# Intersections

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>137</td>
</tr>
<tr>
<td>Intersection Design Principles</td>
<td>138</td>
</tr>
<tr>
<td>Multimodal Intersections</td>
<td>141</td>
</tr>
<tr>
<td>Intersections and Street Types</td>
<td>148</td>
</tr>
<tr>
<td>Placemaking at Intersections</td>
<td>151</td>
</tr>
<tr>
<td>Intersection Geometry</td>
<td>157</td>
</tr>
<tr>
<td>Crosswalk Design</td>
<td>171</td>
</tr>
<tr>
<td>Guidelines for Crosswalk Installation</td>
<td>175</td>
</tr>
<tr>
<td><strong>Signalized Intersections</strong></td>
<td><strong>185</strong></td>
</tr>
<tr>
<td>Transit Accommodations at Intersections</td>
<td>195</td>
</tr>
<tr>
<td>Bicycle Accommodations at Intersections</td>
<td>205</td>
</tr>
</tbody>
</table>
The Boston Transportation Department operates over 800 traffic signals located in Boston. Its Transportation Management Center (TMC) monitors, coordinates, and adjusts signals to improve traffic flow and pedestrian safety on city streets. The TMC computers control over 450 key signals, allowing for real-time adjustments to be made in response to unusual traffic conditions and emergencies. In addition, BTD owns over 100 closed-circuit televisions (CCTV) to monitor traffic conditions, and has access to Boston Police and state agency cameras.

The City of Boston’s policy is to prioritize the safety, comfort, and convenience of all users at signalized intersections. All signalized intersections should contain indications for motor vehicles and pedestrians, and signals for bicyclists and transit where appropriate. By optimizing signal phasing and timings, multiple modes are able to safely move through the intersection with limited conflicts, low delay, and more comfort.

All signal designs must be approved by BTD. For additional signal design guidance, reference BTD’s Traffic Signal Operations Design Guidelines, the MUTCD, and the HCM.
Overview

Signal timing for pedestrians is provided through the use of pedestrian signal heads. Pedestrian signal heads display the three intervals of the pedestrian phase:

- **The Walk Interval**, signified by the WALK indication—the walking person symbol—alerts pedestrians to begin crossing the street.

- **The Pedestrian Change Interval**, signified by the flashing DON'T WALK indication—the flashing upraised hand symbol accompanied by a countdown display—alerts pedestrians approaching the crosswalk that they should not begin crossing the street. The countdown display alerts pedestrians in the crosswalk how much time they have left to cross the street.

- **The Don’t Walk Interval**, signified by a steady DON'T WALK indication—the steady upraised hand symbol—alerts pedestrians that they should not cross the street. The beginning of the Don’t Walk Interval is called the Buffer Interval, which should be displayed for a minimum of a three seconds prior to the release of any conflicting motor vehicle movements.

The total time for the pedestrian change interval plus the buffer interval is called the pedestrian clearance time, or the time it takes for a pedestrian to clear the intersection leaving at the onset of the DON'T WALK indication.

Pedestrian signal heads should be provided at all signalized intersections for all crosswalks; additionally, it is highly recommended to install crosswalks on all legs of a signalized intersection unless determined otherwise by an engineering study. Signal timing for pedestrians should be provided at all newly constructed signalized intersections and incorporated into all signalized intersection improvements. For information on requirements for accessible pedestrian signals, see Accessible Pedestrian Signals later in this chapter.
The following design goals can help improve pedestrian crossing safety and comfort at signalized intersections:

- Reduce vehicle speeds
- Minimize crossing distance
- Minimize delay for WALK indication
- Minimize conflicts with turning vehicles
- Provide sufficient signal time to cross the street

All signal designs must be approved by BTD.

Use

Walking Speed
Pedestrian signals should allocate enough time for pedestrians of all abilities to safely cross the roadway. The MUTCD specified pedestrian walking speed is 3.5 feet per second to account for an aging population. The pedestrian clearance time, which is the total time for the pedestrian change interval plus the buffer interval, is calculated using the pedestrian walking speed and the distance a pedestrian has to cross the street.

Countdown Pedestrian Displays
Countdown pedestrian displays inform pedestrians of the amount of time in seconds that is available to safely cross during the flashing Don’t Walk Interval. Research has shown that pedestrians have a better understanding of the pedestrian phase when countdown displays are provided. All pedestrian signal heads should contain a countdown display provided with the DON’T WALK indication.

Considerations

One of primary challenges for designers is to balance the goals of minimizing conflicts between turning vehicles with the goal of minimizing the time required to wait at the curb for a WALK indication. Intersection geometry and traffic controls should facilitate turning vehicles to yield the right-of-way to pedestrians. Requiring pedestrians to wait for extended periods can encourage crossing against the signal. Concurrent phasing should be considered to reduce delay for pedestrians and motorists. The 2010 HCM states that pedestrians have an increased likelihood of risk-taking behavior (e.g., jaywalking) after waiting longer than 30 seconds at signalized intersections. Strategies to achieve this balance include minimizing signal cycle lengths, concurrent phasing, discussed on the next page, the use of a Leading Pedestrian Interval, discussed later in this chapter, and reducing turning speeds to increase yielding, discussed in Curb Radii and Corners found earlier in this chapter.

Opportunities to provide a WALK indication should be maximized whenever possible. Vehicular movements should be analyzed at every intersection in order to utilize non-conflicting phases to implement Walk Intervals. For example, pedestrians can always cross the approach where vehicles cannot turn at a four-leg intersection with the major road intersecting a one-way street, when the major road has the green indication.
Overview

There are two primary approaches to time the pedestrian phase; an exclusive or a concurrent phase. An exclusive pedestrian phase is an additional phase in the signal cycle that is provided only for pedestrian movements while all vehicular traffic is stopped. A concurrent pedestrian phase is when pedestrians are able to cross while parallel and conflicting vehicular traffic are also moving. Concurrent pedestrian phasing usually provides the least amount of delay for pedestrians, and motorists in most circumstances due to shorter cycle lengths, and therefore can reduce non-compliance (jaywalking) and increase safety.

Another type of phasing is a protected pedestrian phase, which is when pedestrians are able to cross when there are no conflicting movements with motorists resulting from geometry, one-way allocations, or conflicting motorists have a red indication.

BTD’s Traffic Signal Operations Design Guidelines encourage using concurrent pedestrian phases to promote pedestrians crossing with the Walk Interval, and to help reduce delays to pedestrians and motor vehicles.

Use

- Protected pedestrian phases should always be used when there are no conflicting movements with other modes.
- Exclusive pedestrian phases and protected pedestrian phases should generally be used at intersections:
  - Where conflicting turning vehicles are equal to or greater than 250 vehicles per hour
  - Where sight distance is restricted
  - With complex intersection geometry
  - Near elderly housing, schools, recreational areas, medical facilities, or other facilities within a safety zone
  - Concurrent pedestrian phases should be used at all intersections where the above conditions are not present. Concurrent phasing should be accompanied by proper signage, such as TURNING VEHICLES YIELD TO PEDESTRIANS and WATCH FOR TURNING VEHICLES.

Considerations

- Exclusive pedestrian phases increase pedestrian safety but can also increase delay for all intersection users.
- Leading pedestrian intervals may be considered in conjunction with concurrent phasing and are discussed later in this section.
- NO TURN ON RED signs should be considered at intersections with exclusive pedestrian phases and are discussed later in this section.
- TURNING VEHICLES YIELD TO PEDESTRIANS and WATCH FOR TURNING VEHICLES signs should be used at intersections with concurrent pedestrian phases where conflicting vehicle movements are present.
- A leading left-turn (i.e., left-turn arrow) can be confusing for pedestrians who expect it to be safe to step into the roadway once crossing traffic receives a red indication. Where a left-turn arrow is provided for motor vehicles, a lagging left-turn phase should be used wherever possible.
**Automatic vs. Actuated Pedestrian Phases**

**Overview**

Pedestrian phases can be programmed to be automatic each cycle, or be actuated using pushbuttons. Automatic pedestrian phases are preferred and should be used in high pedestrian volume areas where the pedestrian phase is needed during every intersection cycle. Research has shown that only 50% of pedestrians actually use pushbuttons when provided. Vehicles at signalized intersections are detected automatically, so pedestrians should be provided the same service. Pedestrian pushbuttons should be used rarely, and only when absolutely necessary.

**Use**

Where feasible, the pedestrian phase should be automatic during every cycle. In limited situations where pedestrians are present for less than 50% of the time during peak hours, pushbuttons may be considered. In Boston there are very few intersections where this is not the case, and automatic pedestrian phasing may still be appropriate even where pedestrian volumes do not meet 50% during peak hours when determined by an engineering study on a case-by-case basis.

- **Actuated**
  - WALK indication displays when activated by a push button.

- **Pre-timed**
  - WALK indication displays automatically every signal cycle.

Overall the goals of signal design are reliability and consistency. Consistent and predictable movements are crucial for making Boston’s streets safe. Boston has one of the oldest signal systems in the country, and BTD is working to update the system to accommodate all modes equitably and efficiently.

Pushbuttons may be considered in the following situations:

- At intersections that experience infrequent pedestrian use.
- At intersections designed to operate with motor vehicle detection that is actuated or semi-actuated.
- In cases where pedestrians are not able to cross the entire street in one phase. In this situation, a pedestrian pushbutton must be provided in the median and the median must be a minimum of 6’ wide.

**Considerations**

- Accessible pedestrian signals and pushbuttons are required in the U.S. Access Board’s proposed Accessibility Guidelines in Public Right-of-Way when new pedestrian signals are installed. Note accessible pedestrian signals and pushbuttons may be used at automatically timed pedestrian signals; however, they will only call accessible features, not the pedestrian WALK indication. For more information, see Accessible Pedestrian Signals found later in this section.

Where concurrent pedestrian phasing is used at locations where motor vehicles cannot turn onto a one-way street, pedestrian signals provided to cross the one-way street should be given a WALK indication and clearance interval each time while the major street is being served.

Details on where pushbuttons should be provided are located in the latest edition of the MUTCD. Research is also being conducted on developing passive pedestrian detection devices that would activate the pedestrian phase based on the presence of pedestrians either at the curb or within the crosswalk. These devices would eliminate the need for pedestrians to use the pushbutton; however, they can be more expensive to install and maintain.
Leading Pedestrian Interval

Overview

The Leading Pedestrian Interval (LPI) is when pedestrians are given the WALK indication 3 to 7 seconds before conflicting motor vehicles traveling in the same direction are given a green indication. Essentially, pedestrians are given a head start, allowing people to enter the crosswalk prior to turning vehicles, increasing visibility between all modes. The LPI should be timed so a pedestrian can travel across one lane of traffic or establish themselves in the intersection in front of turning vehicles. The FHWA has determined that the LPI currently provides a crash reduction factor for pedestrians of 5%, and especially benefits slower pedestrians.

Use

- The City is looking to expand the use of LPIs with concurrent phasing as an alternative to exclusive phases. LPIs should be considered at intersections with high conflicts of pedestrians and turning vehicles as determined by BTD.
- A lagging protected left arrow for vehicles should be provided to accommodate the LPI.
- Intersections with LPIs should be accompanied by appropriate signage, such as TURNING VEHICLES YIELD TO PEDESTRIANS.
- Newly installed LPIs must provide accessible pedestrian signals and pushbuttons.

Considerations

- NO TURN ON RED signs should be considered with LPIs.
- In general, concurrent pedestrian phasing should appropriately match the motor vehicle signal phasing. At intersections with high pedestrian volumes where drivers have difficulty finding gaps to turn, the green time can be intentionally extended past the Don’t Walk Interval in order to allow the turning movement.
- In addition to the LPI, bicyclists traveling in the same direction as pedestrians should be provided a leading bicycle interval using a bicycle signal head.
Overview

NO TURN ON RED signs are used to restrict vehicles from turning right, or left on intersecting one-way streets, during the red indication. Restricting this movement eliminates conflicts with pedestrians crossing in front of vehicles making turns.

Use

NO TURN ON RED signs should be considered when one or more of the following conditions apply:

- An exclusive pedestrian phase
- An LPI
- High volumes of pedestrian and turning vehicle conflicts
- Poor sight distances and visibility
- Geometry of the intersection may result in unexpected conflicts
- More than three accidents reported in a 12-month period between pedestrians and vehicles where turn-on-red is permitted
- Bicycle boxes

Considerations

- NO TURN ON RED signs can be provided at all times or by a dynamic sign that changes when pedestrians are present, by time of day, by a call made by an emergency vehicle, and/or at rail or light transit crossings.
- NO TURN ON RED signs can also be used in conjunction with LPIs, or bicycle signals that allow through movements when turning vehicular traffic is stopped.
Coordinated Signal Timing

Overview

Coordinated signal timing is the synchronization of multiple signalized intersections in close proximity to improve operations, and is often referred to as the “green wave” for roadway users. The green wave is achieved by designing traffic signals to allow vehicles to progress along a corridor at a set speed in order to obtain green lights at signalized intersections. By coordinating signals, vehicular platoons move through signalized intersections along a corridor with ease and can minimize mid-block speeding.

All signal timing should be developed with an engineering study in conformance to BTD Traffic Signal Operations Design Guidelines.

Use

A well coordinated signalized corridor can enhance traffic flow by minimizing travel times, stops, delay, and pollution. BTD’s TMC monitors, coordinates, and adjusts the city’s traffic signals on a real-time basis. Traffic monitoring cameras are used to monitor traffic conditions and verify incidents in real-time. Signal timing is adjusted as needed by TMC engineers.

Considerations

- Signal progression at slower speeds is a tool that can help calm traffic, however it should be used in conjunction with other methods to deter speed spiking between signals.
- The impacts of coordinated signals for vehicles along a corridor must consider and mitigate the impacts on other users.
- The overall goal of signal design is to minimize cycle lengths to reduce delay for all users. Long cycle lengths make walking less convenient and may encourage unsafe behavior such as pedestrians jay walking and bicyclists running red lights. Signal coordination should be optimized to balance the needs of all users and to minimize the delay for pedestrians, bicyclists, and transit vehicles.
- Bicycle speeds should be considered when designing a coordinated signal system along priority bicycle routes. To the extent possible, the coordination should allow both motorists and bicyclists to travel through multiple intersections without stopping.
Accessible Pedestrian Signals (APS)

Overview

Accessible pedestrian signals (APS) and accessible detectors are devices that communicate information in non-visual formats about the pedestrian phase to pedestrians with visual and/or hearing disabilities. APS and detectors may include features such as audible tones, speech messages, detectable arrow indications and/or vibrating surfaces.

The major functions of the APS are to provide information for:
- Location of pushbuttons, if used
- Beginning of WALK interval
- Direction of crosswalk
- Location of destination sidewalk
- Intersection street name in Braille or raised print
- Intersection signalization with speech messages
- Intersection geometry through detectable maps or diagrams or through speech messages

Non-visual pedestrian signal features should be provided at signalized intersections based on engineering judgment as outlined in the MUTCD.

Vibrodetectable devices vibrate to communicate information through touch. Vibrodetectable arrows indicate when the WALK indication is in effect, and which direction to cross.

Pushbutton locator tones are used for locating the pedestrian pushbutton needed to actuate the WALK interval. Detectable arrows should be located on pushbuttons to point in the same direction as the crosswalk. At corners of signalized locations where two pushbuttons are present, they should be separated by at least 10’.

For automatically called pedestrian phases, pushbuttons can be used to activate accessible pedestrian signal features such as detectable arrow indications and/or speech messages.

All accessible pedestrian signal designs must be approved by BTD and conform to the guidelines set by the U.S. Access Board.

Use

- When new pedestrian signals are installed, APS and pushbuttons are required in the accessibility guidelines for the public right-of-way by the U.S. Access Board.
- For existing pedestrian signals, the proposed guidelines require APS and pedestrian pushbuttons to be provided when the signal controller and software are altered, or the signal head is replaced.
- At new locations where the pedestrian phase is automatic (pushbutton activation is not required as the pedestrian phase recalls every signal cycle) accessible pedestrian pushbuttons only call accessible features, not the pedestrian WALK signal indication.

Considerations

- Audible walk indications should have the same duration as the pedestrian walk indication unless the pedestrian signal rests during the pedestrian phase, in which the audible indication should be provided in the first 7 seconds of the Walk Interval.
- For detailed information on accessible signals and pushbuttons, please refer to the United States Access Board’s website.