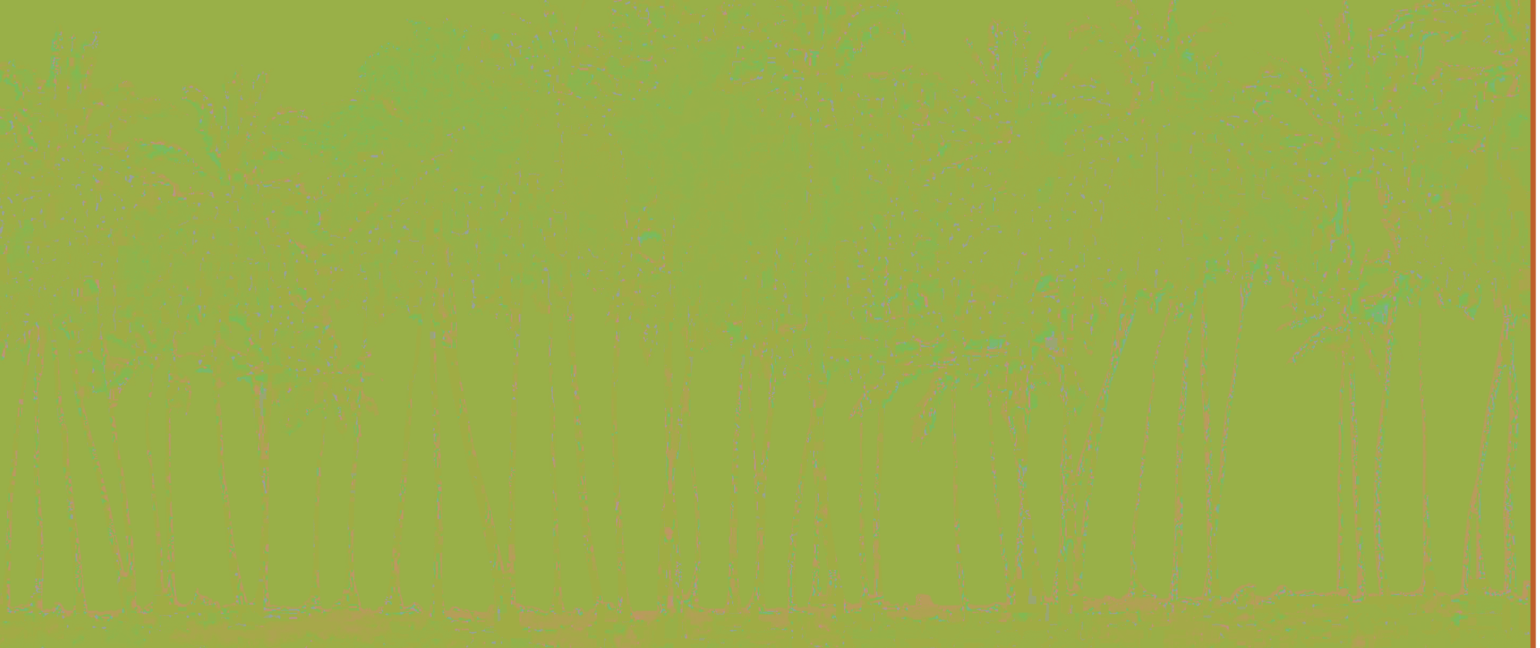


TOOLBOX SECTION 5

Intersections and Crossings

Hawaii's beautiful weather encourages pedestrian activity.

INTERSECTIONS AND CROSSINGS

Intersections and crossings occur wherever the pedestrian network intersects the roadway network. Pedestrians are extremely vulnerable at these locations because they move so slowly relative to vehicles, and they weigh so much less than vehicles. For these reasons pedestrian safety should be a high priority when designing or retrofitting intersections and crossings.

Pedestrians at a marked crosswalk

Since pedestrians are actually *in* the roadway/street at intersections and crossings, many of the recommendations below involve roadway design specifically, including markings, signs, signalization, and geometry. All designers, including roadway and traffic engineers, urban designers, landscape architects, and others should actively use the guidance in this toolbox section to enhance pedestrian safety.

Design Practices at Intersections

Intersection design requires consideration of all potential users, especially pedestrians who are the most vulnerable while crossing. Design solutions need to protect the safety of pedestrians, while also improving their accessibility and mobility. At the same time, design solutions still need to meet the needs of motorists and bicyclists. Carefully implemented engineering studies can help determine the best solutions for each location on a case-by-case basis. Sometimes what is the best design solution for pedestrians does not work well for bicycles and/or vehicles and vice versa. The needs of all intersection users must be considered.

IN THIS SECTION

EXHIBIT 5.1 Basic Principles of Intersection Design to Accommodate Pedestrians

Design compact intersections.
Eliminate unrestricted motor vehicle movements.
Reduce motor vehicle speeds through intersections.
Create crossings on all legs of an intersection.
Design crossing in a direct line, at 90 degrees to the direction of vehicular travel, as feasible.
Clearly identify crossings to all pedestrians, including those with sight impairments.
Avoid multiple and skewed intersections.

Commonly used crossing improvements include: crosswalks, curb ramps, pavement markings, pedestrian refuges, signalization, signage, and lighting. Exhibit 5.1 lists some basic principles of intersection design related to the needs of pedestrians.

DETERMINING THE NEED FOR CROSSING IMPROVEMENTS AT INTERSECTIONS

Intersections can be made more pedestrian-friendly by implementing designs that improve crossing conditions, reduce crossing distances, and minimize conflicts between pedestrians, bicycles, and motor vehicles. In all cases, the crossing treatment should be guided by engineering analysis that clearly determines the needs and provides recommendations for the improvement of pedestrian facilities. Each location should be studied on a case-by-case basis. Special conditions (such as land use, school routes, pedestrians with special needs, etc.) may exist that need to be addressed with pedestrian facilities.

Crosswalk Markings

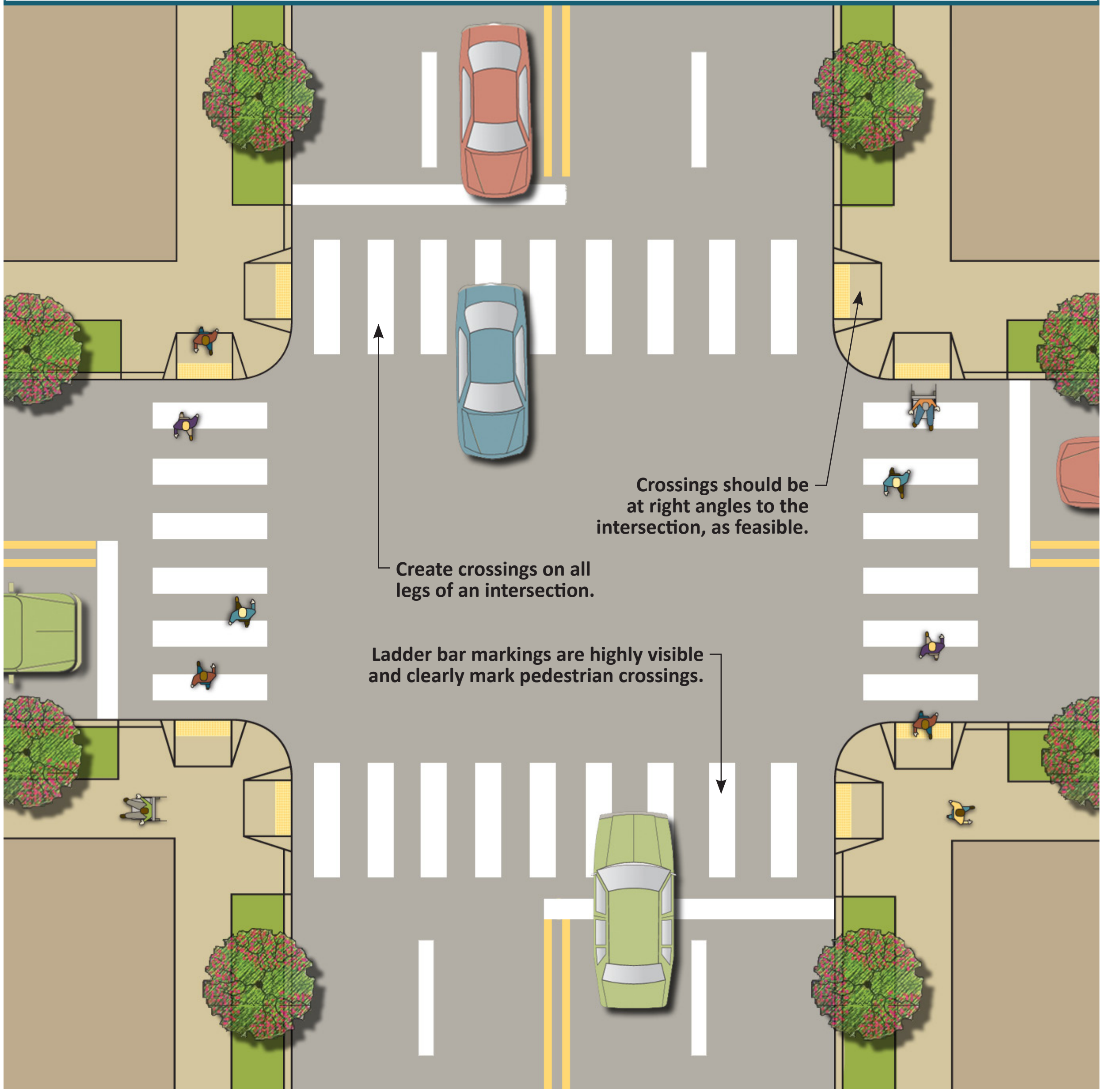
Marked crosswalks alert motorists to the potential of pedestrians crossing and define the area where pedestrians have the right-of-way. At stop-controlled or signalized intersections, the preferred marking, and the Hawaii Department of Transportation (HDOT) standard is the ladder style crosswalk.

On multi-lane roads with an ADT of 12,000 or more, marked crosswalks should always be combined with other pedestrian safety measures, such as stop or yield signs, signalization, or raised medians (see sidebar on page 5-3).

CROSSWALK DIMENSIONS

The HDOT standards require that crosswalks be a minimum of 10 ft (3.0 m) wide and at least as wide as the approaching sidewalk. In high pedestrian areas, crosswalks can be up to 20 ft (6.1 m). The approaching sidewalk and corner area at the intersection needs to be free of obstructions so that pedestrians can freely travel in either direction to cross the street. Exhibit 5.2 shows typical crosswalk markings at an intersection.Exhibit 5.3 shows typical crosswalk dimensions. The HDOT standards call for the width of the ladder bars to be 12 in (30.5 cm) with 18 in (45.7 cm) spacing.

EXHIBIT 5.2 Typical Crosswalk Markings



MARKING CROSSWALKS

The Federal Highway Administration's 2005 study, "Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations", evaluated pedestrian crashes at 1,000 marked crosswalks and 1,000 matched but unmarked comparison sites. None of the sites in the study had traffic signals or stop signs on the approach to the crosswalk. The results of the study indicated:

ON TWO-LANE ROADS

- *There was no difference in crash rates based on the presence or absence of a marked crosswalk.*

ON MULTI-LANE ROADS

- *On roads with an ADT of 12,000 or more, the presence of a marked crosswalk alone, without any other improvements to pedestrian safety, was associated with a higher rate of crashes. (Meaning: additional improvements such as advance and overhead signs, refuge islands, etc. are needed at these locations.)*
- *Raised medians and refuge islands are associated with a significantly lower rate of pedestrian crashes with both marked and unmarked crosswalks.*
- *Painted medians do not significantly improve pedestrian safety at crossings, compared to multilane roads with no median at all.*
- *Older pedestrians have higher crash rates relative to their exposure than other age groups.*

ADVANCE STOP BARS

The advance stop bar increases the time for a vehicle to enter the intersection on green, and may result in a modest reduction in intersection capacity. However, advance stop bars may be of benefit in reducing the frequency of crashes from red-light running.

Crosswalks that lead to public amenities such as a park, beach, or civic building can be considerably wider than ten feet and can be enhanced with special markings or paving treatments (see below for types of markings).

TYPES OF CROSSWALK MARKINGS

Markings at crosswalks include striping patterns, stop bars, advance stop bars and yield signs, and sometimes other features. The ladder bar crosswalk marking pattern is the most frequently used because it is highly visible to pedestrians and motorists and can be spaced to avoid tire friction, thus reducing maintenance costs.

STOP BARS, ADVANCE STOP BARS

Stop bars are typically placed at intersections (where motorists are required to stop) to prevent overhang into crosswalk areas. Stop bars are normally 12 to 24 in wide (30.5 to 61.0 cm) white stripes that extend across all approach lanes. They should be located at least 4 ft (1.2 m) in advance of the crosswalk, and parallel to it. The HDOT standard is a 12 in (30.5 cm) wide white line, a minimum of 4 ft (1.2 m) in advance of the crosswalk. Where there are heavy truck volumes, the stop bar should be set farther back in the receiving street so that large vehicles have ample room to complete their turn. Stop bars

EXHIBIT 5.3 *Crosswalk Dimensions*

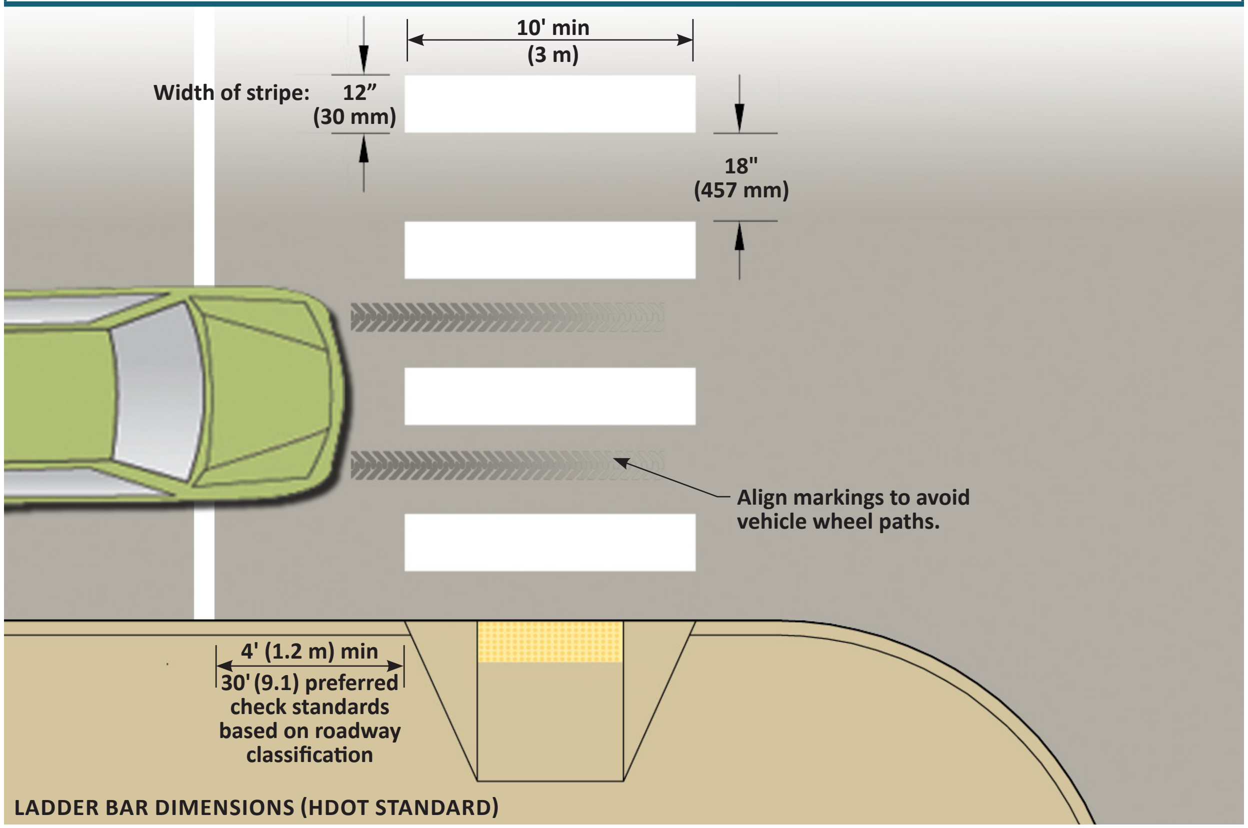
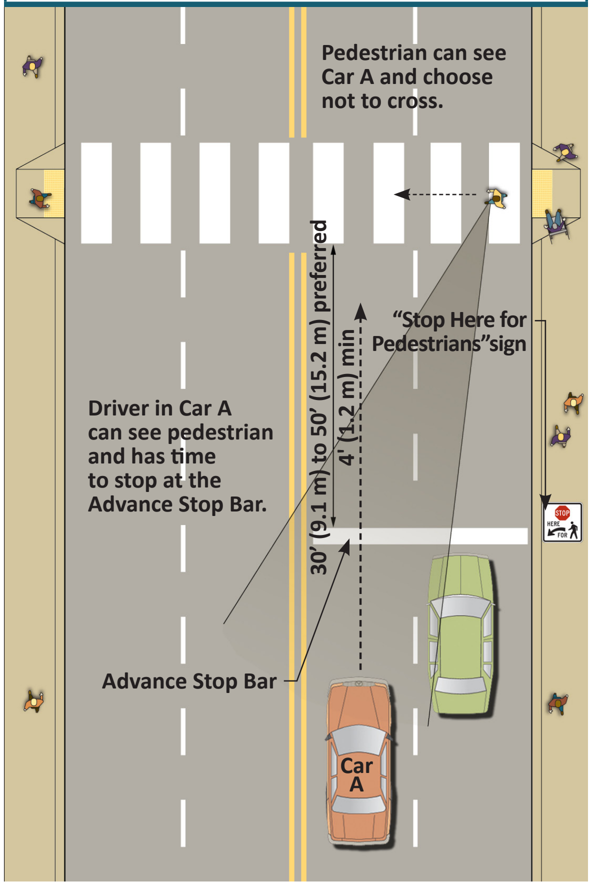


EXHIBIT 5.4 ***An advance stop bar gives both pedestrians and motorists better visibility.***



can be installed at an angle for this purpose. Stop bars should also be used for right-turn-on-red movements and for vehicles turning left from the cross street.

On multiple lane roadways at uncontrolled approaches, advance stop lines increase the safety of pedestrians by reducing the screening effect of vehicles in the right lane. Advance stop bars should be used with a "Stop Here for Pedestrians" sign. (See Exhibit 5.4.)

RUMBLE STRIPS

Rumble strips with raised or recessed pavement treatments are sometimes placed in advance of crosswalks in rows, which create a "rumbling" effect alerting approaching drivers of the upcoming crosswalk. These types of markers should only be used if they can be placed far enough in advance of the crosswalk to be an effective warning device (at the same location as the crosswalk advance warning sign). Raised pavement markers must be placed outside the required clearance area of bike lanes and should only be installed after an engineering study determines they are appropriate. In addition, care should be taken in the use of rumble strips as they

Pedestrians use crosswalks in a variety of ways. (Source: A parrot talks in Chocolate.com)

Wide crossings with no markings create uncomfortable places for pedestrians.

Crosswalk markings clarify the space used by pedestrians.

Painted markings can deteriorate quickly. Regular inspection and maintenance contribute to pedestrian safety.

can cause higher noise levels which could affect nearby residents. They may be more suitable for gateways where frontage property is limited.

CROSSWALK MARKING MATERIALS AND MAINTENANCE

Crosswalk marking materials include inlay tape, thermoplastic, and paint. Exhibit 5.5 summarizes the qualities of each. Specific design details related to pavement striping and marking techniques can be found in the 2009 Manual on Uniform Traffic Control Devices (MUTCD). Other materials such as concrete, unit pavers, painted stencil patterns, and stamped asphalt may be used, but refer to the MUTCD for requirements related to contrast.

EXHIBIT 5.5 ***Crosswalk Marking Materials***

INLAY TAPE	Highly visible, not slippery, requires expertise to install correctly; recommended for new and resurfaced pavement; more cost-effective than paint in the long run
THERMOPLASTIC	Highly visible, not slippery, may be a better option than tape on rough surfaces
PAINT	Low initial cost, but slippery and not as visible as tape or thermoplastic; requires frequent repainting

Source: Pedestrian and Bicycle Information Center (PBIC), Crossing Enhancements

Markings should be monitored regularly, maintained in good condition, and should be removed when no longer needed.

Curb Ramps

Curb ramps are often considered to be the most important elements of an accessible pedestrian environment because they provide accessibility at the grade transition from the sidewalk to the street. They facilitate crossing for wheelchair users, people pushing strollers, bicyclists, and others. When properly located, they can also help direct pedestrians, including people who are blind or have low vision, toward the crosswalk. Toolbox Section 3—Accessibility discusses placement and design of curb ramps.

Signalization

DETERMINING THE NEED FOR PEDESTRIAN SIGNALS

Pedestrian signals should be installed wherever there is a traffic signal, except where pedestrians are prohibited such as on certain highways, as recommended by the Pedestrian and Bicycle Information Center (PBIC). Major factors in pedestrian signalization design include signal timing, types of signals, and placement and design of both signals and pedestrian actuators. Signalization should be designed in accordance with an engineering study. The MUTCD provides guidelines for determining warrants for signalization based on:

1. Vehicular traffic alone
2. A combination of pedestrian and vehicular traffic
3. School zone pedestrian and vehicular traffic
4. Crash experience

See the 2009 MUTCD Section 4C for more information.

The revised minimum pedestrian volume warrant in the MUTCD states that a traffic signal may be warranted when the pedestrian volume crossing the major street at an intersection or mid-block location during an average day is either (1) 100 or more for each of any four hours or (2) 190 or more during any one hour. These volume requirements may be reduced by as much as 50 percent when the predominant crossing speed is below 4 feet per second/fps (1.2 meters per second/mps). A traffic signal may not be needed, however, if adjacent traffic signals consistently provide gaps of adequate length for pedestrians to cross the street at least every minute.

It should be noted that these are guidelines. Engineering analysis should be conducted on a case-by-case basis to determine the need for traffic and pedestrian signals. The analysis may consider special factors, including proximity of the intersection to school zones, as well as areas where pedestrians with special needs may use the intersection (such as near senior centers, hospitals, etc.). The best practice is to consider the needs of pedestrians, along with all other intersection users, in the analysis process.

PEDESTRIAN SIGNAL INDICATIONS

See the American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Planning, Design, and Operation of Pedestrian*

Pedestrian signal showing flashing upraised hand with countdown display, Kirkland, WA

Pedestrians cross streets at various rates of speed.

Mid-block crossings can improve mobility and increase pedestrian activity.

Facilities for locations where pedestrian signal indications should be provided at traffic signals. Provide pedestrian signal indications where:

1. Traffic signals are installed based on meeting the minimum pedestrian volume or school crossing warrants (see MUTCD warrants).
2. Pedestrian pushbuttons are in use.
3. A protected signal phase is provided for pedestrian movements in one or more directions at a signalized intersection, with all conflicting vehicular traffic being stopped.
4. No vehicular indications are visible to pedestrians either starting or continuing their crossing (such as at intersections with pedestrian refuge or crossing islands).
5. The vehicular indications that are visible to pedestrians provide insufficient guidance for them to decide when it is safe to cross, such as at one-way roadways, T-intersections, or multiphase signal operations.
6. An established school crossing is located at a signalized intersection.
7. Engineering judgment determines that pedestrian signal heads would minimize vehicle-pedestrian conflicts.
8. Most of the other signalized intersections are already equipped with pedestrian signals.
9. Significant numbers of older adults or school-age children are present.
10. Wide streets where providing pedestrian clearance is important and moderate to high numbers of crossings occur.
11. Pedestrians request signal heads on the basis of program accessibility at locations where an engineering study confirms that installations of pedestrian signal heads is appropriate.

The above guidance applies to existing intersections with traffic signals. When new intersections are constructed or when existing intersections are reconstructed, intersections must be designed to meet accessibility requirements, including the provision of accessible pedestrian signals. Refer to Toolbox Section 3—Accessibility for more information. Also refer to the *Guide for the Planning, Design, and Operation of Pedestrian Facilities* for more information including innovative pedestrian indication options.

SIGNAL TIMING/PEDESTRIAN CROSSING TIMES

Pedestrian signal timing is based on pedestrian crossing times. A speed of 3.5 fps (1.06 mps) is the new standard used by the 2009 MUTCD. However, studies have indicated that up to 30 percent of the population does not normally walk this quickly, and the Institute of Transportation Engineers (ITE) manual *Design and Safety of Pedestrian Facilities* recommends the use of three fps (.91 mps) for signal timing. When there is a known presence of slower pedestrians (including older adults or people with mobility impairments), a crossing speed of 2.5 fps (.76 mps) is recommended.

Increasing the timing of pedestrian crossing phases can impact intersection capacity for traffic movement (motorists have to wait for longer periods). It is important to balance the needs of all intersection users when establishing signal timing parameters. The context, volume of pedestrians crossing, the presence of pedestrians with special needs, and other factors need to be considered in the decision-making process.

The amount of time given to vehicular travel also influences pedestrian safety. Signals with excessively long waits may cause pedestrians to cross against the signal, increasing the potential for pedestrian/motor vehicle conflicts. Research indicates that many pedestrians stop watching for the light to change when their delay exceeds 30 seconds, and instead they start looking for gaps in traffic to cross streets. Installation of pedestrian actuation devices can help with this problem.

While it is not practical to provide a pedestrian crossing phase every 30 seconds at all intersections, it is important to understand pedestrians' potential reactions to delays and to adjust crossing timing to serve their needs as a best practice. For example, pedestrians can push actuators when provided to activate the pedestrian crossing phase sooner. When pedestrians are not present, phasing can provide more time for vehicle movements. Exhibit 5.6 shows pedestrian crossing times for various distances and pedestrian mobility.

APPROACHES TO SIGNAL TIMING

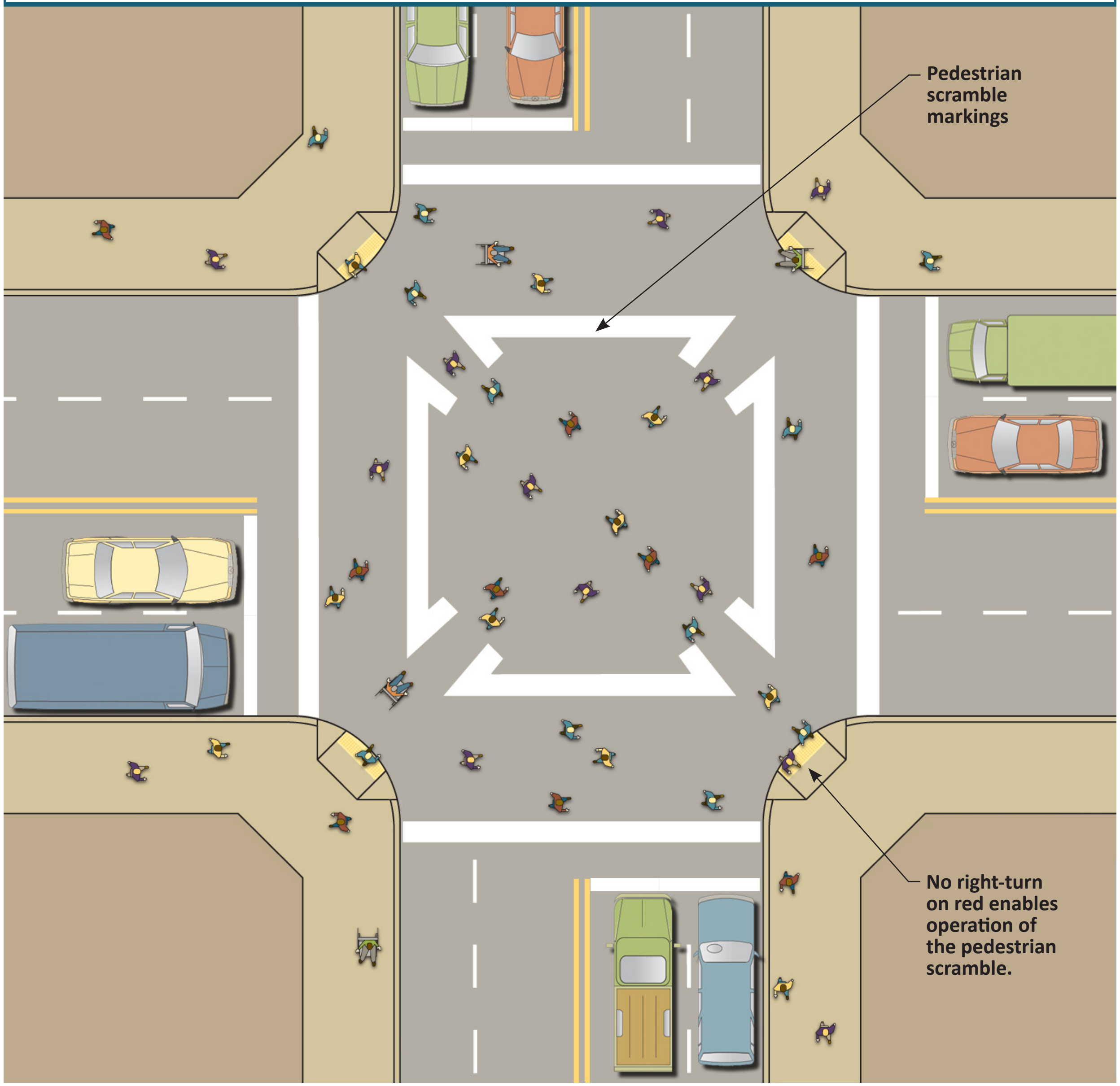
There are three main approaches to signal timing: concurrent, exclusive, and leading pedestrian interval. Shorter cycle lengths and longer walking intervals provide better service to pedestrians, and fixed time signals work best (PBIC). Timing for each intersection needs to be analyzed and set on a case-by-case basis with consideration of all intersection users.

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

**Recommended by 2009 MUTCD*

EXHIBIT 5.7 *Exclusive Signal Timing: At a pedestrian scramble all traffic is stopped and pedestrians can cross in any direction.*



- ***Concurrent Timing:*** The green traffic signal and the walk signal go on simultaneously. Turning motorists are expected to yield to pedestrians in the crosswalk. This type of timing usually provides pedestrians with the shortest waiting times and most opportunities to cross.
- ***Exclusive Timing:*** Stops traffic in all directions and should be used in conjunction with "no right on red." It is useful where there are very high pedestrian volumes (more than 1,200 pedestrian crossings per day per the PBIC), high speed roadways, and high turning movement conflicts. However, pedestrians usually have a long wait for the exclusive signal and may be tempted to cross against the signal, negating the benefits of the exclusive phase. It is also difficult for visually impaired pedestrians who lose the aural cue of traffic moving in one direction or another. The exclusive pedestrian phase increases safety with a crash reduction factor (CRF) of 34 percent, but decreases the efficiency of the intersection (PBIC). Exhibit 5.7 illustrates exclusive timing and the application of a pedestrian scramble at an intersection.
- ***Leading Pedestrian Interval (LPI):*** The walk signal goes on several seconds before the

green traffic signal, allowing pedestrians to enter the crosswalk first, protecting them from turning vehicles and making them more visible to motorists. This technique has been used in New York City successfully for two decades, as well as other cities. LPI is especially good for dual-lane turning movements (PBIC, Crossing Signals), and is also often used in conjunction with “No Right-turn on Red” signs.

Signal timing uses the following intervals:

- Walk (or Walking) Interval
- Pedestrian Change (or Clearance) Interval
- Buffer Interval

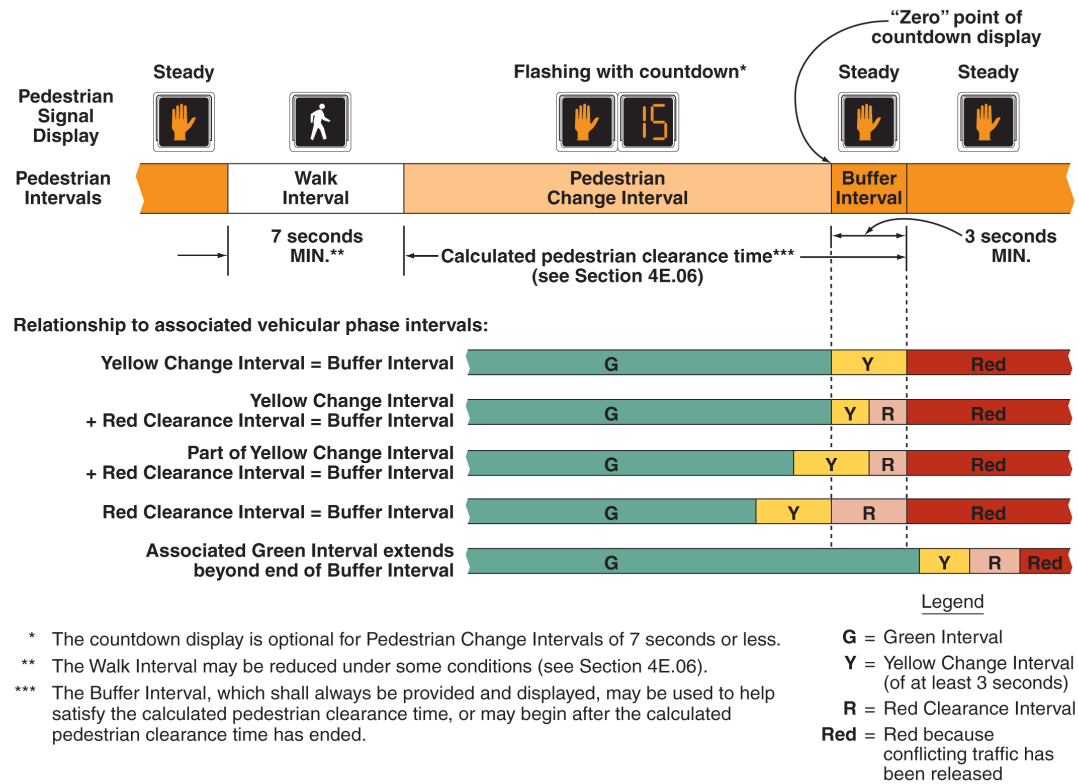
Exhibit 5.8 shows the components of signal timing and the prescribed timings in the MUTCD. During the Walk Interval, the static walking person symbol is displayed, typically for seven seconds or more. During the Pedestrian Change Interval, the flashing upraised hand symbol is displayed along with the countdown display. The countdown display is optional only when the Pedestrian Change Interval is seven seconds or less (a rare situation).

The MUTCD states that the Pedestrian Change Interval:

“should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the Walk Interval to travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.”*

*This is where a decision using a slower walking speed affects the calculated time. The MUTCD states that a slower walking speed can be used if people who walk more slowly or use wheelchairs

EXHIBIT 5.8 *Components of Signal Timing—Pedestrian Intervals*



* The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.
** The Walk Interval may be reduced under some conditions (see Section 4E.06).
*** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.

EXHIBIT 5.9 ***Pedestrian Signal Heads:***
PBIC recommends beginning the countdown signal with the Walking Interval Phase.

RAISED HAND:
Don't Walk Signal

WALKING PERSON:
Walking Interval Signal

FLASHING HAND WITH COUNTDOWN:
Pedestrian Change Interval

EXHIBIT 5.10 ***Sequence for a Pedestrian Hybrid Beacon***

1. Dark until Activated
2. Flashing Yellow Upon Activation
3. Steady Yellow
4. Steady Red During Pedestrian Walk Interval

5. Alternating Flashing Red During Pedestrian Clearance Interval
6. Dark Again Until Activated

LEGEND
SY - Steady yellow
FY - Flashing yellow
SR - Steady red
FR - Flashing red

"routinely use the crosswalk." This involves engineering judgment. 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.

The Buffer Interval shall be displayed for at least three seconds prior to the release of any conflicting vehicular movement. The Buffer Interval displays the steady (non-flashing) upraised hand symbol.

The introduction of the countdown display reduces confusion among pedestrians who find themselves in the middle of an intersection and are puzzled by the meaning of the flashing upraised hand sign. However, many existing intersections lack the countdown display and should be retrofitted with them. Countdown signals provide better pedestrian safety. Results from a San Francisco study showed that there was a 25 percent CRF after countdown signals were installed (PBIC). Exhibit 5.9 illustrates pedestrian signal heads, including countdown displays.

Traffic signals are usually timed for vehicle speeds, causing pedestrians to have to stop at nearly every intersection.

OTHER TYPES OF PEDESTRIAN SIGNALS

Pedestrian Hybrid Beacon (HAWK Signal)

A type of signal installation newly recommended in the 2009 MUTCD is designed for unsignalized crossings. It is activated by pedestrians and uses traditional traffic and pedestrian signal heads. It includes a sign instructing motorists to "stop on red" and a "pedestrian crossing" overhead sign. Exhibit 5.10 shows the signal sequence that stops traffic and allows pedestrians to cross a busy street safely.

Pedestrian Actuated Signals

Pedestrian actuated signals may be warranted at non-signalized intersections and mid-block locations where traffic volumes are high, making it difficult for pedestrians to cross.

- Active pedestrian actuated signals include a push button device.
- Passive pedestrian actuated signals automatically detect the presence of a pedestrian, and some can track the progress of a pedestrian as they cross the roadway.

Install pedestrian actuated signals at locations where they are recommended by a professional engineering study or warranted by the 2009 MUTCD guidelines. Adequate sight distance is necessary at these locations, and warning signs should be installed in advance of the signal. Pedestrian actuated signals may be appropriate at:

- Intersection crossings where the level of pedestrian activity is low, but the traffic volume and speed of vehicles is high, and/or where gaps in traffic are not adequate to allow pedestrians to cross;
- Mid-block crossings on streets where pedestrian activity is high and the volumes and speeds of vehicular traffic are high; and/or
- Heavily used mid-block bus stops (in which case increased responsiveness of the actuation should be provided during times of peak hour pedestrian access to the bus stop).

Extended Crossing Times

Push buttons that add several seconds to the crossing time can also be provided at intersections. The traffic engineer should determine the time extension, which may be based on slower walking speeds, or the analysis may determine that this application should

Visually impaired pedestrians benefit from audible signals.

Pedestrian push button or actuator

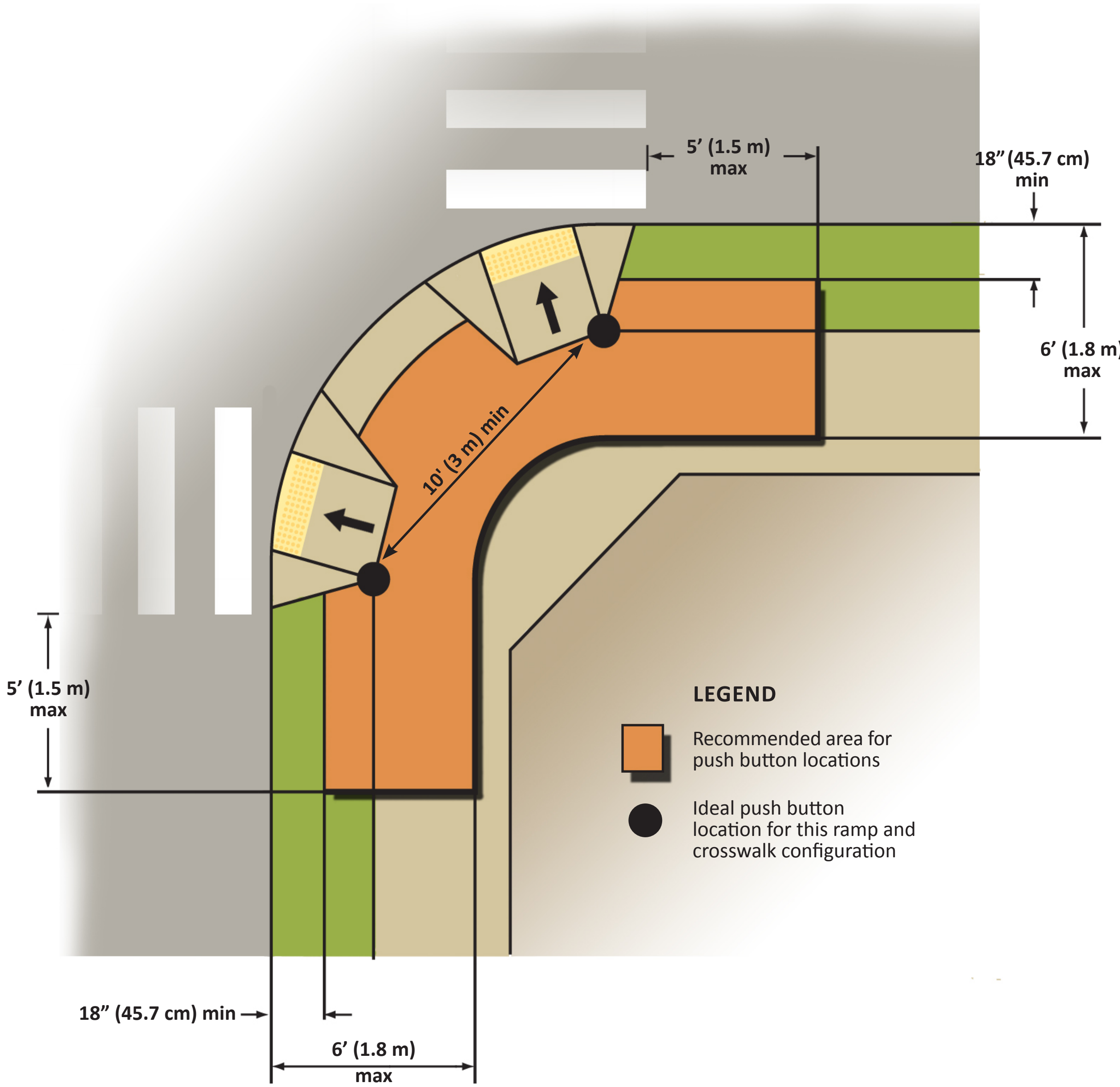
not be installed at the intersection for various reasons, such as major impacts to traffic capacity. (The needs of all intersection users have to be balanced.) Extended crossing times may improve pedestrian safety at:

- Crossings near a hospital, nursing home, retirement home, or other facility that accommodates mobility impaired people;
- Intersections where pedestrian volume varies widely over the course of a day; and
- Other locations as determined through analysis of the context and traffic conditions on a case-by-case basis.

Audible Devices

Audible devices should be considered in areas where a high number of visually impaired pedestrians use the crossing. This may occur near hospitals, retirement homes, or special facilities for the visually impaired. Audible devices should be separated by at least ten feet to avoid confusion about which crossing is open. In some cases it may be wise to include verbal commands to clarify which street to cross. See Toolbox Section 3—Accessibility for additional information.

EXHIBIT 5.11 *Locate push buttons in a convenient place for pedestrians.*



DESIGN AND LOCATION OF PEDESTRIAN SIGNALS

Pedestrian indications and signal heads need to be installed in clearly visible locations from the crosswalk approaches in accordance with the warrants and design guidelines in the 2009 MUTCD. Locate pedestrian push buttons near the end of crosswalks and in easy-to-reach positions. Place them no more than five feet from the pedestrian travel way and face them toward pedestrians. Signs should be mounted on the push-button poles to identify which button to press for each crossing direction. Pedestrian actuators may also be located in pedestrian refuge areas where pedestrians may be caught crossing during the end of the walk cycle. Refer to Exhibit 5.11 for location guidance.

Design and placement of pedestrian actuators should follow the US Access Board Public Rights-of-way Accessibility Guidelines (PROWAG). See Toolbox Section 3—Accessibility for more information.

Pedestrian Related Signs

There are only a few types of pedestrian-related warning signs, creating a clear and simple

EXHIBIT 5.12 ***The diamond-shaped pedestrian signs should be combined with other plaques to alert motorists to upcoming pedestrian conditions. See 2009 MUTCD Section 2C-50.***

AT THE CROSSWALK

Note: Diagonal arrow is required at crosswalk if mounted on a post. It may not be used if mounted overhead.

IN ADVANCE OF THE CROSSWALK

message for motorists to follow. The standard, diamond-shaped pedestrian warning sign can be combined with other signs and plaques (such as “XX FEET,” or “AHEAD”) to give motorists advance warning of an intersection or crossing. Almost all of the pedestrian-related warning signs can use either the standard yellow color, or a yellow-green fluorescent color. Exhibit 5.12 shows some possible sign configurations.

Refer to the 2009 MUTCD for sign design requirements and required distances from crosswalks and intersections. (There are specific signs for trails that cross roadways. Also refer to Toolbox Section 7—Shared Use Paths for more information.)

Other Design Considerations

LIGHTING

Seventy percent of pedestrian fatalities occur at night (NHTSA *Traffic Safety Facts*), so lighting should be a priority at pedestrian crossings. Because pedestrians can easily see a car’s lights, they may assume motorists can readily see them. Lighting provides safety, security, and comfort for pedestrians and enhances the ambience of retail and commercial districts

EXHIBIT 5.13 ***Nighttime Lighting at an Intersection***

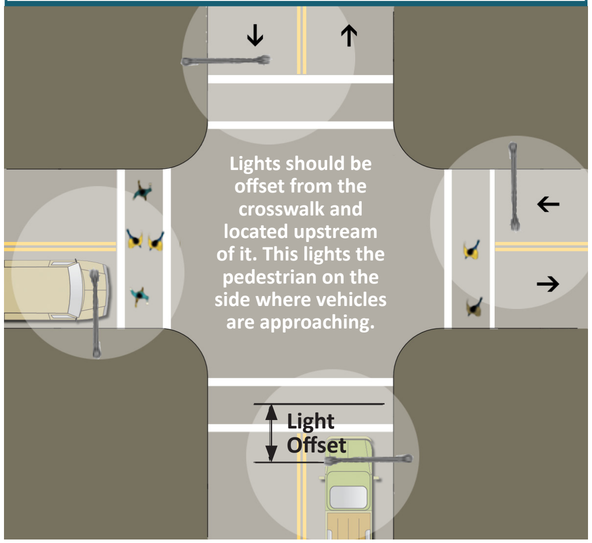
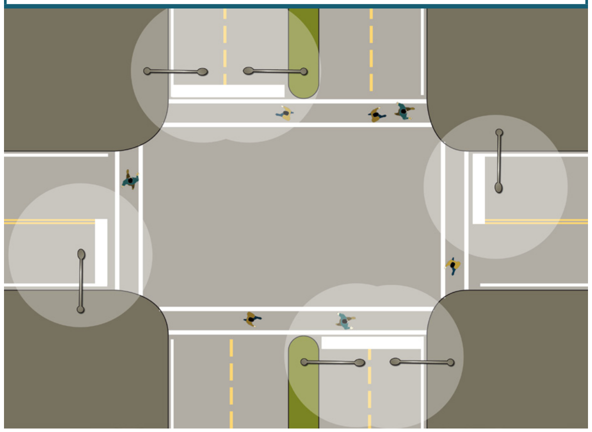


EXHIBIT 5.14 ***New Lighting for a Wide Roadway***



(PBIC). Existing roadway lighting may need to be supplemented with additional pedestrian lighting in areas of heavy pedestrian traffic, at locations where motorists may not expect a crossing, or in other areas determined by a traffic safety analysis or local design priorities.

Crosswalks and the approaches to them should be well lit, with a consistent level of lighting achieved. Overhead road lighting installed at crosswalks generally provides greater visibility distance than headlamps alone. Exhibits 5.13 and 5.14 illustrate lighting guidance for intersections. Preferred types of lighting include light-emitting diode (LED), incandescent, and high-pressure sodium (less expensive). Low pressure sodium has a high level of color distortion (PBIC). LED street lights are more energy efficient than other technologies, and can reduce the cost of keeping streets well-lit when dark.

Refer to the standards and design guidelines of AASHTO, as well as those of the Illuminating Engineering Society of North America. See Toolbox Section 2—Pedestrian-Friendly Streets for more information on lighting.

LOCATION OF DRAINAGE INLETS AND GRATES

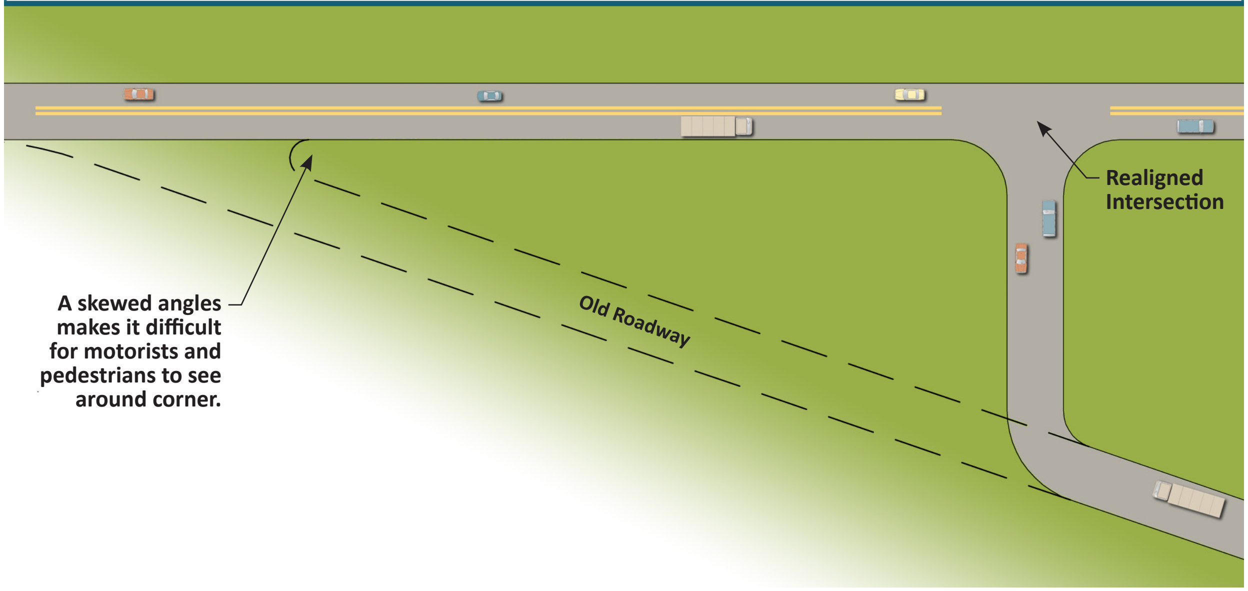
Drainage grates should be located away from crosswalks and curb ramps and outside the route of pedestrian travel. Locate drainage inlets on the upstream side of the crosswalk to avoid excessive drainage flows across the crossing area. Direct road and gutter drainage away from intersection corners and walking areas. This is particularly important given Hawaii's rainfall patterns. The grate tops shall be designed in accordance with PROWAG.

Avoiding or Reconfiguring Multiple and Skewed Intersections

Multiple and skewed intersections should be avoided in all new development. Multiple intersections occur where there are more than four legs or vehicle approaches. They are confusing to pedestrians and motorists alike.

Skewed intersections are created when roadways join at a non-right angle. The acute-angle corner creates poor visibility for both pedestrians and motorists. Intersections where the angle between legs is less than 75 degrees are undesirable, particularly for older pedestrians who may have trouble turning their head to see oncoming traffic.

EXHIBIT 5.15 In rural locations reduced right-of-way costs may make an intersection reconfiguration possible.



Reconfiguring these types of intersections is expensive because of the need to purchase right-of-way. However, a large scale project may warrant the reconfiguration because the improvement to pedestrian safety increases the value of the project. Exhibit 5.15 shows an example of intersection reconfiguration.

Minimizing Crossing Distances

Minimizing the crossing distance at intersections enables pedestrians to cross the street more safely and comfortably by reducing the time of pedestrian exposure in the street. Design techniques for reducing crossing distances include curb bulb-outs and extensions, median and center refuge islands, right-turn channelization and refuge islands, and use of smaller curb return radii.

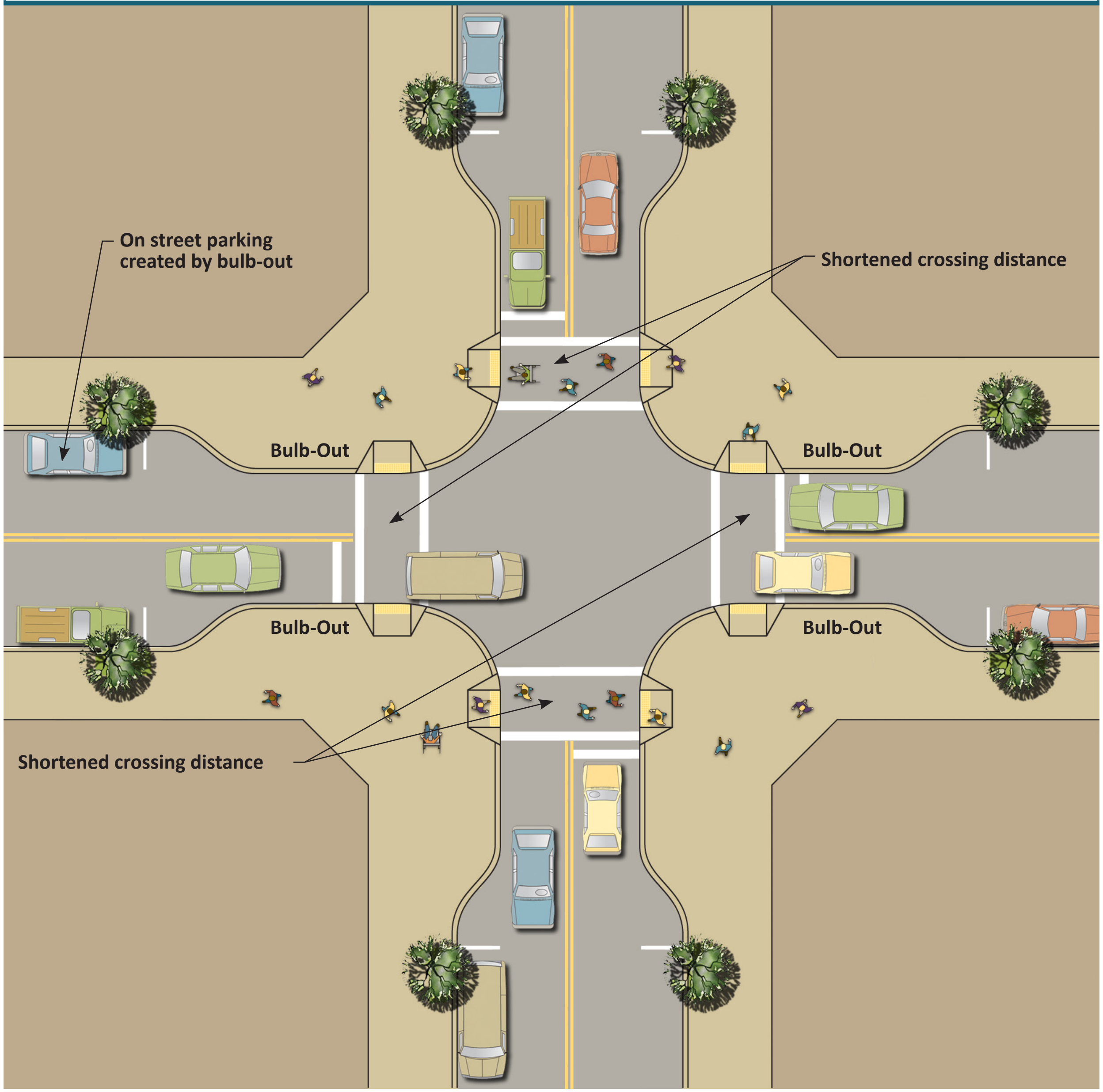
Curb Bulb-Outs and Extensions

Curb bulb-outs and extensions extend the curb and sidewalk into the street area, shortening crossing distances, reducing the crossing time, and making pedestrians more visible

Bulb out provides space for recycling bins and landscaping, in addition to space at the intersection corner for pedestrians, Kirkland, WA

Bulb out with special sign indicating senior citizens crossing activity, Kirkland, WA

EXHIBIT 5.16 *Corner bulb-outs shorten crossing distances and make pedestrians more visible to motorists.*



to vehicles. At intersection and mid-block crossings, curb bulb-outs and extensions may also help slow traffic by narrowing the street. Curb extensions and bulb-outs can be installed in commercial, residential, and other settings, and they work particularly well:

- At intersections on streets with delineated on-street parking zones
- Where there is limited turning traffic by buses and large vehicles (but can be designed to facilitate large vehicle turning requirements)
- For one-way streets
- As a traffic calming technique

Exhibit 5.16 and 5.17 illustrate curb bulb-outs/ extensions.

Medians and Center Refuge Islands

Medians and refuge islands are curbed areas separating the two directions of traffic movement in the street. They eliminate the need for pedestrians to cross both directions of traffic at once. Whether located at intersections or not, they help define the pedestrian walking space and provide protection and refuge from motor vehicles. Refuge islands are similar in design to raised (curbed) medians, but not as long, typically up to 20 ft (6.1 m). Medians or refuge islands are recommended whenever crossing distances exceed 60 ft (18.3 m) (AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities).*

EXHIBIT 5.17 *Corner bulb-outs put pedestrians into the driver's field of vision.*

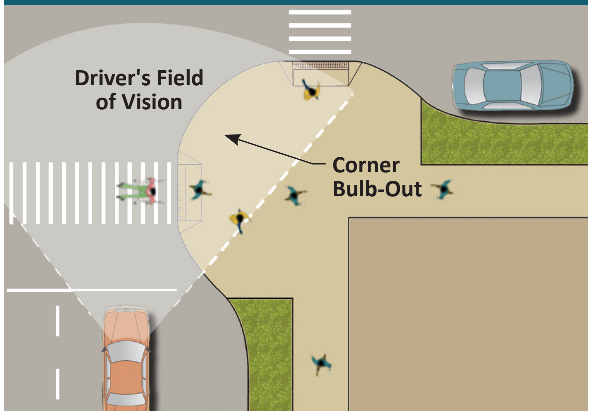
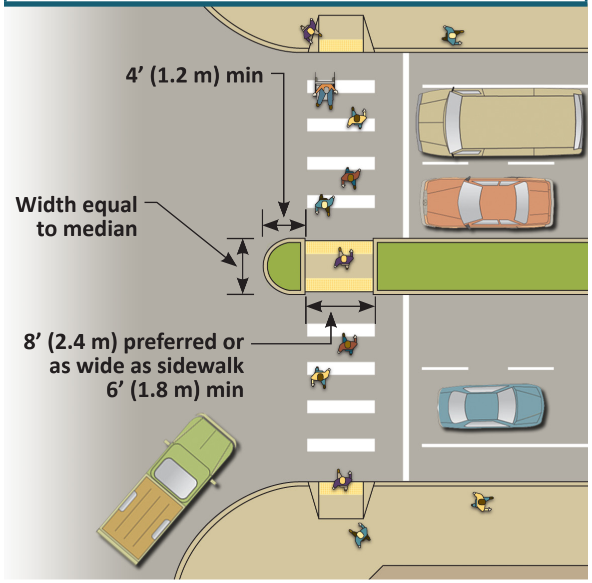


EXHIBIT 5.18 *A median nose added at an intersection crossing provides a refuge for pedestrians, improving their saftety and comfort.*



Because medians control vehicular access and turning movements, they have the ability to isolate traffic flow and increase safety of the roadway. At intersections where there is a median in the roadway, a median nose should be added to create a pedestrian refuge. The refuge should be aligned with the crosswalk, with the nose providing separation from traffic. See Exhibit 5.18.

Medians and center refuge islands need to be wide enough to provide refuge for several pedestrians waiting at once. They preferably should be 8 to 10 ft wide (2.4 to 3 m) and a minimum of 6 ft (1.8 m) in length, measured in the direction of pedestrian travel. The refuge shall be accessible, with either curb ramps or at-grade cuts. The latter are generally easier to construct and easier for pedestrians to negotiate than curb ramps, particularly on smaller islands.

Provide pedestrian push buttons at the refuge when the signal timing doesn't allow all pedestrians to cross the entire street on one crossing phase. Accessible pedestrian signals (APS) shall be provided in accordance with PROWAG.

These areas shall be clear of obstacles such as utilities, including signal control boxes, signal and light poles, signs, and landscaping above two feet in height.

Right-Turn Lanes/Slip Lanes

Ideally, the use of dedicated right-turn lanes and right-turn slip lanes should be minimized, due to the emphasis on easy and fast motor vehicle travel. However, they can be designed to be less problematic. At many arterial street intersections, pedestrians have difficulty crossing due to right-turn movements and wide crossing distances. Well-designed right-turn slip lanes provide pedestrian refuge islands within the intersection and a right-turn lane that optimizes the right-turning motorist's view of the pedestrian. Listed below are four alternatives for design of right-turns, in priority order.

- *Option 1 -* No dedicated right-turn lane; preferred option; see Exhibit 5.19

EXHIBIT 5.19 *No Dedicated Right-Turn Lane*

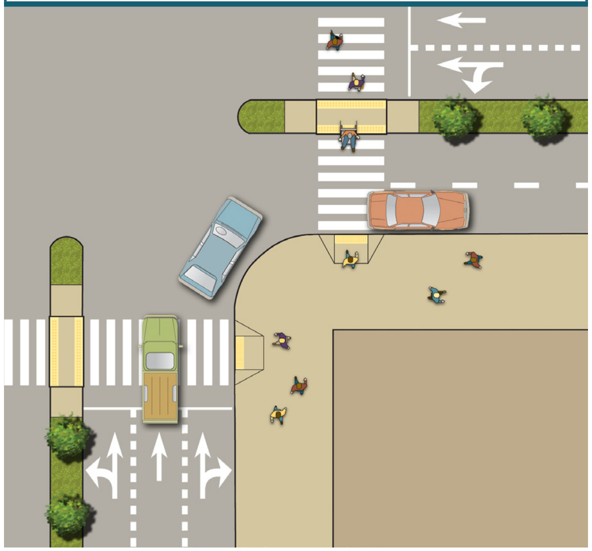


EXHIBIT 5.20 *Dedicated Right-Turn Lane*

EXHIBIT 5.21 *Signalized Right-Turn Slip Lane with Raised Pedestrian Refuge*

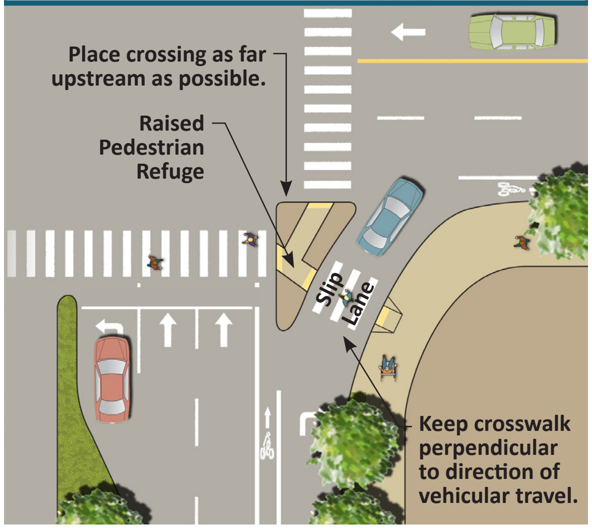


EXHIBIT 5.22 *Yield-Controlled Right-Turn Slip Lane with Raised Pedestrian Crossing*

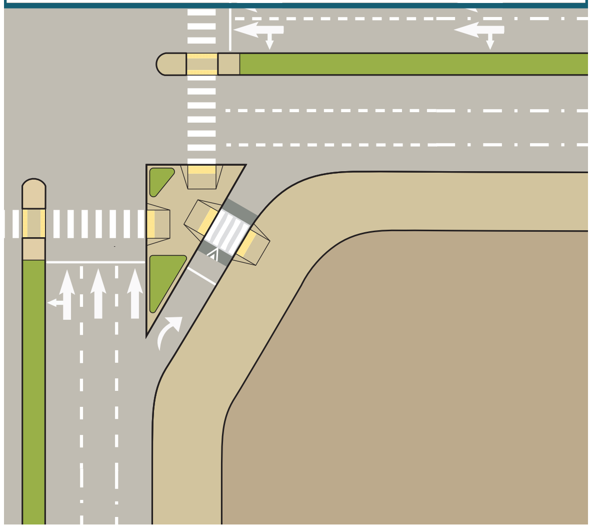
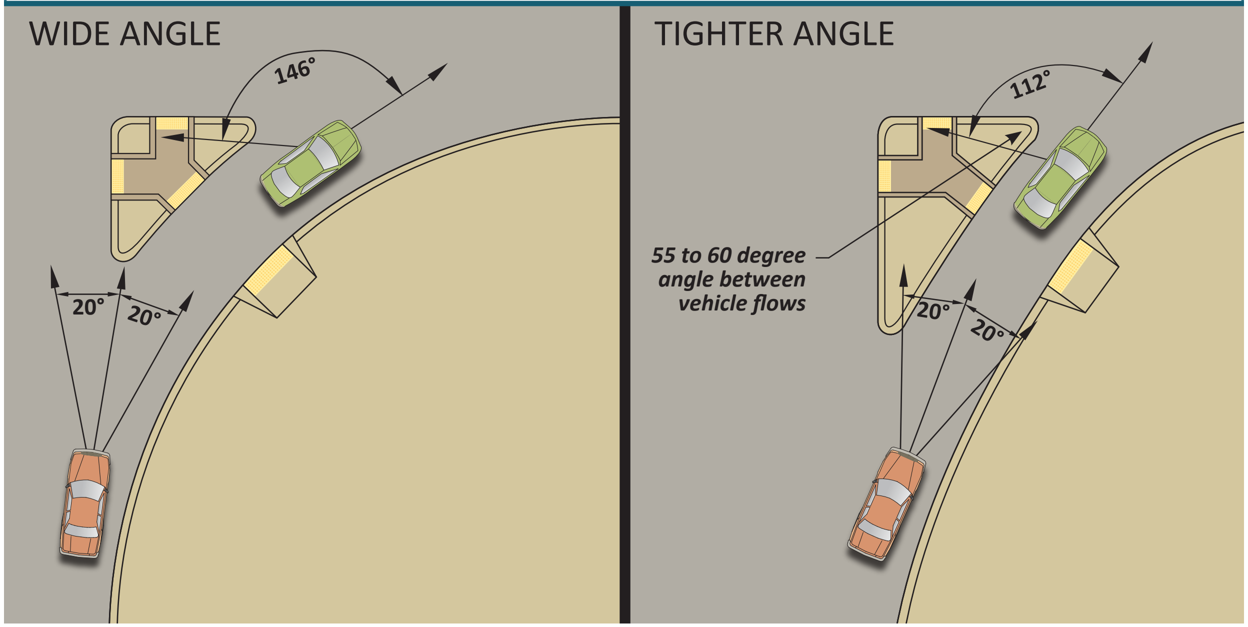


EXHIBIT 5.23 ***Preferred Design of a Channelized Right-Turn Lane***
(Kimley Horn and Associates, Inc. adapted from an illustration by Dan Burden)



High speed, low visibility of pedestrians

NOT RECOMMENDED

Vehicle speeds 17 to 18 mph, good visibility of pedestrians

RECOMMENDED

- *Option 2 -* Dedicated right-turn lane; see Exhibit 5.20
- *Option 3 -* Signalized right-turn slip lane with raised pedestrian crossing; see Exhibit 5.21
- *Option 4 -* Yield-controlled right-turn slip lane with raised pedestrian crossing; see Exhibit 5.22

The provision of a channelized right-turn lane is appropriate only on signalized approaches where right-turning volumes are high or large vehicles frequently turn and conflicting pedestrian volumes are low and are not expected to increase greatly.

The design of a channelized right turn and refuge island should follow the recommended approach in Exhibit 5.23. The exhibit depicts two designs of a channelized right-turn lane. The first shows a wide angle design with a high-speed, low visibility of pedestrians with a 20 degree to 142 degree angle. The second design shows a tighter angle showing a 20 degree to 112 degree angle, with a 55 to 60 degree angle between vehicle flows. Historically, channelized right-turns were often designed like the first example, which is no longer a recommended practice. The preferred design uses an approach angle that lowers speeds and improves visibility.

When channelized right-turn lanes are justified for traffic capacity or large vehicle purposes, the following practices should be used:

- Provide a low-angle right turn (about 112 degrees). This angle slows down the speed of right-turning vehicles and improves driver visibility of pedestrians within and approaching the crosswalk (as shown in Exhibit 5.23).
- Place crosswalks so that a motorist has a clear view of pedestrians.

- Unless the turning radii of large vehicles, such as tractor-trailers or buses must be accommodated, the pavement in the channelized right-turn lane should be no wider than 16 feet. For any width right-turn lane, mark edge lines and cross-hatching to restrict the painted width of the travel way of the channelized right-turn lane to 12 ft (3.6 m) to slow smaller vehicles.
- If vehicle-pedestrian conflicts are a significant problem in the channelized right-turn lane, it might be appropriate to provide signing to remind drivers of their legal obligation to yield to pedestrians crossing the lane in the marked crosswalk. Regulatory signs such as the TURNING TRAFFIC MUST YIELD TO PEDESTRIANS (R10-15) or warning signs such as the PEDESTRIAN CROSSING (W11-2) could be placed in advance of or at the crossing location.

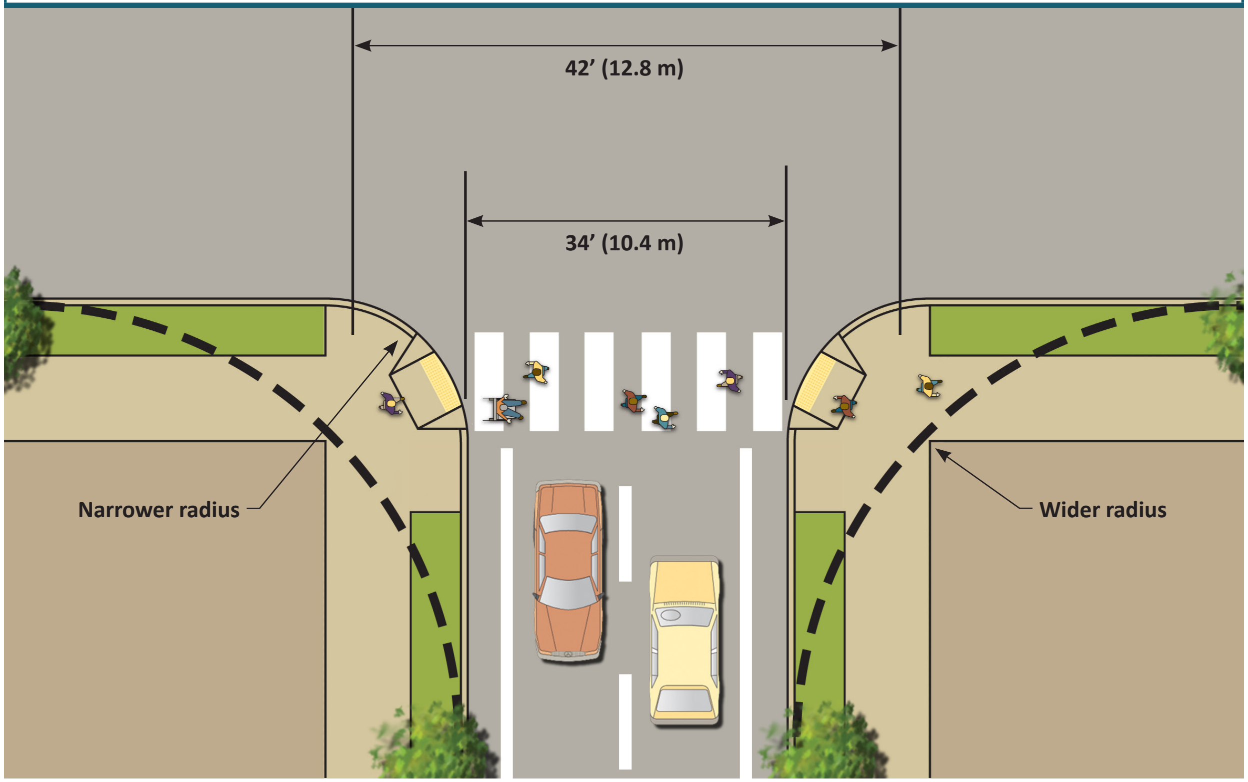
At locations with extremely high numbers of right-turning movements, slip lanes should be equipped with a signal to provide pedestrians opportunities to cross. See previous discussion in this section pertaining to signalization.

Curb Return Radius

The use of smaller curb return radii at intersections reduces pedestrian crossing distances. Reduced radii also help to slow vehicles as they navigate through their turning movement, enabling drivers to respond more quickly to signal changes and crossing pedestrians. Exhibit 5.28 compares the crossing distance between two 15 ft (4.6 m) radius corners and two 30 ft (9.1 m) radius corners at an intersection.

As shown in Exhibit 5.24, the smallest practical curb-return radii should be used to shorten the length of the pedestrian crosswalks. The primary benefits of smaller curb-return radii to pedestrians in urban areas include:

EXHIBIT 5.24 ***Reducing curb radii can shorten crossing distances substantially.***

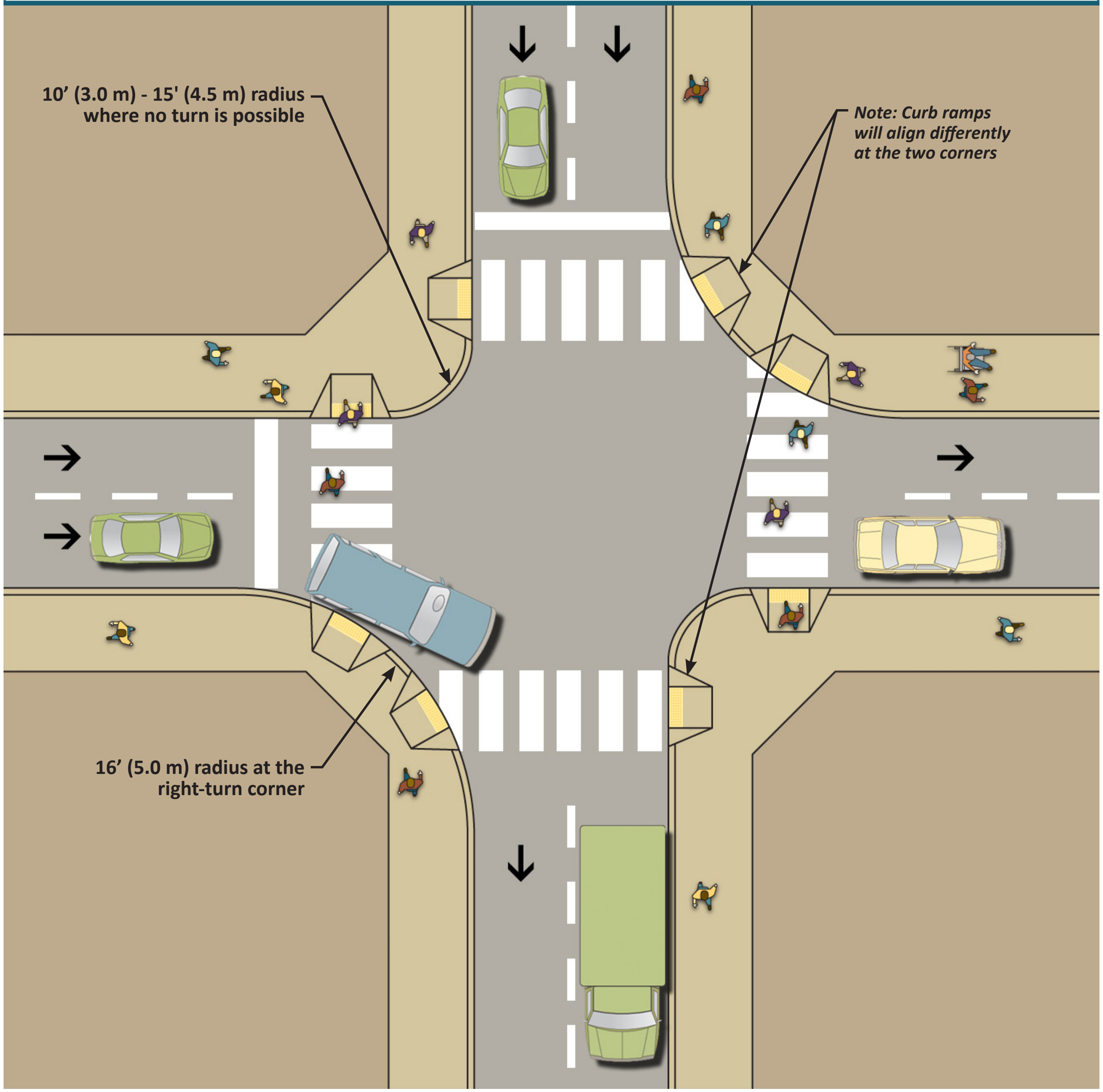


- Increasing motorist visibility of pedestrians waiting to cross the street;
- Reducing pedestrian crossing distance (which also benefits vehicles with a shorter cycle length at signalized intersections) and exposure to traffic;
- Providing the shortest accessible route for people with disabilities; and
- Reducing speed of turning vehicles and as such, the potential severity of crashes.

Intersections designed for the largest turning vehicle traveling at significant speeds with no encroachment result in long pedestrian crossings and potentially high-conflict areas for pedestrians and bicyclists. Radii designed to accommodate the occasional large vehicle will allow passenger cars to turn at high speeds. Curb return radii ranging from 5 to 25 ft (1.5 to 7.6 m) are preferable for walkable areas to shorten pedestrian crossings and slow vehicle-turning speeds, which increase safety for all users.

In town centers and downtowns where pedestrian activity is intensive, curb-return

EXHIBIT 5.25 *One Way Streets with Smaller Curb Return Radii at Non-Turning Corners*



radii should be as small as possible. On multi-lane streets and roadways, large vehicles may encroach into the adjacent travel lanes (in the same direction of travel) when turning. Curb-return radii of different lengths can be used on different corners of the same intersection to match the design vehicle turning at that corner. On one way streets there is an opportunity to shorten the radii of the corners where vehicles do not turn, as shown in Exhibit 5.25.

At intersections with no vehicle turns, the minimum curb return radii should be 5 ft (1.5 m). A curb return radius of 5 to 15 ft (1.5 to 4.5 m) should be used where:

1. High pedestrian volumes are present or reasonably anticipated;
2. Volumes of turning vehicles are low;
3. The width of the receiving intersection approach can accommodate a turning passenger vehicle without encroachment into the opposing lane;
4. Large vehicles constitute a very low proportion of the turning vehicles;
5. Bicycle and parking lanes create additional space to accommodate the "effective" turning radius of vehicles;
6. Low turning speeds are required or desired; and
7. Occasional encroachment of turning school bus, moving van, fire truck, or oversized delivery truck into an opposing lane is acceptable.

Curb radii may need to be larger where:

1. Occasional encroachment of a turning bus, school bus, moving van, fire truck, or oversized delivery truck into the opposing lane is not acceptable;
2. Curb extensions are proposed or might be added in the future; and
3. Receiving thoroughfare does not have parking or bicycle lanes and the receiving lane is less than 12 ft (3.6 m) in width.

An alternative to increasing curb-return radii is setting back the stop line of the receiving street to allow large vehicles to swing into opposing lane as they turn. Setbacks to accommodate right-turn encroachment need to be examined on a case-by-case basis since very tight right turns may require long setbacks.

RECOMMENDATIONS FOR TRUCK ROUTES

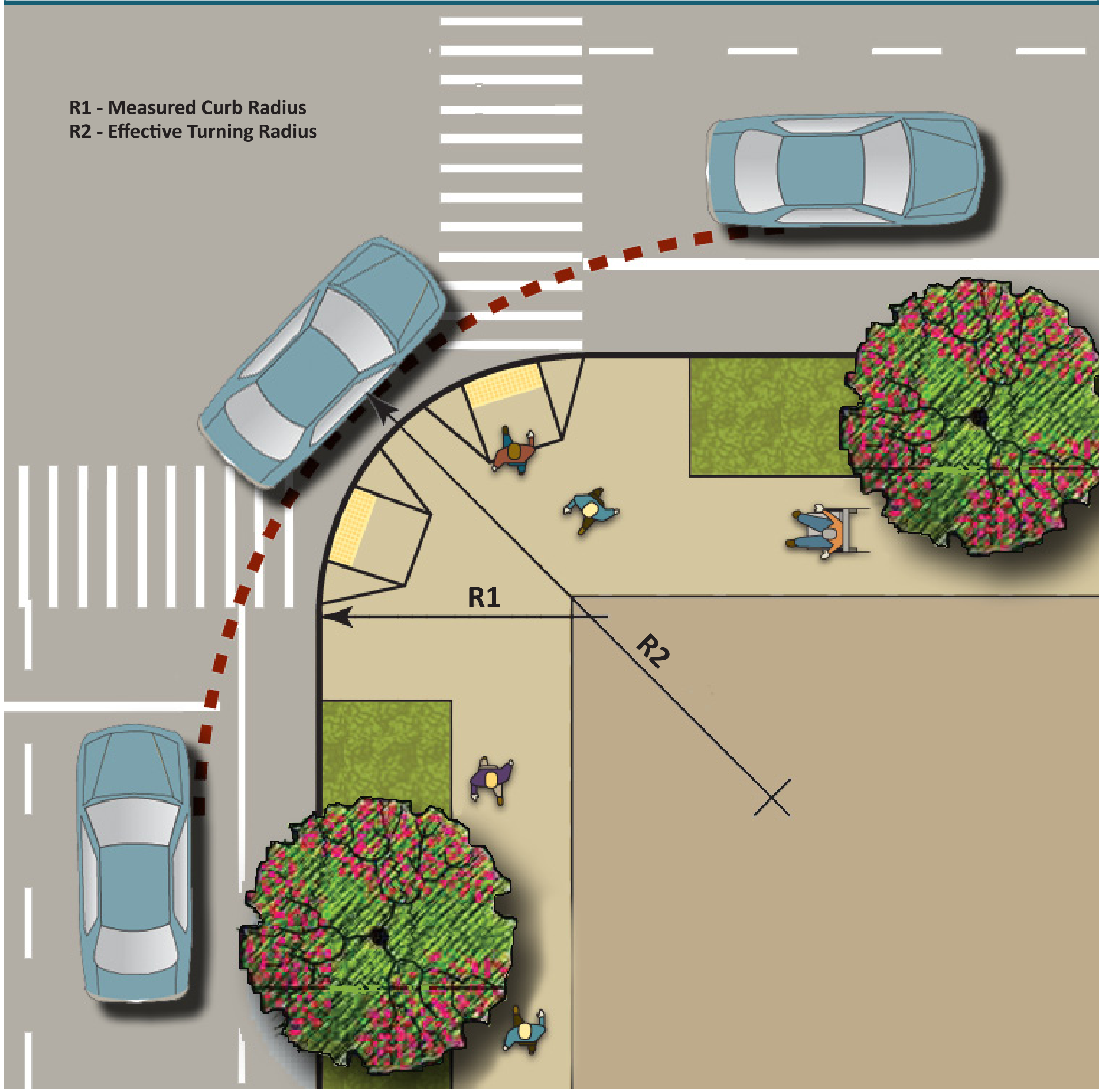
Truck routes should be designated outside of or on a minimum number of streets in walkable areas to reduce the impact of large turning radii. Where designated truck routes

KEEP THE CROSSING DISTANCE AS SHORT AS POSSIBLE

In walkable areas, the first consideration is keeping crossing distance as short as possible. Consider alternatives to lengthening the curb radius first, then consider lengthening the radius if no other alternative exists.

Source: Designing Walkable Urban Thoroughfares: A Context Sensitive Approach, Institute of Transportation Engineers

EXHIBIT 5.26 Effective turning radius is larger than curb radius.



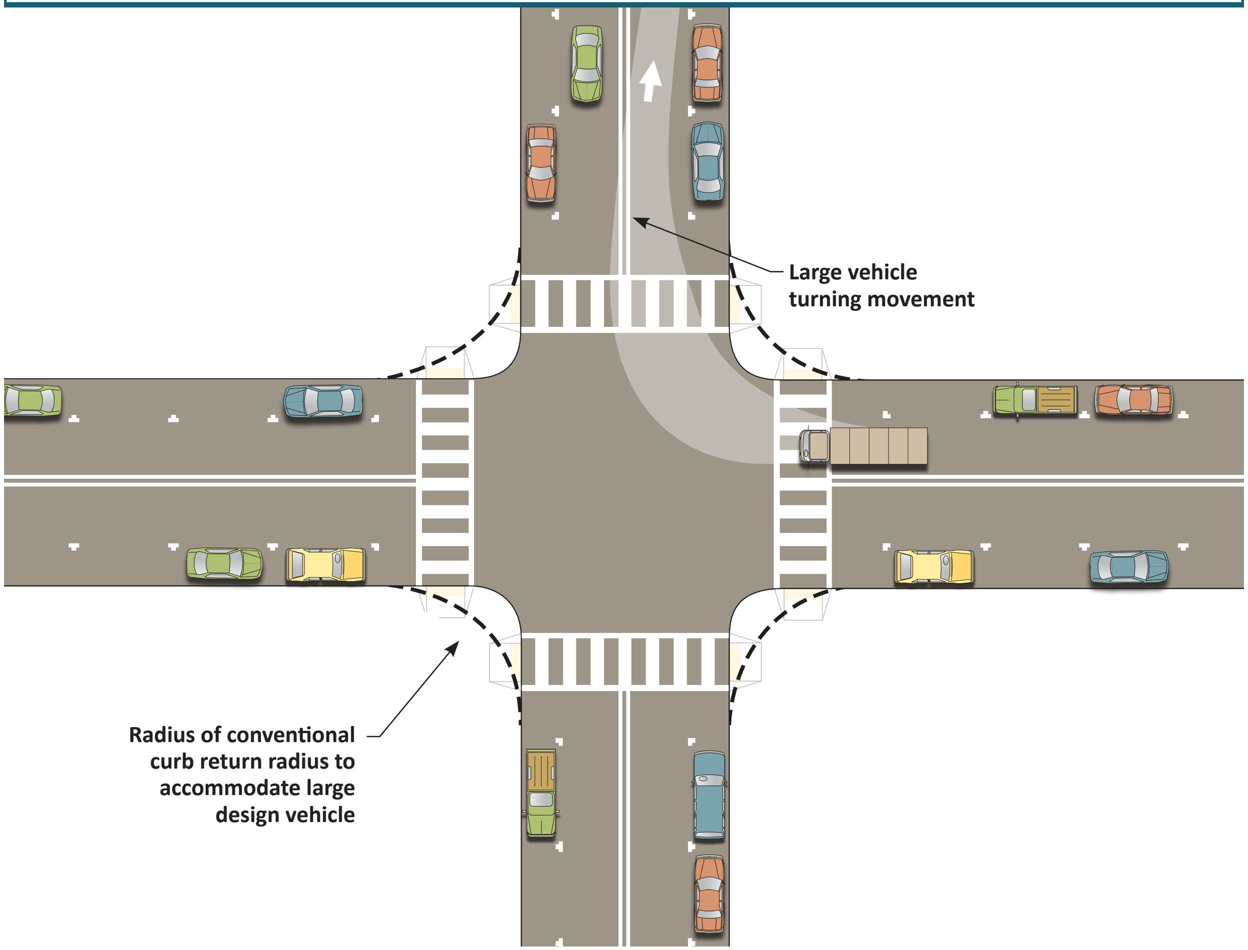
conflict with heavy pedestrian activity, analyze freight movement needs and consider redesignation of truck routes to minimize conflicts. On bus and truck routes, the following guidelines should be considered:

- Curb-return radii design should be based on the effective turning radius of the prevailing design vehicle. Refer to Exhibit 5.26.
- Where the potential for conflicts with pedestrians is high and large vehicle turning movements necessitate curb radii exceeding 50 ft (15.2 m), consider installation of a channelized right-turn lane with a pedestrian refuge island (see discussion earlier in this section).
- Where frequent turning of large vehicles takes place, avoid inadequate curb-return radii as they could potentially cause large vehicles to regularly travel across the curb and into the pedestrian waiting area.

CONSIDERING THE EFFECTIVE TURNING RADIUS

Curb-return radii should be designed to reflect the "effective" turning radius of the corner. The effective turning radius takes into account the wheel tracking of the design vehicle utilizing the width of parking and bicycle lanes. The existence of parking and bicycle lanes creates an "effective" turning radius that is greater than the curb-return radius, as shown in Exhibit 5.26. The use of the effective turning radius allows a smaller curb-return radius while also accommodating larger vehicles. Smaller curb-return radii shorten the distance that pedestrians must cross at intersections. In many cases, the occasional turn made by large trucks can be accommodated with slower speeds and some minimal encroachment into the opposing traffic lanes as shown in Exhibit 5.27.

EXHIBIT 5.27 ***Large Vehicle Turning Movement Adjacent to Shorter Curb Return Radius***
(Kimley Horn and Associates, Inc.)



Mid-Block Crossings

Over 75 percent of pedestrian fatalities occur at mid-block crossings (NHTSA *Traffic Safety Facts*), so the need for well designed, safe crossings at these locations is high. In areas where distances between intersections are long, crossings can provide pedestrians opportunities to cross.

A mid-block crossing may be appropriate wherever pedestrian activity is high, such as between an apartment site and a grocery store; a school and park; or a transit stop and a residential neighborhood.

Determining the Need for Mid-Block Crossings

Locations being considered for mid-block corssings need to be carefully studied. Mid-block crossings should be installed on the basis of a

EXHIBIT 5.28 Where and Where Not to Locate Mid-Block Crossings

LOCATE MID-BLOCK CROSSINGS	AVOID LOCATING MID-BLOCK CROSSINGS
• Where significant pedestrian crossings and substantial pedestrian/vehicle conflicts exist; should not be used indiscriminately. • Where the crossing can serve to concentrate or channelize multiple pedestrian crossings to a single location. • At approved school crossings or crossings on recommended safe routes to schools. • Where land uses create high concentrations of pedestrians needing to cross (such as residential areas across from retail or recreation, and transit stops across from residential or employment). • Where pedestrians could not otherwise recognize the proper place to cross or there is a need to delineate the optimal location to cross.	• Mid-block crosswalks should generally be avoided under the following circumstances (unless they are stop controlled): — Immediately downstream (less than 300 feet) from a traffic signal or bus stop where motorists are not expecting pedestrians to cross (Knoblauch et. al.); — Within 600 feet of another crossing point (Knoblauch et. al.), except in central business districts or other locations where there is a well-defined need. The recommended minimum separation is 300 feet; — On multi-lane streets with no refuge; and — On streets with speed limits above 45 mph.

thorough engineering analysis if they are not located at an existing stop sign, yield sign, or traffic signal. Guidance for determining locations for mid-block crossing installation is provided by the ITE manual, *Design and Safety of Pedestrian Facilities* and summarized in Exhibit 5.28.

Design of Mid-Block Crossings

Design treatments at mid-block crossings are generally most effective when used in combinations (e.g. marked crosswalks and signs). As noted above in the section on Crosswalk Markings, the presence of markings on four-lane roads with an ADT of 12,000 or more and no other pedestrian improvements has been associated with a higher level of crashes, if no other treatments, such as signs, flashing lights, signals, etc. are also provided. For this reason, design treatments should normally be used in combination at mid-block crossings. These may include:

Unsignalized mid-block crossing on a lower volume local street in a residential area, Bellevue, WA

New mid-block crossing in a busy commercial area, designed with flashing signs and high contrast crossing area, Downtown Bellevue, WA

- Markings
- Stop or yield signs
- Signalization
- Pedestrian hybrid beacons
- Pedestrian actuated buttons
- Refuge islands
- Curb extensions
- Signs (sometimes with flashing lights) warning motorists of the presence of pedestrians

Crossing design treatments and related traffic control require careful consideration and a traffic engineering analysis of existing conditions on a project-by-project basis. Exhibits 5.29 and 5.30 illustrate mid-block crossings on two types of streets.

Mid-block crossings should be located where there is adequate sight distance for both the motorist and pedestrian. In addition to proper roadway geometry, any obstacle that would interfere with visibility at the crossing location (e.g. mailboxes, utility poles, street furniture,

EXHIBIT 5.29 ***Curb extensions create space for on-street parking and shorten crossing distances for pedestrians.***

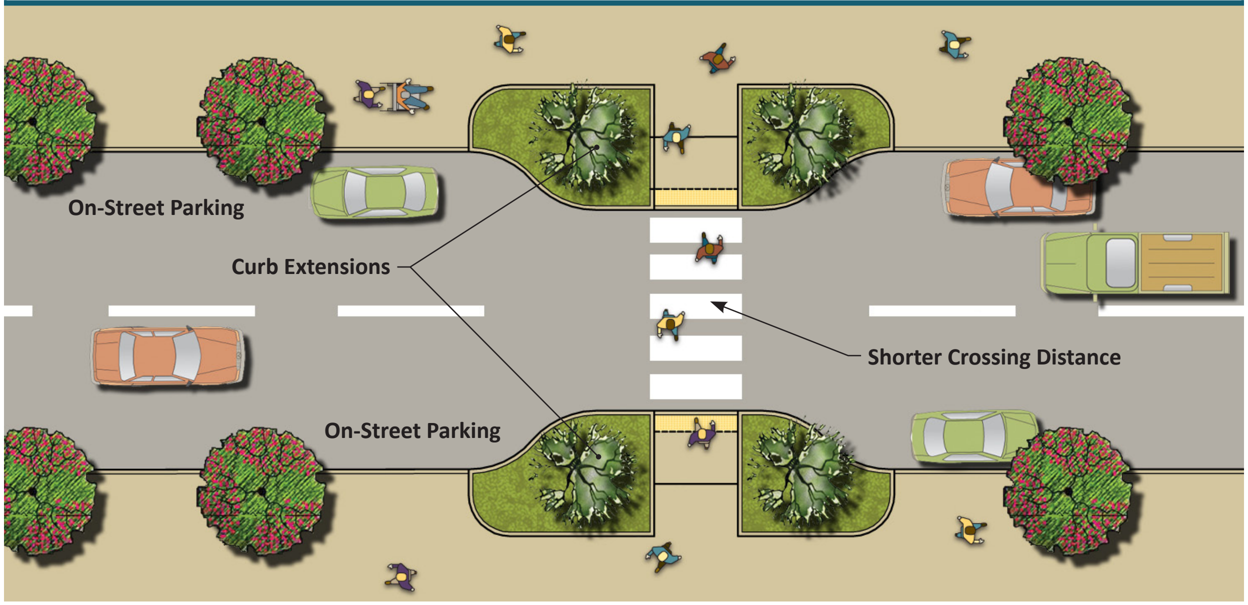
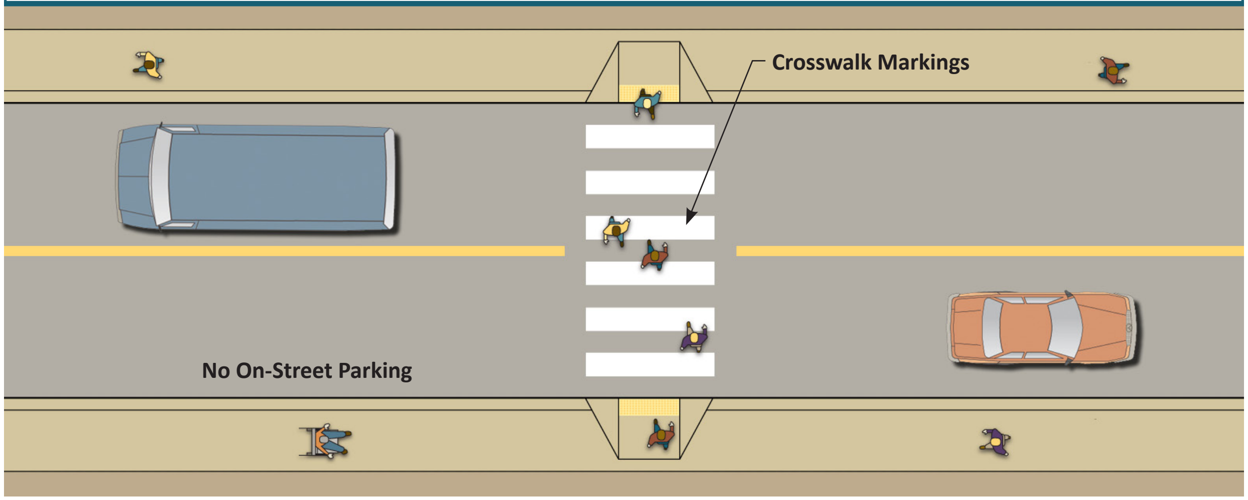


EXHIBIT 5.30 ***Pedestrians have the right-of-way in marked mid-block crossings.***



landscaping, etc.) should be removed or relocated. On-street parking should be set back from the crossing point for improved visibility. See Exhibit 2.5 in Toolbox Section 2—Pedestrian-Friendly Streets for setback dimensions.

REFUGE ISLANDS AT MID-BLOCK CROSSINGS

Raised refuge islands greatly increase pedestrian safety at mid-block crossings. They can be installed by themselves or within a median. On multi-lane roads, raised medians or refuge islands are highly recommended because they greatly increase pedestrian safety. Exhibit 5.31 summarizes design guidelines for medians and refuge islands. Exhibit 5.32 lists locations where median refuge islands are most beneficial.

The refuge islands should be raised to provide a vertical barrier and added protection between vehicles and pedestrians. Refuge islands need to provide curb cuts or cut-throughs for accessible passage. Minimum dimensions for refuge islands as required by AASHTO are:

- Area no smaller than 54 sq ft (5 sq m), but preferably a minimum of 97 sq ft (9 sq m).
- Minimum length of 20 to 25 ft long (6.1 m to 7.6 m)
- A wider area is needed to provide curb ramps and a level area between the curb ramps in the crossing region.
- Medians and pedestrian refuge islands shall be 6 ft (1.8 m) minimum in length in the direction of pedestrian travel. The crossing refuge island shall contain a pedestrian access route of 4 ft (1.2 m) width minimum (PROWAG).

EXHIBIT 5.31 ***Design Guidelines for Medians and Refuge Islands***

Medians and refuge islands should ideally be 8 to 10 ft wide (2.4 to 3 m) and a minimum of 6 ft (1.8m) in length, measured the direction of pedestrian travel. This prevents wheelchairs propelled by attendants, bicyclists, and people with strollers from projecting out into traffic lanes.
In order to obtain appropriate median width, travel lanes can be narrowed to 11 ft (3.3 m), if approved by the appropriate review agency. Where vehicle speeds range from 20 to 30 mph (32 kph to 48 kph), the travel lanes can be reduced further to 10 or 9 ft (3 m to 2.7 m), if approved by the appropriate review agency.
Trees in medians and at the sides of streets can help to narrow the field of vision for approaching drivers, causing them to slow down as they near the crossing point. Landscaping in median refuge islands must be placed carefully. It is essential that landscaping not block the sight lines of pedestrians and motorists at the crossing area.
Cut-throughs or curb ramps should be installed in all median refuge islands. Cut-throughs are more common because the median width is rarely large enough to accommodate ramps that meet the ADA requirements. Cut-throughs should be designed with a 2 percent cross slope for drainage. Truncated domes should be installed as a warning device for visually impaired pedestrians.
A pedestrian push button should be placed in the median of signalized mid-block crossings where the crossing distance exceeds 60 ft (18.2 m). Provide APS per PROWAG.
The use of angled (45 degrees+) refuge areas/cut throughs in the island is recommended to direct the pedestrian to look toward oncoming traffic, helping them to be more aware of approaching vehicles.
Medians and refuge islands should be illuminated.

Sources: AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, WSDOT Pedestrian Facilities Guidebook.

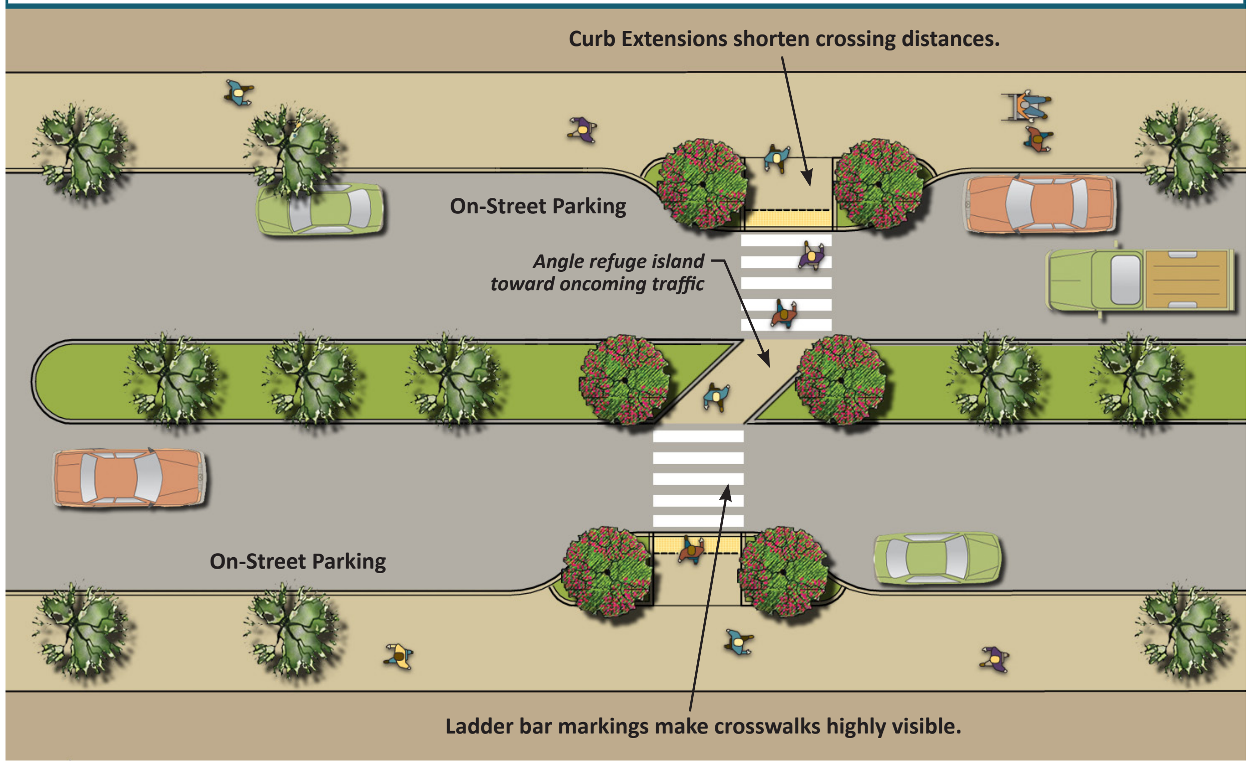
Colorful stencil complements high contrast white lines of the crosswalk.

The crossing area is angled to orient pedestrians to the view of oncoming traffic.

EXHIBIT 5.32 Locations Where Refuge Islands are Most Beneficial

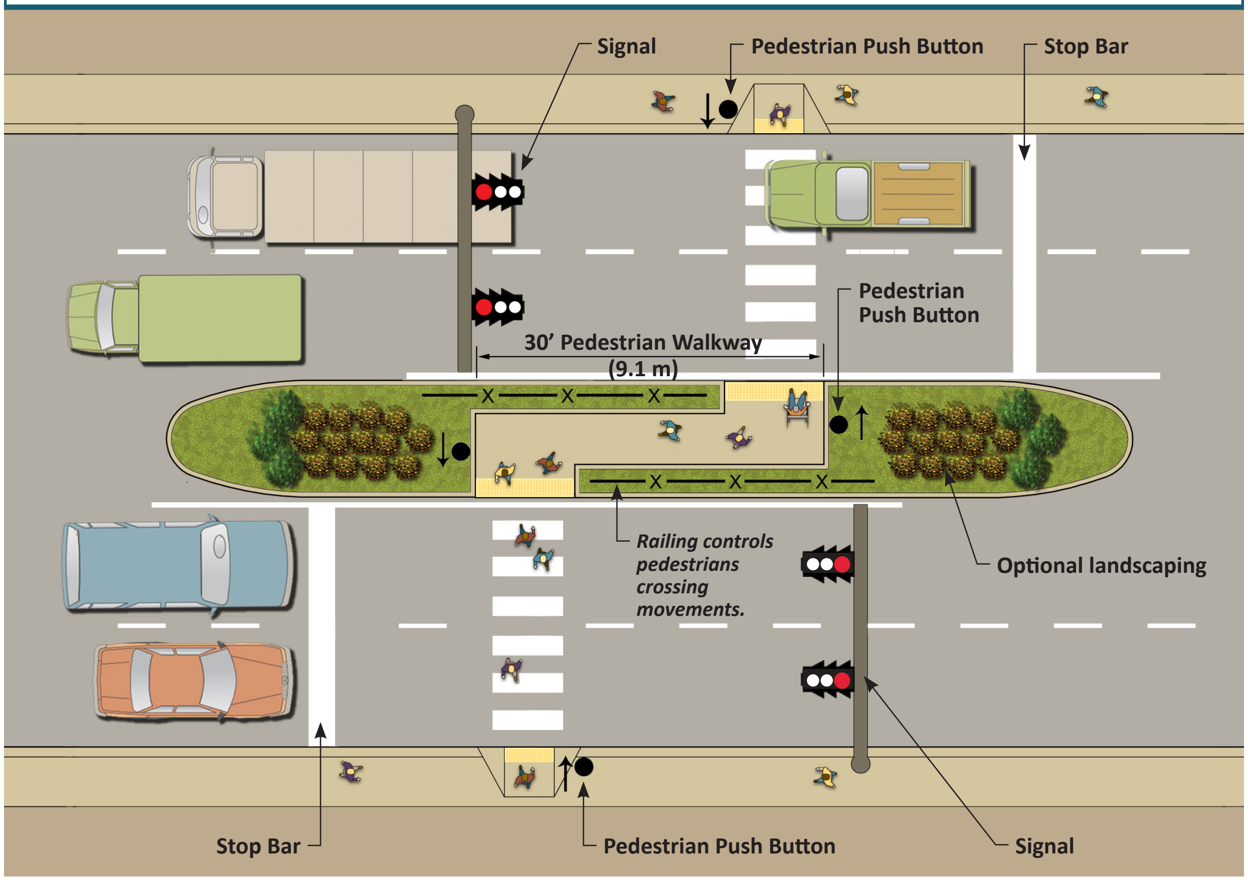
Wide, two-way streets (four lanes or more) with high traffic volumes, high travel speeds and large pedestrian volumes.
Wide streets where children, people with disabilities, or older adults cross regularly.
Wide, two-way intersections with high traffic volumes and significant numbers of crossing pedestrians.
Local and side streets where traffic volumes and flows create insufficient time to cross.
Minor access/local residential streets where they function both as traffic calming devices and street crossing aids.

EXHIBIT 5.33 Medians create a natural place to provide a pedestrian refuge island in mid-block.



A raised refuge island with a cut through in a "Z" form is the best practice as shown in Exhibit 5.33. It offsets the crosswalk so pedestrians will be oriented towards oncoming traffic. A walkway between split crossings can also be provided, as shown in Exhibit 5.34. This approach provides space for pedestrians waiting to cross, and it also forces the pedestrian to view oncoming traffic as they walk from one crossing point to the next. Railing can be installed to control pedestrian crossing movements.

EXHIBIT 5.34 A Well Designed Pedestrian Refuge at a Fully-Signalized Mid-Block Crossing



RAISED MID-BLOCK CROSSINGS

Raising a crossing to the same level as the curb enhances pedestrian safety by making pedestrians more visible and by functioning as a speed hump or speed table, which forces motorists to slow down. They provide additional comfort to the pedestrian by maintaining the grade from curb to curb. Raised crossings should be accompanied by the appropriate roadway markings as shown on Exhibit 5.35. Advance speed hump markings are designed to warn motorists of the upcoming speed hump and may help alert them to the presence of pedestrians as well.

Signalization and Signs at Mid-Block Crossings

Mid-block crossings may be signalized, unsignalized, or use other techniques described in this section to control roadway traffic. Signalization should be designed and installed only on the basis of a professional engineering study.

Exhibit 5.36 lists suggested traffic control treatments for pedestrian crossings of four or more lanes on streets and roadways. These suggestions also apply to shared use paths.

EXHIBIT 5.35 *Speed humps can double as crossings and should be marked with crosswalk markings and speed hump markings.*

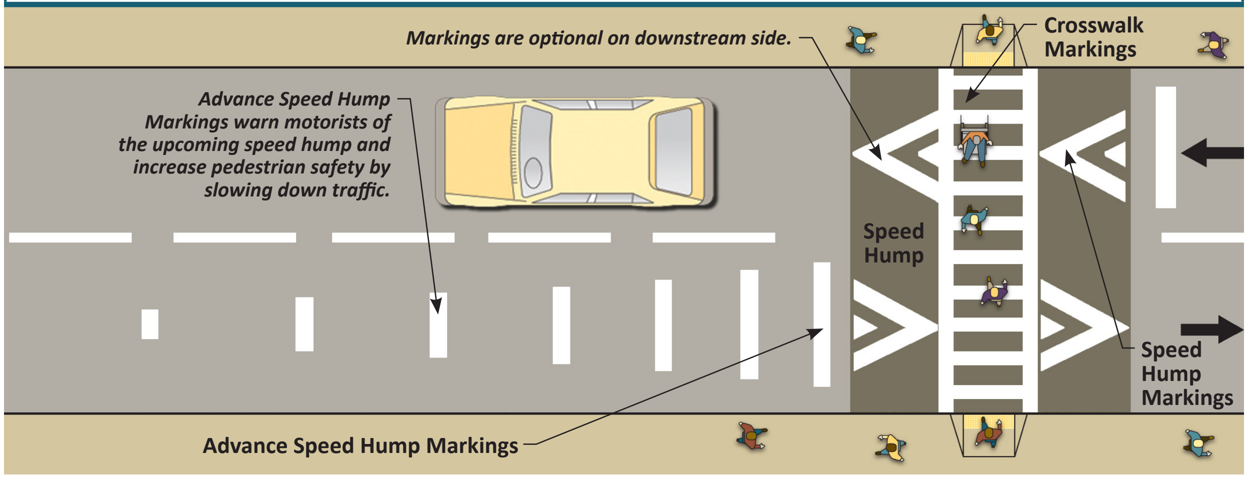


EXHIBIT 5.36 *Suggested Traffic Control Treatments on Four (or More) Lane Road Crossings*

SPEED OF AVG DAILY TRAFFIC ON ROADWAY (85%)	<10,000 ADT	10,000-19,999 ADT	20,000+ ADT
<=35 mph (60 kph)	Refuge area, preferably protected	Protected Refuge or Signal	Signal or grade separated
>=40 mph (65 kph)	Protected Refuge or Signal	Signal	Signal or grade separated

Source: Florida Pedestrian Planning and Design Handbook

MID-BLOCK PEDESTRIAN ACTUATED SIGNALS

Pedestrian actuated signals are often appropriate for roadways that have high traffic volumes or speeds, or four or more lanes. Since these signals only operate in the presence of pedestrian traffic, they do not cause undue delay to vehicles during periods of low pedestrian volumes. A signal warrant analysis should be performed to study specific conditions and determine if a pedestrian actuated signal should be installed. See the previous discussion in this section on pedestrian actuated signals.

WARNING BEACONS

Flashing yellow lights may be used at mid-block crossings to warn motorists of the presence of pedestrians. Two flashing lights can be paired together to flash alternately or simultaneously. They may not be used in the absence of a warning sign (e.g. “Pedestrian Crossing”). The 2009 MUTCD suggests they should be used only if pedestrians are crossing, and as such they should be activated by a pedestrian push button. Warning beacons may also be used at certain school crossings or in places with high pedestrian volumes. They can be combined with speed tables to increase safety. See Toolbox Section 8—Children and School Zones for more information.

Because yellow flashing lights allow drivers to continue without a full stop, care should be taken to position warning beacons only where sight distances are long enough to allow drivers to stop if a pedestrian is in the crosswalk. If traffic volumes or speed are high, or if the crossing distance is long, the Pedestrian Hybrid Beacon may be a better alternative at mid-block crossings.

ADVANCE WARNING SIGNS AND PEDESTRIAN CROSSING SIGNS (SIDE OR OVERHEAD)

Advance Pedestrian Crossing signs should always be installed in advance of mid-block crossings.

Placement of advance warning signs depends on the speed of motor vehicle travel and other conditions, such as available sight distance. Refer to the 2009 MUTCD for sign placement criteria. To avoid information overload and allow for improved driver response, advance pedestrian warning signs should not be mounted with other warning or regulatory signs (except for a supplemental distance sign or an advisory speed plate).

Other Design Considerations

Mid-block crossings should be well lit and may require pedestrian lighting to supplement existing street lighting.

Fences, barriers, signs, or sidewalk ramps can be used at mid-block crossings and refuge islands to channelize pedestrians to the crossing. Trees and landscaping can also be used to enhance and identify the crossing area, but care must be taken to ensure that these do not obstruct visibility at the crossing in any way.

Minimizing Pedestrian/ Motor Vehicle Conflicts at Intersections and Crossings

There are a variety of techniques to minimize conflicts between pedestrians and motor vehicles. These focus on maintaining sight distances, restricting turning movements, on-street parking restrictions, access management, and signalization.

Visibility and Sight Distance

Good sight distance at intersections and mid-block crossings improves pedestrian safety and should be designed into roadway geometry. Uncontrolled intersections and mid-block crossings are of particular concern where inadequate sight distance exists, because there is no control (stop sign or signal) over the movements of vehicles and pedestrians. Facilities such as signs, utility poles, bus stops, benches, and other elements are often added after design and construction of an intersection, inhibiting driver and pedestrian visibility. These elements should not be located in areas that interfere with sight distances, if possible.

Exhibits 5.37 and 5.38 illustrate the area at an intersection that should typically be kept clear

EXHIBIT 5.37 *Clear Travel Area*

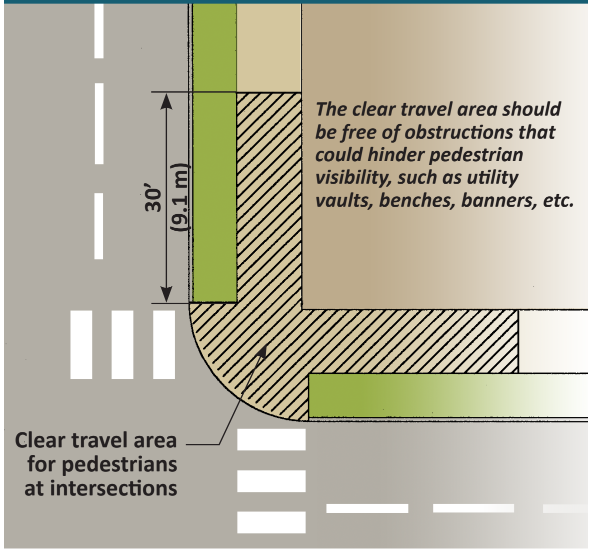
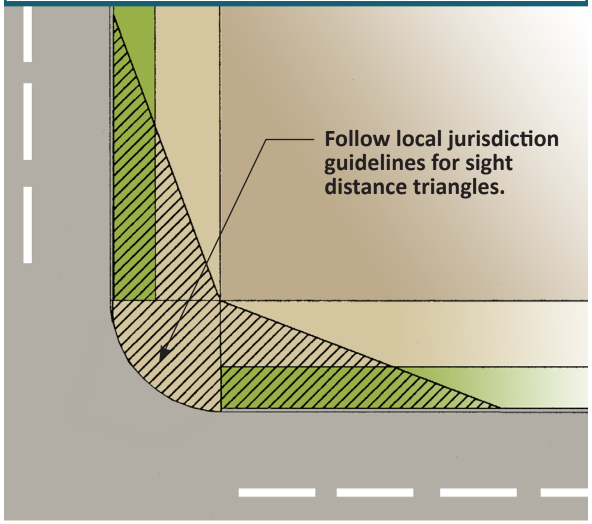
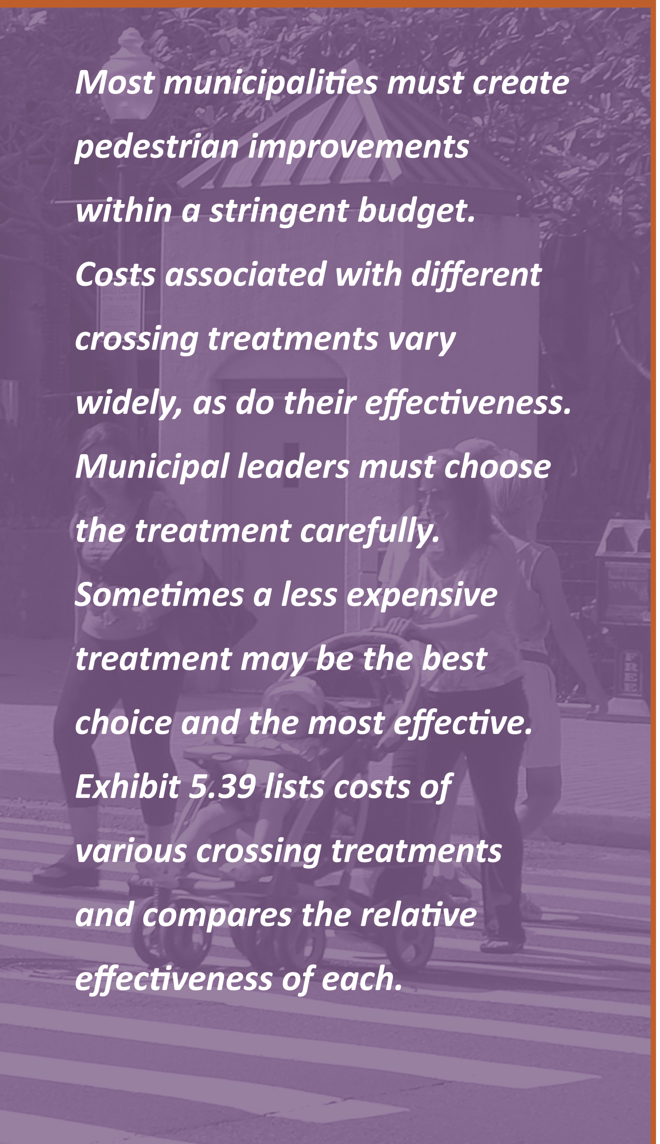


EXHIBIT 5.38 *Adequate sight distance must be maintained at all intersections.*



BUDGET ISSUES



Most municipalities must create pedestrian improvements within a stringent budget. Costs associated with different crossing treatments vary widely, as do their effectiveness. Municipal leaders must choose the treatment carefully. Sometimes a less expensive treatment may be the best choice and the most effective. Exhibit 5.39 lists costs of various crossing treatments and compares the relative effectiveness of each.

of obstructions. Refer to the HDOT standards or local guidelines for sight distance calculations at intersections and driveways.

Elements that obstruct the downward views of high-seat position drivers (such as bus and truck drivers) should also be avoided at intersections (within the sight distance triangle area; see Exhibit 5.38). This includes trees, signs, hanging banners, and other elements.

Curb extensions at crossing points provide space for pedestrians to stand in better view of approaching vehicles, and on-street parking can be placed closer to the crossing point without affecting visibility of pedestrians. (See Exhibit 5.29)

On-Street Parking Restrictions

On-street parking near pedestrian crossing points can interfere with visibility. When cars are parked too close to crossing points, they may block the line of sight between the driver and the pedestrian stepping off the curb to cross. Refer to Toolbox Section 2—Pedestrian-Friendly Streets for specific parking setback guidance.

EXHIBIT 5.39 ***Crossing Treatment Cost Comparison: Both mid-block and intersection crossings can benefit from the wide variety of treatments. The cost of these treatments varies widely.***

CROSSING TREATMENT	COST	EFFECTIVENESS
		* Least Effective ***** Most Effective
SIGNING	$500 - $1,000 each+	*
ADVANCE STOP BARS	$1,000 - $2,000+	****
HIGH VISIBILITY MARKINGS	$2,000 - $15,000+	**
ILLUMINATION	$5,000 - $15,000+	****
MEDIAN ISLANDS	$10,000 - $30,000+	****
SIGNALS	$50,000 - $200,000+	***
OVER/UNDERCROSSINGS	$500,000 - $2,000,000+	*
PROPER LOCATION	"PRICELESS"	*****

Source: Adapted from Pedestrian and Bicycle Information Center. Costs are conceptual–to be verified on every project.

Traffic Regulations and Access Management

Traffic regulation and access management practices can help reduce potential conflicts between pedestrians and motor vehicles at intersections. For more information about access management, refer to Toolbox Section 2—Pedestrian-Friendly Streets.

Turning Movements

Regulating turning movements at intersections can improve conditions for pedestrians. According to the ITE, 37 percent of all pedestrian/motor vehicle collisions at signalized intersections involve turning vehicles. Exhibit 5.40 summarizes possible solutions to minimize pedestrian/motor vehicle conflicts involving turning movements. Many of these techniques are discussed in greater detail in this toolbox section.

DUAL TURNING MOVEMENTS

Dual turning movement lanes are particularly difficult for pedestrians when visibility is impaired by two lanes of vehicles turning at the same time. This increases the level of unpredictable vehicular movement, and motor vehicle speeds may be different in each lane. Drivers may even switch from one lane to the other while turning.

EXHIBIT 5.40 ***Reducing Turning Conflicts***

Design compact intersections with small turning radii that force slower speeds
Prohibit right-turn-on-red
When right-turn slip-lanes are used, place crosswalks as far upstream as possible to provide high visibility for both pedestrians and drivers
Use a separate left-turn phase in conjunction with a pedestrian signal
Restrict left turns at busy intersections during hours of high pedestrian activity
Shorten crossing distance and exposure time with curb extensions or bulb-outs
Provide medians and refuge islands
Place signs to remind motorists of their duty to stop for pedestrians before turning
Consider providing an exclusive "pedestrian only" signal phase at intersections of high pedestrian use

Drivers may not be able to see beyond the car in front or to the side of them to determine if there is a pedestrian crossing the street. Dual turn lanes also create a wide crossing, which is already a difficult situation for pedestrians.

For all these reasons, it is strongly recommended that warrants for dual turn lanes be used to ensure that they are provided only if absolutely necessary. A separate pedestrian crossing phase or leading pedestrian interval signal timing should be used at these locations. (Refer to pages 5-9 through 5-12.)

Interchanges and Expressway Ramps

Expressways and freeways present barriers to pedestrian circulation. Pedestrians crossing exit and entrance ramps conflict with motorists whose attention is focused on other traffic and not on pedestrians. Exhibit 5.41 summarizes pedestrian-friendly design treatments at expressway ramps. Exhibit 5.42 illustrates recommended design practices for pedestrian crossings near on and off ramps.

Grade Separation

Grade separation may be necessary at crossings where extreme conditions dictate the need

EXHIBIT 5.41 **Design Treatments at Expressway Ramps**

Provide as short a crossing distance as possible and at a right angle to the ramp.

Locate the crossing point at either the terminus or the beginning of the ramp, where the vehicle is just entering or has slowed from its exit.

Discourage free-flowing motor vehicle movements at on and off ramps where there is heavy pedestrian crossing traffic. Slowing or stopping of motor vehicles in these areas is strongly recommended.

Connect access ramps to local streets at right angles. This reduces crossing distances and increases visibility. Install controls such as stop signs and signals to provide pedestrians opportunities to cross.

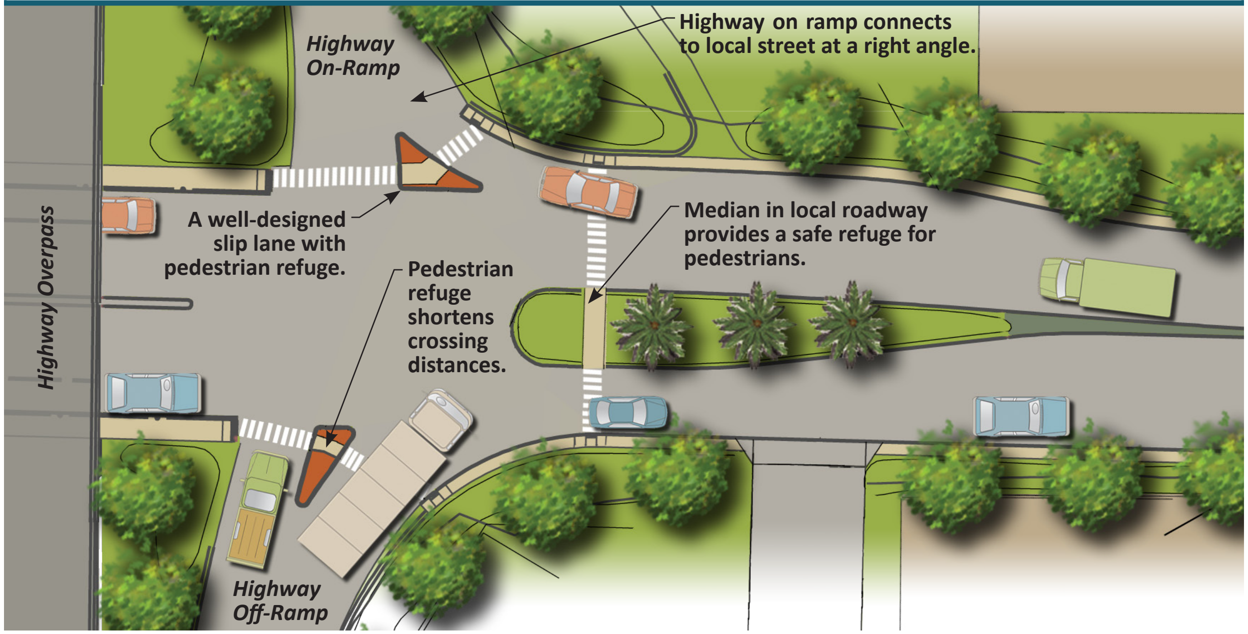
Install raised pedestrian refuge islands at slip lanes where appropriate. See Exhibit 5.42.

Clearly mark pedestrian crossings at controlled access ramps so they are visible to motorists.

Provide good sight distance and visibility at ramp.

Provide grade separation only as a last resort.

EXHIBIT 5.42 *At highway interchanges special design attention must be paid to pedestrian comfort and safety.*



for pedestrians to be completely separated from the roadway (or from railroad tracks or waterways). Overpasses and tunnels can provide safe pedestrian crossing opportunities, however they can also be cost prohibitive, and potentially ineffective. Unless there is sufficient space for ramping it may be difficult to provide accessibility, and elevators may become necessary. If the added travel distances are excessive, pedestrians who want the most direct route may be discouraged from using the grade separated crossing. Grade separated crossings can be costly. Because of this and the barriers they can create to pedestrian travel, they should be used only as a last resort.

OVERPASSES AND BRIDGES

Overpasses and bridges should be easy and convenient for pedestrians to access. They may become feasible when topography or an adjacent building make ramping unnecessary on one or both sides. Pedestrian bridges can vary in their structure and may be pre-fabricated or constructed of cast-in-place concrete, pre-stressed concrete, steel, or wood. Consideration should be given to cost, constructability, maintenance, aesthetics, and physical site constraints. Overpasses and bridges should be designed by a professional bridge or structural engineer and follow the guidelines in the most recent AASHTO *LRFD Guide Specifications for the Design of Pedestrian Bridges.*

All pedestrian bridges must be assumed to provide service to both pedestrians and bicyclists. As a result, a railing to railing width of 12 ft (3.7 m) is preferable. Consideration also should be given to designing the bridge to accommodate emergency and/or maintenance vehicles. If a bridge is to accommodate emergency or maintenance vehicles, a 12 ft width (3.7 m) is mandatory.

Since pedestrian overpasses are lighter structures than vehicular bridges, and therefore less resistant to impacts, the vertical clearance of an overpass should be two feet greater than the clearance for vehicular structures over the same roadway (Hawaii Design Manual). Bridges built over waterways must maintain a minimum clearance above the 100-year flood level.

SKYWALKS AND SKYWAYS

Skywalks or skyways are elevated walkways between buildings. They allow pedestrians to pass between buildings without going to street level. Fully enclosed walkways protect pedestrians from being exposed to weather. Design of skywalks will largely be determined by the buildings into which they are built and thus are not discussed in detail in this toolbox.

UNDERPASSES AND TUNNELS

Tunnels and underpasses provide a walkway for pedestrians underneath the roadway. Pedestrians are often more apt to use overpasses than underpasses or tunnels, and overpasses are easier to supervise and maintain. Tunnels are less desirable than bridges due to greater potential costs, reduced sense of security, challenges with monitoring, the possibility of drainage problems, and a perception of lack of safety. Before choosing to install a tunnel, soil exploration is required to determine whether a tunnel can be feasibly constructed and whether drainage will be a problem. Wide openings are more inviting to pedestrians and let in more natural light. Tunnels should be easy to access and should be as short as possible. Approaches to the underpass should allow continuous vision through it.

Regent undercrossing on University of Colorado campus, Boulder, CO

Iron horse pedestrian crossing, Contra Costa County, CA

A NOTE OF CAUTION ABOUT SKYWALKS

Use of skywalks may lead to a loss of pedestrian activity at the street level, negatively impacting the retail businesses and economic vitality of the area. When skywalks are being considered, ways to ensure that street level retail will still be fully accessible and inviting to pedestrians should be implemented. In addition, any potential violation of the view corridor must be avoided.

Roundabouts

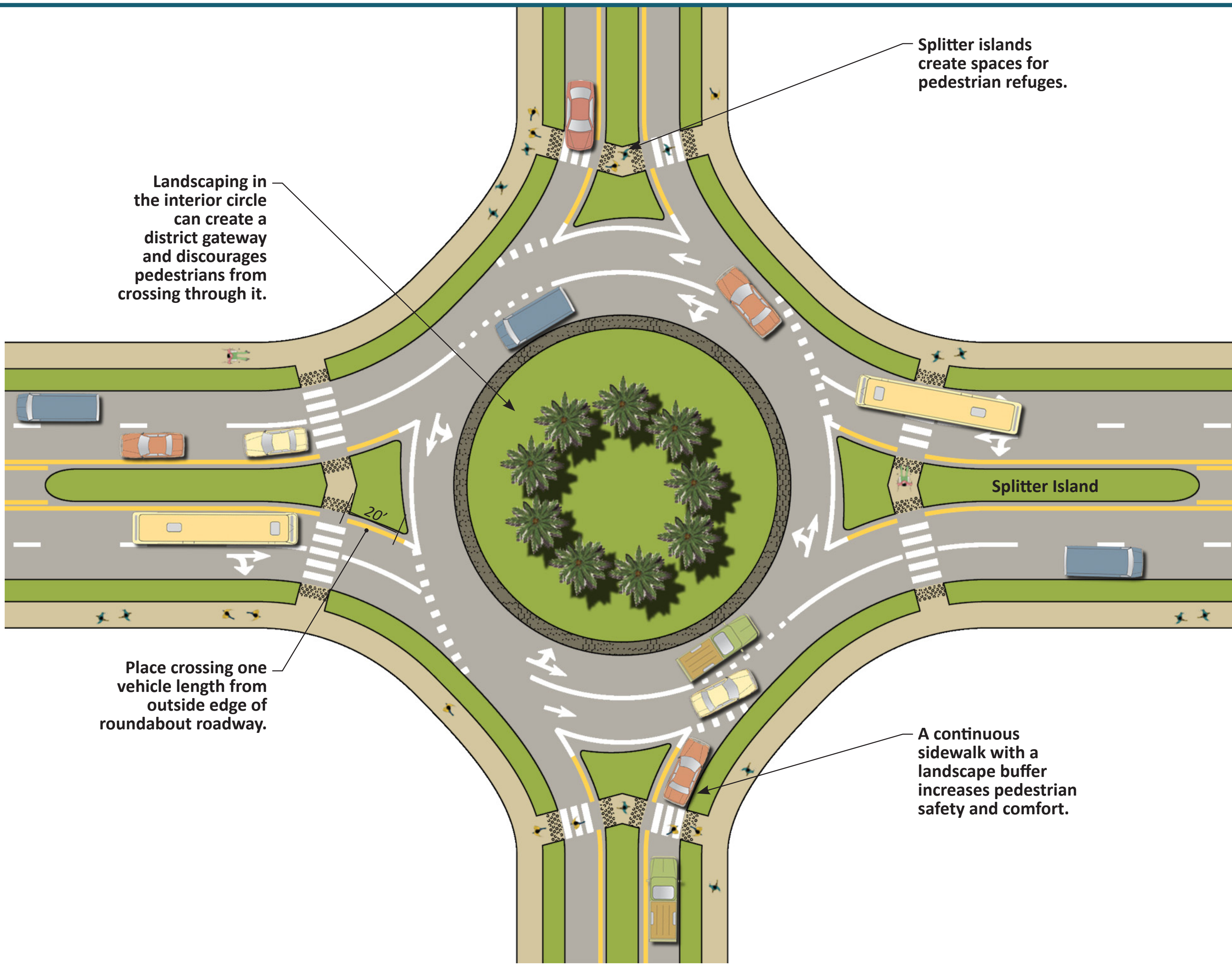
Modern roundabouts are designed to slow traffic, reduce delays, and handle higher traffic volumes. Research has shown fewer pedestrian collisions occur at roundabouts than at signalized or unsignalized intersections. Single lane roundabouts operate more safely than a two-way stop-controlled intersection, and they are less expensive to maintain than a signalized intersection. Single-lane roundabouts are safer for pedestrians than multi-lane roundabouts. Exhibit 5.43 illustrates a roundabout design with pedestrian crossing areas.

Pedestrians are not meant to cross into the center of the roundabout, and the interior of the roundabout can be designed to discourage this type of crossing. The following techniques can serve to discourage pedestrians from crossing into the interior:

- Application of rails along the roundabout legs to lead pedestrians and discourage them from crossing into the interior. As the radius, speed limits, and number of legs increase, rails are more necessary.

Roundabouts can act as district gateways.

EXHIBIT 5.43 *A well designed roundabout can improve traffic flow and provide a safe and comfortable environment for pedestrians.*



Flop over signs call attention to crossings.

- Landscaping that blocks the view across the roundabout (e.g. large shrubs and trees).
- Grade changes, such as small retaining walls, with shrubs, rocks, and other landscape elements on top of them.
- Absence of pedestrian amenities such benches.

Care should be taken to keep sight distances clear for motorists. These same elements can be combined to create an attractive and distinctive focal point for both motorists and pedestrians.

Roundabouts can feel unfriendly to pedestrians because of their size. However design solutions can be used to maximize pedestrian safety and comfort. These include:

- Sidewalks along the entire outer edge of the intersection.
- Crossings on all approaches. They should be located no less than 20 ft (6.1 m) from the outside edge of the roundabout roadway. This allows pedestrians to cross behind the first motor vehicle trying to enter the roundabout. "Stop here for Pedestrian" signs are not recommended. Splitter islands (which deflect the path of motor vehicles and slow them down at these crossings) provide places for pedestrian refuges.

Special attention should be paid to safety for sight-impaired pedestrians, because they rely on the sounds of traffic stopping and starting in different directions, which does not occur at roundabouts. See Toolbox Section 3—Accessibility.

Other Innovative Technologies

Soft Sandwich and Flop-Over Signs

Soft "sandwich board" signs can be an effective means of warning motorists to yield to pedestrians. Because they are typically placed in the center of the roadway they attract motorists' attention. The soft design prevents injuries to pedestrians, bicyclists, and cars if they hit the sign.

Flashing and Warning Lights

Various types of flashing and warning lights have been used in association with pedestrian crossings. Embedded pavement or in-pavement flashing lights have been used by a number

EXHIBIT 5.44 ***In-pavement warning lights make pedestrians more visible at night or in dark, cloudy conditions.***

of jurisdictions throughout the United States and are included in the 2009 MUTCD, Section 4N.02. They should be installed along the entire length of the crosswalk between its outside edge and ten feet from its outside edge. Refer to the MUTCD for recommended flashing rates, the number of lights to install and other design parameters. Compared with other types of warning devices, the effectiveness of embedded pavement flashing lights is high. Upon approach to a crosswalk with embedded pavement flashing lights, drivers are more apt to slow down and yield to pedestrians than when drivers approach a crosswalk with another type of lighted warning device. Also, compared to a crosswalk with no warning device, drivers are more likely to slow down and yield to pedestrians when embedded pavement flashing lights are in place. The device is particularly effective at night. A study conducted in San Jose, among other studies, confirmed the effectiveness of ***embedded flashing lights.*** See Exhibit 5.44.

The MUTCD has issued interim approvals to many jurisdictions across the United States for the optional use of rectangular rapid flashing beacons (RRFB). These devices are affixed to a pedestrian crossing sign and placed at mid-block crossings. Some of these devices use solar-powered, LED illumination, which is energy efficient. Interim approval allows interim use, pending official rulemaking, of a new traffic control device, a revision to the application or manner of use of an existing traffic control device, or a provision not specifically described in the MUTCD.

Puffin and Pelican Crossings

Puffin and Pelican crossings are in widespread use in Great Britain and in some locations in

A pedestrian activating a Puffin crossing in Cumbria, England

Flashing warning light (Rectangular Rapid Flash Beacon—RRFB)

Pedestrian-carried flags - PedFlag program in Kirkland, Washington

the United States. Both use detectors to sense whether pedestrians are in the crossing, and they are both activated by pedestrian push buttons.

Puffin (Pedestrian User Friendly INtelligent Crossing) signals involve the use of special detectors that sense the presence of pedestrians in the crossing and prevent the light from changing until all pedestrians have cleared the roadway. It also allows the light to change when the crossing is clear of pedestrians. This may be a shorter time than a regular signal, allowing traffic to resume its normal flow. The pedestrian signal head is located on the near side of the crossing, at 45 degrees to the road edge facing oncoming traffic at about eye-level, so that pedestrians can see both the signal and oncoming traffic at once.

There is no signal head on the opposite side of the road. Puffin crossings can help at locations where there is high use by slow moving pedestrians (hospitals, schools, and retirement homes).

Pelican (PEdestrian LIght CONtrolled) signals insert a yellow flashing light into the sequence in the change over from red to green. This allows drivers to proceed if there are no pedestrians in the crossing.

Pedestrian-carried Flags

Hand-carried pedestrian flags can be made available at each side of the pedestrian crossing. The pedestrian may be better able to attract the attention of the driver sooner by becoming more visible. This is a low cost device that can be installed for pedestrian use in a timely manner. Once the equipment is installed at the crossing the only ongoing cost is replacement of the flags. Because the pedestrian is aware of picking up and carrying the flag, they are more likely to be aware of crossing and traffic. Although there may be concerns that the flags can give pedestrians a false sense of security, there is no research to support this.

The use of pedestrian-carried flags has gained popularity around the country. Towns and cities in Alaska, Washington, Illinois, California, and other states have installed them. In Kirkland, Washington, the program is called ***PedFlag.***

Most of the evidence gathered shows that pedestrian flags are helpful in encouraging pedestrian safety. A report, available through the Transportation Research Board and National Cooperative Highway Research Program (NCHRP), *Improving Pedestrian Safety at Unsignalized Crossings,* describes the performance of various pedestrian safety treatments including pedestrian flags (see ***NCHRP 562*** page 19, Motorist Warning Signs and Pavement Markings). The use of pedestrian flags is not regulated by the MUTCD because they are not considered to be a traffic control device. (The MUTCD interprets flags to be similar to brightly colored clothing or reflective devices that may be worn by pedestrians.) Authorization for use is the responsibility of the controlling jurisdiction.

Special Pavement Markings

Zigzag and shark's teeth pavement markings are innovative treatments that can be used as traffic calming devices. In the County of Hawaii, zigzag lines have been painted at busy intersections and school zones to get motorists' attention and encourage them to slow down. Shark's teeth markings were also painted on blind curves, and have been observed to be effective at night due to the high reflectivity of the striping.

Effects of Pedestrian Improvements on Vehicle Capacity

As the recommendations in this toolbox suggest, current practices encourage design approaches that improve conditions for pedestrians and fully integrate them into the transportation system. Many of the techniques to improve pedestrian safety may affect vehicle capacity. Principal effects on capacity are caused by signalization, narrowing lanes, introducing curb extensions and bulb-outs, and reducing curb radii. Increased numbers of pedestrian crossings and bus stop relocations may also affect vehicle capacity. While these effects must be accounted for in all traffic engineering studies, they should not deter designers from introducing elements that will improve safety for pedestrians.

Other Resources

The following sources of information are recommended for design of intersections.

- American Association of State Highway and Transportation Officials (AASHTO). *A Policy*

Shark's teeth markings help keep motorists on the roadway at difficult curves.

Zigzag markings alert motorists to busy intersections and areas of high pedestrian activity, such as school zones and other areas.

on the Geometric Design of Highways and Streets, 5th Edition. 2004.

- American Association of State Highway and Transportation Officials (AASHTO). *A Guide for Achieving Flexibility in Highway Design.* 2004.
- American Association of State Highway and Transportation Officials (AASHTO). *Guide for Development of Bicycle Facilities, 4th Edition.* 2012.
- American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Planning, Design and Operation of Pedestrian Facilities.* 2004.
- American Association of State Highway and Transportation Officials (AASHTO). *LRFD Guide Specifications for the Design of Pedestrian Bridges.*
- American Association of State Highway and Transportation Officials (AASHTO). *Roadside Design Guide.* 2002.
- American Planning Association, Wiley & Sons, Inc. publishers. *Planning and Urban Design Standards*. 2006.
- Ewing, R., *Pedestrian and Transit-Friendly Design: A Primer for Smart Growth.* R. Ewing for Smart Growth Network in Florida, 1999. ***http://www.epa.gov/smartgrowth/pdf/ptfd_primer.pdf*** (May 2013).
- Federal Highway Administration. *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians.* FHWA Publication No. FHWA-RD-01-051, May, 2001. ***http://www.fhwa.dot.gov/publications/research/safety/humanfac/01051/index.cfm*** (May 2013).
- Federal Highway Administration. *Informational Report on Lighting Design for Midblock Crossings.* 2008. ***www.fhwa.dot.gov/publications/research/safety/08053/index.cfm*** (May 2013).
- Federal Highway Administration. *Manual on Uniform Traffic Control Devices (MUTCD).* 2009.
- Federal Highway Administration, *Priorities and Guidelines for Providing Places for Pedestrians to Walk along Streets and Highways.* 2000.
- Federal Highway Administration. *Roundabouts: An Information Guide,* FHWA publication #FHWA-RD-00-068. ***http://www.fhwa.dot.gov/publications/research/safety/00068/*** (May 2013).
- Federal Highway Administration. *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations Final Report and Recommended Guidelines,* FHWA Publication No.: FHWA-HRT-04-100, September 2005. ***http://www.fhwa.dot.gov/publications/research/safety/04100/*** (May 2013).
- Institute of Transportation Engineers, *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach.* 2010.
- Institute of Transportation Engineers, Traffic Engineering Council Committee TENC-5A-5, Zegeer, Charles V. (Chair). *Design and Safety of Pedestrian Facilities, A Recommended Practice of the Institute of Transportation Engineers.* 1998.
- National Complete Streets Coalition. ***www.completestreets.org*** (May 2013).
- National Highway Traffic Safety Administration. National Center for Statistics and Analysis. *Traffic Safety Facts.* 2008 Data. Publication No. DOT HS 811 163.

http://www.walkinginfo.org/facts/docs/PedTSF_2008.pdf (May 2013).

- Oregon Department of Transportation and Oregon Department of Land Use and Conservation. Transportation Growth Management Program. *Main Street—When a Highway Runs Through It* (Main Street Handbook). 1999.
- Pedestrian and Bicycle Information Center. ***www.walkinginfo.org*** (May 2013).
- Pedestrian Safety Guide and Countermeasure Selection System, sponsored by the FHWA. ***http://www.walkinginfo.org/pedsafe/index.cfm*** (May 2013).
- Public Rights-of-Way Access Advisory Committee (PROWAAC) to the US Access Board. *Special Report: Accessible Public Rights-of-Way Planning and Design for Alterations.* ***http://www.access-board.gov/prowac/alterations/guide.htm*** (May 2013).
- Seattle Right-of-Way Improvements Manual, City of Seattle, Washington—online access: ***http://www.seattle.gov/transportation/rowmanual/manual/4_21.asp*** (May 2013).
- US Access Board *Public Rights-of-Way Accessibility Guidelines (PROWAG).* Draft-rulemaking in process. ***http://www.access-board.gov/prowac/*** (May 2013).
- US Architectural and Transportation Barriers Compliance Board: *Accessible Rights-of-Way: A Design Guide.* 1999.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