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Literature Review
Leading Pedestrian Intervals

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Pedestrian safety is a high priority for traffic engineers, and for good reason. In 2019, 6,205 pedestrians were killed and another 76,000 were injured in the US (Arun, Haque et al. 2022). Goughnour, Carter, et al. (2018) reported that pedestrian fatalities were responsible for approximately 16 percent of all traffic-related fatalities in the US in 2016. Canadian statistics are similar; Transport Canada's National Collision Database (NCDB) reported that pedestrian fatalities accounted for 15.4 percent of total road user fatalities for that country in 2017 (Guo, Sayed et al. 2020). Even more alarming is the fact that the proportion of pedestrian fatalities among all traffic-related fatalities has been steadily increasing over the past decade according to the National Center for Statistics and Analysis (Arun, Haque et al. 2022). A study which reviewed pedestrian-vehicle crashes in Michigan 2010-2018 found that most of the collisions occurred in intersections. Additionally, most occurred during lighted conditions (daylight or well-lit areas) rather than with dark, unlighted conditions (Alhomaidat and Acosta-Rodriguez 2021). Urban downtown intersections were shown to have three times the rate of pedestrian-vehicle crashes as residential intersections (Fayish and Gross 2010). Children in particular can be negatively affected by visibility and non-yielding behavior because of their shorter height (Saneinejad and Lo 2015).

Over the years, research has evaluated the benefits of a number of pedestrian countermeasures aimed at increasing overall safety. A common request from the public involves the installation of marked crosswalks; however such crosswalks – at least at unsignalized intersections – are not considered safety devices. In fact, studies have shown that pedestrian crash rates were actually higher at marked crosswalks, and rates increase markedly with multi-lane roadways with volumes greater than 15,000 vehicles per day (MnDOT, 2011). Leading Pedestrian Intervals (LPI), which allow a several second interval (generally 3-7 seconds) for pedestrians to take advantage of a green/walk signal prior to a green indication for adjacent vehicles, have been a focus of safety research for a number of years. As early as 1961, the *Manual on Uniform Traffic Control Devices* (MUTCD) gave guidelines for a signal sequence that aligns with those for LPIs, although the term itself was not used until later (Fayish and Gross 2010). Research has generally shown LPIs to have a positive impact on pedestrian safety at signalized intersections, although the degree of impact varies significantly among the studies. It has also been shown that LPIs are not appropriate for all situations, and several studies have determined guidelines for best practices.


An LPI allows a pedestrian to establish a presence in the crosswalk before vehicles are given a green indication. Source: FHWA

LPIs have been a popular safety countermeasure in many cases because they have been shown to decrease pedestrian-vehicle conflicts while having a relatively low cost – often being programmed into existing signal infrastructure. State and local agencies alike have broadly supported the use of LPIs as a low-cost approach to improve pedestrian safety and visibility (Gates, Qu et al. 2022).

In 2018, FHWA published *Toolbox of Pedestrian Countermeasures and Their Potential Effectiveness,* evaluating safety countermeasures based on three types of measures:

- Signalized countermeasures
- Geometric countermeasures
- Signs, markings and operational countermeasures

For each countermeasure, a crash modification factor (CMF) was assigned, indicating the proportion of crashes that are expected to remain after the countermeasure is implemented. Implementation of a leading pedestrian interval (LPI) – one of the signalized countermeasures – received a CMF of 0.413, which indicated a reduction in crashes of almost 59% (FHWA 2018). More recently, FHWA has recognized LPIs as a proven safety countermeasure (FHWA 1921).

Results vary considerably between studies; this can be a result of location, visibility, traffic and pedestrian volume, etc. But it can also be affected by the safety measures used to compile the data. Some studies used actual crash statistics to assess the impact of LPI implementation; others – particularly in areas where pedestrian-vehicle crashes rarely, if ever, occur, results were compiled based on conflicts between pedestrians and vehicles in the intersection. Cottrell and Mu (2004) studied observations of naturalistic and experimenter driven pedestrians at a total of 222 intersections. They used three categories for their observations:

- Yield (desired result): the first vehicle in all right turning lanes yielded to crossing pedestrian
- Conflict: The lead vehicle in one or more right turn lanes made a dangerous maneuver that could have resulted in a crash. Gitelman, Carmel and Pesahov (2020) further defined a conflict situation as a "sudden change in the speed and/or the direction of walking by a pedestrian or of travel by the vehicle in order to avoid a collision".
- Violation: A vehicle failing to yield to a pedestrian in the crossing, leaving the pedestrian on the curb.

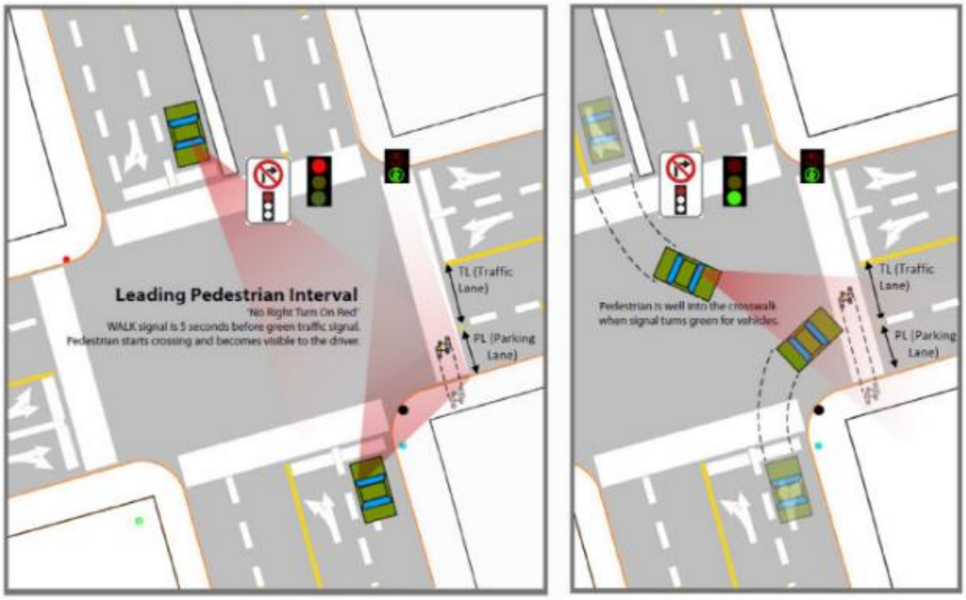
A study from Vancouver, B.C., found an 18.1% - 20.9% reduction in extreme conflicts following LPI installation (Guo, Sayed et al. 2020). The authors determined that by allowing pedestrians to enter the intersection before vehicles, they are established in the crosswalk, resulting in drivers better conforming to yield behavior. Other studies also showed improvement in pedestrian safety; King (2000) found a reduction in crashes of 28% in 26 intersections in New York City. Van Houten, Retting et al. looked at LPI implementation at 3 intersections in St. Petersburg, FL, and found a 95% decrease in conflicts between crossing pedestrians and turning vehicles. Another study of 10 intersections in State College, PA, showed that LPIs reduced pedestrian-vehicle crashes by 59% (Fayish and Gross 2010). The University of South Florida conducted research in effort to establish statewide guidelines for LPI implementation; their study found a wide spectrum of safety benefits among the test locations, ranging between a 25% to 100% reduction in vehicle-pedestrian conflict (Lin, Wang et al. 2017). An FHWA study looked at the effect of LPIs on total crash frequency (all severities combined) in several cities in the US. The effect was measured through the crash modification factor (CMF); the CMF for pedestrian crashes in the combined group of all cities was 0.87, showing a 13% decrease in crashes (Goughnour, Carter et al. 2018). Another FHWA study looked at pedestrian countermeasures in 3 US cities determining measures of effectiveness (MOEs). It concluded that the instillation of LPIs was a highly effective countermeasure (Redmon 2011). Additionally, it does not appear that LPI treatment increases vehicle-vehicle conflicts (Arun, Haque et al. 2022). Washington, D.C. implemented LPIs at 20 intersections with a history of crashes involving right-turning drivers striking pedestrians. The success of this program led to the city expanding it to over 130 intersections (Gates, Qu et al. 2022).

Not all LPI implementations have achieved the desired results. In Anaheim, CA, a LPI installed in a suburban intersection servicing a convention center and Disneyland found the proportion of pedestrians compromised on the curb due to right-turning vehicles went from 18% to 21% at low turn volumes and 23% to 44% at high turn volumes. Within the crosswalk, compromised pedestrians went from 2% to 4% during low right turn volumes, and from 6% to 2% on high right-turn volumes. The author suggested that LPI implementation results in a downtown environment might not translate to a suburban setting (Hubbard, Bullock et al. 2008). In Toronto, Canada, a pilot LPI installation was removed within 6 weeks because of increased non-yielding behavior by drivers. It was determined that this may have been a result of the skewed nature of the intersection, and the city later developed guidelines for successful LPI installations (Saneinejad and Lo 2015). In St. Petersburg, FL, LPIs were discontinued when timing plans were updated by the city, and no public complaints were lodged in response to the action. (Lin, Wang et al. 2017).

Right-turn-on-red (RTOR) actions can decrease the effectiveness of LPIs. In some cases, drivers may be unaware that there was a LPI in place, and turn right on red during the LPI interval without realizing their violation – right-turning vehicles see available gaps in traffic while the signal is red (Cottrell, Mu et al. 2004, Hubbard, Awwad et al. 2007, Dittberner and Vu 2017, Smaglik 2018). This could be an action that could change over time as drivers become more familiar with LPI operations (Hubbard, Bullock et al. 2008, Arun, Haque et al. 2022). However, Hubbard, Bullock et al. (2008) noted that in the case of the intersection in Anaheim, discussed earlier, the predominance of tourists visiting the convention center and/or Disneyland would make this behavioral adaptation unlikely in this situation.

Some guidelines restrict RTOR in conjunction with LPI. In a microsimulation of 15 intersections, Hasanpour & Persaud (2022) determined that prohibiting RTOR could have a 27% decrease in pedestrian-vehicle conflicts. Saneinejad & Lo (2015) recommend RTOR prohibitions for all LPIs, citing that crashes are 70% higher at intersections without RTOR restrictions. The MUTCD (2009) states that RTOR restrictions should be considered for intersection using LPIs, and Georgia DOT's *Pedestrian and Streetscape Guide* (2019) echoes this recommendation. While not specifically referring to RTOR restrictions, a So. Korean simulation study appeared to include that restriction in its modeling. This study found a 92.8% decrease in the number of conflicts. Additionally, conflicts were not shown to increase with increased traffic volume (Kim and Park 2019). Some studies suggested the use of blank-out, or dynamic message signs to limit drivers turning right during the pedestrian interval (Cottrell, Mu et al. 2004, Hubbard, Bullock et al. 2008, Lin, Wang et al. 2017, NYDOT 2017).

Examples of RTOR restrictions:



LPI with "No right turn on red" light. (Saneinejad and Lo 2015)

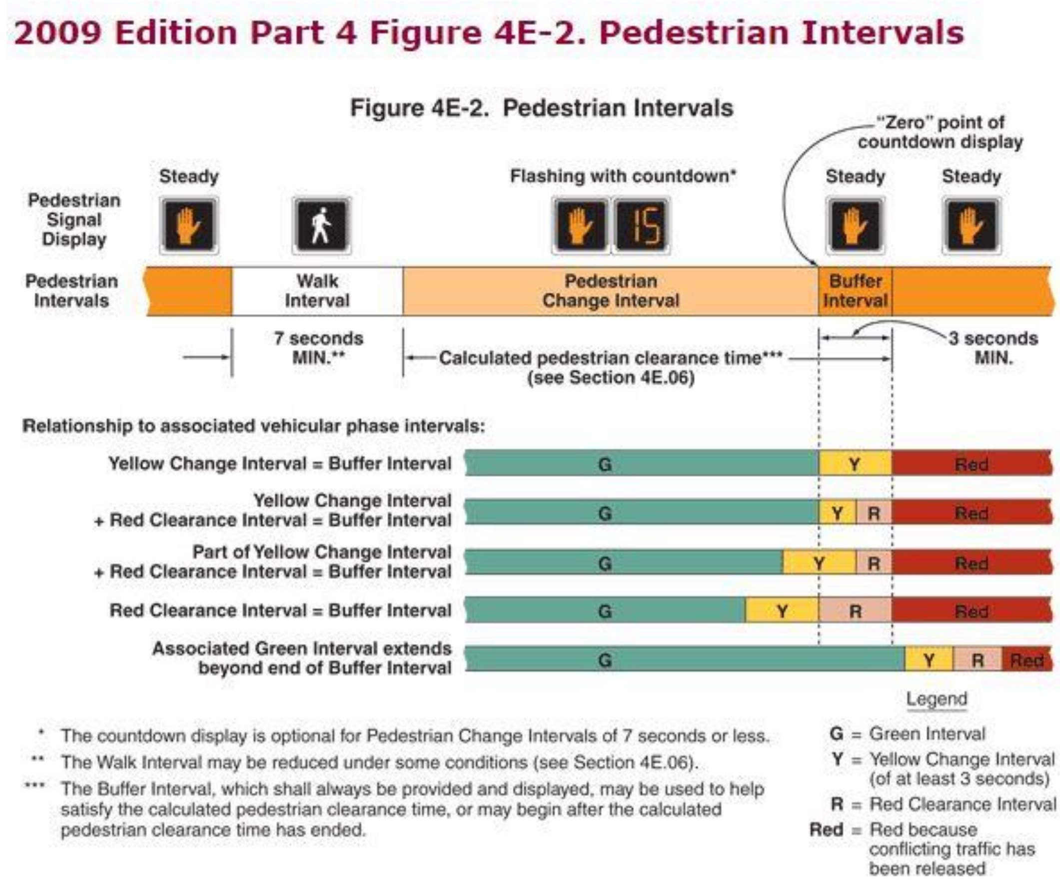
(a) "YIELD TO PEDESTRIANS" sign **(b) "NO TURN ON RED" sign**

Blank-out signs (Lin, Wang et al. 2017)

Pedestrian actions can also impact the effectiveness of LPIs. These treatments can cause delays for pedestrians at intersections, which can result in pedestrian non-compliance (Smaglik 2018). In fact, Gitelman, Carmel & Pesahov (2020) found that the number of pedestrians crossing on red did not decrease after implementation; in fact, they found an increase in evening hours, despite the improvement in pedestrian crossing conditions. The authors agreed with Smaglik's findings, that the intention to cross with a red light increases with a longer waiting time, especially if breaks appear in the traffic. Additionally, a Michigan study found that 16% of pedestrians involved in vehicle-pedestrian crashes were intoxicated – a factor that LPI implementation might not be able to impact (Alhomaidat and Acosta-Rodriguez 2021).

Other considerations might need to be considered for pedestrians with special needs. Blind pedestrians and those with low vision face a number of challenges at crosswalks, including locating the crossing location, determining an appropriate time to cross, and traveling in a straight line while crossing (Barlow, Bentzen et al. 2005). In many crossings using LPI technology, a pushbutton is required to activate the interval, but visually impaired pedestrians observed typically did not find the pushbutton – in fact, the button was not activated in 83.7% of the crossings (Bentzen, Barlow et al. 2004). The authors pointed out that many visually impaired pedestrians rely on the sound of parallel traffic beginning to move as their cue to start crossing the street. This can create problems with LPI intersections, since the pedestrians aren't able to take advantage of the initial interval, so are just beginning to cross as the vehicles receive the green light. Drivers expecting pedestrians to be established in the crosswalk may not be aware that they are just starting from the curb. An Accessible Pedestrian Signal (APS) can provide access to the information on the Walk signal for these pedestrians (Bentzen, Barlow et al. 2004, Barlow, Bentzen et al. 2005, Lin, Wang et al. 2017). LPI intersections that typically have large numbers of visually impaired and/or older pedestrians might need to consider a longer leading interval (FHWA 2009).

The "Pedestrian Control Features" in the *Manual for Uniform Traffic Control Devices* (MUTCD) (2009), gives guidance on LPIs. It features the following pedestrian signal displays:



The MUTCD offers the following recommendations:

- The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk …to travel at a walking speed of 3.5 feet per second to [reach] at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait
- A walking speed of up to 4 feet per second may be used to evaluate the sufficiency of the pedestrian clearance time at locations where an extended pushbutton press function has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time.
- Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time.

- If a leading pedestrian interval is used, the use of accessible pedestrian signals should be considered.
- If a leading pedestrian interval is used, it should be at least 3 seconds in duration and should be timed to allow pedestrians to cross at least one lane of traffic or, in the case of a large corner radius, to travel far enough for pedestrians to establish their position ahead of the turning traffic before the turning traffic is released
- If a leading pedestrian interval is used, consideration should be given to prohibiting turns across the crosswalk during the leading pedestrian interval.

EXHIBIT 5.6 Pedestrian Crossing Times, Speeds, and Distances

CROSSING DISTANCE	AVERAGE PEDESTRIAN CROSSING TIME*	OLDER ADULT CROSSING TIME	MOBILITY IMPAIRED PEDESTRIAN CROSSING TIME
	at 3.5 ft/second (1.06 m/second)	at 3 ft/second (.91 m/second)	at 2.5 ft/second (.76 m/second)
24 FT – 2 LANES (7.3 M)	6.9 seconds	8 seconds	9.6 seconds
34 FT – 2 LANES WITH BIKE LANES (10.4 M)	9.7 seconds	11.3 seconds	13.6 seconds
46 FT – 3 LANES WITH BIKE LANES (14 M)	13.1 seconds	15.3 seconds	18.4 seconds
58 FT – 4 LANES WITH BIKE LANES (17.6 M)	16.6 seconds	19.3 seconds	23.2 seconds
70 FT – 5 LANES WITH BIKE LANES (21.3 M)	20 seconds	23.3 seconds	28 seconds

Pedestrian crossing rates. State of Hawaii, Dept. of Transportation (2013)

As noted earlier, there is a general acceptance that LPIs are not appropriate in every case. One concern is the delay for drivers at the intersection, which increases with an increase in traffic volume. A study from So. Korea found the delay increased from a minimum of 1.58 seconds to a maximum of 6.08 seconds following LPI application (Kim and Park 2019). Another microsimulation study involving 15 intersections determined that, while an LPI installation resulted in a tangible delay for vehicles, the level of service post-LPI was still at an acceptable level (Hasanpour and Persaud 2022). Cottrell & Mu (2004) cited a study that found the simulation analyses for two congested intersections before and after LPI implementation showed only a slight increase, and at times, an actual decrease in average total delay per vehicle following LPI installation. Successful LPI implementation also relies on driver attention and behavior to obey signals. This may involve additional educational efforts, since the operations may not meet most pedestrian or driver expectations (Bower, Sandoval et al. 2021).

In general, locations where geometry and/or vehicle volumes routinely cause problems for pedestrians entering the crosswalk are best suited for LPI consideration (Smaglik 2018). Lin, Wang et al. (2017) considered the following factors for consideration of LPI treatment:

- Crash history between pedestrians and turning vehicles
- Presence of visibility issues blocking driver view of pedestrian
- 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 crossing

Saneinejad & Lo (2015) developed guidelines for the implementation of LPIs in the City of Toronto, Ontario, Canada. An early pilot LPI in the city was removed within 6 weeks because of increased non-compliance by drivers. LPIs were successfully installed at several intersections after 2005, but the process was not streamlined. The authors sought to help traffic engineers determine suitable locations and have operation standards available. As part of the guidelines, a flowchart and worksheet were produced:

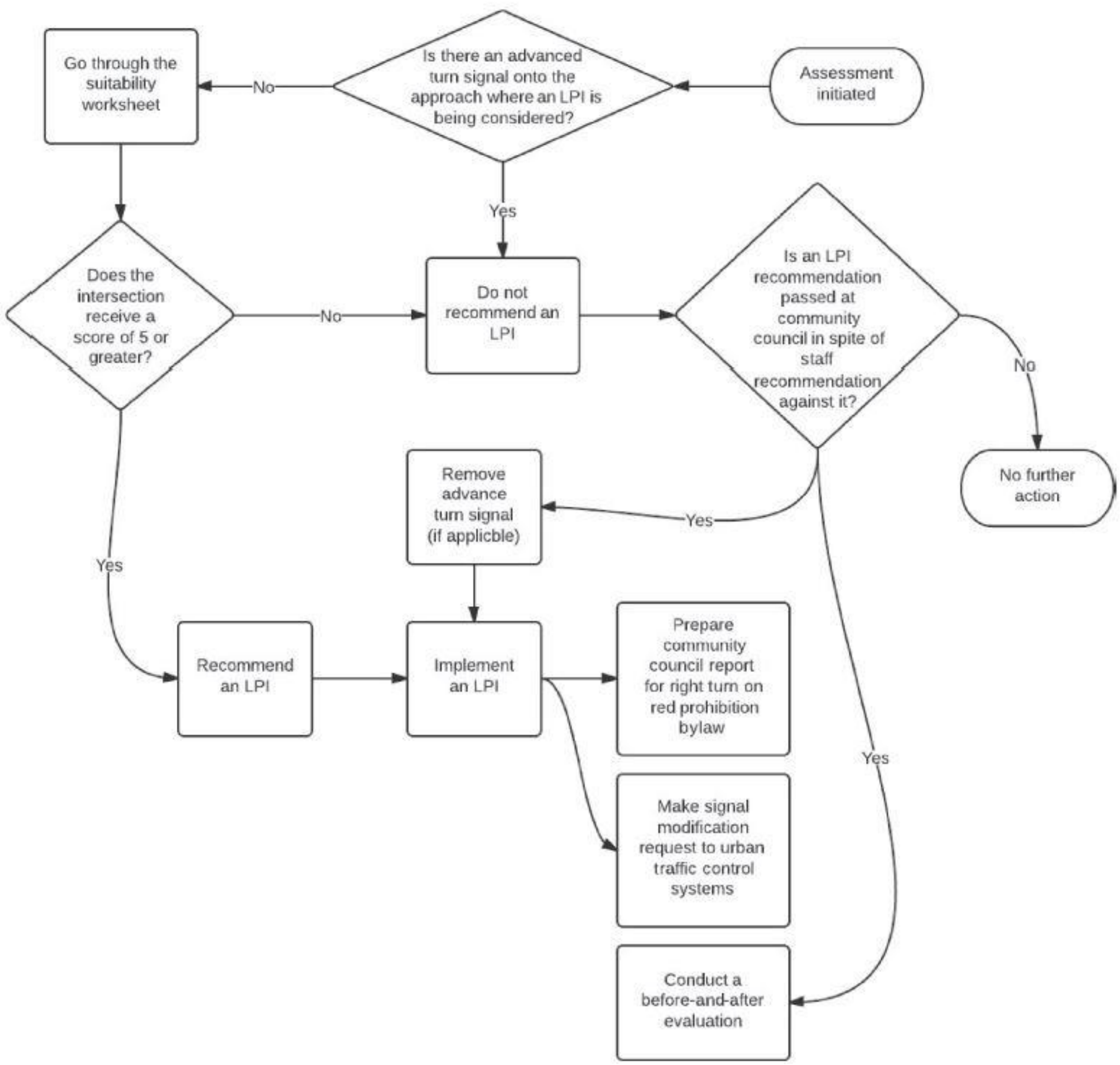


FIGURE 7 Flowchart on LPI suitability assessment and implementation.

(Saneinejad and Lo 2015)

Factor	Values	Score	Score Allocation Guide	Justification	Notes
a. Is the pedestrian crossing at a T-intersection (crossing is parallel to a road that ends at the intersection) **and/or** **Is the pedestrian crossing parallel to a one-way road?**		0 to 2	Yes = 2 No = 0	High level of potential safety improvement with LPI at T-intersections compared with regular intersections because all vehicles approaching a T-intersection make a left or right turn and left-turning vehicles do not need to wait for and yield to vehicles in the opposing direction. Similarly, left turning vehicles traveling on a one-way road do not need to wait for and yield to vehicles in the opposing direction.	
b. Are there issues such as safety concerns verified by staff or visibility issues caused by features such as irregular intersection geometry, wide-turning radius, crosswalk placement, obstructions such as buildings or base of a bridge, blinding sun angle?		0 to 2	Yes (4 or more issues) = 2 Yes (between 1 to 3 issues) = 1 No = 0	High level of potential safety improvement.	
c. 8-h volume of pedestrians (*p*) crossing the leg being considered for LPI		0 to 2	2 if $p > 1{,}000$ 1 if $200 < p \le 1{,}000$ 0 if $p \le 200$	High level of benefit for the highest number of pedestrians.	
d. What is the overall total impact on vehicles using the intersection? **(*a*) What is the increase in intersection total or average delay (%)?** **(*b*) What is the through phase V/C ratio of the signal with LPI?** **(*c*) What is the total 8-h vehicular volume at intersection?**		0 to -6	Overall impact = $-1 \times \lvert \mathrm{Min}(A, B) \times C \rvert$ where $A = \begin{cases} 0 & \text{if } a < 10\% \\ -1 & \text{if } 10\% < a \le 30\% \\ -2 & \text{if } a > 30\% \end{cases}$ $B = \begin{cases} 0 & \text{if } b < 0.9 \\ -1 & \text{if } b \ge 0.9 \end{cases}$ $C = \begin{cases} -1 & \text{if } c < 16{,}000 \\ -2 & \text{if } 16{,}000 \le c < 30{,}000 \\ -3 & \text{if } c \ge 30{,}000 \end{cases}$	High level of negative impact on traffic operations for a large number of drivers.	
e. What is the rate of annual collisions between pedestrians and left- or right-turning vehicles per 1,000 8-h pedestrian crossings at the specific crossing in the past 5 years?		0 to 2	None = 0 0–3 = 1 >3 = 2	High level of potential safety improvement.	
f. What is the rate of conflicts* (conflicts per 1,000 8-h observations) between pedestrians and left- or right-turning vehicles at the specific crossing during 8 h of observation during area-specific pedestrian peak and nonpeak periods?**		0 to 2	None = 0 0–3 = 1 >3 = 2		
g. How far is the location from the nearest elementary school?		0 to 2	<200 m = 2 >200 m and <850 m = 1 ≥850 m = 0	High level of benefit to smaller school children who are more negatively affected by visibility issues. Average distance of walk trips to school in Toronto is 850 m (Transportation Tomorrow Survey). 6% of walk trips to school are less than or equal to 200 m in distance (Transportation Tomorrow Survey).	
h. What is the elderly demand score (*e*) of the area where the intersection is located?		0 to 2	2 if $e = 5$ 1 if $4 \le e < 5$ 0 if $e < 4$	High level of benefit to slower walking pedestrians: elderly.	Look up score using this map.
Total score					

FIGURE 4 Worksheet for assessing LPI suitability (V/C = volume-to-capacity ratio). (*Conflicts and observations are defined in Section 6 of the City of Toronto LPI implementation guideline. **Collect conflict data only if total score without this information is less than 5 but greater than 3.)

(Saneinejad and Lo 2015)

As defined by the MUTCD (2009), the LPI interval should be at least 3 seconds in duration – long enough to allow pedestrians to cross at least the first traffic lane; longer in the case of a wider intersection, to allow pedestrians to establish their position ahead of the turning traffic before that traffic is released. The typical duration for LPIs is 3 to 5 seconds (Furth and Saeidi Razavi 2019), but can be up to 7 seconds if conditions warrant it (Hubbard, Bullock et al. 2008) . If the leading interval is extended too long, the rate of compliance decreases as motorists lose patience (Furth and Saeidi Razavi 2019) .

Dittberner & Vu (2017) calculated the desirable LPI duration as:

> $Dc = Xc \div V$ where:
> Dc = Desirable LPI duration for conflict #c, in seconds
> Xc = Walking distance from the curb to the point of conflict #c, in feet
> V = Walking speed, in feet per second. A speed of 3.5 feet per second is consistent with MUTCD signal timing guidance.
>
> Where pedestrians cross a wide street, the time needed for the pedestrian phase is often longer than the time needed for the concurrent vehicular phase. The difference between these times can be considered "potential LPI duration," calculated as:
> $Ps = W - Gs$ where:
> Ps = Potential LPI duration for signal timing plan s, in seconds
> W = Duration of the Walk plus Flashing Don't Walk (FDW), in seconds
> Gs = Green time for the concurrent vehicular phase in timing plan s, in seconds
>
> Note: Ps should be reduced by the amount of time FDW and concurrent yellow appear together.
>
> P likely varies by time of day if the signal has more than one timing plan. Agencies may not want (or be able) to vary a crossing's LPI duration by time of day. If so, P should be determined for each timing plan, then an intersection's P could be chosen to balance the benefits of the LPI with vehicular operations at different times of day.

The City of Toronto standard for LPI duration:

$$\text{LPI} = \text{greater of 5 s,} \quad \text{or } \frac{\left(\frac{\text{TL}}{2} + \text{PL}\right)}{W}$$

where

LPI = number of seconds from onset of "Walk" signal for pedestrians and green indication for vehicles;
TL = distance on crosswalk to clear the total width of all moving lanes between curb and centerline, not including the parking lane;
PL = distance on crosswalk to clear the parking and merging lane, if any; and
W = walking speed of 1.0 m/s.

(Saneinejad and Lo 2015)

The cost for implementation can range from practically nothing to over $100,000, depending on existing infrastructure (Bower, Sandoval et al. 2021). Fayish and Gross (2010) reported a cost of $1,000 per intersection for LPIs installed in State College, PA in 2005. This cost included controller programming and cabinet wiring to accommodate the existing controller assembly. The authors noted that implementing the LPI phasing into a new controller prior to installation would likely have had little cost. Bower, Sandoval et al. (2021) estimated that timing adjustment to existing infrastructure could range from almost nothing to approximately $3,500. However, they noted that if pedestrian signals are required, costs could range from $8,000 to $75,000 per intersection; additional costs such as pedestrian countdown timers, pushbuttons and other components could push the total cost to approximately $150,000 per intersection. A Florida study showed that older signal controllers (examples: TCT8000, TMP390) may need a new or additional phase for an LPI interval in order to allow the "Walk" signal while all other signals remain red (Lin, Wang et al. 2017).

Efforts have been made to conduct an economic and cost/benefit analysis for LPIs. Fayish and Gross (2010) assumed a 10-yer service life at a discount rate of 2.6% per year. The annualized cost of the LPI was computed to be $115 per intersection (based on the $1000 installation cost in State College). Their study showed an expectation of 30.85 pedestrian-vehicle crashes at the 10 intersections involved in the study without LPI implementation. Fourteen crashes were actually observed during the 3-year after period, which could be expressed as a reduction of 0.56 crashes per intersection. This equated to a cost savings of $92,130 per intersection per year (0.56 crash per year times $164.029 estimate per crash), resulting in a benefit-to-cost ration of 801.

Goughnour, Carter et al. (2018) also conducted an economic analysis, determining a 20-year service life and a real discount rate of 7%. This gave an annual cost of $112.80 per intersection. The project team calculated the aggregate 2016 cost for vehicle-pedestrian crashes at urban intersections to be $414,993, showing a 10.549 total crash reduction for all intersections. Using these estimates, the team determined the annual dollar benefit from reduced crashes due to LPI implementation to be $41,707 per intersection.

In summary, implementation of LPIs – particularly at urban intersections with relatively high pedestrian traffic – has been shown to be very effective under many circumstances. There are challenges, such as driver delays as a result of the leading walk interval, and there are intersections that would not be appropriate for LPI consideration for various reasons. Saneinejad and Lo (2015) worked to simplify the process to determine best practices in LPI implementation, giving traffic engineers a checklist for making decisions. The following table gives examples of policies and guidelines used by state DOTs regarding LPI impementation.

State	Title	Summary
Arizona	Leading Pedestrian Interval (LPI)	Arizona follows recommendations from MUTCD
DC Dept. of Transportation	Pedestrians get more time to cross busy streets under Mayor Bowser's Vision Zero Initiative	News release outlining the District's LPI program
Florida	Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida	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. 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.
Georgia	Pedestrian and Streetscape Guide	**Critical Design Requirements** ・ LPIs should provide pedestrians with a minimum lead of 3 seconds and should be timed to allow pedestrians to cross at least one lane of traffic or, in the case of a large corner radius, to travel far enough for pedestrians to establish their position ahead of the right-turning vehicle, before the right-turning vehicle is released (MUTCD Section 4E.06). ・ An advanced WALK signal should be displayed while red indications continue to be displayed to parallel through or turning traffic. ・ LPIs should be made accessible to visually impaired pedestrians. Refer to Section 5.2 for more information on accessible pedestrian signals. **Additional Considerations** ・ At intersections with a shared use path or bike infrastructure, a leading bicycle interval may be provided along with the LPI to reduce bicycle-vehicle conflicts. ・ Curb extensions may be used in combination with leading pedestrian intervals to improve the visibility between pedestrians and turning vehicles and to shorten the crossing distance. Refer to Section 4.4.2 for more information. ・ "No Turn on Red" (R10-11) prohibitions may be considered during the LPI.
Hawaii	Hawaii Pedestrian Toolbox, Section 5: Intersections and Crossings	Follows recommendations from MUTCD, for the most part. Designates buffer period of at least 3 seconds – more if significant percentage of pedestrians are older or disabled. "Current research suggests that if more than 20 percent of the people in the pedestrian stream are elderly, a slower walking speed of 3 fps should be used". Advocates the use of count-down displays.

Indiana	2011 Indiana Manual on Uniform Traffic Control Devices, Revisions 1, Part 4E	Duplicates the portion of the federal MUTCD regarding LPIs in their state version.
Michigan	Synthesis of national best practices on pedestrian and bicycle design, guidance, and technology innovations	Research sponsored by MDOT. MSU research team performed tasks including a review of current practices, the collection of information from Michigan's stakeholders, the identification of updates to MDOT planning and design materials, and the development of materials to promote pedestrian and bicycle innovations. Contains MSU update to Best Design Practices for Walking and Bicycling in Michigan, include design practice for LPI implementation.
Minnesota	Minnesota's best practices for pedestrian and bicycle safety	The MnMUTCD provides guidance for LPIs. It states that if they are used, designs should include the following: • Accessible pedestrian signals • A minimum 3-second interval, depending on the crossing width, site location, and other factors • Consider prohibition of turns across the crosswalk during the LPI • Intersections that experience patterns of vehicle pedestrian conflicts for all movements and guidance about optimal yellow change interval timing can be found in the FHWA Traffic Signal Timing Manual.
Minnesota	Pedestrian Treatments: Intersections. Practice Summary	Recommends WALK indication 2 to 5 seconds prior to the GREEN ball for vehicles. This technique does require a longer ALL RED interval and will cause a slight increase overall intersection delay
North Carolina	Guidelines for Implementation of Right Turn Flashing Yellow Arrows and Leading Pedestrian Intervals	Offers considerable guidelines for the implementation of FYAs or LPIs considering various intersection geometric features, traffic demands, and signal control strategies. Although there is no current research on its effectiveness as a supplemental sign at these treatment locations, a recommended treatment that could be considered for these sites could be a "blank out" sign that says "Yield to Pedestrians" when the push button is activated. If this additional treatment is utilized, it would be advisable to document the effectiveness of the treatment through a before-and-after study.
Pennsylvania	Leading Pedestrian Interval Policy	The decision process for LPI implementation should be documented using the TE-672 "Pedestrian Accommodations at Signalized Intersections" Form. The decision to implement LPI should be based on engineering judgement. The following are some of the considerations that may influence an engineering judgement decision: a) Local Experiences: Citizen complaints about turning vehicles not yielding to

		pedestrians. b) Crash Data/Conditions: Historical crashes between vehicles turning on green and pedestrians in the crosswalk with the pedestrian walk signal indication illuminated (or the presence of conditions that could potentially lead to such crashes - including, but not limited to, those described in sub-sections 3(c), 3(d), and 3(e)). c) Land-Use Context: LPI can be particularly useful in pedestrian generator locations such as playgrounds, parks, schools, recreation centers, urban areas, hospitals, retirement/assisted-living communities, transit stops, etc. d) Intersection Type and Operation: Intersections with a high proportion of vehicle turning movements that conflict with pedestrians, such as T-intersections or one-way streets. e) Visibility Issues: Concerns for reduced pedestrian visibility by drivers, due to obstructions or poor sight distance. At a minimum, the following should be considered: ♣ Sun angle ♣ Lighting ♣ Intersection geometry
Utah	Development of New Pedestrian Crossing Guidelines in Utah	At particularly busy (pedestrians and vehicles) signalized intersections, consider using a leading pedestrian interval (LPI). The LPI should be between 3 and 5 sec; longer LPIs may be needed at locations with very heavy pedestrian volumes.
Virginia	VDOT Pedestrian Safety Action Plan	Suggestion: Update VDOT-specific guidance on countermeasure selection and treatments at uncontrolled crossings and signalized intersection crossings VDOT does not have statewide guidance in place for installation of countermeasures at signalized intersections. Forthcoming guidance should describe best practices for installing pedestrian signals, Leading Pedestrian Intervals (LPI), and signal timing or split-phasing improvements for pedestrian crossings. A regulatory sign that prohibits right turns during the red signal phase, and it is often installed in areas of high pedestrian volumes or during exclusive pedestrian phases. Together with a leading pedestrian interval, the signal changes can benefit pedestrians with minimal impact on traffic.

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