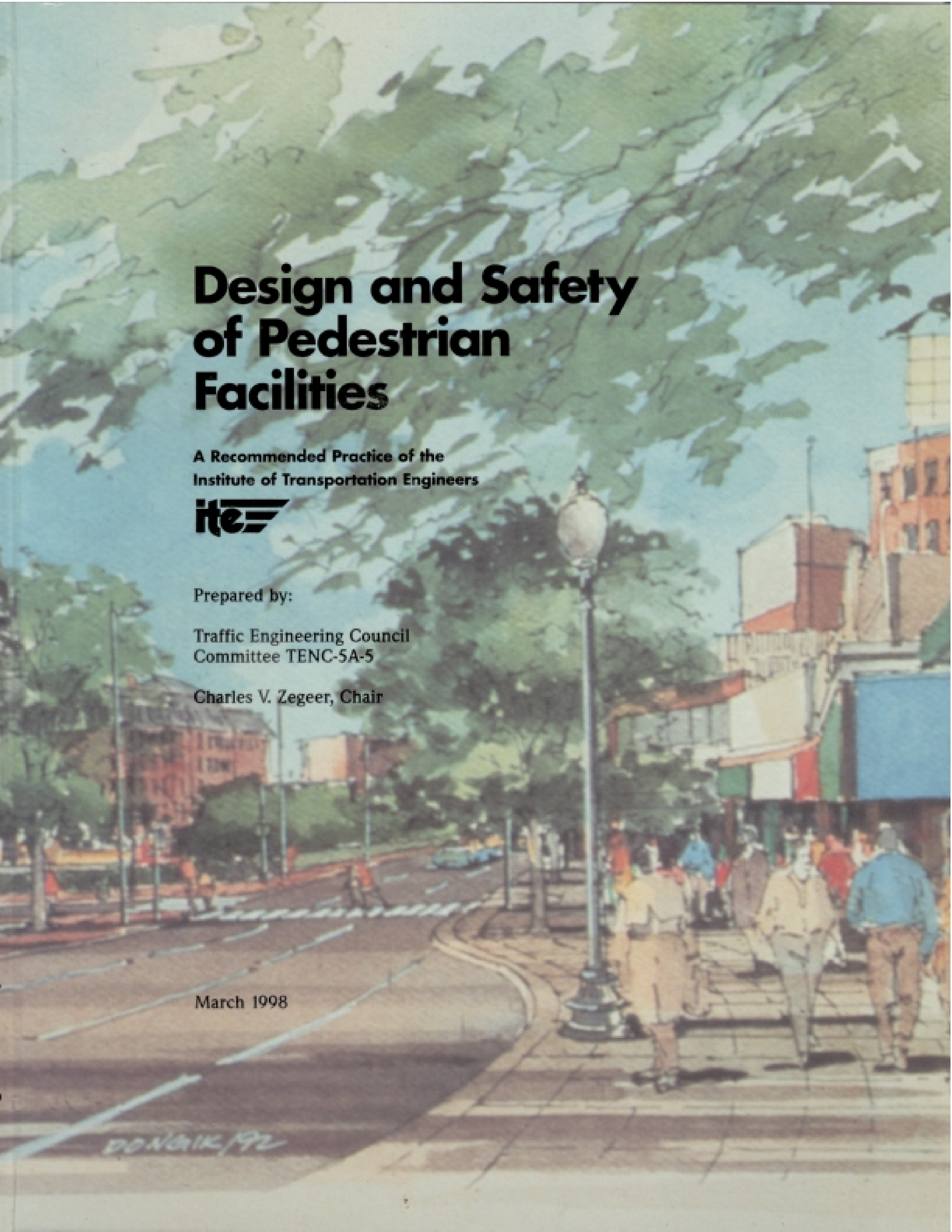

# Design and Safety of Pedestrian Facilities

**A Recommended Practice of the Institute of Transportation Engineers**

Prepared by:

Traffic Engineering Council
Committee TENC-5A-5

Charles V. Zegeer, Chair

March 1998

# *Design and Safety of Pedestrian Facilities*

A Recommended Practice
of the Institute of Transportation Engineers

Prepared by ITE Committee 5A-5

This Recommended Practice discusses guidelines for the design and safety of pedestrian facilities to provide safe and efficient opportunities for people to walk near streets and highways.

This report, *Design and Safety of Pedestrian Facilities,* RP-026A, was approved in June 1997 as a Recommended Practice of the Institute of Transportation Engineers (ITE). It supersedes the Proposed Recommended Practice, RP-026, dated December 1994. The comment period on the Proposed Recommended Practice closed on May 1, 1995. Comments on the December 1994 document have been incorporated into this document.

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1000/AC/BP/398
Publication Number RP-026A

ISBN: 0-935403-17-5

Cover art credits are as follows:
Client: Massachusetts Highway Department
Consultant: Bechtel/Parsons Brinkerhoff, Management
Consultant: Carol R. Johnson Associates, Landscape Architects
Renderer: Dongik Lee, Dongik Architectural Rendering

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# INTRODUCTION

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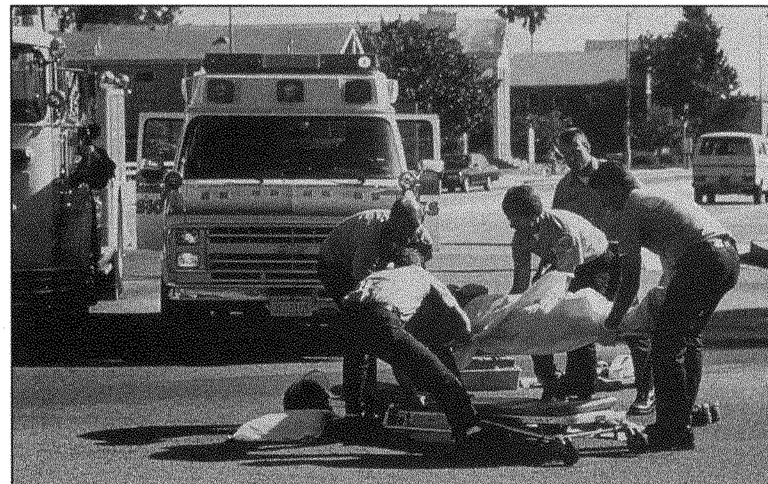

FIGURE I–1. *An estimated 84,000 pedestrians were injured or killed in the United States in 1995.*

## *Background*

Collisions between pedestrians and motor vehicles are a serious problem in the United States and many other countries. A total of 5,585 pedestrians were reported killed in motor vehicle collisions in the United States in 1995.[1] These deaths accounted for 13.4 percent of the 41,798 motor vehicle deaths nationwide. An estimated 84,000 pedestrians were injured or killed in motor vehicle collisions, representing 2.5 percent of the 3.4 million total persons injured in traffic accidents.[1] Although a drop in pedestrian fatalities has occurred in recent years, a serious problem continues to exist in the United States relative to pedestrian deaths and injuries **(figure I–1)**.

## *Typical Problems*

### Pedestrians Most At Risk

Collision involvement rates (collisions per 100,000 population) are the highest for 5-to-9 year old males, which is related in part to their tendency to dart out into the street. Rates for older persons (65 and above) are lower than for most age groups, which may reflect greater caution by older pedestrians (e.g., less walking at night, less darting out into the street) and reduced amount of walking near traffic **(figure I–2)**. However, older adult pedestrians are much more vulnerable to serious injury or death when struck by a motor vehicle than are younger pedestrians. For example, the percentage of pedestrian collisions resulting in death exceeds 20 percent for pedestrians aged 75 and older compared to less than 8 percent for pedestrians aged 14 years or younger, as shown in **figure I–3**.[2]

### Alcohol Impairment

Alcohol impairment is a serious problem not only for drivers of motor vehicles, but for pedestrians as well **(figure I–4)**. From 1980 through 1990, between 37 and 44 percent of fatally-injured pedestrians had blood alcohol concentrations (BACs) of .10 or greater. In 1989, of all adult pedestrians killed in nighttime collisions with motor vehicles, 59 percent had BACs of .10 or greater, while only 31 percent had no alcohol in their blood, as shown in **figure I–5**.[3,4]

### Times of Occurrence

Pedestrian collisions are most prevalent during morning and afternoon peak periods. Fatal pedestrian collisions typically peak later in the day between 5:00 p.m. and 11:00 p.m.[1] These collisions are partly the result of pedestrians being struck after dark along high-speed roads, where the pedestrian and/or driver is alcohol-impaired.[5]

About 43 percent of pedestrian fatalities and 31 percent of pedestrian injuries occurred on weekends (defined as the time period from 6:00 p.m. Friday through 5:59 a.m. Monday). For the time period between 9 p.m. and 3 a.m., 61 percent of pedestrian fatalities occurred on weekends.[1]

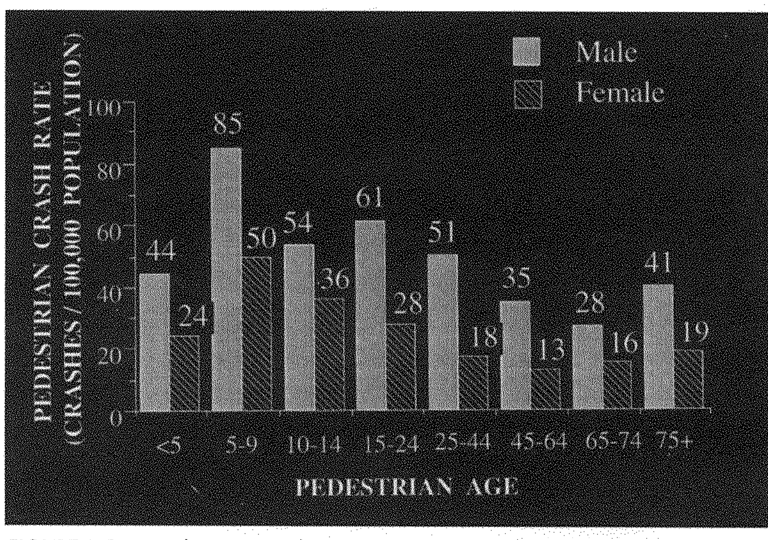


FIGURE I–2. *Pedestrian crash rates vs. age in North Carolina (1980–1990).*

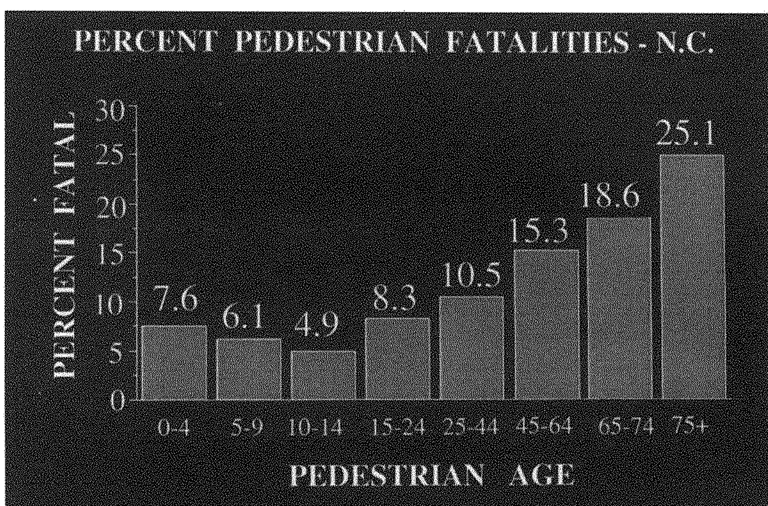


FIGURE I–3. *Pedestrian fatalities vs. age in North Carolina (1980–1990).*

Accidents involving older pedestrians are more evenly distributed throughout the days of week than those involving younger pedestrians; and older pedestrians are more likely to be struck during daylight hours, which reflects their times of exposure to traffic.[2] The months of September through January, with typically fewer daylight hours and more inclement weather, have the highest number of nationwide pedestrian fatalities.[3,5] However, child pedestrian fatalities are greatest in May, June, and July, perhaps because of an increase in outside activity after the winter months.[5]

### Area Type

Pedestrian accidents are primarily an urban problem due to the greater amount of pedestrian activity and generally heavier traffic volumes in urban areas as compared to rural areas. Estimates from the National Safety Council reveal that of all nonfatal pedestrian collisions in the United States, 77 percent occur in urban areas, and 23 percent occur in rural areas. However, 45 percent of pedestrian fatalities occur in rural areas due largely to higher vehicle speeds in rural areas compared to city streets.[5,6]

### Location Type

In terms of accident location, 65 percent of collisions involving pedestrians occur at nonintersections. This is particularly true for pedestrians aged 9 or younger, where dartouts into the street are a major accident cause. For ages 45 to 65, pedestrian collisions are approximately equal for intersections and nonintersections. Pedestrians aged 65 and older are more likely to be struck at intersections (60 percent) than nonintersections (40 percent), since older pedestrians tend to cross intersections more often than younger pedestrians **(figure I–6)**.[6] Moreover, some older pedestrians have physical disabilities that increase problems when crossing busy intersections.[5,6] Studies have shown that older pedestrians are particularly overrepresented in accidents at intersections involving left-turn and right-turn vehicles.[2]

## Pedestrian Collision Types

Since the 1970s, specific classification types have been developed for pedestrian collisions. Following are some of the most frequently occurring types:

- dartout-first-half (24 percent); for example, the pedestrian is struck in the first half of the street being crossed, see **figure I–7**;
- intersection dash (13 percent);
- dartout-second-half (10 percent);
- midblock dash (8 percent), see **figure I–8**;
- turning vehicle accidents (5 percent), see **figure I–9**.[7,8,9]

In a 1996 study, Hunter, et al. further examined pedestrian crash types.[10]

Some accidents are associated with deficient roadway designs and/or traffic control measures for pedestrians and/or motor vehicles. Also, pedestrians and motorists often contribute to pedestrian accidents through a disregard or lack of understanding for laws and safe driving or walking behavior. Pedestrian accidents represent a highly diverse and complex problem that often has no easy solutions.

Improvements to pedestrian safety require a combination of important ingredients, including the following:[11]

- education programs for pedestrians (particularly elementary school children) and motorists;
- enforcement programs of existing traffic laws and ordinances for motorists (e.g., obeying speed limits, yielding to pedestrians when turning, traffic signal compliance, obeying drunk-driving laws) and pedestrians (e.g, crossing the street at legal crossings, obeying pedestrian signals);
- use of retro-reflective clothing and materials by pedestrians at night;
- more forgiving vehicle designs that minimize pedestrian injury from vehicle impact;
- roadway/engineering measures, including traffic-control devices and roadway design strategies implemented on streets and highways for both pedestrian and vehicular movements.

The focus of this recommended practice is on roadway design and traffic control improvements that can be used to reduce the likelihood of a pedestrian accident at a given location. Physical

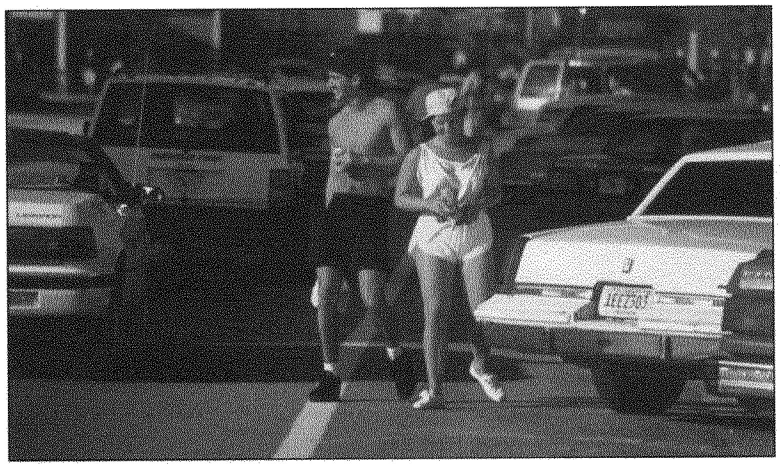

FIGURE I–4. *Alcohol is a major factor in deaths for adult pedestrians.*

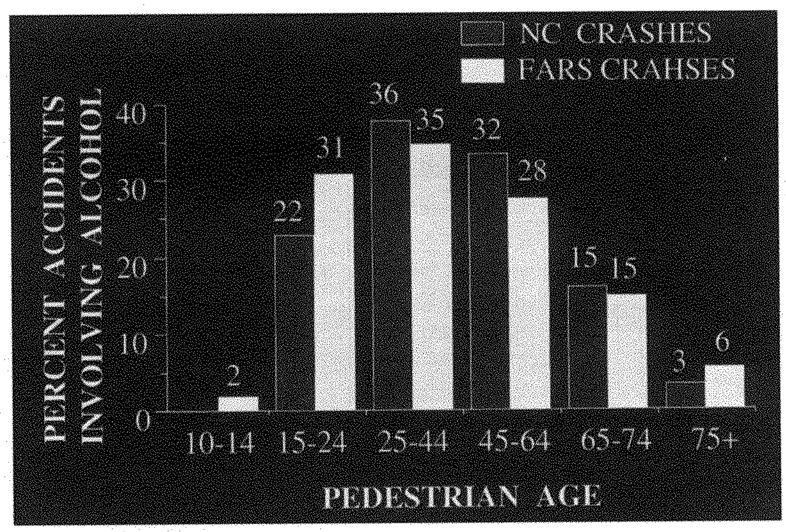


FIGURE I–5. *Alcohol impairment vs. pedestrian age in North Carolina and FARS pedestrian crashes (1980–1990).*

roadway improvements work best when they are tailored to an individual location and traffic problem. Factors to consider when choosing an improvement are location characteristics, pedestrian and vehicle volume and types, vehicle speed, design of a given location, city laws and ordinances, and financial constraints.[12]

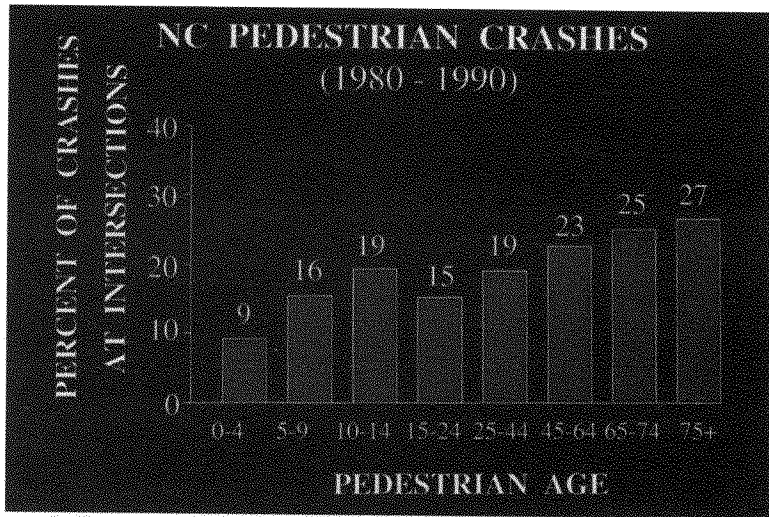


FIGURE I–6. *Intersection crashes vs. pedestrian age in North Carolina (1980–1990).*

FIGURE I–7. *Child dartouts into the street account for a major cause of pedestrian crashes in residential areas.*

## *Organization*

This recommended practice is divided among the following fifteen chapters:

| | |
|---|---|
| Chapter 1. | Roadway Design Considerations |
| Chapter 2. | Pedestrians with Disabilities |
| Chapter 3. | Sidewalks and Paths |
| Chapter 4. | Pedestrian and Motorist Signing |
| Chapter 5. | Signalization |
| Chapter 6. | Crosswalks and Stop Lines |
| Chapter 7. | Pedestrian Refuge Islands |
| Chapter 8. | Pedestrian Barriers |
| Chapter 9. | Curb Parking Restrictions |
| Chapter 10. | Grade-Separated Crossings |
| Chapter 11. | School Practices |
| Chapter 12. | Neighborhood Traffic Control Measures |
| Chapter 13. | Pedestrian-Oriented Environments |
| Chapter 14. | Transit Stops |
| Chapter 15. | Work Zone Pedestrian Safety |

The recommendations given in these chapters relate primarily to the United States and other countries in North America. Some of the recommendations may be appropriate to other countries as well.

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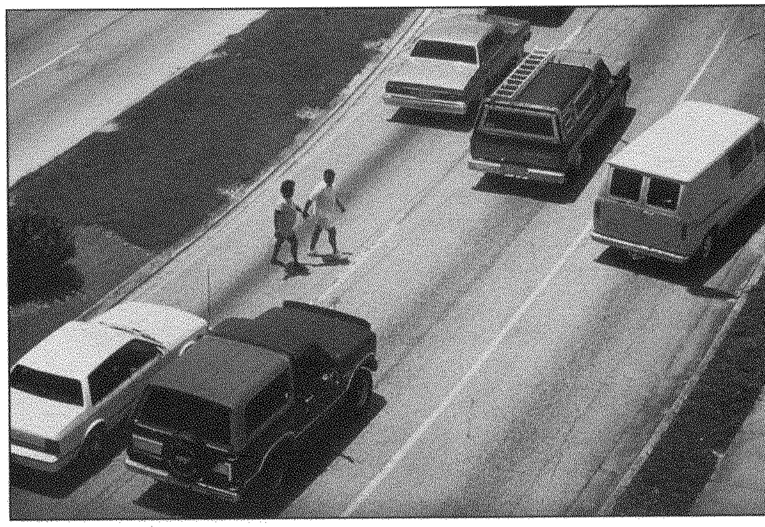

FIGURE I–8. *Many pedestrians are struck in the second half of the street after stepping out in front of oncoming traffic.*

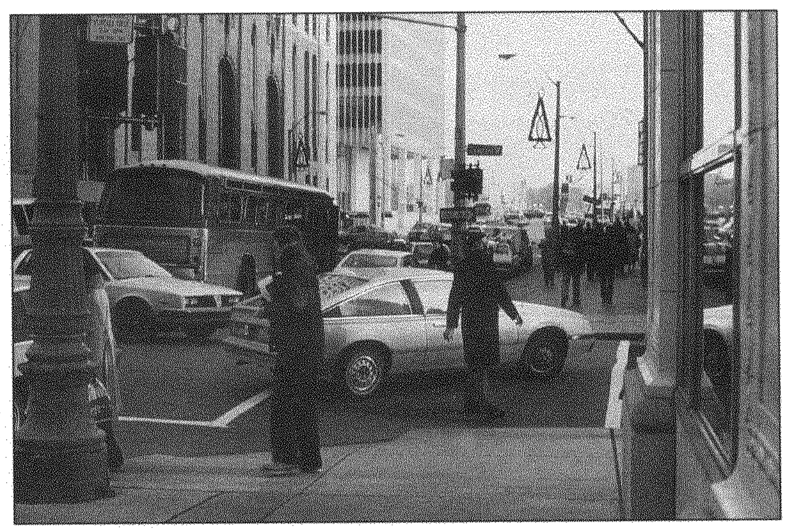

FIGURE I–9. *Motorists often fail to yield to pedestrians when turning right or left at intersections.*

1

# ROADWAY DESIGN CONSIDERATIONS

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FIGURE 1–1. *Too many roadways have little or no consideration for the needs of pedestrians.*

## *Introduction*

Allowing vehicles and pedestrians to share the roadway environment safely and efficiently is not an easy task. The characteristics of these modes of travel are vastly different, and yet, they compete for use of the same street and highway space. For years, there have been independent approaches to the design of highways and streets to accommodate vehicle and pedestrian movements. Effective roadway design involves establishing realistic design criteria and controls for all traffic being served. Thus, it is imperative that the designer understand the full range of traffic to be accommodated by a design **(figure 1–1)**. For motor vehicles, this understanding involves knowing the number and types of vehicles that will use an intersection. In the case of the pedestrian, it implies an understanding of the number and characteristics of the pedestrians that will use an intersection.

The need exists to establish guidelines for highway design that would apply where pedestrians represent the primary mode of traffic. For example, design and operational strategies for such a situation might be to control vehicular speeds, minimize vehicular impedance to the pedestrian, minimize pedestrian-vehicle conflicts, reduce conflicting attention demands, ensure adequate walkway separation, and provide aesthetic designs. Such objectives would be derived from placing a greater emphasis on desired pedestrian pathway attributes such as accessibility, directness, continuity, safety, guidance, and aesthetics rather than movement of vehicular traffic. Experience has shown that designers can find ways for vehicles and pedestrians to safely and conveniently coexist **(figure 1–2)**.[1,2]

## Pedestrian Characteristics

For the designer, it is important to recognize the pedestrian's impact upon street and highway operations, and the influence of physical and behavioral characteristics of pedestrians on the degree of this impact. In that context, the highway designer needs to have an appreciation of some general characteristics of the pedestrian such as body area, walking rates, and capacities for pedestrian-related facilities. Besides knowing about average pedestrians, the designer also needs to know something about pedestrians with physical, visual, or mental disabilities.

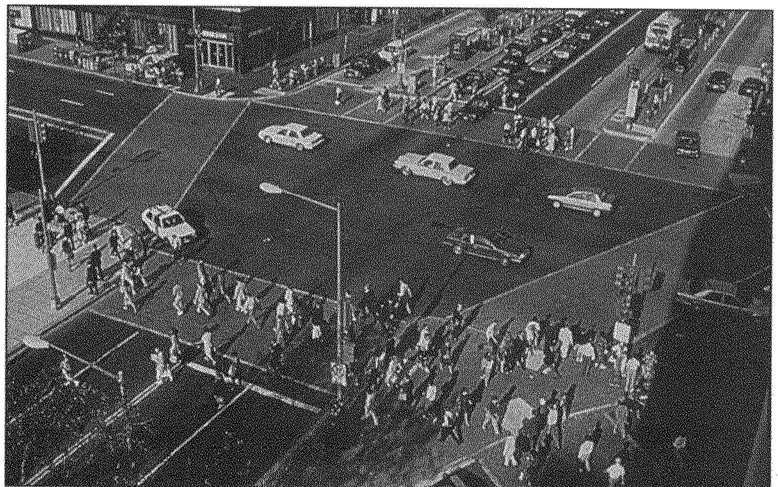

FIGURE 1–2. *Streets and intersections should accommodate those who need or choose to walk.*

Information on the dimensions of the human body (an ellipse of 24" X 18") can be found in the 1990 AASHTO Green Book.[3] This information is based on work by Fruin, and it is consistent with that used in the *1994 Highway Capacity Manual*.[4,5] There is widespread agreement on these dimensions, but it must be noted that they do not take into consideration the increased body ellipse needs of elderly with canes or walkers, adults with shopping carts or baby carriages, or those carrying bags or packages. Also overlooked is the tendency of most pedestrians in groups to walk side-by-side rather than single file. While the need to design for this element of the pedestrian constituency may be small, the designer should still be aware of these diverse user groups.

Walking rates are generally 2.5 to 6.0 feet per second with an average of 4.0 feet per second, which is in accordance with the 1988 MUTCD.[6] Some sources state that, in areas where there are many older people, a walking rate of 3.0 feet per second should be considered **(figure 1–3)**. However, this limited amount of information does not give a full appreciation of walking rate characteristics. Some studies have shown an even wider range in walking rates, approximately 2.5 to 8.0 feet per second.[7] Others state findings for the average walking rate of 4.5 feet per second.[8] In fact, if one assumes a walking speed of 4.5 feet per second to determine the pedestrian clearance interval at a signal, then 78 percent of the pedestrians, observed in one study, would have to quicken their walking speed to safely cross the street during the green. A Federal Highway Administration study dealing with older pedestrian characteristics for use in highway design should yield some useful information about this subject so that a definitive standard can be reached.[9]

FIGURE 1–3. *A slower walking speed of 3.0 feet per second should be considered in areas where there are high concentrations of older pedestrians.*

Pedestrians with ambulatory difficulties are especially sensitive to stairs, curbs, or other horizontal obstructions that are in their paths. Recent research shows that they are also sensitive to the type and condition of the walking surface. Kulakowski et al., found that walkers with certain physical disabilities require higher levels of walking-surface friction than the non-impaired walker.[10] The more important finding may be that the friction needed to safely traverse these pathways frequently exceeds the obtainable friction coefficients for many walking surfaces. These findings may also have some implications when choosing pavement/walkway surface types.

## Design Elements

Sight distance is a principal design element in roadway design and can take on many forms, such as: stopping sight distance, decision sight distance, and passing sight distance. In every roadway design manual, these subjects are all treated from the standpoint of the vehicle operator. The designer must keep in mind that, as important as it is for the motorist to see everything on or adjacent to the roadway, it is of parallel importance for the pedestrian to see equally as well.

In the literature, most treatments of design-related sight distance would be appropriate for pedestrians if only some mention were made of pedestrians. Coverage of the various traffic control and geometric situations is very complete. However, the designer must be told that part of the requirement for providing adequate sight distance should be allowing for the motorist to see the pedestrian and the pedestrian to see the motorist.

Current criteria for minimum stopping sight distances seem to be appropriate for normal pedestrian activity. The most critical aspect is the adequacy of sight lines at intersections for crossing traffic. The highway designer must be mindful that plans only reflect two dimensions. The height of the many obstructions that are found in the right-of-way can be particularly detrimental to pedestrian sight distance (e.g., landscaping, parked vehicles, traffic control devices, or street furniture). These can severely limit sight lines and therefore put the pedestrian in jeopardy.

## Cross Section Elements



Most discussions of cross section elements consider design only in terms of vehicular traffic. While many roads (e.g., suburban and rural) see little pedestrian traffic, people do walk on roadways without sidewalks. This is evidenced by the fact that approximately 15 percent of the pedestrian accidents in these areas occur when a pedestrian is struck while walking along a roadway.[11] When designing a roadway, criteria related to cross section elements, for roadways, both with and without sidewalks, should be examined to see if changes need to be made to accommodate the pedestrian.

### Lane Widths

The subject of lane widths is usually addressed in terms of vehicular traffic, primarily related to vehicle accommodation and highway capacity. However, many designers fail to consider that the roadway is often shared by pedestrians and vehicles in many suburban, rural, and local road applications. Thus, narrower lanes (10 or 11 feet) should not be used where both pedestrians and vehicles must use the travel lane. Ideally, sidewalks should be incorporated to separate the two traffic streams if pedestrian/vehicle conflicts result.

### Shoulders

The shoulder is not only an area for stopped or disabled vehicles but also structural element that laterally supports the roadway. The shoulder is frequently used by pedestrians as the primary link in a trip or by motorists walking to/from a disabled vehicle. Even though the use of the shoulder by pedestrians is to be discouraged in many situations, it must be realized that people do walk and jog on the shoulder when a sidewalk is not present. Thus, any design decisions regarding shoulders should consider pedestrian use and be done in concert with decisions regarding lane widths. However, it must be remembered that shoulders are no substitute for sidewalks.

## Curbs

Along with drainage and vehicle redirection at low speeds, designers should be mindful that a curb is also a barrier to some pedestrians. Handicapped and older pedestrians find it difficult to clamber up high sections of barrier curb. Thus, pedestrian ramps should be incorporated into the design as required by the Americans with Disabilities Act (ADA). For additional coverage of this important topic, the designer should refer to Chapter 2 and to the Federal Highway Administration implementation manual on this subject that was done by Templar.[12]

## Walkways

While there are no pedestrian or vehicular traffic based sidewalk warrants, a set of guidelines for the installation of sidewalks has been proposed by Knoblauch, et al., as discussed in detail in Chapter 3. The guidelines are based on a study of pedestrian accidents related to pedestrian exposure and certain operational and design features. Recommendations are provided relative to land use category, roadway functional class, and development density for both new and existing urban and suburban streets **(figure 1–4)**. As

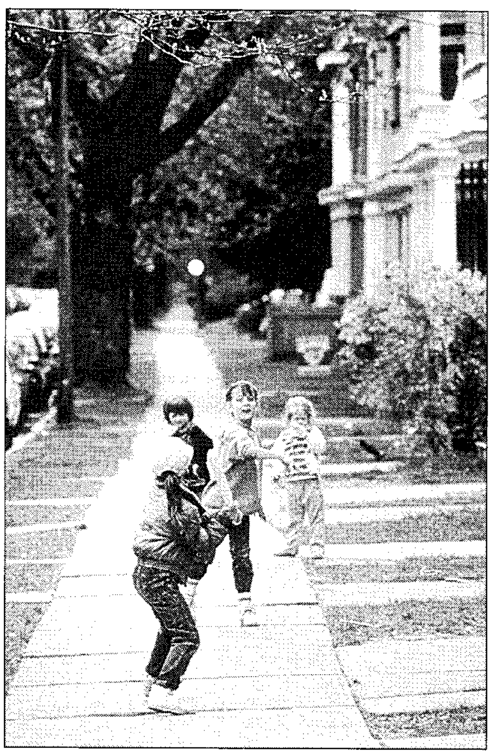

FIGURE 1–4. *Sidewalks and walkways are important design features for pedestrian safety and mobility.*

there are no formal guidelines for providing sidewalks in rural areas, the direction given in the current AASHTO Greenbook provides sound but not definitive advice.

## Traffic Barriers

As with many of the other elements of roadway design, most discussions of traffic barriers in the highway design literature focus entirely on vehicular traffic. Many different types of barriers provide an effective means for channeling pedestrian flows and prohibiting, or at least making undesired pedestrian movements more difficult. Zegeer presents a series of conditions when barriers may be most useful along with a listing of potential advantages and disadvantages.[11]

Barriers should be used with care, since most barriers have proven to be rather ineffective in stopping pedestrians. Instead of stopping pedestrians from travelling along their desired path, a more concerned approach is, wherever possible, to improve the safety of the desired pedestrian path. See Chapter 8 for more information on traffic barriers.

## Medians

Medians control vehicle movements, store stopped vehicles, and act as refuge areas for pedestrians. One of the major problems that pedestrians face, especially older pedestrians, is the crossing of wide streets. At unsignalized intersections, medians allow the pedestrian to perform a simplified crossing task. The pedestrian can look for smaller gaps in the traffic stream and concentrate on locating those gaps in traffic that are coming from only one direction **(figure 1–5)**.

At signalized intersections, due to traffic operations considerations, the available pedestrian crossing time is often the value minimum specified in the MUTCD and the *Traffic Control Device Handbook.*[13] In such cases, there is inadequate time to traverse a wide intersection, given that some pedestrians do not walk at speeds used for design purposes (4.0 feet per second). If the minimum pedestrian indication times were set at slower walking speeds, the capacity of the intersection would be adversely impacted.

In cases where it is desirable to maintain an adequate pedestrian crossing period, a median would provide a place for pedestrians to safely stop and continue their crossing during the next "walk" indication. While this type of operation is less than ideal for pedestrians, especially from the pedestrians' point of view, it does provide a solution to the common problem of pedestrians crossing wide streets. Many cities have used boulevards to provide a more attractive street environment and also to better serve the needs of pedestrians **(figure 1–6)**.

## Intersections

### Intersection Types

Discussions in the literature of the various types of intersections make only limited mention of pedestrians. For example, one often finds discussions of how skew affects the operation of the intersections from a turning vehicle perspective; however, there is seldom mention of how skew would affect pedestrian operations (i.e., create longer crossing distances and greater pedestrian exposure).

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. 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 per AASHTO guidelines.

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.

Reduced pedestrian crossing distances, greater visibility for both pedestrians and motorists, and a certain amount of control over vehicle paths and speeds can be achieved through the use of flared curbs **(see figure 1–7)**. The flared curb is nothing more than the widening of the sidewalk at midblock or intersection locations. If designed correctly, the flared curb offers pedestrians a distinct advantage in making a crossing maneuver while causing minimum interference for vehicle traffic. If poorly designed, the flared curb can create more problems than it was meant to solve, e.g., reduction in right turn capacity or corner drainage problems. Coverage of design considerations for this type of treatment is given in a paper by Pietrucha and Plummer.[15]

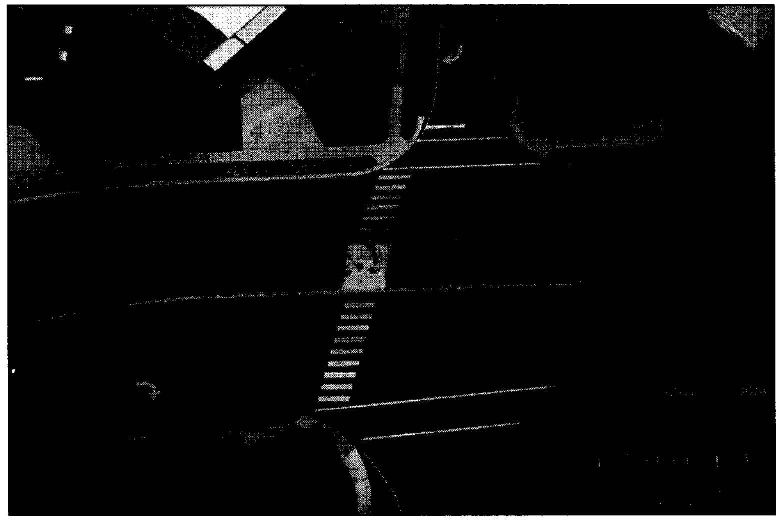

FIGURE 1–5. *Medians can greatly improve conditions for pedestrians on wide, multi-lane arterial streets.*

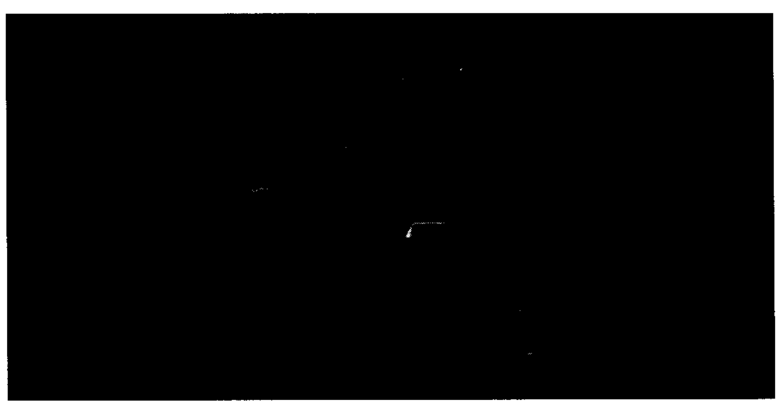

FIGURE 1–6(a and b) *Boulevards can provide an attractive and safer environment for pedestrians on wide streets.*

## Sight Distance

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 avoiding 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 **(figure 1–8)**.

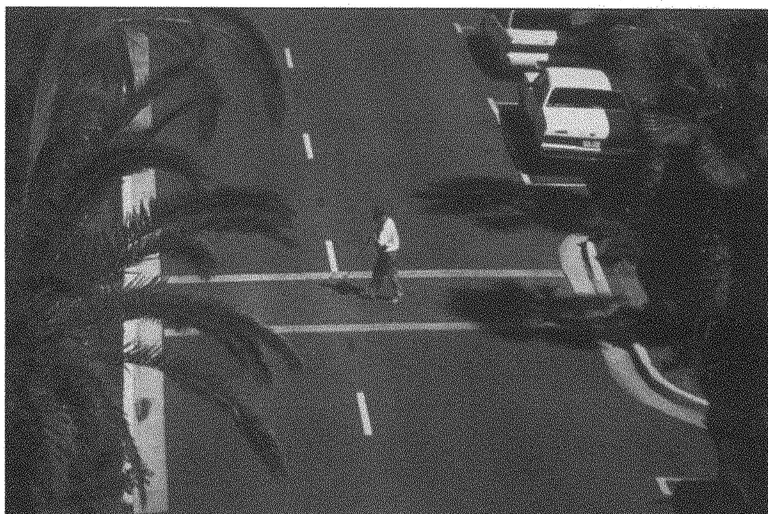

FIGURE 1–7. *Extended or flared curbs can shorten the crossing distance for pedestrians and provide improved visibility between motorists and pedestrians.*

FIGURE 1–8. *Reduced sight distance can present a serious problem for pedestrians who wish to cross the street.*

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.

While signalized intersections seem to offer less of a problem than stop-controlled intersections, signalized intersections must be treated in a similar fashion. Care must still be exercised in the design in anticipation of signal malfunctions or periods when signals are placed in flashing operation. When this occurs, the signal usually defaults to a flashing red on the minor approach and has traffic operations that are analogous to those at a stop-controlled intersection. However, since the major approach defaults to a flashing yellow, the designer should insure that adequate sight lines also exist for pedestrians attempting to cross the major approach.

Although horizontal sight distance is the more frequent problem, vertical sight distance cannot be ignored. For drivers of vehicles with high seat positions (such as trucks), pedestrians standing on the curb may be obscured by signs or trees along the edge of the right-of-way. As with ground level obstructions, the designer should check to see that adequate sight lines are provided.

## Alignment

The AASHTO Green Book recommends the intersection of roadways at 90 degree angles. This design guidance represents the best option for both pedestrian and vehicular traffic. Sight lines are optimal, conflict space limited, and crossing distances (and hence exposure time) are reduced. However, the profile of intersection approaches receives only cursory attention, but it is another complicating factor. The sight lines of traffic approaching an intersection on a significant upgrade are compromised, which limits the opportunities for the pedestrian and the motorist to assess a situation.

## Turning Radii

The size of corner radii can have a marked effect on pedestrian crossing distance, the distance between the crossing pedestrian and right/left turning vehicles and the speed of turning vehicles. Visually challenged pedestrians prefer small radii to give them better direction indication around the intersection and to reduce the speeds of turning vehicles.

However, a balance must be struck between small radii and the turning paths of large vehicles. Too small a radius can cause large vehicles to round the curb and eventually break it up or hit pedestrians who are standing close to the corner. AASHTO allows two types of design:

1. Where the corner radii are based on vehicles turning from the curbside lane into the adjacent curbside lane. This design criteria requires the use of large radii.
2. A radius where vehicles turning from the curbside lane use all of the receiving loadway width. This design is preferred as the balance between vehicle and pedestrian needs.

A third option is to use channelized right turn slip lanes which can provide motorists with smoother turning maneuvers (compared with a small turning radius). These still help to accommodate pedestrians if a refuge island is provided between the slip lane and the through lane(s) **(figure 1–9)**. Ramp-type intersections (turning roadway terminals) can pose a problem to pedestrians, since they promote faster traffic speeds. Therefore, pedestrian crossings should be at 90 degrees across the ramp. The literature provides little guidance on the optimal location of pedestrian crossings at these locations, although it is generally accepted that right angle crossings are the best.

The use of pedestrian-oriented geometric features, such as flared curbs, at an intersection will have the effect of reducing the radius of the curb return. While passenger cars traveling at low speeds usually do not have a problem with the smaller radii, the geometric design requirements for trucks and buses are much more demanding than those for passenger vehicles. Trucks and buses are wider, and generally have longer wheelbases and greater minimum turning radii.

A common practice is to allow the larger vehicles to off-track and have the rear wheels cross the flared curb area. By allowing these trucks and buses to traverse the flared area, one is defeating the entire purpose of having a flared curb. These vehicles may endanger the pedestrians the flared curb was intended to protect. It also causes some concern regarding the service life of the flared corner, since these larger vehicles have heavier axle loads and higher tire pressures. Allowing a steady stream of heavy vehicles to travel over the flared curb area will no doubt prove to be a maintenance headache.

Problems related to reduced radii at corners may also be a concern in areas with heavy right turn volumes. The reduced radius can have an effect on the capacity of the right turn movement. A better approach in this situation would be to use channelization rather than a flared curb.

FIGURE 1–9. *Properly designed right-turn slip lanes with pedestrian refuge islands can enhance crossings for pedestrians.*

## Islands

The objective in the design of islands from a pedestrian point of view is to provide a traversable path. Refuge islands are used in urban areas on exceptionally wide roads or at large, irregularly shaped (skewed) intersections where the combination of heavy pedestrian or vehicular volumes can make pedestrian crossing difficult or dangerous. They protect pedestrians in areas of the intersection where there may be complicated or confusing traffic flow patterns or segregated, high-volume vehicle movements (e.g., turn lanes) **(figure 1–10)**.

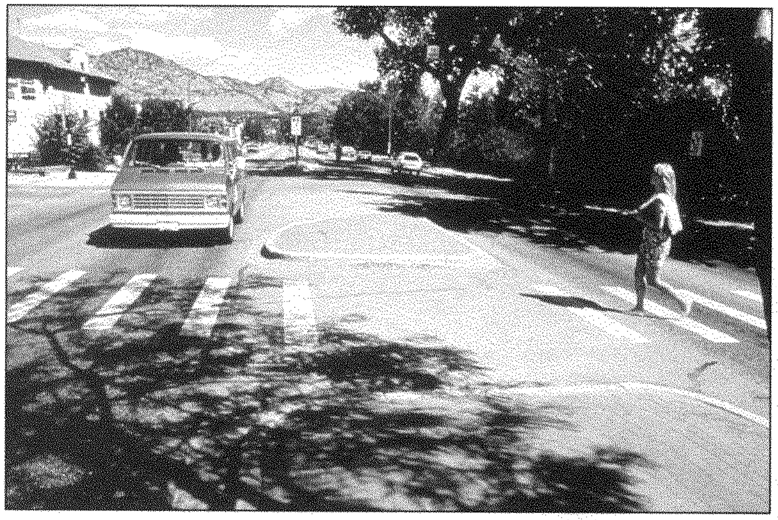

FIGURE 1–10. *Refuge islands offer many benefits to pedestrians wishing to cross wide streets.*

At wide signalized intersections, this type of island can be used to reduce the pedestrian clearance interval by having pedestrians cross one direction during each interval. The island also provides a stopping point for the slow walker who cannot cross the entire street in the allocated pedestrian time even when timed for such a maneuver. At isolated signal locations, the reduced pedestrian clearance time can minimize the signal cycle length and the overall delay to vehicular traffic. Islands should be designed to make the approach clearly visible, allow sufficient time for driver and pedestrian decision making, and assure that the path and approach conditions follow the natural path of movement. Advantages which traffic islands provide include:

- Separation of conflicts
- Control of angle of conflict
- Reduction of excessive pavement areas
- Nearside island provides better location for stop bar and increases capacity of intersection
- At signalized intersections, reduces pedestrian crossing time
- Regulation of traffic and indication of proper use of an intersection
- Arrangements to favor a particular turning movement
- Storage and protection of pedestrians
- Protection and storage of turning and crossing vehicles
- Location of traffic control devices (reduces length of mast arms).

Despite these many advantages, traffic islands, in general, can be difficult to retrofit, make turns more difficult, hinder site access, and sometimes be a hazard to motorists.

It has been proposed that pedestrian refuge islands be provided wherever possible, when the total length of a crosswalk is greater than 75 feet, or in areas where there are many elderly or handicapped pedestrians. Refuge islands should be provided if the intersection cannot be crossed in the walk/green time allotted for the pedestrian movement using an assumed walking rate of 3.5 feet per second.[17] This also assumes that the signal timing cannot be changed to accommodate these special pedestrians.

It is generally believed that any island used for pedestrian refuge purposes needs to give the pedestrian a sense of security when they are placed near moving traffic. Four feet is the recommended minimum width for pedestrian refuge islands.[16] The length of the refuge island should be a function of the use of the island, but should be at least 12 feet long or the width of the crosswalk, whichever is greater. If the refuge island is to be a raised barrier curb design, the island must have an at-grade pedestrian travel path through the island, or there must be sufficient space for curb ramping and a level waiting area large enough for a wheel chair.[17]

## Drainage

Another important area for designers of pedestrian facilities to consider is the storm water drainage system. In older designs, corner catch basins are used to move water from the gutters to the underground drainage system. These catch basins are usually comprised of a throat and grate inlet and are placed in a sump or low point at the intersection. New intersection designs should have the inlet located at the point of curvature (PC) and the point of tangency (PT) upstream of the corner radius to drain the intersection. Such throat inlets are used because they are less likely to be clogged by debris, and they are much less threatening to bicyclists. Another reason for this type of design is that current building or planning regulations usually do not allow water to drain around a corner because it is thought that in heavier rainfall there is a chance that water will begin to pond in the intersection. Careful selection of the location of the sump area should prevent any problems.

## Location of Utilities

The design of a new intersection or the replacement of an existing intersection may make it necessary to move some of the 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. Certain designs could also necessitate the relocation of many underground utilities such as storm water drainage systems; sanitary sewer manholes, lines and laterals; underground electric or telephone cables; and underground traffic signal system hardware. While attention to the pedestrian may not be the most important consideration here, they cannot be totally ignored.

## Capacity

The vehicular capacity of intersection designs need to be evaluated using procedures outlined in the 1994 Highway Capacity Manual (HCM).[5] The HCM also offers an extensive treatment of pedestrian capacity. Its purpose is to describe the basic principles of pedestrian traffic flow and to provide a general framework and procedures for the analysis of pedestrian facilities. The scope of the manual is limited to sidewalks, crosswalks and street corners, but the analysis techniques may be applied to other situations as well. While concentrations of pedestrians are most often found in urban areas, there are situations in rural and suburban areas where pedestrian concentrations are large **(figure 1–11)**. In these situations, inadequate pedestrian facilities affect pedestrian convenience, as well as delay vehicles and reduce capacity.

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.[5] 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 have equal status in analyzing the options at an intersection, and thus, some loss in motor vehicle capacity may be necessary to accommodate pedestrians.

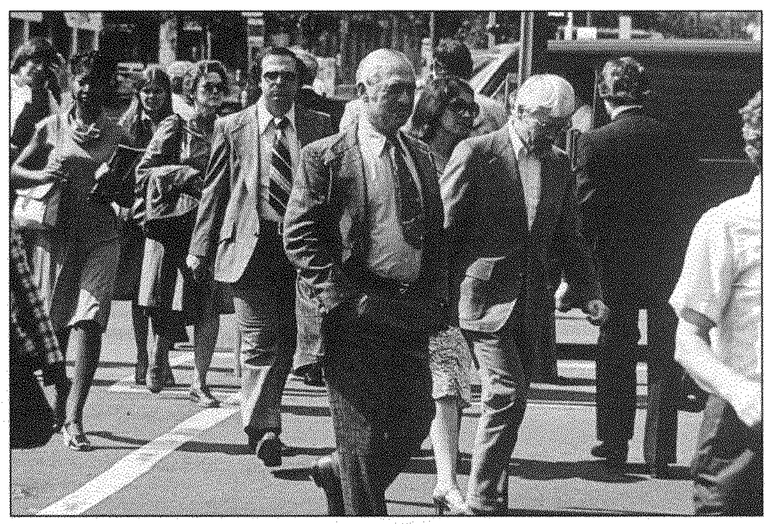

FIGURE 1–11. *Facilities need to be designed with consideration to pedestrian flows and capacity.*

## Traffic Control Devices

Most designers agree that design and control treatments for intersections must be developed in concert. The geometry and cross section of an intersection needs to be considered in conjunction with options for traffic control devices—signals, signs, and pavement markings. The nature of the vehicular and pedestrian traffic must, of course, dictate the selection of appropriate design and control treatments **(figure 1–12)**.

A properly designed intersection can often benefit from properly designed pavement markings, in particular, crosswalk markings and stop bars. The size and placement of these devices could influence the size or placement of other geometric features of the intersection. See Chapter 5 for more information on curb parking restrictions.


FIGURE 1–12. *Signs, signals, and markings should meet the needs of pedestrians and motorists.*

## Parking

Some consideration must also be given to the effects of allowing parked vehicles near the intersection. Some analyses have shown that 50 percent of all urban pedestrian accidents involve dashes into the street at midblock locations or intersections.[11] A frequently cited contributing factor with these types of accidents is that the motorists or pedestrians could not see each other because of on-street, parked cars. Given these facts, the designer should consider the prohibition of on-street parking near intersections. In cases where the vehicle travel speeds are 35 miles per hour or greater, it has been recommended that this distance be at least 100 feet.[8] On neighborhood streets, bulbouts may be constructed at midblock or intersection crossing locations to place the pedestrian out to the edge of parked vehicles where drivers and pedestrians see each other more easily. It should be noted that bulbouts, while often beneficial to pedestrians, can restrict or interfere with large trucks turning at intersections. See Chapter 9 for more information on curb parking restrictions.

## Bus Stops

The location of bus stops must be considered when contemplating the design of the intersection. The objective here is to not place the boarding or alighting passenger at risk because of the design. See Chapter 14 for a discussion of bus stop location.

## Loading Zones

For areas with businesses, another item that must be considered is the location of loading zones. Certain designs could cause problems for delivery truck operators, who unload shipments for nearby businesses, or the pedestrians, who must weave their way through the parked vehicles. In many areas, these vehicles can range from simple step-vans to full-length tractors and semi trailers. As with many other areas, provision of adequate sight lines for drivers and pedestrians is key.

### Driveways and Access Management

Driveways are, in effect, intersections. While there is no argument on this point, a serious deficiency of many design policies are their treatment of driveways. The AASHTO Policy, for example, provides only limited attention to measures that can be applied to control access along major roadways. The goal of access control is to provide improved traffic flow and increased safety on streets and highways. While sidewalks may have a consistent surface material across driveways, there is little else to warn, direct, or control the flow of vehicular or pedestrian traffic. Access control measures should be considered in the design of highways and streets for the benefit of both vehicular and pedestrian traffic. While design accommodations for the pedestrian are notably absent from the list of techniques in documents on access management, there are many ways to serve both pedestrian and access considerations. See the ITE Recommended Practice on driveway location and design.[18]

### Street Furniture

As has been discussed earlier under sight distance, special consideration should be given to the placement of street furniture at or near intersections and the resulting impact on sight distance. Many designers fail to recognize the importance of providing and maintaining adequate sight distance for both motorists and pedestrians for the safe operation of the intersection. It should also be noted that street furniture should not be placed so that normal pedestrian paths are blocked. This is especially true for pedestrians with disabilities.

## *Special Intersection Types*

### Roundabouts

Roundabouts are being widely used in many countries to calm traffic, reduce serious collisions, increase intersection capacity, replace traffic signals to lower operating and maintenance costs, improve the streetscape and improve safety and mobility by reducing vehicle speeds. Vehicle delay may also decrease, and reduced vehicle speeds also reduce the noise levels, thereby improving the whole environment. They are smaller than traffic circles, usually 5 to 120 feet in diameter, with low operating speeds, 12 to 22 mph, and provide a smooth tangential entry and exit.

Pedestrian safety at roundabouts depends largely on the specific design. The roundabout may provide no substantial improvement over traditional intersections (and may even reduce pedestrian safety under certain conditions) if there are no medians or islands on the side streets (or within the roundabout), and the side streets are all two-way. Roundabouts with median islands may make crossings safer than at signalized locations, if adequate gaps are available in traffic for crossings, and if vehicle speeds are lower as a result of the roundabout design.

### Expressway Ramps Intersecting with Urban Streets

Another type of intersection that can adversely affect pedestrian safety is the intersection between expressway ramps and urban 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. Such exiting vehicles may have difficulty stopping when faced with a red signal at the intersection with the urban street. To compound the problem, 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 hazard to pedestrians at ramp intersections is often difficult to correct in cases of such short exit ramps, poor sight distance for exiting traffic, and/or other design deficiencies. However, 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.[11]

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# 2

# PEDESTRIANS WITH DISABILITIES

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FIGURE 2–1. *Well designed facilities are especially important for pedestrians with disabilities.*

Transportation engineers must consider not only the concerns of vehicular traffic but also those of self-propelled individuals such as pedestrians. Pedestrians can be considered the smallest unit of transportation, and as these individuals operate within and among larger vehicles, safety becomes of paramount importance.

Good and effective pedestrian design is needed to ensure the smooth integration of the individual into the flow of traffic among larger, more powerful vehicles. Engineering design flaws frequently can be overcome by the agile, able-bodied person. However, when age or functional disability reduces one's mobility, good and effective design not only is important, it is critical. Better designs not only benefit those with restricted mobility, but all other pedestrians as well **(figures 2–1 and 2–2)**.

Most civil rights statutes define a disability as any physiological or psychological disorder or condition, cosmetic disfigurement, or anatomical loss affecting one or more systems of the body. Moreover, for engineering purposes, a disability can be

FIGURE 2–2. *Wide streets can pose a problem for pedestrians with mobility impairments.*

classified in one or more of three functional categories: mobility impairments, sensory deficits, or cognitive impairments.

Wheelchair users most often come to mind when mobility impairments are considered **(figure 2–3)**. However, the definition is much broader. A person with a mobility impairment is any person who, because of some physical problem or circumstance, is limited in his or her method or ability to move about. This would include, of course, those people who use wheelchairs but also those with braces, crutches, canes, and walkers. It also includes persons with balance or stamina problems and may even include some pregnant women **(figures 2–4 and 2–5)**.

Sensory deficits are most often associated with blindness or deafness; however, partial hearing or vision loss is much more common. Also included would be persons who have lost sensation in some part of their body, lost their sense of balance, or lost a body part (except legs, which would be a mobility impairment). To an even lesser extent, the sense of taste or smell and color blindness, especially of red and green, are considered sensory deficits.

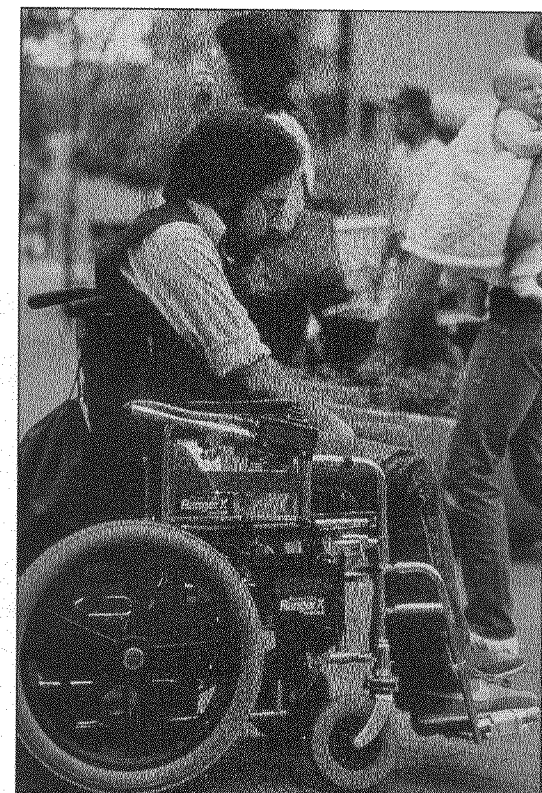

FIGURE 2–3. *Wheelchair users most often come to mind when mobility improvements are considered.*

Cognitive impairments are related to a diminished ability to process information and make decisions. For instance, cognitive impairments apply to those who are retarded or who have a dyslexic type of learning disability and include those who are unable to read or to understand the English language.

Transportation engineers need to be aware of the sizeable proportion of individuals falling into such categories. The following is a detailed examination of the characteristics of such individuals and the pedestrian situations that need to be examined in both urban and rural environments.

## *Personal Characteristics*

For most of us, the image we have of people with disabilities has been brought about by the stereotypes portrayed through television, newspapers, and charitable organizations. Unfortunately, these images are distorted and, in many cases, just simply incorrect. Contrary to the problems that pedestrians with disabilities face, most share many commonalities with able-bodied pedestrians.

The person with a disability traveling independently is usually a shopper, student, or employee going about normal business, and it is the job of the engineer to refrain from erecting new barriers and to eliminate any existing ones. Based on tests conducted on wheelchair users by the Veterans Administration, the level of energy required by a wheelchair user to push a given distance is about 30 percent higher than that needed by a pedestrian to go the same distance. Moreover, a person on crutches or with artificial legs requires 70 percent more energy to go the same distance. If a person using a wheelchair travels a full city block to find no curb cut, doubles back, and travels that same distance in the street, it is the equivalent of an ambulatory person going four extra blocks, not to mention the extra time and inconvenience. Such an example indicates the importance of removing physical barriers from our society and the need to avoid the construction of new ones.

## The Americans With Disabilities Act (ADA)

On July 26, 1990, the Americans with Disabilities Act was signed into law. This piece of legislation, considered a civil rights law, assures that a disabled person will have full access to all of the benefits and facilities of this country. As transportation engineers, it is our responsibility to see that our work is in compliance not only with the letter of the law but with the spirit as well. Dimensions and rules quoted herein are based on the current (1992) standards set by the Architectural and Transportation Barriers Compliance Board, the Uniform Federal Accessibility Standards, and The American National Standards Institute (ANSI) A117.1 codes. However, there are some local or state codes that are more strict, which supersede these codes.

FIGURE 2–4. *Persons with mobility impairments include those with braces, crutches, canes, and walkers.*

## Sidewalks

The most common place to find a pedestrian is on a sidewalk—the roadway of the pedestrian. The lack of sidewalks can create particular problems for pedestrians with disabilities **(figure 2–6)**. Therefore, a well-designed sidewalk should be paved in a relatively smooth, durable material with a good coefficient of friction and be of sufficient size to handle the capacity of the expected load. Ideally, sidewalks should have a minimum clear usable width of at least 36 inches at every point along their length. For example, a telephone pole at one point on the route that reduces the width to less than the clear width of a wheelchair can render the entire sidewalk unusable as a route for wheelchair users.

Sidewalks should be built and maintained in all urban areas, non-interstate public highway rights-of-way, in commercial areas where the public is invited, and between all commercial transportation stops and public areas. Sidewalks are usually needed on both sides of all streets to provide mobility for disabled pedestrians **(figure 2–7)**. A wide planting strip, which serves as a buffer between on-street vehicles and pedestrians on the sidewalk, can be especially beneficial to the blind and to wheelchair users. If concrete sidewalks are used by a municipality, care should be taken with the construction and maintenance of joints. Obviously, sidewalks should be kept in good repair, free from cracks and rough surfaces.

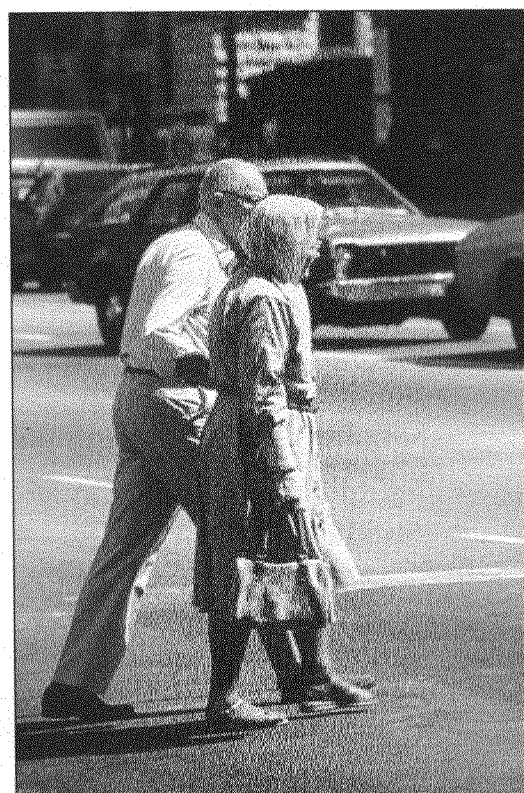

FIGURE 2–5. *Many elderly pedestrians have mobility limitations.*

FIGURE 2–6(a).

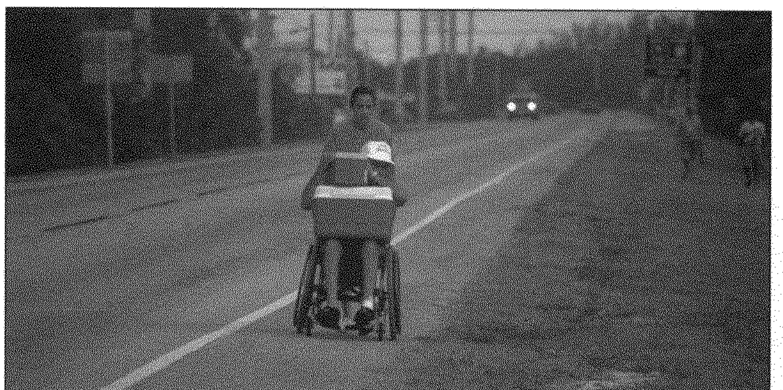

FIGURE 2–6(b). *Lack of sidewalks can create particular problems for pedestrians with disabilities.*

The design of sidewalks and curb ramps should consider wheelchairs and the needs of other pedestrians as well **(figure 2–8)**. To the extent feasible, sidewalks should have the minimum cross slope necessary for proper drainage, with a maximum of 1 inch of fall for every 50 inches of width. A person using crutches or a wheelchair on a cross slope has to exert significantly more effort to maintain a straight course on a sloped surface than on a level surface. Longitudinal grades should be limited to a maximum of 8 percent, and if steep grades are longer than 30 feet, a five-foot level area shall be provided. This is advisable because walking down a steeper slope on crutches or with artificial limbs is extremely hazardous, as these appliances are designed to limit rearward motion of the feet.

Handrails are also required in many cases, particularly along long ramps. Handrails are used by persons in wheelchairs to help pull themselves up and are used by other persons for support. It must also be remembered that going up a steep grade in a wheelchair or with crutches can raise a person's heart rate by as much as 70 percent. Thus, in areas where it is impossible to avoid steep grades, an alternative route, such as an elevator in a nearby building should be provided. The use of informational signs, indicating such facilities, can be placed at the base of the grade or in a guidebook for the area and can make large geographic sections accessible to a great number of persons. It is also possible to make arrangements with the local transit authorities to transport persons with disabilities in public transit at reduced or free fares.

## Street Furniture

Street furniture, such as benches and shelters, has needlessly caused more problems for disabled pedestrians than any other obstacle. To ensure the safety of visually impaired persons, street furniture, to the degree possible, should be out of the normal travel path. For greater conspicuity, high contrast colors, such as yellow, red, and black should be used whenever possible. The following guidelines for positioning of street furniture should be considered:

- No street furniture should hang less than 80 inches high over a circulation path.
- No object mounted on a wall or post, or free standing should have a clear open area under it higher than 27 inches off the ground.
- No object higher than 27 inches, attached to a wall, should protrude from that wall more than four inches.
- No protruding object should reduce the clear width of the circulation path to less than 36 inches. This is extremely important as an object in this area will not be detected by a visually impaired person using a cane.

Another very common problem, particularly for wheelchair users, is the placement of street furniture next to on-street parking. Such placement can make exiting a lift-equipped vehicle difficult. One remedy is to have movable street furniture, such as benches, placed toward the end of a parking space, rather than at the center. Fixed objects, such as telephone poles or street lights, can be placed at the ends of parking spaces rather than in the middle of parking spaces. However, if center placement is unavoidable, engineers should consider increasing the number of reserved handicapped parking spaces (see "PARKING" below).

Revolving doors and turnstiles cannot be used by wheelchair users and are extremely hazardous for others with mobility impairments. Furthermore, they are quite confusing for many persons with cognitive impairments. As a result, their use should be avoided. If these features are necessary, they should always be unlocked during business hours, and a clear path should be provided.

Quadraplegics and people with poor coordination or with prosthetic hands may not be able to operate any piece of street furniture that requires grasping or turning, such as parking meters or pedestrian signal actuators. Prosthetic devices also will not activate heat-sensitive switches, such as those used in elevators. Therefore, alternate methods of usage should be employed. For example, a wheelchair detector system can be built into the sidewalk where an individual need has been determined.

## *Stairways*

Steps or stairs should be avoided whenever possible. When necessary, however, all steps and risers should be uniform in height and depth, with treads no less than 11 inches. Stairs should also have solid risers and gradual nosing undersides that do not exceed 1.5 inches. If nosings are abrupt, people with poor vision or with mobility impairments could catch their toes under the nosing and trip. Effectively designed handrails on stairs should be continuous on both sides of the stairway and between 1.25 and 1.50 inches in diameter, at least 1.0 inch from any adjacent surface, and at least 12 inches beyond the top and bottom of any stair run. Steps should be designed to prevent water accumulation on the surface and with a tactile surface at the top and bottom to alert visually impaired persons.

Single steps are one of the most common entryways to buildings and facilities. While the building design is not the direct responsibility of most transportation engineers and planners, raising the level of a sidewalk when it is constructed, repaved, or repaired can dramatically improve accessibility and eliminate a potential safety hazard.

FIGURE 2–7. *Sidewalks provide mobility for disabled pedestrians, as well as other pedestrians.*

FIGURE 2–8. *The design of sidewalks and curb ramps should consider the needs of wheelchair users.*

## Parking

Before the widespread availability of accessible transit equipment, the private auto was the only method of transportation for a person with a disability. One problem associated with parking and street furniture was discussed above. To reiterate, a person using a wheelchair, leg braces, or artificial limbs must open the car door completely (usually a two-door car with larger doors) in order to get himself and his equipment in and out of the car. A lift-equipped van requires even more room. In general, an area 13 feet in width is the very smallest space that can be used by a person with a lift-equipped van. Therefore, in on-street or parallel parking spaces, the removal of all barriers on the sidewalk should leave at least five feet of clear space for unloading. When diagonal street parking is permitted, there should be a designated handicapped space placed at the ends of every block. In parking structures, some handicapped spaces should be provided in an area with a height of at least 12 feet, which can be utilized by vans with raised roofs, as these are now extremely common forms of transportation among drivers with disabilities.

Of course, using the other strategies discussed elsewhere in this chapter, providing an accessible route to and from all parking is essential. A large number of pedestrian accidents occur with backing vehicles in parking lots. An accessible route should avoid having wheelchair users travel behind other vehicles, because a person in a wheelchair is so low that he/she may not always be visible to drivers of backing vehicles. If two spaces share an access loading area, parking enforcement officials should be made aware that many persons with disabilities can only load from one side. Consequently, vehicles may need to either pull or back into the space.

Cross slopes in handicapped parking spaces in lots should be about 1 or 2 percent to allow for drainage. Cross slopes shall not exceed 2 percent by code and because a relatively level parking space is of critical importance for those persons who must get up from their wheelchairs and then load the wheelchair into the back seat. During the transfer from their wheelchair to the car, they are extremely unstable, and a sloping ground adds greatly to the hazard, especially in wet weather.

In snow regions, it is important that parking spaces be kept clear and not used as a place to store snow. A very common remark on parking lots is, "Pile the snow in the handicapped spaces—they won't be out in this weather." Wheelchairs, especially the new ultra-lightweights and power chairs, have extremely low traction in wet weather. Although the users usually know how to maneuver in such conditions, extra obstacles are to be avoided if possible. It is important to keep in mind that a person with a disability will need two to three times more time and energy to travel the same distance in bad weather, as a person without a disability.

## Curb Cuts and Ramps

The single most common feature employed to improve the mobility of pedestrians with disabilities is the curb cut. It is also the most misunderstood. Surprisingly, curb cuts are often poorly and inadequately designed, placed and maintained. At a minimum, curb cuts or depressions should be 36 inches wide with flared sides that do not exceed a 10 percent slope and should have a tactile warning texture extending the full width and depth of the ramp. Slopes with gradations not exceeding 8 percent contribute to the usefulness of the sidewalk.

The single most important feature of curb cuts is that they be flared into the street surface. Any sudden dropoff in a ramp descent by as little as one-quarter inch may cause a wheelchair to tip over. Flaring is especially critical for the newer ultra-lightweight and sport wheelchairs, many of which have wheelbases as short as 12 inches, used by many active persons today. The smaller the wheelbase, the more acute the problem. Also, many of the power wheelchairs have their batteries secured near the front portion of the chair adding 50 to 75 pounds of nose heaviness. If these chairs suddenly drop off an unflared lower edge of a curb ramp, instability results. Therefore, designers must remember to always flare the lower portion of ramps and curb cuts into the street or sidewalk at the lower end of a ramp or curb cut.

Ramps located in the center of a corner should be avoided. Such locations force the visually impaired and the wheelchair user into the intersection where they must turn to reach and use the crosswalk. Each corner should have two curb cuts, or a broad cut serving both crosswalks. Ramps or cut-through islands, along with push-button walk acuators should also be provided on pedestrian refuge islands.

Drainage is also important, especially in colder areas where ice can form at the base of ramps, making gaining traction impossible. Additionally, if water is obscuring the bottom of the ramp, it is impossible to determine if there is a dropoff, a pothole or piece of debris lying at the base to cause an accident. In addition, any debris that the wheel of a wheelchair rolls through may end up on the hands of the user. Few engineers or planners would put their hands in every mud puddle on the street, but a poor design can require this of every wheelchair user.

Storm drains on access routes should be placed clear of any crosswalks and should not have openings greater than one-half inch in one direction. Wider openings may cause difficulties to the smaller front tires of wheelchairs and may also pose a tripping problem to visually impaired persons and others using walking assisting devices.

## Bus Stops

With the passage of the Americans with Disabilities Act, accessible transit buses now come to all bus stops. As a result, greater attention needs to be focused on the interface between the bus and the sidewalk. There are four major methods of making buses accessible and each engineer should understand the system employed by the local transit authority.

- *The Front Door Wheelchair Lift*–This is the most common form of accessible transit bus and is growing in popularity. The front entrance of the bus converts into a small elevator that lifts persons unable to use the steps into the bus. This form is fast (30–45 seconds) and convenient (the driver never leaves his/her seat).
- *Center Door Lift*–This is the second most popular design but is falling into disfavor in many cities because it requires the driver to leave his/her seat to operate it, requiring considerably more time (three to four minutes). However, for the transportation engineer, it requires the same physical layout with one major exception; center door lift designs require the door of the bus to be positioned within 12 inches of the curb. This usually requires a longer bus stop and more stringent enforcement of the parking laws.
- *Low Floor Bus*–Common in Europe, this type of bus is just beginning to appear on American streets. This type of bus is built so that the entryway is 11 to 13 inches high and there are areas in the bus that can be used without going up any steps. The roadside design requirements for this type of bus are essentially the same as for the front/center door lift bus (the low floor area can be either at the front or center door). However, in this case the curb height of 11 inches is best.
- *The Separate Entry Bus*–Although not commonly used by transit agencies, this is the most common type of access device for intercity buses (e.g., Greyhound). Generally, these buses (two out of three current designs) have greater heights and the lift usually operates on the outside of the bus. Consequently, overhead objects such as awnings or signs could pose a problem in loading areas. The bus usually can be moved and passengers loaded in a different location, but a safe area may not be readily available.

Of course, it is important to make sure that a curb ramp exists at every bus stop where an accessible bus could board disabled passengers. Areas between the sidewalk and the bus waiting area and between the waiting area and the curb should be paved. The waiting area must also be cleared of any street furniture.

A concern that is still being investigated is how to alert visually impaired persons of a bus' arrival and destination. Among the options being investigated are very short-range radios with the transmitters on the buses or infrared systems. The easiest method, however, would be to enforce drivers to announce stops and destinations. Lights could be installed to indicate upcoming stops for the hearing-impaired. As accessible public transit is phased into regular service and as more and more people with disabilities use that service, it is increasingly important to coordinate with local transit authorities in order for the service to operate smoothly.

## Signing

One of the more difficult areas to address is signing. Unlike in Europe, there is no standard directional and information signing system for the disabled in the United States. However, taking into consideration the numerous languages spoken and the various types of cognitive deficiencies (e.g., illiteracy), avoiding signing with words is preferable at all times. Signing must be consistent throughout an area. Whenever color is used to indicate a route or entry, color should be spelled out in that color for those who are color blind or color deficient. Again, high contrast colors should be used whenever possible.

If an entry or route for persons with disabilities is different from the main path, the use of the international access symbol should be displayed along with alternative route instructions.

Vehicles that must be visible or obvious (e.g., buses, construction equipment) should have high contrast striping on the ends. This feature is especially important for older pedestrians and others who are color blind or who have visual deficiencies. Any type of alerting device, such as sirens or flashing lights, always should be unambiguous and appeal to both the sense of hearing and sight.

## Overpasses/Underpasses

Designing pedestrian facilities that require persons with disabilities to travel a more dangerous route than the general public is unacceptable. Many over or underpasses are constructed for safety reasons but are not made accessible to disabled persons on the theory that these persons can simply cross at grade. However, the mere construction of an alternative route is evidence that the given route is hazardous in some way. Because the over/underpass exists, vehicle operators will likely be less alert to pedestrians, especially those slower, less agile, or in a wheelchair.

If elevators or other mechanical devices are included in the design, keeping this equipment in good working order is a high priority item. However, the maintenance needs are also an excellent reason to avoid mechanical devices if possible.

Although many people assume that there will always be someone traveling with a person with a disability, this is less and less often the case. Thus, good effective design that fosters independent operation is crucial.

## Construction Sites

If we build it, at some point it will need repair. Construction and work sites present a great challenge to the person with a disability. Once an accessible route is established, it should never be interrupted without the establishment of an alternate route. In one case, a man in a wheelchair went to work one morning to find that the utility workers had dug a hole between him and his car while he was at work. He couldn't get home, and no one to lend a hand was to be found.

Municipal vehicles should be equipped with portable ramps to place at curbs when curb cuts are disrupted by construction. Heavy equipment operators should be taught how to position their equipment so as not to block ramps, and police should enforce ticketing and towing at curb ramps and other facilities.

Construction traffic control signs should not be placed where they would block wheelchair access along sidewalks. Sidewalks should not be storage facilities for construction signs, barricades, and cones.

## Conclusion

It is the responsibility of each and every transportation engineer to provide for the integration of pedestrians with disabilities into the smooth flow of traffic. Our recognition of their needs is essential in order for these citizens to be able to hold jobs, attend school, and enjoy the recreation facilities our municipalities have to offer and that the law says they have a right to use. As the sidewalks we build today will be with us well into the next century, we are obligated to do the job right for everyone. When the transportation engineer does a proper job, there will be an almost invisible ambiance about the area.

## Bibliography

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3

# SIDEWALKS AND PATHS

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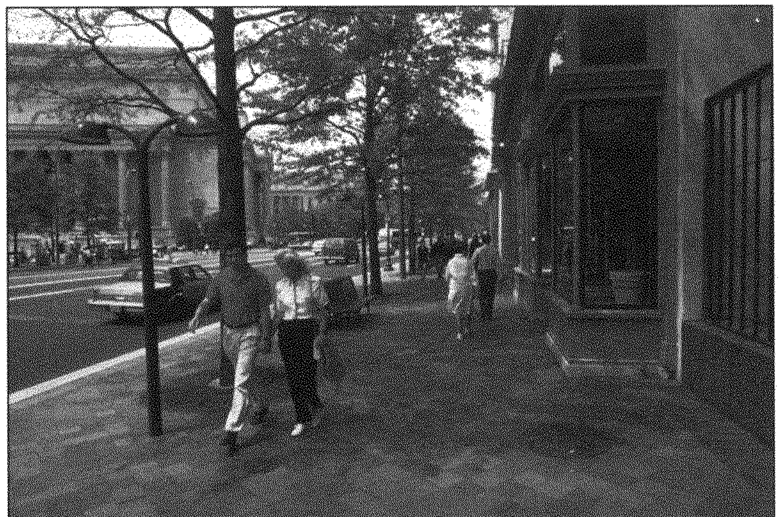

FIGURE 3–1. *Sidewalks are an important transportation feature for pedestrian mobility, safety, and accessibility.*

Properly planned sidewalks and walkways are essential in providing pedestrian mobility, safety, and accessibility, particularly for persons with disabilities, children, and older adults **(figure 3–1)**. Sidewalks reduce the incidence of pedestrian collisions, injuries, and deaths in residential areas and along two-lane roadways **(figure 3–2)**. They separate pedestrians from traffic. In fact, the presence of sidewalks was cited in a Federal Highway Administration (FHWA) study as the one physical factor in the roadway environment with the greatest effect on pedestrian safety in residential areas **(figure 3–3)**.

Residential areas with no sidewalks had 23.4 percent of the pedestrian collisions, but only 2.7 percent of the pedestrian traffic.[1] Sidewalks also provide paved places for children to play rather than in the street and a paved place for all of the public to interact. Sidewalks exist in most urban areas, but they are not usually constructed in rural areas because of low pedestrian volumes and relatively high construction costs.

Knoblauch and Tustin reported that local streets without sidewalks were more hazardous. In fact, they found that streets without sidewalks had 2.6 times more pedestrian collisions than expected (compared to the overall sample of streets) on the basis of exposure, while streets with sidewalks on only one side had 1.2 times more pedestrian collisions than expected. Thus, sidewalks are recommended for both sides of residential streets and other streets and highways where pedestrian activity is expected.[1]

Pertaining to the subject of sidewalks, the American Association of State Highway and Transportation Officials (AASHTO) states that "Sidewalks used for pedestrian access to schools, parks, shopping areas, and transit stops and placed along all streets in commercial areas should be provided along both sides of the street. In residential areas, sidewalks are desirable on both sides of the street, but need to be provided on at least one side of all local streets."[2] However, no application information is included in the AASHTO Green Book on where sidewalks should be installed, their widths, or alternate designs.

Typically, the inclusion of sidewalks is left to the discretion of the engineer or planner on a site-by-site, project-by-project basis. The needs of pedestrians are often ignored in the initial stages of development. Although retrofit of sidewalks can be undertaken, a more expedient and cost-effective procedure is to plan for the pedestrian from the beginning.

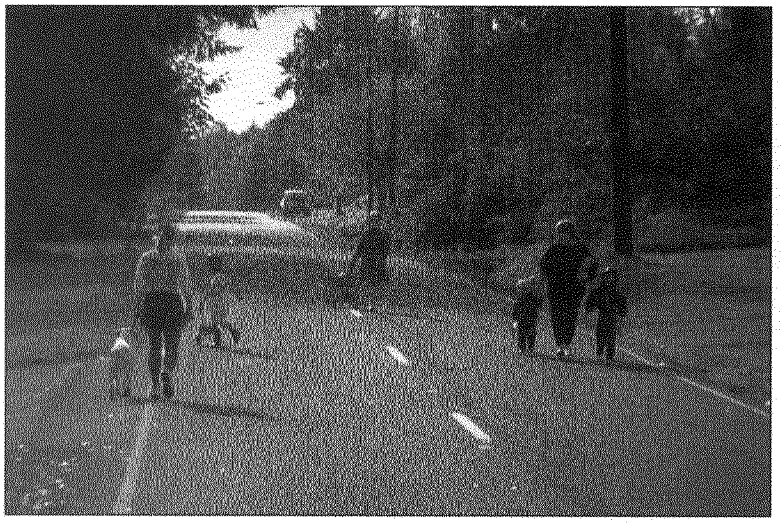

FIGURE 3–2. *The lack of sidewalks can put pedestrians at risk of a motor vehicle collision.*

FIGURE 3–3. *Properly designed sidewalks are important for safe pedestrian movement along residential streets.*

## Definition and Use

Sidewalks and walkways are designed as exterior routes to provide pedestrian accessibility. Walkways are generally pedestrian paths, including plazas and courtyards. Sidewalks are walkways that are parallel to a street or highway.

## Recommended Practice

### Recommended Guidelines for Sidewalk Installation

It is recommended that local and state agencies adopt guidelines for the location and installation of pedestrian facilities consistent with The Americans with Disabilities Act (ADA) rules. Recommended general sidewalk requirements should be based upon land use, roadway functional classification and, in the case of residential areas, dwelling unit density as detailed in **figure 3–4.**

All roadways should have some type of walking facility out of the vehicular traveled way included in the initial construction. A separate walkway is much preferred. In extreme cases, a roadway shoulder can also provide a safer pedestrian accommodation than walking on the travel lanes themselves. In rural typical sections, the walkway should be located near the right-of-way line and beyond the swale.

The purpose of walkways is to provide direct connections between residences and activity areas. It is usually not difficult to ascertain where connections between residential areas and activity centers will be required in the early stages of development. This will prevent the later construction of circuitous routes. Many routes in suburban subdivisions require pedestrians to walk out of the subdivision onto a main road and then to travel parallel with the major road network to arrive at an activity center. This can result in a walking distance five times that of an "as the crow flies" route.

| Land-Use/Roadway Functional Classification/ and Dwelling Unit | New Urban and Suburban Streets | Existing Urban and Suburban Streets |
|---|---|---|
| Commercial and Industrial (All Streets) | Both sides. | Both sides. Every effort should be made to add sidewalks where they do not exist and complete missing links. |
| Residential (Major Arterials) | Both sides. | Both sides. |
| Residential (Collectors) | Both sides. | Multifamily—both sides. |
| | | Single family dwellings—prefer both sides; require at least one side. |
| Residential (Local Streets) More than 4 Units Per Acre | Both sides. | Prefer both sides; require at least one side. |
| 1 to 4 Units per Acre | Prefer both sides; require at least one side. | At least 4-feet shoulder on both sides required. |
| Less than 1 Unit per Acre | One side preferred; shoulder on both sides required. | One side preferred, at least 4-feet shoulder on both sides required. |

**NOTES:**

1) Any local street within two blocks of a school site that would be on a walking route to school—sidewalk and curb and gutter required.

2) Sidewalks may be omitted on one side of a new street where that side clearly cannot be developed and where there are no existing or anticipated uses that would generate pedestrian trips on that side.

3) Where there are service roads, the sidewalk adjacent to the main road may be eliminated and replaced by a sidewalk adjacent to the service road on the side away from the main road.

4) For rural roads not likely to serve development, a shoulder at least 4 feet in width, preferably 8 feet on primary highways, should be provided. Surface material should provide a stable, mud-free walking surface.

*FIGURE 3–4. Guidelines for Installing Sidewalks*

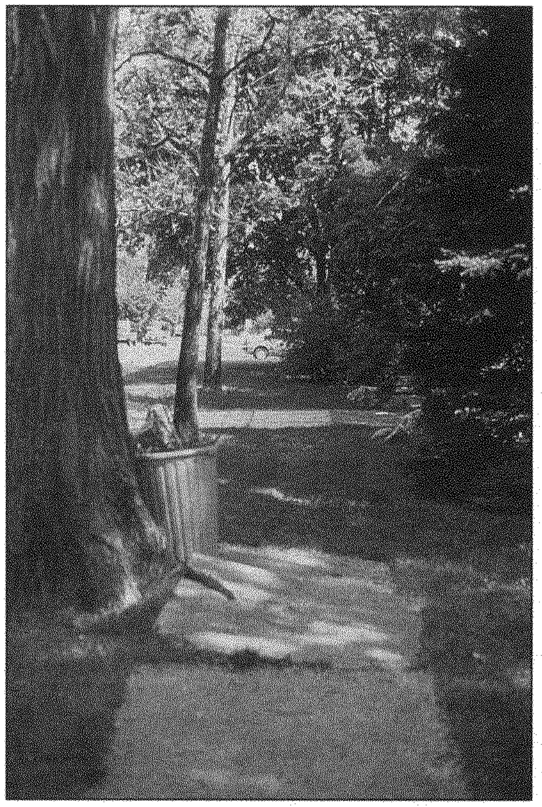

FIGURE 3–5. *Sidewalks that end abruptly should be avoided.*

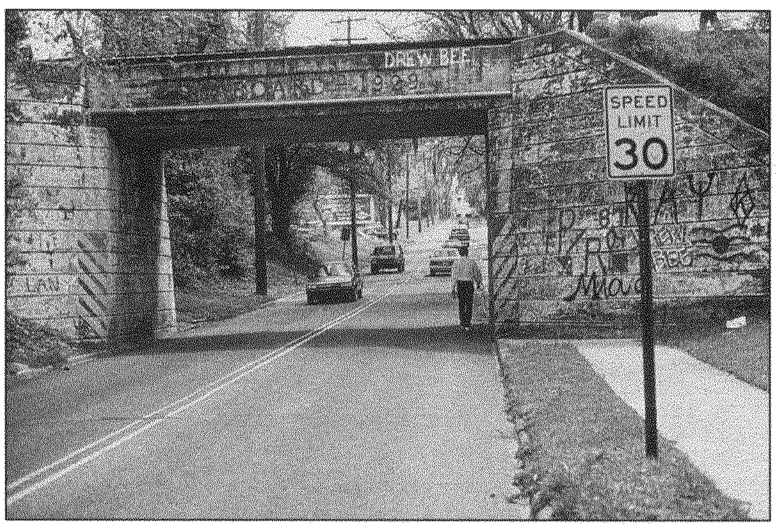


FIGURE 3–6. *Poorly planned sidewalks can place pedestrians at risk.*

Easements permitting pedestrian access through the middle of residential blocks can provide a direct connection for pedestrians with school and commercial needs. As a matter of fact, collector and arterial streets in the vicinity of schools should be provided with sidewalks separated from the roadways themselves to help to improve the safety of walking children. Parking should be closely regulated and designed to maximize sight distance for children and to eliminate hazards. Siting of schools within the neighborhood, as opposed to siting them on the arterial or collector street, can eliminate walking trips along and across the collector and arterial streets.

The actual construction of sidewalks, however, can be provided for when development progresses enough to generate pedestrian demand. Well designed sidewalk routing is best accomplished by concurrent planning of commercial and residential development within an area. Sidewalks should be continuous and installed to the recommended widths, exclusive of street furniture and other appurtenances. Discontinuous sidewalks can create problems for pedestrian access or safety **(figures 3–5 and 3–6)**.

Street furniture, such as benches, bus shelters, and kiosks, can enhance the walking experience by providing pedestrians with amenities. To the extent possible, though, street furniture should be out of the normal travel path and not obstruct pedestrians **(figure 3–7)**. This is especially important for wheelchair users and visually impaired pedestrians.

Sidewalks and walkways may be constructed of materials other than concrete with a smooth debris-free surface. The use of asphalt and limestone screenings can contribute to a park-like atmosphere and alleviate the concerns occasionally expressed by some developers and communities that sidewalks and paths are not aesthetically pleasing. Sidewalks and paths for recreational use need not be elaborate or expensive. Walkways and paths are sometimes constructed away from roadways, such as in parks or scenic areas, which can be quite desirable facilities for walking **(figures 3–8 and 3–9)**.

The setback distance of the sidewalk from the roadway is another important safety and design factor. For example, sidewalks too close to high-speed traffic discourage pedestrian travel due to the high noise level, vehicle spray in wet weather, and the perception of hazard. Consequently, wider setbacks add to the convenience and perceived safety of pedestrian travel and should be used whenever possible **(figure 3–10)**. Setbacks also allow for landscaping, traffic signs, hydrants, lighting, underground utilities, street furniture, and snow storage in northern cities. A setback of 6 feet prevents driveway ramp slopes protruding into the sidewalk, which are a problem for the elderly and people with disabilities.

The growing mobility needs and legal rights of persons with disabilities must be considered in the decision to locate and install sidewalks. For instance, ramped sidewalk curb cuts are required by ADA for new sidewalk construction and are a requirement for federally financed roadway improvements. There should be enough sidewalk cross slope to promote adequate drainage, but the cross slope should not exceed 2 percent to comply with ADA requirements.

Sidewalks are covered in the ITE recommended practices on major streets and residential subdivisions.[3,4]

## Proposed Minimum Sidewalk Widths

The guidelines in **figure 3–4** indicate where sidewalks should be installed. Obviously the width of a sidewalk should depend on where it is installed and the anticipated usage. The following are suggested minimum specifications for the width of the sidewalk to be installed. When determining the appropriate sidewalk width, it is important to consider that the effective sidewalk width for pedestrian movement in most urban environments is reduced by parking meters, planters, mail boxes, light poles, signs, and other street furniture. The minimum widths shown below are exclusive of these effective width-reducing appurtenances.

1. Central business district: Wide enough to meet desired level of service according to methods in the 1994 Highway Capacity Manual. The minimum width should be 8 feet.

FIGURE 3–7(a). *Sidewalks should be clear of poles and other objects.*

FIGURE 3–7(b). *Sidewalks should be designed to be clear of poles and other objects.*

FIGURE 3–8. *Paths can provide a safe and enjoyable walking environment.*

2. Commercial/industrial area outside the central business district: Minimum 5-feet wide with 2-foot planting strip or 7-feet wide with no planting strip. However, wider planting strips of 4 or 5 feet are recommended when possible.

3. Residential area outside the central business district: Arterial and collector streets—Minimum 5-feet wide with minimum 2-foot planting strip.

4. Local streets: Multifamily dwellings and single-family dwellings with densities greater than four dwelling units per acre—Minimum 5-feet wide with minimum 2-foot planting strip. Densities up to four dwelling units per acre. Minimum 4-feet wide with minimum 2-foot planting strip.


FIGURE 3–9. *Multiuse paths for walkers and bicyclists are popular in some areas.*

FIGURE 3–10. *An adequate buffer between a high speed or busy roadway and the adjacent sidewalk is important to the comfort of the pedestrian.*

Where there is adequate space, wider planting strips are desirable. For example, the Florida and Oregon Departments of Transportation recommend 6-foot planting strips. To name a few advantages, wider planting strips offer more separation between sidewalk users and the street, accommodate larger trees, and provide more space for snow storage.

Note that as discussed in chapter 2, new ADA requirements may mandate that sidewalks be installed on both sides of the road. If adopted nationally, ADA requirements should take precedence over the guidelines in **figure 3–4**.

### Recommended Guidelines for Maintenance of Sidewalk

It is the recommended practice of ITE that local and state agencies adopt guidelines for the maintenance of pedestrian facilities. These recommended general sidewalk maintenance requirements should include a regular program of inspection **(figures 3–11, 3–12, and 3–13)**. The specific design elements of sidewalk installation and maintenance should follow ADA guidelines.

## References


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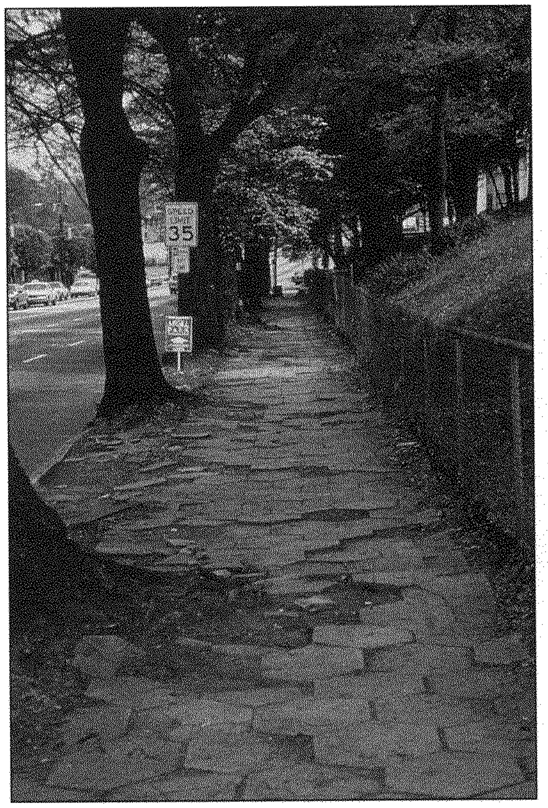


FIGURE 3–11. *Poorly maintained sidewalks may result in trips and falls.*


FIGURE 3–12. *Poor drainage can adversely affect the usefulness of sidewalks.*


FIGURE 3–13. *A program of snow and ice removal from sidewalks should be considered.*

4

# PEDESTRIAN AND MOTORIST SIGNING

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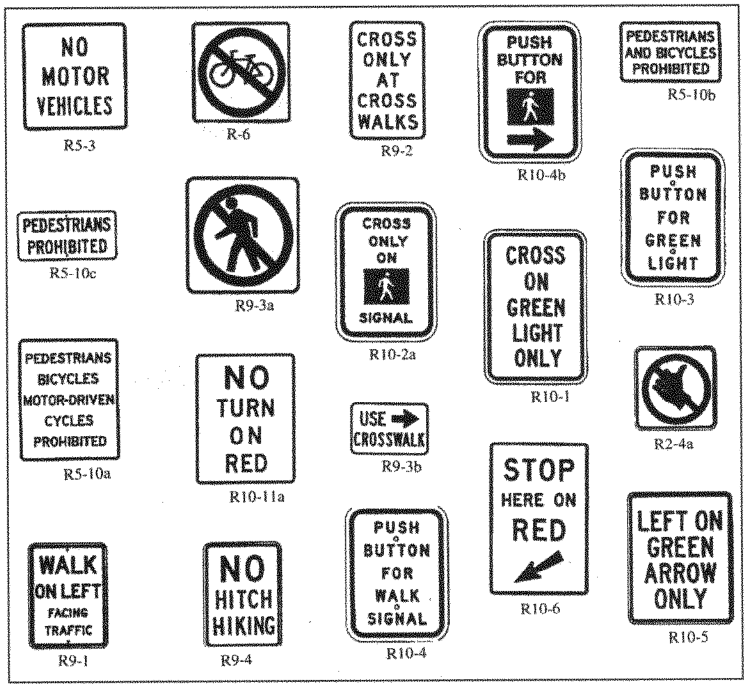


FIGURE 4–1. *Typical regulatory signs relating to pedestrians.*[1]

Signing is governed by the *Manual on Uniform Traffic Control Devices* (MUTCD),[1] which provides specifications on the design and placement of traffic control signs installed within the public right-of-way. Examples of regulatory and warning signs related to pedestrians are given in **figures 4–1 and 4–2**. The MUTCD encourages a conservative use of signs (Sections 2A-1, 2A-6, 2B-1, 2C-1). Signs should only be installed when they fulfill a need based on an engineering study or engineering judgment. In general, signs are often ineffective in modifying driver behavior, and overuse of signs breeds disrespect and diminishes effectiveness.

Unnecessary signs and posts represent a hazard to errant motorists and may cause an obstruction to pedestrians and bicyclists. Furthermore, unnecessary signs are a waste of taxpayer dollars, represent an ongoing maintenance cost, and are a source of visual blight. Sign placement and location criteria may vary between individual state manuals and the MUTCD.

Of the 41 agencies responding to the ITE Committee 5A-5 questionnaire, most reported that they relied solely on the MUTCD or their state sign manual for guidelines on the use of pedestrian-related signs. These agencies were also asked to indicate which type of sign was found the most beneficial to pedestrians. The type of sign noted as being the most helpful was the pedestrian push-button sign (used at pedestrian-actuated signals), while five agencies felt that pavement stencils were beneficial. Four agencies reported that all types of pedestrian-related signs and pavement stencils were helpful. Seven agencies felt that none of the signs or pavement stencils were helpful (or at least had little benefit), and six jurisdictions reported they had not conducted evaluations and did not know if any of the devices were helpful. Some agencies responded that they use these devices in the hope that they will provide some benefit to pedestrians.

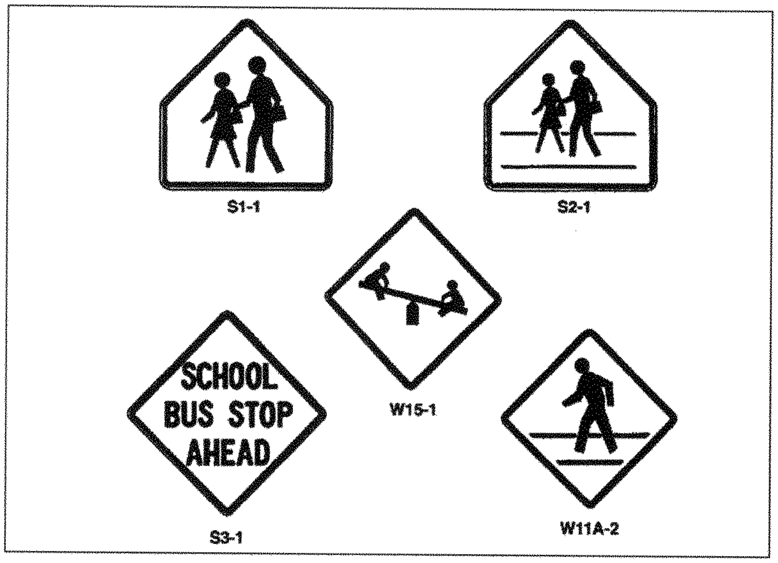


FIGURE 4–2. *Typical warning signs relating to pedestrians.*[1]

## *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 mostly rectangular in shape, usually contain a black legend on the white background, and are reflectorized or illuminated. Many motorist signs, including STOP signs, YIELD signs, turn restrictions and speed limits, have a direct or indirect impact on pedestrians.

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.[1] Considerable controversy has arisen regarding pedestrian safety implications and right-turn-on-red operations, ranging from a study by Zador that indicated a significant increase in pedestrian accidents with right-turn-on-red, to studies by the American Association of State Highway and Transportation Officials and McGee that concluded that right-turn-on-red does not create a pedestrian safety problem.[2,3,4] Of the 41 agencies responding to the ITE 5A-5 Committee Survey, 73 percent reported that they never or rarely prohibited right-turn-on-red to facilitate pedestrians. Three of the responding agencies (7 percent) reported frequent use of right-turn-on-red restrictions for pedestrians.

A study by Zegeer revealed there are more pedestrian conflicts associated with right-turn-on-green (where the pedestrian has a WALK indication and the motorist has a green ball indication) than with right-turn-on-red. When overly restrictive, motorist compliance to NO TURN ON RED signs is low, particularly when the signs are poorly located **(figure 4–3)** and low pedestrian volumes exist.[5] Also, confusing sign messages **(figure 4–4)** should be avoided.

Although other work has indicated that significant safety detriments occur with right-turn-on-red, there are substantial benefits in reduced energy consumption, positive environmental impacts, and reduced operational delays.[6] The use of NO TURN ON RED signs at an intersection should be evaluated on a case-by-case basis. Less restrictive alternatives should be considered in lieu of NO TURN ON RED signs. Also, supplementary signs such as WHEN PEDESTRIANS ARE PRESENT or WHEN CHILDREN ARE PRESENT may be placed below the NO TURN ON RED sign. There are occasions when no-turn-on-red restrictions are beneficial, and specific recommendations relating to pedestrians include the following:

- 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.
- Universal prohibitions at school crossings should not be made, but rather, restrictions should 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, as such, should not be the only criteria for prohibiting turns on red.

There are a number of regulatory signs directed at pedestrians:

- Pedestrians prohibited signs (R5-10c, R9-3a, R5-10a, 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 that may be used at signalized intersection legs with high conflicting turning movements or at midblock locations directing pedestrians to use an adjacent signal or crosswalk. The signs have most applicability in front of schools or other buildings that generate significant pedestrian volumes.
- 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 WALK signal. Pedestrian push-button signs should be used at all pedestrian-actuated signals. It is helpful 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 the push buttons should be accessible to pedestrians with disabilities.

Other signs may be used for pedestrians at traffic signals to define the meaning of the WALK, DON'T WALK, and flashing DON'T WALK signal indications. The decision to use these signs (or alternatively stickers mounted directly on the signal pole) is strictly engineering judgment and is primarily for educational purposes. As such, their use may be more helpful near schools and areas with concentrations of elderly pedestrians—two high-risk areas. This information may also be effectively converted into brochures for distribution and ongoing educational purposes.


FIGURE 4–3. *Regulatory signs may not be easily seen when hidden among a clutter of other motorist signing.*


FIGURE 4–4. *Care should be used to avoid confusing signs.*

# Warning Signs

Warning signs are used to inform unfamiliar motorists and pedestrians of unusual or unexpected conditions **(figure 4–5)**. Warning signs predominantly fall under the permissive category ("may" condition) and should be placed to provide adequate response times. Warning signs are generally diamond-shaped with black letters or drawings on a yellow background, and they are reflectorized or illuminated. Overuse of warning signs breeds disrespect and should be avoided. No accident-based studies have been able to determine the effectiveness of warning signs. However, this is understandable because of the complex nature of events leading into each accident.

FIGURE 4–5. *Pedestrian warning signs are used to inform unfamiliar motorists and pedestrians of unusual or unexpected conditions.*

## Advance Pedestrian Crossing Sign

The warning sign predominantly 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 locations where pedestrians may not be expected to cross. This significantly minimizes their use at most urban intersections since pedestrian crossings 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 it may be used when crosswalk markings do not exist. Where there are multiple crossing locations that 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 mounted with another warning sign (except for a supplemental distance sign or an advisory speed plate) or regulatory sign (except for NO PARKING signs) to avoid information overload and allow for an improved driver response. Care should be taken in sign placement in relation to other signs to avoid sign clutter and allow adequate motorist response. The MUTCD specifies a 30" x 30" sign size. However, it may be helpful to use a larger signs (36" x 36") on higher speed or wider arterial streets.

## Pedestrian Crossing Sign

The pedestrian crossing sign (W11A-2) is similar to the advance pedestrian crossing sign, but it has the crosswalk lines shown on it. This sign is intended to be used at the crosswalk, which is the only warning sign not used in advance of the condition being warned (except for large arrow signs and object markers). 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. When used, it should be preceded by the advance 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).

## Playground Sign

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 darting into the street.

According to the Traffic Control Devices Handbook,[7] CAUTION—CHILDREN AT PLAY or SLOW CHILDREN signs should not be used since they may encourage children to play in the street and may encourage parents to be less vigilant. Such signs also 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 signs on some streets may indicate otherwise. The signs are unenforceable and act as another roadside obstacle to pedestrians and errant motorists. Use of these nonstandard signs may also imply that the involved jurisdiction approves of streets as playgrounds, which may result in the jurisdiction being vulnerable to tort liability.

### School Warning Signs

School warning signs include the advance school crossing signs (S1-1), the school crossing sign (S2-1), SCHOOL BUS STOP AHEAD (S3-1) sign, and others. School-related traffic control devices are discussed in detail in Part VII ("Traffic Controls for School Areas") of the MUTCD. A reduced speed limit sign with flashing lights can be installed ahead of the actual crossing. The lights are set to flash during school hours, alerting drivers that a lower speed limit is in effect when the flashers are operating. Another sign and light combination is SCHOOL SPEED LIMIT XX, where the speed limit is illuminated during school hours.

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 effectiveness and should be based on engineering judgment.

## *Pavement Word and Symbol Markings*

The MUTCD allows for the use of pavement word and symbol markings such as SCHOOL XING or PED XING as motorist warning devices (Section 3B-20). These may be helpful on high volume or high speed 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 an adequate motorist response. Their use should be kept to a minimum to retain effectiveness. Consideration should be given to snow conditions that may obliterate the markings during portions of the year in some regions of the country and the agency's ability to maintain these pavement markings. If used, the word or symbol markings should generally be used in each approach lane (except for the SCHOOL message).

Some agencies have also attempted to communicate with pedestrians using pavement word markings such as LOOK BOTH WAYS or other symbols to encourage pedestrians to look for vehicles and to enter the road cautiously.

All pavement word and symbol markings require periodic maintenance and replacement after resurfacing. If used, it is advisable to maintain an inventory of stencils for periodic checking and refurbishment.

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# 5

# SIGNALIZATION

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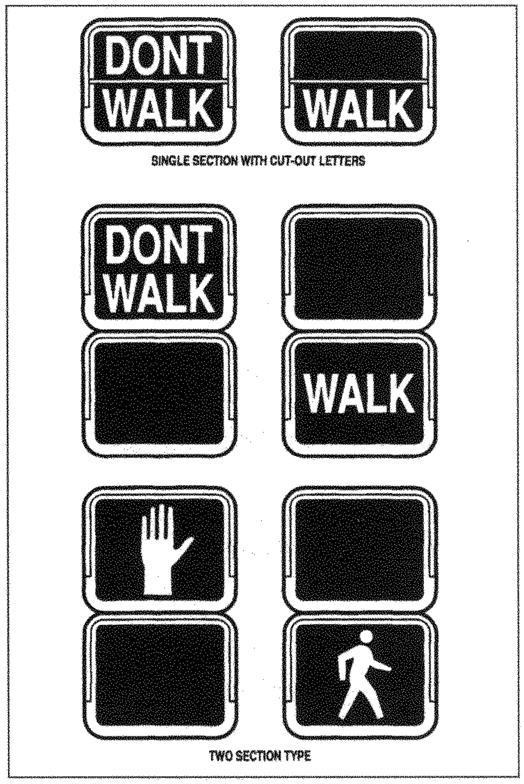


FIGURE 5–1. *Pedestrian signal displays.*[1]

## *Traffic Signals*

Traffic signals are intended to assign the right-of-way to vehicular and pedestrian traffic. When installed appropriately, traffic signals can provide many benefits, including the interruption of heavy volumes of motor vehicles where there are insufficient gaps in motor vehicle traffic for pedestrians to cross safely at intersections or midblock locations. Unwarranted or improperly used traffic signals can cause excessive delay for pedestrians and motor vehicles, signal disobedience, and an increase in certain accident types. Even where warranted, traffic signal installations commonly result in an increase in rear-end and total accidents, with a corresponding reduction in more severe right-angle accidents. The effect of traffic signal installations on pedestrian accidents is not well known, but different locational characteristics of the sites are important factors in the accident experience at signals.[2,3]

While many traffic signals include only the green, yellow, and red signal faces, a variety of signal lens faces may be used, depending on needed signal phasing. Studies have suggested, however, that highly-complex, multiphase signals often result in confusion and hazardous situations for pedestrians. Therefore, in cases where such complex phasing is necessary, pedestrian signals and other pedestrian improvements are strongly recommended.[3]

The Manual on Uniform Traffic Control Devices (MUTCD) provides eleven separate warrants for installing new traffic signals:[1]

- Warrant 1—Minimum vehicular volume
- Warrant 2—Interruption of continuous traffic
- Warrant 3—Minimum pedestrian volume

- Warrant 4—School crossings
- Warrant 5—Progressive movement
- Warrant 6—Accident experience
- Warrant 7—Systems
- Warrant 8—Combination of warrants
- Warrant 9—Four-hour volumes
- Warrant 10—Peak-hour delay
- Warrant 11—Peak-hour volume

Note that warrant numbers 3 and 4 relate directly to pedestrians, and warrant number 6 also makes some reference to pedestrian considerations. Studies have found that only a small percentage of new traffic signals have been installed in the United States based primarily on pedestrian considerations. However, recent revisions in the minimum pedestrian warrant (warrant 3) are expected to result in easier justification of traffic signals based on the needs of pedestrians.[1,3]

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 either (1) 100 or more for each of any four hours, or (2) 190 or more during any one hour. These volume requirements can be reduced by as much as 50 percent when the predominant crossing speed is below 3.5 feet per second (1.1 mph), for example, as would often be the case with older 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.[1,3]

# *Pedestrian Signals*

## Pedestrian Indications

Pedestrian signals include the symbolic man/hand symbol (recommended in the MUTCD) or the WALK/DON'T WALK word message (accepted alternative in the MUTCD)[1] in conjunction with traffic signals at many locations. The steady DON'T WALK or steady hand message indicates when pedestrians should not be in the crosswalk. The flashing DON'T WALK or flashing hand symbol are clearance intervals, that is, pedestrians should not step into the crosswalk, but they may finish crossing if they are already in the crosswalk (i.e., DON'T START). The WALK or walking man symbol indicate that pedestrians may cross the street in the direction of the signal.[3] Pedestrian signal displays are illustrated in **figure 5–1**.

In the past, MUTCD allowed the flashing WALK as an option to the steady WALK indication. Some agencies used the flashing WALK at some locations to indicate to pedestrians that they should watch out for turning vehicles, whereas a steady WALK was used at other locations where no turning vehicles are permitted across the crosswalk (e.g., on the approach of a one-way street). However, since January, 1991, the flashing WALK indication has been taken out of the MUTCD. It is recommended that the flashing WALK message no longer be used and instead be converted to the steady WALK. Further, the symbolic (man and hand) pedestrian messages are suitable alternatives to the WALK and DON'T WALK word messages, and either word or symbolic messages are acceptable.[1,4]

The absence of pedestrian signals at some signalized intersections can create a barrier to pedestrians wishing to cross the street. It may force some pedestrians to take unnecessary risks to cross traffic. This is particularly critical to the two age groups with the most difficulty crossing streets. Children do not possess the experience and judgment to recognize the inherent dangers, and their vision and depth perception have not fully developed to provide accurate information. Older pedestrians may possess limited stamina to cross traffic and declining hearing and vision to recognize and respond to conflicts.

It has been well documented by Federal Highway Administration (FHWA) sponsored research activities that many pedestrians do not understand the meaning of the pedestrian signals and indications, particularly the flashing DON'T WALK.[4] These problems highlight the need for more effectively educating pedestrians—to include distribution of educational materials and signing at schools, such as the on-street R10-2A "CROSS ONLY ON PEDESTRIAN (SYMBOL) SIGNAL" and the R10-4B "PUSH BUTTON FOR (PEDESTRIAN SYMBOL)" signs. An additional pedestrian education sign has also been used as shown in **figure 5–2**,[5] although not yet incorporated into the MUTCD. In addition to educational signs, educational flyers and brochures are recommended in cities or areas where pedestrian violations are a problem.

Besides a lack of understanding, some pedestrians violate the signals because of their impatience or other reasons **(figure 5–3)**. Motorists often put pedestrians at risk when they run red lights or make right and left turns while failing to yield the legal right-of-way to pedestrians. Police enforcement is often the best solution for these problems.

## Warrants for Pedestrian Signal Indications[1]

The MUTCD contains four recommendations for the installation of pedestrian signal indications:[1]

1. when traffic signals are installed based on meeting the minimum pedestrian volume or school crossing warrants;
2. when an exclusive pedestrian interval is provided (i.e., with all conflicting vehicular traffic being stopped);
3. when the vehicle signals are not visible to pedestrians (such as at one-way streets or "T" intersections);
4. at signalized intersections within established school crossing locations.

Pedestrian signal indications are recommended when there are: multiphase signals; complex geometry (more than four legs, wide streets, refuge islands); areas where compliance is high; areas where older adults or young children are present; or pedestrian push-buttons are in use.[1]

Section 4B-28 of the MUTCD on "Provisions for Pedestrians," describes three specific conditions that must be considered:[1]

1) Signal indications must be visible to pedestrians. This can be accomplished for a given pedestrian movement by

   a) provision of pedestrian indications;

   b) a red-yellow-green signal face for an adjacent vehicular movement visible to pedestrians; or

   c) vehicular indications for conflicting movements that can be conveniently viewed by pedestrians, and from which pedestrians can readily and accurately deduce when they have the right-of-way.


FIGURE 5–2. *Example of an educational sign for pedestrian signal display.*

FIGURE 5–3. *Pedestrian violations can be quite high at some traffic signals.*

2) There must be an opportunity to cross without undue delay. Pedestrian actuation shall be installed at traffic control signals where the signal operation does not otherwise provide this opportunity.

3) Pedestrians should be provided with sufficient time to cross the roadway. This may be accomplished by adjusting the signal operation and timing to automatically provide this assurance via pedestrian actuation.

## Visibility of Devices

Most state statutes require pedestrians to obey the vehicular traffic signals when pedestrian signals are not present. Frequently, the vehicular signal heads are not visible because of the geometry and the signal equipment used. Pedestrian lack of compliance with traffic signal indications can be traced partly to a lack of visibility.

It is recommended that pedestrian signal indications be provided when the pedestrian cannot see the vehicular signals to determine the right-of-way **(figure 5–4)**. This would include situations when diagonal spans, optically programmed signal heads, or tunnel visors are used. In addition, many sight-impaired or elderly pedestrians cannot see the pedestrian signal heads across wide streets (e.g., 75 feet or wider). Thus, pedestrian signals may be necessary in the medians of such wide streets. Other conditions are described in the section on design considerations.


FIGURE 5–4. *Pedestrian signal indications should be provided when the pedestrian cannot see the vehicle traffic signal.*

## Pedestrian Signal Timing

The MUTCD recommends at least a 4- to 7-second walk interval **(figure 5–5)**. However, at some intersections, this may present a dilemma to pedestrians who see a DON'T WALK display before they are more than one or two lanes across the street. In actual practice the pedestrian almost always continues forward rather than return to his or her starting point. It would be very desirable to provide a longer WALK interval at some locations if possible.

The fifteenth percentile walking speed should be used for setting the design walk speed where there is a high proportion of elderly pedestrians. In the absence of a specific study this would be between 3 and 4 feet per second, depending on the presence of slower pedestrians.

## Pedestrian Push-Button

At locations where pedestrian activity is infrequent and pedestrian signal phasing is not warranted on a full-time basis, the use of pedestrian-actuated signals (i.e., push-buttons) may be justified **(figure 5–6)**. Pedestrian push-buttons are appropriate where occasional pedestrian movements occur and adequate opportunities do not exist for pedestrians to cross.[1] Where no pedestrian signals are present, actuation of the push-buttons may be used to extend the green phase to allow pedestrians sufficient crossing time. Push-buttons may also be used with pedestrian signals to provide a quicker WALK interval with extended WALK time for safer pedestrian crossing.[3]

Pedestrian push-buttons should be mounted 3 ½ to 4 feet above the sidewalk and placed in a conspicuous, convenient location,[1] preferably next to curb ramps. Such placement will reduce the need for signing to explain which button needs to be pushed to cross the street. 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 SECOND AVENUE). Push-button devices may also be needed on medians and refuge islands where signal timing does not allow pedestrians to cross the complete street width during one signal phase.[1,3]

Pedestrian safety can be enhanced by pedestrian push-buttons only if they are correctly installed and maintained. Many agencies resist installing pedestrian push-buttons because they are either infrequently used or often used improperly by pranksters wishing to disrupt traffic flow. Problems that have been identified contributing to pedestrian push-button nonuse include the following.[6]

- Many push-button devices are hidden from pedestrian view or out of reach (such as on telephone poles 10 to 20 feet from the crosswalk).
- Signing is often nonexistent or confusing and does not indicate which push-button corresponds to each crosswalk.
- At many locations, timing requires that pedestrians wait one minute or more after the buttons are pushed before the WALK interval is displayed. Often, pedestrians push the button and cross the street before the WALK interval begins. Then traffic is stopped when no pedestrians are present.
- Some push-buttons are inoperative or operated only during off-peak hours (and pedestrians were not instructed that the push-buttons only worked during certain periods of the day).

The following are recommendations to improve the effectiveness of pedestrian push-button devices.[6]

- Repair and maintain the push-buttons as necessary to make them more responsive to pedestrians (for example, time them to provide a WALK interval to pedestrians within thirty seconds after the buttons are pushed).
- Provide signs with push-buttons explaining the specific streets that should can be crossed when activated.

FIGURE 5–5. *The MUTCD recommends at least a 4-to 7-second walk interval, but a longer interval is desirable.*


FIGURE 5–6. *Pedestrian push-buttons are often provided at locations with intermittent pedestrian volumes to call for the WALK message and/or extend the crossing interval.*

- Provide illuminated push-buttons similar to those used with elevators to indicate when the actuation device is operational. These types of push-buttons reassure pedestrians that their signal call has been received by the controller.
- Provide a sign explaining the operational times at those pedestrian actuation devices that are designed to only operate at specific times of the day.

## Left- and Right-Turn Phasing

Thirty-seven percent of all pedestrian accidents at signalized intersections involve left- or right-turning vehicles. One FHWA study found that the left turn vehicle-pedestrian accident rate was twice that involving right-turning vehicles, because of the increased obstruction of the driver's vision.[7] Potential solutions to pedestrian collisions involving right- or left-turn vehicles in some situations include the following:

- design compact intersections with small turning radii that force slower speeds,
- prohibit right-turn-on-red,
- use a separate left-turn phase (in conjunction with a WALK/DON'T WALK signal).

The prohibition of a turn movement may shift the problem to another location and have a very negative effect on capacity and delay. However, there are situations with heavy pedestrian volumes where left-turn prohibition may be justified.

## Partial Crossings

Walking distances at large intersections are often excessive, even for very mobile pedestrians. These walking distances require long WALK and flashing DON'T WALK clearance intervals. At heavily loaded intersections, especially with high volume left turns and four or more phases, the pedestrian timing requires a high percentage of the cycle length. This can lead to critical signal timing, resulting in intersection vehicle capacity deficiencies. Ideally, it is highly desirable for pedestrian convenience and compliance to cross an approach in one signal cycle. Where partial crossings exist, the following guidelines are recommended:

1. Use raised channelizing islands (particularly for right-turn lanes) to reduce the curb-to-curb walking distance and signal cycle lengths.
2. Construct a median refuge island to reduce the walking distance. This may require slow pedestrians to cross the approach during two signal cycles. Pedestrian push-buttons would be installed on the median. Refuge islands are very beneficial to the elderly and to the young; they can reduce pedestrian exposure to traffic. Ideally, median widths should be 10 feet or wider to provide enough space for pedestrians to stand. As mentioned in chapter 1, median refuge islands should be at least 6 feet wide and in no case less than 4 feet wide.
3. Provide the necessary pedestrian crossing time and accept a reduced capacity for motor vehicle traffic.
4. As a last resort, prohibit pedestrian movements and direct them to a safer, nearby crossing location if the walking distances and signal timing are still unacceptable.

It should be remembered, however, that the prohibition of a pedestrian movement can greatly increase the walking distance and time to cross the intersection. If the pedestrian movement across one approach of a four-legged intersection is prohibited, then a pedestrian would have to cross the other three legs of the intersection to reach the intended corner. This could increase the walking distance as much as 300 percent and the walking time by six to nine minutes, and this may not be in strict compliance under ADA, which requires the provision of continuous routes for pedestrians. A balance is needed between the needs of motor vehicles and pedestrians.

## Pedestrian Signals in a Coordinated Signal System

Coordinated signal systems along a route involve timing the signals in sequence, so a motor vehicle may proceed at a constant speed and get a green light at each signal along the system. The use of pedestrian features in a coordinated signal system can significantly influence the effectiveness of the signal system. It is not unusual to have signalized intersections, where the pedestrian timing exceeds those for its companion vehicular movements because of walk times.

The length of the WALK and DON'T WALK intervals can pose major limitations on the cycle length of the coordinated signal system. When the timing demands of the WALK and flashing DON'T WALK intervals are greater than the vehicle timing demand in concurrent pedestrian signal phasing, the resulting cycle lengths may be ninety seconds or greater. The limitations of system cycle lengths can significantly reduce the operation and flexibility of the system to respond to various traffic demands. One alternate timing scheme is to design the system timings without the pedestrian timing. Then, when the pedestrian push-buttons are activated, the local intersection is disconnected from the system for one cycle to service the pedestrian movement. This practice will degrade the effectiveness of the system if the pedestrian timing is activated frequently, since the system will consistently be transitioning into coordination.

It is recommended to use one of the following guidelines for handling motor vehicles and pedestrians in coordinated signal systems.

1. Use actuated pedestrian signals when pedestrian volumes are light and when WALK times limit the vehicle movement timings. This will minimize the effect of the pedestrian signal timing on the operation of the system. The pedestrian timing should be compatible with the system coordination timing or the system could be out of step as much as three cycles for each actuation.

2. Use fixed-time pedestrian signals with concurrent pedestrian phasing and pretimed signals. Since the vehicular movements will be displayed every cycle, there is no benefit to actuating the pedestrian movements as they will be displayed concurrently with vehicular movements every cycle.

## Pedestrian Signal Phasing

Signal phasing operations exist that can reduce timing demand and improve signal system performance. The four alternatives below may be appropriate under certain situations, to handle the operation of a traffic signal for pedestrians and vehicles.[6,7]

1. Standard (or concurrent) timing involves a WALK indication that is displayed concurrently with the green light for motorists, where motor vehicles may turn left or right after yielding to pedestrians.

2. The early release of pedestrian signal operation displays red for the vehicular movements (particularly the right turn) while the WALK signals are displayed. The vehicular signals then get a "green" indication.

3. The late release of pedestrian signal operation displays the vehicular green indications before display of the WALK indications.

4. Exclusive pedestrian phasing displays WALK signals without green indications for any vehicle movements.

5. Scramble pedestrian phasing incorporates a separate pedestrian phase where pedestrians are allowed to walk in any direction, including diagonally across the intersection.

One method to evaluate these alternative phasing operations includes the conversion of all pedestrian and vehicular delay to "person delay," by using an assumed auto occupancy rate. Often, concurrent pedestrian phasing produces minimum total delay. However, a study of accident data revealed that there was no significant difference in accident rates for signals with no pedestrian signals and those with concurrent pedestrian signal phasing.[6] Thus, the installation of standard-timed pedestrian signals should not necessarily be expected to improve pedestrian safety at traffic signalized intersections. At intersections with less than 1,200 pedestrians per day, there is no significant difference in pedestrian accidents between exclusive pedestrian signal phasing, concurrent pedestrian phasing, and no pedestrian signals.[6]

The early release of pedestrian signal operation always produces higher total delay. The late release of pedestrian signal operation produces higher total delay for low vehicular volumes (i.e., four vehicles or less per approach per cycle). Total delay is lowered in higher vehicular volumes (six vehicles per approach per cycle) and heavy pedestrian volumes (i.e., twenty pedestrians per approach per cycle) for late release pedestrian signal operations. Late release pedestrian signal operations can produce higher right-turn capacities.[6,7]

Exclusive pedestrian phasing is an alternative that works well to reduce turning vehicle, turn-merge multiple threat, and trapped pedestrian accidents. A turn-merge accident includes a vehicle that is turning and merging into a new traffic stream. A multiple threat accident involves one or more vehicles stopped in traffic and the pedestrian is hit by a vehicle where the driver's vision is obstructed by a stopped vehicle. A trapped vehicle accident involves a pedestrian hit at a traffic signal after he or she is trapped in the street by a traffic light change. One major study found that the use of exclusive pedestrian signals was associated with approximately a fifty percent reduction in pedestrian accidents as compared to signalized intersections with concurrent signal timing or with no pedestrian signals.[6]

It should be mentioned, however, that scramble pedestrian phasing operates well only in very special situations. This operation works best in a situation of high pedestrian volume (i.e., 1,200 or more pedestrians per day), long right turn queuing resulting from conflicts, low through volumes, and narrow streets. Streets with widths greater than sixty feet increase the length of the scramble phase such that it becomes marginally effective. If driver violations are high, then scramble phasing can be dangerous. Good compliance produces safer results for scramble phasing over conventional phasing; however, pedestrian and motorist delay is always higher than the signal timing options and is rarely practical to install. Care should be exercised when using scramble pedestrian phasing. Since the diagonal pedestrian movement across the intersection is permitted, the walking distance and resultant pedestrian clearance times are much longer than normal. In addition, the sight distance of the pedestrian indications is obstructed by the visors for the diagonal pedestrian movements. A recommended methodology to assist selecting pedestrian signal phasing is given in **figure 5–7** based on research conducted for FHWA by Abrams and Smith.[7]

The use of continuous through lanes at "T" intersections is not recommended. Their use requires the prohibition of pedestrian movements that would cross the continuous through lane. It is not reasonable to assume that pedestrians will comply with that prohibition. The use of an actuated pedestrian phase for what is normally the prohibited movement at a "T" intersection has been found to be an acceptable solution in some cases. The vehicular through movement that would normally have been a simple continuous green becomes a three-section signal that is continuously green, except when the pedestrian movement is actuated.

## Considerations for Persons with Disabilities

Senior citizens and people with disabilities often have limited stamina and mobility. The placement of push-buttons in inaccessible locations discourages their use and creates noncompliance. If it is not practical or possible to locate the pedestrian push-button next to the sidewalk, then an apron should be installed around the pole or cabinet supporting the pedestrian push-buttons.

The presence of blind and visually impaired pedestrians crossing at intersections presents unique design problems for the engineer. The conventional method of crossing a street is mainly predicated on the pedestrian's sense of sight. Blind and visually impaired pedestrians have to identify the direction cars are traveling and the approach they are on primarily by sound and touch. Blind and visually impaired people are taught to determine the direction cars are traveling, either parallel or perpendicular to their intended path, by hearing. They determine by touch with a cane where the edge of the street is located and to sense slight slopes in roadway crowns, sidewalks, or ramps. They can also detect, by subtle clues, where they are. For example, blind and visually impaired pedestrians are taught to feel for debris in the gutter as an indicator for the edge of the road.

The use of audible pedestrian signals to assist the visually impaired is a source of much discussion. Audible pedestrian signals can aid the blind and visually impaired in crossing streets under certain circumstances, such as a complex intersection near a school or community adjustment center for the visually impaired used frequently by the students. However, the presence of audible pedestrian signals may give some visually impaired pedestrians a false sense of security, thus causing them to tune out traffic clues that may override the audible signal that indicates it is safe to walk. In addition, the audible signal can hamper their hearing of traffic noise—the primary tool for vehicle detection available to the blind and visually impaired. The use of audible pedestrian signals should be left to the judgment of the local traffic engineer, based on specific site conditions and the characteristics of the pedestrian population that routinely uses the intersection.

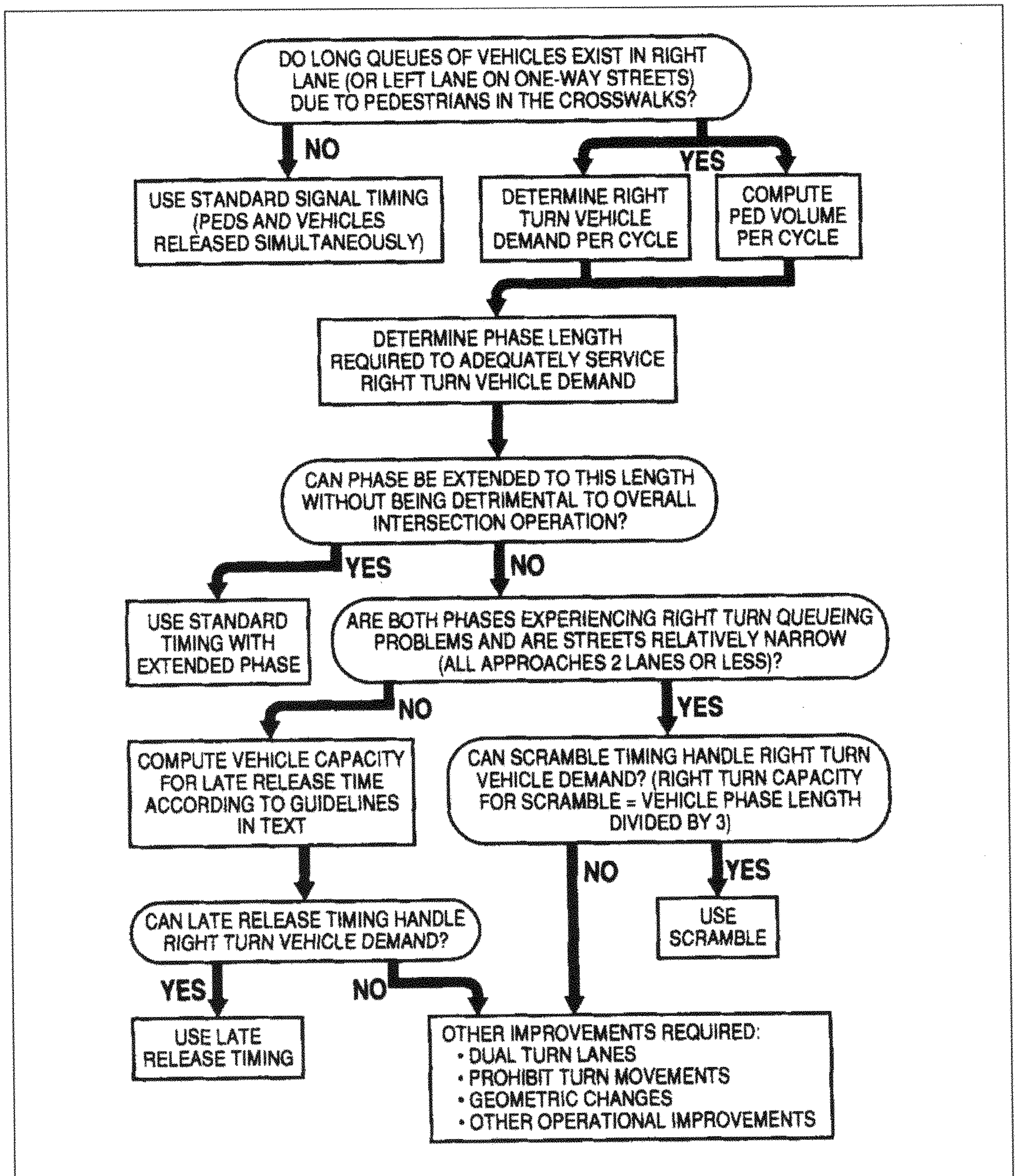


FIGURE 5–7. *Flow chart for selecting pedestrian signal phasing. Reprinted with permission. Source: C. M. Abrams and S. A. Smith. Selection of Pedestrian Signal Phasing. In* Transportation Research Record 629, *Transportation Research Board, National Research Council, Washington, D.C., 1977.*

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6

# CROSSWALKS AND STOP LINES

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A crosswalk is generally defined as the portion of roadway designated for pedestrians to use in crossing the street. Crosswalks may be marked or unmarked. At intersections, a sidewalk or a pedestrian walkway extension across the street defines a legal crosswalk. Generally, there is no legal difference between a marked or unmarked intersection crosswalk; however, at times markings can be used to designate a wider crosswalk or to designate a mid-block crosswalk.

Crosswalks may be marked using different designs as shown in **figure 6–1**.[1] The standard crosswalk consists of two parallel white lines; however, diagonal or longitudinal lines may be added for increased visibility.

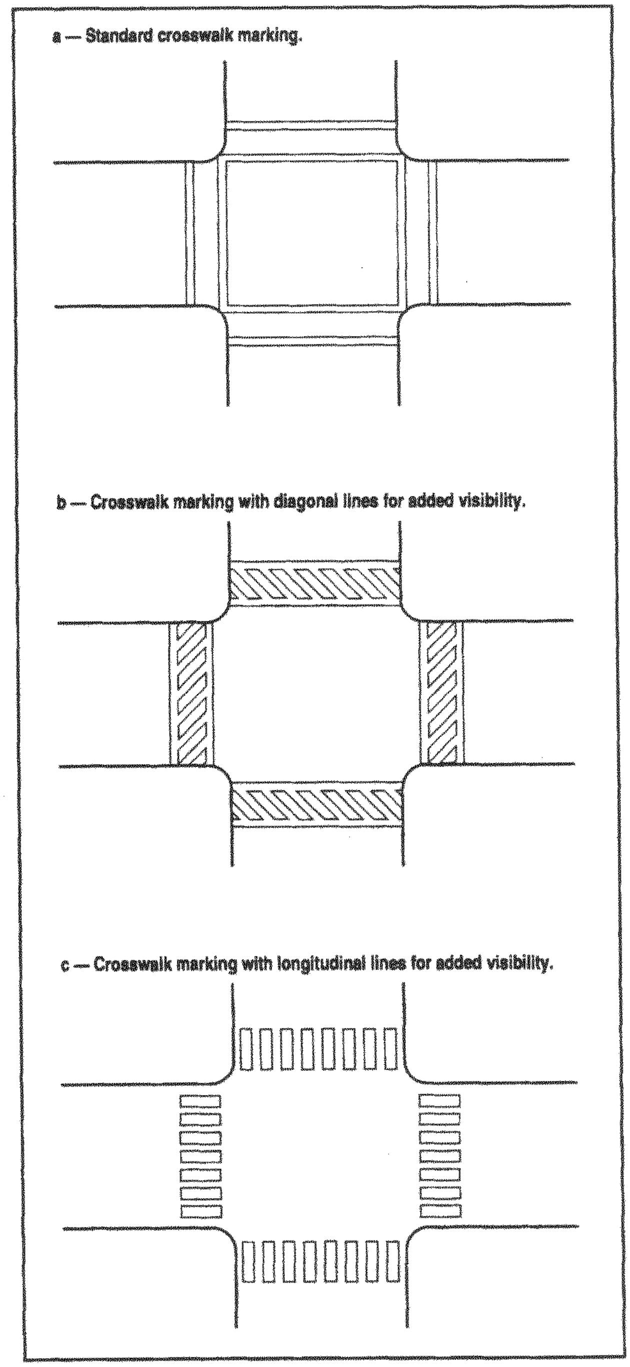


FIGURE 6–1. *Typical crosswalk markings.*[1]

In the1950s and 1960s, crosswalk markings were thought of as a public service under the concept that marked crosswalks were generally safer than unmarked crosswalks, and the more the better. Studies conducted in the early 1970s in San Diego and elsewhere began to change that way of thinking.[2,3] While these studies indicated that marked crosswalks were successful in encouraging more pedestrians to cross within the markings, improved safety could not be shown even when correcting for higher pedestrian volumes. In fact, marked crosswalks were associated with an even higher pedestrian accident experience than similar unmarked crosswalks. An examination of the possible contributing factors for these results led to the conclusion 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 lines cannot stop an inattentive or impaired driver. While the study did not conclude that marked crosswalks were hazardous, it did indicate that inappropriate use and overuse of crosswalk markings was of little benefit and therefore a waste of taxpayer dollars.

A more recent study had different results indicating marked crosswalks were as safe or safer than unmarked crosswalks for all conditions studied. The case studies examined indicated that installation of crosswalk markings had little effect on driver speeds but were successful in attracting pedestrians to cross within the markings, minimizing their exposure times in the street.[4] A current study for the Federal Highway Administration (FHWA) is re-examining the controversy of the safety of marked vs. unmarked crosswalks. This study is attempting to determine conditions where it is safer to provide marked crosswalks and conditions that justify no crosswalk markings.

Forty-one jurisdictions in the United States and Canada responded to a survey on crosswalk use conducted by ITE Committee 5A-5. Sixty-one percent of these agencies reported that the *Manual on Uniform Traffic Control Devices* (MUTCD) is the only guideline used for the placement, design, and use of marked crosswalks, while 38 percent use other guidelines to supplement the MUTCD. Most agencies reported a conservative use of marked crosswalks. Fifty-eight percent stated they did not use a high-visibility crosswalk design (longitudinal or diagonal markings). Of those agencies who did not use a high visibility design, most kept this use to a very small percentage of their total marked crosswalks (less than 5 to 10 percent). Factors considered to warrant the use of high-visibility crosswalk markings included one or more of the following: high vehicle speeds, high pedestrian volumes, school crossings, midblock crosswalks, unexpected crossing locations, and engineering judgment. One agency reported that the continental crosswalk marking is its standard design. While these results are not intended to represent a cross-section of crosswalk use in North America, it does provide some insight into the state of the practice.

The MUTCD guidelines on crosswalk design and placement are contained in Section 3B-18. The MUTCD has the following provisions, stating that crosswalks:[1]

### SHALL

- Have six-inch minimum width markings consisting of solid white lines.

### SHOULD

- Have six-foot minimum crosswalk width.
- Be used where substantial pedestrian and 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 if installed midblock 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 markings are added.
- Use unique markings for diagonal crossings at signals when an appropriate exclusive pedestrian phase is used.

## Recommended Practices for Crosswalk Markings

The most essential tool for crosswalk placement is engineering judgment. No set of guidelines can cover every condition or guarantee improved safety. However, overuse should be avoided to maximize effectiveness for those crosswalks that are marked. Agencies should also strive for uniformity to give motorists and pedestrians a consistent, predictable traffic environment. Another important consideration is economics and the ability to properly maintain marked crosswalks within the jurisdiction.

Marked crosswalks are generally recommended under the following conditions:

- signalized intersections with pedestrian signal indications or substantial pedestrian crossings;
- where a marked crosswalk can concentrate or channelize multiple pedestrian crossings to a single location;
- where there is a need to delineate the optimal crossing location when it is unclear because of confusing geometrics or traffic operations;
- at approved school crossings or for crossings on recommended safe school routes;
- at other locations with significant pedestrian crossings and pedestrian and vehicle conflicts.

Smith and Knoblauch developed criteria relating pedestrian and vehicle volumes for determining when crosswalk markings may be beneficial **(figure 6–2)**.[5] Their chart also takes into account street widths and other factors (such as concentrations of children or elderly and disabled pedestrians). Satisfaction of these criteria does not mean that crosswalk markings are required, but it does indicate their benefits may outweigh possible disadvantages and may be helpful.

Crosswalk installation should also consider the following factors:

- Adequate sight distance for the motorist and pedestrian should exist. This includes examination of on-street parking; street furniture, such as mailboxes, utility poles, and newspaper stands); and landscaping.
- Crosswalks should not be located immediately downstream from bus stops.
- An examination of streetlighting should be conducted. It is advantageous to locate a marked crosswalk at a streetlight, particularly if nighttime crossings are common.
- When possible, it is best to mark crosswalks at 90 degrees to vehicle traffic to designate the shortest path for pedestrians (minimizing exposure) and to avoid having the pedestrian's back turned to oncoming traffic.

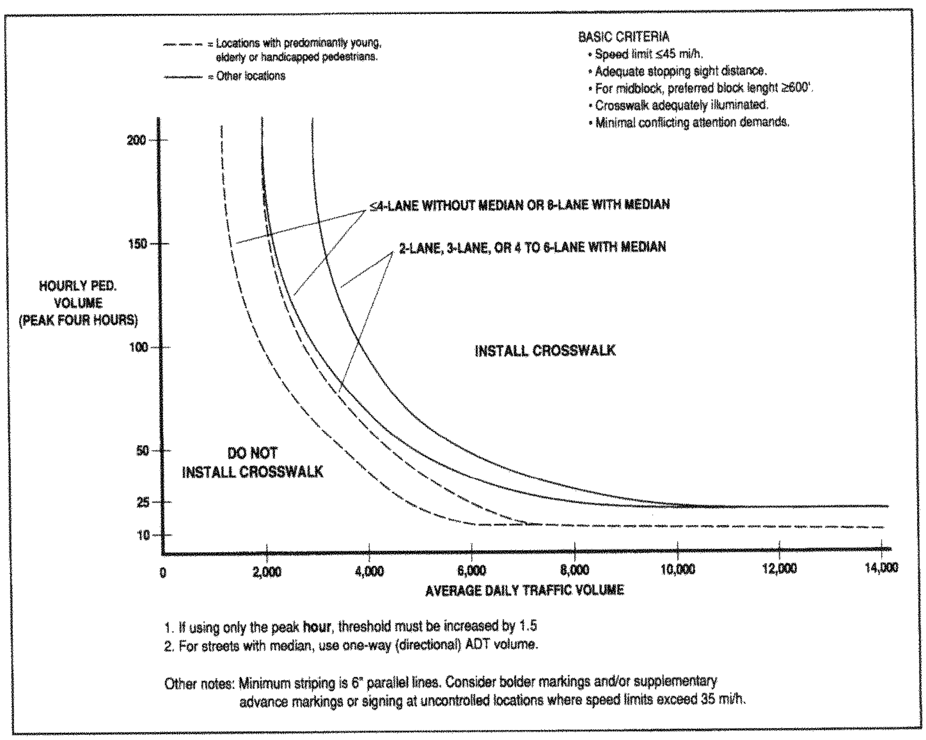


FIGURE 6–2. *Guidelines for the installation of marked crosswalks at uncontrolled crossings. Reprinted with permission. Source: Steven A. Smith and Richard L. Knoblauch. Guidelines for the Installation of Crosswalk Markings. In* Transportation Research Record 1141, *Transportation Research Board, National Research Council, Washington, D.C., 1987.*

Midblock crosswalks and those marked at intersections immediately downstream from a traffic signal should be discouraged. Motorists will least expect pedestrians to cross at these locations. In addition, it is reasonable to expect pedestrians to walk a block (300 to 600 feet) out of their way to a better crossing location. Where it is considered desirable to install midblock crosswalks, pedestrian warning signs should be used as well.

If the primary intent is to warn motorists of pedestrian crossing activity, it is best to do so by use of the advance pedestrian crossing sign (W11-2) or by supplementing the marked crosswalk with this sign. This is especially important in northern climates where snow obscures the pavement markings or in jurisdictions where pavement marking maintenance is low. If total reliance were placed on pavement markings, legal liability could result if the markings were worn or covered with snow. Also, markings are difficult to see at night during rain. Fences, barriers, signs, or sidewalk ramps may be used to channelize pedestrians to the crossing.

Marked crosswalks should be avoided on high speed streets (with limits above 45 miles per hour) where no traffic signal exists. In some instances, it may be best to avoid the crosswalk altogether at uncontrolled locations and to find other means for crossing the street. Use of traffic signals, raised medians, raised crosswalks **(figure 6–3)**, speed humps, and bulbouts are measures that may help pedestrians cross streets with or without crosswalks. On multilane divided roads, having crosswalks that are angled to the right through the median can increase the likelihood of pedestrians seeing oncoming vehicles before crossing the second half of the street **(figure 6–4)**.

FIGURE 6–3. *Raised crosswalks provide a traffic-calmed environment and elevate pedestrians to make them more visible to motorists.*

## Crosswalk Design

There is no evidence to prove that more crosswalk markings will provide safer conditions, and there is no requirement to install "high-visibility" crosswalks. There are offsetting concerns of an increased "false sense of security" to pedestrians on one hand with improved conspicuity to motorists on the other. These extra markings seem to be of questionable value when compared to their installation and maintenance costs.

In a recent FHWA study, a laboratory experiment was conducted to determine the optimal crosswalk pattern. Based on laboratory results and cost considerations, a ladder design using a 12-inch stripe with a 24-inch space was recommended.[4] No conclusive accident studies are available to compare the value of each design, and some agencies have opted to not install high-visibility markings.

Because of the high "move-in" costs associated with crosswalk installation and operational concerns with narrow crosswalks, it is beneficial to install wider crosswalks and more crosswalk marking material than the minimum MUTCD requirements **(figures 6–5 and 6–6)**.[1] Therefore, a 10-foot crosswalk is the recommended standard width, 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 10 inches to 12 inches in width are recommended with wider lines (18 to 24 inches) used when greater emphasis is considered helpful. At intersections it is desirable that the line on the intersection side be offset at least two feet from the edge of the roadway.

The placement of crosswalk markings should take the wheelchair ramp design into consideration. **Figure 6–7** shows recommended crosswalk placement for various wheelchair ramp designs from the 1991 Americans with Disabilities Act (ADA).[6] Marked crosswalks should be placed such that wheelchair pedestrians can access the ramps without leaving the crosswalk.

When a diagonal curb ramp exists, the bottom of the curb ramp should have 48-inch minimum clear space as shown in **figure 6–7 (c) and (d)**. This figure should be used with care, and the crosswalk should not be marked so that pedestrians are directed to walk in the parallel traffic lane.

High-visibility crosswalks are suggested for those locations where greater motorist information is considered beneficial and where pedestrians may not be expected to cross (i.e. midblock) or where there are substantially higher pedestrian crossing volumes. These crosswalks are generally not suggested where other traffic control devices exist (such as signals or STOP signs) or at all marked locations since the extra emphasis will be diminished at those locations where it is needed. When used, the 12-inch line with the 24-inch gap will provide the most cost-effective pattern. It may be helpful to consider vehicle tire paths when selecting the spacing of markings for ladder or continental crosswalk designs to reduce maintenance needs. Consideration should also be given to the slipperiness of the marking surface where wet weather or snow conditions exist. If this problem occurs, alternate marking patterns or crosswalk materials should be used.

Crosswalks marked with raised buttons or reflectors are generally not recommended. Any rumble effect given to motorists is provided too late for use as advance warning, and the pedestrians who walk along the lines may trip on the raised pavement markers. Raised pavement markers are also detrimental to wheelchair users and bicyclists. In northern areas, snow plows may displace the markers. Such markers may be used, however, upstream of the crosswalk in combination with pedestrian warning signs to enhance motorist awareness.

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 makes painted crosswalks less desirable than longer life plastic materials and, ultimately, more expensive to maintain. Plastic materials are also generally more difficult to remove, requiring special equipment. Once installed, the crosswalks should be monitored for continued applicability and usefulness. When no longer useful, crosswalk removal may be coordinated with street resurfacing programs.

FIGURE 6–4. *Angled or staggered crosswalks through a median can encourage pedestrians to cross one half of the street at a time.*

FIGURE 6–5. *Standard marked crosswalks of two parallel lines are commonly used but are not as visible as ladder or other "high visibility."*

FIGURE 6–6. *Continental crosswalk markings are used by some agencies instead of parallel lines.*

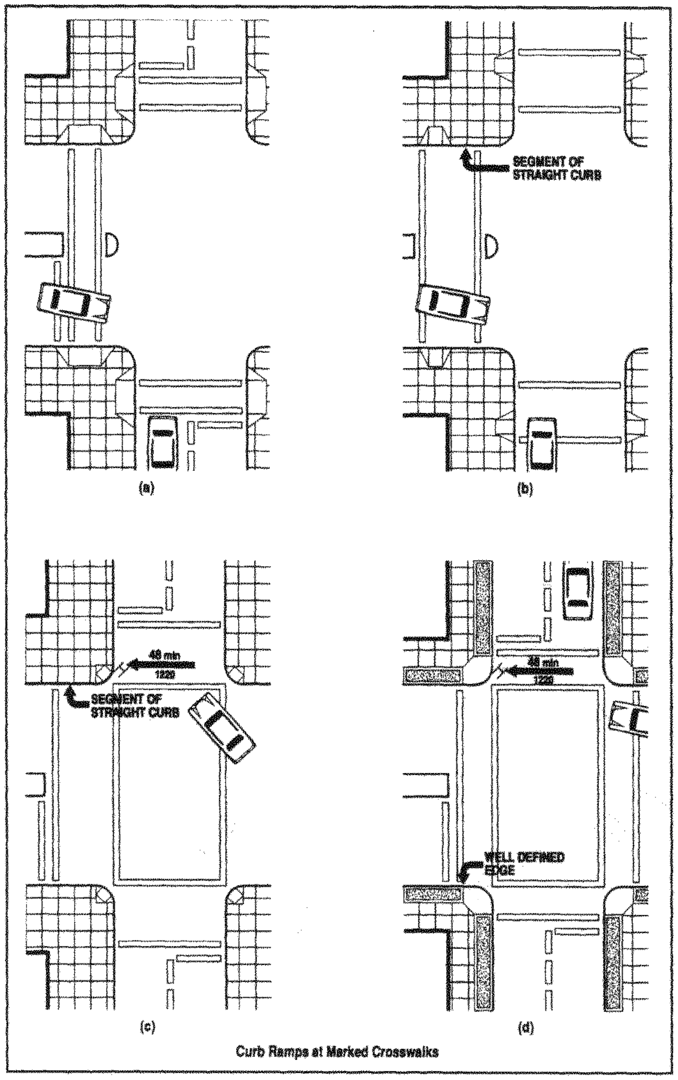


FIGURE 6–7. *Guidelines for crossing placement at intersections.*[6]

FIGURE 6–8. *Angled or offset stop lines may help improve driver and pedestrian sight distance on some multi-lane approaches.*

## *Recommended Practices for Stop Lines*

Stop lines are solid white lines, normally 12 inches to 24 inches wide extending across all approach lanes. They are used to indicate the optimal stopping point to motorists. Stop lines may be helpful in preventing motorists from encroaching into crosswalks. When used, they should be installed four feet in advance of and parallel to the nearest crosswalk line. Some jurisdictions have installed stop lines further in advance of midblock crosswalks (i.e., 20-foot setback) in an attempt to improve visibility between pedestrians and moving vehicles approaching the crosswalk. This can reduce the likelihood of multiple threat crashes; that is, crashes where one vehicle has stopped to let a pedestrian cross in a crosswalk and the pedestrian is struck by a trailing vehicle in the adjacent lane.

Other jurisdictions have installed stop lines perpendicular to the street at skewed intersections where the stop line is not parallel to the crosswalk. This layout helps improve visibility of pedestrians, and improves operations for right-turn-on-red vehicles and for vehicles turning left from the cross-street. Generally, parallel lines are all that is needed at an intersection, especially if all intersections are treated uniformly to increase driver awareness. Angled or offset stop lines may be considered on multilane approaches at any signalized intersection to help improve sight distance in the right lane relative to pedestrians **(figure 6–8)**.

Stop lines should be used only where it is important to indicate the point where a vehicle must stop in compliance with a traffic signal, STOP sign or other specific requirement to stop. In general, stop lines are not necessary at most marked crosswalks. When a need exists, the use of a wider crosswalk or wider crosswalk line can effectively be used in lieu of a stop line.

Stop lines may be beneficial at signalized intersections and occasionally at stop-controlled intersections with unmarked crosswalks to designate the optimal stopping point, encouraging motorists to yield to pedestrians.

Stop lines are occasionally placed to designate an optimal stopping location beyond the unmarked crosswalk due to visibility obstructions at an intersection. Care must be taken at these locations to determine if the disadvantages to pedestrians (i.e. possibly discouraging motorists to yield to pedestrians before stopping at the intersection) is offset by the need to indicate a location where visibility of cross-street traffic is optimized for the motorist.

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# 7

# PEDESTRIAN REFUGE ISLANDS

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FIGURE 7–1. *Refuge islands provide a safety area for pedestrians who cannot cross the entire street on one cycle.*

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 are commonly found along wide, multi-lane streets where adequate pedestrian crossing time could not be provided without adversely affecting the traffic flow. These islands provide a resting area for pedestrians, particularly those who are wheelchair-bound, elderly, or otherwise unable to completely cross an intersection within the provided signal time **(figure 7–1)**.

When evaluating whether a refuge island is needed, both crossing time and safety must be considered. For example, in suburban areas with long distances between intersections and traffic signals, a large proportion of pedestrian crossings occur at unsignalized intersections and at midblock locations. However, with a median, a pedestrian would only have to look in one direction to cross to the median, and in the opposite direction to cross from the median to the far side of the street. Pedestrians crossing an undivided, multilane street may experience delays 10 times longer than the delay incurred crossing a street with a median as shown by the pedestrian crossing delay curves provided in NCHRP Report 294A.[1]

The effect of refuge islands and medians on pedestrian safety has been studied in the United States and abroad in recent years. A 1993 study for the Federal Highway Administration has found that streets with raised medians, in both CBD and suburban areas have lower pedestrian crash rates compared to streets with a painted two-way left-turn lane or undivided streets **(figure 7–2)**.[2] Guidelines on median use in suburban and developing rural areas have been developed in a 1987 study.[1]

Refuge islands can be beneficial under certain conditions and inconsequential or even harmful under others. The typical conditions where refuge islands are most beneficial include:

- Wide, two-way streets (four lanes or more) with high traffic volume, high travel speed, and large pedestrian volume **(figure 7–3)**;
- Wide streets where the elderly, people with disabilities, and child pedestrians cross regularly;

- Streets with insufficient signal timing for pedestrians to cross the entire street;
- 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 i.e., low side street volumes in combination with high main street volumes may warrant short green times for the side street, which in turn does not allow enough time for the pedestrian to cross the entire street.

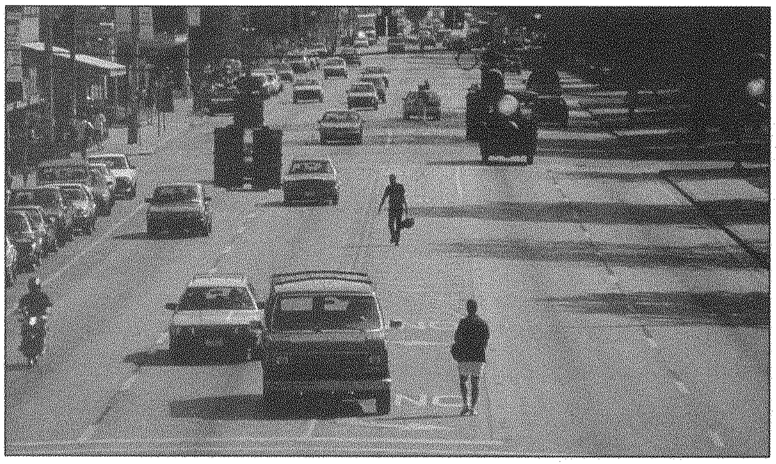

*FIGURE 7–2. Streets with a raised median will usually have lower pedestrian crash rates compared to arterials with two-way left-turn lanes and undivided streets.*

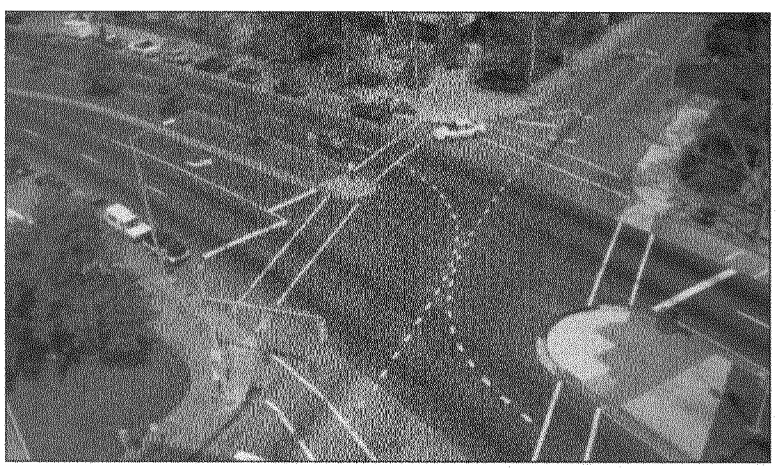

*FIGURE 7–3. Pedestrian refuge islands can create a safer crossing for wide streets.*

The typical conditions where refuge islands are least beneficial or possibly harmful include:

- Narrow streets and/or streets where substandard-width refuge islands are used;
- Instances in which a high turning volume of large trucks exist;
- Conditions in which the roadway alignment obscures the island, thereby making it likely for vehicles to drive into the island; and
- Areas where the presence of a safety island will severely hamper snow plowing.

In areas where refuge islands are beneficial, the advantages to pedestrians are many, including:

- Reducing pedestrian crossing time by splitting crossing distances (i.e., providing staged crossing of pedestrians), thereby reducing green time required for pedestrian crossing phase;
- Providing pedestrians with a resting place when crossing wide roads or intersections **(figure 7–4)**;
- 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 (shorter mast arms) and utility pole installations.

The disadvantages of pedestrian refuge islands include:

- a false sense of security or safety to pedestrians;
- street sweeping or snow plowing problems;
- damage to vehicles if struck;
- installation costs will be higher; and
- generally, more right-of-way is required.

## Recommended Practice

Pedestrian refuge islands may be installed at intersections or midblock locations as deemed appropriate by engineering studies. Refuge islands should be considered during the design of complex intersections or streets rather than after construction has been completed. They must be visible to motorists at all times and should be delineated by curbs, guideposts, signs, or other treatments. Refuge islands should be designed to minimize the potential hazard to motorists and pedestrians alike.

### Island Design Features

Pedestrian refuge islands must be designed in accordance with the AASHTO policy and the MUTCD requirements.[3,4] Design considerations should include the following.

- Areas at traffic signals where the total length of crosswalk cannot be readily travelled in one pedestrian phase. Special consideration should be given to intersections where a large number of elderly pedestrians and/or people with disabilities will be present. Special consideration also should be given to 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.
- Raised curbs with cut-through ramps at pavement level or curb ramps for wheelchair users **(figure 7–5)**. 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 48 inches along at the same level as the top of the raised median to provide a level area for wheelchair users.
- Areas at least six feet wide from face-of-curb to face-of-curb. The minimum width should not be less than four feet wide face-of-curb to face-of-curb. The island should not be less than 12 feet long or the width of the crosswalk, whichever is greater. The minimum island size should be 50 square feet.
- An approach nose, offset from the edge of the traffic lane, appropriately treated to provide motorists with sufficient warning of the island's presence. This can be achieved through various considerations such as illumination, reflectorization, marking, signing, and/or size.
- Pedestrian push buttons and signing adjacent to crosswalks.
- Guidestrips for the blind.
- Placement on wide (four lanes or more) streets with high traffic volumes.
- No obstruction to visibility by such features as foliage, barriers, or benches.
- Barriers that may be necessary to keep pedestrians from stepping into traffic at improper locations.

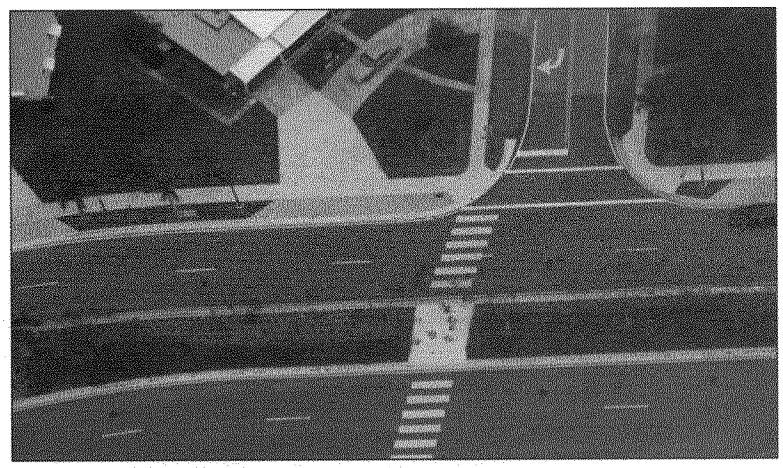

FIGURE 7–4. *Refuge islands provide pedestrians with a resting place when crossing roads or intersections.*

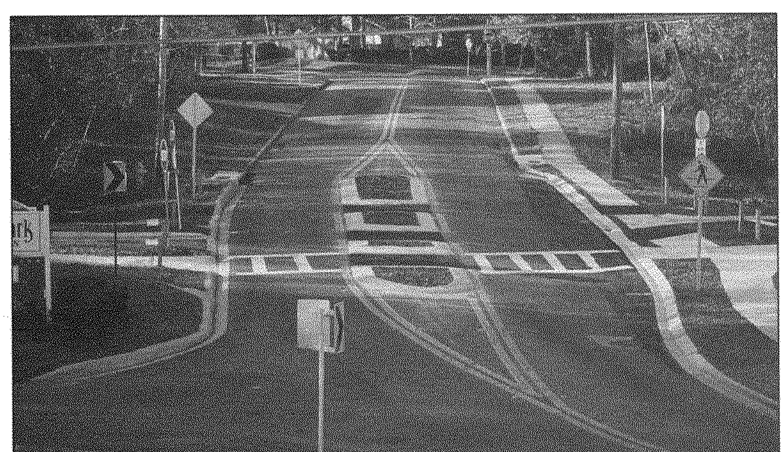

FIGURE 7–5. *Cut-through ramps should be provided on refuge islands and medians to accommodate wheelchair users.*

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# 8

# PEDESTRIAN BARRIERS

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*FIGURE 8–1. Barriers can prevent unsafe pedestrian crossings where hazards exist.*

Fatal Accident Reporting System data from the United States Department of Transportation show a consistent pattern of about 15 percent of all deaths occurring each year as a result of vehicles striking pedestrians.[1] In urban areas, approximately 25 to 50 percent of traffic deaths involve pedestrians. Many countermeasures are available to deter or inhibit vehicle-pedestrian conflicts, including the use of barriers of various kinds primarily to discourage pedestrians from making dangerous, unauthorized movements into the roadway.

At some locations, crossing a street would expose the pedestrian to a very high risk of being struck by a motor vehicle. In these instances, the preferred treatment consists of modifying or reconstructing the roadway to make it safer for pedestrians to cross. However, in extreme cases where this is not practical, it may be necessary to prohibit certain pedestrian crossings. Since signs ("DO NOT CROSS HERE") are often ineffective, barriers should be considered to direct pedestrians away from hazardous crossings **(figure 8–1)**. Sites where barriers may be justified include:

- Locations with high volumes of right turning vehicles at high speeds, particularly where vulnerable pedestrians such as school-aged children and older adults cross regularly.
- Midblock locations at high-speed or high-volume arterial streets where crossing at midblock is much more hazardous than crossing at a nearby intersection.
- Locations where barriers can channel pedestrians to use an overpass or underpass instead of crossing at street level.
- Other hazardous sites, as determined by the local traffic engineer.

Barriers should be placed at locations that most effectively prevent pedestrians from crossing streets at undesirable points, and that direct them to alternative crossings. They should be placed several feet from the travel lane to minimize the chances that they will be struck by a motor vehicle. Barriers may be built out of railings, chain links, or other materials, as appropriate. They need to be of sufficient height to prevent pedestrians from easily climbing over or under them.

### Positive Barriers

At least several hundred fatalities are the result of vehicles leaving the travelled way or where other vehicle-pedestrian conflicts are involved that can be controlled in some instances through the use of positive, or crashworthy, barriers. Appropriate positive barriers, both permanent and temporary installations, can often secure substantial long-term benefits in protecting pedestrians from vehicle impacts. However, since the institution of crashworthy barriers primarily for pedestrian protection may be an expensive capital investment requiring subsequent long-term maintenance of the systems, careful engineering analyses of need and cost-effectiveness should govern the decision on installations. As a result, these decisions must be guided by confirmation of a high potential for vehicle encroachments into a given pedestrian space.

Universal warrants for pedestrian barriers do not presently exist in any nationally recognized manual or study, although there has been acknowledgement of the generic problem of separating pedestrians from vehicle movements.

With respect to positive or crashworthy barriers, all contemporary engineering guidance as related to vehicle characteristics and motorist safety is fairly specific.[3,4] However, only two sets of current engineering specifications that are nationally applicable deal directly with the special needs of pedestrians.[5,6] These publications are entirely confined to bridges with pedestrian walkways. Consequently, careful engineering judgment must discern the highway, street, and bridge locations where the potential is especially high for vehicle intrusion into pedestrian areas. The chances of significant vehicle encroachment into a pedestrian space is a function of three principal considerations:

1. *Traffic Volume:* Daily counts and times of roadway peak volume and the extent to which this correlates with high pedestrian volume.
2. *Traffic Speed:* Prevailing vehicle speeds exceed the design speed of the facility.
3. *Vehicle-Pedestrian Conflicts:* The extent to which traffic control and other prevailing conditions promote or ensure conflicts of vehicles with pedestrian movements. This includes such features as the extent of lateral separation between moving traffic and pedestrian areas, and the propensity of both vehicles and pedestrians to make unauthorized, hazardous maneuvers with high accident potential.

The following sites should typically be evaluated for possible barrier installations; it should be stressed that collateral benefits to bicyclists often accrue when an affirmative decision is made to install a barrier system:

- Areas of heavily concentrated and vulnerable foot traffic, for example, on bridge walkways where pedestrians have little opportunity for refuge from errant vehicles because of the lateral restrictions of bridge deck widths.
- Especially narrow cross-section widths of roads and streets where substantial foot traffic occurs, for example, school-age children near schools.
- On the outside of horizontal curves on higher-speed facilities with consistent and substantial pedestrian presence, particularly where alignment discontinuities and significant speed differentials have been noted.
- On any permanent roadway segment where a significant concentration of consistent accident experience has occurred involving off-road impacts with pedestrians.

- In highway and street work zones, where the protection of both workers and pedestrians is needed by preventing vehicle encroachments beyond the designated work zone vehicle travel paths. A major special case to be noted here is when building contractors in urban areas encroach onto contiguous sidewalks, thereby forcing pedestrians off the curb into direct conflicts with vehicles.

It should be stressed that curbs alone do not constitute a barrier to protect pedestrians from an errant vehicle. Except at very low speeds and shallow angles of impact, vertical curbs up to a foot or more in height can be readily mounted or ramped by errant vehicles. Although curbs provide important channelizing information to the motorist and serve as visual deterrents to leaving the travelway, they cannot substitute for positive barriers at sites where the latter clearly are needed.

However, because barrier systems are generally designed to contain and redirect vehicles even at prevailing freeway speeds, they are costly for application to lower-speed facilities, particularly in urban and suburban locations where a barrier system is desirable but cost-prohibitive. Current research is evolving new varieties of barriers, which may be less costly, whose economy and tested performance to date show significant promise for use in low to moderate speed conditions in preventing vehicle impacts with pedestrians.

Work zone barriers are a special application of barrier technology and engineering judgment. The high level of exposure of both workers and pedestrians to adjacent vehicles, particularly in urban and suburban traffic conditions, often warrants the expense and labor involved in deploying and maintaining temporary barriers. Where temporary barrier protection is needed in a work zone for pedestrian safety, only certified systems with known performance should be used. Contractor-constructed wooden railings and chain link fencing are examples of unacceptable substitutes when placed close to traffic: they cannot prevent vehicle intrusion and they fragment or distort on impact and may be dangerous to pedestrians and workers.

As in the case with permanent barrier installations, low deflection and prevention of vehicle intrusion into the work zone and designated pedestrian areas are the main targets in the use of temporary barriers, and these aims are often met by the installation of portable concrete systems. Usually constructed in segments of 12 to 20 feet in length, the two most important considerations in the use of temporary concrete and other low-deflection systems (e.g., guardrail with closely spaced, rigid posts) is, first, to avoid the use of short, intermittent segments, and second, to ensure that the up-stream, leading ends of each longitudinal barrier run are properly flared and/or protected by impact attenuators.[4] Improperly connected or unconnected short runs of barriers are unable to perform properly in containing and redirecting vehicles on impact and frequently increase the severity of accidents to both vehicle occupants as well as to workers or pedestrians. Moreover, the use of many short runs of barriers encourages the presence of unprotected, blunt leading ends.

In summary, the determination of need for positive barrier protection of pedestrians must be a product of a careful analysis of the ensuring benefits of installation based on the realization that any barrier system constitutes by itself an additional fixed-object hazard. The decision to use a barrier sometimes leads to a significant increase in property damage and motorist injury accidents and, therefore, the judicious engineer should carefully gauge the tradeoff value of increased pedestrian protection against the potential for the disbenefits of motor vehicle barrier impacts. Most importantly, if a barrier is chosen for pedestrian safety reasons, it must be correctly installed and maintained. Improper installation or rehabilitation can effectively negate any projected increase in pedestrian protection and can also aggravate both the frequency and severity of vehicle accidents.

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5. Also see Chapter 15 by the author on pedestrian work zone safety in this compendium.
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9

# CURB PARKING RESTRICTIONS


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FIGURE 9–1. *On-street parking typically results in less visibility between motorists and pedestrians.*

On-street parking has an important relationship to pedestrian and motorist safety, the capacity and level of congestion on a street, and the economic well-being of adjacent businesses. It can create a buffer, separating pedestrians on the sidewalk from motor vehicle traffic on the adjacent roadway. The presence of on-street parking may also reduce motorists' speed, further enhancing pedestrian safety and comfort.

On the other hand, on-street parking typically results in less visibility between motorists and pedestrians, especially for children **(figure 9–1)**. The pedestrian dart-out, often involving children, is one of the most common types of midblock pedestrian collisions in residential areas. Therefore, the restriction of on-street parking in areas with pedestrian activity may improve pedestrian safety.

The issue of curb parking restrictions concerning pedestrian safety is related to the level of congestion within an urban area, the type of roadway, and the land use **(figure 9–2)**. Rural areas are not considered in this chapter due to the low number of parked cars and the low number of pedestrians present in such areas.

The primary documents for determining curb parking restrictions are the Uniform Vehicle Code (UVC) and Model Traffic Ordinance. The standards for most local jurisdictions state that "No person shall:

1. Stop, stand or park a vehicle:
   a. on a sidewalk;
   b. within an intersection;
   c. on a crosswalk;
2. Stand or park a vehicle, whether occupied or not, except momentarily to pick up or discharge a passenger or passengers:
   a. within 20 feet of a crosswalk at an intersection;
   b. within 30 feet upon the approach to any flashing signal, Stop sign, Yield sign or traffic-control signal located at the side of a roadway."

## Urban Area Characteristics

The urban areas where curb parking is typically present include the central business district (CBD), the central city and the suburbs. Each has unique requirements for parking related to the type of street and the traffic control devices.


FIGURE 9–2. *Curb parking is very common, and often essential in central business districts.*

### Central Business District

From the pedestrian perspective, the CBD normally has slower moving vehicles, typically 25–30 mph, marked crosswalks at most intersections, and restrictions on parking. Even where parking is permitted near the intersection, most intersections are controlled by some sort of traffic control device. Parking spaces are often governed by meters and, on occasion, may be marked on the pavement to avoid encroaching intersections and marked crosswalks. As long as the requirements of the UVC are met and enforced, no additional parking restrictions are generally needed.

### Central City

The highest density of housing and thus on-street parking occurs in the central city. People come home from work to find parking at a premium, which forces them to park a significant distance from their homes. During the winter, this period may be during darkness with reduced pedestrian visibility. Corner parking restrictions have to be signed and enforced according to the UVC. Thus, the keys are to have an effective enforcement program and well established and maintained signs. One of the two types of signs that do not have to be reflectorized, according to the MUTCD, are parking signs. This may adversely impact upon their effectiveness.

### Suburbs

Two distinct roadway types are present in the suburbs: the higher speed major routes and the lower speed collector and local streets. Because off-street parking is available on local streets in the suburbs, curb parking restrictions are normally not applicable. Housing is typically less dense, so pedestrian volumes are normally lower than in the CBD or central city.

## Roadway Type

Not only is the location within the urban area a determining factor in the type of on-street parking restrictions, but the type of roadway (major arterial streets vs. collector streets) must also be considered.

### Major Arterial Streets

These streets are wider, have higher speeds and usually have parking restrictions. Pedestrians are normally accommodated at marked crossings controlled by traffic control devices or at unmarked crosswalks. The curb parking restrictions listed previously are applicable to the arterial streets.

### Collector Streets

Generally the width and speed of the collector streets are lower than those of arterial streets. Collector streets tend to have more on-street parking and small neighborhood shopping centers. The neighborhood stores located along the block faces of collector streets pose a particular problem due to the high volume of pedestrian traffic and the desire of merchants to provide as much on-street parking as possible. More signing is often necessary near these small centers with particular attention given to sight distances for pedestrian crossings.

## Special Land Uses

Special areas of land use also need to be addressed. The areas discussed below are not meant to be an all inclusive list of potential curb parking problem areas but are meant to alert the traffic engineer to these and other similar areas.

### Loading Zones

The primary vehicle using a loading zone is a truck. Not only are trucks wider than automobiles, but trucks are also taller. Whereas pedestrians can often see over or through an automobile, they cannot observe approaching traffic past trucks and vans. Loading zones should not be located so that such vehicles stand closer than 30 feet from the crosswalk area.

### Parks

Although located along local or collector roadways, community or regional size parks attract large numbers of parked vehicles during events. Due to the overflow of parked cars onto public streets, parking restrictions on the park curb faces should be considered. Not only do children run into the road during events, but every space between parked cars also constitutes a potential crosswalk. Because parks attract pedestrian trips, particularly for children, the surrounding land use must also be examined. A local park in a single family neighborhood may have little if any added on-street parking. However, on-street parking may be a problem for a local park located within a high density housing area. Parking restrictions can be imposed to limit the continuous parking in front of building entrances. Fencing can be considered to channelize pedestrian flow to crosswalks at specific park entrances.

### Schools

School zones represent an area of movement of small children and considerable pick-up and drop-off traffic. Some school block faces may be restricted to use by school buses only. Parking of private cars along school blocks should generally be avoided. This, however, should be coordinated with the proper school authorities.

### Businesses

Parking has to be viewed in terms of pedestrian paths to and from businesses. Looking at the location of attractors and generators of pedestrian traffic is important. Paths, particularly informal paths that cross streets at midblock locations, need to be examined for parking restriction needs. Certain specialty stores, such as ice cream facilities, tend to attract children, and may require increased parking restrictions or special monitoring. Parking restrictions should be imposed where building entrances access directly to high speed or high density roadways (although some jaywalking is inevitable), or pedestrian barricades should be considered. Curb parking should be reduced in front of other facilities with high pedestrian traffic and direct access to the street system, such as a small shopping center pedestrian entrance or movie theater side door.

### Sight Distance and Parking Restrictions

The primary purpose of restricting parking at intersections is to improve sight distance. In the past, this has been done mainly for the motorist and only resulted as a side benefit for the pedestrian. The basic requirement for sight distance applies to the crosswalk area and is the stopping sight distance from the AASHTO manual **(figure 9–3)**. Assuming an adult standing on the curb, with the basic parking set back of 20 feet, the adult can see 60 feet without looking over or through the vehicle **(figure 9–4)**. This is not adequate. If the adult pedestrian steps halfway through the parking lane, 3 feet into the street, the visibility increases to 120 feet **(figure 9–5)**.

| Design Speed (mph) | Assumed Speed for Condition (mph) | Brake Reaction | | Coefficient of Friction f | Braking Distance on Level (ft) | Stopping Sight Distance | |
|---|---|---|---|---|---|---|---|
| | | Time (sec) | Distance (ft) | | | Computed (ft) | Rounded for Design (ft) |
| 20 | 20-20 | 2.5 | 73.3-73.3 | 0.40 | 33.3-33.3 | 106.7-106.7 | 125-125 |
| 25 | 24-25 | 2.5 | 88.0-91.7 | 0.38 | 50.5-54.8 | 138.5-146.5 | 150-150 |
| 30 | 28-30 | 2.5 | 102.7-110.0 | 0.35 | 74.7-85.7 | 177.3-195.7 | 200-200 |
| 35 | 32-35 | 2.5 | 117.3-128.3 | 0.34 | 100.4-120.1 | 217.7-248.4 | 225-250 |
| 40 | 36-40 | 2.5 | 132.0-146.7 | 0.32 | 135.0-166.7 | 267.0-313.3 | 275-325 |
| 45 | 40-45 | 2.5 | 146.7-165.0 | 0.31 | 172.0-217.7 | 318.7-382.7 | 325-400 |
| 50 | 44-50 | 2.5 | 161.3-183.3 | 0.30 | 215.1-277.8 | 376.4-461.1 | 400-475 |
| 55 | 48-55 | 2.5 | 176.0-201.7 | 0.30 | 256.0-336.1 | 432.0-537.8 | 450-550 |
| 60 | 52-60 | 2.5 | 190.7-220.0 | 0.29 | 310.8-413.8 | 501.5-633.8 | 525-650 |
| 65 | 55-65 | 2.5 | 201.7-238.3 | 0.29 | 347.7-485.6 | 549.4-724.0 | 550-725 |
| 70 | 58-70 | 2.5 | 212.7-256.7 | 0.28 | 400.5-583.3 | 613.1-840.0 | 625-850 |

FIGURE 9–3. *Stopping sight distance (wet pavement). Reprinted with permission. Source:* A Policy on Geometric Design of Highways and Streets, *Copyright 1994 by the American Association of State Highway and Transportation Officials, Washington, D.C.*

If the pedestrian, either adult or youth, stands at the edge of the parking lane, the sight distance is limited only by the individual's visual capability.

Angle parking at 90 degrees means the adult has to be 13 to 16 feet into the road before adequate sight distance is available. With the same 20-foot distance restriction from the crosswalk, the sight distance reduces to 40 feet **(figure 9–6)**. To have the same sight distance with 90 degree parking as with parallel parking, angle parking at 90 degrees should be restricted within 30 feet of the intersection. Angle parking at less than 90 degrees, for example 60 degrees, increases available sight distance for the pedestrian looking to the left, but reduces it for the pedestrian looking to the right **(figure 9–7)** Angle parking at 60 degrees also does not quite match the sight distance as with parallel parking (55 feet for angle, and 60 feet with parallel).

As the speed of travel on the thru street increases, the drivers' stopping sight distance increases. Therefore, the parking restriction area near the intersection has to be increased. For 35 to 45 mph, it is recommended that parking be restricted to 50 feet from the crosswalk. Above 45 mph, parking should be restricted to 100 feet from the crosswalk.

As housing density increases, the demand for parking increases. This often leads to parking on sidewalks, and in turn, the pedestrian is forced onto the street. Parking restrictions must be enforced on sidewalks and on the area between sidewalks and curbs. Midblock pedestrian crossings are usually marked with crosswalks. These crossings require greater advance parking restrictions than crosswalks at intersections, typically 100 feet minimum.

Conditions in which curb parking restrictions are most beneficial are:

- where pedestrian dart-out accidents are common,
- where no sidewalk exists or sight distance at the intersection is poor
- where vehicles park too close to the crosswalk and inhibit the pedestrian's sight distances.

Disadvantages to restricting curb parking are that it: eliminates parking spaces for motorists, is usually opposed by nearby business owners, and could lead to increases in vehicle speeds after on-street parking is removed (which is undesirable for pedestrians).

Chokers or "bulbouts" (or curb bulbs) are extensions to the curb line that extend to the edge of the parking lane and eliminate one or more parking spaces on the corner near intersections (or at midblock in some situations). Chokers improve the sight distance between pedestrians and oncoming motorists and shorten the crossing distance for pedestrians **(figure 9–8)**. More discussion of chokers is given in Chapter 12.

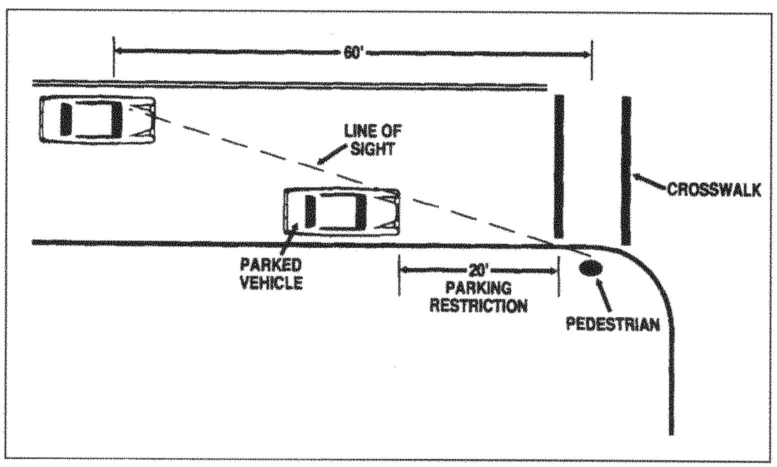


FIGURE 9–4. *Pedestrian sight distance and parking restriction needed for parallel parking.*

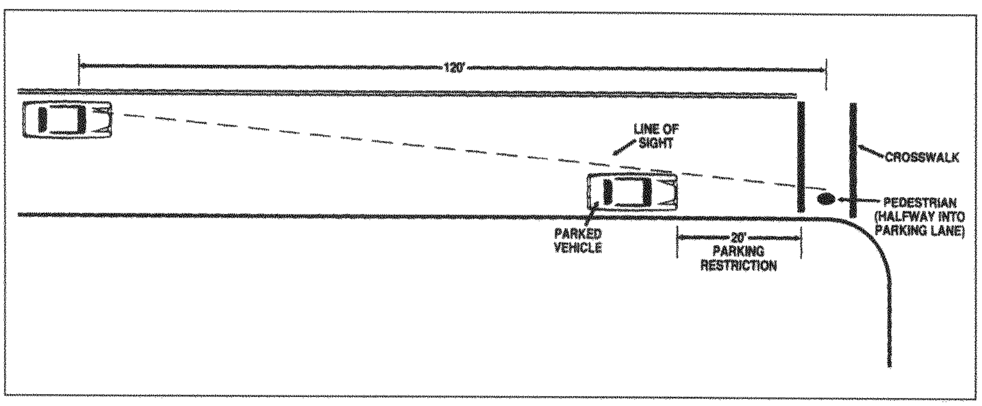


FIGURE 9–5. *Pedestrian sight distance and parking restrictions.*

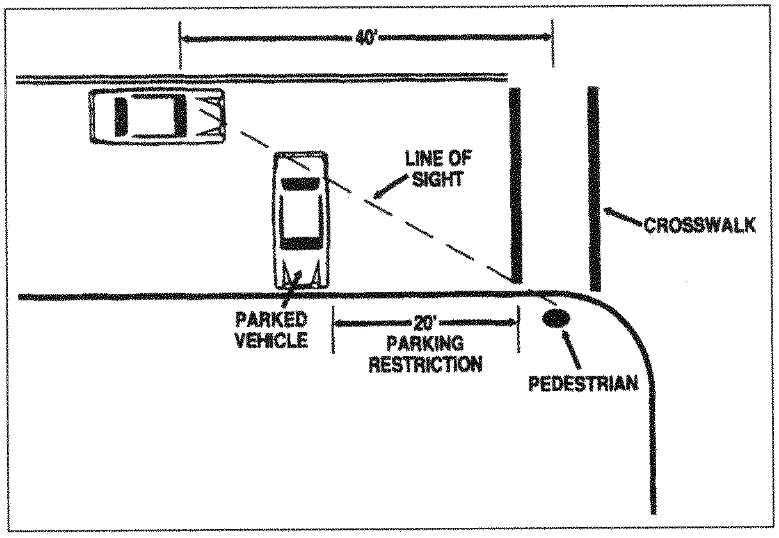


FIGURE 9–6. *Pedestrian sight distance and parking restrictions.*

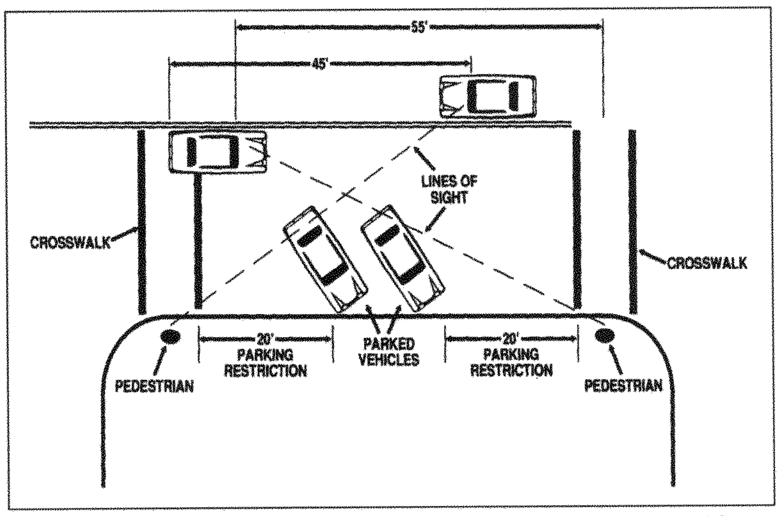


FIGURE 9–7. *Pedestrian sight distance and parking restrictions needed for 60 degree angle parking.*

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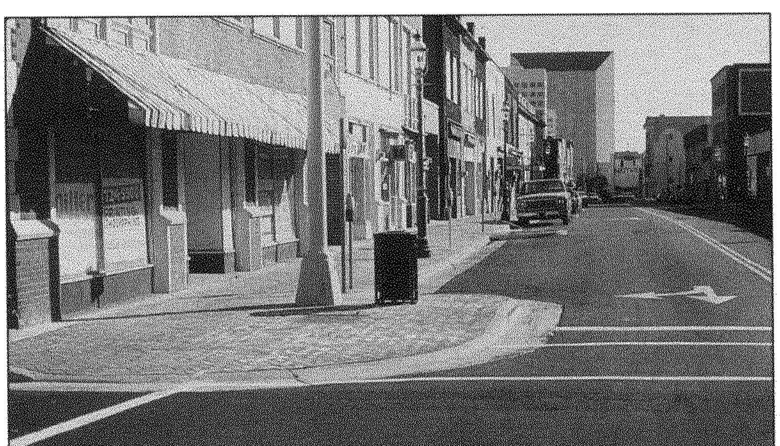

FIGURE 9–8. *Chokers or bulbouts improve sight distance between motorists and pedestrians and shorten the crossing distance for pedestrians.*

# 10

# GRADE-SEPARATED CROSSINGS

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FIGURE 10–1. *Pedestrian overpasses and bridges are often needed for high-speed or heavily travelled roadways.*

Grade-separated crossings refer to facilities that provide for pedestrians and motor vehicles to cross at different levels, and such facilities can greatly reduce pedestrian-vehicle conflicts and potential accidents. Not only have grade-separated structures been found to substantially improve pedestrian safety, they can also reduce vehicle delay, increase highway capacity, and reduce vehicle accidents when appropriately located and designed.[1,2]

## Types of Facilities

Several types of grade-separated crossings have been used, including:

### Overpasses:

1. *Pedestrian Overpasses/Bridges*—These are passageways for pedestrians constructed over a roadway in which stairs or ramps generally lead up to the overpass **(figure 10–1)**. ADA requires that stairs should not be the only means to access an overpass or underpass, although they can be used with a ramp. In some cases, however, the road is depressed and the bridge is at ground level.
2. *Elevated Walkways*—These refer to sidewalks or walkways above ground level that often run parallel to the flow of motor vehicles. Such facilities may be freestanding or connected to adjacent buildings.
3. *Skywalks/Skyways*—These typically refer to enclosed walkways built one or more levels above ground level that connect buildings at midblock **(figure 10–2)**. These crossings allow for walking between buildings without being exposed to inclement weather and are especially beneficial to elderly and physically disadvantaged pedestrians with lesser mobility.

**Underpasses:**

4. *Pedestrian Tunnels/Underpasses*—These generally involve stairs or ramps that lead down to a below-ground passageway. In some cases, however, the underpass is at ground level and the road is elevated **(figure 10–3)**.

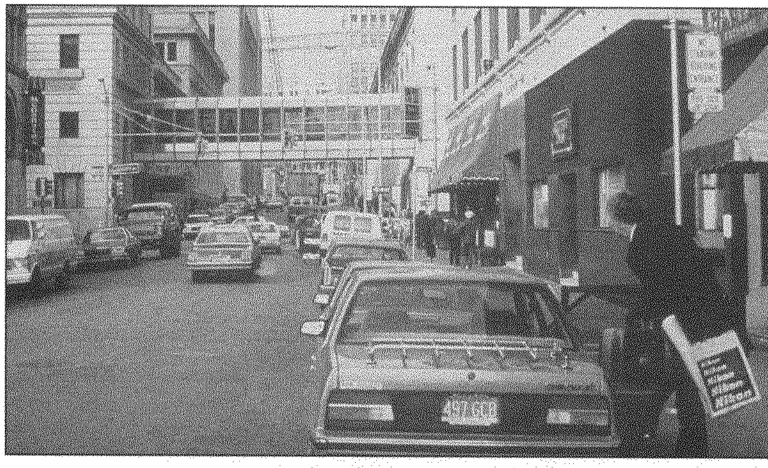

FIGURE 10–2. *Typical pedestrian skywalk.*

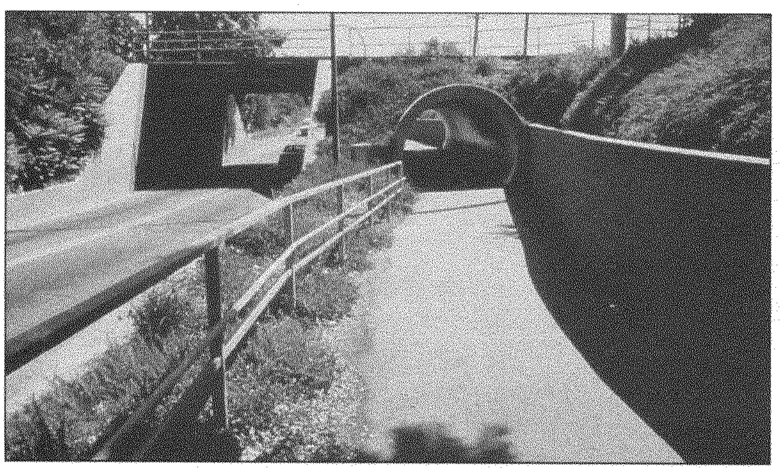

FIGURE 10–3. *Pedestrian tunnels or underpasses generally involve ramps below ground, or at the grade of another roadway.*

5. *Below-Grade Pedestrian Networks*—These facilities refer to extensive underground walkways that carry pedestrians parallel and perpendicular to the flow of motor vehicles traveling above them.

These networks are sometimes used in conjunction with subway systems.

## Planning Considerations

Locations that are prime candidates for grade-separated crossings are located in areas where the pedestrian attractors such as shopping centers, large schools, recreational facilities, parking garages, or other activity centers are separated from the pedestrian generators by high-volume and/or high-speed arterial streets. Grade-separated facilities are sometimes found in suburban and rural areas to connect residential areas with shopping centers or schools that are separated by freeways or high-speed arterial highways. In downtown areas, urban renewal projects provide an opportunity for adding grade-separated crossings.[2,3,4,5]

The effectiveness of grade-separated crossings depends on their perceived ease of accessibility by pedestrians, because an overpass or underpass will not necessarily be used simply because it improves safety. Instead, pedestrians tend to weigh the perceived safety of using the facility against the extra effort and time required.[2] One study by Moore and Older found that the degree of use of overpasses and underpasses by pedestrians depends on walking distances and convenience of the facility. A convenience measure, $R$, was defined as the ratio of time to travel on the overpass or underpass divided by time to travel at ground level. The percentage of pedestrians using the facility is shown on the y-axis in **figure 10–4**. Thus, for example, 95 percent of pedestrians likely would use an underpass and 70 percent would use an overpass if the travel time were equal to the crossing time at-grade (i.e., $R = 1$). However, virtually nobody would use an overpass if it took 50 percent longer to cross than an at-grade crossing ($R = 1.5$).[6]

Studies have also shown that grade-separated crossings should ideally be on the normal path of pedestrian movements. However, fences, medians, railings, or other barriers may also be needed to prevent pedestrians from crossing at-grade.[2,7] Otherwise, pedestrians tend to cross at locations they believe to be more direct.

## Overpasses vs. Underpasses

The decision of whether to use an overpass or underpass involves the consideration of the relative advantages and disadvantages of each. Overpasses, more commonly used than underpasses, require more vertical separation to provide clearance for large trucks. Underpasses need only to be seven to eight feet (less than half the height of an overpass) and require shorter ramps and less right-of-way than overpasses. One disadvantage of underpasses is their possible greater expense and costs related to relocation of utility lines and possible drainage problems. Also, potential security problems often discourage pedestrians from using underpasses, particularly at night. Overpasses should be enclosed to prevent the dropping of rocks or other debris onto vehicles passing below.[2,8]

## Warrants for Overpasses and Underpasses

Because of the high costs associated with grade-separated facilities, they should be incorporated into the early stages of planning new developments which are intended to generate substantial volumes of pedestrians. According to a 1988 synthesis study by Zegeer and Zegeer,[1] State and local government agencies consider grade-separated crossings to be most beneficial under the following conditions:

- Where there is moderate to high pedestrian demand to cross a freeway or expressway.
- Where there is a large number of young children (i.e., particularly near schools) who must regularly cross a high-speed or high-volume roadway.
- On streets having high vehicle volumes and high pedestrian crossing volumes and where there is an extreme hazard for pedestrians (e.g., on wide streets with high-speed traffic and poor sight distance).
- Where one or more of the conditions stated above exists in conjunction with a well-defined pedestrian origin and destination (e.g., a residential neighborhood across a busy street from a school, a parking structure affiliated with a university, or apartment complex near a shopping mall).

While these criteria are somewhat general, they do provide important factors for designers, planners, and developers to consider in determining where pedestrian facilities should be constructed. More specific warrants were developed by Axler in 1984 for grade-separated pedestrian crossings:[9]

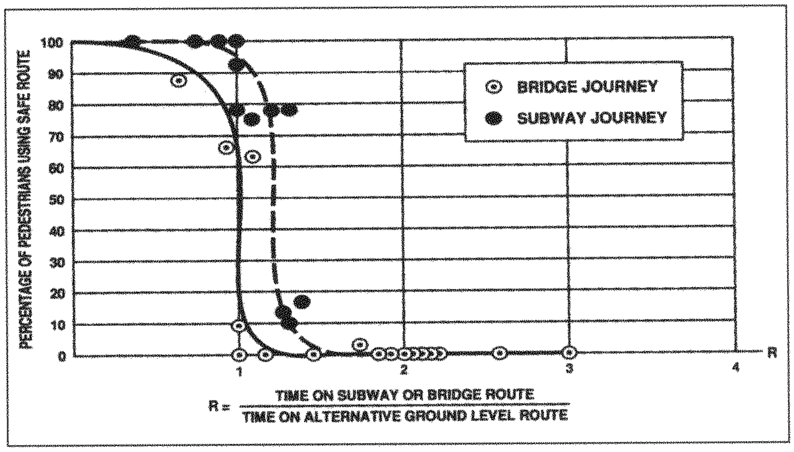


FIGURE 10–4. *Pedestrian use of grade separated crossing.*

1. The pedestrian hourly volume should be more than 300 in the four highest continuous hour periods if the vehicle speed is more than 40 mph and the proposed sites are in urban areas and not over or under a freeway. Otherwise, the pedestrian volume should be more than 100 pedestrians in the four highest continuous hour periods.
2. Vehicle volume should be more than 10,000 in the same four-hour period used for the pedestrian volume warrant or have an ADT greater than 35,000 if vehicle speed is over 40 mph and the proposed site(s) are in urban areas. If these two conditions are not met, the vehicle volume should be more than 7,500 in the four hours or have an ADT greater than 25,000.

3. The proposed site should be at least 600 feet from the nearest alternative "safe" crossing. A "safe" crossing is defined as a location where a traffic control device stops vehicles to create adequate gaps for pedestrians to cross. Another "safe" crossing is an existing overpass or underpass near the proposed facility.
4. A physical barrier is desirable to prohibit at-grade crossing of the roadway as part of the overpass or underpass design plan.
5. Artificial lighting should be provided to reduce potential crime against users of the underpasses or overpasses. It may be appropriate to light underpasses 24 hours a day and overpasses at nighttime.
6. Topography of the proposed site should be such as to minimize changes in elevation for users of overpasses and underpasses and to help ensure that construction costs are not excessive. Elevation change is a factor that affects the convenience of users.
7. A specific need may exist for a grade-separated crossing based on the existing or proposed land use(s) adjoining the proposed development site that generates pedestrian trips. This land use should have a direct access to the grade-separated facility.
8. Funding for construction of the pedestrian overpass or underpass must be available prior to a commitment to construct it.

Note that these criteria provide specific volumes of pedestrians and motor vehicles and vehicle speeds for which a pedestrian overpass or underpass is justified. However, while these specific values may be considered appropriate in certain instances, many economic and other factors also should be considered before making a final decision about installing high-cost grade-separated facilities for pedestrians. Additional details on provisions for people with disabilities on grade-separated crossings are given in Chapter 2.

Formal procedures have been established for assigning benefits and costs associated with adding overpasses and underpasses.[10] Benefits are weighed based on their perceived importance to the local community. Lists are given in **figures 10–5 and 10–6** of evaluation variables and cost items associated with such facilities. Benefits can include not only improved safety to pedestrians, but also reduced travel time, maintenance of the continuity of a neighborhood, and many others. Facility costs include design and construction costs, but also site preparation, finishing touches (e.g., lighting, landscaping), and operation and maintenance costs. Further details on quantification of benefits and costs for grade-separated pedestrian crossings are given in NCHRP Report No. 189 ("Quantifying the Benefits of Separating Pedestrians and Vehicles," 1978) and NCHRP Report No. 240 ("A Manual to Determine Benefits of Separating Pedestrians and Vehicles," 1981).[11,12]

| | |
|---|---|
| **Pedestrian Transportation** | 1. Travel time<br>2. Ease of Walking<br>3. Convenience<br>4. Special Provision for Various Groups |
| **Other Transportation** | 5. Motor Vehicle Travel Costs<br>6. Use of Automobiles<br>7. Impact on Existing Transportation Systems<br>8. Adaptability to Future Transportation Development Plans |
| **Safety** | 9. Societal Cost of Accidents<br>10. Accident Threat Concern<br>11. Crime<br>12. Emergency Access/Medical & Fire Protection |
| **Environment/ Community** | 13. Pedestrian-Oriented Environment<br>14. Effects of Air Pollution<br>15. Noise Impacts<br>16. Health Effects of Walking |
| **Residential/ Community** | 17. Residential Dislocation<br>18. Community Pride and Cohesion<br>19. Community Activities<br>20. Aesthetic Impact, Compatibility with Neighborhood |
| **Commercial/ Industrial Districts** | 21. Gross Retail Sales<br>22. Displacement, Replacement, or Renovation Required or Encouraged by Facility<br>23. Ease of Deliveries & Employee Commuting<br>24. Attractiveness of Area to Business |
| **Urban Planning** | 25. Adaptability to Future Urban Development Plans<br>26. Net Change on Tax Receipts and Other Revenue<br>27. Public Participation in the Planning Process |

FIGURE 10–5. *Pedestrian facility evaluation variables.*

| | |
|---|---|
| **1. Design and architect costs** | |
| **2. Financing costs and legal fees** | |
| **3. Site preparation** | ■ Real estate acquisition<br>■ Demolition<br>■ Drainage<br>■ Grading<br>■ Utilities relocation<br>■ Foundations<br>■ Required permits |
| **4. Construction** | ■ Height, width and length of facility<br>■ Length of span (if any)<br>■ Method of support<br>■ Enclosures (if any)<br>■ Materials<br>■ Walkway paving, curbs |
| **5. Finishing touches** | ■ Lighting<br>■ Street furniture<br>■ Amenities<br>■ Landscaping |
| **6. Operation and maintenance** | ■ Cleaning<br>■ Gardening<br>■ Maintenance and repairs<br>■ Lighting<br>■ Security<br>■ Taxes<br>■ Insurance |

FIGURE 10–6. *Major cost components of pedestrian facilities.*

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# 11

# SCHOOL PRACTICES

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## *School Trips and Operation*

The trip a child walks to and from school, in general, is a safer one in relation to other pedestrian activities of children. The American Automobile Association and its local auto clubs pioneered the "Golden Path to School" in the 1920s and developed the School Safety Patrol Program. Traffic engineering practices benefitting the safety of walking school children were developed by local practitioners during the 1930s and summarized into a recommended practice of the Institute in 1962, and updated in 1981 as "School Trip Safety Program Guidelines," the Recommended Practice of the ITE.[1] The Federal Highway Administration published guidelines for the development of safe walking trips and school maps in 1975 as "School Trip Safety and Urban Play Areas-Volume V." [2]

## *Information and Data Supporting Recommended Practice*

Children aged 5 to 14 constitute only 14 percent of the population, yet accounted for 27 percent of the pedestrian collisions during 1988. Young pedestrians, under 15 years of age, experience a pedestrian collision involvement rate twice that of all pedestrians **(figure 11–1)**.

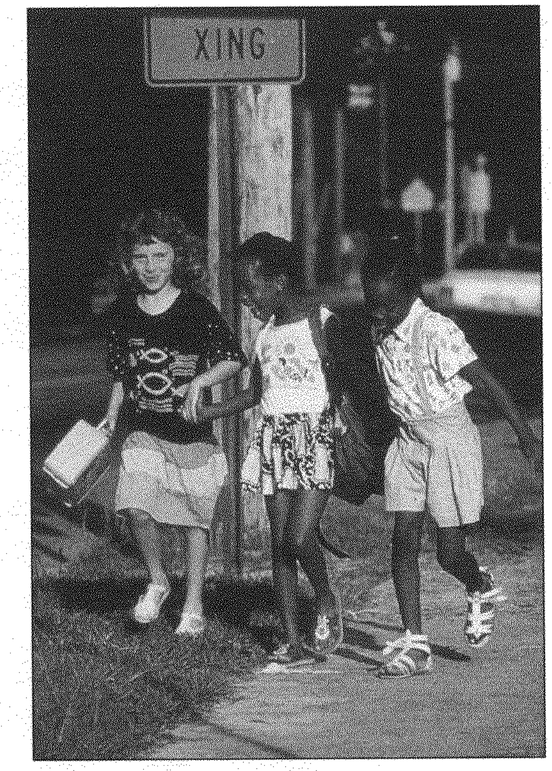


FIGURE 11–1. *Pedestrians under age 15 are twice as likely to be struck by a vehicle than an older pedestrian.*

The youngest students of 5 to 8 years in age are particularly over-involved in midblock dartout crashes. They cannot be treated as short adults; they are not able to judge the speed of approaching vehicles, nor the adequacy of gaps in traffic, and their peripheral vision is not as well developed. Young children are also often inattentive and careless in crossing streets.

Most young pedestrians (66 percent) will use marked crosswalks at uncontrolled intersections, while 83 percent will use them at signalized intersections. Nearly all children will use marked crosswalks at locations if there are adult crossing guards present **(figure 11–2)**.

FIGURE 11–2. *Adult crossing guards are often needed to monitor young children crossing busy or high-speed streets.*

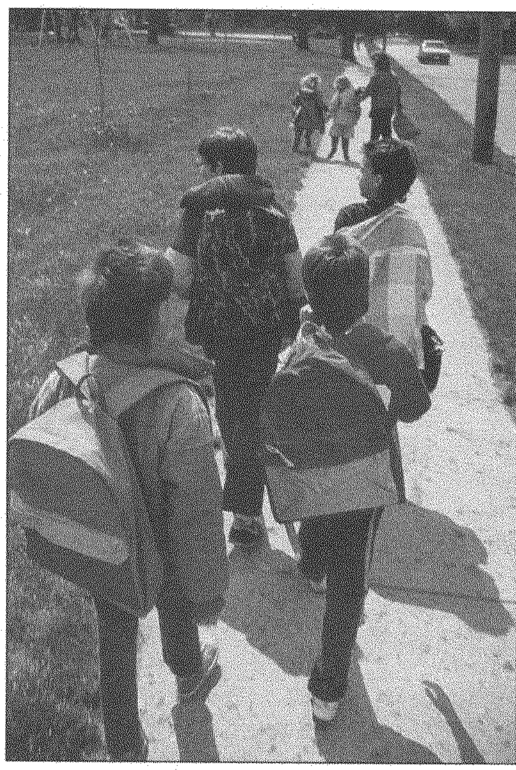

FIGURE 11–3. *Sidewalks are a key component around schools.*

At crossings with traffic signals, nearly all school children will cross on the green phase when activated by an adult guard. Only about 65 percent will cross on green without a crossing guard and more than half of school children will cross during gaps in traffic without activating pedestrian push buttons at signals without crossing guards.

The majority of motorists do not reduce vehicular speed in school zones unless they perceive a potential risk such as the presence of police or crossing guards, or clearly visible children.

## Definition and Use

A program ensuring the safety of walking school children consists of two parts: the physical facilities and the operation plan. Sidewalks and walkways separate school children from the flow of vehicular traffic. They are a key component in the physical facilities related to the safety of walking school children **(figure 11–3)**. The operational plan consists of the traffic control devices and the supervisory/control elements for school trip safety.

The selection of appropriate school zone traffic control is dependent upon traffic characteristics, school location, and the ages of the pupils. In general, the most effective method of school zone traffic control includes well-trained, adult, crossing guards **(figure 11–4)**. Inappropriate use of traffic control devices can increase pedestrian accidents.

## Recommended Practice

### Recommended Guidelines for School Trips and Operation

It is the recommended practice of the Institute of Transportation Engineers that local and State agencies adopt guidelines for the safety of school children, which includes the selection of safe walking trip routes to school and traffic control measures selected in accordance with ITE Recommended Practice "School Trip Safety Program Guidelines," **(figure 11–5)** and a supervision/control plan based upon the procedures of the American Automobile Association's Safety Patrol and Adult Crossing Guard program.

A committee at the local level should be responsible for the appropriate and uniform application of school crossing protection measures. Committee members might represent the school, police, parent/teacher association, engineering department, mayor's traffic safety committee, etc.

The six steps in developing a school program based upon the "School Trip Safety Program Guidelines" are:

1. Setting up the school trip safety process.
2. Identification of deficiencies in routes.
3. Designate route map for the safe route to school.
4. Selection of route improvements and control measures.
5. Implementation of route improvements.
6. Periodic evaluation of routes.

Sidewalks and walkways shall be installed upon the designated routes of the "Safe Route to School Plan" in accordance with ITE Recommended Practice *School Trip Safety Program Guidelines*.[1]

At school zone crossings, standard traffic control signals are sometimes needed to create adequate gaps in vehicular traffic to allow school children to cross safely. Signal installations at school crossing locations have several advantages over police supervision or crossing guards, in that they can be coordinated with adjacent signals to minimize traffic disruption and have relatively low operating costs. However, school crossing signals may still require the supplemental use of adult crossing guards to realize a safe operation of the signalized crossing.

Factors such as sight distance, crash history, vehicular speeds, age of children, and other locational characteristics should be considered in determining the specific type of traffic control appropriate at each school crossing location **(figure 11–6)**.

School crossing traffic signals are generally warranted at established school crossing locations when the number of gaps in the traffic stream during school crossing periods is less than the number of minutes in that same period.[3] Pedestrian signal indications should be provided at each signalized school crossing. The pedestrian school crossing phase should be activated by push-button operation under the control of an adult guard. The school advance and school crossing warning signs and markings should be used for the school crossing. The school crossing traffic signal should be pedestrian actuated when located at an intersection. For non-intersection crossing locations, parking should be prohibited for 100 feet or more in advance of the crosswalk and 20 feet beyond it.

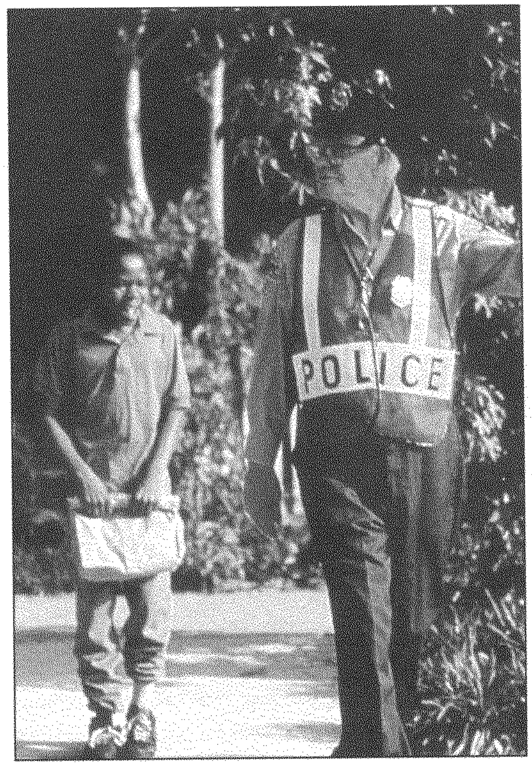


FIGURE 11–4. *Effective school zone traffic control includes well-trained, adult crossing guards.*

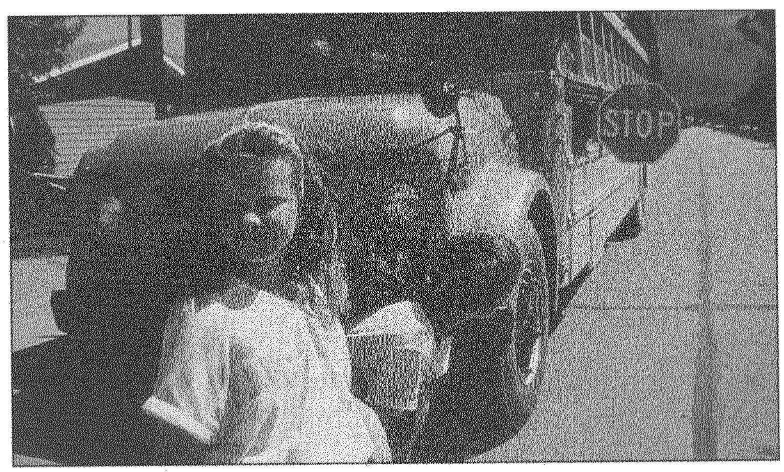


FIGURE 11–5. *Local and state agencies should adopt guidelines for the safety of school children.*

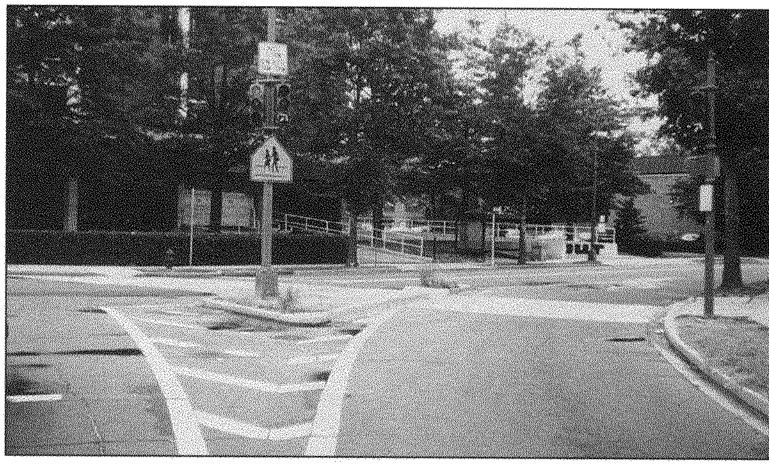

FIGURE 11–6. *Factors such as sight distance, crash history, vehicular speeds, age of children, and other locational characteristics should be considered in selecting traffic control devices at school crossings.*

Supervision of crossing school children may be carried out by adult guards and members of the school safety patrol. Control of vehicular traffic may be exercised only by a police officer or authorized and trained adult guard. Adult guards should be considered when special problems exist which make it necessary to assist school children in crossing safely.

The primary functions of school safety patrols are:

1. To instruct, direct, and control students in crossing the streets and highways at or near schools.
2. To assist teachers and parents in the instruction of school children in safe pedestrian practices at all times and places.

Patrols should not be permitted to halt or direct vehicular traffic. They may assist adults or police officers who are directing traffic by controlling the children waiting to cross.

The school safety patrols should be organized and administered by each school, with the principal being responsible for the leadership in determining the overall school safety patrol policy. Administrative responsibility for actual operation of the patrol may be delegated to an individual teacher or committee. Various civic and service organizations may be willing to work cooperatively with the schools in helping with the program. The local automobile club is a resource for everything needed to operate a patrol program, and in conjunction with the local safety council, parent-teacher association, and others, cooperates by offering assistance to school administrators for the successful operation of school safety patrols. Such community participation fosters the development of community understanding and support for the school safety patrol program.

The school safety patrol members should be selected from the upper grade levels, preferably not below the fifth grade. Qualities such as leadership and reliability should be considered in selection, and patrol service should be voluntary and open to all who qualify. They should have written approval of parents or guardians.

School safety patrols offer a way of extending traffic safety education beyond the classroom. Careful instruction and supervision of patrol members are essential if the patrol is to be efficient and continuous. The best results are obtained by delegating the continuous guidance to a teacher, supervisor, or other professional person within the school system who is interested in safety education.

New patrol members, after instruction, should serve with and under the guidance of experienced members until qualified to assume their duties.

On-site supervision of a school crossing may be appropriate where walking routes to elementary schools cross major, high-volume roadways. Specifically, adult crossing guards should be considered when special problems exist which make it necessary to assist the children in crossing the street, such as at an unusually complicated intersection with heavy vehicular turning movements and/or high vehicular speeds.

It is the recommended practice of the Institute of Transportation Engineers that warrants for the use of adult crossing guards include the following in developing local criteria:

1. At uncontrolled crossings where there is no alternate controlled crossing within 600 feet, and:
   a. In urban areas where the vehicular traffic volume exceeds 350 in each of any two daily hours during which 40 or more school children cross while going to or from school whenever the critical approach speed exceeds 40 mph, the warrants for rural areas should be applied.
   b. In rural areas where the vehicular traffic volume exceeds 300 in each of any two daily hours during which 30 or more school children cross while going to or from school.
2. At stop sign controlled intersection crossings:
   a. Where the vehicular traffic volume on undivided highways of four or more lanes exceeds 500 per hour during any period when the children are going to or from school.
3. At traffic signal-controlled intersection crossings:
   a. Where the number of vehicular turning movements through the school crosswalk exceeds 300 per hour while the children are still going to or from school.
   b. Where there are circumstances not normally present at a signalized intersection, such as crosswalks more than 80 feet long with no intermediate refuge, or an abnormally high proportion of heavy commercial vehicles.

Adult guards are usually civilians under the jurisdiction of the local police agency. Although they may be considered as special police officers, they do not have the same regulatory authority as the uniformed police officer. It is recommended that crossing guards wear an easily recognized uniform. In practice, civilian guards seldom wear uniforms identical to the police department officers. In some instances, a distinctive colored vest worn over civilian clothes is a common practice. The vest should be retroreflectorized for use during reduced visibility conditions.

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# 12

# NEIGHBORHOOD TRAFFIC CONTROL MEASURES

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## Introduction

It is generally recognized that traffic issues are a substantial component in the quality of life of residential areas. As traffic volumes increase on a particular residential street, there is a significant decrease in the actual and perceived quality of life for the residents who live on that street. This was proven in studies conducted on three streets in San Francisco that showed that, as traffic volumes increased, there were substantial increases in safety hazards, noise, stress, and pollution. An area of increased traffic is clearly an environment less friendly to pedestrians.[1]

In many instances, it is difficult to balance an efficient use of a street between motor vehicles and pedestrians. Conflicts between vehicles and pedestrians can be pronounced on residential access streets, as the streets are often used as playgrounds by children and as gathering places by adult neighbors. Streets in residential areas are

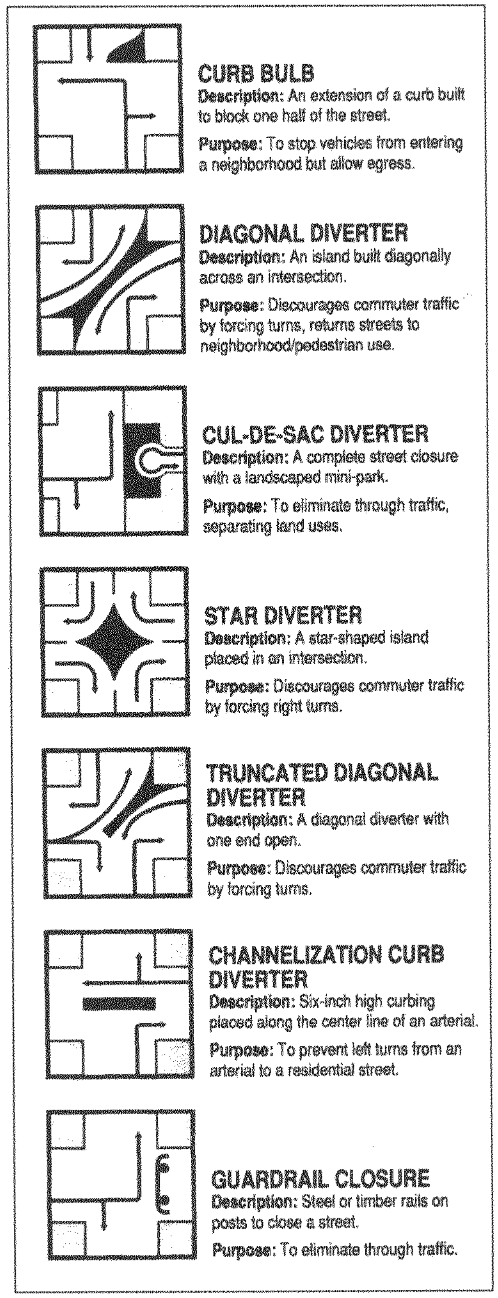


FIGURE 12–1. *Neighborhood traffic control measures: Types of diverters.*

typically viewed as an extension of the home territory for recreational walking and jogging. As traffic on these streets increases, the ability of residents to use the street for these other functions substantially decreases. In an effort to improve the pedestrian environment on neighborhood streets, we should try to reduce the number of possible conflicts (and the potential for injury when the conflicts involve speeding traffic) between cars and other reasonable uses (i.e., children on bikes, street crossers, pets, etc.). An agency's goal could be to promote an environment friendly to pedestrians, or even where people feel comfortable near the street area and are not threatened by noise and pollution to the point of retreating to their homes.

Neighborhood, residential access streets are designed to carry low traffic volumes (less than 2,000 vehicles/day) at low speeds. When this norm is exceeded, it is reasonable to take measures to force traffic to operate safely in an environment of pedestrians and their homes. It has been found that volumes exceeding 2,000 vehicles/day are considered a problem by residents.[1] Some measures, when implemented as a program (such as traffic circles), can become very popular and force an agency to rate the relative need of each location when allocating funds. Then, only those judged most needed would be funded. In cases where public funding is not available, neighborhoods may pay the cost of installing these measures themselves, as long as the proposed location is reasonable and otherwise fits the program criteria.

Two basic approaches can be used to facilitate pedestrian movement, safety, and general livability in neighborhoods: 1) installing physical controls requiring vehicular reroutes; and 2) managing traffic in place. The primary difference between the approaches is the extent to which conflicts between vehicles and pedestrians are separated. The vehicular rerouting measures include the following:

- street closures
- cul-de-sacs
- diverters (diagonal or semi-diverters)

Measures used to manage traffic in place include:

- traffic circles (minicircles)
- woonerven (streets for living)
- chicanes
- flares, chockers
- speed humps
- speed limit signs and speed zones
- speed watch and enforcement programs
- sidewalks and walkways
- parking controls
- stop and yield signs
- other signing

Note that some traffic diversion may also result indirectly from these measures, depending upon the type of design and the availability of convenient alternate routes.

## *Controls Involving Traffic Rerouting*

Neighborhood traffic control measures forcing traffic reroutes are geometric features that, by their physical form, force or prohibit a specific action such as a turn or a thru movement. Geometric features have the advantages of being largely self-enforcing and of creating a visual impression, real or imagined, that a street is not intended for thru-traffic. Their disadvantages relative to other devices are their high cost, their negative impact on emergency and service vehicles, the loss of convenient access to some parts of a neighborhood, and a resulting increase in traffic on nearby streets. They are also static and must be appropriate at all hours of the day and night. Many of these types of traffic diverters are shown in **figure 12–1**.

### Street Closures

Street closures are generally installed with curbs forming street-ends, diagonals across intersections, or bulbs at intersections that restrict or limit vehicular traffic. Landscaping is often included with these measures to serve as a visual cue to motorists, and as a visual enhancement for the neighborhood.

## Cul-de-sacs

An intersection cul-de-sac is a complete barrier of a street at an intersection, leaving the block open to local traffic at one end, but physically barring the other. Thus, a cul-de-sac represents the most extreme technique for deterring traffic short of barring all traffic from the street in question. A cul-de-sac, however, can be designed to allow emergency vehicles to pass through, by use of mountable curbs, or removable barriers.

Since a cul-de-sac is completely effective at its task of preventing through traffic, the choice of where or whether or not to use it depends largely on other aspects of traffic movement. For example, a cul-de-sac is less desirable in the vicinity of fire, police, or ambulance stations where emergency vehicle movements are frequent. It is also less desirable in areas where multi-alarm fires are more likely. A cul-de-sac is desirable adjacent to schools and parks, where the vacated street can be converted into additional play space.

Cul-de-sacs are extremely effective at limiting traffic volumes. They normally reduce traffic to that generated by the land uses that are adjacent to the street. Although a cul-de-sac is not a speed attenuating device, it may serve the purpose since the street comes to a dead end.

It should be mentioned that on many existing streets, the right-of-way may not be wide enough to accommodate a cul-de-sac, sidewalks on both sides, street lights, signs, or fire hydrants. Also, right-of-way should be sufficient to allow cars to turn around in the cul-de-sac. With a cul-de-sac diameter of 33 ft, most cars can turn around in one maneuver, but sanitation vehicles, school buses, fire trucks and other large vehicles cannot.

A cul-de-sac placed within one block, rather than at one end, performs the same function as an intersection cul-de-sac. Midblock cul-de-sacs are typically used when two different traffic-generating land-use types are adjacent to each other. An example of this is when a commercial area is backed by a residential area. The cul-de-sac is placed at the transition so that the commercial area is afforded the access, yet its traffic does not intrude into the residential area.

## Diagnonal Diverters

A diagonal diverter is a barrier placed diagonally across an intersection to, in effect, convert the intersection into two unconnected streets, each making a sharp turn **(figure 12–2)**. The primary purpose of a diagonal diverter is the same as that of forced-turn channelization to break up the cut-through routes, making travel through a neighborhood more difficult, while not actually preventing it.

FIGURE 12–2. *A diagonal diverter is a barrier placed diagonally across an intersection to convert it into two unconnected streets. This is an example from England, which allows free access to pedestrians and bicylists.*

Studies of systems of diverters have shown that traffic on streets with diverters can be reduced from 20 to 70 percent depending on the system of devices in the area. In these studies, traffic on adjacent streets with no diverters increased by as much as 20 percent. These devices have little to no effect on speeding, other than in the immediate area of the diverter, and a minimal effect on traffic safety.

Diverters and cul-de-sacs should only be used in cases where a reasonable arterial or access street alternative is available and easily accessed. Otherwise, vehicular traffic will simply reroute to other residential streets and likely result in similar problems on those streets. Diverted traffic should be directed to the nearby arterial street, and signing should be used with diverters to discourage thru-motorists from entering the neighborhood. As with cul-de-sacs, pedestrian, bicycle, and emergency vehicle access can still be provided with this treatment.

Public participation in determining use and location of diverters is essential to successfully address traffic concerns of a neighborhood. Residents should have a voice in the design and operation of the streets on which they live. Community, neighborhood, and political forces also need to be in favor of these controls before proceeding.

Careful thought needs to be given to circulation patterns resulting from diverters/closures. A trial installation is strongly recommended by use of barricades, barrels or guardrails. A trial period on the order of six to eighteen months gives ample time to collect data showing new traffic patterns and to evaluate community support again. In the event of permanent installation, small park features can be included in the diverter/closure area to further enhance pedestrian and neighborhood surroundings.

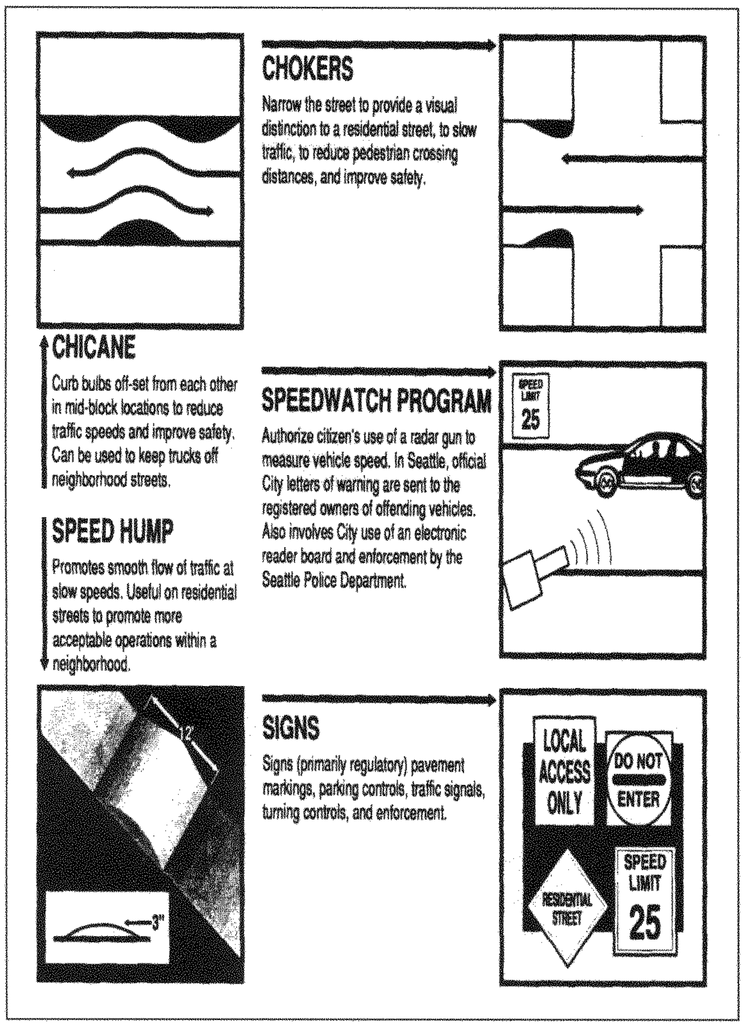


FIGURE 12–3. *Neighborhood traffic control measures: Managing traffic in place.*

## Managing Traffic in Place

When the street system or community and political climate do not favor street closures or diverters, there are numerous effective measures to manage traffic in place and still provide improved pedestrian surroundings. Each of the measures to manage traffic in place can be used in areas where there is a desire to slow down traffic and reduce collisions or collision potential. While reducing speeds and collisions, these measures normally have small effects on traffic volumes. Cost may be an important factor in finally deciding which measures to use; however, some can be installed inexpensively, using temporary installation schemes. All of these measures have positive results for pedestrian use and activities on neighborhood streets **(figure 12–3)**.

### Recommended Practices

Traffic circle (minicircle)—Traffic circles involve the use of raised circular islands in the center of an intersection, which creates a one-way, circular flow of traffic within the intersection area. Traffic circles separate points of conflict and often slow speeds of vehicular traffic **(figure 12–4)**.[1]

Circles of an intermediate size (in the order of 10 feet in diameter), have been used mainly as speed control devices within the intersection of two local streets. A secondary objective is to reduce traffic volumes by using them as a part of a group of circles or other devices that slow or bar a driver's path.

The following three guidelines regarding traffic circles have been developed:

- If the objective is to reduce traffic speeds along a section of a residential street, two or more traffic circles at adjacent intersections should be used. A single traffic circle will slow traffic in the immediate vicinity of the intersection, but its impacts on traffic speed will generally be confined to within approximately 100 feet of the circle.
- A traffic circle should not be installed in an intersection with a high volume of left-turn movements. Many motorists will make left turns on the left of the circle. This creates conflicts with traffic approaching from the left.

- Circles should be designed with mountable curbing on the perimeter to accommodate unusually large service vehicles.

Studies which have examined traffic volume effects of traffic circles have also included other devices in their proximity. Traffic volume effects of circles are not attributable or quantifiable to the individual circle but to the system of controls within which they are deployed. The assumption is, however, that volume reductions result from psychological rather than physical impacts on traffic. Their presence when viewed from a distance gives an impression of an obstruction to traffic. If drivers have encountered real barriers at other points in the community, they are likely to believe that the circle is yet another one and change routes before they get close to see what it actually is.

*Woonerven*—Woonerf ("streets for living") is a Dutch term for an area in which the local access function clearly predominates provisions for vehicles. Woonerven are streets raised to the same grade as curbs and sidewalks on which pedestrians, bicyclists, children at play, and vehicles share a common space. Vehicles are slowed to the pace of pedestrians by narrow curvilinear paths, trees, parking areas and planters. Woonerven should only be used on very low-volume, limited-use local access streets, whereby automobile access for residents can be maintained, while thru traffic is eliminated. An example of a Woonerf from Germany is given in **figure 12–5**. It is suggested that entry into a woonerf be made via a driveway to clearly indicate to motorists the change in street usage.

*Chicanes*—These are alternately placed curb extensions into the street that force motorists to drive in a serpentine pattern **(figure 12–3)**. The curb extensions narrow the road to one lane, with two-way operation. Chicanes are effective at reducing speeds and collisions. Installations result in loss of on-street parking, so if parking demand is high, this measure may not be appropriate. In such situations, parking controls should be used, as discussed below. Chicanes may be effective on streets with a large population of non-English speaking residents who may be unfamiliar with the risks of sharing the street. A few years ago, Seattle experienced a large number of pedestrian collisions on a street that had a high number of recently relocated Cambodian refugees. A chicane installation solved the problem.

FIGURE 12–4. *Traffic circles (minicircles) separate points of conflict within an intersection and often slow speeds of vehicular traffic.*

FIGURE 12–5. *Woonerven (streets for living) are very low-volume, limited-use local access streets.*

*Chokers*—A choker (also known as a curb bulb, nub, or gateway) is a narrowing of a street, either at an intersection or midblock, in order to reduce the width of the traveled way **(figure 12–6)**. While the term usually is applied to a design which widens a sidewalk at the point of crossing, it also includes the use of islands which force traffic toward the curb while reducing the roadway width. Streets narrowed at the cross-walk reduce the distance over which pedestrians are exposed to vehicular traffic **(figure 12–7)**. Bulbs provide safe areas for people to walk or play, or may provide added area for landscape or gateway features, thereby improving the appearances of the neighborhood.

FIGURE 12–6. *A choker is a narrowing of the street, either at an intersection or midblock, in order to reduce the width of the traveled way.*

FIGURE 12–7. *Streets narrowed at the crosswalk reduce the pedestrian exposure to vehicular traffic.*

FIGURE 12–8. *Curb bulbs can improve safety by providing pedestrians and drivers with an improved view of one another.*

Studies to date have shown that curb bulbs reduce traffic volume only when they either reduce the number of lanes of travel or add friction to a considerable length of street. Curb bulbs may also have significant effect on speed and can improve the safety of an intersection by providing pedestrians and drivers with an improved view of one another **(figure 12–8)**. They also reduce pedestrian crossing distance, thereby lowering their exposure time to vehicles. Chokers or curb bulbs can be considered to be either normal extensions of the existing curb or channelizing islands as defined in the MUTCD and design manuals.

*Speed Limit Signs and Speed Zones*—Speed limit signs are regulatory devices that are intended to inform the motorist of the speed limit of the roadway. Speed limit signs usually have no effect on traffic volumes and little if any effect on traffic speed, since drivers usually drive at what is perceived to be safe and reasonable under existing conditions. Studies in Europe, have showed that where speed limit signs were placed and speed zones were implemented, a reduction in traffic accidents occurred. However, other traffic calming techniques have often been used in conjunction with reduced speed limit signing where such effects have been observed. Speed zoning requires extensive enforcement for them to be effective in reducing speeds.

*Speed Watch and Enforcement Programs*—Neighborhood residents often feel uneasy when they perceive motorists are traveling too fast on their streets. This uneasiness can keep residents from enjoying their own surroundings as pedestrians. Most neighborhood traffic control measures address speeding in addition to creating other effects. Speed watch and enforcement programs primarily address speeding issues.

Speed watch programs normally include: the use of radar to check speeds of passing motorists, the recording of license plate numbers of speeding motorists, and notification of those speeding motorists and the residential nature of the street on which they were caught speeding. In Seattle, residents participate in the process of collecting the speed data and license plate numbers of offenders, and the engineering department sends letters to offenders. Enforcement presence or follow-up is often effective. Many of the motorists speeding on residential streets live in the neighborhood themselves, so this is really a neighborhood awareness program, where neighbors participate in a process to help return their streets to a safer, more comfortable atmosphere.

*Speed Humps*—Also known as road humps, undulations, or "sleeping policemen," speed humps were developed by the Transport and Road Research Laboratory in Great Britain. The purpose of speed humps is to promote the smooth flow of traffic at slow speeds (around 20 to 25 miles per hour) **(figure 12–9)**. They are not meant to reduce vehicle speeds to 5 to 10 miles per hour, as are speed bumps. They have undergone extensive demonstration and evaluation in both Britain and the United States. Some cities have constructed raised intersections, where the entire intersection is raised after a motorist encounters a hump on each approach **(figure 12–10)**. Findings from this research are contained in the FHWA report, Improving the Residential Street Environment (1981).

The speed hump is an elongated hump with a circular-arc cross-section rising to a maximum height of three inches above the normal pavement surface and having a chord distance of 12 feet in the direction of vehicular travel **(figure 12–3)**. Speed humps have proven to be more effective, quiet, and safer than conventional speed bumps, and speed bumps are not recommended for street use.

Humps are extremely effective in reducing traffic speeds to reasonable levels on local residential streets. Substantial reductions in the speeds of the fastest cars can be expected along with an 85th percentile speed of about 25 miles per hour. Typical average speeds on hump-equipped streets are under 20 miles per hour. Although humps can be traversed safely at high speeds, virtually no drivers do so.

The ITE Technical Council Committee 5B-15 has stated that the individual municipal traffic engineer should be responsible for determining the safety of the design and the criteria used for installation of speeds humps, including signs and/or markings. For guidance in the design and installation of speed humps, refer to the "ITE Guidelines for the Design and Application of Speed Humps—A Proposed Recommended Practice." Representatives from the municipality should evaluate speed humps once they have been installed by collecting speed, volume, and accident data to determine their continuing effectiveness.

*Sidewalks and Walkways*—It is common for cities to have some streets without sidewalks. Sidewalks are paved (usually concrete) walkways which are separated from the street, usually by a curb and gutter. Walkways are an excellent, lower cost substitute (often made of asphalt or crushed stone) for concrete sidewalks on streets lacking a reasonable pedestrian/vehicular separation. Walkways and on-street parking serve to separate traffic from pedestrians and provide a safe, comfortable area for walking.

Arterial streets within a neighborhood area should receive highest priority for sidewalks or walkways, since traffic conflicts are more numerous, and speeds are higher—exactly the reason why arterial traffic should be kept off residential access streets. Other areas of top priority are: criteria for placing priority on traffic control, school walking routes, elderly and disabled citizen usage, vehicular speeds and volumes, and constructability.

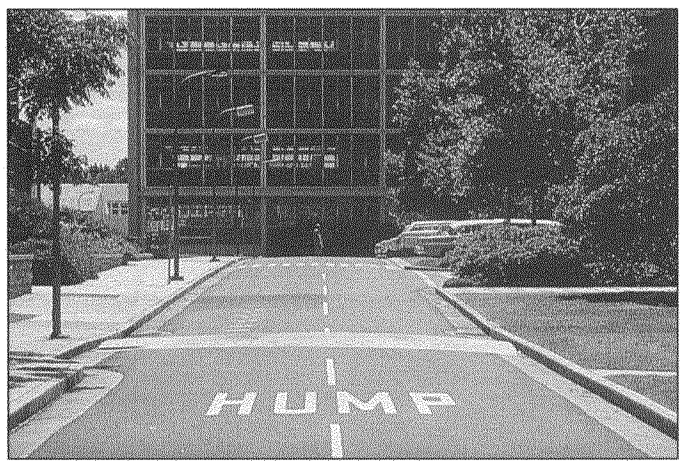


FIGURE 12–9. *Speed humps reduce traffic speeds to about 20 to 25 mph.*

FIGURE 12–10. *Raised intersections can enhance pedestrian safety by reducing traffic speeds.*

*Parking Controls*—While parking restrictions are often used to improve sight angles at intersection, parking controls can also be used to control traffic speeds through a neighborhood, making streets safer for pedestrians. Parking can also be installed alternately on each side of neighborhood streets to create serpentine patterns similar to chicanes. On narrow residential streets, parking can be allowed on both sides, effectively reducing the street to one travel lane of two-way traffic. This requires sharing the street, and reduces traffic speeds.

On the other hand, the presence of parking on narrow residential streets reduces visibility, making it more difficult for motorists and pedestrians (especially children) to see each other. This increases the risk of crashes involving dart-outs (often children). Chokers (bulbouts) placed at intersections and midblock locations can improve visibility.

*Stop and Yield Signs*—The purpose of a two-way stop sign is to assign the right-of-way at an intersection. Two-way stop signs are suitable for protection from cross traffic on arterials and collectors, and when there is poor sight distance. Stop signs do not reduce speeding on local streets, except for approximately 200 feet prior to the intersection, and are expressly prohibited for this purpose by the MUTCD. Stop signs, however, do stop vehicles at intersections, where pedestrians typically cross the street. Two-way stop signs have little to no effect on reducing traffic volumes and the results on traffic safety are mixed.

Four-way stop signs are rare outside of the U.S and Canada. They are usually intended as a stop-gap measure when funding is not available for traffic signal where collector and/or arterial streets meet. Four-way stops are frequently used as a speed control device, yet recent studies have shown that only five to twenty percent of the motorists come to a complete stop when overused, forty to sixty percent come to a rolling stop (below five miles per hour), and twenty to forty percent pass through the stop sign at speeds higher than five miles per hour. Studies have also shown that violation rates are higher at stop signs that are placed as speed control devices.

Yield signs are used to protect traffic on one of two intersecting streets without requiring traffic on the other street to come to a complete stop. In the United States, this sign is used where sight distances at the intersection of two non-arterial streets permit traffic on the controlled street to approach safely at 15 miles per hour or higher. In many countries, the sign is the standard for protecting the right of way of vehicles on an arterial street. Yield signs offer virtually no protection to pedestrians, since motorists generally yield only to other motor vehicles, and pedestrians must choose gaps in traffic to cross.

*Other Signing*—Signs such as "Residential Street," and "Local Access Only," are sometimes used in neighborhoods in conjunction with other measures. These signs by themselves have if any, a limited effect in reducing vehicle speeds and/or volumes. A number of the measures for managing traffic in place require regulatory signs such as "Do Not Enter," "Not A Thru Street," and "Dead End." The MUTCD and engineering practices will serve as a guide as to what to use and when.

*Public Participation*—Three key groups should be included in the public participation process: the residents of the neighborhood, the public works officials of the community, and the elected officials of the community. The residents of the area should have a voice in the design, function, and operation of the streets where they live. They ultimately are the ones at risk on an unsafe street and must live with any improvements brought about by a traffic management program. The public works professionals of the community, including city planners, traffic engineers, transit officials, police, firefighters, and emergency medical services, have a responsibility to identify these problems and to assist the residents in formulating alternative solutions. The elected officials ultimately will make the decisions regarding the implementation of a proposed traffic management program. For this reason, they should be involved from the on-set and should be made aware of the existing problems, alternative solutions, and the final implementation plan.

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13

# PEDESTRIAN-ORIENTED ENVIRONMENTS

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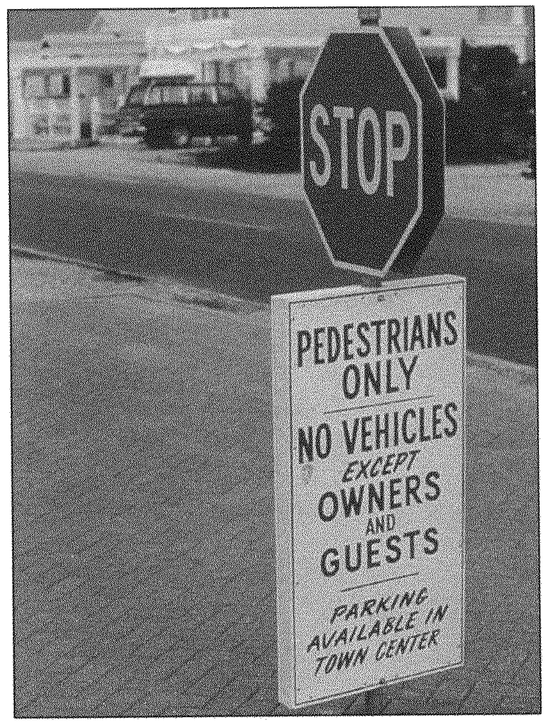


FIGURE 13–1. *Full or partial street closures to motorists can improve pedestrian mobility and safety.*

The closing of streets to motor vehicles to provide for environments partially or totally for pedestrians is often a good solution for improving pedestrian safety and movement (**figure 13–1**). However, this could create problems for motorists and/or businesses in the area. The development of pedestrian malls and other auto-free areas is usually the result of an urban renewal or downtown revitalization effort and is not usually undertaken for pedestrian-safety considerations.

Various alternatives have been implemented to restrict motor vehicles from the pedestrian environment, including residential yards, play streets, pedestrian malls, and transit malls.

## *Residential Yards*

The residential yard's function differs from a conventionally designed residential street. The same paved area is used for various functions including driving, playing, cycling, walking, and parking, and is intended for application only along low-volume streets having minimal parking demand. Motor vehicles must move with great care and may park only in designated areas within the yard. Pedestrians and children may use the entire street width but not unnecessarily obstruct the progress of motor vehicles.

Specific legal and behavioral rules apply to traffic in the residential yard. In the Netherlands, an experiment has been proceeding on this concept, and the most outstanding new traffic regulations which apply to the residential yards are:

- Roads located within a designated residential yard may be used over their entire width by pedestrians and children at play.
- Drivers must move with the greatest caution, being "intruders" within the residential yard.

- Pedestrians and children must not unnecessarily obstruct the progress of drivers.
- Motor vehicles with more than two wheels can park in a residential yard only at places with a parking sign or a letter "P" in spaces on the road surface.
- Signs are installed to indicate residential areas designated as residential yards.

## Play Streets

Play streets have been implemented in Philadelphia and New York City in center-city neighborhoods to provide safe play areas within residential areas. A play street is a residential street closed to vehicular traffic during specified hours to permit a supervised program of recreational activities to take place in the roadway. The streets can be marked for games and equipment provided for group activities, and they may be closed using police barricades, pipe and chain/cable, and/or signs. Development of such streets may produce multiple safety benefits to children.

An examination of past accident and behavioral research shows the following:

- Children playing in urban streets are the most highly represented group in pedestrian accident statistics.
- The major cause of child pedestrian accidents is the child darting into the street.
- The majority of accidents involving children occur in residential areas, near the child's home.
- Children involved in accidents tend to live in areas with few play facilities.
- Development of play and recreation areas in congested, high accident areas has significantly reduced the frequency of child pedestrian accidents.

There are a number of advantages to play streets including:

- Complete separation of children from vehicular traffic.
- Potential reduction in accidents involving children playing in or darting into the street.
- Inexpensive compared with the alternatives (parks and playgrounds).
- Provision of safe places for children to play.

However, there are also disadvantages for play streets, including:

- Available parking space is reduced.
- Vehicle circulation is reduced.
- Access for delivery vehicles is restricted.
- Adult commitment and time are needed.
- Official city approval is required.

Successful play streets which have been developed in a number of urban areas have the following characteristics: 1) community support and a continuation of community activities at times when the street is open to traffic, 2) a sponsoring organization (police, recreation departments), 3) majority of residents in favor of the play street, and 4) commitment from adults to supervise the play street.

Further information on play streets and their design is available in a Federal Highway Administration report *School Trip Safety and Urban Play Areas* (FHWA/RD-75/104).

## Pedestrian Malls

Pedestrian malls are streets which have been closed to all vehicular traffic and are reserved for the exclusive use of pedestrians, with few exceptions. Delivery and refuse collection access may be permitted during specified times of the day, and emergency service access must be permitted at all times.

Pedestrian Malls can be developed in each of the following manners:

(a) Modified Street—One block of a conventional street is closed to vehicular traffic for the exclusive use of pedestrians.

(b) Plaza or Interrupted Mall—Several blocks of a retail street are exclusively designated for pedestrian use, with cross streets left open to vehicular traffic.

(c) Continuous or Exclusive Mall— A multiblock area, which may include more than one street, is exclusively designated for pedestrians, with the exception of emergency, maintenance, and delivery vehicles. The area extends the full length of the shopping area, through intersecting streets, without interruption.

(d) Displaced Sidewalk Grid—A pedestrian walkway is developed away from the regular sidewalk grid through alleys and laneways, arcades, and/or lobbies within buildings.

## Transit Malls

Transit malls are streets where pedestrians share the space with transit buses or light rail vehicles (and sometimes bicycles, delivery and refuse collection vehicles and taxis), but other vehicles are not allowed, except for emergency and maintenance vehicles. Transit vehicles operate on a narrow right-of-way within the mall space.

## Planning Considerations for Pedestrian Malls and Street Closures

For urban street malls to be successful, they must provide a viable and attractive alternative to regional shopping malls **(figure 13–2)**. This can be difficult when it is considered that street malls must necessarily be planned and designed around existing roadway configurations, traffic patterns, parking, retail mix and other constraints. Street widths can be too wide, walking distances too long, and retail development poorly located to encourage the patterns and volume of pedestrian activity needed to support a successful urban mall. The regional shopping mall, on the other hand, offers a climate controlled and attractively designed environment, plentiful nearby parking, concentrated retail exposure within short walking distances, freedom from exposure to vehicular conflicts and pollution, off-street truck facilities, and other advantages over the street mall. In order to succeed, the street mall must, therefore, capitalize on its primary advantage as an outdoor activity space by promoting parades, street fairs, bicycle and track races, antique car rallies, marching band competitions, concerts, and other similar public events to encourage pedestrian activity and establish an area identity.

FIGURE 13–2. *For urban street malls to be successful, they must provide a viable and attractive alternative to regional shopping malls.*

The success or failure of an urban pedestrian mall is dependent upon many factors, some of which are directly controlled during the planning process. Providing a rigid planning framework is not possible due to the physical layout and socioeconomic composition of the proposed development site. Planning considerations are, therefore, presented as a series of concerns with references, where appropriate, to concepts that have both failed and succeeded. The primary objectives of the pedestrian mall should be to reestablish or fortify an urban area's economic viability while simultaneously creating a social setting capable of responding to a variety of needs. The following considerations identify elements of planning essential to the effective realization of pedestrian malls.

## Relationship of Mall to Central Area Development

Pedestrian malls succeed or fail according to their degree of accessibility either by public transit or by private automobile. The success of a pedestrian zone is also directly related to its ability to create a range of activities to suit a variety of users **(figure 13–3)**. For example, Albany's government mall in New York State has suffered a loss of vitality because it is only able to attract patrons during lunch break hours and is practically deserted otherwise. A more balanced use of the area's resources over extended periods of time, a high level of urban vitality, and an increased feeling of safety can be achieved by attracting a full spectrum of users through mixed use zoning.

FIGURE 13–3. *The success of a pedestrian mall is directly related to its ability to create a range of activities to suit a variety of users.*

## Cooperation and Support

Progress in implementing the planned improvements can be much more rapid when commercial and public interest can be demonstrated to coincide. Many proposals meet opposition from shop owners who believe that their trade will suffer if vehicular access is restricted along their premises. Shop keepers are often resistant to the mall concept until they are made aware of the potential benefits. It is important to obtain the cooperation of commercial interests at the initial planning stages in order to ensure viability of the proposals.

Community involvement can often be generated by launching instant beautification campaigns in order to project a new image for the main downtown area to be redeveloped. Vacancies can also be temporarily eliminated by providing store front space at nominal rents to service oriented businesses, public interest organizations, or businesses likely to increase the level of urban viability in the area. Similarly, clean-up campaigns, the elimination of signs of vandalism and neglect, wall paintings, and the introduction of landscaping elements can prove helpful in generating hope and enthusiasm for the downtown challenge. Eliciting public support during the course of the pedestrian mall development is important in guaranteeing the success of the mall. The creation of a pedestrian mall affects a wide range of user groups whose participation is vital. These groups should be consulted and involved during the early planning stages of project implementation.

## Existing Vehicle Traffic Patterns

Some cities have radically altered circulation patterns in order to decrease traffic congestion and redistribute vehicular traffic flow in the area of the pedestrian mall. This can be accomplished by developing one-way streets, restricting turning movements, limiting access to certain categories of vehicles, redesigning intersections, and retiming traffic signals.

## Public Transit Services

Most cities with successful pedestrian malls have introduced policies that encourage the use of public transport. The success of these policies has varied depending on the extent of traffic congestion and the efficiency of the public transportation system. As always, public transit should be inexpensive, fast, comfortable, safe and enjoyable to ride. Other tactics that can be successful are reserved lanes for public vehicles, low fares, convenient pickup and drop-off locations within the mall, and better security. Those pedestrian malls that are built as transit ways can provide increased mobility to pedestrians by dropping them at major department stores or activity centers within the mall itself.

## Parking Supply

Effective parking policies have a significant impact on both the regulation of parking density and the attractiveness of parking spaces to mall users. Some cities use different strategies to meet the demands of employees seeking day-long parking and visitors looking for short-term parking. Some cities offer park-and-ride systems to allow downtown or mall employees to park their cars at the periphery of the city limit and ride to work via rapid transit or special buses. On-street parking meters and multi-level parking facilities at the edge of the pedestrian mall areas can provide short-term parking needs; time can be charged in incremental rates to promote a quick turnover.

## Mobility of Goods

Oppositions of many merchants to the idea of a pedestrian mall results from the problem of delivering merchandise to stores and making it possible for customers on foot to handle the purchases easily. One of the most common strategies has been to allow structural changes in the street pattern to make possible store deliveries from courtyards and alleys as well as using time restrictions on the use of pedestrian mall space by commercial trucks. Some downtown merchants have introduced free pushcarts in order to meet customer demand for assistance in delivering their goods to either the central transportation terminal or to where their car is parked. Other establishments that sell bulk goods, such as grocery stores, should be relocated to the periphery of the mall where ready access to parked vehicles is available.

## Essential Services

Essential services such as emergency fire, police, medical, refuse removal, taxis, vehicle pick-up and drop-off, truck delivery and pick-up, and mall cleaning must also be considered. Provisions must be provided to allow emergency service vehicles to quickly access areas within the pedestrian mall. Problems are often encountered in that the effective width of the street is made smaller to encourage pedestrian movement with the placement of amenities, such as benches and planters, within the street right-of-way. Additional amenities within the pedestrian mall such as canopies and covered ways will need to be sufficiently high in order to enable emergency vehicles to pass underneath. It is important, therefore, to consult with the appropriate emergency services at an early stage in the planning of the pedestrian mall. In addition to the fact that emergency vehicles will need to have access to the pedestrian mall during all hours of the day, there are also certain types of businesses that require such access for other vehicle types. For example, a hotel located on the street to be made into a pedestrian mall will need to provide continuous access to taxis for its viability. Similarly, security vehicles will need to reach banks and businesses located within the pedestrian mall during nighttime hours.

## Accessibility Needs

Care must be taken that the paving system used does not provide impediments to the safe and easy movement of wheelchairs. Planters, benches and other amenities should be placed in a straight line to satisfy the expectancy of the visually impaired.

## Design Considerations

Quality of design and durability of construction materials have proven to be essential elements in the success of pedestrian malls. The ideal pedestrian mall design occurs where there is a relatively narrow street right-of-way, with concentrated shopping and commercial land uses within the normally accepted walking distance limit of one-quarter mile, and larger traffic generators ("anchors") located at opposite ends of the mall to encourage walking along the mall. Excessively wide streets dilute pedestrian activity, making a mall appear dull and uninteresting, and also reduces exposure to retail edges due to the increased sight distances.

Amenities such as benches arranged in groups in small rest areas, local street maps and points of interest displays, programs of future events, transit stop enclosures, and transit system information displays will improve the convenience and attractiveness of the mall.

Some successful street malls are located in areas such as historical districts where there is an established pattern of tourist and visitor activity. When this pattern exists, it can be enhanced by design treatment of storefronts and street furniture in keeping with the "theme" of the site. Where this pattern does not exist, it is necessary to develop design and marketing strategies which will encourage downtown activities and use of the mall. The primary advantage of a street mall is the ability to conduct large-scale outdoor events. Event spaces for setting up concerts, grandstands, outdoor skating rinks, and other activities, should be considered in the mall design.

Street furniture, paving treatments, and lighting are important design considerations. In order to reduce clutter, street furniture elements should be of modular design incorporating several components in a single unit. Pavers are a popular surface treatment in malls, but the pavers must be placed on a substantial sub-base to avoid settlement or "frost-heaving" and dislodgement, which can result in tripping hazards. Since emergency vehicles require access to all parts of the pedestrian mall, the paved areas need to be designed to take the weight of service and emergency vehicles and allow them to move around easily. Pedestrian oriented lighting, with control of overhead illumination so as not to overpower shop window lighting, is preferred to restore a more intimate and natural scale to the converted street. Landscaping should be carefully chosen, not only for appearance, but for maintenance and growing characteristics. Plants or trees that interrupt sight lines and potentially provide concealment can reduce perceived security and discourage pedestrian activity at night.

Crosswalks must be provided for pedestrians in transit malls, interrupted malls, and plazas where pedestrian-vehicle conflicts are eminent. Such conflicts may be minimized through: 1) one-way cross streets, and 2) signals and warnings to the motorists, such as signs, traffic bumps, or contrasting pavements at the mall crossings.

## *Implementation Considerations For Pedestrian Malls and Street Closures*

Feasibility studies which determine the levels of political, business, and general public support are essential. Included in these evaluations should be potential effects on traffic, area economics, and the social environment. Temporary pedestrian malls or street closures can be set up as part of a feasibility study to determine a more permanent need.

Successful implementation requires a great deal of cooperation and organization. A primary leadership group and working committees must coordinate and administer the process. Public and private interest should be developed through the media, informational meetings, pamphlets and displays. Management, financial and scheduling plans should be developed and followed. In addition, periodic review sessions should be held to: 1) consider and develop alternative concepts, and 2) ensure that all concerned parties have adequate opportunity to contribute as they see fit.

## *Advantages of Pedestrian Malls and Street Closures*

Several advantages exist from the design and implementation of pedestrian malls, including:

- A reduction in pedestrian delays and/or pedestrian congestion.
- Enhancement of the aesthetic and social environment of the downtown area.
- Greater pedestrian accessibility to retail merchants.

- An increase in the use of public transportation.
- A decrease in noise and air pollution on affected streets.
- A potential increase in revenues, sales, and land values.
- Implementation can occur in stages.
- Shelter is provided for pedestrians.
- Unification of commercial or recreational areas.
- Increase in the efficiency and time savings of mass transit in transit malls.

Along with the advantages of pedestrian malls, there also exist several disadvantages, including:

- A potential high cost of installation, maintenance and operation.
- Rerouting of vehicle traffic to other streets.
- Potential reduction in retail activity and an increase in noise and air pollution on nearby streets.
- Disruption of utility and emergency services.
- Disruption of bus routes and delivery of goods.
- Placement problems with street furniture for visually handicapped pedestrians.
- Potential parking problems for visitors and employees.
- Potential security and policing problems.
- Potential maintenance problems (e.g., snow removal).
- Conflicts between pedestrians and transit vehicles in transit malls.
- Pedestrian-vehicle conflicts at cross streets in a plaza or interrupted mall.
- Conflicts between pedestrians and vehicles at midblock locations where displaced sidewalk grids are used.

## Summary

In summary, the conversion of streets to full pedestrian malls is an ideal way to provide for safe and free-flow movement of pedestrians in a desired area, such as for retail shopping. Although the conversion of streets to pedestrian malls is usually the result of efforts to revitalize downtown areas, improved pedestrian safety can be a beneficial result of such malls. Also of value seems to be the total closing of residential streets to motor vehicles during certain hours of the day, such as with play streets. However, a lesser degree of success has resulted from closing streets only partially to motor vehicles, such as with residential yards and transit malls.

Conditions where pedestrian malls are most beneficial are:

- In central business districts (CBD) and high pedestrian volume areas.
- Where sidewalks are overcrowded and vehicle volumes are low.
- In high density downtown shopping areas with heavy pedestrian activity.
- Where vehicular traffic circulation would not be adversely affected.

Conditions where such malls are least beneficial or possibly harmful are:

- In high-crime areas.
- In high-speed areas with relatively low pedestrian activity.
- Where vehicle traffic cannot be rerouted without adversely impacting nearby streets.

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# 14

# TRANSIT STOPS

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FIGURE 14–1. *Pedestrian needs must be met in the design and placement of transit stops.*

The transit stop could best be described as a pedestrian traffic generator, because all transit riders are pedestrians at one end of their trip and frequently at both ends. Therefore, the needs of the pedestrian must be paramount in the design and placement of transit stops **(figure 14–1)**. A transit stop must allow for the smooth interface between the individual (pedestrian) and the group (transit riders). No transit stop should be considered without dialogue and coordination between the transit operator and the jurisdiction in which it operates.

Transit stops have some unusual and unique characteristics that make designing effective and efficient transit stops important. They can range from isolated street corners, where individuals may wait long periods of time for a bus, to subway stations where large crowds may gather for the commute to work. There are two major groups of transit systems to keep in mind when designing pedestrian facilities: (1) the exclusive right-of-way and (2) the nonexclusive, or shared right-of-way, systems.

In the exclusive right-of-way systems, transit vehicles have their own separate transit way. Most common of these types are the commuter rail, subway, and light rail systems. Other less common types include ferries, monorails, and busways. However, all of these modes share a single important feature—the exclusiveness of the right-of-way. With few exceptions, only transit vehicles use the right-of-way.

The more common nonexclusive right-of-way system is that of the city buses. However there are exceptions, for example the older trolley systems and the newer light rail systems that exist in a few cities. A few systems have both exclusive and nonexclusive rights-of-way. It is not as important to classify transit systems as it is to understand the differences in how pedestrians relate to the different types of transit systems.

# Nonexclusive Systems

## Motor Bus

The simple bus stop is usually a sign on a pole and a place for the bus. Several concerns must be considered when designing the bus stop, including the bus's dimensions and the driver's situation. The modern motor coach can be up to 65 feet long and 8 and 1/2 feet wide. The driver is dealing with traffic, giving directions, handling fares, and trying to stay on a tight schedule, all while maneuvering one of the largest motor vehicles on the street.

Bus stops are usually located at the curb every block or so along the transit route. In suburban areas, stops are farther apart and speeds tend to be a bit higher. Each transit system has a typical size for its preferred bus stop, and transit planners should be consulted to determine the locally preferred size and location for bus stops.

Some general standards for the bus stop are that it should be between 2 and 3 times the length of the vehicle that will use it. This generally means that a stop will need to be 100 to 150 feet long. The roadway under the bus stop itself should be as close to level as possible and should be designed to handle the repeated stopping action of a 25,000 to 35,000 pound bus.

One type of pedestrian accident problem involves pedestrians who step into the street from in front of a stopped bus and are struck by vehicles moving in the lane adjacent to the bus. Such accident situations develop when the line of sight between the pedestrian and the oncoming motorist is blocked, or when the pedestrian simply does not look for oncoming vehicles. One study found that approximately 2 percent of pedestrian accidents in urban areas and 3 percent in rural areas are related to bus stops.[1]

One possible solution for this type of accident is to relocate a transit stop from the near side of an intersection to the far side, so that more pedestrians will cross the street from behind the bus than in front of it. This generally results in making pedestrians more visible to motorists approaching from behind the bus. The relation of a transit stop or school bus stop from the near side to the far side of an intersection is often relatively inexpensive and has been shown to be beneficial to pedestrians in certain situations. For example, a 1975 study by Berger found that undesirable crossing behavior was virtually eliminated at two sites after converting to far-side stops.[2]

Not only can far-side bus stops reduce the potential for bus stop accidents involving pedestrians, they are also less likely to obscure traffic signals, signs, and pedestrian movements at intersections, as opposed to near-side bus stops. Also, conflicts between buses and right-turning vehicles can be reduced by using far-side bus stops. However, some problems at far-side bus stops may also occur when cars are illegally parked in far-side bus stops, thus preventing buses from completely clearing the cross street. An increase in the time of bus operation could also occur with the implementation of far-side bus stops, because traffic signal delays at signalized intersections will no longer be used for pickups and dropoffs of passengers.[3]

Conditions under which far-side bus stops are generally the most beneficial include signalized or unsignalized intersections with one or more of the following characteristics:

- in central business district (CBD) areas or in areas with heavy volumes of pedestrians and high traffic volumes;[4]
- along streets or roads with moderate or heavy volumes of traffic making right turns off the bus street,[3,4] so thru buses will not block the right-turning traffic);
- on roads with high volumes of bus traffic and ridership (or with exclusive bus lanes);[4]
- at intersections having one-way streets that move from left to right or at two-way streets where buses make left turns.[3]

Situations in which near-side bus stops may be more desirable include the following:

- Where the pedestrian demand is predominantly near-side or where large volumes of pedestrians would have to cross a busy street to reach the far-side bus stop.[3]
- Intersections of one-way streets that move right to left.[3]
- Where buses make a right turn.[3]

- Where the traffic turning onto the street that the buses stop at is greater than the traffic turning off of it[3] (i.e., vehicles turning right onto the "bus stop" street would not be blocked if the bus is stopped on the near side of the intersection).

The considerations for locating and designing bus stops are covered in the Transit Cooperative Research Program's 1996 report (number 19) *Guidelines for the Location and Design of Bus Stops.*[5]

*Street furniture*—Buses usually stop at the farthest end of the transit stop toward their direction of travel. Support poles, newspaper vending boxes, and other permanent fixtures should be minimized in this area. At suburban locations, for example, drivers often stop their cars in bus zones while buying from newspaper vending boxes. However, a trash receptacle is frequently useful as many people will eat, smoke, or drink while waiting for their bus, since these activities are not permitted on board.

Wheelchair lifts on buses extend several feet from the side of the bus. There should be at a 5-foot by 8-foot wheelchair landing pad at the bus stop so that a wheelchair lift can be deployed safely. Lifts are now required on all new buses.

Waiting shelters, where provided, should be sturdy and vandal resistant. Plexiglass shelters are very popular. Schedule boards are frequently useful at more popular stops. There should be sufficient clearance between the edge of the curb and the shelter to maneuver a wheelchair. The shelter should be designed to allow easy access for the wheelchair user.

*Lighting*—Sufficient lighting is especially important and practical at transit stops. Not only a deterrent to criminal activity, lighting is also important for safety. A brightly lit stop makes it easier for the transit operator to observe waiting passengers and allows motorists to see boarding and alighting pedestrians. Because the most dangerous area on a transit vehicle for accidents is the step well, a brightly lit area will assist boarding and alighting passengers as they judge distances and locations of steps and curbs. New buses are required to have auxiliary lighting in the step well, but it will be many years before this feature is universal.

*Curb height*—Older buses tend to have a bottom step that is 14 to 18 inches above the roadway. Bottom steps of newer buses can be as low as 11 inches above the road. To help prevent falls during passenger boarding and departing, the curb height should not be higher than the height of the bus step. This is a particularly serious problem in older cities where storm drains are located in the area where the front wheels stop.

*Signing*—BUS STOP signs should be uniform and consistent throughout the service area. The BUS STOP lettering and/or logo should be on both sides of the sign. Parking prohibitions should be clear. Illegal parking at bus stops is one of the primary causes of bus and automobile accidents as well as boarding and departing accidents. When the bus cannot pull to the curb, the first step of the bus is as much as 18 inches above the roadway. In bad weather, roadways can be much more slippery than sidewalks. Also, a car following the bus may not see a pedestrian who has only just departed from the vehicle and is still in the roadway. It may also be advantageous to place directional signs near major bus stops to direct pedestrians who are unfamiliar with the area to major travel destinations.

### Other Placement Concerns

Other considerations for bus stop locations include the use of midblock stops and special bus stops along freeway rights-of-way. While midblock stops are not commonly used in some jurisdictions, they may be appropriate on long blocks, or in front of major activity generators (e.g., stadiums or shopping centers), or when stopping at the adjacent intersection would cause traffic problems.[3] The placement of the bus stop locations should also consider the origin and destination of passengers, the need for vehicle parking and truck loading, nearby land uses, and physical site characteristics, such as the location of driveways, fire hydrants, trees, and utility poles.[3]

Special bus stops are sometimes needed along freeway rights-of-way, such as when buses use freeways to link the CBD with outlying areas or when freeway routes link important circumferential routes near the edge of the CBD.[3]
Where diamond interchanges are used, bus operators often take the off-ramp and stop at the intersecting street to drop off passengers, thus

minimizing walking distance for pedestrians. Where more complex interchanges exist in which considerable time would be lost by buses leaving the freeway, special stops may be used with approach and exit lanes on the freeway, and pedestrian paths may connect bus stop locations with the intersecting street. Such bus stop locations typically require acceleration and deceleration lanes and other interchange design features to facilitate bus movement into and out of the freeway thru lanes.[3]

The placement of bus stops should be reviewed periodically within a city or other jurisdiction to determine whether modifications are needed **(figure 14–2)**. A study of pedestrian accidents should be routinely conducted to identify intersections or midblock locations where pedestrian accidents related to bus activity have occurred. This may require reviewing sketches and accident descriptions from police reports to properly identify such accidents. A review of transit agency collision reports may be a useful supplement to police reports. This may also help to identify accidents involving people injured while boarding or exiting the bus (which likely

FIGURE 14–2. *The placement of bus stops should be reviewed periodically.*

would not be reported by police as a motor vehicle collision). Such accidents could be related to poor bus stop design or location. Sites with one or more bus-related accidents could then be reviewed for possible bus stop relocation or improvements.

## Nonmotor Bus

In some areas of the country, alternatives to the motor bus share the city streets. Some of these vehicles are transit in nature, while some are more recreation-oriented.

## Trackless Trolley

This vehicle is essentially a motor bus with an electric motor. Other than the maneuverability limits of the overhead wire from which it receives its power, it should be treated essentially as a motor bus. However, care should be taken in construction areas or where illegal parking is common in the path of the trackless trolley to avoid forcing the vehicle too far from the overhead wire.

## Trolley

Some old fashioned trolleys still run in the streets of a few American cities. The biggest safety problem is that passengers often get on and off in the middle of traffic. Visitors from other areas are frequently unaware that pedestrians may be standing and waiting for a transit vehicle in the middle of a major street. Safety islands and other boarding areas must be clearly delineated and signed.

A modern variant of the trolley known as a light rail vehicle, or LRV, is returning to many city streets in this country. Few require center-of-the-street loading and their stops are much like a small subway stop. However, a few do load at some stops from the side of the road.

## Tourtrams

These vehicles are frequently underpowered and operate below normal speed limits. Tourist pedestrians are frequently unfamiliar with the surroundings and are often paying more attention to guides and the sights than traffic in the area. Stops for these vehicles should be especially well defined and routes to and from the sights being visited should be clearly marked. Stops should be out of the flow of commuter pedestrians.

## *Exclusive Right-of-Way Transit*

Exclusive right-of-way transit usually refers to the subway but more and more often it can apply to contraflow services, light rail vehicles, commuter trains, and busways. Most often the transit provider will designate, design, and build the specific station. However, the pedestrian flow routes are frequently ignored outside the station entrance.

Fixed guideway transit systems exists to move large numbers of persons quickly. During peak periods, a commuter train could arrive with several hundred people on-board. All of these people will depart from the transit vehicle and attempt to use the pedestrian facilities immediately. Therefore, the pedestrian facilities must be adequate to handle such peak loads.

If the service operates late at night, lighting is of critical importance as is the elimination of "hiding places." Transit stations have reputations as places of criminal activity. Even though most statistics belie this fact, it is important to create the feeling of a safe environment as much as it is necessary to actually provide it.

Steps or changes of level should be avoided whenever possible, as they may result in tripping or slowing hazards. If absolutely necessary, steps should be wider than the route feeding into it to allow for the slower pedestrian speed and should be well lit and delineated. If alternative entrances (for persons with disabilities) are provided, they should be as well lit and protected as the main entrances.

### Light Rail and Busways

It is important for the waiting areas and stops to be open, inviting, and easily accessible. It should also be possible for police or other enforcement personnel to access the stop area quickly and easily.

### Grade Crossings

In light rail and surface commuter rail systems, the need frequently arises to cross a roadway and sidewalk at grade. The pedestrian crossing must have clear lines of sight and good visibility so that pedestrians will be able to see approaching rail vehicles. Coordination with the local transit authority on grade crossing protection is essential. One of the most effective and low-cost solutions to the visibility problem is a very high contrast front end on the vehicle and the placing of high intensity strobe lighting on the vehicle. If wheeled vehicles are expected to use the crossing (e.g., strollers, wheelchairs, or bicycles), there should be as smooth and as level a crossing of the tracks as possible with safe train operations in mind.

If the trains or LRVs stop close to the pedestrian crossing at bi-directional operation facilities, care should be taken to warn the pedestrian of a train approaching from the opposite direction that may be blocked from view by the vehicle stopped at the station. It is frequently possible by the judicious use of fencing or shrubbery, to guide pedestrians to safer crossing points. Consideration should be given under some circumstances to use pedestrian-only crossing gates or other warning devices. Finally, as in all transit operations, care should be given to protect late pedestrians running for the transit vehicle.

## *Conclusion*

The transit rider may ultimately be the pedestrian and as such, is more affected by changes in the pedestrian pathway than the person walking to a car due to the need to coordinate the trip with the transit schedule. The transit rider presents an unusual challenge that offers large rewards; for every pedestrian who becomes a transit rider, there is one fewer motor vehicle that needs to be accommodated on the roadways.

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# 15

# WORK ZONE PEDESTRIAN SAFETY

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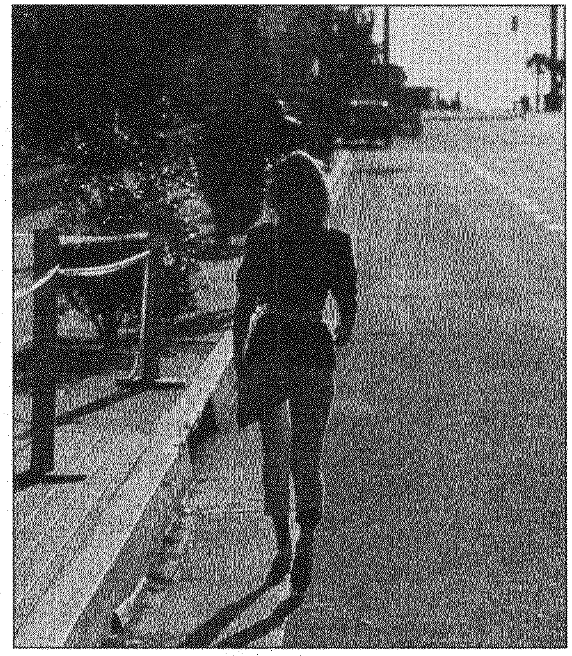

FIGURE 15–1. *Pedestrians must not be forced into direct conflict with moving traffic at a work site.*

Three threshold considerations should be taken into account when planning for pedestrian safety in highway and street work zones:

- Pedestrians must not be led into direct conflicts with work site vehicles, equipment, and operations. This both impedes the efficient execution of work and increases the risks of pedestrian injury.
- Pedestrians must not be led into direct conflicts with mainline traffic moving through or around the work site **(figure 15–1).**
- Pedestrians must be provided with a safe, convenient travel path that replicates as nearly as possible the most desirable characteristics of sidewalks or footpaths.

In accommodating the needs of pedestrians at work sites, it should always be remembered that the range of pedestrians that can be expected is very wide, including the visually impaired, the hearing impaired, and those with ambulatory disabilities. All of these pedestrians need to be provided a smooth, clearly delineated travel path that will afford them protection from potential injury.

Therefore, every effort must be made to separate pedestrian movement from both work site activity and adjacent traffic. Whenever possible, pedestrians should be appropriately diverted from direct encounters with work sites by advance signing, as approved in Parts II and VI of the *Manual on Uniform Traffic Control Devices*, that requires providing safe crossings on opposite sides of streets and roads.[1] These signs should be placed at intersections so that pedestrians, particularly in high traffic volume urban and suburban areas, are not confronted with midblock work sites that will induce them to attempt skirting the work zone or making a midblock crossing. It must be recognized that pedestrians will infrequently retrace their steps to a prior intersection for a safe crossing. Consequently, ample advance notification of sidewalk closures is critically important **(figure 15–2)**.

When pedestrian movement through or around a work site is necessary, the aim of the engineer must be to provide a separate, safe footpath without abrupt changes in grade or terrain.[2] A minimum width of 4 ft is recommended for pedestrian walkways through work zones. Wider walkways are needed where there are high pedestrian volumes or where multiple wheelchair users need to traverse the work zone.[2]

Walkway surfaces should be free of holes and cracks, slip resistant, and level. The most common types of temporary walkway surfaces include stabilized earth and gravel, asphalt, concrete, wood, and steel plates. The appropriate type of surface to be used depends on the pedestrian volume, project duration, the stability of the underlying surface, the extent to which elderly and disabled pedestrians use the existing walkway, and other factors.[2]


FIGURE 15–2. *Ample advance notification of sidewalk closures is important.*

Whenever it is feasible, closing off the work site from pedestrian intrusion is preferable to channelizing traffic along the site solely with temporary traffic control devices such as cones, pylons, barricades, plastic drums, or other systems with proven performance. Great care must be taken not to use systems, such as wood fencing, that are vulnerable to splintering or fragmentation by vehicle impacts. Similarly, temporary traffic control devices used to delineate a work zone pedestrian walkway must be lightweight and, when impacted upon, present only a minimum threat to pedestrians, workers, and impacting vehicles. Only minimally necessary ballasting with safe, lightweight materials should be used with these devices.

Movement by work vehicles and equipment across designated pedestrian paths must be minimized and, when necessary, should be controlled by flaggers or temporary signalization. Moreover, staging or stopping of work vehicles or equipment along the sides of pedestrian paths should be avoided, because this practice encourages the movement of workers, equipment, and materials across the pedestrian path. Also, cuts into construction areas across pedestrian walkways should be kept to a minimum because they often create unacceptable and even dangerous changes in grade and rough or muddy terrain. Pedestrians cannot be expected to willingly traverse these areas, and in most cases, will tend to avoid the cuts by attempting non-intersection crossings.

Additional physical protection of pedestrians from encroachments by work equipment, traffic, and construction activity is often needed at work sites. In the case of mobile and constantly moving operations, such as pothole patching and striping operations, both workers and adjacent pedestrians are better protected from impacts by errant vehicles if the work crew is followed at the appropriate distance by a shadow vehicle, preferably equipped with a rear-mounted impact attenuator.[3] In addition, the appropriate upstream channelizing or merging tapers for short-term work should be properly installed to ensure diversion of approaching traffic from the captured lane where work is in progress.

At fixed work sites of significant duration, especially in urban areas with high pedestrian volumes, a canopied walkway is frequently needed to protect foot traffic from falling debris. These covered walkways should be sturdily constructed and adequately lit for nighttime use.

When pedestrians are judged especially vulnerable to impact by errant vehicles, all foot traffic must be separated and protected by longitudinal barrier systems. Where a positive barrier is clearly needed, it must be met by systems of sufficient strength that have low deflection characteristics in order to avoid intrusion by an impacting vehicle into the pedestrian space. In addition, short, intermittent segments of longitudinal systems, such as concrete New Jersey barriers, must be avoided because they nullify the containment and redirective capabilities of the design, increase the potential for serious injury both to vehicle occupants and pedestrians, and encourage the presence of blunt leading ends. All upstream leading ends that are present must be appropriately flared or protected with properly installed and maintained impact attenuators.[4,5] With regard to concrete barriers in particular, it is crucial to ensure that adjacent segments are properly joined in order to effect the overall strength required for the system to perform properly.

A number of studies carried out in the 1950s, and confirmed by many subsequent years of operational history, have shown that vertical curbs cannot prevent vehicle incursions onto sidewalks and, therefore, are not satisfactory substitutes for positive barriers when these clearly are needed. Similarly, contractor-constructed wooden railings, chain link fencing with horizontal pipe runs, and similar systems placed directly adjacent to vehicle traffic are not acceptable substitutes for crashworthy positive barriers and, when struck, are dangerous to vehicle occupants, workers, and pedestrians. In many instances, temporary positive barriers may be needed to prevent pedestrians from unauthorized movements into the active work area and to prevent conflicts with traffic by eliminating the possibility of midblock crossings. However, positive barriers should not be installed to channelize pedestrian movement, unless a high potential also exists for vehicle incursions into the pedestrian space. If this potential does not exist, standard traffic control devices can satisfactorily delineate a work zone pedestrian path, but fail-safe channelization can never be guaranteed with these devices because of the gaps between them. Although tape, rope, or plastic chain strung between devices can help to inhibit dangerous pedestrian movements off the designated pathway, they cannot eliminate them entirely.

Good engineering judgment in each work zone situation should readily determine the extent of pedestrian needs. The engineer in charge of work zone traffic control should always be guided by the understanding that he/she must provide both a sense of security and safety for pedestrians walking past work sites and consistent, unambiguous channelization in order to maintain foot traffic in the desired travel paths. Engineers with area-wide responsibilities must be vigilant in their oversight of work sites and operations that needlessly jeopardize the safety of both pedestrians and workers. One example of a major area of concern is urban and suburban building contractor encroachments onto contiguous sidewalks which force pedestrians off-curb into direct conflicts with moving vehicles. In this and many other work zone situations, the engineer with area-wide responsibilities must be willing to regularly patrol work sites so that safe, effective pedestrian traffic control is maintained.

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# SUMMARY AND CONCLUSION

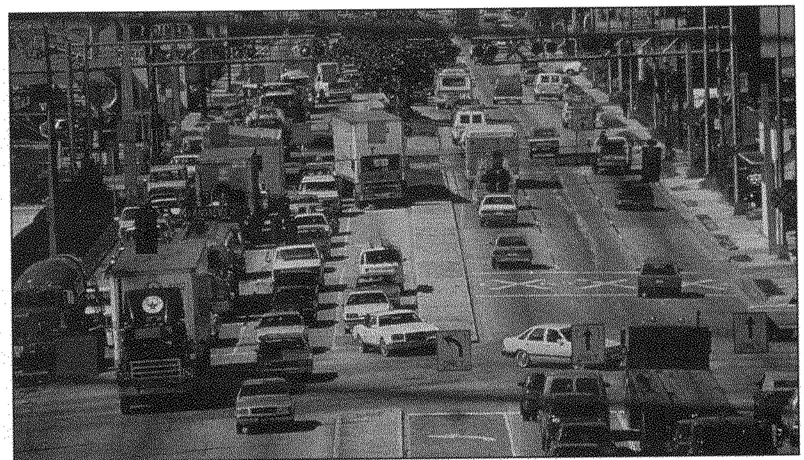

FIGURE S–1. *Streets and highways are too often designed solely with the interests of motorists in mind.*

While traffic engineers have a responsibility to provide for the relatively safe and efficient flow of all types of road users, streets and highways are too often designed with the sole interests of motorists in mind, and pedestrians are left to "fend for themselves" on streets with inadequate crossing times, confusing traffic-control devices, excessive delays, and construction zones with little or no provisions for those who walk **(figure S–1)**. Although some transportation agencies have for years attempted to provide for non-motorized as well as motorized road users, many state and local agencies should place more emphasis and priority on the needs of pedestrians on public streets and highways **(figure S–2)**. ISTEA legislation provided more flexibility for making pedestrian improvements with a variety of funding choices, and current NEXTEA legislation continues these provisions.

Improving pedestrian safety requires a comprehensive program of engineering, education, and enforcement **(figures S–3 and S–4)**. Such programs have already been implemented in several States and localities. In terms of roadway improvements, dozens of measures can be effective at a given location to improve pedestrian safety, depending on specific site characteristics. Such improvements may include the use of sidewalks and walkways, facilities for the handicapped (e.g., curb cuts, increased WALK time), far-side bus stops, improved nighttime lighting, improved traffic control devices (e.g., signs, push-button signals, use of pedestrian signals where warranted), school zone improvements (e.g., crossing guards, parking prohibitions near intersections), safety islands (on wide streets), neighborhood traffic control measures (e.g., traffic circles, roadway diverters), pedestrian malls, and others. To be most effective, however, such measures should be tailor fit to a given location, and overuse or inappropriate use of any engineering measures is not recommended.

To develop a successful pedestrian safety program, agencies should conduct studies of pedestrian accident types and the location of these accidents and compile information on sites with unsafe pedestrian and motorist behavior (e.g., jaywalking, pedestrian and motorist signal violations, speeding motorists, drunk driving and walking). The best project alternatives should then be carefully selected and implemented **(figure S–5)**. Finally, the effectiveness of those measures on pedestrian accidents should be evaluated so the program can be maintained in the best possible manner.

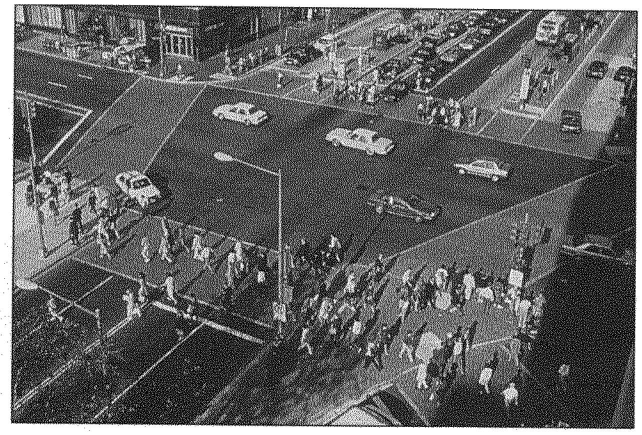

FIGURE S–2(A).


FIGURE S–2(B). *Many state and local agencies should place more emphasis and priority on the needs of pedestrians on public streets and highways.*

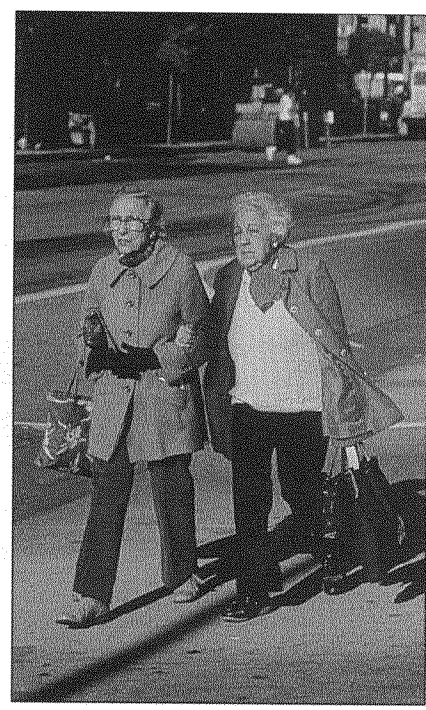

FIGURE S–3(A).

FIGURE S–3(B). *Educating pedestrians and motorists is an important component of promoting pedestrian safety.*

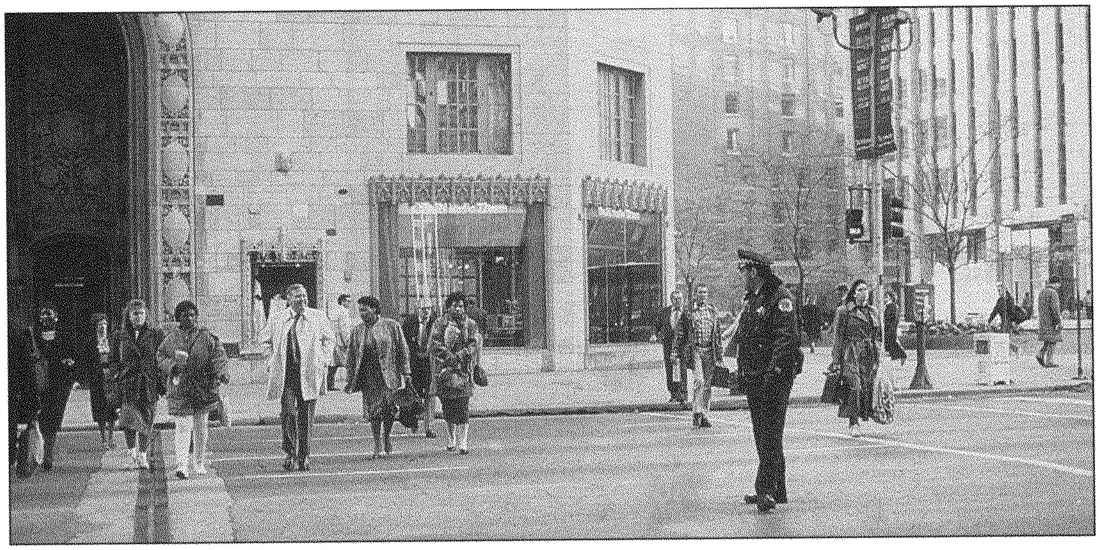

FIGURE S–4. *Enforcement of pedestrian-related laws and regulations is essential.*

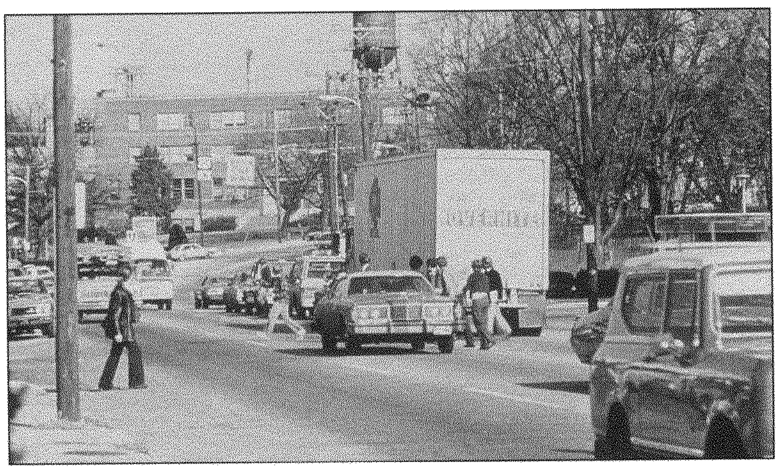

FIGURE S–5. *A routine program is needed to identify sites with pedestrian safety problems, and then to make needed improvements and conduct follow-up evaluations.*

# Appendix A

## *STANDARD ITE METRIC CONVERSION*

During the service life of this document, use of the metric system in the United States is expected to expand. The following common factors represent the appropriate magnitude of conversion. This is because the quantities given in U.S. Customary units in the text, tables or figures, represent a precision level that in practice typically does not exceed two significant figures. In making conversions, it is important to not falsely imply a greater accuracy in the product than existed in the original dimension or quantity. However, certain applications such as surveying, structures, curve offset calculations, and so forth, may require great precision. Conversions for such purposes are given in parentheses.

**Length**
1 inch = 25 mm (millimeters—25.4)
1 inch = 2.5 cm (centimeters—2.54)
1 foot = 0.3 m (meters—0.3048)
1 yard = 0.91 m (0.914)
1 mile = 1.6 km (kilometers—1.61)

**Volume**
1 cubic inch = 16 $cm^3$ (16.39)
1 cubic foot = 0.028 $m^3$ (0.02831)
1 cubic yard = 0.77 $m^3$ (0.7645)
1 quart = 0.95 L (liter—0.9463)
1 gallon = 3.8 L (3.785)

**Speed**
foot/sec. = 0.3 m/s (0.3048)
miles/hour = 1.6 km/h (1.609)

**Temperature**
To convert °F (Farenheit) to °C (Celsius), subtract 32 and divide by 1.8.

**Area**
1 square inch = 6.5 $cm^2$ (6.452)
1 square foot = 0.09 $m^2$ (0.0929)
1 square yard = 0.84 $m^2$ (0.836)
1 acre = 0.4 ha (hectares—0.405)

**Mass**
1 ounce = 28 gm (gram—28.34)
1 pound = 0.45 kg (kilograms—0.454)
1 ton = 900 kg (907)

**Light**
1 footcandle = 11 lux (lumens per $m^2$—10.8)
1 footlambert = 3.4 cd/$m^2$ (candelas per $m^2$—3.426)

For other units refer to the American Society of Testing Materials (1916 Race St., Philadelphia, PA 19103) Standard for Metric Practices E 380.