suitability at the studied approach of an intersection.

G-6 Changes in Peak-Hour Warrant

Preliminary Guidelines
One-hour vehicular and pedestrian volume criteria were proposed to evaluate LPI suitability at approach levels, where, if "In 1 hour, approach turning vehicle volume (movement A) ≥100/hour, pedestrian volume at crosswalk (movement B) ≥80/hour, and through traffic volume of cross street (movement C) ≥400/hour/lane, consider an LPI for that one hour," an LPI shall be considered.

Refined Guidelines
The One-Hour Warrant is replaced by 2 peak-hour warrants, including Vehicle Peak-Hour Warrant and Pedestrian Peak-Hour Warrant, and different criteria are defined as follows:

Vehicle Peak-Hour Warrant:

"The need for an LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied (see Figures 6-1 and 6-2 for movement definition):

- For vehicle traffic peak hour of an average day, approach turning vehicle volume (movement A) ≥130/hour, pedestrian volume at crosswalk (movement B) ≥25/hour; or
- If either turning vehicle volume (movement A) ≥130/hour or pedestrian volume at crosswalk (movement B) ≥25/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥500/hour/lane is also satisfied."

Pedestrian Peak-Hour Warrant:

"The need for an LPI shall be considered at the studied approach of intersection when an engineering study finds that one of the following conditions is satisfied (see Figures 6-1 and 6-2 for movement definition):

- For pedestrian volume peak hour of an average day, approach turning vehicle volume (movement A) ≥100/hour, pedestrian volume at crosswalk (movement B) ≥50/hour; or
- If either turning vehicle volume (movement A) ≥100/hour or pedestrian volume at crosswalk (movement B) ≥50/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥400/hour/lane is also satisfied."

Support for Changes

All traffic volume criteria were listed as individual warrants to be examined in the refined guidelines, following the MUTCD Traffic Signal Warrant format, which is easier to follow and more informative.

Instead of using one-hour traffic counts, criteria for vehicular and pedestrian peak-hours were proposed, and detailed pedestrian volume, turning vehicle volume, and through traffic volume of cross streets were defined based on traffic count information in the before-after study in Tasks 4 and 5. In the before-after study, it was observed that vehicular traffic peak hours are generally early in the morning (7:00–8:00 AM) or late in the afternoon (5:00–6:00 PM). However, pedestrian volume peak hours may differ at different sites. Pedestrian volume peak hours overlapped with vehicular peak hours at certain testing sites, such as E Fletcher Ave @ USF Palm Dr, Tampa, FL, which is close to the USF campus, but pedestrian volume peak hours also appeared around 12:00 noon when people walked to lunch or ran personal errands within walking distance based on local business distributions (restaurants, banks, etc.). Therefore, given the difference between pedestrian and vehicular traffic volume peak hours, it was necessary to develop different traffic volume criteria with respect to peak-hour periods.

For vehicular traffic peak hours, turning vehicle hourly volume is higher than the average hourly volume of 4-hour or 8-hour volume. The highest turning vehicle volume during vehicle traffic peak hours generates the most potential conflicts between turning vehicles and pedestrians crossing the intersection.

Data review results revealed that, at the testing sites at which LPIs were found effective when those lowest hourly turning vehicle volumes were about 130 vehicles/hour and those lowest pedestrian hourly volumes were around 25 persons/hour. In addition, 500 veh/lane/hour is a reasonable observed number as the threshold for through traffic of a cross street during a vehicle peak hour.

For pedestrian volume peak hour, especially for 12:00 noon, data review results revealed that, at the testing sites at which LPIs were found effective when those lowest hourly turning vehicle volumes were about 100 vehicles/hour, and those lowest pedestrian hourly volumes were around 50 persons/hour. In addition, 400 veh/lane/hour is a reasonable observed number as the threshold for through traffic of a cross street during a pedestrian peak hour where LPI were found effective

but turning vehicle volume or pedestrian volume threshold was not met. Therefore, these statistics are proposed as the thresholds during pedestrian volume peak hours.

Also, as shown in the refined LPI implementation guidelines, the through traffic volume of a cross street was revised as a secondary criterion to be examined after either turning vehicle volume or pedestrian volume criteria are not met. The reason for this change is that turning vehicles and crossing pedestrians are the two parties directly associated with pedestrian safety, and LPI implementation, and should be considered with a higher priority. Through traffic volumes of cross streets impose indirect influence on turning vehicle behavior, and it is expected that high through traffic volumes on cross streets will lead to a low possibility of right-turn-on-red movements (when "NO TURN ON RED" signs is not implemented) and will induce fast turning movements at the onset of pedestrian signals, during which turning vehicle drivers may miss or ignore the presence of crossing pedestrians.

G-7 Changes in Four-Hour Vehicular and Pedestrian Volume Warrant

Preliminary Guidelines

Four-hour vehicular and pedestrian volume criteria were proposed in the preliminary guidelines to evaluate LPI suitability at the approach level, where, if "In 4 consecutive hours, approach turning vehicle volume (movement A) ≥120/hour, pedestrian volume at crosswalk (movement B) ≥70/hour, and through traffic volume of cross street (movement C) ≥400/hour/lane (consider LPI for those 4 hours)," an LPI should be considered.

Refined Guidelines

A revised Four-hour Vehicular and Pedestrian Volume Warrant was proposed in the refined guidelines as follows:

> "The need for LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied for each of any 4 hours of an average day (see Figures 6-1 and 6-2 for movement definition):
>
> - Approach turning vehicle volume (movement A) ≥105/hour, pedestrian volume at crosswalk (movement B) ≥30/hour; or
> - If either turning vehicle volume (movement A) ≥105/hour or pedestrian volume at crosswalk (movement B) ≥30/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥400/hour/lane is also satisfied."

Support for Changes

Different from those in the preliminary guidelines that requires data from 4 consecutive hours in accordance to the detailed LPI time-of-day implementation plan, data for any 4 (or 8) hours of an average day were used for criteria examination. The reason for this change is that during the before-after study, unless requested for change, the LPI on the targeted approaches remained effective for the whole day after it was implemented by FDOT Districts or local transportation agencies. In addition, LPI implementation based on time-of-day might cause confusion and safety issues for drivers and pedestrians, as it becomes difficult for them to track the presence or absence of an LPI. Therefore, given the default practice of LPI implementation, it is of better practical benefit to release the restriction of "consecutive hours."

In addition, these criteria were revised based on the collected traffic volume data on the testing sites before and after LPI implementations or engineering experience. As was discussed in Deliverables 4 and 5, LPIs were found to be effective at several testing sites, and the hourly turning vehicle volume, pedestrian volume, number of vehicle-pedestrian conflicts before and after LPI implementation, and through traffic hourly volume of the cross streets before LPI implementation were summarized.

The criteria for any 4 hours of an average day were generalized based on the traffic volume statistics for those testing sites at which LPIs were found effective. It was found that the lowest hourly turning vehicle volume during an arbitrary 4 hours among these sites was around 105 veh/hour, and the lowest hourly pedestrian volume among these sites was around 30 persons/hour. In addition, field observation and data review revealed that a typical cycle length is 120–150 seconds, and, therefore, there were around 30 signal cycles per hour. Pedestrian volume ≥30/hour indicates that, on average, there is at least one pedestrian crossing street per cycle. Therefore, these two numbers were used as the threshold for LPI suitability assessment at the approach level. As for the criteria for through traffic volume of cross streets, given the fact that this works as a secondary criterion, hourly volumes were examined for all-day data for these sites, and it was found that an appropriate number was around 400 veh/lane/hour base on the volume statistics of intersection approaches where LPI were found effective but turning vehicle volume or pedestrian volume threshold was not met. Given daily traffic variations, it is reasonable to use 400 veh/lane/hour as the threshold. The through traffic volume of a cross street is also used as a secondary criterion in this warrant.

G-8 Changes in Eight-Hour Vehicular and Pedestrian Volume Warrant

Preliminary Guidelines

Eight-Hour Vehicular and Pedestrian Volume criteria were proposed in the preliminary guidelines to evaluate LPI suitability at the approach level, where, if "In 8 consecutive hours, approach turning vehicle volume (movement A) ≥125/hour, pedestrian volume at crosswalk (movement B) ≥60/hour, and through traffic volume of cross street (movement C) ≥400/hour/lane (consider LPI for those 8 hours)," an LPI should be considered.

Refined Guidelines

A revised Eight-Hour Vehicular and Pedestrian Volume Warrant is proposed in the refined guidelines as follows:

> "The need for LPI shall be considered at the studied approach of an intersection when an engineering study finds that one of the following conditions is satisfied for each of any eight hours of an average day (See Figures 6-1 and 6-2 for movement definition):
>
> - Approach turning vehicle volume (movement A) ≥100/hour, pedestrian volume at crosswalk (movement B) ≥25/hour; or
> - If either turning vehicle volume (movement A) ≥100/hour or pedestrian volume at crosswalk (movement B) ≥25/hour, but not both, is satisfied, and through traffic volume of cross street (movement C) ≥400/hour/lane is also satisfied."

Support of Changes
Similar to the Four-Hour Vehicular and Pedestrian Volume Warrant, the restriction of "consecutive hours" was released in this warrant.

The criteria for any 8 hours of an average day were determined based on the 4-hour threshold values and all-day data. For those sites at which LPI were found effective, the minimum turning vehicle volume were above 100 veh/hour, whereas for the remaining sites where LPI was not effective or no pedestrian conflicts were observed, the maximum hourly turning vehicle volume of the site that had the overall lowest turning vehicle volume was around 97 veh/hour. Similarly, the maximum hourly pedestrian volume at the testing site of the lowest overall pedestrian volume was 28 persons/hour. In addition, the 8-hour volume threshold is designed to test traffic flow stability over hours of a day, and it is reasonable to assume that the 8-hour volume threshold is slightly lower than the corresponding 4-hour threshold. Therefore, the criteria of 100 veh/hour and 25 persons/hour were designed as the thresholds for turning vehicle volume and pedestrian volume, respectively. The through traffic volume of a cross street is also used as a secondary criterion in this warrant.

G-9 Changes in LPI Duration Configuration

Preliminary Guidelines
The suggested LPI duration is a minimum of 3 seconds and "should allow pedestrians to clear half width of one lane in direction of moving traffic to increase visibility of pedestrians to turning traffic." The equation used to calculate LPI duration is:

$$LPI = (ML/2+PL)/W$$

where:

LPI = number of seconds (rounded value) between onset of "Walk" signal for pedestrians and green indication for vehicles
ML = distance on crosswalk to clear width of one moving lane, in ft
PL = width of parking lane, if any, in ft
W = walking speed (3.5 ft/s for pedestrian clearance calculation suggested by MUTCD, or 3.0 ft/s for aging population suggested by FHWA)

Refined Guidelines
The suggested LPI duration is a minimum of 3 seconds and "should allow pedestrians to clear the width of one lane in the direction of moving traffic (and the width of a parking lane, if any) to increase visibility of pedestrians to turning traffic." The equation used to calculate LPI duration is:

$$LPI = (ML+PL)/W$$

where:

LPI = number of seconds (rounded value) between onset of "Walk" signal for pedestrians and green indication for vehicles
ML = distance on crosswalk to clear width of one moving lane, in ft
PL = width of parking lane, if any, in ft

W = walking speed (3.5 ft/s for pedestrian clearance calculation suggested by MUTCD, or 3.0 ft/s for aging population suggested by FHWA)

Support of Changes

In the refined LPI implementation guidelines, the specification of LPI length has been revised as "Timing should allow pedestrians to clear the width of one lane in the direction of moving traffic (and the width of a parking lane, if any) to increase visibility of pedestrians to turning traffic." This change was based on the LPI calculation from a number of peer studies [7], [8], [14], [20], and it is reasonable to clear the full width of a moving lane and any parking lane to fully reveal the presence of crossing pedestrians.

G-10 Changes in Supplemental Design Recommendations for LPI Implementation

In the refined guidelines, the "LPI Duration Recommendations" (Step III in the preliminary guidelines) and "Supplemental Design Recommendations for LPI Implementation" (Step IV in the preliminary guidelines) are combined as a single section, which is clearer and more informative to transportation researchers and practitioners.

In addition to the listed supplemental design recommendations in the preliminary guidelines, several items were added in the refined guidelines, as follows.

- Section 6.1.9, Item 04: "Transportation engineers should determine whether to implement an LPI for a whole day or on a time-of-day basis."
- Rather than stated as "users with slower crossing speeds can be weighted twice (children, older adults, persons with physical disabilities)," it is suggested in the refined guidelines in Section 6.1.9, Item 06 to "consider extended LPI at approaches with a large portion of users with lower crossing speeds (children, older adults, persons with physical disabilities)," "or at approaches where the pedestrian detector location is not immediately adjacent to the curb (or, if no pedestrian detector is present, a location 6 feet from the face of the curb or from the edge of the pavement may be considered for calculating extended LPI)," which is more reasonable and adjustable based on intersection-specific pedestrian demographic features.
- Section 6.1.9, Item 08 was added to recommend field observation and safety improvement evaluation after LPI implementation for potential further adjustments in LPI configuration to maximize safety benefits for crossing pedestrians.
- Two additional items (Section 6.1.9, Items 10 and 11) were added to LPI utilization efficiency and pedestrian compliance, which provide additional inference for LPI implementation. Section 6.1.9, Item 10: "These guidelines aim to provide maximum safety for pedestrians and cyclists using crosswalks, and, therefore, the vehicular and pedestrian volume thresholds are conservative. These thresholds may increase driver complaints when an LPI is activated but crossing pedestrians are not present. Engineering judgment and rationale should be applied to a turning approach on LPI implementation." Section 6.1.9, Item 11: "Lengthy traffic signal cycles should be avoided to reduce pedestrian wait time and increase pedestrian compliance behavior with pedestrian signals."