

Sidewalks, Walkways, and Paths



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Areas that are designed to allow pedestrians to move efficiently and safely from one location to another can typically be classified as one of the following:

- ◆ **Sidewalk**—This is a paved area (typically concrete) which normally runs parallel to vehicular traffic and is separated from the road surface by at least a curb and gutter. Sidewalks are common in urban areas, may be used in some suburban locations such as residential areas, and are not often present in rural areas, primarily due to the high installation cost and low anticipated use.
- ◆ **Walkway**—This is an area for general pedestrian use (other than a sidewalk or path) such as courtyards, plazas, and pedestrian malls.
- ◆ **Path**—This is a temporary or permanent area that is normally dirt or gravel, although some paths are asphalt. A path typically indicates the common route taken by pedestrians between two locations and often indicates the need to provide a sidewalk or at a minimum, a paved surface.

This chapter primarily focuses on the design criteria for sidewalks. However, many of the same criteria apply to pedestrian paths. Walkways are part of exclusive pedestrian facilities (Chapter 16).

Properly planned, designed, and constructed sidewalks are essential...

Properly planned, designed, and constructed sidewalks are essential for increasing pedestrian mobility, accessibility, and safety, especially for persons with disabilities, the elderly, and children (Figure 6-1). Sidewalks increase pedestrian safety by separating pedestrians from vehicle traffic. One recent FHWA study cited the presence of sidewalks in residential areas as the one physical factor in the roadway environment having the greatest effect on pedestrian safety.¹

Figure 6-1.
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Placement

The inclusion of sidewalks is often determined by the engineer or planner on a site-by-site or project-by-project basis, without specific criteria for determining where sidewalks should be used. The most specific guidance provided by the American Association of State Highway and Transportation Officials (AASHTO) is for urban collectors and local streets as follows:

“Sidewalks used for pedestrian access to schools, parks, shopping areas, and transit stops and placed along all streets in commercial areas should be provided on both sides of the street. In residential areas, sidewalks are desirable on both sides of the streets but need to be provided on at least one side of all local streets.”²

It is the policy of the Florida DOT that all new urban roadway projects will include sidewalks if pedestrian traffic can be expected. There are some other general principles to consider in the placement of sidewalks.^{1,3}

- ◆ All roadways where pedestrian travel is expected should have a walking area that is out of the vehicle travel lanes. While a separate sidewalk or path is preferred, a paved roadway shoulder, particularly in rural areas, may serve the need. However, this provides the lowest level of service for pedestrians and does not serve children, older adults, and people with disabilities.
- ◆ Efforts should be made to provide direct connections between residences and activity areas such as shopping centers and transit stops. The most direct, and thus preferred, routes can usually be determined during the planning stages of a development. Incorporating these direct routes into the developments through easements or other means is preferred by residents and most cost effective when done at the planning stages.

- ◆ Developers should be required to incorporate sidewalks into every residential, commercial, and industrial project. Where undeveloped areas exist between already developed areas, local jurisdictions should fill in the gaps by connecting the developments with properly designed sidewalks.
- ◆ Schools should be required to incorporate sidewalks into their sites, and the sidewalks should be wider than adjacent areas to accommodate the high numbers of children during peak arrival and dismissal times.
- ◆ Whenever possible, sidewalks should be continued with their full width on bridges. Sidewalks on bridges should be placed to eliminate the possibility of pedestrians falling into the roadway, or over the bridge itself. Sidewalks should be placed on both sides of all bridges. Under extreme conditions sidewalks can be used on one side only, but should only be done when safe crossings can be provided on both ends of the bridge.

One additional factor that must be considered when determining sidewalk placement is the Americans with Disabilities Act (ADA). The ADA specifically states that: “At least one accessible route *within the boundary of the site* shall be provided from public transportation stops, accessible parking, accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance they serve.”⁴

If any part of this accessible route is part of a public sidewalk or other public pedestrian facility, efforts must be made to comply with requirements of the ADA. Many of these requirements are addressed in the design elements that follow.

Design Elements

Width

The width required for a sidewalk will depend on where it is installed and its anticipated level of use. When determining sidewalk width, it is important to remember two things: 1) a pedestrian requires a specific amount of lateral and longitudinal space for walking, and 2) the determined width is the “effective width,” exclusive of any obstructions. The minimum width for a sidewalk shall be 1.5 m (5.0 feet), or 1.8 m (6.0 feet) when placed at the back of the curb.

The “effective width” of a sidewalk can simply be defined as the total width minus the width for shy distances from buildings, the street, and other objects, and minus the width for objects placed on the sidewalk such as light poles, parking meters, newspaper stands, trash cans, mail boxes, and other street furniture. Recommended effective widths based on type of area, type of roadway, and number of dwelling units are shown in Figure 6-2.⁵ A planting strip wider than 0.6 m (2 ft) is often needed to accommodate traffic signs and utilities and provide enough space to maintain grass and other landscaping. Wider landscaping strips are usually easier to maintain than very narrow strips. Florida DOT recommends a minimum 1.8 m (6 ft) planter strip to place the sidewalk far enough back so that the driveway slope does not encroach into the sidewalk.

Whenever the sidewalks are protected by a wide utility strip, the sight distance should be carefully checked. Vegetation, fences, or buildings on private property can obstruct the view of a driver at the stop line. Whenever this situation occurs, the sidewalk should be brought closer to the street in the vicinity of the intersection. This permits the stop bar to be moved closer to the street. The exact amount of the shift is dependent on available right of way and the sight obstruction.

Type of Area (land use, roadway functional classification, or number of dwelling units)	Recommended Minimum Effective Width
Central Business District (CBD)	Wide enough to meet the level of service based on methods found in the 1985 Highway Capacity with a minimum width of 2.4 m (8 ft.).
Commercial and Industrial - outside the CBD	1.5 m (5 ft.) wide with a 0.6-m (2-ft.) planting strip or 2.1 m (7 ft.) without a planting strip
Residential-Arterials and collectors outside the CBD	1.5m (5 ft) wide with a 0.6-m (2-ft.) planting strip
Residential - local streets, multi-family and single family	(1 to 4 dwelling units/acre) 1.5m (5 ft.) wide with a 0.6-m (2-ft.) planting strip

Figure 6-2. Recommended minimum effective sidewalk widths based on area type, roadway type, and number of dwelling units per acre.⁵

In areas with insufficient right-of-way width, the following alternatives are offered in order of preference:

1. Construct roads with narrower travel lanes.
2. Use a 0.6 m (two-foot) utility strip with sign posts against the sidewalk or with signs behind the sidewalk.
3. Use a reduced sidewalk width (no less than 1.5 m (five feet)) that provides a lower level of service to the pedestrian.
4. Place sidewalk against curb. Some consideration should be given to installing guardrails between travel lanes and sidewalks for higher speed roads, particularly in school zones. If sidewalks are placed against the curbs, they must be widened to a 1.8 m (six-foot) minimum.

Pedestrian Buffers and Setback Distances

A buffer between pedestrian and motor vehicle traffic can offer many advantages to the comfort and safety of the pedestrian. A buffer can be in the form of a landscape strip, a parking lane, an on-street bike lane or a pedestrian fence or jersey barrier between the sidewalk and motor-vehicle lane.

On-street parking is generally not recommended along high speed arterials for obvious reasons, but it is generally needed along lower speed streets in residential, commercial and business districts and in the CBD. While parked cars can provide an effective safety barrier and separation between moving vehicles and pedestrians, care must be taken to reduce any visual screening of pedestrians crossing midblock and at intersections.

Bike lanes provide a helpful buffer area between motorized traffic and pedestrians. Pedestrian fencing can provide a barrier to help prevent pedestrians from darting into the street or from crossing at unsafe or less desirable locations. However, fencing may create a maintenance problem if placed close to the street, and may also create a visibility problem at driveways and intersections. Alternatively, landscaping may be used to direct pedestrians toward desired crossing locations.

The distance of the sidewalk from the roadway is defined as the setback distance and is an important design element. Sidewalks built close to the travel lane, particularly where vehicle speeds are high and where there is a high number of trucks,

discourage pedestrian travel due to perceived safety risks, increased noise levels, and splashing during wet weather. Though sometimes not feasible, sidewalks should be built as far from the road surface as physically possible, ideally near but not at the right-of-way line. Setbacks of 1.5 m (5 ft) or greater are recommended for purposes of:⁶

- ◆ Providing a margin of safety between the pedestrian and passing vehicles.
- ◆ Minimizing vehicle/pedestrian conflicts.
- ◆ Reducing potential splashing of pedestrians by passing vehicles.
- ◆ Providing space for utilities, parking meters, traffic control devices, landscaping, street furniture, and snow storage.
- ◆ Preventing driveway slopes from encroaching into the sidewalk, which may present a problem for the elderly or persons in wheelchairs or on crutches.

However, when sidewalks are placed at the back of a swale, they must be brought closer to the parallel roadway at intersections. On bridges for high speed

roadways, it may be desirable to build a jersey barrier between the sidewalk and the curb lane. This will compensate for the lack of setback and avoid the high cost of extra bridge width while providing a high level of security and safety for pedestrians.

Where setbacks or other forms of pedestrian buffers can not be provided, it is recommended that wider sidewalks be constructed. In addition, there should be a 0.3 to 1 m (1 to 3 ft) space between the sidewalk and the right-of-way line. This will reduce the chance of the landscaping infringing onto private property or the sidewalk, and help with sight distances.

Pavement Surfaces

Sidewalks are typically constructed of concrete. However, other materials may be used to create a smooth walking surface, including asphalt and pavers of various materials. Care should be taken to ensure that the material selected does not become overly slippery when it gets wet and that required maintenance is minimal. On pathways, inexpensive materials such as well compacted limestone screenings or wood chips can be used to create a



Figure 6-4. A wide setback distance increases pedestrian comfort.



Figure 6-3. Sidewalks should be properly maintained, free from obstructions and potential problems for pedestrians.

functional facility. The use of materials other than concrete can often produce aesthetically pleasing environments that are well received by local residents. However, care must be taken to maintain these materials at a level that will be usable by people in wheelchairs.

Maintenance

Once installed, sidewalks need to be maintained to avoid creating obstructions and potential problems for pedestrians. A program of inspection and cleaning should be established by the local maintenance, traffic engineering, or public works department. Assistance in reporting problems may be requested from other

government personnel such as police or letter carriers who are commonly on the sidewalks. Local ordinances should be passed requiring adjacent property owners to be responsible for minor maintenance of sidewalks along their property; requirements may include debris removal, and clearing of overgrown trees and bushes.

Care should also be taken to make sure private landscaping, such as fences or decorative walls, does not create vision obstructions, and thus sight distance problems, at driveways, alleys or intersections. While the public agencies are not the caretakers of private property, they should develop a system to notify individuals who create vision obstructions which require corrective action. This system can greatly enhance the pedestrian environment.

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Motorist & Pedestrian Signs & Markings



Signs and markings are governed by the Manual on Uniform Traffic Control Devices (MUTCD), which provides specifications on the design and placement of traffic control devices installed within the public right-of-way.¹ The MUTCD encourages a conservative use of signs. Signs should only be installed when they fulfill a need based on an engineering study or engineering judgement. In general, signs are often ineffective in modifying driver behavior, and overuse breeds disrespect and diminishes their effectiveness.

Unnecessary signs and posts represent a hazard to errant motorists and may cause an obstruction to pedestrians and bicyclists. Unnecessary signs also represent an ongoing maintenance cost and are a source of visual blight. Sign placement and location criteria are provided in the MUTCD.

Regulatory Signs

Regulatory signs are used to inform motorists or pedestrians of a legal requirement and should only be used when the legal requirement is not otherwise

apparent. They are generally rectangular in shape, usually consisting of a black legend on a white background and must be reflectorized or illuminated. The most common types of regulatory signs related to pedestrians are shown in Figure 7-1. Signs used on roadways are to have the dimensions shown, whereas signs used on trails are generally smaller. Many motorist signs, including “Stop” and “Yield” signs, turn restrictions, parking restrictions and speed limits also have a direct or indirect impact on pedestrians.

The MUTCD encourages a conservative use of signs.

The Institute of Transportation Engineers has taken the position that no overall significant safety detriments occur with right-turn-on-red, while allowing it results in significant benefits in reduced energy consumption, positive environmental impacts, and reduced operational delays.²

However, Right Turn on Red is known to increase pedestrian/motorist conflicts. Typically the motorist is searching to the

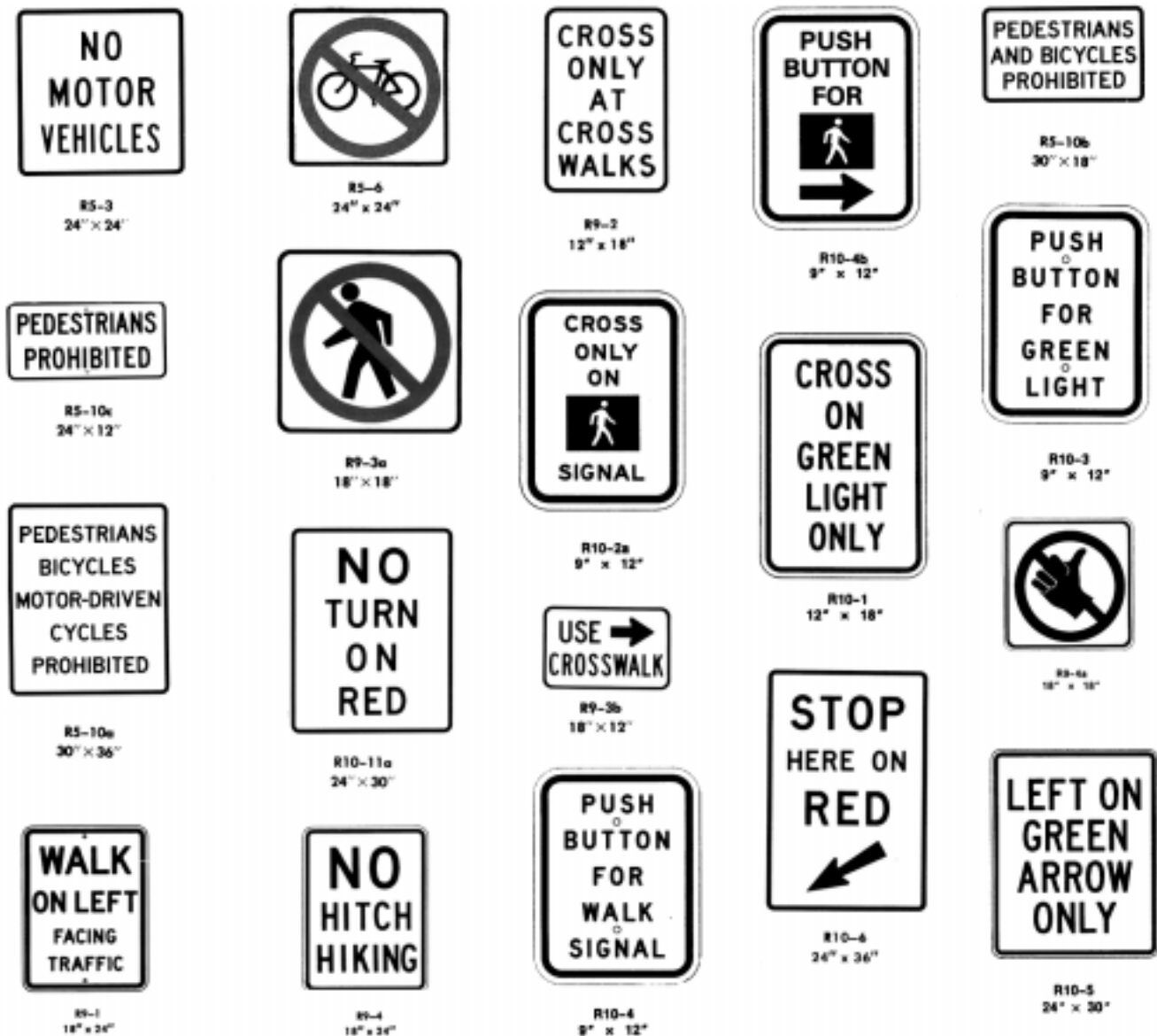


Figure 7-1. Typical regulatory signs relating to pedestrians.¹

left while the pedestrian is being directed by another traffic control device (a pedestrian WALK signal) to proceed. The pedestrian falsely assumes that the motorist will comply with the law and yield to them.

The "No Turn On Red" (R10-11a) sign may be used in some instances to facilitate pedestrian movements. The MUTCD lists six conditions when no-turn-on-red may be considered, three of which are directly related to pedestrians or signal timing for pedestrians. Considerable controversy has

arisen regarding pedestrian safety implications and right-turn-on-red operations, ranging from one study which indicated a significant increase in pedestrian accidents with right-turn-on-red³ to other studies which concluded that right-turn-on-red does not pose a pedestrian safety problem under most circumstances.^{4,5}

Consideration should also be given to pedestrian conflicts associated with right-turn-on-green (where the pedestrian has a WALK indication and the motorist has a

green ball indication) if right-turn-on-red is prohibited. Often, motorist compliance to “No Turn On Red” signs is low, particularly when the signs are poorly located and low pedestrian and cross-street traffic exists.

The use of “No Turn On Red” signs at a traffic signal should be evaluated on a case-by-case basis, and less restrictive alternatives should be considered in lieu of “No Turn On Red” signs. Recommendations relating to pedestrians include:

- ◆ Part-time restrictions should be discouraged; however, they are preferable to full-time prohibitions when the need only occurs for a short period of time. Although not in the MUTCD, the use of the “No Turn On Red When Pedestrians Are Present” sign may be an appropriate alternative.
- ◆ Universal prohibitions of right-turn-on-red are discouraged at school crossings. Restrictions should be made on a case-by-case basis and be sensitive to special problems of pedestrian conflicts, such as the unpredictable behavior of children and problems of the elderly and persons with disabilities. Pedestrian volumes should not be the only criteria for prohibiting turns on red.

Other regulatory signs relating to pedestrians include:

- ◆ Pedestrian prohibited signs (R5-10c, R9-3a, R5-10b) to prohibit pedestrian entry at freeway ramps.
- ◆ Pedestrian crossing signs (R9-2, R9-3a, R9-3b) are used to restrict crossings at less safe locations and divert them to optimal crossing locations. Various alternatives include the “Use Crosswalk” (with supplemental arrow) sign which may be used at signalized intersection legs with high conflicting turning movements or at midblock locations directing pedestrians to use an adjacent crosswalk. The signs have the most applicability if placed in front of schools or other major pedestrian generators.

- ◆ Extreme caution is urged in use of the R9... series. If there are high left turning volumes on a Tee-intersection, directing the pedestrian away from the unopposed turns is a smart safety measure. Signs should not be used to direct pedestrians away from a specific leg of an intersection crossing if they subject the pedestrian to increased levels of conflict and substantial increases in crossing time. Trading off increased motoring efficiency of the intersection to sacrifice the safety and mobility of the pedestrian is not a fair trade.

- ◆ Traffic signal signs (R10-1 to R10-4) include the pedestrian push button signs or other signs at signals directing pedestrians to cross only on the green light or walking man (WALK) signal. Pedestrian push button signs should be used at all pedestrian actuated signals. It is essential to provide guidance to indicate which street the button is for (either with arrows or street names). The signs should be located adjacent to the push button and be visible to approaching pedestrians.

Florida’s roadway design standards call for two separate poles, one for each pedestrian activator button. The poles are placed at the top of each of two curb cuts. Although this potentially doubles the cost of the actuators and pedestrians must push both buttons, the increased cycle efficiency can be a significant capacity benefit.

Other educational signs may be used for pedestrians at traffic signals to define the meaning of the walking man/hand symbol (or WALK, flashing DONT WALK and DONT WALK) signal indications. The decision to use these educational signs (or stickers placed directly on the signal pole) should be based strictly on engineering judgement. Their use may be more helpful near schools and in areas with a concentration

Figure 7-2. Typical warning signs relating to pedestrians.¹



of elderly pedestrians. This information may also be effectively converted into brochures for distribution and ongoing education purposes.

Warning Signs

Warning signs are used to inform motorists and pedestrians of unusual or unexpected conditions and when used, should be located to provide adequate response times. Warning signs are generally diamond-shaped with black letters or symbols on a yellow background and must be reflectorized or illuminated. Special lime-green fluorescent signs are being tested in the U.S. for special emphasis pedestrian crossings. Typical warning signs relating to pedestrians are shown in Figure 7-2.

The sign used to warn motorists of possible pedestrian conflicts is the Advance

Pedestrian Crossing sign (W11-2). This sign should be installed in advance of midblock crosswalks or other crossing locations where drivers may not expect pedestrians to cross. Typically this sign is placed 250 feet in advance of the crossing. This significantly minimizes their use at most urban intersections since pedestrians are an expected occurrence. This sign may also be selectively used in advance of high volume pedestrian crossing locations to add emphasis to the crosswalk. The advance pedestrian crossing sign provides more advance warning to motorists than crosswalk markings, and on some occasions may be used when crosswalk markings do not exist.

Where there are multiple crossing locations which cannot be concentrated to a single location, a supplemental distance plate may be used (NEXT XXX FEET). The advance pedestrian crossing signs should not be comounted with another warning sign

(except for a supplemental distance sign or an advisory speed sign) to avoid information overload. Care should be taken in sign placement in relation to other signs to avoid sign clutter and allow an adequate motorist response. The MUTCD specifies a 0.75 m by 0.75 m (30 in by 30 in) sign size. However, it may be helpful to use larger 0.90 m by 0.90 m (36 in by 36 in) signs on high speed or wider arterial streets.

The *Pedestrian Crossing* sign (W11A-2) is similar to the *Advance Pedestrian Crossing* sign, but has the crosswalk lines shown on it. This sign is intended for use at the crosswalk. Because of its placement and the motorist's inability to distinguish and comprehend the subtle difference between the two signs (W11-2 versus W11A-2), its usefulness is limited. If used, it should be preceded by the advance crossing warning sign and should be located immediately adjacent to the crossing point. To help alleviate motorist confusion, a black and yellow diagonally downward pointing arrow sign may be used to supplement the pedestrian crossing sign (W11A-2). Stop signs need to be placed before crosswalks so that motorists will be more likely to stop

before they encroach upon the sidewalk.

The Playground sign (W15-1) may be used in advance of a designated children's play area to warn motorists of a potential high concentration of young children. This sign should generally not be needed on local or residential streets where children are expected. Furthermore, play areas should not be located adjacent to high speed major or arterial streets, or if so, should be fenced off to prevent children from running into the street.

"Caution - Children at Play" or "Slow Children" signs are not valid MUTCD signs and *should not* be used since they may encourage children to play in the street and may encourage parents to be less watchful of their children.⁶ These signs provide no guidance to motorists in terms of a safe speed, and the sign has no legal basis for determining what a motorist should do. Furthermore, motorists should expect children to be "at play" in all residential areas, and the lack of signing on some streets may indicate otherwise. The use of this nonstandard sign may imply that the local agency approves of streets as



Figure 7-3. Pedestrian crossing signs along the edge of the roadway may be supplemented by signs in the median, overhead signs, and high-visibility crosswalk markings.

playgrounds, which may result in extra vulnerability to tort liability.

School Warning signs include the advance school crossing signs (S1-1), the school crossing sign (S2-1), “School Bus Ahead” (S3-1) and others. Additional information can be found in Chapter 14 of this document. School related traffic controls are discussed in detail in Part VII (Traffic Controls for School Areas) of the MUTCD.

The MUTCD allows for the development of other specialty warning signs based on engineering judgment for unique conditions. These signs can be designed to alert unfamiliar motorists or pedestrians of unexpected conditions and should follow the general criteria for the design of warning signs. Their use should be minimized to retain their effectiveness and minimize sign clutter.

Pavement Markings

Pavement word and symbol markings such as “SCHOOL XING” or “PED XING” may also be used as motorist warning devices. These may be helpful on high speed arterial or major streets with unusual geometrics (such as vertical or horizontal curves) in advance of a pedestrian crossing area. Markings should be white and placed to provide adequate motorist response. Their use should be kept to a minimum to retain effectiveness. Consideration should be given to the agency’s ability to maintain these markings. If used, the word or symbol markings shall be white and should generally be used in each approach lane (except for the SCHOOL message). Pavement word markings need not be used on both approaches to a crosswalk if conditions differ between the approaches.

All pavement word and symbol messages require periodic maintenance, and replacement after resurfacing. If used, it is advisable to maintain an inventory of pavement stencils to assist in periodic monitoring and maintenance.

Pavement Messages for Pedestrians

Florida has recently tested special signs and pavement markings that alert the pedestrian to search “left-right-left” before entering the street. Markings were used selectively at signalized intersections. The educational/instructional information substantially increased the number of pedestrians who look for traffic before entering the roadway.

Voice Messages for Pedestrians

Florida also recently tested voice messages giving the pedestrian a friendly reminder to search “left-right-left” before crossing the roadway. This message was well received, and substantially increased the number of pedestrians who searched for traffic before entering the roadway. A side benefit to this technique was that it told blind pedestrians which street they were about to cross.

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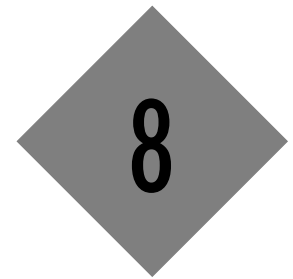
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Signalization

Signal Warrants

Traffic signals are intended to assign the right-of-way for vehicular and pedestrian traffic. When installed appropriately, traffic signals can provide many benefits, such as creating gaps in heavy motor vehicle traffic for pedestrians to cross safely at intersections or midblock. Unwarranted or improperly used traffic signals can cause excessive delay for pedestrians and/or motor vehicles, signal disobedience, and an increase in certain crash types. Even where warranted, traffic signal installations commonly result in an increase of rear-end and total crashes, but generally with a corresponding reduction in more severe right-angle crashes. The *Manual on Uniform Traffic Control Devices (MUTCD)* provides 11 separate warrants (Table 8-1) for installing new traffic signals.¹ Note that warrant numbers 3 and 4 relate directly to pedestrians, and warrant number 6 (and in some instances warrant 8) also makes some reference to pedestrians. In reality, only a small percentage of new traffic signals have been installed based primarily on pedestrian considerations. In most cases traffic signals are installed based on vehicular traffic considerations. However, revisions to the minimum pedestrian volume warrant (warrant 3) are expected to provide easier justification of traffic signals based on the needs of pedestrians.^{1,2}



The revised minimum pedestrian volume warrant states that a traffic signal may be warranted when the pedestrian volume crossing the major street at an intersection or midblock location during an average day is:

- ◆ 100 or more for each of any four (4) hours; or
- ◆ 190 or more during any one (1) hour.

Past experience shows that traffic signals are often among the highest pedestrian accident locations.

These volume requirements can be reduced by as much as 50 percent when the predominant crossing speed is below 1.1 m per second (3.5 feet per second) as would be the case if there is a high percentage of elderly or disabled pedestrians. In conjunction with these volumes, there shall be less than 60 gaps per hour in the traffic stream of adequate length for pedestrians to cross during the same period.

Simply meeting a warrant does not necessarily justify installation of a traffic signal. Strong consideration must be given to signal spacing, signal synchronization, and sight distances. Where practical, it is more

Warrant Title

- 1 *Minimum vehicular volume*
 - 2 *Interruption of continuous traffic*
 - 3 *Minimum pedestrian volume*
 - 4 *School crossings*
 - 5 *Progressive movement*
 - 6 *Accident experience*
 - 7 *Systems*
 - 8 *Combination of warrants*
 - 9 *Four-hour volumes*
 - 10 *Peak-hour delay*
 - 11 *Peak-hour volume*
-

Table 8-1. Warrants for installing new traffic signals.

desirable to signalize intersections instead of midblock crossing locations where drivers may be less likely to expect pedestrian crossings.

Warrant 6 (Accident Experience) may be used to justify a traffic signal if 5 or more “correctable” collisions occur in the previous 12 months, and at least 80 percent of the Minimum Volume warrant (warrant 1), the Interruption of Continuous Traffic warrant (warrant 2), or the Minimum Pedestrian Volume warrant (warrant 3) is met. Pedestrian collisions should be considered when using the Accident Experience warrant if the pedestrian is in the process of crossing the street in a reasonable manner. However, past experience shows that traffic signals are often among the highest pedestrian accident locations. Traffic signals cannot be expected to reduce or eliminate pedestrian collisions unless the signal is designed, operated and maintained properly and if pedestrians and motorists use reasonable care when crossing and when driving.

Pedestrian Signals

Pedestrian signals may be needed at highly complex or multiphase traffic signals where pedestrians regularly cross and where confusion may exist. Pedestrian signals may also be needed for crossings of wide streets where the vehicle signal indication does not provide ample signal change (clearance) information to pedestrians (Figure 8-2).

Pedestrian signal indications consist of the symbolic man/hand signal display or the WALK/DONT WALK signal display in conjunction with traffic signals. The steady hand symbol (or DONT WALK) indicates that the pedestrian should not be in the street. The flashing hand symbol (or flashing DONT WALK) is a clearance interval that means the pedestrian should not start crossing, but should have enough time to complete their crossing if they are already in the street (i.e., don’t start). The walking man symbol (or WALK) indicates that pedestrians may cross the street in the direction of the signal after searching to determine that it is safe. Pedestrian signal displays are illustrated in Figure 8-1. The WALK/DONT WALK signals are currently suitable alternatives to the (walking man/hand) symbolic displays. However, the next version of the MUTCD plans to phase out the use of the word message at new signal installations. It is recommended that agencies now program a “soft replacement” from WALK/DONT WALK messages in favor of the international walking man and hand symbols.

It has been well documented that many pedestrians do not understand the meaning of the pedestrian signal indications, particularly the flashing hand (or flashing DONT WALK). These problems highlight the need for more effective education of pedestrians to better understand the meaning of pedestrian signals. Education should include distribution of educational pamphlets or programs through schools, libraries, and community centers as well as signage such as the R10-4B “Push Button

For Walk” (or Pedestrian Symbol) sign (Figure 8-3). Although not incorporated into the MUTCD, an additional pedestrian education sign that may be used is shown in Figure 8-4 and is similar to ones used in cities throughout the U.S.

Besides a lack of understanding, some pedestrians violate signals due to impatience. Motorists put pedestrians at risk



Figure 8-1. Pedestrian signal displays.

when they run red lights and when making right and left turns while failing to yield the right-of-way to pedestrians lawfully in the crosswalk. Police enforcement is often the best solution to these problems.

Warrants for Pedestrian Signal Indications

Pedestrian signal indications should ideally be installed at all traffic signals, even if pedestrian crossings are rare. Also, crosswalks should be installed at all signalized intersections (and signalized midblock locations) to guide pedestrians to cross at the preferred crossing location. According to the MUTCD, pedestrian signal indications are normally required under the following circumstances:¹

- ◆ When the traffic signal is installed based on meeting the Minimum Pedestrian Volume or School Crossing Warrant.
- ◆ When an exclusive pedestrian crossing interval is provided (i.e. all conflicting vehicular traffic is stopped for pedestrians).
- ◆ When the vehicle signals are not visible to pedestrians (such as at one-way streets or “T”-intersections) or when the vehicle signals are not in a position to adequately serve pedestrians.
- ◆ Signalized intersections at established school crossing locations.
- ◆ Crossings of wide streets where the vehicle signal does not provide an adequate pedestrian clearance interval.
- ◆ When multiphase timing (as with split phasing or left turn arrows) is used and extra guidance is needed for pedestrians.
- ◆ When pedestrian push buttons are used.
- ◆ When optically programmed signal heads or tunnel visors are used and the traffic signal is not visible to the pedestrian.

Location of Pedestrian Signal Indications

The pedestrian signal heads must be positioned in alignment with the crosswalk so they can be seen by pedestrians while they are waiting on the curb at the other side of the street, and while crossing the street. The base of the signal housing is required to be between 2.1 m (7 ft) and 3.1 m (10 ft) high so that it will not normally require pedestrians to duck or be blocked by a car.

On wide streets, it may be advisable to install pedestrian signals in the medians, particularly where there are high numbers of elderly or visually impaired pedestrians. At tee-intersections, the pedestrian crossing should be located so the left-turning vehicles do not cross the pedestrian crossing.

Visors should be used for the pedestrian signal indication so that the signal is not readily visible outside of the crosswalk. This should hopefully encourage more pedestrians to cross in the crosswalk.

After the pedestrian signal is installed, each crosswalk should be inspected to make sure that traffic signs, trees, utility poles and other obstacles do not block the view of the signal indication. Periodic maintenance of landscaping may be needed to make sure the signal indications remain unobstructed.



Figure 8-2. Crosswalks, traffic signals, and pedestrian signals give pedestrians the opportunity to cross streets predictably and effectively.



Figure 8-3. Example of an instructional sign for pedestrians to activate the signal.

Pedestrian Signal Timing

For traffic signals at wide intersections, pedestrian crossing times are often the overriding factor used in determining green splits and cycle lengths. This also often leads to using minimum WALK and clearance (flashing DONT WALK) intervals.

The MUTCD requires at least a 4 to 7 second walking man (WALK) interval. At times this may present a dilemma to pedestrians who see a flashing hand (or flashing DONT WALK display) before they are more than one or two lanes across the street. While pedestrians almost always continue to cross rather than return to their starting point, it is desirable to provide a longer WALK interval where possible. When the vehicular green time is longer than that required for a 4 to 7 second WALK interval plus the pedestrian clearance interval, the WALK time should be extended to the maximum possible.

Recent research conducted for FHWA by Knoblauch indicates that senior adults often need 1.5 seconds just to get into the street. Curb ramps and audible signals may enable them to get into the street sooner. Seniors often allow younger pedestrians to go first, thereby entering the street last, after the WALK phase has ended. A slower walking speed should be used for calculating the clearance interval at locations with high numbers of elderly pedestrians. In the absence of a specific study, a walking speed of 0.9 to 1.2 m per second (3 to 4 ft per second) is recommended.

The clearance interval should be used on the full curb to curb walking distance (i.e., all the way across the roadway). This distance is measured from the center of the crosswalk. It is important to know that previous MUTCD language only required the engineer to get the pedestrian to the middle of the last lane. That language was found to be unsafe, and has been dropped. This requires upgrading of many existing intersection signal cycles.

Extra crossing time may be needed at signals with school crossing guards or with high pedestrian volumes to clear the queue of pedestrians waiting to cross. These locations should be evaluated on a case by case basis. Walking distances at some wide intersections may be excessive even for very mobile pedestrians. However, Florida DOT does not recommend pedestrian signal timing that only allows enough time to cross to a median. Signals should be timed to allow the pedestrian to cross the entire street on one crossing interval.

To help combat this dilemma we emphasize again the need for a design team approach. The traffic operations of an intersection must influence preliminary design and geometrics. Overly wide intersections may look good on paper, but they remain unsafe for motorists and pedestrians who must muscle their cars or their bodies in order to get through them quickly.

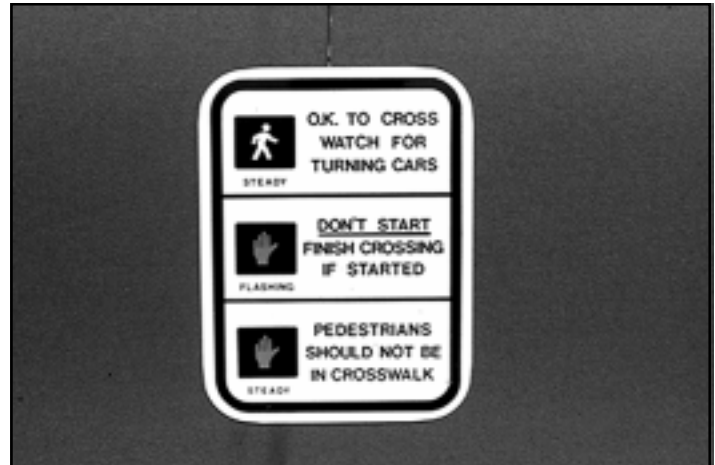


Figure 8-4. Example of an educational sign for pedestrian signal displays.

Case Study of Intersection Compression

In one fully designed intersection that was 55 m (180 ft) wide, trained engineers were able to apply channelized right turn slip lanes on all 4 quadrants, reduce lane widths to 3.4 m (11 ft) and take other measures that brought the pedestrian crossing width down to a more manageable 28 m (92 ft). This savings of 27 m (88 ft) on all four legs brought the signal cycle down 62 seconds, and greatly improved the efficiency and performance of the intersection for all roadway users.

Designers are also reminded never to trade pedestrian mobility and safety for maximum motorized capacity. To abandon the pedestrian on any leg of a four-cross intersection in order to achieve a higher level of efficiency is not condoned. By closing a leg to pedestrians the individual must now cross through the three remaining legs, encounter up to triple the conflict, and have substantial delays in trip time. The overriding principle in the design of a balanced transportation system is always to provide equal care and treatment for all users.

Left and Right Turn Phasing

Thirty-seven percent of all pedestrian accidents at signalized intersections involve left- or right-turning vehicles. One national study found that the left turn vehicle-pedestrian accident rate was twice that

involving right-turning vehicles.³ Potential solutions to pedestrian collisions involving right- or left-turning vehicles in some situations include:

- ◆ Design compact intersections with small turning radii which force slower turning speeds. This technique should not be used if it would result in capacity failure in locations with large left-turning truck volume. Instead, slip lanes may be required.
- ◆ Prohibit right-turn-on red (Figure 8-6). However, consideration should be given to the potential increase in right-turn-on green conflicts.
- ◆ Where channelized right-turn slip lanes are used to accommodate high right-turn volumes or truck traffic, place the crosswalk as far upstream as possible to make pedestrians more visible to the right-turning driver. The right-turn slip lane should be designed with 50 to 60 degree intersect angles which will limit vehicle speeds to 15 to 20 mph so as to make crossings safer for pedestrians. Motorists entering a crosswalk area at speeds in the 15-20 mph range almost universally yield to a pedestrian who is communicating an attempt to cross. Motorists entering a slip lane at 25-30

mph are less likely to stop. Motorists entering at higher rates of speed rarely stop for a pedestrian. Slip lanes should further be designed with the tail facing toward the approaching motorist (see Figure 11-4).

- ◆ Use a separate left-turn phase for motorists (left turn arrow), where pedestrians can not cross during the left-turn interval.
- ◆ Far left signal heads may be used for left-turning vehicles.

Left Turn Prohibitions

Many downtowns and urban cores like “K” Street and others in Washington, D.C., High Street through downtown Columbus, Ohio and U.S. Route 101 through San Francisco, California, have corridor-long prohibition of left turns. This adds to the system efficiency on the main route, and reduces conflicts with pedestrians. It also is a benefit to older drivers who are at high risk attempting to make left turns. Motorists reach their destination through a series of much safer right turns.

Be selective in this type of treatment. This is an aggressive approach that should be considered as part of a larger traffic management strategy for the district. The prohibition of a turn movement may shift the problem to another location and have a very negative effect on capacity and delay. However, heavy pedestrian volumes may justify left-turn prohibitions.

Pedestrian Signal in a Coordinated Signal System

The accommodation of pedestrians in a coordinated signal system may significantly influence the effectiveness of the signal system. It is not unusual to have signalized intersections where the pedestrian timing needs exceed those for its companion vehicular movement.

The length of the walking man (WALK) and flashing hand (DONT WALK) clearance intervals can have a major impact on the cycle



Figure 8-5. Pedestrian push button and signal heads are placed in channelized islands to guide pedestrians over a shorter crossing distance.

length in a coordinated signal system. This may result in longer cycle lengths, which will result in longer waits for pedestrians and vehicles on minor street approaches to traffic signals.

One solution is to design the system timing to operate without the pedestrian timing unless pedestrian actuation is detected. Then when a pedestrian push button is activated, the local intersection is disconnected from the system for one cycle to service the pedestrian movement. While this may work for areas with low pedestrian volumes, frequent pedestrian activations will severely disrupt the efficiency of the system. If high numbers of pedestrian crossings exist, it is best to accommodate the pedestrian on every cycle and eliminate the need for pedestrian actuation.

Signals in coordination should have the flashing “DONT WALK” end on the yellow. The first part of the through green should be “WALK”. As a minimum, the “WALK” interval should be:

$$3 + (n-1) 2 \text{ seconds,}$$

where 3 seconds = pedestrian perception/reaction time,

n = number of rows in the 85th percentile group, and

2 = additional seconds for each additional row of pedestrians.

Pedestrian Signal Phasing

Five signal phasing alternatives exist to accommodate pedestrian crossings at signalized intersections.

1. Standard (concurrent) timing - a walking man (or WALK) indication is displayed concurrently with the green light for motorists on the parallel street. Left or right turning motorists must yield to pedestrians in the crosswalk.
2. Early release of pedestrians - the signal displays red for the parallel vehicle movement, particularly the right turn, while the walking man (or WALK)



Figure 8-6. Right-turn-on-red restrictions can improve pedestrian safety when used properly. The top sign creates confusion and should not be used. The bottom sign conveys a much clearer message.

signals are displayed. The vehicular traffic then gets a green signal indication. This can be used at some intersections to reduce left-turning and right-turning crashes with pedestrians.

3. Late release of pedestrians - vehicles on the parallel street get a green signal indication before pedestrians get the walking man (or WALK) indication.

4. Exclusive pedestrian phasing - All vehicular traffic is stopped while

pedestrians are allowed to cross in any crosswalk.

5. Scramble pedestrian phasing - All vehicular traffic is stopped while pedestrians are allowed to cross in any crosswalk or diagonally across the intersection (sometimes called Barnes dance).

In actual practice, the concurrent signal timing is appropriate in most applications. Early or late release of pedestrians may be appropriate where there is a very high volume of right or left turning traffic. Under rare circumstances where there are very high pedestrian volumes (more than 1,200 pedestrians per day) and vehicle flow and signal synchronization is less of a concern, the exclusive pedestrian phase or scramble phasing may be used, which increases pedestrian safety, although it increases delay to pedestrians and motorists. While early release and late release timing may be used at locations with high vehicle turning movements, it is often preferred to also prohibit right turn on red and use protected left-turn phasing with these timing options.

Studies of various pedestrian signal phasing reveal that overall delay is lowest when using the concurrent signal timing. Exclusive or scramble pedestrian intervals may be safer for pedestrians where there are very high pedestrian crossing volumes (over 1,200 pedestrians per day), but results in the highest overall delay for motorists and pedestrians. If scramble timing is used, the clearance interval must be based on the longest crossing which is usually one of the diagonal crossings.

Pedestrian Push-Button

At locations with actuated traffic signals and signals where pedestrian activity is infrequent and pedestrian phasing is not warranted on a full-time basis, the use of pedestrian-actuated signals (i.e. push-buttons) is appropriate. When push buttons are used, there should always be a pedestrian signal head. Using pedestrian

buttons to activate a green traffic signal is inconsistent and can be confusing.

Designers are cautioned to not use actuated push buttons on crossings where there is always adequate time to phase a pedestrian. Pedestrians should not be required to push buttons when it is not essential for adding time. Many pedestrians do not push buttons. It is the engineer's job to give them a WALK signal whenever possible. Otherwise they give up on these information systems, and fail to use them, even when they have a specific purpose.

Where to Locate Push Buttons

Pedestrian push-buttons should be mounted at the top of and as close as possible to each of the two ADA ramps. This indicates the ideal standing location, provides a uniformity that allows the pedestrian always to push the correct button and simplifies the finding the button by a blind person. If there is only one ramp (due to an earlier design), two poles are still needed, positioned to indicate to the pedestrian the street to be crossed. In all placements, the pedestrian push-button must be easily accessible to a pedestrian in a wheelchair. Push-button devices are most often needed on intersection medians and refuge islands.

Where Not to Locate Buttons

Pedestrian push-buttons and pedestrian signal heads are not placed on each side of the intersection when channelized islands are used. All instrumentation is placed in the channelized islands. The pedestrian crosses to the island, activates the button and uses the WALK and signal phase to cross the shorter distance. This technique adds to the efficiency of the pedestrian crossing, often subtracting 12-15 m (40-50 ft) (10-12 seconds) from the crossing time (see Figure 8-5).

Improving the Effectiveness of Push-Buttons

Signs such as "Push Button for Walk Signal" are needed with the actuation devices to explain their meaning and use.

When two actuation devices are placed close together for crossings in different directions (e.g. at intersections), it is important to indicate which crosswalk signal is controlled by each push-button (e.g., “Push Button To Cross Central Ave.” or the standard arrow symbol indicating which street to cross).

The following are recommendations to improve the effectiveness of pedestrian push-buttons:

- ◆ Inspect and maintain the push-button on a schedule similar to that of vehicular traffic signals so that it is always operating properly.
- ◆ Assure pedestrians that the push-button is responsive to pedestrians by displaying the WALK signal within a reasonable amount of time after the button is pushed (i.e., preferably within 30-60 seconds).
- ◆ It is best to use push-buttons that are large and concave and do not require a substantial amount of force to activate. This will make it easier to use by young children, elderly and handicapped pedestrians.

Considerations for Persons with Disabilities

Pedestrians with disabilities may include those with a lack of mobility, stamina, visual impairments, hearing impairments and others.

Accommodation of blind and visually impaired pedestrians at traffic signals presents a unique challenge to the traffic engineer. Many visually impaired pedestrians are taught to use audible cues from the traffic to determine when it is appropriate to cross. When this is not possible, there is often a request to install audible pedestrian signals. Audible pedestrian signals may be appropriate near a school for the blind or community centers where large numbers of visually impaired pedestrians cross.

It has been found that audible pedestrian signals do more than assist blind

pedestrians. All pedestrians waiting to cross benefit by a prompting sound. The Australian audible signal has been found to be so helpful to everyone that it is used in most urban locations. The device uses a low, slow clicking (as loud as a pen being clicked) to guide visually impaired to the top of the ramp. When the signal has changed the clicking rate increases. This clicking guides the blind pedestrian to the ramp on the opposite corner. This audible cue alerts all pedestrians that it is time to search and begin their crossing.

There are no warrants for audible pedestrian signals and no standardization in the audible message which may lead to confusion for pedestrians. Until warrants and improved guidelines are developed, the use of audible pedestrian signals is left to the judgment of the local traffic engineer based on site specific conditions and the characteristics of the pedestrian population that routinely uses the intersection. The Florida Department of Transportation hopes to test and release standards by 1997.

Also of value to people with disabilities are handicapped ramps and proper ramp surface treatment, such as tactile warning surfaces. Chapter 5 covers ramps in more detail.

References

1. Manual on Uniform Traffic Control Devices for Streets and Highways, Report No. FHWA-SA-89-006, Federal Highway Administration, Washington, DC, 1988.
2. Bowman, B., J. Fruin, and C. Zegeer. Handbook on Planning, Design and Maintenance of Pedestrian Facilities, Report No., Federal Highway Administration, Washington, DC, March 1989.
3. Zegeer, C.V., K.S. Opiela, and M.J. Cynecki. Pedestrian Signalization Alternatives, Report No. FHWA/RD-83/102, Federal Highway Administration, Washington, DC, July 1985.

Crosswalks, Stop Lines, Curb Ramps, and Refuge Islands

Crossing a street at an intersection or designated midblock crosswalk generally requires a pedestrian to proceed from a sidewalk, down a curb ramp, through the crosswalk, up the curb ramp, and onto the sidewalk. If the street is excessively wide or if traffic volumes are extremely heavy, a refuge island may be encountered in the middle of the street. This chapter discusses the design criteria for these three elements associated with crossing the street.

Crosswalks

A crosswalk is defined as the portion of roadway designated for pedestrians to use in crossing the street (Figure 9-1). Crosswalks may be marked or unmarked. At intersections, there is no legal difference between a marked or unmarked crosswalk. If no markings are present, the width of the sidewalk or path extended across the street defines a legal crosswalk. Where markings are present, the legal crosswalk is defined by such markings. While markings are not needed to designate a crosswalk at intersections, they are needed to designate a midblock crosswalk.

In the 1950's and 1960's, crosswalk markings were thought of as a public service under the assumption that marked crosswalks were generally safer than unmarked crosswalks, and the more the better. Studies conducted since that time have produced mixed results with respect to the safety benefits of marked crosswalks.^{1,2,3,4,5}

This chapter discusses the design criteria for these three elements associated with crossing the street.

Two efforts indicated that marked crosswalks were successful in encouraging more pedestrians to cross within the markings, but that pedestrian safety may be reduced at unsignalized intersections where marked crosswalks are used.^{1,2} One of the conclusions for these results was that pedestrians may "feel safer" within a marked crosswalk and expect motorists to act more cautiously. In reality, crosswalk markings are not as visible to motorists as they are to pedestrians, and the pavement markings cannot stop an inattentive or impaired driver. Another research effort showed marked crosswalks to be as safe or safer than



Figure 9-1. Properly designed crosswalks, curb ramps, and refuge islands can greatly enhance a pedestrian's ability to cross a street.

unmarked crosswalks for all conditions studied.³

In practice, marked crosswalks are typically assumed to be most beneficial at signalized intersections, particularly in urban areas and where pedestrian signals (i.e., walking man/hand signals) are present. The use of marked crosswalks is discouraged at some types of midblock locations and at unsignalized intersections of high-speed roads. In particular, midblock crosswalks may be inappropriate on moderate- and high-speed roads (e.g., with speed limits of 40 mph and above) and where sight distance is limited.

Placement

Crosswalks should be placed in accordance with the Manual on Uniform Traffic Control Devices (MUTCD).⁴ A summary of the MUTCD provisions for crosswalk markings is provided in Table 9-1. Other criteria, based on various levels of pedestrian and vehicle volumes, have also been developed to assist in determining when and where crosswalk markings may be beneficial.⁵ As shown in Figure 9-2, if the combination of pedestrian and vehicle volumes is great enough to produce an intersecting value to the right of the appropriate curve, then a crosswalk may prove to be beneficial on that particular leg of the intersection. Note that the chart takes

into account the type of pedestrian, number of lanes, presence or absence of a refuge area, and also assumes that the basic criteria (shown in the top right-hand corner) have been met.

The most essential tool for use in determining crosswalk placement is engineering judgement. No set of guidelines can cover every situation or guarantee improved safety. Agencies should strive for uniformity to give motorists and pedestrians a consistent, predictable traffic environment. Overuse should be avoided to maximize the effectiveness of those crosswalks that are marked. Marked crosswalks are generally recommended at the following locations:⁶

- ◆ Signalized intersections. In general practice, signalized intersections in urban areas should have marked crosswalks on all four legs.
- ◆ Locations where a marked crosswalk can concentrate or channelize multiple pedestrian crossings to a single location.
- ◆ Locations where there is a need to delineate the optimal crossing location, due to confusing geometrics or traffic operations.
- ◆ Approved school crossings or at crossings on recommended safe routes to school.
- ◆ Other locations with high numbers of pedestrian crossings (more than 25 pedestrians per hour) and/or pedestrian/vehicle conflicts.
- ◆ To reach channelized islands when the volume of pedestrians times the number of vehicles exceeds 800 per hour. Do not use crosswalks at lower levels of conflict.

Where it is considered desirable to install midblock crosswalks, advance pedestrian warning signs should be used to warn motorists of pedestrian crossing activity (*see chapter 7 for more information on signs and markings*). Markings may be difficult to see during adverse weather conditions. Other actions that should also be considered when

installing a midblock crosswalk include positioning it near a street light (or installing additional lighting) and installing a pedestrian refuge island for the crosswalk.

Other factors that should be considered in the design and installation of crosswalks include:

- ◆ Adequate sight distance for the motorist and pedestrian should exist. (If it takes 11 seconds to enter and exit the crossing then an 11 second stopping sight distance is needed). This includes examination of on-street parking, street furniture (e.g. mailboxes, utility poles, newspaper stands) and landscaping. In some instances, curb bulbouts may be an excellent way to bring the pedestrian forward of parked cars and street furniture.

Marked crosswalks should not be located immediately downstream from bus stops, traffic signals or other marked crosswalks.

- ◆ An examination of street lighting should be conducted. It is highly advantageous to locate a marked crosswalk at a streetlight, particularly if nighttime crossings are common.

Here is additional guidance for midblock crossings:

A minimum enhancement that benefits pedestrians is a raised median island. This allows pedestrians who cross midblock to focus on one direction of traffic at a time, thus simplifying the crossing task. Medians may be essential on multilane roadways. More information about medians can be found in Chapter 12.

Crosswalks may be placed up to every five hundred feet when pedestrian volumes warrant. The use of marked midblock crosswalks at appropriate central business district locations channelizes pedestrian crossings, and helps motorists focus their attention on those areas where they should be the most alert.

Table 9-1. Recommended guidelines for crosswalk design and placement.⁴

Condition Level ¹	Requirement Description
Shall	Have 150 mm (6-in) minimum width markings of solid white lines.
Should	Have 1.8-m (6-ft) minimum [3 m (10 ft) desirable] crosswalk width
	Be used where substantial pedestrian/vehicle conflicts exist.
	Be used at appropriate points of pedestrian concentration or where pedestrians could not otherwise recognize the proper place to cross (e.g., loading islands, midblock pedestrian crossings.)
	Not be used indiscriminately.
	Be installed based on an engineering study if located other than at a STOP sign or traffic signal.
	Have advance warning signs installed at midblock crossings where pedestrians are not expected, and allow for restriction of parking for adequate visibility.
May	Be marked with white diagonal or longitudinal lines (parallel to vehicle traffic) for added visibility.
	Omit the transverse crosswalk lines when the extra diagonal or longitudinal markings are added.
	Use unique markings for diagonal crossings at signals when an appropriate exclusive pedestrian phase is used.

Refuge islands can be added when median islands are not practical. Crosswalk markings are appropriate when refuge islands are used. More information about refuge islands can be found later in this chapter.

Midblock crossings can be signalized when warranted. On multilane highways, pedestrians face the threat of one motorist stopping while a motorist in the adjoining lane continues forward. To reduce the likelihood of a pedestrian being hit by the second motorist, the stop bar should be placed back 36-50 feet from the crosswalk.

Design of Crosswalks

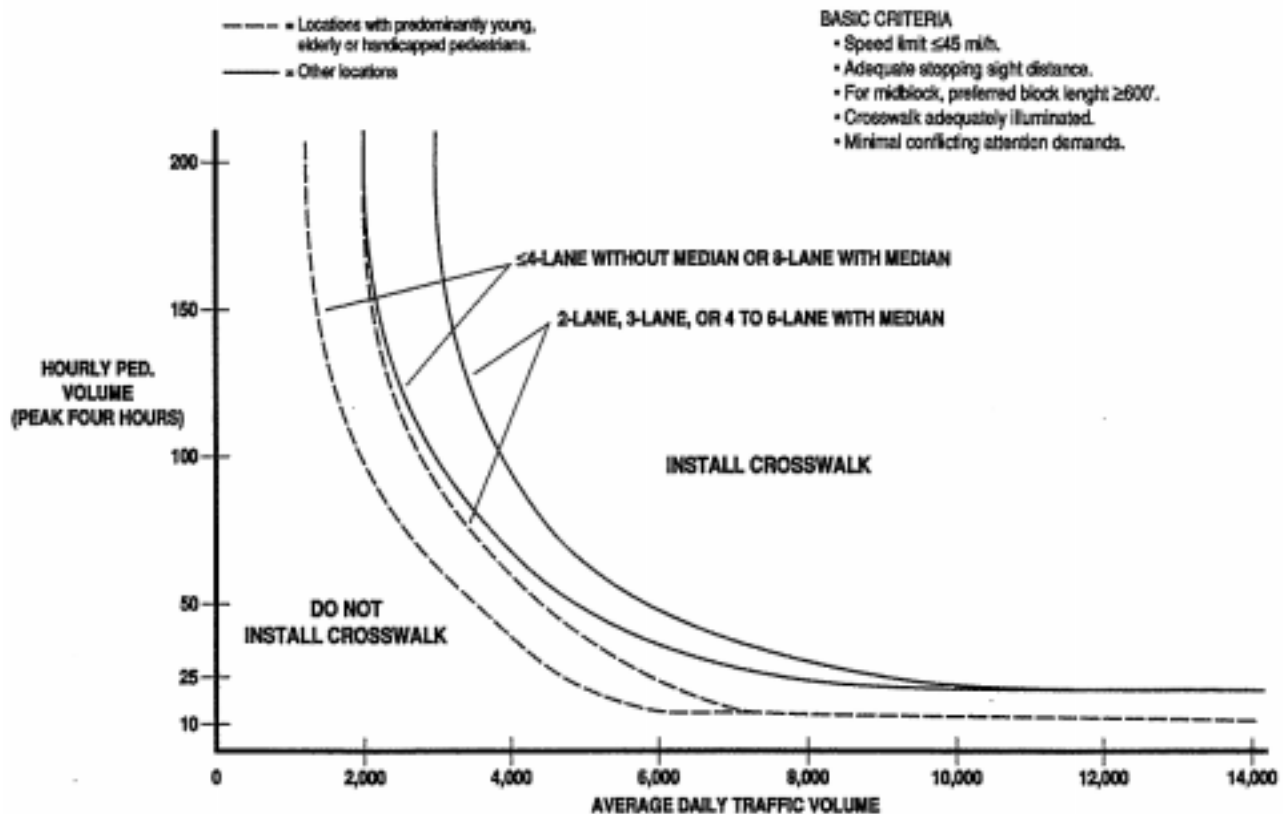
There are operational concerns with narrow crosswalks. Also, there are high costs associated with their installation. For these reasons, it is recommended that wider

crosswalks with wider pavement markings be installed than is required by the MUTCD. It is suggested that a 3 m (10 ft) wide crosswalk be installed, while wider crosswalks may be used where higher pedestrian volumes exist or where it is desirable to increase the conspicuity of the crosswalk. Similarly, crosswalk lines of 250 to 300 mm (10 to 12 in) in width are recommended, with wider lines or advanced stop lines used when greater emphasis is considered helpful.

Crosswalks at Skewed Intersections

Crosswalks need to be kept close to the turning traffic so that pedestrians stay within the driver's line of sight. The MUTCD recommends keeping the crosswalk lines within 0.6 m (2 feet) of the lateral lines of

Figure 9-2. Guidelines for crosswalk installation at uncontrolled intersections and midblock crossings.⁵



1. If using only the peak hour, threshold must be increased by 1.5
2. For streets with median, use one-way (directional) ADT volume.

Other notes: Minimum striping is 6" parallel lines. Consider bolder markings and/or supplementary advance markings or signing at uncontrolled locations where speed limits exceed 35 mi/h.

the highway. If this cannot be achieved it is essential to stay as close as practicable.

On skewed or highly skewed roadways there is a trade-off between making a 90 degree crossing of a roadway, or matching the junction of the roads (Figure 9-3). This skew also adds another 3.1-9.2 m (10-30 feet) to the crossing width. By dropping back to a 90 degree crossing, the crosswalk may end up 3.1 m (10 ft) or even 9.2 m (30 feet) from the intersection. This creates one of two problems. Either the motorist tends to move closer to the intersection, thus blocking the intersection, or he/she picks up high speed that endangers the pedestrian on the right turn leg of the intersection. Therefore, it is FDOT policy that crosswalks follow the skew and stay close to the turning traffic.

Crosswalk Placement on Hills and Curves

Avoid placing crosswalks on hills where vertical stopping sight distances are restricted. Motorists need at least 4 seconds to detect, react and slow down for a pedestrian in a crosswalk. At locations where crosswalks are needed, placement at the top of a hill is much better than just below the crest.

Likewise, avoid placing crosswalks on curves where horizontal stopping sight distances are restricted. Placement where the motorist has been slowed by a curve and is now able to view the pedestrian fully is desirable. There will be locations where crosswalks are needed along a corridor with curves. Often a refuge or median island will help slow the motorist, and provide a low conflict crossing for pedestrians.

If inadequate vertical or horizontal stopping sight distances exist, the use of traffic calming measures (such as the refuge or median island mentioned above) to reduce motorist speed, or special signing, beacons, even signalization is desirable. Begin the median island before the curve.

Crosswalk Markings

Three different designs, as shown in



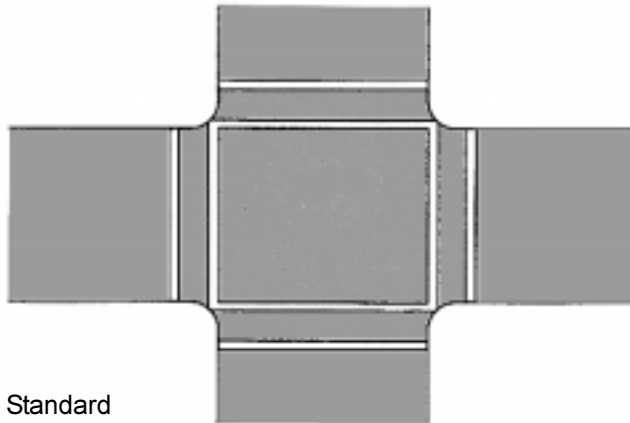
Figure 9-3. A crosswalk at a skewed intersection — there is a trade-off between making a 90-degree turn and staying close to the turning traffic.

Figure 9-4, are typically used to designate crosswalks. The standard crosswalk consists of two parallel white lines (scenario a). However, diagonal or zebra (scenario b), or longitudinal or ladder (scenario c) lines may be used for increased emphasis. Special markings (Figure 9-5, bottom) should be used where a high volume of wheelchairs or roller bladers (trail crossings) can be anticipated. This open design permits those with thin wheelchair casters and wheels or rollers to cross a high visibility marking without ground interference.

High Visibility Crosswalk Markings

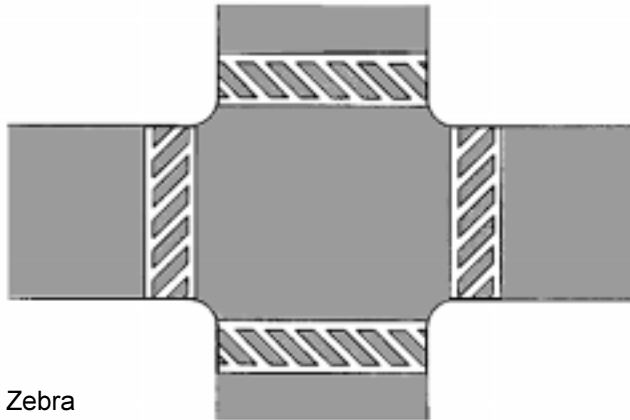
The advantage of type (b) is higher visibility and reduced maintenance. Properly placed, the wheels of crossing motorists can fall between the open spacing, thus allowing the markings to remain visible much longer than with other markings. Another benefit of (b) and (c) as high visibility markings is that bicyclists traveling perpendicular to the crosswalk can pass between the markings. Wide markings can be slippery to bicycle wheels when wet. Care should be taken in maintaining type (b) and type (c) markings, since successive overcoats of paint or thermoplastic creates a buildup that can slow or hamper wheelchairs and roller bladers. The high visibility markings shown in Figure 9-5 (bottom) are not found in the MUTCD. Their use can be justified by

a — Standard crosswalk marking.



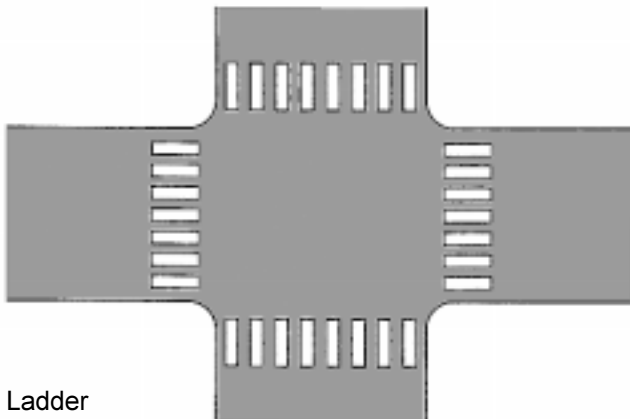
Standard

b — Crosswalk marking with diagonal lines for added visibility.



Zebra

c — Crosswalk marking with longitudinal lines for added visibility.



Ladder

Figure 9-4. Typical crosswalk markings.⁴

having demonstrated improved maintenance and operational characteristics which are a benefit for wheelchairs and rollerbladers.

There is debate among some engineers whether high-visibility crosswalks should be reserved for places where added emphasis is needed, such as at midblock crossings, schools or high volume pedestrian crossings (Figure 9-5). In contrast to this philosophy is the desire to use these markings in all locations, in order to reinforce a simple, clear, consistent visual message to motorists that this more readily detected crosswalk marking is a place to expect pedestrians.

Paver Stone Crosswalks

Some downtowns have made a significant investment in the use of color rich paver stones to delineate the intersection and crosswalks. These include Washington, DC; Portland, Oregon; Ft. Lauderdale (A-1-A), Florida; Daytona Beach, Florida; and Orlando, Florida. Pavers can be used to create useful patterns. For instance, on the highly successful boulevard style “K” street in Washington, DC, designers created different colors to indicate when a pedestrian is in a conflict versus a nonconflict (refuge-protected) zone.

If paver stones are used, they must be designed to eliminate the movement of the stones or bricks. A solid granite or concrete parallel strip must be used along with a solid re-bar reinforced concrete pad for the full length and width of the crossing. If these levels of care are not followed, the paver stones will float and create depressions and gaps that trap narrow heels and dislodge bicyclists.

Raised Crosswalks

At airports, on traffic calmed neighborhood streets, and some collector roads, where speeds are maintained at or below 40 km/h (25 mph), it is possible to raise the entire crosswalk area 150 mm (6 inches). An approach and departure change in grade of 1:12 is used, and the minimum 3 m (10 foot) or greater width crosswalk is

used. When traffic calming is used in these types of locations it is always desirable to have the traffic calming feature at the specific location where pedestrians cross. In this way the motorist's gaze is directed at the crossing rather than at an upstream or downstream location.

One especially effective raised crosswalk is found at the Daytona Beach, Florida airport. The raised crossing has imbedded yellow lights and prisms on the approach taper. Although expensive, this high use pedestrian zone treatment leads to a nearly 100 percent yielding behavior by motorists.

RPMs and Marked Buttons

Crosswalks marked with buttons or reflective raised markers (RPMs) are not recommended. Any rumble effect given to motorists at this point is provided too late for use as advance warning, and the pedestrians who walk along the lines (especially older adults and blind pedestrians) may trip on the RPMs. RPMs are also detrimental to wheelchairs and bicyclists. RPMs may be used upstream (not in bike lanes) from a crosswalk in conjunction with advance pedestrian warning signs in an attempt to enhance motorist awareness of the upcoming crosswalk. These devices should not be used in bike lanes or where bicycling traffic can be anticipated.

Maintenance

Marked crosswalks should be kept in good condition and should be removed when no longer needed. Shorter service life, longer dry times and the need for more extensive barricading make painted crosswalks less desirable than longer life plastic materials and ultimately more expensive to maintain. However, plastic pavement markings are more difficult to remove, often requiring special equipment.

It is desirable to maintain an inventory of crosswalk locations for periodic maintenance and monitoring purposes. Once installed, the crosswalk should be monitored for continued

applicability and usefulness. When no longer useful, crosswalk removal may be coordinated with a street resurfacing project.

Stop Lines

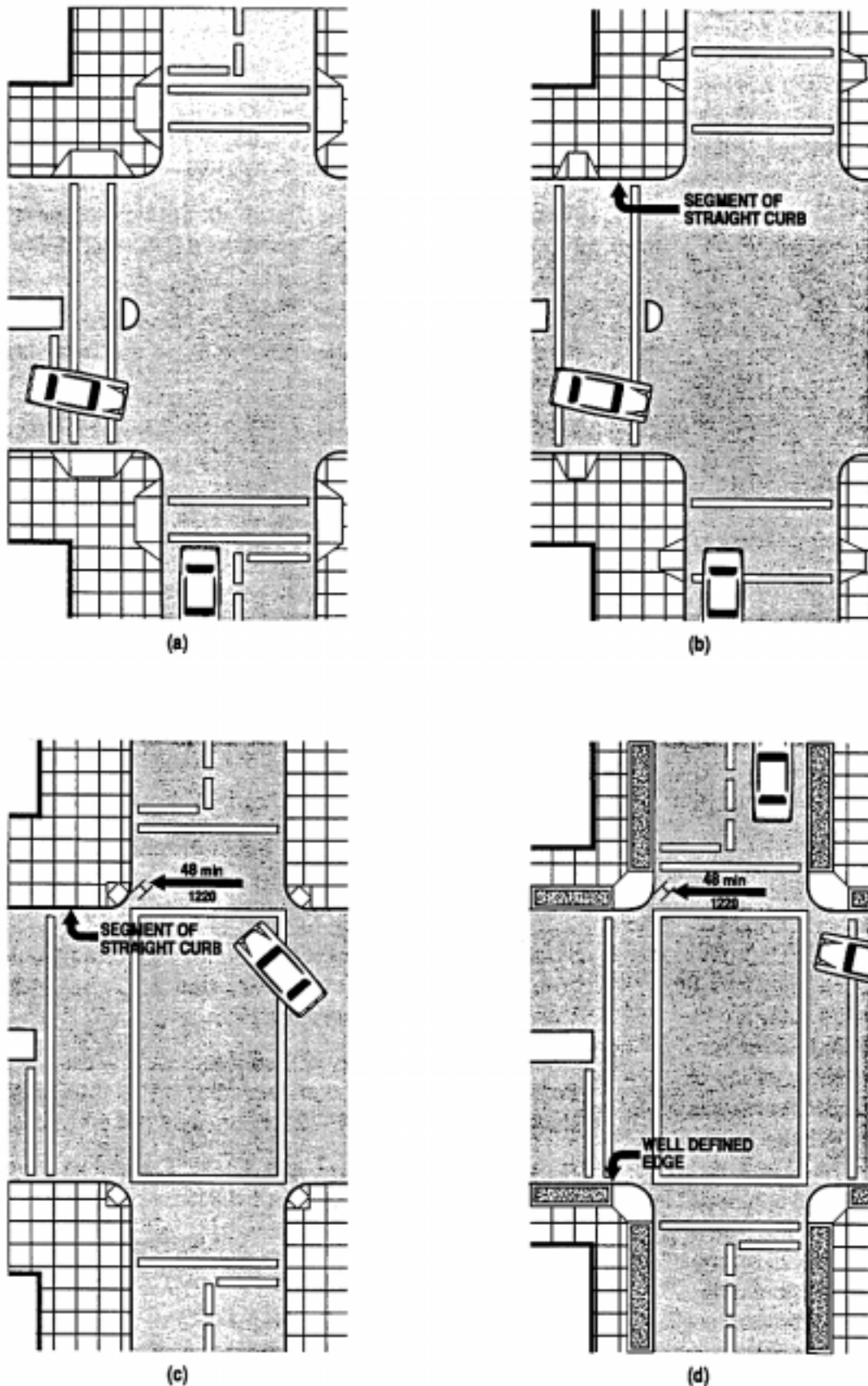
Effective traffic operations are needed to prevent motorists from stopping in crosswalks. Stop lines may be used as a guide to indicate the optimal stopping location for motorists, and may be used in advance of marked crosswalks to help encourage motorists to stop further back from the crosswalk. They are intended to be used at locations where motorists are required to stop, and may be used on approaches to traffic signals, stop signs (with or without marked crosswalks), or uncontrolled marked crosswalks.



Figure 9-5. High-visibility markings such as longitudinal lines may be used in crosswalks for increased emphasis.

*Crosswalks, Stop Lines,
Curb Ramps, and Islands*

Figure 9-6.
Crosswalk
placement in
accordance with
various ramp
designs. (A) and
(b) are the
preferred
treatments in
Florida. (C)
and (d) should
be used only if
there are right-
of-way
constraints or if
significant
retrofitting of
drainage
facilities would
be required.



Curb Ramps at Marked Crosswalks

When used on the approach to a marked crosswalk, stop lines should normally be placed about 1.2 m (4 ft) in advance of the nearest crosswalk marking. This distance may need to be extended back in those locations where high end semitrailers (long haul designs) are frequent, since their high nose prevents their drivers from seeing young children or those in wheelchairs.

Staggered Stop Lines

While stop lines are generally installed parallel to the crosswalk line, they may be installed at an angle, or staggered (offset) in each lane, which offers the benefit of allowing motorists in all lanes of a multilane approach to have a better view of pedestrians.

Midblock, Multilane Stop Lines

When a midblock crossing is used on a multilane highway, the stop line is best placed 12.2 m (40 feet) back from the nearest point in the crosswalk (see figure 9-7). By doing so, a stopped vehicle does not block the pedestrian or next lane motorist from seeing one another. This stop-line location greatly reduces the “multiple threat” type of pedestrian/vehicle conflict (see figure 4-4). Generally motorists will comply with this marking. If not, an enhancement sign “Stop Here When Pedestrian Is Crossing” with a downward arrow greatly increases compliance.

Agencies that do not deem stop lines cost effective must consider the trade offs:

- ◆ having motorists (especially high nose trucks) create sight distance problems for themselves and others
- ◆ the impact to pedestrians when crosswalks are blocked
- ◆ when older or disabled pedestrians are forced to wait a full cycle, or
- ◆ when younger pedestrians are forced to cross in the inner intersection, behind the offending vehicle or other unsafe positions.

Signal Loop Detector Placement

Signal loop detectors should not be placed in front of the stop line. There is a tendency in traffic engineering to move loop detectors forward when there is a high level of motorists creeping forward into the crosswalk area. If there is a high level of noncompliance with the stop line, consider increasing the stop line visibility (wider), and adding a regulatory sign (“Motorists Must Stop Here,” with downward arrow, or “\$75 Fine for Blocking Crosswalk”).



Figure 9-7. The failure to use stop lines encourages many motorists to stop too close to the intersection, forcing pedestrians into the parallel roadway. A midblock stop line queues motorists back 40 feet, reducing the chance for a multiple threat crash.

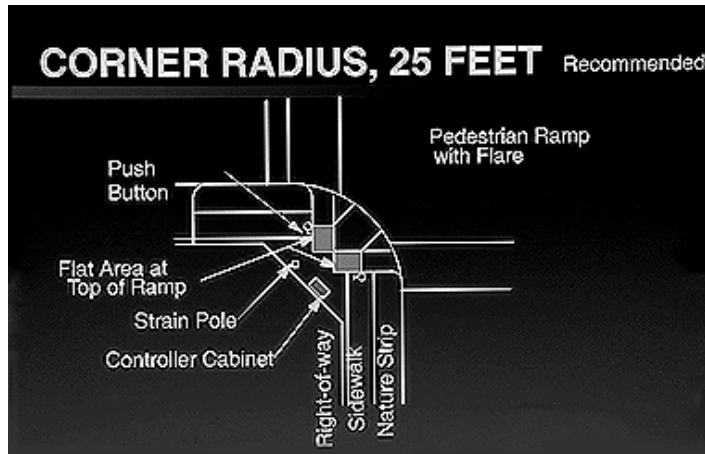


Figure 9-8. Side treatments for curb ramps.

Curb Ramps

Properly designed curb ramps allow for a safe and efficient transition from the elevated sidewalk surface to the street surface or vice versa. It is important that these ramps be designed and installed to meet the needs of those persons for whom they were intended, i.e., those who have difficulty negotiating a curb.

Placement

In accordance with the Americans with Disabilities Act, curb ramps shall be provided wherever an accessible route crosses a curb. The ramps shall be wholly contained within the crosswalk, as shown in Figure 9-6. Diagonal ramps are not recommended; instead, one ramp should be used for each crossing direction. Other considerations for the placement of curb ramps are as follows:^{7,8}

- ◆ Curb ramps should not be placed so that pedestrians have to cross storm water grates or inlets, manhole covers, other access lids, or ponding water. The Florida DOT uses a standard calling for curb inset inlet grates on each side of the corner connected to a diagonal pipe that feeds into one stormwater drain.
- ◆ Curb ramps that service adjoining crosswalks should be separated as much as possible.

- ◆ Curb ramps should be located within the crosswalk. Wider than minimum curb ramps are encouraged to permit the maximum number of people to enter and leave a sidewalk at one time. Full crosswalk width ramps are encouraged. Curb ramps should be located to prevent their obstruction by parked vehicles.
- ◆ Curb ramps in bulbouts achieve several added benefits including higher visibility of the pedestrian while waiting to cross, improved geometrics, improved sight distances in general, and reduced crossing distance.

Design

The slope of a curb ramp (measured as shown in Figure 9-8) shall not exceed 1:12 in compliance with ADA. If the curb ramp is located where pedestrians would normally walk across the ramp, or where it is not protected by handrails or guardrail, then flared sides should be used as shown in Figure 9-8. The flared sides should have a maximum slope of 1:12. If the curb ramp is located where pedestrians would not normally cross it, then returned curbs, like the one shown in Figure 9-8, may be used. The minimum width of a curb ramp, exclusive of the flared sides, shall be 1 m (40 inches). As mentioned earlier, widths greater than the minimum are always desirable. Where large volumes of pedestrians are expected, a minimum width curb ramp will result in pedestrian delays and capacity problems.

Designs for new wheelchair ramps should include a flat landing area at the top of the ramp for the entire width of the ramp and 1.2 m (4 ft) long, to give wheelchair users a good surface to maneuver and change directions. The surface of a curb ramp should be stable, firm, and slip-resistant. The texture of the ramp should be coarse enough so that it is not slippery when wet, yet smooth enough not to cause problems for wheelchair users. The ADA's requirements for tactile curb surfaces are

currently being reviewed. One possible treatment is shown in Figure 9-9.

Designs must pay close attention to the lip between the bottom of the ramp and the pavement. Wheelchairs have difficulty handling more than a 6.3 mm (1/4 inch) transition lip (elevation change) (see Figure 5-3). Access through medians and channelized islands is best handled by not ramping up and down, but by maintaining a cut through the entire area. To drain the island a slight (2%) slope can be used.

Although minimum widths must be observed, wider sections are encouraged. When practicable, the ramp should encompass the entire width of the crosswalk. This practice is essential for multiuse trail crossings.

Maintenance

A program of routine maintenance should be developed to inspect and clean curb ramps, and to repair any damage noted during the inspections. This should be done at the same time that marked crosswalks are inspected.

Refuge Islands and Medians

Pedestrian refuge islands are defined as the areas within an intersection or between lanes of traffic where pedestrians may safely wait until vehicular traffic clears, allowing them to cross a street. Refuge islands, like the one shown in Figure 9-10, are commonly found along wide, multilane streets where pedestrians may not be able to safely cross without adversely affecting motor vehicle traffic flow. These islands provide a resting area for pedestrians, particularly those who are disabled, elderly, or otherwise unable to completely cross an intersection within the available gap or provided signal time.

Refuge islands also provide pedestrians the advantage of allowing them to search for vehicles in only one direction as they cross from the curb to the island or from the island to the curb. The delay for pedestrians can also be reduced significantly. One study found that pedestrians crossing an



Figure 9-9. A tactile curb ramp.

undivided, multilane street may experience delays 10 times longer than the delay incurred crossing a street with a median.⁹ This is because pedestrians need a much larger gap to feel safe crossing the undivided street.

Placement

Pedestrian refuge islands may be installed at intersections or midblock locations deemed appropriate through engineering studies. As a general policy, FDOT prefers to use medians to limit access and improve efficiency, safety, and aesthetics for all roadway users. This recommendation applies to roads with speeds of 65 km/h (40 mph) and higher, but can be done on all roadways with sufficient right-of-way.

Refuge islands should be considered during the design of complex intersections or streets rather than after construction has been completed. They must be visible at all times with the stopping sight distance as the minimum distance requirement. Refuge islands should be designed to minimize the potential hazard to motorists and pedestrians alike.

Refuge islands and medians can be beneficial under certain conditions but may involve some trade offs and can cause increased problems if not designed and installed properly. The typical conditions where refuge islands can provide the greatest benefit, and thus are recommended, include:⁶

- ◆ Complex or irregularly shaped intersections where islands could provide a pedestrian with the opportunity to rest and become oriented to the flow of oncoming traffic.
- ◆ Wide, two-way streets (four lanes or more) with high traffic volumes, high travel speeds, and large pedestrian volumes;
- ◆ Wide streets where the elderly, people with disabilities, and children cross regularly;
- ◆ Wide, two-way intersections with high traffic volume and significant numbers of crossing pedestrians; and
- ◆ Low volume side street traffic demands with insufficient green time to cross.

Five and seven lane streets, with a center two-way left-turn lane, are not “pedestrian friendly.” In addition to the sheer width of the roadway, the two-way left-turn lane exposes pedestrians to traffic from both directions. Motorists are looking for gaps in oncoming traffic and may not be watching out for pedestrians.

It is more desirable to construct a four- or six-lane street with a raised median that includes left turn slots at intersections. This will provide a better continuous pedestrian refuge island and allow for a landscaping buffer between traffic flows for improved aesthetics. Florida DOT design standards



Figure 9-10. Refuge islands allow pedestrians to cross one direction of traffic, rest if necessary, and then cross the other direction of traffic.

now prohibit the building of five- and seven-lane highways. Refuge islands should be of sufficient width for safe pedestrian storage. Typically, a refuge should have a minimum width of 2.4 m (8.0 feet), although even a width of 0.9 m (3.0 feet) is better than none at all. It is also helpful to avoid small discontinuous islands which motorists may not see, making it likely for vehicles to drive into the island.

In areas where refuge islands are designed and maintained properly, the advantages to pedestrians are many, including:⁶

- ◆ Providing pedestrians with a resting place when crossing wide roads or intersections;
- ◆ Providing a pedestrian storage area;
- ◆ Increasing the capacity of the intersection with a near-side island that provides a better location for the stop bar;
- ◆ Loading and unloading transit riders (although curbside locations provide a better alternative); and
- ◆ Providing location for traffic control and utility pole installations (but not in the crosswalk area).

Design

Pedestrian refuge islands should be designed in accordance with the AASHTO policy and the MUTCD requirements.^{4,11} Design considerations should include:

- ◆ Raised curbs with cut-through ramps at pavement level or curb ramps should be provided for wheelchair users. Cut-through ramps should be graded to drain quickly and should also have special provisions to assist the visually impaired in identifying the refuge island. Islands with ramps should have a level area at least 1.2 m (4 ft) long at the same level as the top of the raised median to provide a level area for wheelchair users.
- ◆ The smallest curbed island that should be considered is 4.6 square meters (50

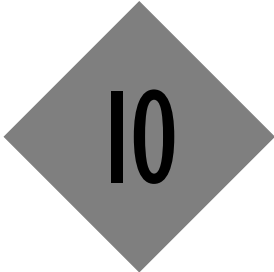
square feet) for urban areas and 7.0 square meters (75 square feet) for rural areas with 9.3 square meters (100 square feet) a desirable minimum for both areas. Triangular islands should not be less than 3.7 m (12 feet), and preferably 4.6 m (15 feet) on a side after the ends of the radii. Elongated or divisional islands should not be less than 1.2 m (4 feet) wide and 6.1 to 7.6 m (20 to 25 feet) long.

- ◆ An approach nose, offset from the edge of the traffic lane, should be constructed and appropriately treated to provide motorists with sufficient warning of the island's presence. This can be achieved through illumination, reflectorization, marking, signage, and/or size.
- ◆ Pedestrian push buttons and signage adjacent to crosswalks on the pedestrian refuge should be provided at all signalized crossings.
- ◆ Guidestrips for the blind should be considered, particularly if they are provided on other nearby facilities.
- ◆ No obstruction to visibility by such features as foliage, barriers, or benches.
- ◆ Barriers may be necessary to keep pedestrians from stepping into traffic at improper locations.

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One-way Streets



10

One-way streets can be beneficial to pedestrians when properly designed and placed. However, when designed to increase traffic speeds they can make a formerly quiet, pleasant place hostile and uninviting. In that case, the speed of traffic through a town not only poses increased risk to the public, but it also increases noise and creates other discomfort.

Advantages of One-way Streets

Crossing one-way streets is generally much safer for pedestrians than crossing two-way streets. A study of nearly 1300 intersections in 15 cities across the United States revealed lower levels of pedestrian collisions occurred at intersections of two one-way streets than at intersections of two-way streets.¹ One-way streets reduce the complexity for pedestrians who are crossing a street allowing them to concentrate on only one direction of traffic. In addition, drivers can devote more of their attention to pedestrians since all vehicles are traveling in the same direction.

One-way streets are most applicable in Central Business Districts or densely developed central city areas where pedestrian traffic is generally higher. One-way streets operate most efficiently in pairs that are no more than 0.4 km (0.25 mile)

apart. If the one-way street pair is further than 0.4 km (0.25 mile) apart, the operational efficiency is usually lost. Motorists wishing to travel a short distance in the opposite direction of the one-way street must travel a considerably longer distance out of their way. The ideal spacing for a one-way pair is typically one block apart.

Based on past experience, properly-placed one-way streets will generally reduce pedestrian crashes 10 to 15 percent.

Advantages of one-way streets include the following:

- ◆ Safer for pedestrians and motorists. Not only will pedestrian accidents be reduced, but total accidents will generally be 10 to 50 percent lower based on past experience.²
- ◆ Improved traffic capacity. One-way streets are much more efficient for through traffic and may increase the capacity of a street as much as 50 percent.³
- ◆ Reduced conflict points for turning vehicles on the one-way street. Since there is no opposing traffic, left turning traffic should be able to concentrate more on pedestrians. This means that left-turns should be as simple as right-



Figure 10-1. One-way streets offer a number of advantages for pedestrians.

turns. Studies indicate that vehicles turning left on one-way streets tend to hit pedestrians much more frequently than right-turn vehicles. This may be due to roof support pillars obstructing the view of the parallel crosswalk on the left side of the vehicle.³

- ◆ Signal timing is much simpler and signal progression much easier to obtain on a one-way street. One-way streets can better accommodate closely spaced and poorly spaced traffic signals in the CBD area.
- ◆ May allow retention of parking on narrow streets where it is generally not possible to do so with two-way operation.

On one-way streets where signal cycle lengths are kept short (60 seconds or less), the pedestrian receives significant opportunities to cross either at signalized or unsignalized crossings. However, one-way streets with 3 or more lanes may increase speeds and conflicts and it becomes hard to keep cycle lengths short. The removal of a lane can provide substantial improvements to crossing times, and give main street designers more room to provide adequate sidewalk and buffer widths.

The recent conversion of Lake and Lucerne, a pair of three-lane, one-way streets in Lake Worth, Florida to two lanes has reduced crossing widths, allowed a second lane of on-street parking to be placed, increased sidewalk widths, allowed space

for bulbouts and outdoor cafes, and allowed the placement of additional landscaping. The effects of these changes on traffic is a reduced travel speed through the downtown (reduced from 56 to 40 km/h (35 to 25 mph). Capacity of the roadway has remained constant. The level of service before the treatment was “C,” and is still “C.”

Disadvantages of One-way Streets

One-way streets are detrimental to the pedestrian and urban design if they speed motor vehicle traffic in the area. The designer must ask the question, “Will this treatment merely let people drive into and out of the downtown faster, or is there some other significant benefit to all roadway users?”

The use of one-way streets can have substantial negative effects on a downtown main street or shopping district. Small towns in Florida like Brooksville, Havana, Plant City and Lake Worth chose to place one-way streets to channel more traffic into and through their downtowns in recent decades. These towns are now trying to determine how to reduce the speed of these vehicles to compatible levels. In some cases taking a lane away (Lake Worth), narrowing lanes, adding parking buffers, bulbouts on corners, reducing the progression rate of traffic signals, or eliminating progression altogether, is being considered. Traffic calming is discussed in Chapter 15.

These and other disadvantages of one-way streets are listed below.

- ◆ Motorists are likely to drive faster than they would on two-way streets and thus present a greater hazard to pedestrians.
- ◆ Crossovers at each end of the one-way pair are expensive to build.
- ◆ Traffic circulation in a one-way street system is less direct. This extra travel distance will likely increase the amount of fuel used and travel time (and thus, stress) for those motorists.



Figure 10-2. One-way streets that contain wide travel lanes can result in higher than desired vehicle speeds, which can cause problems for pedestrians.

- ◆ Signal progression for those streets crossing the closely-spaced one-way pair is difficult, if not impossible to achieve in both directions.
- ◆ May adversely affect transit operations if transit vehicles are forced to use two streets instead of one. This may also adversely affect walking distances for transit patrons.
- ◆ Emergency vehicles may need to take a more circuitous route.
- ◆ One-way streets require much more signing than a two-way street.

Converting to a one-way street system should be thoroughly planned and take into account the changes in pavement marking, signing, positioning of parking meters, curb parking restrictions, and traffic signal design and signal detectors. One-way signing is needed at alleys and driveways where not previously needed. Planning for one-way street conversion should include the following parties:

- ◆ The local business community,
- ◆ Area neighborhoods and other affected property owners, as well as the local transit agency,
- ◆ Other investors,
- ◆ Sanitation, police, and fire departments,
- ◆ Representatives from the affected school

district, and

- ◆ Others that may be affected by the change.

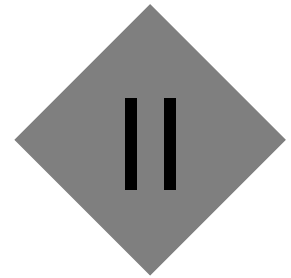
The conversion to one-way streets should be preceded with a comprehensive public information campaign that should include informational signs prominently posted along the streets that are to be converted, providing a projected conversion date.

The community needs to understand the full impact of converting to or from one-way streets. The decision should not be left up to the current slate of politicians. The recent Lake Worth decision was made following an intense seven-day planning charrette that involved over 200 people.

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Intersections



Many roadway intersections in Florida do not adequately accommodate pedestrian crossings. This chapter is adapted from pages II-7 through II-11 of the *Florida Pedestrian Safety Plan* and chapter 1 of the *ITE's Design and Safety of Pedestrian Facilities: Recommended Practice*. It offers many policy, design, and technical recommendations for facilitating pedestrian crossings at intersections.

Discussion

Intersections, particularly signalized intersections, are the most dangerous part of the road network for pedestrians (Figure 11-1). Most pedestrian fatalities in Florida occur at intersections. There are 32 possible vehicle- pedestrian conflicts at the four-way intersection of two roads. Many occur at high speeds.

Another type of intersection that can adversely affect pedestrian safety is the intersection between expressway ramps and local streets. Such sites often involve high-speed vehicles coming off the ramps and passing through the intersection or attempting to merge with the surface street. Exiting motorists may place their attention primarily on other traffic and not on pedestrians. Moderate to high volumes of pedestrians and exiting traffic can further

increase the hazard. Pedestrian safety can be severely threatened at such sites, unless appropriate safety enhancements are made.¹

The level of hazard at many of these intersections can be lessened through the use of appropriate traffic-control devices (e.g., warning signs) to reduce vehicle speeds and alert motorists and pedestrians. In some instances, pedestrian barriers, modified signal timing (e.g., longer vehicle clearance intervals), or even grade separation (e.g., pedestrian overpasses) in extreme situations may be needed to reduce a serious pedestrian safety problem.²

Pedestrian safety can be severely threatened at intersections.

It is preferable that intersection areas (conflict zones) be as small as possible to reduce the:

- ◆ pedestrian crossing distances
- ◆ pedestrian/bicyclist to vehicle exposure
- ◆ vehicle to vehicle exposure

These practices make the vehicle paths clearer and reduce the relative speed between opposing movements. Channelization with medians, and right turn slip lanes with channelization islands can also reduce the

Figure 11-1.
Traffic
engineers face
their greatest
dilemma at the
intersection.



conflict zone and provide safe refuges for pedestrians. Prohibited turns which are dangerous to pedestrians can be blocked. (See *AASHTO*, pp. 828-830.)³

Right-turn-on-red (RTOR) has the potential to increase pedestrian accidents. The person most at risk is the pedestrian crossing from the right to the left in front of a driver. The driver focuses his attention to the left and can start to turn before noticing the pedestrian on his right. Sixty-seven percent of RTOR/pedestrian accidents involve this movement. (See figure 61 in *Bowman et al.*)⁴

Modern roundabouts can be an effective treatment for reducing pedestrian/vehicle conflicts and vehicle speeds in residential neighborhood streets. In crossing the modern roundabout, the pedestrian only needs to cope with one direction of vehicle movement.

Recommendations

Policy Recommendations

1. A prohibition of Right-Turn-On-Red should be considered at those intersections where pedestrian volumes are significant and field studies suggest this treatment.

2. Install two pedestrian curb ramps per corner as near as possible to the pedestrian push button, to aid the handicapped, sight impaired, persons with strollers, etc. in crossing at crosswalks. A single ramp design is not desirable as it will direct pedestrians into through traffic.

3. Medians are recommended whenever the crossing distance exceeds 18 m (60 feet) to provide a refuge for slow or late crossing pedestrians. Push buttons should be installed in the median and handicap ramps or a full cut should be provided through the median. Refuge islands should preferably be at least 1.8 m (6 feet) and in no case less than 1.2 m (4 feet) wide to keep island users, particularly those in wheelchairs propelled by attendants, from projecting into the traffic lanes. (See *Bowman, et al.*, p. 124.)⁴ Pedestrian signals should be timed to allow adequate time for pedestrians to cross the full width of the street. This is because placing push buttons in the median may encourage the use of quicker walking speeds for design. This means the pedestrian would have to wait an entire cycle, sometimes as much as 4 minutes, to finish crossing the street. In this case, the pedestrian may choose to cross against a red light.



Figure 11-2. Medians are recommended whenever the crossing distance exceeds 60 feet to provide a refuge for pedestrians.

Otherwise he is left, although on a refuge, in a vulnerable location. Refuge islands are covered in Chapter 9 of this document.

4. Where warranted, install pedestrian buttons in accordance with *DOT Standard Index #17784* in a standardized manner at all signalized crosswalks and in medians. Pushbuttons should be installed on separate poles according to illustration. This enables use by handicapped and sight impaired users and reduces the confusion normally associated with these devices for the general population.

5. Pedestrian signal heads should be installed at all urban signalized intersections. Install pedestrian signals on the poles that support the push buttons so they relate to the signal display. If the distance between the pedestrian signals across the road is greater than 18.3 m (60 feet), another pedestrian signal should be installed in the median if possible. This will enable elder and sight impaired pedestrians

to see the signalheads. All signal heads should be brought up to current standard shown in MUTCD Figure 4-3 (page 4D3).⁵ These standards specify the use of white and Portland orange colors only, since elder pedestrians may have difficulty distinguishing color differences on the nonstandard signal heads. Symbols should be used instead of words as the illustration depicts.

6. Where possible, move existing and install new drainage structures out of the curb radius to prevent pedestrians from design-induced tripping. Where possible, install drop inlets on the upstream side of corners to prevent large volumes of water flowing around corners. Also ensure that the road and gutter take water away from the pedestrian crossing.

7. When diagonal spans supporting traffic signalheads would prevent pedestrians from seeing the current vehicle phases, convert existing span wire installations and install new traffic signal installations using pole/mast arm mounted signals or box spans.

8. Parking should be prohibited within 18.3 m (60 feet) of the approach to, and 9.2 m (30 feet) on the departure from, a signalized intersection. Vehicles parked close to an intersection block a driver's view of pedestrians. (*See Zegeer and Zegeer, Pedestrians and Traffic Control Measures, pp. 19, 21 and 60.*)²

9. When advantageous, provide full corner and half corner sidewalk flares (bulbouts) on streets with parking. This rarely reduces vehicle capacity, yet provides the pedestrian with a shorter crossing distance and increased visibility and height. This treatment is generally not recommended on new arterials. For more detail, see Chapter 15 of this document.

10. When approaching drivers' view of pedestrians is restricted, clean up the corner by using joint-use poles to support traffic signals, street names, lighting, and signs. Relocate or remove all other items or trim



Figure 11-3. Signals frequently used by elderly or physically impaired pedestrians should be retimed to provide a crossing time commensurate with their ability.

trees or shrubs.

11. When there is inadequate pedestrian walk and clearance time, retime existing and new signals to ensure adequate crossing time for pedestrians. Signals frequently used by elder or physically impaired persons should be retimed to provide a crossing time commensurate with their ability (Figure 11-3).

12. The design of a new intersection or the replacement of an existing intersection may make it necessary to move some of the



Figure 11-4. This intersection could be improved in many ways. Note that pedestrians leaving the lower right corner must walk a distance of over 20 feet just to get to the first lane to be crossed—a channelized slip lane would reduce this distance.

above ground utilities located at the intersection. For example, fire hydrants or utility poles may have to be relocated. When these relocations occur, consideration of the pedestrian circulation paths in and around the intersection is critical. While attention to pedestrians may not be the most important consideration here, they cannot be totally ignored.

Design or Technical Recommendations

Many signalized intersections are unfriendly to pedestrians because of the speed and complexity of vehicle movements and the number of lanes added for capacity. The AASHTO Green Book describes various types of basic and enhanced intersection designs, with limited discussion on how different design treatments can be used to accommodate pedestrians.³ Devices such as flared curbs (bulbouts), curb ramps, channelization islands, pedestrian refuge islands, and medians have been used to shorten crossing distances, increase pedestrian and vehicle visibility, simplify the crossing task, control vehicle paths, and control vehicle speeds. Intersections should be designed to be as compact as possible as per AASHTO standards.

Although these pedestrian-sensitive treatments are conceptually simple, they do require a significant amount of planning and engineering design, as well as consideration of their operational effects and maintenance requirements. This is especially true at locations where these types of treatments are used as retrofit solutions rather than new construction (see Chapter 15).

Use of pedestrian-related geometric features at an intersection could have an effect on the vehicular capacity of the intersection. The principal effect on capacity will be caused by narrowing lanes and reducing curb radii. While narrowed lanes have a direct computational effect on intersection capacity, the effects of reduced curb radii are much harder to quantify.⁶

Other factors that may affect intersection

capacity include the increased number of pedestrian crossings caused by an improved pedestrian environment and the relocation of bus stops caused by the reconfiguration of the intersection. Pedestrians and vehicles must be given equal status when analyzing the options at an intersection, and thus, some loss in motor vehicle capacity may be necessary to accommodate pedestrians.

To reduce the risk of roadway crossings, to the maximum extent practicable, future planning and project development should consider the following:

- ◆ Use one-way streets or divided roadways with refuges so that pedestrians will have to watch traffic from only one direction.
- ◆ Use paired one-way streets properly designed with slip lanes and medians to reduce number of lanes to be crossed.
- ◆ Construct T-intersections which have fewer conflict points for pedestrians.

The AASHTO Green Book recommends the intersection of roadways at 90 degree angles.³ This design standard represents the best option for both pedestrian and vehicular traffic. Sight lines are optimal, conflict space is limited, and crossing distances (and hence exposure time) are reduced.

- ◆ Restrict left turns in downtown or commercial zones. At signalized intersections, use protective phase left turns whenever practicable.
- ◆ Consider modern roundabouts at intersections as they effectively reduce vehicle speed and pedestrian/vehicle conflicts. (Figure 11-5).
- ◆ Consider roundabouts at intersections that are not part of a coordinated sign system as roundabouts increase capacity and decrease crashes, especially for pedestrians.

When roundabouts are used, marked pedestrian crossings should be placed

one full car length back from the yield line. A channel cut should be placed in the splitter island to assist pedestrians in their crossing.

- ◆ Use right-turn slip lanes under yield control instead of double or triple-turn lanes under signal control.

Factors affecting the danger to pedestrians by right-turning vehicles include the number of turning lanes, turning volume, turn radius and distance from start of turn to crossing pedestrian.

Turning radii should be no larger than necessary. When radii are too large, and sidewalks are placed at the back of the curb, the crossing distance and exposure time for pedestrians increase. There is a tendency to use suburban design corner radii in urban areas. As a general rule, corner radii should be no more than 6.1-7.6 m (20-25 feet) for central business districts and residential neighborhoods, and 9.2 m (30 feet) for side streets entering major roadways. Using three centered, compound radii and channelization where truck volumes are high helps to keep radii reasonably small.

A balance must be struck between small radii and the turning paths of large vehicles. Too small a radius can cause large vehicles to mount the curb and eventually break it up or hit pedestrians who are standing close to the corner. Radii of 9.2 m (30 ft) or more are



Figure 11-5. Modern roundabouts can reduce vehicle speed and pedestrian/vehicle conflicts.

only recommended when large trucks or buses turn frequently. In these situations, right turn slip lanes should be considered, as they will provide a better operating environment for the large vehicle and the pedestrian (Figure 11-6). By comparison, double right turn lanes are very dangerous for pedestrians as the driver in the second lane has his vision of pedestrians blocked by the vehicle in the right-most lane.

When intersections are overly wide for pedestrian crossings, channelized right turn lanes can be beneficial. The angle of 55-60 degrees shown in Figure 11-7 maximizes motorists' tendency to yield to pedestrians, keeps speeds at a prudent level, maximizes viewing angles, and maximizes the turning capacity of motorists.

Since T-intersections create fewer pedestrian-motor vehicle conflict points compared to a four-way intersection (9 vs. 32), their use enhances highway efficiency, reduces conflicts, and improves the safety of both motorists and pedestrians in the area. T-intersections should be considered in future roadway reconstruction projects. T-intersections are also recommended in residential neighborhoods and near schools.

Angle ("Y") intersections invite high

motorist turning speeds and result in wide pedestrian crossings. During reconstruction and when safety conditions warrant improvement, these intersections can be tightened into 90 degree corners. Often the captured land can be turned into a nicely landscaped area that enhances the aesthetics of the street and walking experience.

Five- or six-legged intersections present multiple conflict points for pedestrians and bicyclists as motor vehicles arrive from several directions. Such intersections can often be redesigned as four-way intersections. One or more legs can be reconfigured to create a minor intersection at a different point along the main roadway. Alternatively, traffic can be restricted on one or more streets to reduce the number of vehicle movements in the intersection. A roundabout can be installed so that pedestrians walk around the roundabout and cross one street at a time, as a series of T-intersections.

A commonly overlooked element of the design or redesign of an intersection, from a pedestrian perspective, is the provision and maintenance of adequate intersection sight distance. Maintenance of adequate sight distance for drivers is important in

Figure 11-6. Right-turn slip lanes, where the right-turning traffic must yield before entering the roadway, are a safer alternative for pedestrians than double right-turn lanes.



preventing both vehicle-vehicle and vehicle-pedestrian conflicts. However, provision of adequate sight distance for pedestrians through the design process is equally important in avoiding vehicle-pedestrian conflicts.

Often an intersection design includes the use of pedestrian design features such as bollards, landscaping, benches, or bus shelters. Although these items clearly enhance aesthetics and the overall quality of the pedestrian experience, they can also limit the available sight distance for vehicles approaching or departing from the intersection, as well as for pedestrians waiting to cross at the intersection. This is most acute at stop-controlled intersections. Frequently, these items appear after the intersection has been constructed or reconstructed. Therefore, not only is it important to consider sight distance during the initial design phase, but also during the operational life of the intersection when other features are added.

Although horizontal sight distance is the more frequent problem, vertical sight distance cannot be ignored either. However, for pedestrians, the problem with vertical sight distance at intersections comes from high seat position operators (e.g., truck drivers) who have their line of sight to the pedestrian standing on the curb blocked by trees, signs, or other low-hanging obstructions. As with the ground level obstructions, the careful designer should check to see that adequate sight lines are provided.

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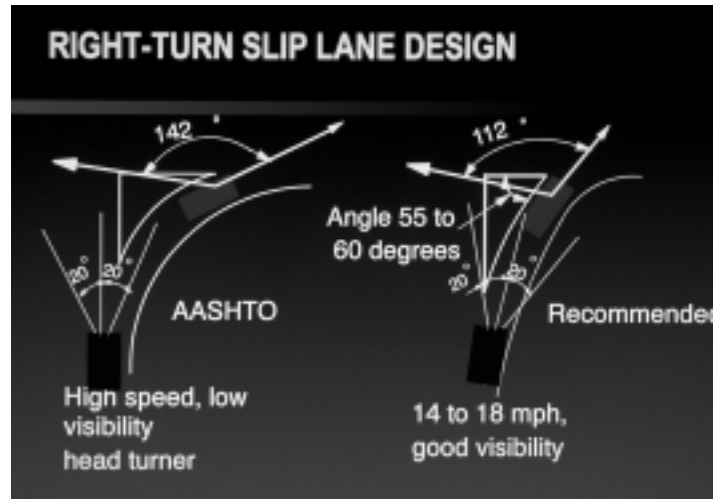


Figure 11-7. AASHTO's standards for right-turn slip lanes (left) encourage high motor vehicle speeds and provide low visibility. By comparison, FDOT's recommended standards encourage low motor vehicle speeds and provide good visibility.

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